

A Saga of Progress

COMPENDIUM OF 50 YEARS OF ACHIEVEMENTS



PUNJAB AGRICULTURAL UNIVERSITY
LUDHIANA - 141 004, INDIA

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OF
50 YEARS OF ACHIEVEMENTS
(1962-2012)



PUNJAB AGRICULTURAL UNIVERSITY
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FOREWORD

India has made tremendous progress in agriculture. Food grain production increased from 50 mt in 1950-51 to 257 mt in 2011-12. A food-deficient nation during 1950s and 1960s, it has now not only exportable surplus of certain commodities but is among the top exporters of rice, one of three most important crops. Punjab state has played a leading role in this agricultural transformation. Food grain production in the state was 3.1 mt in 1960-61 and it increased to 29.2 mt during 2011-12. More importantly, productivity of wheat rose from 12 to 51 q/ha and that of paddy from 15 to about 60 q/ha. In fact, rice production increased by nearly 50 times. With 38-75 and 25-45 % contribution of wheat and rice, respectively, to the central food grain pool for public distribution, the State became mainstay of national food security and came to be known as bread basket of India.

The agricultural transformation was technology led. It started with the introduction/development of high yielding dwarf, input responsive varieties of wheat in mid 1960s followed by that of rice and the package of complementary production-protection technologies, the adoption of which ushered in an era of “Green Revolution”. Different institutions were active in this endeavour. But going by the data on quantity of seed production of improved varieties by PAU, spread of area under their cultivation accompanied by phenomenal jump in productivity and production fanning out from Ludhiana, the location of main campus of the University, PAU is rightly “the Mother of Green Revolution”.

The University has completed 50 years of glorious service to the nation in agricultural research, education and extension. Besides development of improved varieties of field and horticultural crops and their production-protection technologies, PAU has remarkable contributions to its credit in saline-alkaline soil reclamation, cropping-systems, farm mechanization, cross-breeding of cattle, introduction of Italian honey bee, mushroom cultivation etc. These research achievements were coupled with innovative technology transfer approaches, such as, interaction between scientists and farmers at *Kisan Melas*, establishment of Farmers Service Centre and distribution of seeds of new varieties in a large number of minikits. Over the years, the University has produced a large scientific manpower that has brought laurels at the national and international levels. In recognition of its outstanding contributions to the nation, PAU was the first agricultural university to be conferred with the “Best Institution Award” by the Indian Council of Agricultural Research (1995) and also the first to get as large grant as Rs. 100 crore from the Government of India (2007).

Government policy aiming at national food security and technology advances led to the emergence of highly remunerative paddy-wheat cropping-system in North-West Indo-Gangetic plains. The large scale adoption of this high yielding but input intensive system has stressed natural resources. For example, underground water table has declined, water quality, soil health and environment have been adversely affected, and biodiversity has dwindled. The University reoriented its research agenda and technology dissemination programmes in late 1970s towards sustainable development *i.e.* productivity enhancement accompanied by conservation/amelioration of natural resources. It focused on integrated management of insect pests, diseases, nutrients and water, and conservation agriculture with tangible results. The University has also throughout contributed significantly towards farm mechanization resulting in the Punjab as the most mechanized state and hub of farm machinery industry. However, mechanization is undergoing rapid advances which we need to assimilate to promote precision agriculture. We have a long history of research in food science, technology, processing and nutrition with appreciable contributions. But impact of these research contributions is not visible, the limiting factors being emphasis on quantity rather than quality of the produce and on farmers rather than industry. With as high level of productivity as about 110 q/ha of wheat and paddy, post-harvest technologies including value addition and coordination with industry need to be paid due attention.

Climate change has emerged as a new challenge. In this context, weather extremities and appearance of new insect pests and diseases need specific attention. To meet these challenges, we need multi-dimensional expansion of our research programmes. Mobilization of genetic resources through novel techniques of biotechnology are going to be extremely helpful in developing climate resilient varieties. In fact, besides biotechnology, other technologies such as information and communication technology, remote sensing, nanotechnology, etc. are fast emerging. All these need to be integrated into our programmes which demand large resources. This also requires development/strengthening of partnership in research and linkages with industry and market at national and international levels. Further, to upgrade mass awareness to the required level, we need to develop new extension methods and their integration with information and communication technology tools. Apparently, reprioritization of our agenda is a continuous process in this fast changing scenario.

A compilation of work over a period of 50 years of such an institution as Punjab Agricultural University, which has tremendous contributions to its credit, is an awesome difficult task. But it is important to review the achievements so as to identify strength and weakness keeping in mind the past scenario and emerging needs, challenges and opportunities. Only then one is enabled to meticulously plan ahead and reorient research, teaching and extension agenda. I appreciate the efforts of Drs. S.S. Gosal, T.S. Thind, P.S. Chahal and all others who contributed to the preparation of this compendium of achievements on the occasion of the Golden Jubilee Year of the University. I hope it will serve as a repository of information for the scientists, policy makers and other stakeholders.

Ludhiana
November 12, 2012



(Baldev Singh Dhillon)
Vice Chancellor

PREFACE

During the past 50 years, Punjab Agricultural University (PAU) has played a pivotal role in ushering in the Green Revolution and transformed the State of Punjab to food grain bowl of the country. The productivity and production of crops have been immensely enhanced. In major crops like wheat and rice, the productivity has been increased by four times, whereas, the total production in the state has increased by 10.3 times in wheat and nearly 50 times in rice. Having just 1.53 per cent geographical area of the country, Punjab has been producing up to 22 per cent of wheat, 11 per cent of rice and 10 per cent of cotton of the country.

The PAU has developed/recommended 707 varieties/hybrids of different crops. Out of these, 117 varieties/hybrids have been released at the national level. It is pioneer in the world for developing first pearl millet hybrid (HB-1), first single cross maize hybrid (Paras) and first hybrid of gobhi sarson (PGSH 51). Besides, matching crop production and protection technologies have been developed and disseminated. The university developed several key technologies such as reclamation of salt affected and water logged soils, soil testing, cropping systems, chemical weed management, kinnow cultivation, integrated pest/disease/nutrient/water management, conservation agriculture such as zero tillage, leaf colour chart, tensiometer & happy seeder, agroforestry systems, farm machinery, protected cultivation, web-based decision support system for late blight of potato, biofertilizers, biocontrol agents, pesticide residue analysis, value addition & processing, bioenergy, micropropagation, doubled haploid production, Marker Assisted Selection, quality seed & nursery production, honey & mushroom production, cross breeding of dairy cattle, embryo transfer technology, and foot and mouth disease management that had a remarkable impact on Punjab agriculture.

Punjab agriculture is currently passing through a difficult period. Declining under ground water table, deteriorating soil health and ground water quality, changing climate, environmental degradation, crop residue management, diminishing farm size, increasing cost of agri-inputs, machinery, energy & labour and marketing constraints have become major problems.

We have to focus more in future to develop technologies that can help in enhancing production per unit of land and water, without adversely affecting the environment. Special attention needs to be given to develop climate resilient technologies that are better suited to the small and marginal farmers. Due attention needs to be given towards germplasm enhancement, accelerated and precision breeding, conservation of natural resources, crop diversification, precision farming, micro irrigation and fertigation, site specific nutrient management, rational use of pesticides, post harvest and supply chain management, plant health management, value addition and processing, use of bio and solar energy, efficient machinery, web-based decision support systems, bio-fortification for nutritional security and food contamination and food safety. There is a need to develop well trained human resource having national and international exposure to better understand the changing needs in agriculture. To give impetus to transfer of technology to the farming community, the role of modern communication methods can be of a great help. The PAU has taken initiatives to address the current as well as emerging challenges of the Punjab's agriculture.

The Compendium document has been prepared that gives holistic information about the past achievements of the University in the areas of teaching, research and extension activities. I express my sincere thanks to Dr. B.S. Dhillon, Vice Chancellor, for providing stimulus and initiative in bringing out this compilation on completion of 50 glorious years of PAU. I am grateful to all the Deans, Directors, Heads of Departments and Directors of Regional Research Stations of the University for providing the necessary information for this document. My special thanks are due to Dr. T.S. Thind, former Additional Director of Research (Natural Resource and Plant Health Management), now Emeritus Scientist, and Dr. P.S. Chahal, Associate Director of Research for their help and support in compiling this document.



(S.S. Gosal)
Director of Research

Ludhiana
November 9, 2012

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INTRODUCTION

The Punjab Agricultural University (PAU) has attained a special status in the history of Indian agriculture for its pivotal role in ushering in the Green Revolution in India. Contributions of PAU in consonance with the support of the State/Central governments as well as the efforts of the hard-working peasantry of the State are well recognized in this regard. In recognition of its outstanding contributions in agricultural research, education and extension, PAU was the first to be adjudged as the Best State Agricultural University by the Indian Council of Agricultural Research in the year 1995. A special grant of Rs. 100 crore was awarded to PAU by the Central Government in 2006 for its contributions to the Green Revolution and to continue to work towards excellence.

The University was established in 1962 on the pattern of the U.S. land grant system. It has its origin in the Punjab Agriculture College and Research Institute, Lyallpur (now Faisalabad) in Pakistan, which was established in 1906. After the partition of the country in 1947, the College was re-established in a building belonging to Khalsa College, Amritsar. The College was shifted to its present site in 1957 and upgraded as a university in 1962 through the Punjab Agricultural University Act passed by the Punjab Legislature on October 17, 1961. Originally, the University had three campuses, one each at Ludhiana, Hisar and Palampur. PAU was bifurcated by an Act of the Parliament on 2nd February, 1970 to establish Punjab Agricultural University at Ludhiana and Haryana Agricultural University (now CCS Haryana Agricultural University) at Hisar. Palampur campus was separated and upgraded as Himachal Pradesh Krishi Vishva Vidyalaya (now CSK Himachal Pradesh Krishi Vishva Vidyalaya) in July, 1970. There were five constituent colleges of the PAU namely, College of Agriculture, College of Agricultural Engineering, College of Basic Sciences and Humanities, College of Veterinary Science and College of Home Science. In April 2006, PAU was again bifurcated to establish Guru Angad Dev Veterinary and Animal Sciences University at Ludhiana and the College of Veterinary Science was merged in it. There are now 30 departments, 4 schools and one Institute of Agriculture (Gurdaspur) in the 4 constituent colleges of the University. All these Departments/Schools are involved in agricultural education, research and technology transfer activities. The PAU had a good faculty strength uptill 2005-06 that started to decline thereafter, During 2011-12, there were 858 faculty members including those at the outstations.

MANDATE

- To impart education in agriculture, agricultural engineering, allied basic sciences, and home science for developing quality human resource
- To conduct research for seeking solutions to the emerging problems in agriculture and allied fields
- To disseminate agricultural technologies to the farmers through various extension programmes.

MISSION

To serve the farming community through generation and dissemination of knowledge for sustainable agricultural production.

This compendium highlights salient achievements of the PAU in the areas of teaching, research and extension activities made during the past 50 years.

TEACHING PROGRAMMES

Punjab Agricultural University (PAU) has been a preferred destination for world-class agricultural education and consequently enrollment of students has gradually increased over the years and also the number of the teaching programmes. The University, since its inception, has produced more than 27000 students in different streams of agriculture and allied sciences. At present, there are nearly 2,800 students on the roll of the University of which more than 50% are postgraduate students. Enrollment of rural students in B.Sc. Agri. (Hons.) programme appreciably increased after the introduction of 6 year B.Sc. Agri. Programme after 10th class in the academic session 2008-09. New/ revised UG and PG course curricula have been implemented with special emphasis on Experiential Learning in Commercial Apiculture, Mass Production of Bio-agents, Protected Cultivation of Vegetables, Mushroom Production, Entrepreneurship in Bakery and Confectionary Products, Child Care Providers' Training Laboratory, Apparel Manufacturing, Training Unit in Artistic Creations, Hands on Training in Production of Agricultural Machinery and Hands on Training in Drip, Sprinkler & Poly-houses. New courses have been initiated in the frontier areas of Biotechnology, Bioinformatics, Conservation Agriculture, ICT-based Agriculture, Agribusiness, Bio-safety, Environmental Science and Nanotechnology,

As a measure to check in-breeding, PAU has signed various MoUs/ Agreements with reputed national / international institutions for the exchange of faculty and students. This has provided opportunity for several PG students to conduct research in world class foreign universities. The students also avail other opportunities such as under the Beachell-Borlaug Fellowship, Dr Hargobind Khurana Fellowship, Sandwich Degree Programme under Agriculture Knowledge Initiative, and Fulbright Fellowship for doing a part of their research work in reputed foreign laboratories. Another such measure is sending the Ph. D. students to other reputed universities in India for one semester for taking courses. Under an international agreement, in-service faculty is pursuing Ph.D degrees in Washington State University, Pullman, USA. Students of B.Tech Food Technology of PAU are also studying in Kansas State University, USA to earn dual degrees. To encourage the Ph. D. students to publish their research, from the session 2012-13, Ph.D. theses will be submitted in a new format containing research papers instead of Results and Discussion chapter. To strengthen international collaboration in education, a provision has been made to have foreign reputed scientists on the advisory committee of PG students. The university has decided to impart six months Induction Training to the newly recruited faculty members, one month each at its outstations at Ballawal Saunkhari, Gurdaspur, Faridkot, Bathinda and the University Seed farms after initial placement for one month at Ludhiana campus.

College of Agriculture

The College of Agriculture is one of the four constituent colleges of Punjab Agricultural University. This College had its roots in the Punjab Agricultural College and Research institute, Lyallpur (now Faisalabad, Pakistan). In 1963, the College of Agriculture had five departments viz. Agronomy, Extension Education, Horticulture, Plant Breeding and Soils and now there are 12 departments viz., Agronomy, Agricultural Meteorology Entomology, Extension Education, Floriculture & Landscaping, Food Science & Technology, Forestry & Natural Resources, Horticulture, Plant Breeding & Genetics, Plant Pathology, Soil Science and Vegetable Crops and School of Agricultural Biotechnology. The College of Agriculture imparts resident instructions in different disciplines of agriculture for developing human resources in agriculture. Besides, it lays thrust on carrying out research in agriculture and allied fields and disseminating the research findings among the farmers of the Punjab state for providing the security of sustainable livelihood to them. It has produced more than 7000 graduates, thereby contributing significantly towards the development of human resources in agriculture and allied fields. The college received the Federation of Indian Chambers of Commerce and Industry Award in 1977 in recognition of its outstanding contribution to the field of agriculture. The Alumni of the College have earned distinctions and are occupying top level positions in National and International R & D establishments and other areas of public service.

College of Agricultural Engineering and Technology

The College of Agricultural Engineering (renamed as College of Agricultural Engineering & Technology) was established in the year 1964. In addition to imparting education in various aspects of agricultural engineering, the College has also played a leading role in solving the problems of the farmers and the industry by undertaking problem-oriented research and speedy technology transfer. In recognition of its outstanding contributions, a prestigious programme by way of a Centre of Advanced Studies in 'Postgraduate Teaching and Research in Agricultural Engineering' was launched at the college by the United Nations Development programme and the Indian Council of Agricultural Research in 1974. The college further received another recognition by way of getting a prestigious programme on Centre of Advanced Studies on Energy Management in Agriculture by the prestigious FAO/UNDP and ICAR in 1984. The notable achievements of the College were also recognized at the national level when the Federation of Indian Chambers of Commerce and Industry Award was received in 1975. The College has 5 departments viz. Farm Machinery and Power Engineering, Processing and Food Engineering, Soil and Water Engineering, Mechanical Engineering and Civil Engineering, and has two schools viz. School for Energy Studies in Agriculture and School of Electrical Engineering and Information Technology.

College of Basic Sciences and Humanities

Keeping in view the significance of basic sciences for proper understanding and development of different areas of agriculture and allied fields, a School of Basic Sciences and Humanities was conceived which subsequently led to the establishment of College of Basic Sciences and Humanities in October, 1975. Close interaction between the basic and the applied sciences has added a new vigour to agricultural education and research. As a key constituent of the University, the College of Basic Sciences and Humanities, since its inception, has been striving to be a centre of excellence for advanced studies in basic sciences apart from providing basic understanding of the various processes to agricultural sciences. At present, the college has eight departments viz., Agricultural Journalism, Languages & Culture, Biochemistry, Botany, Chemistry, Economics & Sociology, Mathematics, Statistics and Physics, Microbiology, and Zoology apart from newly established School of Business Studies.



College of Home Science

College of Home Science was established in 1966 to cater to the need of empowering rural and urban women to contribute to family economy and improve their quality of life. Through its integrated programme of teaching, research and extension, the College grew rapidly, playing a significant role in improving the socio-economic conditions of rural as well as urban families, thereby, giving them opportunity to lead a better life. The mainstay of College of Home Science is the B.Sc.(Hons.)Home Science 4 year programme after 10+2. The College has the distinction of being the first Home Science College in State Agricultural Universities to start UG and PG programmes in allied fields by introducing B.Sc. (Hons.) Fashion Designing and B.Sc. (Hons.) Nutrition & Dietetics. The College houses five departments viz. Food & Nutrition, Family Resource Management, Clothing & Textiles, Human Development and Home Science Extension & Communication Management. The alumni of the College have brought laurels to their alma mater by occupying several positions of distinction nationally and internationally.

College of Veterinary Science (now with GADVASU)

The College of Veterinary Science was established in November 1969 with the objective of imparting resident instructions in veterinary and animal sciences, furthering the advancement of knowledge by undertaking research, and dissemination of this knowledge to the farmers for improving the productivity of farm livestock and better health care. Initially, the college started with six departments, but subsequently the number of departments were raised to twelve. In May 1998, the college was re-organised with 18 departments, namely Animal Breeding & Genetics, Animal Nutrition, Animal Reproduction, Gynaecology & Obst., Clinical Vety. Medicine, Ethics & Jurisprudence, Epidemiology & Preventive Vety. Medicine, Livestock Production & Management, Livestock Products Technology, Veterinary Anatomy & Histology, Veterinary & Animal Husbandry Extension, Veterinary Biochemistry, Veterinary Clinical Complex, Veterinary Microbiology, Veterinary Parasitology, Veterinary Pathology, Veterinary Pharmacology & Toxicology, Veterinary Physiology, Veterinary Public & Health and Veterinary Surgery & Radiology.



College of Veterinary Science

The course curriculum including the internship programme of the B.V.Sc. & A.H. programme was also modified in the light of the Veterinary Council of India (VCI) Regulations w.e.f. 1994. Initially B.V.Sc. & A. H. Programme was of 4 years duration comprising of 12 trimesters. In 1979, the compulsory six months internship programme was added increasing the duration of B.V.Sc. & A.H. programme to 4 ½ years. The trimester system of education was changed to semester system in 1988 and duration of B.V.Sc. & A.H. programme was increased from 4 ½ years to 5 years. The post-graduate programme was started in 1969. Since 1998, with the re-organization of the College, the M.V.Sc. and Ph.D. programmes are available in 14 disciplines. The College of Veterinary Science has excellent teaching and research facilities and many new programmes have been launched in different departments of the college with funds from State Government, Indian Council of Agricultural Research and Ministry of Agriculture, Government of India. In recognition of their contributions and the infrastructure available, two departments of this College viz. Department of Surgery & Radiology and Department of Reproduction, Gynaecology & Obstetrics have been identified by the Indian Council of Agricultural Research as the “Centres for Advanced Studies” in their respective disciplines.

Human Resource Generation

The University is a preferred centre of learning for the students interested to receive education in agriculture and allied disciplines and consequently enrollment of students has gradually increased over the years and also the number of teaching programmes being offered by the University. At present, a total of 84 teaching programmes

are offered by the University; 10 UG, 43 Master’s and 27 Ph.D. apart from 3 Certificate and one Diploma courses. During the formative years of the University (about 50 years ago), at times, there was not even a single girl student in the B.Sc Agri. programme whereas the percentage has now increased to nearly 50 % in the UG programmes and more than 64 % in PG programmes of the University; and on the whole, percentage of girl student has been recorded to be more than 57 %. Till now, more than 27,000 students have passed out from various UG and PG degree programmes (Fig. 1,2).

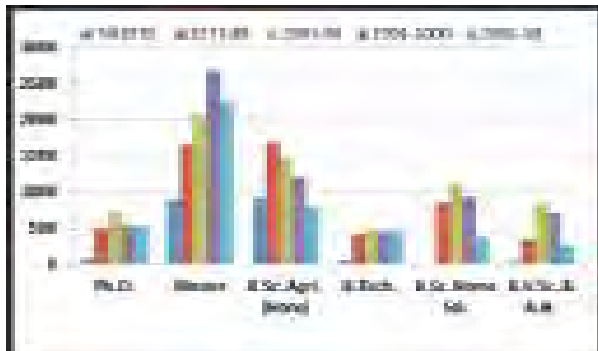


Fig. 1. Human resource generated at PAU

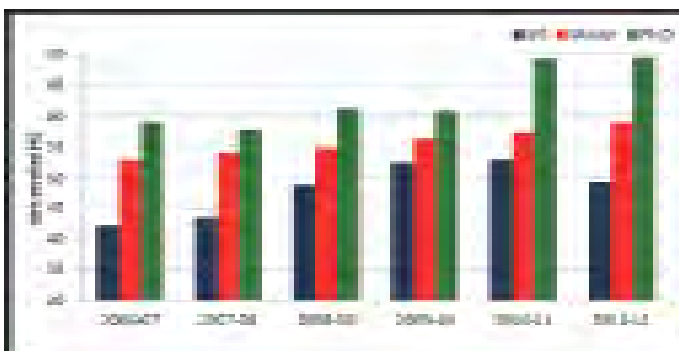


Fig. 2. Increase in enrollment of girl students at PAU

The PAU, since its inception, has attracted a large number of foreign students and during the earlier years scores of international students registered themselves in UG programmes offered by the University from various Asian (Afghanistan, Bangla Desh, Bhutan, Indonesia, Iran, Iraq, Malaysia, Mauritius, Nepal, Singapore, Sri Lanka, Thailand, Timor, Uzbekistyan), African (Egypt, Ethiopia, Guyana, Kenya, Liberia, Mozambique, Nigeria, Rwanda, Somalia, Sudan, Tanzania) and other some other countries including Canada, USA, France, Peru and Fiji. Subsequently, number of foreign students decreased in the UG programmes and it started increasing in the PG programmes; at present there are more than 30 PG students on roll of the university (Fig. 3) from Afghanistan, Egypt, Ethiopia, France, Guyana, Kenya, Liberia, Nepal, Rwanda, Sri Lanka, Sudan, Tanzania, Uganda and Vietnam.

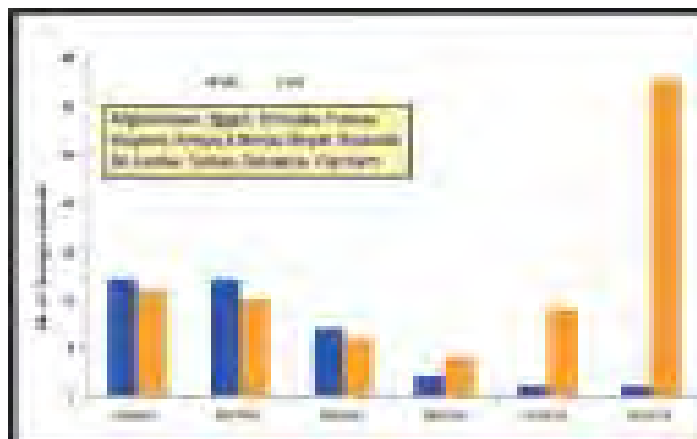


Fig. 3. Enrollment of international students in PAU

Resident Instructions

The University has excelled in imparting agricultural education with competent faculty and required infrastructure in its 4 colleges and 3 schools. The number of teaching programmes have increased over the years and at present 84 teaching programmes are offered by the university viz. 10 UG, 43 Masters, 27 Ph.D., 3 certificate and one diploma course. Twenty one new teaching programmes were started in the XI plan and 16 of these are in the self-supporting mode earning income of about Rs. 316 lacs per year with net benefit of about Rs. 153 lacs per year which is likely to increase subsequently. The list of these programmes is given in Table 1.

Table 1. List of various UG and PG teaching programmes in PAU

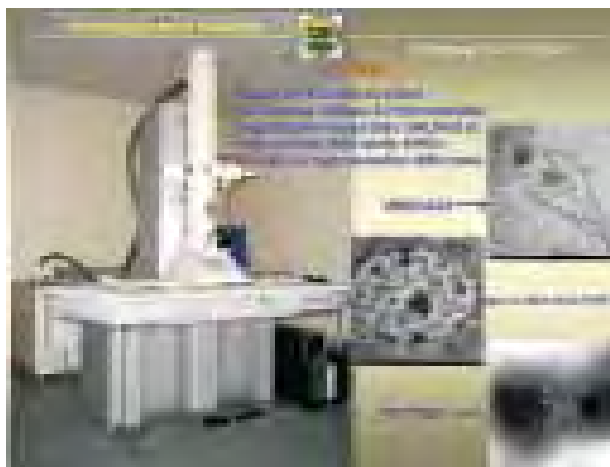
College of Agriculture	College of Agricultural Engineering & Technology	College of Basic Sciences & Humanities	College of Home Science
Undergraduate Programmes			
B.Sc. Agri (Hons.) 4year B.Tech. Food Tech. (Hons.)* B.Sc. Agri. (Hons.) 6year Certificate Course in Agri. at Gurdaspur* B.Ed. B.Sc. Biotechnology*	B.Tech. (Agril. Engg.)	Diploma in French Certificate course in French Certificate course in Interactive Skills & Personality Enhancement	B.Sc.(Hons.) Home Science 4 year B.Sc. (Hons.) Home Science 6year B.Sc.(Hons.) Fashion Designing* B.Sc. (Hons) Nutrition & Dietetics*
Postgraduate Programmes			
Masters: Agronomy Agrometeorology Extension Education Entomology Food Technology Pomology Vegetable Crops Floriculture & Landscaping Plant Breeding & Genetics Plant Pathology Nematology Soil Science Forestry Biotechnology*	Masters: Farm Power & Machinery Soil & Water Engineering Processing & Food Engg. Civil Engineering (Hydrology & Water Resources Engineering/ Structural Engineering) Computer Sci.&Engg. Computer Applications* Remote Sensing* Ph.D.: Farm Power & Machinery Soil & Water Engg. Processing & Food Engg. Energy Sci.& Tech.	Masters: Biochemistry Botany Microbiology Zoology Chemistry Agri. Economics Sociology Agribusiness Business Admin. Physics Integrated M.Sc. (Hons.): Biochemistry* Chemistry* Microbiology* Botany* Zoology* Master in Journalism and Mass Communication* PG Diploma: Agri. Journalism & Mass Communication* Ph.D.: Biochemistry Botany Chemistry Agril. Economics Sociology Microbiology Zoology Business Admin.	Masters: Food & Nutrition Family Resource Mgt. Clothing & Textiles Human Development Home Sci. Ext. & Comm. Mgt. Clothing & Textiles Human Development Home Sci. Ext. Edu. Fashion Designing* Ph.D.: Food & Nutrition Family Resource Mgt. Clothing & Textiles Human Development Home Sci. Ext.& Comm. Mgt.

Initiatives and Achievements

- Enrollment of rural students in B.Sc Agric. (Hons.) programme appreciably increased after introduction of 6-year B.Sc Agric. Programme and thus the primary mandate of the university could be realized. In addition to this programme at the Ludhiana campus, a similar course has also started at Gurdaspur to benefit the rural students from the backward and remote area.
- New/revised UG course curricula (as per recommendations of 4th Deans' Committee) has already been implemented with special emphasis on Experiential Learning/Hands-on training to meet the needs of stakeholders and also to make the students 'Job Providers rather Job Seekers'. Postgraduate course curricula revised in the light of recommendations of NCG (National Core Group) was also implemented w e f academic session 2010-11 to meet the national and global challenges. New courses contained substantial information on new and challenging topics such as nanotechnology, bioinformatics, biotechnology, precision/conservation agriculture, ICT-based agriculture, agri-business, IPR, Bio-diversity, bio-safety, environmental science, bio-diversity, bio-safety and IPR.
- Till now, 13 scientists of the University have been awarded national professorship/national fellowship of the ICAR. The PAU was sanctioned five Centres of Advanced Studies/Centres of Advanced Faculty Training and two Niche Areas of Excellence. Presently, two Centres of Advanced Faculty Training are operational, one each in the Department of Soil Science and Plant Breeding & Genetics and one Niche Area of Excellence is running in the Department of Soil Science.
- A number of scholarships/fellowships/awards have been made available for the benefit of the students of the University. Ph.D dissertations of 17 students from different disciplines (excluding those in the veterinary sciences) were awarded 'Jawaharlal Nehru Award' as recognition of excellence in doctorate research by the ICAR. In the first-ever Anveshan competition organized by All India Universities Association in 2009, the first position at the national level was won by the PG student of PAU. The University has filed three patents from the research done by PG students of the University.



Tissue culture laboratory in SAB



Transmission Electron Microscope in EMN lab.

- Electron Microscopy and Nanotechnology (EMN) laboratory was established in the year 2005 which is equipped with Transmission Electron Microscope (TEM), Scanning Electron Microscope (SEM), Energy Dispersive X-ray Spectroscopy (EDS), and Scanning Probe Microscope (SPM), Optical Upright Research Microscope, Ultracut Microtome and Cryo Attachment, and Ion Sputter Coater facilities. These facilities have greatly impacted the research by the university PG students and faculty apart from providing access to other stakeholders. A PG course in nanotechnology is also being offered by the university.

- As a measure to check in-breeding, avenues for collaboration in PG research were opened by signing various MoUs/Agreements with reputed national/international institutions/universities. Several PG students have conducted/are conducting their research in world class universities abroad in collaborative programmes such as Beachal-Baurlaug fellowships, Dr Hargobind Fellowship, Sandwich degree programme under AKI, Fulbright Fellowship. Recently, an agreement was inked with Washington State University (WSU) wherein in-service PAU faculty will have the opportunity to pursue their Ph.D programmes at WSU with waived off 'out-of-state fee'.
- To promote scientific understanding and awakening among students and faculty, the university has set up PAU Science Club. Under the aegis of this club, eminent scientists and educationists of national and international repute are invited for delivering talks on emerging topics of interest.
- Recognising excellence of the University in teaching, research and extension, the University was accredited by the ICAR in the year 2004 till 2009 and appreciating continuance of excellence by PAU, the accreditation was further extended.

Library

Named after Dr. Mohinder Singh Randhawa, a renowned administrator and the second Vice Chancellor of PAU, the university library caters to the informational needs of the academia of PAU. It plays a pivotal role in supporting ongoing research, study, teaching and extension activities of the university. The library, at present, has a collection of 3,83,937 documents along with subscription to 222 (158 Indian and 64 foreign journals) print journals, 8 online databases, 2 CD-ROM databases, 43 online journals and 51 e-books. However, campus wide access to 31,518 online journals through Consortium of e-Resources in Agriculture (CeRA) and J-Gate: Agricultural and Biological database is provided to the users. The documents available in the library include a rich collection of text books, reference books, periodicals, dissertations, project reports, newspapers and CDs. Library facilities have been updated to provide free access to online databases. The library has the following special features:

Museum of History of Agriculture: Thirteen paintings, made by an outstanding artist of Punjab, S. Jaswant Singh, are displayed. These relate to the important stages in the history of man and agriculture depicting growth of human civilization from the African ape man to the green revolution.

Hall of Fame: Seventeen portraits of eminent international scientists and administrators are displayed here. These scientists made significant contributions in the field of agriculture and were associated with the Punjab Agricultural University in its development.

Library Auditorium: Auditorium, with a seating capacity of 70, was established to facilitate the library users training programmes and other lectures. At present, keeping pace with the modern technologies, LCD projector with audio-video facility has also been added.

Research Carrels: Thirty-nine research carrels are available to the postgraduate students, research scholars and faculty members engaged in library oriented research work.

Text Book Section: The library has a rich textbook collection to assist the students for preparation of their examination. To strengthen the collection, the library also organizes book fairs from time to time in which publishers and vendors from all over India participate and display their publications.

Theses Section: All theses and dissertations submitted by the M.Sc. and Ph.D. students of PAU are housed in this Section for reference of the library users.

Dr. M. S. Randhawa Section: Rare documents authored by Padam Bhushan Dr. Mohinder Singh Randhawa and other artefacts donated by him are displayed.

Progressively, coping with the technological advancements and ever-growing demands of the users, the following features have been introduced recently:

Competitive Book Section: To keep pace with the competitive world, a section namely Competitive Books Section has been created. Documents relating to various competitive examinations like UPSC, ASRB NET, GMAT, IELTS, TOEFL, GRE, etc. are displayed in this Section.

Archives of PAU: To preserve the PAU publications, documents published and written by the PAU faculty are housed in this Section for future reference.

Saxena Reading Hall: This Wi-fi reading hall has been set up to extend service to the members where they are allowed to bring their personal books.

Multimedia Laboratory: This multimedia laboratory is equipped with multimedia resources and practice material required for IELTS/TOEFL/GMAT/GRE, etc. examinations.

Map Room: The geographical world maps are displayed in this Section to provide single platform access to the users.

ICAR Publications Corner: All the ICAR publications are of incredible significance for providing latest information of the ongoing national agricultural research. Thus, all such publications are housed separately for the speedy retrieval by the users.

Library Services

The library offers all traditional services to its members like reference service, Issue and Return, Registration of Members, Current Awareness Service, Selective Dissemination of Information Service, Photocopy Service, Abstracting Services, Indexing Services, etc. The last decade has been a period of continuous progress and achievements for the library despite of the recession in economy and consequential financial constraints. Perhaps, a commendable transformation of library facilities, operations and services was recorded to expand the use of information resources. The following services have been appended:

Digital Library

The Digital Library is well furnished and equipped in terms of infrastructure, e-resources and technical know-how to compete with the rapidly changing era of information technology. It provides access to all the e-resources subscribed by the library through three servers and fourteen computers. The digital library has also been extended to the first floor reading hall by installation of sixteen more computers. Library provides campus wide access to the following databases along with 43 online journals:

1. **Online Public Access Catalogue (OPAC):** OPAC helps the users to quickly access the library documents. Computers are placed at all floors of the library to facilitate the access.
2. **CD-ROM Databases:** Two abstracting databases (CAB Abstracts and Food Science & Technology Abstracts) provide bibliographic citation along with the abstracts of currently ongoing global research in machine-readable format.
3. **Online Databases :** The library has been equipped with the following on-line databases for easy access by the researchers :
 - **Consortium for e-resources in Agriculture (CeRA) :** This is the ICAR sponsored online database of full-text online journals, accessible to PAU fraternity.
 - **Krishiprabha:** Krishiprabha is an online database of full-text Indian Agricultural Doctoral Dissertations of all the State Agricultural Universities and agricultural research institutes from the year 2000 onwards.

- ***J-gate Agricultural & Biological Abstracts***: It is an electronic gateway to journal literature indexed from 28,574 e-journals with links to full text at publisher sites.
- ***Indiastat.com***: This online database provides statistical information about India upto block level. It is accessible from the Digital Library.
- ***My library***: It provides full-text access to 22 e-books published by CABI in the field of agriculture.
- ***CRCnetBASE***: It is a database of 12 online books published by Taylor & Francis in the field of agriculture and allied areas.
- ***EBSCOnetlibrary***: It is a database of 17 online books in agriculture and related subjects.
- ***ISO Standards on Food Products***: This online database provides to the standards in the field of Food Technology, Food Processing and Food Products.

These e-resources have strengthened the existing library base in supporting academic and research needs of PAU students, teachers, researchers and extension specialists. All the e-resources like online journals, e-books, OPAC and online databases are provided campus wide access to the users through library webpage. In addition, library webpage also acts as a platform of dissemination for various other e-resources like Open Access Dictionaries, Encyclopedias and online journals received free with print subscription.

User Orientation Programmes

In order to optimize the use of library services, the library organizes various training programmes for library users every year to help them to be better conversant with the library services. More emphasis is laid on the use of online resources in these training programmes.

Automated Library Operations

The library has automated its services and operations like registration of membership, cataloguing of books, journals & theses, issue and return of books, generation of bar codes & spine labels, catalogue of library holdings known as Library OPAC using Libsys4 (library management software).

Wi-fi Facility

The library became Wi-fi quite recently. This facility enabled the students, faculty, researchers and staff of PAU to use various online databases subscribed by the library as well as internet facility for academic purpose on their laptops.

Library Web Page

The library has its own web page through www.pau.edu which provides complete information about resources, rules & regulations, services, online literature, list of print journals, Directory of PAU Faculty, circulars and new additions to library. The web page is updated regularly.

Sports and Co-curricular Activities

The students of the constituent colleges have excelled in sports and other co-curricular activities under the Directorate of Students Welfare. The directorate is engaged with the task of providing boarding & lodging facilities to the students in hostels, maintaining discipline among hostel residents, directing programme of student – counseling, assisting in the placement of graduates and post-graduates of PAU through campus placement, maintaining contact with the alumni association of the university, supervising sports/extra - curricular activities of students, holding annual athletic meet, organizing PAU inter-college tournaments, preparing and sending teams for participation in North Zone/All India Intervarsity/ All India Agri-Varsity Tournaments, organizing annual NSO coaching camp, organizing PAU inter college youth festival, preparing and sending teams for participation in North Zone/All India

Intervarsity Youth Festival/All India Inter Agri Youth Festivals and promoting national service scheme by organizing NSS camps within PAU and at outstations.

Achievements in Sports

Participation in International Games

PAU has a unique history of producing Olympians and world cup players in hockey. Three alumni of the university namely Charanjit Singh, Prithipal Singh and Ramandeep Singh Grewal participated as Captain of the Indian hockey team in the Olympic games held in Tokyo (1964), Mexico (1968) and Sydney (2000), respectively. They were also members of the Indian hockey team that participated in Olympic games held in 1960, 1960 & 1964 and 1996, respectively. In the Asian games also, these three alumni were members of the medal winning Indian hockey team in 1962, 1962 & 1966 and 1998, respectively, while an other alumnus Rakesh Pattu participated in Equestrian in 2006. Similarly, Rajwinder Singh, Lata Mahajan and Ramandeep Singh Grewal participated in World Cup for hockey in 1971, 1976 and 1998, respectively, as members of the Indian hockey team. Twelve student alumni of PAU also represented India as a member of Combined University Hockey team against other countries like Germany, Japan, Australia during 1967 to 2008. Ramandeep Singh Grewal represented Indian hockey team in 34 International tournaments/series between 1994-2000. Yadwinder Singh Deol (2002) secured 1st position in Junior Asia Cup representing Indian hockey team.

Apart from hockey, PAU students also participated in other international events. Six students were members of the Indian teams for events like India-Sri Lanka Cycling Meet, International Handball Tournament, World Universiade, Commonwealth Club Championship, Partille Cup for handball held in different countries.

National Level Participation

Several students of the University, both boys and girls, have participated in various sports events at the national level and brought laurels to the institute. Thirty six students participated in hockey tournaments at senior level and 15 at junior level. In handball, 41 students participated in senior championships while 28 participated in junior championships. While nine students participated in athletics, six competed in shooting event at senior level. Apart from this, 57 students at senior level and 12 at junior level have also participated in other national games and events such as volleyball, basket ball, table tennis, wrestling, lawn tennis, swimming, kabaddi, cricket, badminton, weight lifting, cycling, chess and yoga.

North Zone/ All India Inter Varsity Championships (Team Games)

Hockey : PAU hockey team secured 2nd position in All India Inter Varsity Hockey (M) in 1979, 1980, 1999 and 3rd position in 1988 and 1991. The hockey team got 2nd position in North Zone Inter Varsity Hockey (M) Tournament a number of times viz. in 1971, 1973, 1975, 1978, 1982, 1988, 1989 and 1990. The team obtained 3rd position in North Zone Inter Varsity Hockey (M) in 1977, 1984, 1991, 1992 and 1999.

Handball : PAU handball team secured 1st position in the All India Inter Varsity Handball (M) in 1980, 1990, 1992, 2nd position in 1979, 1981, 1984 and 3rd position in 1989. It got 1st position in North Zone Inter Varsity Handball (M) in 1990, 1992 and 2nd position in 1991. Likewise, in 1980, 1981, 1983, 1984, the university team secured 2nd position in All India Inter Varsity Handball (W) and 2nd position in North Zone Inter Varsity Handball (W) in 1984 and 1987.

Lawn Tennis : Second position was secured by the PAU lawn tennis team in North Zone Inter Varsity Lawn Tennis (M) in 1980 and 3rd position in 2007.

Volleyball : The volleyball team secured 3rd position in North Zone Inter Varsity Volleyball (M) in 1989.

All India Inter Varsity Championships (Individual Events)

Cycling: Students of the University have secured top positions in inter varsity championships in 1979 (2nd position), 1983 (3rd position), , 1988 (2nd position), 1989 (3rd position), 1990 (1st position), 1992 (3rd position), 1994 (3rd position) and 1998 (3rd position).

Wrestling: One student obtained 2nd position in 1971 and three secured 3rd position during 1970,1971 and 1992.

Athletics: One student secured 1st position (Pole Vault), 2nd position (High Jump) during 1971, Bimi Singh secured 1st position (Shot Put) & 2nd position (Discus Throw) during 1998 & 1999.

Weightlifting: Two students secured 2nd position in 1981 and 2001, while one obtained 3rd position in 1988.

Swimming: One student secured 3rd position during 1977.

Boxing: One student secured 3rd position during 1984.

Shooting: One student secured 1st position during 2012.

All India Inter Agri Varsity Championships

PAU contingent won Overall Champion Trophy during All India Inter Agri Varsity Championships held in 2000, 2002, 2004, 2007,2008, 2009, 2010, 2011 and 2012 at different places.

Achievements in Cultural Activities

National Inter University Youth Festival

PAU alumni and students have won top positions several times in the national level cultural festivals as well held in various universities. One student secured 1st position in clay modeling in 1990 and folk dance team secured 3rd position in 1992. PAU team secured 3rd position in cultural procession in 1998 one student secured 1st position in Rangoli during 2006. PAU mime team secured 2nd position twice in 2010 and 2011.

North Zone Inter University Youth Festival

PAU students have also excelled in North Zone Inter University Youth Festivals by securing top positions in different cultural events. It is worth mentioning that the 1st position has been won in a number of events such as light vocal solo, instrumental western solo, quiz and cartooning (1985), on the spot painting & clay modeling (1989, 1999, 2001), collage making (1996), skit, and western solo (1998, 1999). PAU folk dance team & skit team secured 2nd position during 1995. Similarly, 2nd and 3rd positions have been secured many times by the students individually and in teams in various events as mentioned above and others like rangoli, western group song, folk dance, mimicry, debate and poster making.

All India Inter Agricultural Universities Youth Festival

PAU contingent secured overall trophy during 1999-2000, 2005-06, 2006-07 and Overall Runner up trophy during 2004-05. Likewise, the university won overall trophy in literary events during 2007 festival. In 2010, the team from PAU secured overall trophy in theatre & music events and also overall runner up trophy. Overall trophy was also secured in 2011 in music events.

RESEARCH ACHIEVEMENTS

AGRICULTURE

CROP IMPROVEMENT

Plant Breeding

Wheat and Barley

Wheat is the predominant grain crop in Punjab which is grown on an area of around 35 lakh hectares and occupies about 80 per cent of the total cropped area in the season. Punjab produces about 20 per cent of the wheat produced in the country from 12 per cent of the area under this crop. The state is food bowl of country which is testified by the fact that 40 to 60 percent of wheat to the national food reserves is made by Punjab alone. Taking 1965-66 as a base year, wheat yield has increased from 1.1 t/ha to 5.1 t/ha and production from 1.9 mt to 17.9 mt in the year 2011-12.

Since inception, PAU has developed 49 varieties of wheat which include 37 of bread wheat, 7 of durum and 5 of triticale. Eight barley varieties have been released during this period. Bread wheat varieties are recommended for timely sown irrigated conditions, late sown irrigated conditions and rainfed conditions. Durum wheat varieties are recommended for timely sown conditions whereas triticale varieties have been recommended for both timely and late sown irrigated conditions.

Bread Wheat

The bread wheat variety C 306 (1965) was the first variety released for Punjab after the establishment of the Punjab Agricultural University in 1962. It became very popular both in Punjab as well as in several other states of the country. Even today, it is being grown on considerable areas under rainfed conditions. Semi dwarf Mexican wheats were introduced to India in 1962. Of these Sonora 64 and Lerma Rojo 64 which outyielded Indian check varieties by 30% were approved by Central Variety Release Committee (CVRC) during 1965. The variety Sonora 64 proved unsuitable for cultivation in Punjab because of its susceptibility to yellow rust. Lerma Rojo 64 was well received. Subsequent selections from advanced generation material (613) received from CIMMYT, Mexico in 1963 led to the development of landmark varieties like PV 18, Kalyansona and Sonalika, which were released respectively in 1966, 1967 and 1968, and revolutionized wheat production in India. Kalyansona, the amber grained Mexican wheat became very popular. It had largest acreage under any single variety at that time. Sonalika was an early maturing variety especially suitable for late sown conditions. A semi-dwarf variety WG 357 with excellent chapati making quality introgressed from tall traditional wheat was released in 1971.



Wheat variety PBW 343

Wheat variety PBW 621

Another landmark achievement in wheat improvement was the development and release of WL 711 variety of bread wheat in 1976. It was officially recommended in Punjab, Haryana, U.P., Rajasthan and Delhi. It was also recommended in Pakistan. WL 711 was followed by other widely cultivated varieties recommended in the NWPZ viz., PBW 154 and HD 2329. PBW 154 had very good *chapati* making quality. HD 2329 remained the most predominant variety from 1984 to 1994 and occupied about three fourth of total wheat area. For rainfed conditions,

loose smut resistant variety WL 410 and excellent grain quality variety PBW 175 came to be grown over large areas.

Another significant yield jump came with germplasm derived from winter wheat x spring wheat crosses- a strategy initiated at CIMMYT in the 1970s. Bread wheat variety PBW 343 released for timely sown irrigated conditions in 1995 is the most successful representative of this strategy. An Attila sib line which entered into coordinated testing as PBW 343, was subsequently identified by the All India Wheat Research Workers Workshop in 1994 and released for general cultivation in the entire North Western Plains Zone including Punjab in 1995. PBW 343 has acquired the status of a landmark variety on account of its wide cultivation for more than a decade. PBW 343 produces higher number of grains per square meter, is photosynthetically more active and keeps its canopy cool on account of higher stomatal conductance. It also exhibited a higher level of tolerance to drought and heat stress resulting in greater stability of production even when grown primarily under irrigated conditions. It has a strong crown root system and was lodging tolerant. Soon it was recognized as the new miracle genotype and a suitable replacement for the previous ruling cultivar, HD 2329, which had succumbed to new race of stripe rust. PBW 343 went on to become the highest yielding variety in the country and was ranked first in All India Coordinated wheat varietal trials for eight consecutive years from 1991-92 onwards. Since its release in 1995, the area under PBW 343 increased from 9.09 per cent in 1996-97, to 46.39 per cent in 1997-98 and further to 79.47 per cent in 1998-99. This tremendous popularity in a short time span is a unique example in the history of wheat improvement in the state. The predominance of this high yielding remarkable variety has played a key role in increasing wheat production in the state as well as in adjoining states. An estimate of economic benefit of PBW 343 to Punjab state is given in Table 1.

Table 1. Estimated additional economic benefit from PBW 343 in the first five years of its cultivation in Punjab

Year	Area under PBW 343 (lakh ha)	Additional wheat production* (lakh tones)	Minimum support price (Rs/quintal)	Additional benefit (Rs in crore)
1996-97	2.94	1.6	380	62.5
1997-98	15.31	8.6	475	407.2
1998-99	26.53	14.9	510	757.6
1999-00	29.37	16.4	550	904.5
2000-01	29.83	16.7	580	969.0
1996-97 to 2000-01	-	-	-	3100.8

*@ 5.6 q/ha average yield margin of PBW 343 over HD 2329

With PBW 343 succumbing to both stripe and leaf rust, a set of new high yielding cultivars for timely sown conditions of North western Plains Zone such as HD2967, PBW 621, PBW 550 and DBW 17 have been released. Within the state, the current varietal spectrum represents a transition from PBW 343 to the next set of varieties. The combined area under PBW 550 and DBW 17 cultivars is now about 40% of wheat acreage. PBW 621, a new bread wheat variety, has been released and is now at the farm-gate. HD 2967 (bread wheat), already identified at the national level, under timely sown-irrigated conditions. Area under the two new varieties PBW 621 and HD 2967 was about 6% each in 2011-12 and is expected to expand rapidly.

Varieties for Rainfed Late Sown Conditions

In the Wheat Section of Department of Plant Breeding and Genetics, a part of the varietal development program is devoted to rainfed (drought) and late sown (terminal heat stress) environments under the All India Coordinated Wheat and Barley Improvement Project. Several varieties have been released for these two agro-climatic situations. Currently PBW 175 , PBW 527 and PBW 644 are recommended for rainfed conditions and

PBW 373, PBW 509 and PBW 590 for late sown conditions in the zone. PBW 596 has been recommended for timely sown restricted irrigation conditions of Peninsular Zone. Restricted irrigation trials have become a regular feature of coordinated trials with the aim to reduce water use without sacrificing productivity.

Durum Wheat

In order to impart diversification in wheat cultivation, varietal improvement work on durum wheat was initiated in PAU during 1973-74. DWL 5023 was the first semi dwarf durum wheat variety released in 1980 in North Western India. The traditional durums had become highly susceptible to stripe rust and gone out of cultivation. With the release of this variety durum wheat cultivation restarted in Punjab after a lapse of about 40 years. DWL 5023 demonstrated the yield potential and adaptation of semi-dwarf durum wheats but suffered from yellow berry, the soft grain problem. The next durum wheat release, PBW 34, took care of this problem. PBW 34 created two distinct regional niches in Punjab—one in the Majha tract of Gurdaspur and Amritsar and a larger pocket around Khanna, the town with the largest grain market in Asia. By early 1990s durum wheats came to occupy about 8% of the wheat acreage. Private traders at Khanna grain market started offering a small bonus price for durum wheats. The increase in acreage was, however largely in response to a yield advantage enjoyed by durum wheats (over prevailing bread genotypes such as HD 2329) when they were planted early (last week of October) on high fertility soils. With increase in adoption of durum wheats in the state the focus shifted to quality. It was felt, that in spite of being a surplus state it was very hard to export bread wheat due to shortfall in processing quality (bread quality) and the quarantine issues related to Karnal bunt problem. Durum wheat was promoted as an export-oriented crop. This was well supported by release of two high quality durum wheats – PDW 215 and PDW 233. PDW 233 was in fact recognized as the best quality durum of the country, which excelled not only for grain characters but also possessed high gluten strength and caretenoid content. PDW 233 met the international quality standards, but exports failed to take off due to several reasons. In the late 1990s area under durum wheat in the state declined, primarily due to advent of long duration, high yielding bread wheat cultivars like PBW 343, which were capable of capitalizing on the early planting-conferred yield advantage. The loss of acreage could not be reversed despite excellent subsequent releases such as PDW 274 and PDW 291, mainly due to lack of market incentives.

Triticale

The promise of triticale lies in combining the favorable features of the two parents-wheat and rye. The rye parent does not have processing attributes of wheat and cannot be used for making *chapati* or normal bread. However it has high nutritional quality, besides resistance to diseases and abiotic stresses. Research efforts on triticale have been directed towards bringing triticale into the ambit of cultivated crops of the State. With this objective triticales with hard textured, amber coloured grains have been developed, thus creating an altogether new germplasm (Initially triticales were almost exclusively red and soft grained). The first variety to be released by PAU was TL 419 in 1981 for timely sown irrigated conditions in the state. Another variety TL1210 was released for late sown irrigated conditions in 1986. A new variety of triticale TL 2908 was released during the year 2004 for timely sown irrigated conditions of the state. This variety has bold and amber grains besides high yield and resistance against almost all the diseases and major insect pests. All the production and protection practices for triticale are similar to that of wheat. Triticale has been adopted by a few dairy and poultry farmers in Punjab but the scale of adoption is too small to have an impact in terms of diversification of the cropping pattern. Two triticale varieties developed by the department TL 2942 and TL 2969 have been released for North Hill Zone of the country. Information about varieties of wheat and triticale released by PAU is given in Table 2.

Table 2. List of varieties of wheat and triticale released by PAU for cultivation

S.No	Variety	Year of release	Yield (q/ha)	Parentage	Salient features
1.	Lerma Rojo 64	1964	45.00	(YAQUI50-NORIN10) BREVER x LERMA52/ LERMA ²	Red grained variety for timely sown irrigated conditions
2.	Sonora 64	1964	45.00	(YT54 X NOB) Y54 ²	Red grained variety for timely sown irrigated conditions
3.	C 306	1965	25.00	Regent1974/3*CHZ//2* C591/3819/C281	Excellent grain quality bread wheat variety recommended for timely sown-irrigated and rainfed conditions
4.	PV 18	1966	45.00	Sister line of Kalyan Sona	Red grained variety for timely sown irrigated conditions
5.	Kalyan Sona	1967	44.00	FRONTANA/KENYA 58 // New Thatcher/3/ NORINO BREVOR/ 4/GAB055	Amber grained variety for timely sown irrigated conditions
6.	Sonalika	1968	42.50	II 54.388/AN/3/YT 54/N10B/LR 64	Early maturing, bold and amber grained variety for timely sown irrigated conditions
7.	WG 357	1971	46.25	PV 18/C273	Excellent <i>chapatti</i> making quality variety for timely sown irrigated conditions
8.	WG 377	1972	46.25	(WG143/USA255)*PV18	Early maturing and high yielding variety recommended under timely sown irrigated conditions in South West districts of Punjab
9.	HD 2009	1976	50.00	LERMA ROJO 64 A/ NAINARI 60	High yielding variety with mottled grains, recommended for timely sown irrigated conditions
10.	WL 711	1976	53.00	NP/TOB'S'/3/8156 //KAL/BB	Very high yielding, semi dwarf variety for timely sown irrigated conditions
11.	KSML3	1977	25.00	ML 253 RON-CHA* KALNOR67 ML 265 (CNOSON-KL.REND)* KAL ² ML277GTO-KAL* BBCNO	First multiline recommended for North West India Extensively grown in foothills of H.P.
12.	WL410	1978	49.00	SONORA 63/ S 326 // KALYAN	Loose smut resistant variety recommended for North West India under timely sown irrigated conditions
13.	WL 1562	1979	49.00	KALYAN/ JUSTIN //UP 301	Excellent grain and chapatti making quality; resistant to Karnal bunt, recommended for timely sown conditions
14.	DWL 5023	1980	53.00	CRANE'S'/LANGDON'S' //GAJRAR'S'	First semi dwarf durum wheat for North-West India; resistant to loose smut and Karnal bunt , recommended for timely sown irrigated conditions
15.	TL 419	1981	51.00	ARS/KLA	First triticale variety released in the country for timely sown irrigated conditions
16.	PBW 12	1982	53.00	CNO-GALLO/WL 711	High yielding red grained variety for timely sown irrigated conditions
17.	TL1210	1982	45.00	CINNAMON/RAJ 821 //IN 19- Turkey 602/ 3/ AYMC	Early maturing triticale recommended for late sown irrigated conditions
18.	WL 2265	1982	33.50	NAPO/TOB'S'//8156 //3KAL/BB	Semi-dwarf variety recommended for timely sown irrigated conditions of North West India
19.	HD 2285	1982	43.50	HD 1918/HD 1592/3/HD 1962//E4870/K65/4/HD 2160/5/HD2180	Short duration variety recommended under late sown irrigated conditions
20.	PBW 54	1983	53.00	HD 2160/WG 377	High yielding recommended for timely

21.	SKAML 1	1983	42.50	C-20(BONZA55ML 212) *(KAL-HD1960) C-21-NOR 67- CNO*SKA ² C22-LR64-NA 160*SKA ² C23-CNO-INIA* SKA ² C24-GTOKAL *SKA ² C25E6006*SKA ² C26 BB-GALLO*SKA ²	sown-irrigated conditions Short duration variety recommended for timely sown-irrigated
22.	PBW 34	1985	55.00	AA'S'/FGO'S'	Durum wheat variety recommended under timely sown irrigated conditions in the entire North-west India
23.	PBW 138	1985	47.00	RAVI43/HD 2177	Early maturing, resistant to loose smut and suitable for late sown irrigated conditions
24.	HD 2329	1985	53.00	HD1962//E4870/K65/ 3/HD 1553/UP 262	Most widely grown bread wheat under timely sown-irrigated conditions
25.	PBW 120	1985	55.00	WG 377/HD2160	Karnal bunt resistant variety recommended for timely sown irrigated conditions
26.	PBW 65	1985	35.00	USA 255/K 816//WL202	Bread wheat variety with multiple resistance to rusts, loose smut and Karnal bunt, recommended for timely sown rainfed conditions in entire North-West India
27.	PBW 154	1987	53.00	HD2160/HD2177	High yielding and excellent grains; resistant to Karnal bunt; recommended for timely sown irrigated conditions of entire North-West India
28.	PBW 175	1987	36.25	HD 2160/WG1025	Drought tolerant, recommended for timely sown rainfed conditions
29.	PBW 226	1989	47.00	WG138/JUSTIN// CHRIS/HD1941	Short duration , recommended for North-western Plains Zone
30.	PBW 222	1990	53.00	NP 890/HD2160	High yielding dwarf variety for timely sown irrigated conditions
31.	PDW 215	1990	55.00	DWL5031/DWL 5002	Semi-dwarf durum wheat with high quality grains for export purpose
32.	CPAN 3004	1991	53.00	GLL/AUSTII-61-157// CNO67/NO/3/VEE'S'	High yielding, recommended under timely sown-irrigated conditions
33.	PBW 299	1991	36.25	BLUEBIRD/KALYAN //WL711/PBW65	Recommended under timely sown-rainfed conditions of Punjab and North-Western Plains Zone of India
34.	WH 542	1993	55.00	JUPATECO/BLUEJAY //URES	Long duration , high yield potential variety; recommended under timely sown irrigated conditions
35.	PBW 343	1995	56.00	ND/VG9144//KAL/BB/3 /YACO'S'/4/VEE5'S'	High yielding variety with wider adaptation; occupied maximum acreage during its peak cultivation
36.	PDW 233	1995	55.00	YAV'S'/TEZ'S'	Semi dwarf durum with high yield potential, high carotene, excellent pasta making quality and suitable for export; recommended for timely sown irrigated conditions
37.	PBW 373	1996	42.50	ND/VG9144//KAL/BB /3/YACO'S'/4/VEE5'S'	High yield potential under late sown irrigated conditions
38.	Raj 3765	1996	46.00	HD 2402/VL 639	Recommended for late sown-irrigated conditions
39.	PBW 396	1998	37.00	CNO67/MFD// MON'S'/3/SERI	Timely sown rainfed conditions
40.	PDW 274	2001	52.50	DWL 6018/KARPASIA	Durum wheat variety with bold grains and suitable for pasta was recommended for timely sown irrigated conditions of Punjab
41.	PBW 502	2004	51.00	W 485//PBW343 /RAJ 1482	High yielding variety recommended for timely sown-irrigated conditions
42.	PBW 509	2004	39.50	W 1634/PBW 381	Recommended for late sown-irrigated conditions
43.	TL 2908	2004	41.00	TL 2614/JNIT 141	Amber coloured triticale variety recommended for timely sown-irrigated conditions

44.	PBW 527	2005	34.25	PBW 175/PBW 389	Recommended for timely sown-rainfed conditions
45.	PDW 291	2005	48.50	BOOMER21/MOJO2	High yielding durum wheat variety, recommended for timely sown irrigated conditions
46.	PBW 550	2007	52.00	WH 594/RAJ 3856 //W 485	High yielding , short duration, dwarf and bold grained variety; recommended for timely sown irrigated conditions of Punjab
47.	DBW 17	2008	52.20	CMH 79A.95/3*CNO 79// RAJ 3777	Dwarf, high yielding, susceptible to stripe rust, recommended under timely sown irrigated conditions of North Western Plains Zone of India
48.	PBW 590	2009	41.00	WH 594/RAJ 3814 //W 485	Dwarf, better grain quality, high yield under late sown irrigated conditions
49.	PDW 314 (at national level only)	2010	48.00	AJAIA12/F3LOCAL (SEL.ETHIO.135.85)// PLATA13/3/SOMAI3/4/ SOOTY9/RASCON37	Dwarf, stay green habit, suitable for past products, recommended for timely sown irrigated conditions
50.	PBW 621	2011	52.80	KAUZ//ALTAR84/ AOS/3/MILAN/KAUZ /4/HUITES	High yielding, tolerant to stripe rust, bread wheat variety recommended under timely sown conditions of the entire North Western Plains Zone of India
51.	HD 2967	2011	53.50	ALD/CUC//URES/ HD 216 OM/HD 2278	High yielding, tolerant to stripe rust, bread wheat variety recommended under timely sown conditions of the entire North Western Plains Zone of India
52.	WHD 943	2011	49.50	GLARE/PLATA-16// AJAIA-3/SILVER16	High yielding durum wheat variety recommended for timely sown irrigated conditions
53.	PBW 644	2011	-	PBW 175/HD 2643	Recommendation for timely sown-rainfed conditions

Barley

Barley (*Hordeum vulgare*) is an important *rabi* crop grown on an area about 12000 ha in the Punjab state whose acreage has decreased over the years with the spread of wheat-rice rotation. Work on Barley was initially carried out at national as well as University level independently of wheat. With the shifting of Directorate of Wheat Research to Karnal, barley and wheat were brought under a common coordinated project, referred to as All India Coordinated Wheat and Barley Improvement Programme (AICW&BIP). Initial work on barley was on feed varieties whereas now more emphasis is being laid on the development of malt barley. In Punjab, barley is generally cultivated on marginal lands and in soils with inadequate irrigation facilities because of its ability to thrive well in drought conditions. Barley can be efficiently used as human food, cattle feed and industrial raw material. It fits well in the different crop rotations particularly after cotton in the south-western tract of Punjab state due to its short duration (130-140 days). It gives good returns to the farmers with limited irrigation facilities and in poor soils or marginal lands as compared to wheat. The list of barley varieties released for cultivation in the state is given in Table 3. The university has developed very good feed barley varieties like PL 426 and PL 172 for irrigated conditions and PL 419 for rainfed conditions. Though the variety PL 426 was very popular among the farmers particularly in the south-western tract of Punjab, but it has become susceptible to leaf blight and yellow rust. A new feed barley variety, PL 807 was therefore released for general cultivation. It has fair degree of resistance to yellow rust, brown rust and leaf blight diseases.

The PAU has run a collaborative project with United Breweries Ltd, Patiala for the development of high yielding barley varieties suitable for malt purpose. As a result of this collaboration two malt barley two-rowed varieties namely VJM 201 and DWRUB 52 have been released for the farmers of Punjab state. These varieties are specifically bred for malt industry and meet almost all the malt quality standards. Malt industry is undertaking contract farming of these varieties in Punjab state and paying a price equivalent to wheat to the farmers. The variety DWRUB 52 has high yield potential and is becoming popular among the farmers of Punjab.

Table 3. List of varieties of barley released by PAU for cultivation

S.No	Variety	Year of release	Yield (q/ha)	Parentage	Salient features
1	DL70	1974	37.50	BG1/MEX 5-13	High yielding, non-lodging resistant to yellow rust, recommended for irrigated areas. Mature in about 128 days.
2	PL56	1975	30.00	Mutant of C 104	Tall plants with upright broad leaves and colourless sheaths, resistant to yellow rust, recommended for rainfed areas. Matures in about 132 days.
3	PL172	1984	45.0	RD178/DW472	Stiff strawed variety; purple coloured leaf sheath, ears uniform, drooping at maturity, grains with thin husk. Matures in about 132 days.
4	PL426	1994	47.75	KARAN92/PL101	Stiff-stemmed, highly resistant to lodging and diseases; ear compact, grains bold and thin husked. Matures in about 124 days.
5	PL419	1995	40.00	PL101/BH182	Dwarf variety with upright leaves, bold and thin husked grains is recommended for rainfed area. Matures in about 130 days.
6	VJM201	2005	37.00	1-89-666/CLIPPER /NATASHA	Two rowed, narrow and upright leaves, medium tall, less lodging, dense ears; grains bold and thin husk; fairly, resistant to yellow rust, brown rust, loose smut and stripe disease. Matures in about 135 days
7	PL751	2007	46.80	K266/PL426	Six-rowed, short statured with dense ears; resistant to stem rust and tolerant to leaf blight. Matures in about 107 days. Recommended for Central Zone of India.
8	DWRUB52	2008	44.30	DWR17/K551	Two rowed barley variety with narrow and upright leaves, less lodging, grains bold and thin husk; fairly resistant to yellow rust, brown rust, loose smut and other diseases. Mature in about 140 days
9	PL807	2009	43.04	LENT/BLLU//PINON	Semi-dwarf and stiff-stemmed feed barley variety with dark green erect leave, highly resistant to lodging; fairly resistant to yellow and brown rusts and leaf blight. Mature in about 135 days

Rice

Indian Punjab, which is traditionally not a rice-growing region, has made tremendous progress in rice productivity and production during the past 45 years. Prior to 1965, only tall varieties of Basmati and 'Jhona' were grown. During 1965-66, 0.29 million hectares were planted under rice, which produced 0.29 million tones, with productivity of just 1.0 t/ha. However, during 2010-11, rice occupied an area of 2.8 million hectares, with a total production of 11.24 million tones and productivity of 4.0 tones per hectare. The increased production was made possible by a 9-fold increase in area under rice and a 4-fold increase in productivity per unit area. In rice, productivity of Punjab ranks first in the country. The increased productivity, in turn, resulted from development and release of high yielding varieties by the Punjab Agricultural University and from improved production and protection technologies that were popularized among hard working and technology savvy farmers of Punjab. The productivity of rice in the state is comparable to China (Fig.4). The advent and adoption of semi-dwarf, high yielding varieties, along with matching production and protection technologies, have made Punjab a major contributor of rice to the central pool of food grain in the country. The average contribution of rice from Punjab state to the central pool is around 30%, the highest being 60% in 1979-80.



Fig.4. Rice productivity in Punjab and other regions

Since its inception, PAU has released 31 rice varieties (Table 4) which included 21 non-basmati and 10 basmati/aromatic rice types. Since 1994, this center has developed 10 varieties of rice viz., PR 111, PR 113, PR 114, PR 115, PR 116, PR 118, PAU 201, Punjab Basmati 2, PR 120 and Punjab Mehak 1. All these varieties, except Punjab Basmati 2, possess genetic resistance against bacterial blight. The variety PAU 201 also possesses moderate level of resistance against white backed plant hopper. Release of fine grained non-basmati type varieties was a significant landmark as it heralded the era of bacterial blight resistant varieties. It is worth mentioning that as a result of release and cultivation of bacterial blight resistant varieties there had been no epidemic of bacterial blight disease in the state for the last more than two decades.

Table 4. List of varieties of rice released by PAU for cultivation

S.No	Variety	Year of release	Yield (q/ha)	Parentage	Salient features
Coarse grain varieties					
1.	TN 1	1966	4000	Dee-geo-woo-gen/ Tsai Yuan Chung	First semi-dwarf, high yielding variety
2.	Jhona 351	1967	5000	Pure line selection	High yielding variety with heavy panicles
3.	IR 8	1968	6500	Peta/ Dee-geo-woo-gen	First popular semi-dwarf, high yielding coarse grain variety
4.	Jaya	1971	6500	TN 1/ T 141	High yielding popular coarse grain variety
5.	HM 95	1972	4000	Jhona 349/ TN 1 (F ₂ seed irradiated)	Very early maturing variety
6.	PR 113	1998	7000	IR 8//RP 2151-173-1 8/IR8* ⁴	First coarse grain variety resistant to bacterial blight
Non-basmati fine grain varieties					
7.	Palman 579	1972	5200	IR 8/ Tadukan	Short duration, good quality rice variety
8.	RP 5-3(Sona)	1972	6000	GEB 24/TN 1	Good quality fine grains, high yielding
9.	PR 106	1976	6500	IR8//Peta* ⁵ /Belle Patna	Medium maturity, long slender grains, high yield
10.	PR 103	1978	5500	IR 8/IR 127-2-2	Early maturing (125 days) long slender grains, high yielding variety
11.	PR 4141	1982	6000	IR 8/BJ 1// IR 22	Resistant to bacterial blight
12.	PR 108	1986	6625	Vijaya/Ptb21	Tolerant to white backed plant hopper and sheath blight
13.	PR 109	1986	6500	IR 19660-73-4/IR 2415- 90-90-4-3-2//IR 54	Resistant to bacterial blight and tolerant to white backed plant hopper
14.	PR 110	1992	6500	TN1/Patong 32//PR 106* ⁶	High yielding semi dwarf bacterial blight resistant, long slender grains
15.	PR 111	1994	6750	IR 54/PR 106	High yielding semi dwarf bacterial blight resistant, long slender grains
16.	PR 114	1999	6875	TN1/Patong 32//PR 106* ⁴ //IR8	High yielding bacterial blight resistant, long slender grains
17.	PR 115	2000	6250	RP2151-173-1-8/ PR 103* ³	Early maturing (125 days) long slender grains, erect flag leaves bacterial blight resistance
18.	PR 116	2000	7000	PR108//TN1/Patong32 //PR106* ⁶ //PR108	Long slender grains, sturdy plant bacterial blight resistant
19.	PR 118	2003	7250	Pusa 44/PR 110// Pusa 44* ³	Medium slender grains, resistant to bacterial blight
20.	PAU 201	2007	7500	PR 103/PAU 1126	High yielding, long slender grains, bacterial blight resistant, moderately resistant to white backed plant hopper
21.	PR 120	2009	7133	PAU 1196/SR817-255 grains, mid-early maturity	High yielding, bacterial blight resistant, long slender grains, mid-early maturity
Basmati/aromatic rice varieties					
22.	Basmati 217	1962	5750	PureLine Selection	Semi-erect plants, panicles medium long, semi compact. Grains medium long and thin.

23.	Punjab Basmati No.1	1982	4000	Sona /Basmati 370	First improved variety of basmati
24.	Pusa Bas 1	1990	4000	Pusa 150/ Karnal Local	Semi-dwarf, high yielding
25.	Bas. 385	1992	3700	Introduction from Pakistan	High yielding and high quality basmati rice variety
26.	Bas. 386	1994	2875	Selection from Pakistan Basmati	Extra long grains, good cooking quality with strong aroma
27.	Super Basmati*	2003	3500	Basmati 320/IR 661	Extra long grains, good cooking quality with strong aroma
28.	Pusa Sugandh 2	2004	4630	Pusa 1238-1/Pusa 1238-81-6	Extra long grains, high yield, good cooking quality and aroma.
29.	Punjab Basmati 2	2007	3152	Basmati 386/ Super Basmati	Extra long grains, bacterial blight resistant, good cooking quality with strong aroma
30.	Pusa 1121	2008	3425	Pusa 614-1-2/P 614-2-4-3	Extra long slender grains with longest cooked rice
31.	Punjab Mehak 1	2009	4248	IR70423-170-2-3/IR 70446-85-3-2//IR 70423-170-2-3	Extra long grains, good cooking quality with strong aroma

Also recommended is Basmati 370 released in 1933. *Withdrawn since less acceptability/area under cultivation in Punjab state.

PAU 201 variety of rice, released by PAU in the year 2007, is a very high yielding variety surpassing the existing varieties by 10-15% in grain yield. It also matures in about 15-20 days earlier than Pusa 44 and other varieties released during last one decade. Since its release, no other new line out yielded this variety in terms of grain production per unit time. Thus it not only has the potential to increase average state paddy production by about 10% but also saves considerable amount of water. This variety also out yields all other lines when planted under aerobic (dry direct seeded) conditions. Apart from very high yield, PAU 201 is resistant to most of the pathotypes of Bacterial Blight disease of rice and is moderately resistant to white backed plant hopper. Therefore, it requires less application of insecticides and is thus environment friendly. PAU 201 is fast spreading in other states. There was demand of 92 quintals of Breeder seed of this variety from the states of Bihar, Uttar Pradesh, Uttrakhand, NGOs and private seed agencies which is highest of any other variety so far requested from Punjab. Similarly, PR 120 is a mid-early maturing variety with high yield, long slender grains and resistance to most of the pathotypes of bacterial blight pathogen prevalent in the state.

Both these varieties, however, suffered due to red aleurone color. This trait is genetic and red grain is considered better in quality compared to white grains due to presence of phenolic compounds like proanthocyanidins and flavonols which act as anti-oxidants. The biochemical analysis of brown rice of paddy varieties PAU 201, PR 120, PR 114 and Pusa 44 revealed that the varieties PAU 201 and PR 120 which have deep brown aleurone layer as compared to PR 114 and Pusa 44 possessed higher activity of anti-oxidative enzymes like peroxidase, superoxide, dismutase catalase. The rice varieties PAU 201 and PR 120 possessed higher content of flavonol, proanthocyanidins, total phenols and ascorbate as compared with non-brown varieties (Table 5).

Table 5. Biochemical composition of brown rice of different rice varieties

Phenols/antioxidative enzymes	PAU 201	PR 120	PR 114	Pusa 44
Total Phenols (mg g ⁻¹)	1.53	1.04	0.64	0.60
Flavonol content (mg g ⁻¹)	1.49	0.87	0.51	0.47
Proanthocyanidin content (mg g ⁻¹)	0.44	0.29	0.13	0.11
Peroxidase activity (3% A min ⁻¹ gm ⁻¹)	2.11	1.53	1.24	1.04
Superoxide dismutase activity (min ⁻¹ gm ⁻¹)	83.99	94.88	44.92	45.74
Catalase activity (μ moles of H ₂ O ₂ decomposed min ⁻¹ gm ⁻¹)	1539.61	1813.56	1337.43	1134.49
Ascorbate content (μ moles gm ⁻¹)	0.29	0.31	0.13	0.07

Development of new rice varieties/breeding materials

During the last five years (2007-2011), 2100 crosses were attempted and their subsequent generations were raised for developing high yielding rice breeding materials of varying growth durations possessing lodging tolerance, multiple resistance and good grain quality. Forty eight entries were nominated by PAU, Ludhiana in the different AICRIP trials, out of which 13 were identified as resistant donors against various diseases and insect pests. The resistance genes for bacterial blight have been transferred in different high yielding backgrounds. As a result of these efforts, many promising rice strains possessing high yield, resistance against all the 10 prevalent pathotypes of BB pathogen, good grain quality and suitable growth duration are in advance stages of testing. During kharif 2012, two new non-basmati rice genotypes RYT 3129 and RYT 3240 are being tested in adaptive trials at farmers' fields. Both these genotypes possess three bacterial blight resistance genes (Xa4+Xa13+Xa21) and are resistance to all the 10 pathotypes of bacterial blight pathogen (*Xanthomonas oryzae* pv. *Oryzae*) prevalent in the state.

Improvement of traditional Basmati varieties of rice

Besides agro-ecological factors, consumers' quality preferences have also played an important role in the evolution of rice and its genetic differentiation into distinct varietal groups. One such varietal group in the Indian subcontinent is the 'Basmati rice'. Basmati rice varieties which are cultivated in the foothills of Himalayas in the north- western parts of Indian sub-continent are characterized by unique quality features- pleasant aroma, long slender grains with delicate curvature, remarkable linear elongation, minimum breadth wise swelling combined with excellent flaky soft texture on cooking. This scented rice is popular in Asia and has gained wider acceptance in Europe and United States. Basmati rice fetches a preferential price treatment both in domestic and international markets. Basmati rice is grown in restricted regions in the states of Punjab, Haryana and Uttar Pradesh in India and the average holding size in these regions is small.

Varietal improvement of basmati rice was initiated in 1932 at Kala Shah Kaku in erstwhile Punjab (Now in Pakistan). Earlier, efforts were made to develop varieties through pure line selection from available land races/cultivars. At Kala Shah Kaku, Basmati 370 was selected and released by Late Sardar Mohammad Khan in 1933. Basmati 370 proved to be the most valuable traditional quality rice, which became a standard variety for export in this category and brought export boom in both Pakistan and India. Pakistan basmati was also selected and released by the same station in 1968. With the introduction of dwarfing genes in the early sixties, the rice variety development programme made spectacle gains in productivity. Main emphasis was on increased productivity. Basmati 217 was one of the first traditional basmati rice varieties developed by pure line selection at Rice Research Station (PAU) at Kapurthala in 1962 followed by Punjab Bas.1 in 1982, Basmati 385 in 1992 and Basmati 386 in 1994.

In 2008, two new basmati cultivars 'Pusa 1121' and 'Punjab Basmati 2' with extra-long, slender, aromatic grains and excellent cooking and eating qualities were recommended for cultivation in the state. The 'Punjab Basmati 2', a cross between 'Basmati 386' and Super Basmati', is 125 cm tall and is weakly photoperiod-sensitive. Grains of this cultivar are strongly scented. Grains almost become double after cooking, are non-sticky and soft to eat. This cultivar matures in about 140 days after seeding. Its mean yield is 3.2 tones of paddy per hectare.

The state of Punjab, that produces about 10.0 million tones of rice annually, is facing an acute ground water shortage due to intensive rice cultivation. Basmati rice, generally planted late in the season (that coincides with the onset of Monsoon) requires relatively less water than the *indica* rice varieties grown early in the season. Area and production of basmati rice in Punjab had been highly fluctuating in the past but for the last three years it has registered a continuous increase. India has been a traditional exporter of high quality basmati rice and earning foreign exchange. In the year 1990-91, India exported 2.32 lakh metric tones of basmati rice worth Rs. 294 crores. During 2010-11 the export of basmati rice rose to 27.37 lakh metric tones and India earned Rs. 12957 crores. So there was more than 11 times increase in basmati rice exports and more than 43 times increase in foreign earnings from basmati exports. Its importance increased with the country becoming self-sufficient in food grains.

The farmers in Punjab are encouraged to put more and more area under basmati to increase their returns. At present more than 87% of basmati rice is being exported to Gulf countries and Pusa 1121 constitutes the major chunk of it. The exports to the European Union has seen decline during the recent past. As the basmati rice in this part of the continent is being grown since times immemorial, so, keeping the geographical indications in mind we should promote the cultivation of basmati varieties especially Punjab Basmati 2 and other traditional ones which command a special status in the European market. Concerted efforts have been made to improve the traditional basmati varieties Basmati 370 and Basmati 386 through the use of molecular markers linked to disease resistance, aroma and dwarfing genes. The seeds of improved versions of Bas 370 and Bas 386 are being multiplied for their large scale testing. RYT 3267, a bacterial blight resistant (Xa13+Xa21) and dwarfing version of Basmati 386 is being tested in adaptive trials at farmers' fields during kharif 2012. These varieties will help in recapturing the European basmati market.

Development of water use efficient rice varieties

Work on dry direct seeded rice was initiated at PAU, Ludhiana in the year 2004 and germplasm was screened under aerobic conditions to assess the variability. Under the project entitled 'Enhancing water use efficiency and productivity in rice and basmati through molecular interventions' funded by DBT 2007-2010 three recombinant inbred lines (RIL) populations were developed from three promising crosses viz. PAU 3116/ CT 6510-24-1-2; PR 120/UPLRi7 and PR 115/ CRR 615-PR-27699-D-808-4-4 with a current population size of 228 F₈, 194 F₈ and 378 F₇ lines respectively. Some lines bulked from these crosses were evaluated in initial aerobic trials in 2011 & 2012.

Efforts are being made to develop an ideal plant type for aerobic conditions with suitable growth duration, grain quality and multiple biotic and abiotic stress resistance so as to save irrigation water and labour with minimum yield reduction as compared to transplanted conditions. To achieve this objective during *kharif* 2012, 1864 lines in different filial (F₃ to F₅) generations and 15 F₂ populations were evaluated and 27 new crosses were attempted.

Resistance breeding

Three new pathotypes of *Xanthomonas oryzae* pv. *oryzae* (causing bacterial blight of rice) have been identified on the basis of international differentials/NILs/cultivars in Punjab. There are now 10 designated pathotypes of *X.o.o* in the Punjab state which showed virulence on bacterial blight resistance single gene (*Xa3*, *Xa4*, *xa5*, *Xa7*, *xa8*, *xa13*, *Xa21*) as well as gene combination (*Xa4+ xa5*, *Xa4+Xa21*, *xa5+Xa21*, *xa13+Xa21*). The breeding lines PAU 3762-3-3-2-2-2, 3832-196-4-1-2, 3832-196-4-1-3, 3586-6-1-1-4-2, 3588-6-1-7-3-1-2, 3832-136-4-2-1 and 3832-194-3-1-1 have shown resistant reaction to all the pathotypes of the BB.

Seed box screening (SBS) and Modified Seed Box Screening (MSBS) techniques for screening of host plant resistance to Brown Plant Hopper in rice have been standardized. Rice varieties/ lines, viz. Ptb 33 (*bph2*, *Bph3*), Rathu Heenathi (*bph 2*, *Bph 17*) IR 65482-7-216-2-B (*Bph 18*), IR 71033-121-15-B (*Bph 23*), Sinnasivappu (*bph2*, *Bph3*), IR 62 (*Bph3*), IR 74 (*Bph3*), ADR 52 (*bph25*, *Bph26*) and MO1 (WbphN, WbphO) have shown resistant/moderately resistant reaction in SSBS and MSBS trials.

Maize

In maize, 34 high yielding hybrids and composites have been developed and released for general cultivation in the state (Table 6). These varieties have contributed significantly to the increased productivity in the State in spite of the fact that the better managed and irrigated areas under maize shifted to rice cultivation since early eighties. The productivity of maize has increased from 1335 kg/ha in 1961-65 to 3414 kg/ha in 2010-11. These varieties have also played a significant role in enhancing the productivity of maize at the national level.

The research efforts are directed to develop hybrids and composite of different maturity groups possessing high yield, multiple disease resistance, stress tolerance and management responsiveness to cater to the specific requirements of different agro-climates, cropping patterns and seasons. Three pairs of heterotic pools viz., Makki Safed and Tuxpeno pool, Indigenous Semi Exotic pool; Ludhiana Lancaster (LL) and Ludhiana stiff stalk pool

(LSS) have been established for the varietal development for long duration and well managed areas, for average fertility and rainfed conditions and for winter season, respectively. At present, the major emphasis is on the development of single cross hybrids. Hybrid Paras was the first single cross hybrid released in the country in 1995. Among all the released varieties, it was the highest yielder. Since then the research work on inbred line development was strengthened at PAU and a number of single cross hybrids have been released namely, PMH 1, PMH 2, PMH 3, PMH 4, PMH 5, JH 3459, Parkash, Maize PAU 352, Sheetal and Buland.



Maize hybrid Parkash

Maize hybrid PMH2

Besides the main season crop, an extra early maturing maize composite ‘Punjab Sathi 1’ has been released in 1994 for summer season (March/April sowing) as a catch crop. A composite variety ‘Pearl pop corn’ was released in 1995 for the first time in the Punjab state. Research was undertaken to develop cold tolerant varieties and appropriate production technology for winter season in which maize showed very high yield potential. It led to the first ever recommendation of winter maize cultivation in Punjab in 1983. Besides cold tolerant composite Partap1, the sowing of seed on the southern slope of east-west ridges and other components of production technology helped this crop to establish in certain pockets in Punjab. Another outstanding achievement was the development of technology of transplanted maize in winter season in 1987. The cold tolerant single cross hybrid Buland performs exceedingly well during *rabi* season.

Concerted efforts of the maize breeders have made it possible to grow maize round the year round. The cultivation of maize can be done successfully during August (late *kharif*) and 20th January-15th February (spring season). Area under spring maize cultivation is increasing year after year and the hybrids PMH 1, PMH 2 and JH 3459 have been recommended for spring season also. The cultivation of baby corn (hybrid Parkash and composite Kesri) and sweet corn (Punjab Sweet Corn 1) has also been recommended to enhance crop diversification and better returns to the farmers. Currently, the emphasis in maize breeding at PAU is on the development and improvement of germplasm for late maturity and high biomass, tolerance to biotic and abiotic stresses, QPM, baby corn and other specialty corn.

Table 6. List of varieties/hybrids of maize released by PAU for cultivation

S.No	Variety/ hybrid	Year of release	Yield (q/ha)	Parentage	Distinguishable characters
1.	Ganga Hybrid Makka 101	1961	40.0	(CM 103 x CM 104) x (CM 201 x CM 105)	Double cross hybrid with strong stem, leaves broad and dark green, ears long, well filled with tight husk cover extending beyond the cap of the cob, grains attractive, bold, round, hard and orange yellow; plant stay green at harvest. Resistant to downy mildew and other diseases.
2.	Ganga Safaid Hybrid Makka 2	1964	43.0	(CM 400 x CM 300) x CM 600	Double top-cross hybrid, plants with strong stem; leaves erect and broad; ear placement medium with good husk cover; grains round, medium and white; moderately susceptible to leaf blight and rust but tolerant to stem borer.

3.	Ganga Hybrid Makka 3	1964	35.0	(CM 109 x CM 110) x (CM 202 x CM 211)	Double cross hybrid, early maturing, plants vigorous with good husk cover; grains bright orange yellow, medium, bold and flint; resistant to downy mildew.
4.	Him 123	1964	45.0	(CM 202 x CM 205) x (CM 113 x CM 112)	Double cross hybrid, tall plants, medium ear placement; grains yellow, bold and semi flint; recommended for hilly areas.
5.	Vijay	1967	60.0	J 1 (JML 1)	Dual purpose composite, leaves broad, ears bold thick with light husk cover, average to low ear placement, tassel open, generally white silks, grains moderately bold, semident to flint and yellow to orange.
6.	Ganga Hybrid Makka 5	1968	45.0	(CM 202 x CM 111) x CM 500	A medium stature double top cross hybrid with medium maturity, grains bold, yellow and semi flint.
7.	Rattan	1972	40.0	Opaque version of Vijay	A medium maturity composite, leaves broad, medium ear placement, grains light yellow, semi flint, soft and dull.
8.	Makki Safed 1	1974	37.5	Bhodipur white	Early maturing, erect plant type, grains dull white.
9.	Ageti 76	1976	39.0	Chain crossing among 26 early maturing inbreds	Early maturing, grains bold, attractive, medium round and orange yellow, usually flint, wider adaptability.
10.	Partap	1980	45.0	Compositing of Vijay x Pioneer 102; Ganga 5 x Pioneer 104; Pioneer 104 x Vijay.	Medium tall composite with low ear placement, stem strong, medium thick, ears long thick with tight husk cover, grains flint to semi-flint, medium and orange yellow.
11.	Sangam	1981	50.0	Makki Safed 1 x Tuxpeno PBL	Medium tall, vigorous hybrid with strong stem, average ear placement, grains white, bold semi-flint to dent.
12.	Navjot	1982	41.0	Partap x Tarun	Early maturing composite, compact plant type, grains attractive, medium sized, yellow orange and mostly flint type.
13.	Partap 1	1983	62.5	Recurrent selection in Partap	Cold tolerant, high yielding winter maize composite, resembles Partap for morphological traits.
14.	Parbhat	1987	44.0	Partap x Suwan 1	Medium tall plants; stem medium thick, lodging resistant, medium ear placement; ears medium long and thick with well developed husk cover; grains bold yellow orange and semi-flint to flint.
15.	Sartaj	1987	50.0	(CM 122 x CM 123) x (CM 124 x CM 125)	Double cross hybrid, strong stem, medium plant height, low ear placement, leaves dark green and narrow, relatively erect, tassel light, ears long and medium thick, grains medium bold, yellow orange and flint.
16.	Kiran	1988	38.0	21 elite Punjab locals x J 650	Average ear placement; leaves medium broad, early maturity, grains usually orange flint.
17.	Megha	1990	30.0	JS 2 x Arun	Early maturity, medium tall plants with medium ear placement, drought tolerant, grains yellow orange and flint.
18.	Kesri	1992	40.0	(Ludhiana local x J 2014) x Parbhat	Early maturity, plant height and ear placement medium, ears thick at the base and tapering towards the tip, good tip filling and husk cover, grains deep orange flint. Also recommended for baby corn.
19.	Punjab Sathi 1	1994	22.5	Modified mass selection of local	Sathi maize from Gurdaspur (PB). Heat tolerant, extra early maturity, plants short with medium ear placement, leaves narrow, short, semi-erect to erect, tassels light and open, silks generally light green, ears short, thin with light husk cover, grains small, orange and flint.
20.	Paras	1995	55.0	LM 5 x LM 6	Single cross hybrid, tall, medium stout stem and ear placement; medium sized semi erect leaves; tassel medium; anther and silks green; ear thin and long; grain yellow bold flint with a few semi dents; cob white thin.

21.	Pearl Popcorn	1995	30.0	Purdue popcorn x Amber popcorn; Purdue popcorn x VL Amber popcorn; Purdue popcorn x NSC popcorn.	Medium plant height and ear placement, ears thin long and cylindrical, grains small, round and flint.
22.	Parkash	1997	48.0 (I) 36.0 (R)	CM 139 x CM 140	Short duration and drought tolerant hybrid, plants medium tall, medium ear placement, leaves medium sized and semi erect, tassel medium sized and open, ear long and tip slightly blank, grains yellow orange and flint, cobs white. Also recommended for baby corn.
23.	Bio 9637*	1999	45.0	Closed pedigree	Tall plants, medium ear placement; leaves broad and medium long, tassel open and medium sized, ears medium long and thick, grains yellow and semi-dent to flint; cobs white, medium maturing hybrid developed by a private company.
24.	Sheetal	2001	70.0	LM 9 x LM 10	Medium tall winter hybrid, medium ear placement, leaves medium size, ears uniform, medium long, medium breadth, ear tip slightly blank, tassel medium and open, anther colour cream, grains orange, yellow flint, few grains with caps, cobs white.
25.	JH 3459	2000	51.0 (I) 40.0 (R)	CM 143 x CM 144	Plants medium tall, medium ear placement; leaves medium sized and dark green, tassel open with spreading branches and medium, ears uniform, medium long with shinning orange flint grains, tips comparatively filled, cobs white, plants have stay green characteristics.
26.	Buland	2002	77.5	LM 11 x LM 12	Medium tall plants, ear placement medium, leaves large broad with rough surface, tassel open and medium in size, glumes green with anthocyanin pigment at the base; ears thick, grains bold, yellow orange and flint. Cold tolerant
27.	F 9572 A*	2003	51.2	Closed pedigree	Tall plants, medium ear placement, plants have stay green trait at harvest, stem thin, leaves narrow, tassel medium; ears thin, long with good tip filling, grains attractive, orange and flint, resistant to lodging.
28.	PMH 1	2005	65.0	LM 13 x LM 14	Tall plants, stem with purple colouration, zig-zag and sturdy, leaves medium broad, tassel open and medium, ears medium long with yellow orange and flint grains.
29.	PMH 2	2005	45.0	LM 15 x LM 16	Short duration hybrid, medium plant height, medium ear placement; leaves medium sized and dark green, tassel medium and semi open, silks green, ears medium long; grains yellow orange, flint with yellow caps, resistant to lodging
30.	PAU 352	2007	57.5	LM 15 x CML 32	Single cross, short duration hybrid for North-western plains of India; medium tall plants, drought tolerant, tassel medium sized, semi compact, silks green; orange flint kernels with yellow caps, cobs white.
31.	Punjab. Sweet	2008	32.5	MBRs x Parbhat. Corn 1	Tall plants, medium thick stem, medium ear placement, leaves broad, tassel open with creamish anthers, silks usually creamish at the time of emergence, husk cover well developed, grains orange at maturity.
32.	PMH 3	2008	67.0	LM 17 x LM 14	Tall plants, medium ear placement; ears conical and long, tassels open, grains orange and flint, cobs white, recommended for North-West plains of India.

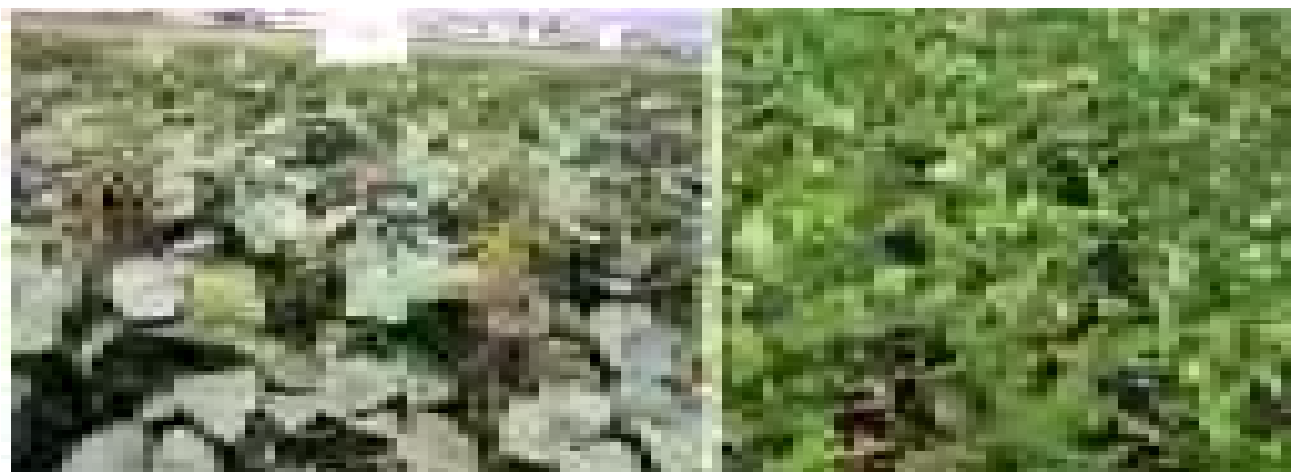
33.	PMH 4	2010	83.0	LM 5 x LM 16	Medium plants, medium ear placement, ears conical and medium, tassels open, silk green, grains yellow orange flint with cap, cobs white, recommended for North-West plains of India.
34.	PMH 5	2010	58.9	LM 16 x LM 18	Medium plants, medium ear placement, ears conical and medium, tassels open, silk green, grains orange red flint with slight capping, cobs white, recommended for Zone V of India.

* Hybrid/Variety from private sector; I=Irrigated, R=Rainfed

Pulses

Mungbean

Mungbean [*Vigna radiata* (L.) Wilczek.] is one of the most important pulse crops of the Punjab state as it is grown in summer as well as *kharif* seasons. There is a great scope and need to increase area under mungbean particularly in the summer season since a large area (>2 million ha) remains fallow between wheat harvest and rice transplantation. The cultivation of summer mungbean as a catch crop improves income of farmers and soil fertility besides facilitating to avoid early transplanting of rice, resulting in great saving of irrigation water. The major breeding objectives in mungbean are to develop high yielding, disease resistant varieties with extra-early maturity (55-60 days). SML 668 with yield potential of 2.0 t/ha and maturing in 60 days, is a remarkable variety. This variety is occupying large area (80,000 ha) not only in Punjab, but in states like Rajasthan, Haryana, Himachal Pradesh, Bihar and Jharkhand. A new variety of summer mungbean SML 832 having shining medium bold grains is expected to fetch more price due to superior quality grains.



Mungbean variety SML 668

Urdbean variety Mash 114

Urdbean

Blackgram or urdbean [*Vigna mungo* (L.) Hepper] is another pulse crop of Punjab that can be grown in summer as well as *kharif* seasons. Summer urdbean is grown in the central and sub-montaneous tracts of Punjab after potato/*toria*. The main objective is to develop high yielding disease and insect tolerant variety with early and synchronous maturity having erect plant type.

Pigeonpea

Pigeonpea is an important pulse crop of *kharif* season grown for food and fuel purposes. The major objective in pigeonpea breeding is to develop early maturing (135-140 days) and high yielding varieties and cytoplasmic genetic male sterility (CGMS) based hybrids with resistance to diseases and insect pests that fit well in pigeonpea-wheat rotation. A new variety, PAU 881 maturing in 132 days, fits well in pigeonpea-wheat rotation. Genetic male

sterility (GMS) based hybrid PPH 4 was developed in 1994. However, due to problem in seed production of GMS based hybrid, the adoption remained limited in Punjab. Pigeonpea hybrid programme based on CGMS system was initiated in 2007 and hybrids synthesized with A₄ cytoplasm, are under multilocation testing.



Pigeonpea variety PAU 881



Chickpea variety PBG5

Soybean

Soybean, the miracle bean, has about 20 per cent oil and 40 per cent protein. The major emphasis in breeding is on yellow mosaic virus resistance and high yielding varieties. The varieties SL 295 and SL 525 have become popular because of tolerance to yellow mosaic virus and yield potential of 2.0 t/ha. A new high yielding variety SL 744 with 11% higher yield than previous varieties has been released.

Ricebean

Ricebean has inherent YMV resistance. The breeding objectives are to develop high yielding, early maturing varieties having good culinary properties. RBL 6 is released for cultivation in the state.

Chickpea

In chickpea, the major bottlenecks for increasing productivity are susceptibility to *Ascochyta* blight and *Botrytis* grey mould (BGM). The first *Ascochyta* resistant variety, C 235, developed in 1960 was cultivated in large scale in the Punjab state as well as neighbouring states, however, resistance was broken down in 1980-81 due to blight epidemic. Variety, G 543, was released for *Ascochyta* blight prone areas of submontaneous region of the Punjab state. Three other chickpea varieties namely PBG 1, GPF 2 and PBG 5 were also released subsequently. A *kabuli* variety, L 550, released in 1975 had become a landmark variety and remained as national check for several years. Later emphasis has been given to develop extra large seeded (>30 g/100 seed weight) varieties due to consumers' preference and higher economic returns. As a result, L 552 a *kabuli* variety has been developed. Besides this, short duration cold tolerant chickpea varieties for *chholia* purpose are being developed.

Lentil and Fieldpea

In lentil, the major objectives are breeding for high yield with resistance to diseases and pests. LL 699 and LL 931 are the popular varieties in the state. In fieldpea, the major breeding objectives are to develop high yielding varieties having resistance to rust and powdery mildew. Two varieties, PG 3 and LFP 48 are being cultivated for dry peas.

Information about varieties of pulse crops released by PAU is given in Table 7.

Table 7. List of varieties of pulses released by PAU for cultivation

S.No	Variety/ hybrid	Year of release	Yield (q/ha)	Parentage	Distinguishable characters
A Mungbean (Spring/Summer)					
1.	Shining Mung No.1	1962	With- drawn	Selection from China Mung	Recommended for cultivation in hills and does well in plains also if sown in 2 nd fortnight of March.
2.	G65	1971	11.25	Local Selection	It is short duration variety, maturing in 70-75 days.
3.	SML 32	1981	11.90	T1 x G65	It is short statured and early maturing (70 days) variety with green bold grains.
4.	SML 134	1994	12.50	V2164 x ML 258	It is short duration (70 days) with synchronous maturity. It possesses shining bold green seeds.
5.	SML 668**	2002	11.25	Selection from NM 94	Short-statured with early and synchronous maturity. Bold grains with good cooking quality. Tolerant to MYMV and thrips.
6.	SML 832	2010	11.60	SML 302 x Pusa Bold 1	Medium stature with early maturity, medium sized, shining grains with good culinary properties. Tolerant to MYMV and thrips.
Kharif Mungbean					
7.	ML 1	1973	17.50	Hyb.45 x P23-67	Possesses good resistance to MYMV.
8.	ML 5	1976	13.00	No. 54 x Hyb. 45	Released at the National level. Tolerant to MYMV
9.	ML 131	1980	14.00	ML1 x ML 23	Possesses good resistance to MYMV disease. Identified for Peninsular zone of India.
10.	ML 267*	1986	14.50	ML 1 x LM 987	Released in Punjab & NWPZ. Matures in about 85 days. Fairly tolerant to MYMV.
11.	ML 613	1995	15.50	ML192 x ML229	Fairly tolerant to MYMV, CLS, BLS and tolerant to whitefly. Matures in 85 days. Grains are bold & shining.
12.	PBM 1	1998	12.50	Induced mutation of ML 131	Released for SW districts. Bold size grains. Matures in 75 days.
13.	ML 818*	2003	12.25	5145/87 x ML267	Released in NWPZ. Matures in 80 days. Moderately resistant to MYMV, BLS and CLS. Grains are medium bold and shining green.
14.	PAU 911	2007	12.25	ML613 x K92-140	Fairly resistant to YMV, BLS and CLS. Matures in 75 days. Grains shining green & medium bold.
B Urdbean (Spring/Summer)					
1.	Mash 218	1988	10.00	G 31 x T9	Short stature, profuse podding with bold and black grains. Matures in about 75 days.
2.	Mash 414	1994	10.60	Local selection	Short duration variety with bold and blackish grains. Matures in about 72 days.
3.	Mash1008	2004	11.25	SML 32 x Mash 1-1	Fairly tolerant to yellow mosaic virus and leaf crinkle virus. Grains are bold with good culinary properties. Developed from interspecific cross.
4.	Mash 391*	2010	7.68	KUG 92 x UG 841	Released at national level in south zone. Resistant to MYMV and leaf crinkle virus. Matures in 71 days.
Kharif Urdbean					
5.	Mash 1-1	1966	8.75	Local selection	Matures in about 115 days. Fairly resistant to fungal and viral diseases.
6.	Mash 338	1993	8.75	UG 201 x PDU3	Short duration, grains bold & blackish. Matures in about 90 days. Fairly resistant to YMV, BLS and CLS and tolerant to whitefly and jassid.
7.	Mash 114	2008	9.00	Mash 338 x RBL 1	Developed from interspecific cross, bold, black grain. Matures in about 83 days. Fairly resistant to YMV, BLS and CLS.

8.	Mash 479*	2010	11.77	UG562 x Pant U19	Released at national level in NWPZ. Resistant to MYMV, CLS and other foliar diseases and insect pests. Matures in 82 days.
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C Pigeonpea

1.	T 21	1973	11.50	T1 x T190	Indeterminate in growth habit. Matures in about 160 days. Photosensitive.
2.	AL 15*	1981	13.75	Selection	Short duration and determinate, plants short statured, maturity relatively. Matures in about 135 days.
3.	AL 201	1992	15.60	AL-16 x QLP200	Early maturing, indeterminate growth. Flower yellow with prominent red streaks on the standard petal. Matures in about 140 days.
4.	PAU 881	2007	14.0	H89-5 x ICPL85024	Early maturing variety with indeterminate growth habit. Matures in about 132 days

D Soybean

1.	Bragg	1971	13.75	Jackson x D 49-2401	Grains are bold and cream in colour. Matures in about 110 days
2.	Punjab Soybean No.1	1972	12.50		Selection from Kangra (HP) Bold, yellow attractive grains. Matures in about 120 days
3.	SL 4	1982	16.00	EC 7965 x Bragg	Semi determinate and erect. Moderately resistant to YMV. Matures in about 106 days.
4.	SL 96	1986	18.00	Batate x JS 3	Semi determinate and erect. Tolerant to YMV. Lodging resistant. Matures in about 125 days.
5.	PK 416	1988	20.45	M 534 x S 38	Resistant to yellow mosaic virus, high yielding, hilum brown in colour, Matures in about 140 days.
6.	SL 295	1996	23.00	PK 416 x PK 564	Highly resistant to YMV and good germinability
7.	SL 525*	2003	15.25	PK 416 x PK 1023	Resistant to YMV and tolerant to stem blight and root-knot nematode. Matures in about 144 days.
8.	SL 688*	2007	24.30	PK 416 x SL 317	Green leaves, purple flowers, resistant to YMV
9.	SL 744	2010	18.25	SL 457 x SL 459	Shining light yellow coloured grains with grey hilum, resistant to YMV & soybean mosaic virus. Matures in about 139 days.

E Ricebean

1.	RBL 1	1985	17.00	Selection from Rajasthan	Photosensitive and vigorous spreading growth habit, highly resistant to YMV and stored grain insect pests.
2.	RBL 6*	2002	17.50	Selection from district Nagaur, Rajasthan	Medium maturing, photosensitive, spreading with many lateral intertwining branches, vigorous growth. Immune to stored grain insect pests.

F Chickpea (Gram) Desi

1.	C 235*	1960	11.50	C 1234 x IP 58	Blight resistant and widely adapted cultivar at national and international levels.
2.	C 214	1971	13.00	G 24 x (G 24 x IP 58)	Frost tolerant variety for rainfed areas
3.	G 130	1971	15.00	No. 708 x C235	Wilt resistant
4.	Hare Chhole 1	1973	12.00	S 26 x GG Bijapur	Green seeded variety
5.	G 543	1977	14.40	C 235 x C 168	Blight tolerant variety
6.	GL 769	1981	17.50	H 223 x L 168	Resistant to wilt for both rainfed and irrigated areas.
7.	PBG 1*	1987	16.00	GG 578 x NEC 206	Resistant to blight and wilt complex, also released at national level & NWPZ.
8.	GPF 2*	1996	17.50	GL 769 x H 75-35	Semi-erect with lush green leaves, grains bold.
9.	PDG 3	1997	18.25	GL 769 x GNG 146	Suitable for rainfed areas, semi-erect with dark green leaves, for rainfed conditions.
10.	PDG 4	2000	19.65	(GL 769 x GF 88421) x GF 8976	Plants semi-erect with dark green leaves, long fruiting branches

11.	PBG5	2003	17.0	BG 257 x E 100 Y	Plants have thick stem with dark green foliage. Grains are medium bold. Fairly resistant to AB and wilt complex.
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Chickpea (Gram) Kabuli

12.	C 104	1960	-	Pb.7 x Rabat	Bold seeded <i>kabuli</i> type for irrigated conditions
13.	L 550*	1974	15.0	C 104 x NP 12	Plants bushy
14.	BG 1053	2001	20.50	Introduction from IARI, New Delhi	Early in flowering, bushy plant type
15.	L 552	2011	18.25	GLK95091 x PBG 68	Bold seeded variety with 100-seed weight of 33.6 g. Seeds are creamy with good culinary properties.

G Lentil

1.	L 9-12	1962	10.00	Local selection	Widely adapted. Resistant to rust.
2.	LL 56	1982	12.85	L9-12 x L32-1	Resistant to rust, possesses good cooking quality. Average yield is 1285 kg/ha.
3.	LL 147	1987	13.75	PL 284-6 x NP21	Plants short, erect and profuse branching and podding, early in flowering.
4.	LL 699	2002	14.25	PL 639 x PL77-2	Plants short, erect, profuse branching, tolerant to pod borer, moderately resistant to rust and blight.
5.	LL 931	2009	12.06	LH90-103 x LL608	Plants short, erect, profuse branching and podding, fairly resistant to rust.

H Fieldpea

1.	T 163	1970	12.50	Introduced from UP (selection from Bulland Shahr areas)	It is trailing type with indeterminate growth.
2.	PG 3	1977	17.50	T 163 x Bonneville	Short-duration variety, grains creamy white, slightly wrinkled and possess high swelling capacity.
3.	LFP 48	1993	19.00	PG 3 X (Bonneville x E. Dcc)	Early maturing variety green seeds with high swelling capacity.

*Released at National level; **National check in NWPZ and also released in Rajasthan, Haryana, Bihar and Himachal Pradesh.

Oilseed Crops

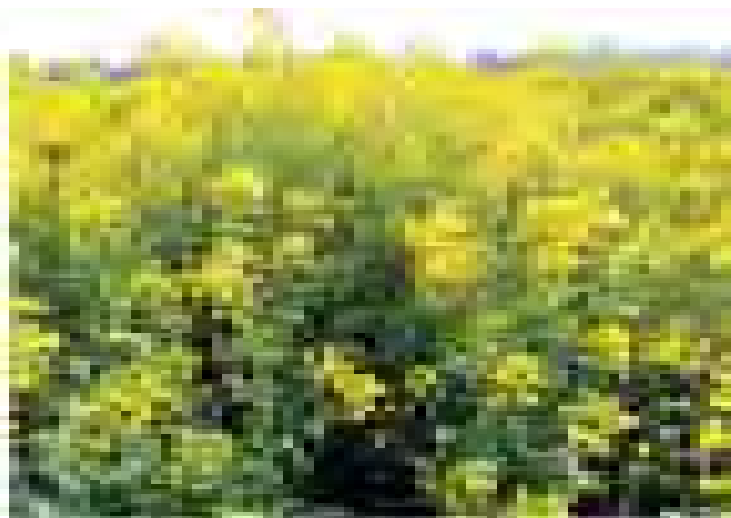
Rapeseed-mustard, sunflower and groundnut are the major oilseed crops in Punjab, whereas sesame and linseed are confined to some pockets of the state. At present, oilseed crops are grown annually on about 65 thousand hectares in the state. Acreage under oilseed crops in the state has decreased drastically owing to shift of major area to wheat during *rabi*, and to paddy during *kharif*. It is expected that there may be revival of some area under rapeseed- mustard owing to development of F₁ hybrid cultivars for which technology has been perfected, and a few superior F₁'s are in advanced stage of testing.

Rapeseed-Mustard

Rapeseed- mustard group of crops comprises Indian mustard (*Brassica juncea*) also known as *raya*, *Gobhi sarson* (*B. napus*) and *toria* (*B. rapa*). Rapeseed-mustard crops occupied a maximum area of 146 thousand hectare in 1980-81, but subsequently it declined drastically. Presently it is cultivated on approximately 33 thousand hectares in the state during *rabi* season. Efforts in rapeseed-mustard improvement in Punjab date back to 1937, when the varieties RL 18 of *raya* and T-1 of yellow *sarson* were released for general cultivation in the state. Mutagenesis and hybridization were initially employed to release a number of improved cultivars in *raya*. During early nineties, emphasis of research shifted towards canola quality and hybrids in mustard. Intensive efforts were carried out to develop '0'/'00' canola quality cultivars and success has been achieved for the release of first '0' erucic acid mustard variety RLC 1 in 2007. Marker assisted selection is being used to develop '00' version of RL 1359 and PBR 210.



Mustard variety RLC 1



Gobhi sarson variety GSC-6 (canola type)

Gobhi sarson (*B. napus*) was introduced in the state during early eighties and first variety GSL 1 was released in 1985. In a significant breakthrough in hybrid technology, first ever Indian bred CMS based hybrid, PGSH 51 was released for general cultivation in the state during 1994-95. During the same year, another landmark variety GSL 2 of this crop was released. It was the first *Brassica* variety in the country which was genetically fortified with resistance to weedicide atrazine and hence was suitable for chemical weed management especially in intercropping with sugarcane. Later on emphasis shifted towards development of canola quality cultivars in gobhi sarson. Success was achieved for the release of first Indian canola quality variety GSC 5 in 2004. Subsequently another high yielding canola quality variety GSC 6 was released in 2007.

Toria (*B. rapa*) has been cultivated as a catch and cash crop in the state since ages. Four varieties TL 15, TLC 1, PBT 37 and TL 17 with varying crop durations were developed and released for general cultivation in Punjab to fit in prevalent cropping patterns involving wheat/sugarcane/sunflower. *B. carinata* was recommended for cultivation in the state during 1994 with the release of its first variety PC 5. A major advantage of this variety was the freedom from white rust and a higher degree of tolerance to *Alternaria* blight and aphids.

Sunflower

Research on sunflower (*Helianthus annuus*) was first initiated at PAU during 1969-70 with its introduction in the state. Evaluation of a few exotic introductions led to the identification of a variety Rumsun Record introduced from Romania. This was released for general cultivation in the state during 1978. Crop improvement activities in sunflower can really be traced to initiation of ICAR project, “Promotion of Research and Development efforts on Hybrids” in selected crops, in the year 1990. The research on heterosis breeding was intensified as a result of which the PAU bred short duration, semi dwarf hybrid PSFH 67 was released in the state during 1992-93. Further research led to the development of new short duration hybrids PSFH 118 and PSH 569. This crop has been adopted by the farmers in the state in the recent years as the area under the crop has increased from negligible in 1988-89 to about 22000 hectares during 2009-10. This has been made possible by the release of a number of private sector hybrids for general cultivation in the state during spring season.

Groundnut

Groundnut (*Arachis hypogea*) is an important *kharif* oilseed crop in Punjab and is mainly grown in Hoshiarpur, Sangrur, Bathinda, Ludhiana, Muktsar, Mansa, Faridkot, Ferozepur and Ropar districts. It was initially introduced in the state in 1931. It occupied maximum area of 222 thousand hectares during 1967 which at present has decreased to about 3 thousand hectares. The less acreage is despite of the fact that several studies have shown that groundnut cultivation can be successfully done during spring, summer and *kharif* seasons, and is as profitable as paddy in the areas of constrained water availability. Its productivity in the state was about 1773 kg/ ha during 2010-11.

Sesame

Sesame (*Sesamum indicum*) cultivation is mainly confined to *Kandi* areas of Gurdaspur, Hoshiarpur, Ropar and to South-Western districts of the state. It is grown as a rainfed crop on marginal soils by resource poor farmers. The incidence of phyllody, for which no resistance is available, is the major constraint in sesame cultivation. At present it is cultivated on about 8000 hectares in the state. Punjab Til No. 1 was the first variety to be released for the crop. The variety is still prized for its export as a confectionary item. Recently another variety RT 346 has been released.

Linseed

Linseed (*Linum usitatissimum*) is generally grown under dryland conditions on marginal soils as a subsistence crop by resource poor farmers of the *Kandi* area of the state. Area under the crop in the state is about 100 hectares which is too low to be of significant research interest. Four varieties have been developed and released by the university. Latest among these is LC 2063, which combines higher productivity with improved oil content.

Information about varieties of oilseed crops by PAU is given in Table 8.

Table 8. List of varieties of oilseed crops released by PAU for cultivation

S.No	Variety	Year of release	Yield (q/ha)	Parentage	Salient Features
A. Raya (<i>B. juncea</i>)					
1.	RLM 198	1975	17.50	Induced mutagenesis of RL 18	Aphid tolerant
2.	RLM 514	1980	17.50	Induced mutagenesis of RL 19	Suitable for both irrigated and rainfed conditions
3.	RLM 619	1983	20.00	Induced mutagenesis of RL 20	Wide adaptability
4.	RL 1359	1986	21.50	RLM 514 x Varuna	Higher productivity
5.	PBR 91	1994	20.30	(RLM 51H x PR 18) x Zem 1	White rust tolerant
6.	PBR 97	1997	13.00	DR202 x (PR34 x V3) x (RLM1359 x Varuna)	Rainfed cultivation
7.	PBR 210	2002	21.10	RLM 619 x RH 8812	White rust tolerant, profused branching and higher no. of siliqua per plant
8.	RLC 1	2007	16.50	QM4 x Pusa Bold	First '0' quality variety
9.	RLC 2**	2011	21.74	QM4 x Pusa Bold	'0' quality variety
10.	PBR 357**	2011	26.64	(PBR 91 x RLM 514) x Bio 902	Higher yield, bold seed size
B. Gobhi sarson (<i>B. napus</i>)					
1.	GSL 1**	1985	20.00	Selection form local germplasm	First variety of Gobhi sarson, escapes frost, free from white rust, 44.5% oil content
2.	GSL 2	1994	18.65	Triton x GSL 8851	Atrazine resistant.
3.	PGSH 51	1995	19.00	TCMS-PR-05A x TFR 91	Early maturing high yielding hybrid of gobhi sarson
4.	GSC 5	2005	15.80	Hyola 401 x (Agat x GSL 8888)	'00' canola quality variety, early maturing (147 days), oil content (42%)
5.	Hyola PAC 401*	2003	16.85	Closed pedigree	'00' canola quality hybrid. Early maturing (150 days). Oil content (42%)
6.	GSC 6**	2007	17.23	NECN 13 x Tribute x NECN 13	'00' canola quality variety
C. Toria (<i>B. rapa</i>)					
1.	TL 15**	1978	9.75	Selection from Ramgarh local Germplasm	Early maturing for toria-wheat rotation (88 days), 41.1% oil content

2.	TLC 1	1983	11.25	Composite	Tall, profuse branching, long pods suitable for toria-sugarcane /sunflower, groundnut rotation, matures in 100 days, 39.6% oil content.
3.	PBT 37	1994	13.45	Selection from TLC 1	Early maturing (91 days), long main shoot laden with pods, profuse branching, long pods and seeds bold and dark brown in colour.
4.	TL 17	2011	13.0	Selection from TLC 1	High yield, early maturity
D. Brown sarson (<i>B. rapa</i>)					
1.	BSH 1	1966	9.00	Selection from local germplasm	Aphid tolerant
E. Yellow Sarson (<i>B. rapa</i>)					
1.	YSPb 24	1966	10.25	Selection from local germplasm	Very high oil content
F. Ethiopian Mustard (<i>B. carinata</i>)					
1.	PC-5	1995	22.85	S67 x Kranti	Resistance diseases, aphid tolerance
2.	PC 5-17**	2004	22.2	Selection from PC 5	Tolerance to diseases, aphid and drought
G. Taramira (<i>Eruca sativa</i>)					
1.	TMLC2	1990	9.00	Selection form local germplasm	Suitable for rainfed condition
H. Sunflower (<i>Helianthus annuus</i>)					
1.	MSFH 8*	1990	12.50	Closed pedigree	High oil yielding
2.	Megha 363*	1993	16.30	Closed pedigree	High yielding
3.	PSFH 67	1992	15.79	CMS 234A x P35R	Short duration
4.	Jawalamukhi*	1993	17.27	Closed pedigree	High yielding
5.	GKSF 2002*	1993	15.47	Closed pedigree	Tall, late maturing
6.	Rumsun Record	1978	-	Introduction	-
7.	NSFH 592*	1994	14.65	Closed pedigree	Short duration
8.	SH 3322*	1997	16.02	Closed pedigree	High yielding
9.	PAC 302*	2001	15.53	Closed pedigree	Short duration
10.	DK 3890*	2001	14.41	Closed pedigree	High yielding
11.	PSFH 118	2002	13.67	CMS 10A x P61R	Shortest duration hybrid
12.	SH 88*	2002	13.00	Closed pedigree	Short duration
13.	PSH 569	2007	20.5	CMS 234A x P69R	High seed and oil productivity
I. Groundnut (<i>Arachis hypogea</i>)					
1.	M 145	1968	14.25 (R) 22.00 (I)	A-1-1x D3	Recommended for both irrigated and rainfed conditions. 1-3 seeds, kernels red coloured
2.	M 13	1972	30.00	Selections from NC 13	Spreading plants, kernels bold
3.	M37	1980	16.25	A-1 x C6-4-7-2	Spreading variety for rainfed conditions
4.	M197	1982	18.75	C501 x U4-7-2	Semi-spreading, 1-3 seeds
5.	M 335	1986	23.00	M 13 x F 7	Spreading variety, kernels bold, matures in 124 days
6.	SG 84	1986	20.6 (S) 25.00 (K)	Selection from ICGS 1	Bunch type variety, profuse primary and secondary branches
7.	M 522	1995	22.5	PG 1 x F 334-AB14	A semi-spreading, high yielding, early maturing variety, pods medium bold with two kernels
8.	M 548	2003	15.0	M 37 x Blanco Puro white	A spreading rainfed variety, kernels purple red
9.	SG99	2004	25.0	Introduction of ICGV 89280	Spanish bunch variety, tolerant to bud necrosis viral disease.
J. Sesame (<i>Sesamum indicum</i>)					
1.	Pb.Til No.1	1966	5.00	Selection from local Germplasm	White and bold seeds, alternate and flat capsules
2.	TC 289	1986	5.25	Pb. Til No.1 x TC 25	Medium plant height, bold seeds, better oil quality, capsule opposite

3.	RT346	2009	6.75	RT 127 x HT 24	Dense long, non hairy alternate pods, profuse branching
K. Linseed (<i>Linum usitatissimum</i>)					
1.	LC54	1970	12.5	K-2/Kangra local	White flowers, higher no. of capsules and brown medium seeded variety
2.	LC185	1979	11.25	-	Short statured, good tillering, blue flower and grains yellow
3.	LC2003	1988	11.25	Flake x LC 54	Suitable for both rainfed and irrigated conditions
4.	LC2063	2007	12.22	1509 x LC 54	Bold seed, higher oil content

* Private sector hybrids recommended for cultivation by PAU

** Varieties identified at national level

Sugarcane

Sugarcane crop is grown between 35° N and 35° S latitude from sea level to 1600 m above sea level. It is cultivated on a variety of soils around the world from loamy sand to clay. The crop accounts for nearly 60 percent of the world sugar. In India, the sugar industry is the second largest industry next to textiles.

Sugarcane is also one of the most favorite cash crops among the farmers of Punjab State. During the year 2011-12 the crop occupied an area of 93 thousand hectares in the state. The research efforts of the sugarcane group are mainly aimed at 'Ensuring global competitiveness of sugarcane farming in Punjab, through enhanced cane and sugar production, value-addition and promotion of alternate uses of the crop'. The intensive efforts made by the research group have led to release of improved varieties supplemented with new seed cane production and protection technologies. In turn this has led to the increase in productivity from 27.9 t/ha (1966-67) to 70.4 t/ha (2010-11). This also led to a massive development of the multimillion sugar industry in the Punjab state as the number of sugar mills being going up from six in 1970-80 to 22 at present.



Sugarcane variety CoJ 64

Since its inception, PAU is credited with the release of 20 sugarcane varieties (Table 9) some of which have high level of adoption among the cane growers of the state and finding favor among the neighboring states. Though several varieties were recommended over the years but it was the release of CoJ 64 in the year 1976 by PAU, heralded an era of intense breeding for early maturing sugarcane genotypes. Sugar recovery, which was less than 8.5 % increased to more than 10.5 % thus changing the status of Punjab from low recovery zone to the high recovery zone of the country. Also, the development of early varieties benefitted the farmers as it facilitated wheat sowing after harvesting sugarcane, which was not possible earlier since the major planted area was under mid and late maturing popular varieties.

The CoJ 64 variety has remained the most popular early maturing variety in the state for more than two decades. CoJ 85 is another popular early maturing variety occupying about 42 percent of the total sugarcane area at present in the Punjab. It has thick green colored canes with average yield being 306 quintals per acre. Its juice contains 16.0-17.0 percent sucrose in the month of November and 18.0 to 18.5 percent in the month of December.

CoJ 88 is an early mid maturing variety with the sucrose content in juice being 17-18 per cent in December. The average yield is 337 quintals per acre and it is an excellent ratooner. Its *gur* quality is excellent. From the last few years majority of the sugar mills are doubling up as sugar complexes opting for cogeneration in addition to sugar production. This variety is an ideal candidate for cogeneration. Considerable area was shifted to sugarcane cultivation from cotton in the southern districts of Punjab around the year 2000 and varieties performing well under brackish water became another breeding objective at that time. This variety has been found to perform best under saline water conditions and has been recommended for cultivation under such conditions.

During recent years, a considerable area under sugarcane cultivation is grown after wheat. A sugarcane variety CoJ 89 released in 2004 has been found suitable for late planting. A mid maturing variety CoH 119 had been released during the year 2008 and is being becoming greatly popular among the farmers because of its luxuriant growth. The sugarcane varieties released by PAU are presently occupying an area of 73.75 per cent in the Punjab state.

The time to time recommendations for the control of various insect-pests and diseases has led to a sustainable production of sugarcane crop in the state. Recommendation on use of micropropagated seedlings as a source of disease free seed has helped farmers to raise a healthy seed crop maximizing the net yields. Recommendations of production technologies like intercropping of different crops in Autumn and Spring planted cane, fertilizer use and irrigations has led to the optimal use of natural resources per unit area per unit time enhancing the economic gains of the farmers of the state. The recent recommendation of trench planting technique has led to considerable water saving (15-20 %) and higher yields besides providing other advantages like easy propping and other cultural operations.

Information about varieties of sugarcane released by PAU is given in Table 9.

Table 9. List of varieties of sugarcane released by PAU for cultivation

S.No	Variety	Year of release	Yield (q/ha)	Parentage	Salient Features
1.	CoJ 46	1962	-	Co 312 x Co 421	Late maturing; good ratooner; medium thick canes; erect habit; non- lodging
2.	Co 1148	1967	900	PoJ 4383 x Co 301	Late maturing; high yielder; excellent ratooner; good quality
3.	CoJ 58	1969	800	Co 312 x Co 421	Good yielder; average ratooner; high tillering; Erect , non-lodging , medium thin canes
4.	Co 975	1969	850	Co 527 x Co 617	Medium thick canes, average ratooner, good sucrose, tolerant to frost and water logging.
5.	Co 1158	1969	750	Co 421 G.C.	Mid-maturing, average yielder, good ratooner, medium thick solid canes
6.	CoJ 64	1975	750	Co 976 x Co 617	early maturing, excellent quality, high yielder, good ratooner, excellent for jaggery making
7.	CoJ 67	1976	850	Co 527 x Co 617	Good germinator, profuse tillering, high stalk population, susceptible to red rot
8.	CoJ 81	1988	920	Co 798 x Co 775	Late maturing, thick canes, good yielder, poor ratooner, good in quality
9.	CoJ 79	1989	920	NCo 310 x CoJ 64	Mid-maturing, high yielder, good germinator, average ratoons
10.	CoS 767	1991	950	Co 419 x Co 313	Late maturing, very high yielder, excellent ratooner, average quality, matures by Feb. end
11.	CoJ 84	1992	950	Co 1148 x Co J 65	Mid maturing, excellent yields in plant crop and ratoon, good in quality
12.	CoJ 83	1992	750	CoJ 64 x Co 1148	Early maturing, good yields, average stalk population, performs better under high fertility soils with frequent irrigation, possesses tolerance to red rot.
13.	CoPant 211	1993	675	Co 6806 x Co 6912	Early maturing , good yielder, shy tillering, tall, medium thick canes, resistant to red rot
14.	CoJ 82	1995	870	CoJ 64 x CoJ 75	Mid-maturing, excellent quality, good plant crop yields average ratooner, medium thick canes
15.	CoJ 86	1999	740	Co 6912 x Co 7201	Early maturing, good quality, high tillering and good ratooner, tolerant to red rot
16.	CoJ 85	2000	855	Q 63 x CoJ 70	Early maturing excellent quality, high cane yields
17.	CoS 8436	2000	800	MS 6847 x Co 1148	Mid maturing thick canes; High yields & good quality; Non- lodging; Performs better under high fertility soils

18.	CoJ 88	2002	845	CoJ 82315 x Co 1148	Tall, medium thick, excellent ratooner, good for cogeneration, suitable for growing under brackish water, excellent for jaggery making,.
19.	CoJ 89	2004	817	LG 72115 x CoJ 82315	Tall, medium thick, very good ratooner, good for cogeneration, suitable for late planting
20.	CoH 119	2008	850	Co 7704 GC	Tall, thick canes, average ratooner, tolerant to frost.

Cotton

Cotton (*Gossypium spp.*) has become the third important crop next to wheat and rice in the state. The production of cotton rose from 3.59 lakh bales in 1962-63 to over 18.00 lakh bales in 2010-11, the highest being 26.78 lakh bales in 2006-07. The productivity improved from 289 kg lint/ha to 750 kg lint/ha in 2006-07. This spectacular progress in production in the state has been achieved through the development and cultivation of high yielding cotton varieties (Table 10) and matching production technologies. Though there had been decline in area and production of cotton from 1996 to 2002 due to heavy pest attack, but cotton cultivation has revived with the introduction of Bt transgenic cotton in the state in 2002.

The research priorities reoriented with time have yielded rich dividends by bringing reduction in maturity period of varieties from 270 days to 170 days, shift from mono-cropping to double cropping, increase in per day productivity and harvest index, improvement in fibre quality from medium to superior medium and incorporation of high degree of resistance to cotton leaf curl virus and tolerance to jassid, bacterial blight, *Fusarium* wilt and para wilt.

Presently recommended varieties in *hirsutum* cotton are F 1861 and LH 2076; and Bt hybrids are MRC 6301, MRC 6304, MRC 7017 and MRC 7031 which are suitable for spinning at 30s counts, and variety LH 1556 and non Bt hybrid LHH 144 for 40s counts. In *desi* cotton the high yielding recommended varieties LD 327, LD 694 and FDK 124, and hybrid PAU 626H fall in coarse staple category and their lint is highly valued for export. The recommended varieties and hybrids are capable of yielding 25-32 q/ha seed cotton yield under good management conditions and are highly suitable for adoption in cotton-wheat rotation. The recommendation of LH 1556, LH 2076 and all the Bt and non-Bt cotton hybrids fall in superior medium staple category which enables the farmers to earn higher price for quality cottons.



Cotton variety LH 2076



Cotton hybrid LHH 144

Table 10. List of varieties/hybrids of cotton released by PAU for cultivation

S.No	Variety	Year of release	Yield (q/ha)	Parentage	Salient Features
1.	J 34	1966	14.0	45F x LSS	Matures in 190 days, resistant to jassid with 34.8% GOT
2.	J 205	1973	15.0	J 2 x UL 48	Matures in 185 days, resistant to jassid with 34.3% GOT
3.	F 414	1977	15.0	Selection from Bikaneri Narma	Matures in 180 days, tolerant to jassid and bacterial blight with 34.2% GOT
4.	LH 372	1980	16.8	G 67 x American nectariless	Matures in 180 days, tolerant to jassid & angular leaf spot with 33.3% GOT
5.	F 286	1983	21.0	F 414 x Empire 61 WE	Matures in 180 days with 33.8% GOT
6.	LH 900	1985	27.5	LH 223-480 x LH 223-343	Short duration (165 days) and short statured variety with bright green leaves having upright margin, susceptible to CLCuD having 33.9% GOT
7.	F 505	1986	24.0	F 414 x A 231	Semi-sympodial variety with dark green leaves possessing 34.6% GOT
8.	LH 886	1988	26.1	LH 62 x EC 34859	Semi-spreading variety which matures in 170 days with 35.0% COT
9.	LH 1134	1990	27.0	IAN 6074 x LH 96-4	Medium tall long linted variety having tolerance to jassid with 35.5% GOT
10.	F 846	1992	27.5	F 452 x LH 223-481	High yielding variety with broad lobed leaves, susceptible to CLCuD having 35.3% GOT
11.	F 1054	1992	28.6	F 470 x A 258	Early maturing short duration (160 days) variety with 34.6% GOT
12.	Fateh	1994	29.0	Suman x LH 660	Semi-sympodial intra-specific hybrid with 2-3 monopods, tolerant to jassid having 34.2% GOT
13.	LH 1556	1995	21.2	(LH 886 x LH 901) LH 952	Semi-sympodial short duration (165 days) variety, tolerant to CLCuD and water logging, possessing 34.0% GOT and 27.7mm span length
14.	F 1378	1996	24.0	(SRT 1 x F 413) CP 32	Semi-sympodial variety with broad lobed light green leaves having 35.5% GOT
15.	LHH 144	1998	19.1	PIL 43 x PIL 8	High yielding intra- <i>hirsutum</i> hybrid with okra leaves, big round bolls (5.5g) tolerant to CLCuD and bacterial blight with 33.0% GOT and possess 28.8mm fibre length.
16.	F 1861	2002	16.2	F 505 x F 380	Semi-spreading variety with big round bolls, tolerant to CLCuD having 33.5% GOT.
17.	*Ankur 651	2002	17.5	Unknown	Early maturing short duration short statured intra- <i>hirsutum</i> hybrid, tolerant to CLCuD having 32.5% GOT
18.	*Whitegold	2002	16.3	Unknown	Semi-sympodial intra- <i>hirsutum</i> hybrid with 2-3 monopods, tolerant to CLCuD and jassid, with 30.0% GOT
19.	*RCH 134 Bt	2006	28.7	Unknown	High yielding intra- <i>hirsutum</i> Bt cotton hybrid with resistance to spotted and American bollworms, susceptible to CLCuD, with 34.4% GOT and 25.0g/tex fibre strength
20.	*RCH 317 Bt	2006	26.2	Unknown	Intra- <i>hirsutum</i> Bt cotton hybrid with resistance to spotted and American bollworms, tolerant to CLCuD, with 33.9% GOT
21.	*MRC6301Bt	2006	25.0	Unknown	Intra- <i>hirsutum</i> Bt cotton hybrid with resistance to spotted and American bollworms, good boll size (4.3g), tolerant to CLCuD, with 34.7% GOT

22.	*MRC6304Bt	2006	25.2	Unknown	Intra- <i>hirsutum</i> Bt cotton hybrid with resistance to spotted and American bollworms, good boll size (3.9g), tolerant to CLCuD, with 35.2% GOT and 29.0mm fibre length.
23.	*RCH 308 Bt	2008	20.0	Unknown	Intra- <i>hirsutum</i> Bt cotton hybrid with resistance to spotted and American bollworms, good boll size (3.7g), tolerant to CLCuD, with 35.2% GOT and 28.4mm fibre length.
24.	*RCH 314 Bt	2008	20.5	Unknown	Intra- <i>hirsutum</i> Bt cotton hybrid with resistance to spotted and American bollworms, good boll size (3.9g), tolerant to CLCuD, with 35.2% GOT and 28.2mm fibre length.
25.	LH2076	2008	19.5	F 1378 x LH 1911	High yielding CLCuD resistant variety with an average plant height of 153cm, with 33.4% GOT and 27.1mm fibre length.
26.	*MRC 7017BGII	2010	26.0	Unknown	Intra- <i>hirsutum</i> BGII cotton hybrid with resistance to spotted and American bollworms, and tobacco caterpillar, tolerant to CLCuD, with 33.6% GOT and 29.7mm fibre length.
27.	*MRC 7031BGII	2010	24.5	Unknown	Intra- <i>hirsutum</i> BGII cotton hybrid with resistance to spotted and American bollworms, and tobacco caterpillar, tolerant to CLCuD, with 33.4% GOT and 29.4mm fibre length.
28.	*Ankur 3028 BGII2012	2012	24.2	Unknown	Intra- <i>hirsutum</i> BGII cotton hybrid with resistance to spotted and American bollworms, and tobacco caterpillar, tolerant to CLCuD, with 31.4% GOT

Desi cotton

1.	231 R	1959	12.8	Selection from kapara mixtures	Monopodial plants with deep cut narrow lobbed leaves and white flowers, seeds very small with short fuzz.having 15.5mm staple length and 42.0% GOT.
2.	G 27	1969	15.0	Selection from Sanguineum	Pigmented plants with reddish brown leaves, stem and other parts, possessing 38.0% GOT
3.	LD 133	1978	16.9	Selection from Cocanadas	Green plants with narrow lobed leaves and creamy white flowers, having 38.9% GOT.
4.	LD 230	1981	26.0	G 27 x 231R	Short duration variety with green plants with narrow lobed leaves and creamy white tubular flowers, having 37.8% GOT.
5.	LD 327	1987	28.5	G 57 (G 27 x LD 124)	High yielding semi-sympodial variety with reddish brown plants having narrow lobbed deep cut leaves and pink flowers, tolerant to Fusarium wilt with 41.9% GOT
6.	LDH 11	1994	31.3	LD 327 x IC 30839	Intra- <i>arboreum</i> hybrid with red pigmented plant body, narrow lobbed deep cut leaves, and pinkish red flowers, tolerant to Fusarium wilt and bollworms, having 40.1% GOT.
7.	LD 491	1995	23.1	LD 251 x Gao 20	<i>Desi</i> cotton variety with narrow lobbed deep cut green leaves with cream white flowers, resistant to bacterial blight and jassid and tolerant to Fusarium wilt, with 38.9% GOT.
8.	LD 694	2001	17.5	LD 260 x LD 360	<i>Desi</i> cotton variety with dark red pigmented plant body, narrow lobbed leaves, pink flowers with red spot inside the petal, resistant to jassid & tolerant to Fusarium wilt, with 40.9% GOT.

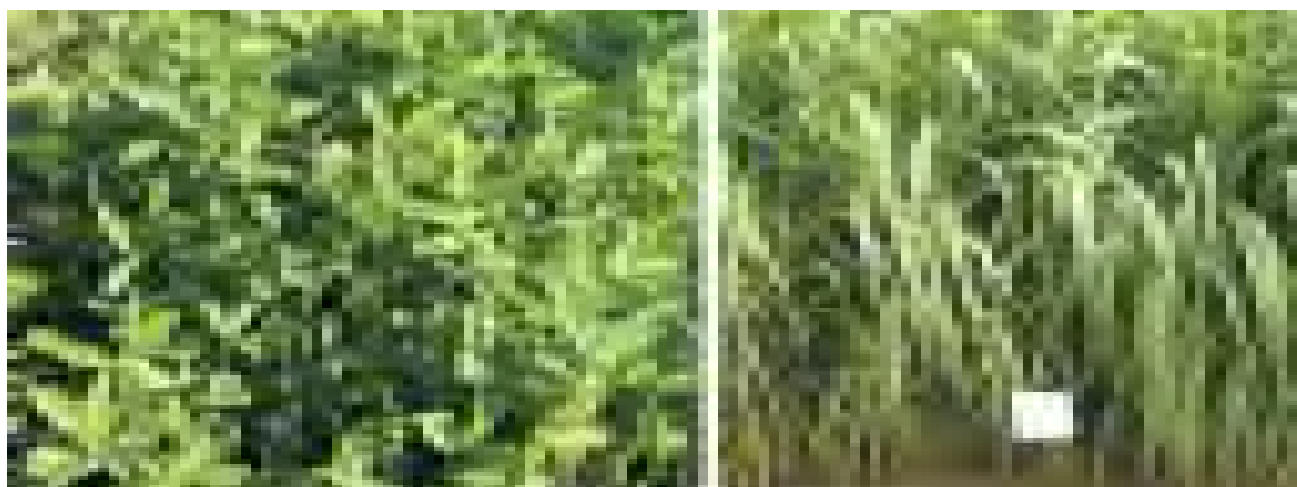
8.	Moti	2004	21.3	DS 5 x LD 210	Genetic male sterility based <i>desi</i> cotton hybrid with green plant body and narrow lobbed leaves and white flowers, tolerant to Fusarium wilt, and have 38.6% GOT.
9.	PAU 626 H	2007	24.5	DS 5 x LD 694	High yielding genetic male sterility based <i>desi</i> cotton hybrid with pigmentation on stem & leaves and okra type leaves, pink flowers with yellow anthers, tolerant to Fusarium wilt and bacterial blight, and have 40.0% GOT.
10.	FDK 124	2011	23.2	Selection from LD 830	High yielding <i>desi</i> cotton variety with green plants, narrow lobed deep cut leaves, creamy white flowers with yellow anthers, tolerant to jassid, white fly, Fusarium wilt, bacterial blight etc. and have 36.4% GOT

* Private sector hybrids recommended by PAU

Forage Crops

The research on forage crops was initiated at Punjab Agricultural University, Ludhiana during 1968 and was further strengthened with the introduction of All India Coordinated Research Project on Forage Crops during 1988. Keeping in view the objectives of development of high yielding quick growing varieties/hybrids which offers resistance to biotic and abiotic stresses with special reference to drought and salinity, several landmark varieties were developed and released in the State. In berseem crop, a late maturing variety BL-10 having forage yield of 1025 q/ha was developed during 1983. This variety gives one additional cutting of fodder and thus supplies fodder for a longer duration. There was problem of seed production in BL-10 due to late maturity during rains. In order to overcome the problem of seed production, BL-42 was released that matures one week earlier than BL-10 and produces ample quantities of seed. In maize, variety J-1006 with fodder yield of 400 q/ha was developed during 1989. This variety is being used as a check variety at the national level.

PAU was the first institute to release a hybrid variety Pb. Sudax Chari No. 1 of multicut sorghum in the public sector which is resistant to red leaf spot disease. This variety was released in 1991 and has forage yield of 1200 q/ha. In napier bajra, a hybrid PBN-233 having green fodder yield of 2750 q/ha was developed and released for cultivation in the year 1999. A new crop of Guinea grass was introduced during 1981 and a number of varieties were released. The variety PGG-518 was released at state level during 1998, gave green forage yield of 1875 q/ha. This variety gives 5-6 cuttings of fodder from May to November. Another crop ryegrass was also introduced and variety Pb. Ryegrass No. 1 with fodder yield of 765 q/ha was released in 1991. This variety gives 4-5 cuttings of fodder from November to May. Recently during 2009, first fodder purpose hybrid bajra PHBF-1 has been released. This hybrid has succulent stem, long and broad leaves and is ready for cutting after 50-55 days of sowing. This hybrid is also resistant to downy mildew disease.



Berseem variety BL 10

Napier bajra hybrid PBN 233

The varieties developed and released since inception of the university are listed below in Table 11.

Table 11. List of varieties of forage crops released by PAU for cultivation

S.No	Variety	Year of release	Yield (q/ha)	Parentage	Salient Features
Berseem					
1.	BL-1	1977	950	Selection	Bold seeded variety
2.	BL-10	1983	1025	Selection from Irradiated material of Mescavi	Longer duration variety. Moderately resistant to stem rot
3.	BL-22*	1987	700	Selection from Irradiated material of Mescavi	Late maturing variety recommended for Hill zones.
4.	BL-2*	1989	422	Multiline	Medium late maturing variety.
5.	BL-42	2003	1100	Selection from Irradiated material of BL 2	High seed setting capacity. Moderately resistant to stem rot. Superior in forage quality.
6.	BL-180*	2005	625	Selection from Irradiated material of BL 10	Moderately resistant to stem rot
Lucern					
1.	LLC-5	1982	700	Synthesized from 125 downy mildew resistant clones selected from Kutchh Lucerne from Gujarat state	Resistant to downy mildew.
2.	LLC-3*	1985	780	Synthesized from 20 clones	Erect plants, broad leaves with purple flower having wider adaptability.
Shaftal					
1.	Shftal-69	1994	975	Irradiation of local shaftal	Highly resistant to stem rot disease.
Senji					
1.	Senji Safed-76	1977	320	(Strain No.341 x (Strain No. 174)	White flowers, late season variety
2.	YSL-106	1983	320	(FOS 1 x Strain No. 87)	Yellow flowers, early season variety
Oats					
1.	Kent	1986	525	Introduction from Australia	Bold seeded variety
2.	OL-9	1987	575	N P hybrid x Kent	Leafy with profuse tillers and medium sized seeds.
3.	OL-125*	1995	500	Appler x IPC 63	Tall, quick growing, medium broad leaves, wider adaptability. Seeds are medium in size.
Ryegrass					
1.	Pb. Ryegrass No. 1	1991	765	Introduction from Australia	Quick growing with soft stem and leaves, tolerant to cold conditions
2.	Metha				
3.	ML-150	1995	250	(Type 8 x Type 36)	Dark green leaves, moderately resistant to powdery mildew and stem rot diseases.
Maize					
1.	J-1006	1989	400	Bulk of balance seed of top crosses from reciprocal recurrent selection in Makki Safed-1 x Tuxpeno PB	Moderately resistant to <i>maydis</i> leaf blight and brown stripe downy mildew diseases. Grains are white in color.
Sorghum					
1.	SL-44	1974	600	JS-263 x SSG 59-3	Sweet, juicy and thin stem variety.
2.	Pb. Sudax Chari-1	1991	1200	2077 A x SGL-87	Multicut, sweet, juicy and resistant to red-leaf spot disease.

Pearl millet					
1.	FBC-16	2003	575	Developed from five late maturing lines	Flowers 8-10 days later as compared to other varieties, hence provides fodder for a longer period
2.	PHBF-1	2009	640	408 A x PIB 213	Leaves are long and broad, remain green till maturity. It has succulent stem and gives two fodder cuttings.
Teosinte					
1.	TL-1	1993	565	Mass selection of indigenous material	Highly resistant to maize borer and has minor incidence of leaf spot disease
Napier bajra hybrid					
1.	NB-21*	1968	1500		Recommended at National level
2.	PBN-83	1984	2400	Bajra Selection-1 x N-3 (Napier)	Non-hairy, smooth leaves, fast growing and late flowering hybrid.
3.	PBN-233	2000	2750	Bajra composite-1 x N-23 (Napier)	Non-hairy, long and broad leaves. Winter dormancy period is about 15 days less than PBN-83
Guinea grass					
4.	PGG-1	1981	470	Introduction from Australia CPI-69985	Medium tall, multicut, long loose panicle and, small seeds
5.	PGG-9*	1986	470	CPI-63540 (Sexual) x CPI-60013 (apomict)	Tall, profuse tillering, long and broad leaves, bold seeds with semi-compact panicles
6.	PGG-19	1987	1500	CPI-63540 (Sexual) x CPI-60013 (apomict)	Early maturity, profuse tillering, bold seed having whitish grey colour
7.	PGG-14*	1988	932	CPI-63540 (Sexual) x CPI-60013 (apomict)	Tall, profuse tillering having long and broad dark, green leaves. Low seed shattering
8.	PGG-101	1991	1690	CPI-63540 (Sexual) x CPI-60013 (apomict)	Profuse tillering and leafy growth. Loss of nutrients is less on delay in harvesting.
9.	PGG-518	1998	1825	P-5 (Sexual) x clone PGG9	Flowers 5-7 days later than PGG-101 and thus maintains its forage quality for a longer duration.
10.	PGG-616*	2000	475	P-5 (Sexual) x clone PGG 101	Multicut, erect, tall plants with profuse tillering. Seeds are bold with low degree of seed shattering.
Cowpea					
1.	CL-74	1975	200	(FS-68 x strain No. 102)	Dual purpose variety. Does not possess the twining habit. Medium sized white grains.
2.	Cowpea-88	1990	250	Irradiation of F1 of Cowpea-74 x H2	Its plants are erect with dark green leaves. It is resistant to yellow mosaic virus and anthracnose diseases
3.	CL-367	2005	270	Cowpea-74 x Strain No.90 followed by pedigree selection	This is a dual purpose variety suitable for fodder and pulse crop. Its grains are small in size and creamish white in colour.
Guara					
1.	FS-277	1971	300	Selection	Moderately resistant to bacterial leaf blight and Alternaria leaf spot
2.	AG-111	1973	-	(326 x FS 277)	Dwarf early variety with unbranched stem bearing pods in clusters on each node. Seed yield is 17.5 q/ha.
3.	AG-112	1980	-	(326 x FS 277) x 315	Unbranched and medium in height. Bears clusters of pod at each node and has bold grains. seed yield is 20.0 q/ha
4.	Guara-80	1982	365	(FS 277 x strain No. 119)	Recommended for rainfed and irrigated conditions, resistant to guara leaf blight and stem breakage.

* Varieties released at national level

With increasing demand of milk and milk products due to better quality of life and increase in per capita income, crossbred animals have been introduced which need more fodder. Large numbers of farmers are adopting dairy enterprise in organized way and keen to rear high milk yielding animals. This has also led to the increasing demand for forage. To meet this demand there is need to increase the production per unit area and per unit of time through improved varieties, production and protection technologies. The research efforts are underway to develop water use efficient and multicut forage sorghum and bajra fodder varieties which can withstand the high temperature of summer and can yield sufficient fodder during that period. On the other hand, the development of multicut cold

tolerant varieties of Oats and cold tolerant varieties of Berseem for *rabi* season is underway to increase the fodder production during *Rabi* season and to provide sufficient fodder during cold period.

Pearl Millet

The bajra (*Pennisetum glaucum*) as grain crop was adopted by Punjab farmers particularly in south-western districts of Punjab with great enthusiasm and brought large area under this crop during 1970 to 1980. There was significant decrease in area after 1990 due to shift in other crops because of rise in water table and climate change in these districts. Pearl millet is being grown all over the state for fodder purpose, but southwestern districts are the traditional areas for grain crop. Punjab farmers prefer this crop because of its tremendous potential for biomass production and good quality fodder. For fodder production it is next to sorghum during *khariif* season. Now, there is a preference for dual-purpose, bristle type and fodder purpose hybrids having high yield and resistance to diseases and insect-pest. The first ever hybrid HB1 was released by PAU in 1965 utilizing the CMS system. Research on this crop was strengthened with the establishment of Bajra Research Scheme during the year 1968. The first downy mildew resistant hybrids PHB 10 and PHB 14 were released during 1975.

The research on bajra was further strengthened with the inclusion of PAU, Ludhiana as a regular centre under All India Coordinated Pearl Millet Improvement Project during 1979. Another bristled hybrid PHB 47 was released in 1983. This hybrid was also resistant to downy mildew. Adding to the list of these achievements, a new hybrid PHB 2168 was released during 2006, this hybrid is high grain yielding and downy mildew resistant. PHB 2168 was later released at national level in 2007. As far as development of composites is concerned, five composites viz., PSB 8, PCB 15, PCB 138, PCB 141 and PCB 164 have been developed and released. Two additional sources of male sterility L 66 (A2) and L 67(A3) were identified at Ludhiana. A large number of diverse male sterile lines have been developed at Ludhiana centre. In addition, new CMS sources viz., A4, A5, Gero and *Violaceum* have been procured from ICRISAT. These lines have been extensively used in hybrid breeding program. Availability of diverse male sterile lines belonging to different sources of sterility and large number of inbred lines is the biggest strength of the centre. The pearl millet varieties and hybrids developed and released by PAU since its inception are listed below in Table 12..

Table 12. List of varieties of pearl millet released by PAU for cultivation

S.No	Variety	Year of release	Yield (q/ha)	Parentage	Salient Features
1.	S530	1965	22.5	Indian x African Population	High yielding bristled variety
2.	PSB 8	1980	28.8	Chain crossing	First composite variety of 60 elite inbreds
3.	PCB 15	1985	29.0	Half-sib families	Resistance to downy mildew, compact ears
4.	PCB 138	1990	29.0	Togo S2 lines	Early, bold grained, tolerant to terminal heat stress
5.	PCB 141	1992	29.5	Random mating of six varieties	Dual purpose. It gives 126 q/ha dry fodder yield.
6.	PCB 164	2003	37.5	Random mating of seven open pollinated populations	Dual purpose composite variety & resistant to downy mildew. It gives 525 q/ha green fodder yield
Hybrids					
7.	HB 1	1966	25.6	Tift 23 A x BIL3B	High yielding, first ever bajra hybrid
8.	PHB 10	1975	32.5	Pb 111A x PIB 155	Downy mildew resistant, long ears, plants remain green till maturity
9.	PHB 14	1975	32.5	Pb111A x PIB228	Downy mildew resistant, ear head bristled, plants remain green till maturity
10.	PHB 47	1983	34.0	Pb111A x PIB 1234	Downy mildew resistant, bristled and long ear heads, plants remained green till maturity
11.	MH 179	1989	34.0	81A x ICMP 451	Downy mildew resistant, bristled ears.
12.	PHB 2168	2006	41.0	ICMA 92333A x PIB686	High yield with medium long ears, downy mildew resistant, identified at National level in 2007

Agricultural Biotechnology

A small tissue culture laboratory was initiated during 1976 in the Department of Plant Breeding which was further strengthened during 1986 with the state government grant for setting up of a Plant Biotechnology and Tissue Culture Centre. This later on led to the establishment of the Department of Biotechnology in 1992 and the new building was designated as “Khush Laboratories” in 2001. On 16th January 2009, an independent School of Agricultural Biotechnology was established to strengthen teaching, research and training facilities in the area of agricultural biotechnology. The major focus of research has been in the following areas :

- Tissue culture and Genetic Transformation
- Gene Cloning
- Gene Mapping and Molecular Breeding
- Genome Sequencing
- Wide Hybridization and Alien Introgression

Tissue Culture and Genetic Transformation: PAU has developed protocols for micro propagation of 17 plant species *viz.*, sugarcane, potato, gladiolus, chrysanthemum, carnation, liliun, citrus, strawberry, banana, *Eucalyptus*, neem, poplar, *Paulownia*, mentha, brahmi, safed musli and *Aloe vera*. Some of these protocols have been commercialised in the state for large scale production of elite planting material for rejuvenation and quick spread of new varieties. For sugarcane, the protocol has been transferred to some sugar mills of Punjab for the large-scale production of disease-free seed for the quick spread of the new varieties. Efficient tissue culture systems have been developed for induction of somatic cell cultures, somatic embryogenesis and plant regeneration in important field, horticultural and forest plant species. Protoplast to plant systems have been established in rice. Production of haploids and doubled haploids have been standardized to compress breeding cycle of rice. Further, somaclones have been developed in sugarcane.



In vitro shoot multiplication of Sugarcane



Hardening of plantlets in glass house

Agrobacterium and ‘particle gun methods’ have been standardized for genetic transformation of rice, maize, wheat, tomato and sugarcane. Attempts have been made to introduce gene(s) for traits like insect resistance, drought tolerance and water use efficiency. Genes like *Glyoxalase I*, *Glyoxalase II*, *ZAT12* and *DREB1a* are being transformed individually or in combination in maize, rice, wheat and sugarcane for improving salinity and drought tolerance. Rice transgenic carrying *Glyoxalase I* gene have been evaluated for salt tolerance using three different salt concentrations *viz.*, control (0 dS/m), 4.0 dS/m and 8.0 dS/m, under controlled conditions. Transgenic PR118 carrying *DREB1a* gene has been produced and are in T₁ generation. The method for evaluation of transgenic rice material for salt tolerance under transgenic greenhouse has been standardized. Protocol for genetic transformation of maize inbreds using immature embryos and mature split grains has been established in which direct regeneration system was adopted.

Gene Cloning: Cloning of genes of bacterial and fungal origin is an important activity. Chitinase and glucanase genes from *Trichoderma viride* have been cloned. *Trichoderma* strains that are effective against *Phytophthora parasitica* disease in citrus have been used for cloning these genes. The genes have been cloned, constructs generated and are being transferred into citrus root stock Rough lemon (Jatti Khatti) through *Agrobacterium tumefaciens* mediated gene transfer.

Gene Mapping: A recombinant inbred line (RIL) population was developed in diploid A-genome species *Triticum boeoticum* acc.pau5088/*T. monococcum* acc. Pau14087. Using this RIL population a linkage map consisting of 180 molecular markers was developed. This map has been uploaded on Graingenes ([http://wheat.pw.usda.gov/report?class=mapdata&name= T.%20boeoticum%20x%20monococcum](http://wheat.pw.usda.gov/report?class=mapdata&name=T.%20boeoticum%20x%20monococcum)). Two stripe rust resistance genes *QYrta.pau-2A* and *QYrtb.pau-5A* and two cereal cyst nematode resistance genes *Qcre.pau-1A* and *Qcre.pau-2A* have been mapped using this map. In addition, two QTL for grain Fe, *QFe.pau-2A* and *QFe.pau-7A*, one QTL for grain Zn, *QZn.pau-7A* have been mapped. This map had some marker scanty regions, so another 30 SSR/STS and 646 DArT markers were analyzed on the population. A high density linkage map consisting of 844 markers has been developed and used for mapping traits of economic importance. Two powdery mildew resistance genes *PmTb7A.1* and *PmTb7A.2* and a QTL for grains/spikelet *Qgnu.pau-4A* and two QTL for grain weight *Qgw.pau-3A* and *Qgw.pau-7A* have been mapped on this A-genome map. Two other RIL populations from crosses WH542/Synthetic43 and PBW534/C306 are also being used for developing framework maps.

A number of biotic and abiotic resistance genes have been mapped to specific chromosomes and linked markers have been identified. Several genes viz. *Lr57*, *Lr58*, *Yr40* (conferring rust resistance in wheat) and number of yet to be designated genes for leaf rust, stripe rust, Karnal bunt, powdery mildew and cereal cyst nematode genes have been mapped using molecular markers. Genes/QTL for wheat quality and productivity traits are being also mapped. In rice, three new genes conferring resistance to bacterial blight including *Xa38* have been identified and tagged with markers (Fig. 5).



Fig. 5. Transfer and mapping of BB resistance gene *Xa38* from *Oryza nivara*

Genes/QTL responsible for water use efficiency, Fe deficiency induced chlorosis under aerobic conditions in rice are being mapped. Likewise in corn, QTL for tolerance to water logging and drought tolerance are being mapped.

Molecular Breeding: Gene pyramiding through marker-assisted selection (MAS) has been an important activity at this School. Three genes for bacterial blight resistance *xa5*, *xa13* and *Xa21* have been pyramided into cultivars PR106 and Pusa44. These stocks have become a base material for breeders and new lines now being evaluated by rice breeders at national level trials have resulted from crosses involving the pyramid lines. Using MAS new improved semi dwarf and bacterial blight resistant versions of Basmati 370 and Basmati 386 have been developed and are being evaluated in advanced varietal trials at national level. These lines have been developed through MAS by pyramiding of bacterial blight resistance genes *xa13* and *Xa21*, semi dwarfing gene *sd1* and monitoring the retention of genes conferring aroma, amylose content and grain elongation genes (Fig. 6).



Fig.6. Development of improved Basmati386 and Basmati 370 through MAS by pyramiding of bacterial blight resistance genes *xa13* and *Xa21*, semi dwarfing gene *sd1*

In wheat, leaf rust resistant genes *Lr24* and *Lr28* were pyramided in the most popular wheat cultivar PBW343 background which have become susceptible to new virulences of leaf rust and stripe rust. These pyramid lines are being used

as base material for stacking additional rust and Karnal bunt resistance genes. Two stripe rust resistance genes *Yr10* and *Yr15* have already been pyramided alongwith *Lr24* and *Lr28* in PBW343 background. These pyramid lines are being used as recipient parent for introgressing drought tolerance QTL in an international project under Generation Challenge Programme (GCP) of CIMMYT. In wheat, a high grain protein gene *GpcB1* has been transferred to elite wheat lines using MAS. Advanced backcross lines with high grain protein content have been developed and are being evaluated for yield and quality parameters.

In Maize, 92 inbred lines were evaluated under excess moisture stress (EMS) and tolerant and susceptible maize genotypes have been identified. These maize genotypes were grouped into different heterotic pools on the basis of 80 SSR markers. Mapping populations have been generated between selected tolerant and susceptible lines for water stress for mapping genes/QTL for drought and water logging tolerance. Selected drought and water-logging mapping populations have been advanced to generate RILs. For developing high quality maize lines, *opaque2* allele along with modifiers, has been transferred through MAS to parental inbred lines viz. LM11 & LM12 (hybrid Buland), LM13 & LM14 (hybrid PMH1). The BC₂F₃ progenies are being evaluated phenotypically for kernel modification and also for lysine & tryptophan content.

Genome Sequencing: PAU is the coordinating centre and has the responsibility for generating physical map and sequencing of long arm of chromosome 2A of wheat. Bacterial artificial chromosome library consisting of 76,000 BAC clones have been procured and will be used for SNAPshot fingerprinting and BAC end sequencing. Using next generation sequencing technology, 300x and 98x sequencing data for short and long arm of 2A, respectively has been generated. Preliminary assembly has been developed and the sequencing data is being used for gene annotations.

Wide Hybridization and Alien Introgression: Among all the State Agricultural Universities and the national institutes, PAU has the largest collection of wild species of wheat and rice. PAU has more than 1200 accessions of wild species of wheat and more than 2400 accessions of rice. Genetic diversity in *Ae. tauschii* and *Ae. speltoides*, wild progenitor species of wheat, was analysed with SSR markers and genetically diverse accessions with desirable traits have been identified and used in the crossing programme. More than 20 genes conferring resistance to diseases, insects, for quality and productivity related traits have been transferred from different wild species such as *T. monococcum*, *T. boeoticum*, *Ae. tauschii*, *Ae. ovata*, *Ae. triuncialis*, *Ae. umbellulata*, *Ae. caudata* and *Ae. variabilis* to cultivated wheat background and the material is being evaluated.

Three genes transferred from non-progenitor species have been designated and catalogued so far. Linked genes *Lr57-Yr40*, transferred from non-progenitor species *Ae. ovata* has been mapped on short arm of wheat chromosome 5D and the alien introgression carrying *Lr57-Yr40* is the smallest introgression characterized so far (Fig. 7). Similarly, a leaf rust resistance gene transferred from *Ae. triuncialis* was mapped using RFLP and SSR markers on long arm of wheat chromosome 2B and designated as *Lr58* (Fig. 7). All the three genes are being mobilised to other wheat backgrounds using MAS in the wheat breeding programme. Two stripe rust, two cereal cyst nematode, two powdery mildew and one Karnal bunt resistance genes have been mapped to specific chromosomes and linked markers have been identified. A leaf and a stripe rust resistance gene transferred from *Ae. umbellulata* as well as *Ae. caudata* have been mapped to wheat chromosome 5DS. A leaf rust resistance gene introgressed from *Ae. variabilis* has been mapped on 2BL. A leaf and a stripe rust resistance gene transferred from *Ae. tauschii* is being mapped to identify its location and linked molecular markers. Some of the alien introgression lines are being evaluated by breeders for release as varieties. Wild wheat germplasm has also been screened for terminal heat tolerance and *Ae. speltoides* has been identified to be most tolerant to terminal heat stress. More

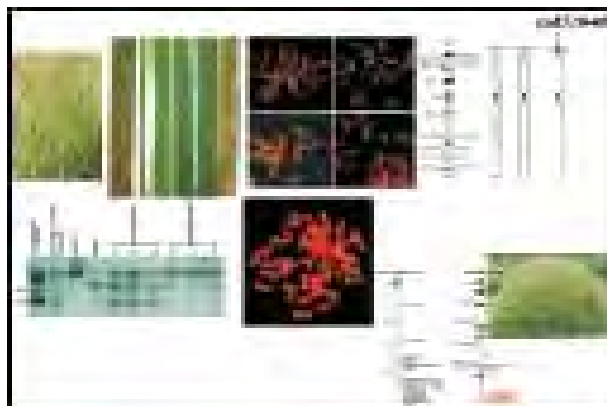


Fig. 7. Transfer and mapping of leaf rust and stripe rust resistance genes from *Aegilops geniculata* and *Ae. triuncialis* in wheat.

than 800 introgression lines have been developed which are being analysed for heat tolerance and its component traits. In addition, selected accessions of *Ae. tauschii*, *Ae. ovata* and *Ae. triuncialis* were also observed to possess terminal heat tolerance..

In case of rice, a set of 300 accessions belonging to six A genome species of *Oryza* has been analyzed with microsatellite markers and levels of genetic diversity within each species assayed. A selected set of 5-10 diverse accessions from each of the six 'A' genome species *O. glaberrima*, *O. barthii*, *O. nivara*, *O. rufipogon*, *O. meridionalis*, and *O. glumaepatula* was used for identification, mapping and transfer of novel alleles for productivity related QTL from these species using the AB-QTL strategy. A set of 2000 introgression lines having alien genome from more than 30 accessions of five different species have been generated and are being evaluated for their agronomic performance. Some lines having higher yield than the recurrent parent have been identified and these have been analyzed using for SSR markers and graphical genotypes of some of the introgression lines have been generated to for identifying the alien chromatin. Some of these lines are under evaluation in multi location trials also and some are being used as parents in rice breeding programme for broadening genetic base of their working germplasm.

A large number of wild species accessions of rice have also been screened for bacterial leaf blight (BB) resistance and novel sources of resistance identified. Three new BB resistance genes, two from *O. nivara*, and one each from *O. glaberrima* and *O. barthii* have been mapped and transferred to cultivated rice *O. sativa*. One of these genes was designated as *Xa38*. These genes have been tagged and are being used for MAS.

CROP PRODUCTION

Agronomy

Tillage

Research on no - tillage / minimum - tillage was initiated in 1971 and recommendations for no – tillage maize – wheat and no – tillage wheat following puddled transplanted rice were made in the years 1979 and 1981 , respectively. In Punjab, area under zero tillage wheat increased from 800 hectare (2000-01) to 7.23 lac hectares during 2009-10. Farmers could save about 209.67 crores of rupees by skipping tillage operations at the time of seed bed preparation on the basis of a saving of about Rs.2900-4400/ha. This technology helped to save 50 to 60 litres of diesel/ha (36.15 m l) and avoided CO2 emission by 130 to 156 kg/ha (93990 t). It eventually helped to reduce air pollution to a great extent if 2.6 kg CO2 production/ litre of diesel burnt is taken as the basis. Similarly, there was 1.9 ha-cm saving of irrigation water from the first irrigation (13732 ha-m) at state level.



Sowing of zero till wheat with Happy Seeder



Wheat crop sown with zero tillage

Zero tillage also saves the energy @ 30%/ha (4077.72 m MJ) of total energy (18800 MJ/ha) used for sowing of wheat. Taking cue from zero tillage wheat, now this technology has been recommended for barley, oats, *raya*, linseed, summer *moong*, maize, *kharif moong*, soybean and *arhar*. Recommendation on incorporation of about

11.8 m t (about 50 % of total) rice straw ,otherwise used to be burnt, will save 59.0, 17.7 and 295 thousand tones of N,P and K, respectively, because rice straw contains 0.5, 0.15 and 2.5 % N, P and K, respectively. In addition to this huge saving of nutrients, the production of about 17.23 mt of CO₂, which is a great ecological hazard, will be avoided.

Time of Sowing / Transplanting

Sowing time of sunflower was advanced from first fortnight of January to first fortnight of December and for short duration hybrids from second fortnight of January to first fortnight of January. The optimum time of transplanting for Basmati 386 and Basmati 370 was found to be second fortnight of July. Likewise, Super Basmati, Pusa Sugandh - 2 and Pusa Basmati No.1 were recommended for transplanted in first fortnight of July.

Multiple Cropping

Research on intensive cropping systems was started in 1969 . A large number of crop rotations identified as most productive and remunerative are maize-potato-wheat-*moong* , maize-potato-summer mungbean , rice-potato-wheat-mungbean , maize/rice-potato-sunflower, rice-*toria*-wheat, maize/rice-*gobhi sarson*-mungbean , rice/maize-potato-wheat, rice-wheat-summer fodders (maize/cowpeas/*bajra*), soybean-wheat, maize-potato-onion , summer groundnut-potato-*bajra* (fodder), maize-*gobhi sarson*-summer moongbean, basmati rice-field peas and basmati rice-sunflower, basmati rice-mentha, basmati rice-berseem (fodder & seed), basmati rice-celery-*bajra* fodder, maize-potato-mentha, maize (August)-mentha, maize (August)-wheat-*bajra* fodder and maize (August)-celery-*bajra* fodder. The introduction of these systems has led to an increase in the cropping intensity from 154 per cent in 1970-71 to 190 per cent in 2008-09 which resulted in an increase in total food production from 73.1 lakh tones (1970-71) to 273.26 lakh tonnes (2008-09).

Inter-Cropping

In autumn planted sugarcane intercropping of potato, *raya*, *toria*, *gobhi sarson*, wheat and winter maize has been recommended while summer mungbean, *mash* and mentha have been recommended for growing as inter-crops in spring planted sugarcane. . Intercropping of *gobhi sarson* and *toria* resulted into yield levels at par with that of *toria*-wheat (25-32 q/ha) crop sequence. Two rows of mentha can be successfully intercropped between two lines of sunflower grown at 120 cm x 15 cm in North-South direction in end January . During winter, when the napier *bajra* hybrid is dormant, oats, senji, mentha, *berseem* or Japan rape can be intercropped. Sorghum + *guara* mixture with about 30 kg sorghum and 20-25 kg *guara*/ha should be sown in lines spaced 25 cm apart. NB-21 + cowpea should be sown in the fresh as well as in the old planting of NB-21 in the first week of March. Berseem-ryegrass when grown together makes a very compatible mixture.

Crop Nutrition

Fertilizer application schedules for different crops and cropping systems have been formulated in view of changing cropping pattern and increased cropping intensity situations. Integrated nutrient management studies have shown the possibility of substituting nitrogen by 50 per cent in rice and maize by incorporation of 40-50 day old crop of *dhaincha*, sunhemp or cowpea. Likewise, burying of mungbean straw after picking of the pods has also been found to contribute 60 kg N equivalent. Another significant contribution has been in reducing the field duration of green manure crops from 9 weeks to 6 weeks through proper agronomic management. N-contribution to the extent of 60-70 kg/ha have been realized from well raised crops of cowpeas, sunhemp and *dhaincha*, thus making their inclusion in the system possible.

Results from long term experiments have shown that to maintain high productivity in maize –wheat and rice-wheat system, it was essential to apply balanced dose of N, P and K. Combined application of N and P was found essential for boosting the crop yields. *Rhizobium* vs. phosphorus interaction studies in lentil showed that the application of 20 kg P₂O₅ /ha is essential to attain potential yield of this crop. In groundnut-wheat sequence, application of phosphorus to groundnut can be skipped if wheat crop is given recommended dose of phosphorus. *Gobhi sarson* when grown on loamy sand soil was found to require 150 kg N/ha instead of 100 kg/ha. Different

Brassica species (*raya*, *gobhi sarson*, *hyola* and African sarson) responded to potash application only upto 15 kg K₂O/ha on soils testing low in available K .

The summer mungbean sown after potato in rice/maize-potato-summer mungbean rotations needs no fertilizer. Nitrogen @ 60 kg/ha to sunflower should be applied in two splits on coarse textured soils *i.e.* half at the time of sowing and half one month after sowing. Broadcasting of 45 kg urea/ha in two equal splits has been recommended in basmati rice. The first dose has to be applied at three weeks and second at six weeks after transplanting (tall var. Basmati-386).

Nitrogen use for potato in the sugarcane + potato intercropping system has been reduced to 50 per cent of the recommended one without any reduction in the yield either of potato or sugarcane, whereas, *raya* in the sugarcane+*raya* intercropping system can be grown even without any N application.

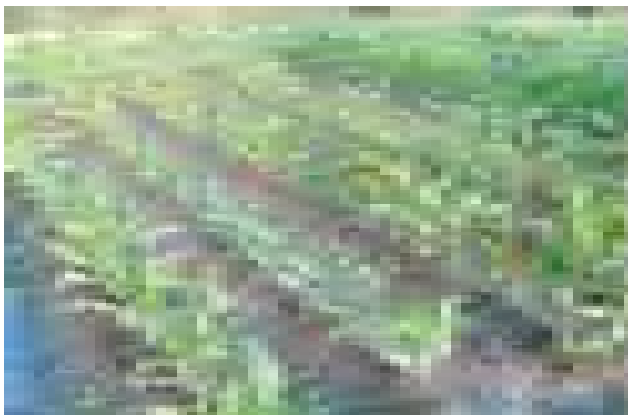
Organic Farming

Organic farming is one of the fastest growing sectors of agriculture with an average growth rate of 25 to 30 per cent. The research on organic farming of field crops was started during 2004. The university has recommended organic cultivation of turmeric alone and rice/ basmati rice – wheat , maize/soybean – wheat , maize – durum wheat – cowpea (fodder) and maize – potato – onion cropping systems under Punjab conditions.

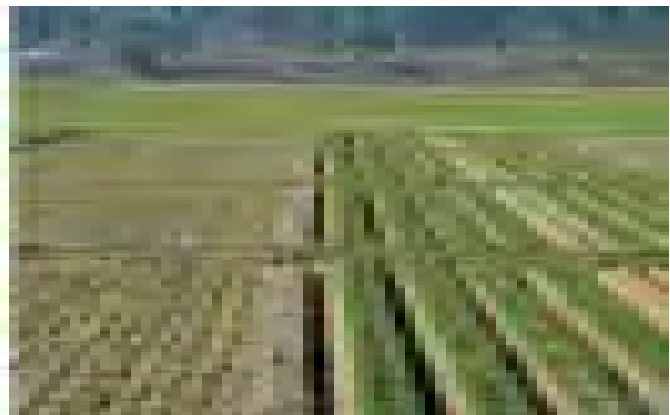
Water Management

Rice-wheat system has dominated the Punjab agriculture for the last three decades. Rice being the heavy water feeder has resulted in the problem of declining water table in the state. Presently water table is declining at an annual average rate of 0.60 m. One hundred three blocks out of 141 blocks in the state have fallen in the over exploited category. The state has short supply of water to the tune of 1.27 Mha-m in comparison to its water needs. For arresting the ground water table decline, irrigation schedules for various crops were recommended.

The initial ponding period for establishment of transplanted rice was reduced to two weeks, thereby, resulting in a saving of about 25% of irrigation water as compared to continuous ponding. Further, if the whole area under rice is irrigated as per PAU irrigation schedule. It will help to save about 19.5 lakh ha-m of water when compared with the situation if this crop is grown under continuous flooded conditions. Practices like ridge planting of cotton, maize and sunflower ; transplanting *gobhi sarson* ; sowing of soybean, *moong*, summer *moong*, wheat on beds and paired row trench planting of sugarcane were recommended to save about 20-30% applied irrigation water in these crops.



Ridge sown maize crop



Flat sown vs bed planted wheat

Maize-potato-onion and maize-potato-summer *moong* were found to save 38-40% irrigation water over rice-wheat system. On the whole the water management recommendations helped in increasing the total irrigated area from 2888 thousands hectares in 1970-71 to 4064 thousands hectares (2005-06) which constitutes 97.4% of net sown area in Punjab state.

Aromatic, Spices and Medicinal Crops

Aromatic spices and medicinal crops have started carving out a niche for them as good crop diversification option because of their being more remunerative as is clear from Table 13.

Table 13: Economics of aromatic, spices and medicinal crops (Rs./ha) as compared to rice and wheat

Crop	Gross returns	Net returns	
*Mentha		60,000	26,375
*Celery		30,600	19,360
*Turmeric	70,000	35,700	
*Fennel	31,800	24,600	
*Dillseed	25,500	18,360	
*Fenugreek	25,250	18,618	
**Paddy		33,800	18,600
**Wheat		38,850	23,740

*at average yield

**at potential yield

At present, mentha is cultivated on about 10, 000 ha and there are about 100 mentha distillation units in the state. The establishment of these units in the rural area has not only increased the total earnings of the farmers but also has increased the employment opportunities in the rural area. Celery is another crop being cultivated commercially in the state for its seeds which is an export item. India dominates in the international market for the celery trade and Punjab state alone contributes about 90% of the total production in the country. At present, India is exporting celery seed and its products worth Rs. 580 lakh. Turmeric cultivation has also been taken up by the progressive farmers of the state and they are getting good yield but lack of processing industry is a bottleneck in its adoption on large scale. In addition to these crops there is a great scope for adoption of seed spices like fennel, coriander, fenugreek, dillseed and other promising medicinal plants like aloe, stevia, *safed musli*.

Weed Management

Weeds compete with crop plants for various inputs such as nutrients, soil moisture, space etc. The losses due to weeds depends upon intensity and type of weed flora associating the crop as well as nature of growth of the crop. In general 20 to 50 per cent losses due to weeds are quite common. Because of the continuous growing of rice and wheat in sequence, the use of herbicides remained in vogue over 90 and 95 per cent of area under wheat and rice, respectively. In addition to this the recommendations for chemical control of weeds in other field and vegetable crops were made. Continuous use of herbicides though made the state farmers richer by Rs. 89.25 crore incase of rice and Rs. 160 crore in wheat but at the same time resulted in the problems of herbicide resistant biotypes in 1995 and shift to hardy weed flora warranting the use of alternative costly herbicides and looking out for cultural and integrated weed control measures. Right methods of herbicide application have been worked out.

Crop rotations like rice-potato-wheat, rice-potato-sunflower and rice-berseem, early sowing of wheat on 25th October and deep tillage were recommended for cultural control of *Phalaris minor* in wheat. Similarly the recommendations (i) growing one or two rows of cowpea for fodder in between maize rows and harvest it 35 to 45 days after sowing before it starts twining the maize plants. No herbicide or weeding operation is required after harvest of cowpea and (ii) either the delayed sowing of *berseem* by mid October or mixing *raya* seed in *berseem* seed, were made to manage weeds in maize and to control *Trianthema monogyna* in *berseem*, respectively. Due to less persistence behavior of dinitroaniline group of herbicides, integration of one hand hoeing with the pre-emergence/ pre-plant application of these herbicides was made in cotton, oilseeds, pulses, vegetables, etc. Similarly, due to high persistence nature of atrazine/ simazine in maize, band application of these herbicides was recommended, so that half to



Right method of herbicide spraying

two-third dose of herbicide can be saved. These are sprayed in bands on crop rows only and from the inter-row area, weeds can be controlled with interculture. *Lantana camara*, *Cyperus rotundus* and *Parthenium hysterophorus* can now be easily controlled in non-cropped areas with use of herbicides.

Soil Science

In the discipline of soil science, research efforts were focused towards characterizing soil and water resources, monitoring macro- and micro-nutrient deficiencies, and developing fertilizer and water management technologies to address productivity, nutritional and environmental concerns.

Resource Inventorization

The soils of Punjab are generally alkaline in reaction, sand to clay loam in texture, and belong to four orders of soil taxonomy viz., Inceptisol, Entisol, Aridisol, and Alfisol. The soils developed on different land forms viz., alluvial terraces, flood plains, sand dunes, Siwalik hills, piedmonts have been characterized and classified. A soil map of Punjab at 1:500,000 scale showing associations of soil families was prepared for diagnosing the nature and extent of their limitations and developing optimum land use plans (Fig. 8). Multi-date satellite imageries have been employed to diagnose the nature of salt affected soils and the extent of their reclamation. The soils of south-west region suffer from the problem of wind erosion, water-logging and soil salinity, while submontane Punjab in Shiwalik region is prone to soil erosion due to excessive run-off water. Chemical and mineralogical analyses and correlation with remotely-sensed data have indicated the occurrence of salt affected soils in Siwalik hills and piedmont plains. Soil test analyses have shown that 61% samples tested low in soil organic carbon, 36 % samples low in available P and 7% samples low in available K. Physical and hydraulic characteristics of some soil series were assessed and correlated with particle size fractions for estimating available water capacity.

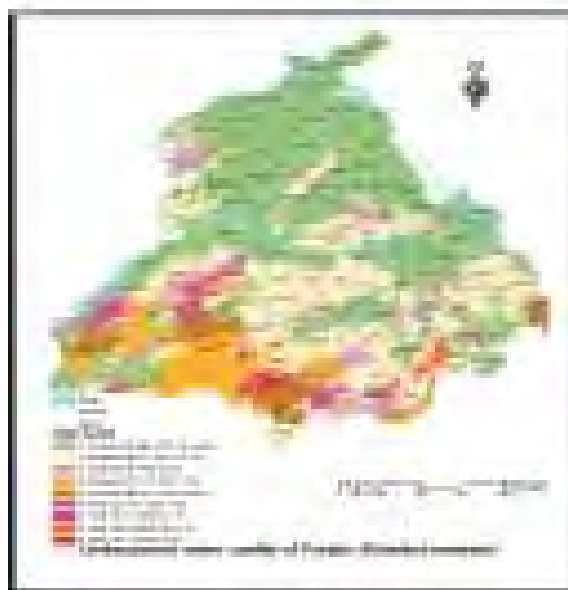


Fig. 8. Map depicting quality of ground water in Punjab

A groundwater quality map of Punjab depicting salinity and sodicity hazards has been prepared. The groundwater of submontane Punjab is of very good quality, while quality deteriorates towards south-west region. High residual sodium carbonate coupled with medium to high salinity is dominant in this region. Detailed survey has been conducted in select districts to evaluate temporal changes in groundwater quality. Mineralogical investigations have revealed that coarse fraction in Punjab soils is dominated by quartz, followed by feldspars, micas and in some cases by calcite. The finer fraction is dominated by illite, followed by smectite, vermiculite, chlorite and small amount of kaolinite. Due to this mineral composition, the Punjab soils are rich in potassium (K). Thermodynamic studies on K minerals have shown illite to be a stable mineral, and biotite is the source of K nutrition. The soils are also rich in alkali and alkaline earth metals, but poor in micro-nutrients. Silicon followed Al, K, Fe, Mg and Ca are in abundance, while Zn, Mn, Co and Cu are in trace amounts. Presence of carbonate nodules is a common feature in sub-soils of Punjab. Pockets of seleniferous soils have been identified in north-eastern parts of Punjab. These soils have a selenium content of 2.1 and 1.2 ppm in the surface and sub-surface layers. Rice- based cropping systems have induced changes in soil morphology, and increased Fe and Mn content in poorly drained fine-textured soils.

Soil Fertility and Plant Nutrition

In-depth research has been conducted using approaches of long-term fertilizer trials, soil test-crop response

correlation, plant analyses, and site-specific management for macro- and micro-nutrition of different crops and cropping systems.

Nitrogen management: Rice -wheat is a major cropping system of Punjab occupying about 2.7 million ha. A crop yield of 7 t ha⁻¹ of paddy and 5 t ha⁻¹ of wheat removes more than 300 kg N, 30 kg P, and 300 kg K ha⁻¹ from the soil. Urea is the main source of fertilizer N. Application of fertilizer N at 120 kg ha⁻¹ has been found to be optimum for both rice and wheat. In soils testing low in organic carbon, significant and economical responses of rice have been observed up to 150 kg N ha⁻¹. Three equal splits of N at transplanting, tillering (21 days after transplanting (DAT) and panicle initiation (42 DAT) have proved more efficient. Application of fertilizer N in two equal split doses - half at sowing and half at crown root initiation stage (along with first irrigation) in wheat has been found beneficial in increasing its grain yield and N uptake. Application of first half N dose with pre-sowing irrigation resulted in significantly higher wheat yield than its application at sowing due to transport of N to soil depths where it was less prone to losses. On coarse-textured soils, three equal split doses of N at sowing and with first and second irrigation has been recommended in wheat. Real-time N management using leaf color chart (LCC) in rice, maize and wheat has helped in saving 15-20 % fertilizers without any reduction in crop yields.



Use of leaf colour chart in maize

Fertilizer N use efficiency of maize improved considerably with balanced use of NPK. Long-term fertilizer experiment demonstrated higher recovery of fertilizers. Application of N alone resulted in average recovery of 17 % in maize and 32 % in wheat, while application of P and K along with N almost doubled N recovery in these crops.

Phosphorus and potassium management: Rice generally responded up to 13 kg P ha⁻¹ while wheat responded to 26 kg P ha⁻¹. Application of P fertilizer in excess of the plant demand results in fixation of the excess P into inorganic form. It is estimated that 20-25% of applied P is used by cereal crops and the rest is retained in the soil as residual P. Thus, P application should be made to wheat and omitted to kharif crops like rice, maize and cotton. In a long term experiment on soil low in available phosphorus under maize- wheat- cowpea (fodder) cropping system, response of maize to addition of P along with N (100% NP) over 28 years ranged from 0.23 to 0.90 t ha⁻¹. Initial residual P fertility of soil significantly reduced the fraction of P derived from fertilizer in maize. The efficiency of a P source varies depending upon proportion of water-soluble P and soil properties like pH, P-fixing capacity and organic carbon (OC). In wheat, drilling and placing P below the soil surface and into the root zone is preferred. Phosphorus use efficiency in case of placement in wheat was reported to be 1.5 times greater than with broadcast. There is a strong interaction effect of OC and fertilizer P on crop yields. It has been shown that for OC between 0.4-0.6 %, fertilizer P need to be reduced by 25% and 50% in soils testing medium and high in available P. Among oilseed crops, groundnut met its P requirements from native soil and residual fertilizer P when succeeded well-fertilized wheat. Lentil and chickpea responded to 9 kg P ha⁻¹, while field pea and pigeon pea registered a response up to 13 kg P ha⁻¹. Application of nitro-phosphates (20:20) with 60-80 % water soluble fraction to wheat was as efficient as di-ammonium phosphate and single super phosphate.

Due to dominance of illite mineral in Punjab soils, crop response to K fertilization is substantial in soils testing low in available K. Studies have shown that application of 50 kg K ha⁻¹ caused yield gain in cereals like rice, wheat and maize. In coarse-textured soils, split application of K in both rice and wheat may give higher nutrient use efficiency than its single application due to reduction in leaching losses and luxury consumption of K. Long-term studies have shown that K balance in rice-wheat is highly negative that can be improved by returning crop residues. An approach based on soil test value of a nutrient, nutrient requirement of the crop for a yield target and the recovery efficiency of the applied fertilizer was developed to refine fertilizer recommendations for targeted yields of cereals like wheat, maize and rice.

Secondary-and micro-nutrient management: Crop responses to secondary- and micro-nutrients vary widely. Sulphur deficiency has been quite widespread especially in coarse-textured soils and in areas with irrigation source other than groundwater. Sulphur requirement has been reported to be 20-40 kg ha⁻¹ for oilseeds, 10-25 kg ha⁻¹ for pulses and 5-10 kg ha⁻¹ for cereals. The pattern of crop response to NPK application has been affected by sulphur use. Among micro-nutrients, zinc application in deficient soils enhanced mean yield by 0.3-1.0 t ha⁻¹ for cereals, 0.2-0.4 t ha⁻¹ for millets and 0.1-0.3 t ha⁻¹ for oilseeds and pulses. Zinc hydroxide and zinc carbonates were immediate reaction products of fertilizer zinc in Punjab soils, and were responsible for low availability of applied Zn. Next to zinc, deficiency of iron (Fe) may affect the productivity of rice in high permeability soils that can be corrected by foliar application of FeSO₄. The deficiency of manganese (Mn) in wheat and Bersem were characterized in field environments. The magnitude of wheat response to foliar application of Mn differed with Mn status of soil. The relative tolerance of wheat for Mn, and sorghum and chickpea for Fe were established. It was observed that durum wheat was more sensitive to Mn deficiency than bread wheat. There are some reports of copper (Cu) deficiency in rice-wheat system in sandy soils that can be corrected by foliar spray of 0.2 % CuSO₄.

Integrated nutrient management: It implies combined use of fertilizers with organics like farmyard manure (FYM), green manure, crop residues and agro-industrial wastes for improving crop productivity and enhancing soil health. Organic manures like FYM and green manures (Sesbenia and Sunhemp) helped in saving 40-60 kg ha⁻¹ fertilizer N in rice. Poultry manure in rice showed significant residual effects in wheat equivalent to 30 kg N and 13 kg P ha⁻¹. Application of 15 t ha⁻¹ pressmud cake with 40 kg fertilizer N ha⁻¹ produced rice yield similar to 120 kg ha⁻¹ fertilizer N. The residual effect of pressmud cake in the following wheat was equivalent to 40 kg N and 13 kg P ha⁻¹. Regular application for 4 years caused significant increase in organic carbon and available P content of the soil.

Increased mechanization, more so in the dominant rice-wheat system, has led to large amounts of surplus crop residues. Technologies have been developed for using crop residues as an alternative to burning. It has been observed that incorporating rice residues 2-3 weeks prior to planting improved crop yields and soil health. Studies have also demonstrated that incorporation of residues of sunflower, cotton, and legumes can improve soil and crop productivity. The 'Happy Seeder' machine directly plants wheat into heavy rice residue loads by managing part of straw which is coming just in front of furrow openers. Mulched residue provided non-N benefits such as conservation of soil water and control of weeds. A simple technology has been developed for composting rice residues as value added manure. Inoculation of legumes (soybean) with Rhizobium culture helped in improving grain yield.

Plant analysis: Nutrient indexing of field, vegetable and fruit crops through plant analysis helps in improved fertilizer scheduling to crops. A survey of fruit crops showed that about 100, 58, 15 and 100 % of litchi orchards were deficient in Zn, Mn, Mg, and S; while in mango orchards, the deficiency of Zn, Cu, Fe, Mn, Ca, Mg, and S was 100, 33, 8, 50, 85, 60 and 100 % respectively. Generally, mango and litchi orchards contained only low to medium contents of these nutrients, while kinnow orchards had high amounts. Nutrient indexing survey of rice indicated that 11, 1.5 and 2% samples were deficient in K, Mn and Zn. In addition, methodologies for extraction of nutrient elements have been refined for efficient and precise estimates. A temperature correction factor for Olsen P was developed for routine analysis in soil testing laboratories of the state. Ammonium bicarbonate - DTPA mixture was found suitable for extracting all available nutrients for soil testing for Punjab soils. It was also established that AB-DTPA was most suitable extractant for estimation of Fe and 0.15 % CaCl₂ for estimation of sulphur in soils.

Soil Physics and Water Management

Concerted efforts have been made towards better understanding of the transport processes, and devising practices for efficient water management and alleviation of soil physical constraints for improved crop yields and input use efficiency.

Transport processes: Controlled studies have shown that seed germination and seedling emergence was influenced

by interaction of soil wetness, soil temperature, and seeding depth. Wheat seeds showed greater sensitivity to adverse seed zone conditions than barley and gram. With adequate seed zone moisture, seedling emergence decreased with increase in seeding depth; but in drier seed zone, deeper seeding was beneficial. Displacement of non-reactive chloride was affected by initial wetness, water application rate, soil type, and layering sequence in the profile. Soil aggregation and residue mixing caused shallower salt peaks, whereas compaction and puddling displaced salts to greater depths in relation to un-amended soil. This information has implication for leaching efficiency of water, and fertilizer use efficiency. Laboratory studies on soil water evaporation from bare, tilled and mulched soil columns has helped in better understanding of the loss pattern in relation to soil type, evaporate demand, time and type of tillage, and rate and mode of residue application. Shallow tillage reduced evaporation loss by affecting soil hydraulic characteristics, and residue mixing was more effective than residue mulching in water conservation.

Several simple and rapid methods have been developed for better characterization of soil and plant processes viz. soil wetness, bulk density, particle size analysis, seedling emergence force, and root growth pressures.

Efficient water management: Research on judicious water management has focused on optimal irrigation scheduling to crops under plentiful water supplies, appropriate irrigation methods, soil management practices, and rational use of rain water in dry lands. Water economizing irrigation schedules were developed for principal crops of the state based on a simple weather-based (IW/ Pan-E) approach that promotes the use of profile stored water by inducing deeper rooting in crops. Based on this approach, a simple- to-follow irrigation calendar for wheat was computed that saved 2 irrigations compared to traditional practice of irrigating at fixed growth stages. This concept was followed by other water management research centers of the country. Intermittent submergence in rice (after 2 weeks of continuous ponding following transplanting) economized a substantial amount of irrigation water without any yield loss. Use of tensiometers for scheduling irrigation to rice has further economized on irrigation water.



Tensiometer for irrigation in rice

Canopy temperature as an indicator of plant water status has a potential for scheduling irrigation to crops. Timing limited irrigation to wheat at 3-4 weeks after sowing was most gainful as it reduced mechanical resistance ahead of root zone and enhanced fertilizer availability. Simulation techniques were employed to estimate water use (ET) in relation to soil, crop, and climate and management factors. Analysis of water balance components showed that average ET was 60- 65 cm for rice (transplanted first fortnight of June), 45 -50 cm for maize, 55-60 cm for cotton, 35 -40 cm for wheat and 110- 130 cm for sugarcane. Model and field analysis demonstrated that end June transplanted rice had comparable yield and greater water productivity than mid May transplanted crop. Field research has shown that N application improved wheat grain yields by enhancing ET, transpiration (T) component of ET and T efficiency.

Alleviating soil physical constraints: Field practices of tillage and mulching have an important role in alleviating soil-related constraints to improve crop performance. Deep tillage (30-35 cm) of coarse-textured soils reduced mechanical resistance in stirred zone that led to deeper and denser rooting and improved yield of maize, sunflower, and mustard. However, tillage gains are influenced by soil type, evaporative demand, and other irrigation and fertilizer management. Repeated puddling in rice culture to reduce percolation losses in coarse-textured soils led to the development of plough pan at 15-20 cm depth, which may hamper root development in the following upland crops. Medium puddling (wet tillage) in rice was optimum as it reduced percolation losses without affecting the yield of succeeding wheat. Use of surplus residue as a mulch material in growing crops during summer month improved crop performance by influencing hydro-thermal regimes, and saved irrigation water. Field studies have shown that tailoring root growth through tillage, straw mulching, and irrigation can help in improve crop yields and input use efficiency. Long term effects of green manuring and residue incorporation (of legume and non-legume

crops) incorporation in maize-wheat and rice-wheat system improved soil physical environment in terms of reduced bulk density and penetration resistance, and greater aggregation resulting in better plant water-relations and crop yields.

Dry land technology: A technology package has been developed in respect of soil and water conservation, selection of suitable crops and cultivars, fertilizer use in relation to water supplies, runoff harvesting and recycling as supplemental irrigation to post-rainy crops for improving yields of dry land crops in submontane Punjab. Empirical modeling of dryland wheat yield data demonstrated that a given yield target could be realized with different combinations of available water at seeding, rainfall distribution, supplemental irrigation, fertilizer N and inherent soil fertility status. Efforts have been made towards understanding mechanisms of soil erosion by water and devise measures to conserve soil, water and nutrients in this region.

Managing poor quality waters and soils: Technology for reclamation of saline-sodic soils has been developed and evaluated for bringing a large chunk of such soils under cultivation. Conjunctive use of good and poor quality waters, along with use of amendments like gypsum and manures hold a promise for sustaining crop yields without a build-up of salt load in soils of south-west Punjab. Field research has shown that yield of rice, wheat, cotton and sunflower with alternate use of canal water and sodic groundwater was comparable to that with canal waters alone. High alkalinity, presence of CaCO_3 and poor air-water relations in sodic soils and soils irrigated with sodic waters, affect the availability of nutrients. Consequently, these soils are poor in available N, and respond to higher N rates than normal soils. In these soils, high Na content and low amounts of Ca generally leads to antagonistic effects on K uptake; and crops may respond to K application. The availability of Zn to plants grown on alkali soils is adversely affected by high pH and presence of CaCO_3 , and need Zn application.

Environmental Impacts

Increased fertilizer and pesticide consumption in Punjab has led to gradual build up of nutrients and other chemicals in soils and groundwater. There are reports of eutrophication of water bodies due to high nitrate and phosphate concentration, increased levels of NO_3^- in groundwaters, and accumulation of heavy metals from industrial effluents in soil and water. In a survey analysis of groundwater samples from 21- 38 m depth, 78 % samples had less than 5 mg $\text{NO}_3^- \text{-N l}^{-1}$, and 22 % had 5-10 mg $\text{NO}_3^- \text{-N l}^{-1}$. Sixty percent of water samples from shallow (9-18 m) depths had 5-10 mg $\text{NO}_3^- \text{-N l}^{-1}$ and 2 % samples had more than 10 mg $\text{NO}_3^- \text{-N l}^{-1}$ that is the safe limit for the drinking water. Denitrification losses during the rice crop were high (23 to 33 % of applied N).

It has been observed that sewage and industrial effluents of major cities of Punjab (Ludhiana, Jalandhar, and Amritsar) have high concentration of Pb, Cd, Ni, and Cr. The level of these metals in soils irrigated with Buddha Nullah waters were 1.8, 3.6, 14.3, and 35.5 times more than soils irrigated with groundwater. The threshold levels Cd and Ni toxicity in tops of vegetable and forage crops viz., alfalfa, cowpea, Egyptian clover, maize, oats, pearl millets were established. Selenium toxicity can be ameliorated by regulating entry of Se into food chain. Gypsum application resulted in substantial reduction in Se content in wheat, maize, oats and sugarcane. Among tree species, poplar, eucalyptus, and mulberry have a potential for phyto-remediation of excessive selenium from the soil. Vehicular emission resulted in accumulation of lead in soils and vegetation along the roadside and the level of accumulation depended upon the frequency of vehicles.

Agricultural Meteorology

Climate Change and Crop Modeling

Using a dynamic simulation model, an assessment of within-season temperature change effect on wheat crop was studied. The growth and yield of rice and wheat was reduced by an increase in temperature, but increased with a decrease in temperature from normal. With an increase in temperature by 1.0 to 2.0 °C, the simulated grain yield in rice and wheat decreased by 8.07 to 15.15% and 9.8 to 18.0% from normal, respectively.

Research on climate based dynamic crop growth and yield simulation models for wheat, rice, groundnut, soybean and chickpea has been conducted. The CERES group of models on wheat (CERES-Wheat), rice (CERES-

Rice), pearl millet (CERES-Millet) and the GRO group of models on groundnut (PNUTGRO), soybean (SOYGRO) and chickpea (CHICKPGRO) have been validated to simulate-crop phenology, crop growth, seed / Grain yields and soil water balance. The calibrated and validated simulation models namely MUSTARD model for brassica crop, OILCROP-SUN model for Sunflower crop and PNUTGRO model for groundnut crop were employed to conduct sample simulation studies to demonstrate the applicability of these simulation models as an agronomic and user friendly tool. The WOFOST-model for rice was validated under central Punjab conditions.

The models for prediction of the “Yield Deviation” arising due to the “Weather variability component” were developed from the simulated trend yield deviations and the observed trend yield deviations.

Crop-Weather-Pest Interaction

Crop-weather-disease relationships for potato blight, tomato blight and Alternaria blight of radish were studied. Epidemiological model for Karnal Bunt of wheat was developed based on weather parameters. Different Crop-weather-disease calendars for rice diseases viz. sheath blight, false smut and rice blast and wheat diseases viz. Yellow rust, Karnal bunt, powdery mildew and for mustard aphid were prepared to find out the role of weather on crop growth and their development. These calendars can be used for advising the farmers for the need based use of pesticides. Rice sheath blight incidence and severity were high in closer (20cm X 15cm) spacing as compared to wider (20cm X 20cm) spacing irrespective of variety and transplanting dates. AUDPC was recorded much higher in crop under closer spacing (20cmx15cm). Rice sheath blight incidence was low in wider spacing (30cmx10cm) and high in closer spacing (20cmx15cm) in PR-116 and PR-118 cultivars. The mean percent incidence of sheath blight was more in flat/conventional planted crop as compared to furrow planted crop. Flat sown crop having spacing of 30X10 cm showed least incidence of sheath blight as compared to recommended spacing.

A conceptual model was developed for mustard aphid attack based on date of sowing. According to this model the crop can be saved from aphid infestation by sowing in the month of October. For obtaining the maximum yield, crop should be sown in the first fortnight of October under Punjab conditions. Growing degree day model was validated under Punjab conditions and it was found that aphid attack was inversely related to growing degree days. The incidence of stem borer in rice was higher in conventional planted crop (3.91 per cent) than furrow planted crop (3.54 per cent) because of more radiation interception and low relative humidity in furrows as compared to conventional methods.

Microclimate Modification

Modifications of field microclimate were studied using live crop and permanent shelterbelts, flat and ridge plantations, plant geometry and varying population overhead cover of polythene, various types of mulches and screen houses. Crops of groundnut, summer mung, winter maize and vegetable crops were studied under control and modified microclimate environments. Crop growth and microclimate observations on temperature, evapotranspiration, wind speed, relative humidity, soil moisture were made in control and altered microclimate plots. These results revealed that groundnut yields better when raised with guara as shelter crop. Summer mung yields better when shelters are provided against hot winds. Winter maize grows well using ridge plantation (south facing slopes) due to favourable temperature regimes. Tomato nursery grows faster in protected condition when shelter on the north of nursery bed is painted white in order to reflect more solar radiation towards nursery bed. Muskmelon seedlings also germinate and grow faster when raised along the south of white painted protection. The survival and performance of onion seedlings during summer increases if raised under partial shade (sarkanda / straw cover). Use of overhead polythene cover provided favourable temperature during winter and increased tomato yields. Microclimate modification inside the screen house favoured better crop growth environment for vegetable crops (Tomato and Pepper). No fruit borer attack in tomato was observed under net house. Fruit yield of tomato and pepper were higher in net house as compared to open conditions.

Crop-Weather Relationships

Crop-weather relationship studies were conducted to relate crop growth and development in relation to microclimate and weather parameters. The experiments were conducted on rice, wheat, brassica, soybean, mungbean etc. and different agroclimatic indices were developed. In wheat crop, the research findings on close row spacings for late sown wheat and for onion, a special method of raising nursery by evading heat stress has been recommended.

Computation of Energy-Water Balance Parameters

The energy-water balance from satellite data was calculated in a project funded by SAC, Ahmadabad. Utilization of geostationary data (INSAT) has been done for the first time in India. Internationally, very few advanced countries are using geostationary satellite data for atmospheric parameters estimation. It has several advantages over polar orbiting satellite.

Different energy-water balance parameters like sensible heat flux, daily total surface insulation, diurnal insulation, surface albedo, land surface temperature were studied. Evapo-transpiration computation was done on the basis of data collected from farmers field at Dakha, Birmi and Pandori villages and the data collected from different satellites (INSAT 3A or KALPANA VHRR & CCD, METSAT VHRR, Radiosonde). Methodology was developed for retrieval of such parameters.

Evapotranspiration

Evapo-transpiration in wheat crop was estimated using different methods. Multiplicative & additive ET and yield models were developed which indicated that moisture stress during reproductive growth (flag leaf emergence to soft dough stage) of wheat crop significantly affected the grain yield.

Weather Forecasting and Agro-advisory

Punjab Agricultural University was the first University in India to start weather forecasts and Agro-advisories. Keeping the weather scenario, crop status and animal health in view, a comprehensive weather agro-advisory is prepared and sent to T.V. Centre, Radio Station Jalandhar, press and is updated on the website of CRIDA twice a week for national dissemination. About 60% of the farmers re-adjust their agricultural schedules based upon the forecast provided by PAU. These accurate predictions help the farmers to plan their farm operations accordingly and able to save costly inputs, electricity, diesel, insecticides, pesticides and man-hours worth millions of rupees per year in the State.

CROP PROTECTION

Plant Pathology

Wheat

Smuts: Loose smut (*Ustilago segetum tritici*) and flag smut (*Urocystis agropyri*) can cause significant direct losses in yield if not managed properly. Three races of the loose smut pathogen i.e. T-0, T-10 and T-11 have been identified in the State of which T-11 is the most virulent race. An embryo test method has been developed which is useful in quick evaluation of varieties as well as fungicides. Transmission studies in loose smut of wheat demonstrated differences in floral morphology of different varieties to varied varietal reactions. Solar heat treatment for the control of loose smut during the month of May and June has been perfected. A remarkable success in controlling loose smut and flag smut has been obtained by recommending seed treatment with systemic fungicides such as Vitavax (2g/kg seed), Bavistin/Derosal (2.5 g/kg seed) and Raxil (1g/kg seed). Average loose smut

incidence has been brought down from 2.09 to 0.07% resulting in enormous economical gain. Due to rice-wheat cropping system, the incidence of flag smut has been reduced. A technique involving seed smearing with teliospores of *U. agropyri* has been developed for artificial screening of germplasm and six wheat cultivars viz. PBW34, PBW65, PBW138, PDW215, TL419 and TL1210 were found resistant to flag smut.



Yellow rust of wheat



Karnal bunt of wheat

Karnal bunt: Karnal bunt had become important in intensive cropping system with the release of high yielding varieties. It is a disease of quarantine importance. It adversely affects germination grains and deteriorates gluten quality. It appeared in epidemic form in late 1970s and early 1980s in the State. Incidence was found less in dry areas of S-W districts. Boot leaf inoculation technique has been standardized which is quite useful for artificial disease creation. The chance landing of sporidia on spikelets leads to uneven spread of the disease within an ear head. Karnal bunt infection predisposes grains to saprophytic fungi like *Aspergillus niger* that produces aflatoxin. Recommendation of Tilt 25 EC and Folicur 25 EC (200 ml/acre) at 50% heading has provided excellent control of Karnal bunt and helped in healthy seed production. Wheat varieties, namely PBW 34, PBW 154 and PV 18 were found to be comparatively resistant to the disease. Inheritance studies revealed that resistance is controlled by minor genes. It was established that rainfall and cloudiness favours occurrence and development of Karnal bunt. A weather-based disease prediction model has been developed for timing fungicide application.

Rusts: Rusts were a major problem in the State in the past and regular epidemics occurred during 1960s. Due to strong breeding programme, rusts got reduced to low incidence. But due to recent appearance of a new pathotype 78S84 of yellow rust and the susceptibility of widely grown wheat variety PBW 343, yellow rust has again become a major problem in the State. The disease first appears in sub-mountainous districts of Ropar, Fatehgarh Sahib, Nawanshahar, Hoshiarpur and Gurdaspur. During 2008-09 it appeared in severe form in many fields in these districts.

In 2010, the disease was recorded as early as in middle of December in wheat sown in the poplar fields. Single application of Tilt 25 EC was found highly effective to manage yellow rust, brown rust and powdery mildew diseases. Bayleton has been recommended for the control of both rusts and powdery mildew. New fungicides Nativo, Amistar Top and Opera have also been found effective for yellow rust. It was effectively managed through a campaign by not sowing susceptible varieties like PBW 343 in the sub- mountainous areas and destruction of initial foci of infection by spot application of fungicides.

Powdery mildew: Eight races of *Erysiphe graminis* have been identified based on international set of host differentials. Resistance against different races has been determined and genes controlling this resistance have been marked. Incidence of powdery mildew has increased on account of wide scale cultivation of wheat variety PBW 343 and due to comparatively warm temperature during the months of February in Punjab.

Ear-cockle nematode: Ear cockle nematode, *Anguina tritici* used to cause significant losses in wheat yield. The yield loss due to earcockle nematode galls (also called *mammani*) depends on the level of seed gall mixture at sowing time. The development of disease was found more in wheat sown in second half of December as compared to wheat sown in November first week. Regular surveys of the grain markets of various districts revealed a gradual decline in its incidence from 12.17 % in 1989 to 0% by 2000. Use of gall free clean seed (by winnowing or by floatation method using ordinary water) is a significant step in disease management.

Rice

Bacterial leaf blight: It is the most important disease of rice caused by a bacterium *Xanthomonas oryzae* pv. *oryzae* and its kresek phase at seedling stage results in maximum losses. The seed-borne inoculum of the pathogen has been found to be the main source of perpetuation of the bacterium. Excessive use of nitrogenous fertilizers increased susceptibility to the disease. Host plant resistance often breaks down due to emergence of new pathotypes. The pathogen is highly variable and the *Xoo* population is being regularly monitored. Seven distinct pathotypes have so far been identified in the State.



Bacterial leaf blight of rice

False smut of rice

Three new *Xoo* pathotype variants have been identified from cultivars Pusa 1121, PR120, PAU 201 in 2010. These cultivars were resistant to all the seven earlier identified pathotypes. Pathotype Pb Xo 7 is most prevalent pathotype in the State. A laboratory protocol based on PCR identification of *Xoo* has been developed that showed remarkable diversity among different isolates of *Xoo* at molecular level. The disease incidence and spread is high in early transplanted crop supplemented with more than recommended nitrogenous fertilizers. Sowing of disease free seed and its treatment with Emisan (5g/10 litres water) along with Streptocycline (1.0 g/10 l water) has been recommended and found effective for controlling seed-borne inoculum. A regression model based on weather parameters for forecasting bacterial blight has been developed. Two antagonists viz. *Pseudomonas fluorescens* and *Bacillus subtilis* proved effective in controlling BLB of rice when used as seed and spray treatment.

Sheath blight: Sheath blight due to *Rhizoctonia solani* has emerged as a major problem of rice in the State and losses are mainly due to unfilled grains. All the cultivated varieties are susceptible to sheath blight. Weed grass *Cynodon dactylon* on the bunds around fields and sclerotia of the causal fungus in the soil are found responsible for spread of sheath blight. Tillering to ear emergence stage was found to be highly susceptible for disease development. Clean cultivation devoid of weeds helps to check the disease spread. Spray application of Monceren 250SC and Tilt 25 EC @ 200ml in 200 l water/acre has been recommended and found highly effective in checking the development and spread of sheath blight.

Sheath rot: *Fusarium moniliforme* was identified as main cause of sheath rot of rice. PR 106 was found highly susceptible to this disease. PR 117 and 118 were also found susceptible. It was established that the pathogen of sheath rot is mainly seed borne in nature and the infected seed is a main cause for disease occurrence. The

pathogen was found to be located in endosperm and embryo. Infection of sheath rot increases the chaffiness of grains and causes grain discolouration. The disease was effectively managed by application of Tilt 25 EC @ 0.1 % at boot stage.

False smut: False smut has emerged as an important disease in rice. High humidity and rainfall at the time of flowering favour infection of false smut. It was found that in addition to losses due to grain infection it also causes sterility in uninfected grains. Viability of green and yellow coloured spores of false smut was studied and it was found that yellow spores remain viable for 3 months and green spores never germinated. The varieties PR 114, PR 116, PR 118, HKR 47 and HKR 127 were found more susceptible to false smut. First spray of Blitox @ 500 g/acre at booting stage following by application of Tilt 25 EC @ 200 ml/acre after 15 days interval was found effective for controlling the disease.

Brown leaf spot: Incidence and severity of brown spot of rice is found more in light soils. Varieties PR 114 and PR 116 were found to be more susceptible and the disease severity increased during the year of low rainfall. Application of Tilt 25 EC at boot stage was found highly effective to check the disease. Green manuring before transplanting was found effective in reducing the incidence of brown spot and grain discolouration.

Kernel smut: The floral characteristics like opening duration of flowers and availability of pollens play important role in occurrence of the disease. The panicle wetness upto 74 hrs favoured infection of kernel smut. Two sprays of Tilt 25EC @ 200 ml/200 litres of water/acre have been recommended for controlling the disease. Higher doses of nitrogen and early planting favours development of kernel smut. Some non- hosts like maize, sorghum and certain weeds helps in the multiplication of kernel bunt pathogen.

Foot rot: Foot rot has emerged as a major problem in *Basmati* rice in the State with the cultivation of Pusa 1121 variety. The disease is seed-borne and results in significant yield losses. Use of healthy seed for nursery raising is important. For its effective management the seed should be taken from disease free seed and should be soaked in solution of 0.2% Bavistin 50 WP for 12 hours before sowing. Nursery should also be dipped in 0.2% solution of Bavistin for 6 hours before transplanting. Destroying of infected plants in nursery as well as in field helps to reduce the disease incidence. To produce disease free seed, one spray of Tilt (200 ml/200 l water/acre) has been recommended. *Tichoderma harzianum* formulation has also been recommended for its management.

Rice nematodes: *Meloidogyne graminicola* causing root knot is an emerging problem in light soils and has been observed in rice nurseries as well as the main fields. Likewise, *Hirshmanniella oryzae* is a predominant rice root nematode in Punjab with high frequency in Kapurthala, Ferozepur and Sangrur. Nursery bed treatment with Furadan 3G @ 4 kg a.i. / ha at the time of sowing was observed effective in decreasing nematode infection in nursery plants.

Rapeseed and Mustard

Albugo candida causing white rust of raya was found to infect a number of cruciferous hosts. Oospores of the fungus present in the soil were found to be important for initial appearance of disease. Morphological variations in white rust (*Albugo candida*) of crucifers, occurring on rape seed and mustard was worked out and the pathotypes of the pathogen were identified. The genotypes of rapeseed and mustard possessing resistance to white rust have been identified. A laboratory technique for fungicide evaluation against this disease has been standardized. Effective spray schedule using Indofil M-45 and Score was developed for the management of Alternaria blight and white rust of rapeseed and mustard.

Pulses

The seed borne nature of *Xanthomonas campestris* pv. *vignicola* (bacterial blight of cowpea) and *X. campestris* pv. *vignaeradiatae* (bacterial leaf spot of green gram) was established. Seedling symptom test was devised to detect a very low level of infected seeds (0.1%) in a seed sample. The presence of small, shrivelled and discoloured seeds in seed lots of cowpea and green gram serves as a very good indicator for the presence of infected seeds. Seed treatment with Captan/Thiram @ 3g/kg seed has been found effective in checking seed borne diseases.

Field evaluation of antagonists for the control of bacterial leaf spot of green gram revealed that *Bacillus subtilis* proved most effective in reducing the disease incidence by 50 per cent along with 35 per cent increase in grain yield. For the control of bacterial and *Cercospora* leaf spots and reddening of green gram, first two sprays Streptocycline (100ug/ml)+Bavistin (0.025%) + Blitox(0.1%) followed by last two sprays of Blitox (0.2%) alone at 10 day interval have been recommended.

Pot culture, cut twig and field screening techniques have been developed for *Ascochyta* blight and gray mold of chickpea. These techniques are useful in identifying the resistant plants without damaging the crop and the identified plants can be used in crossing in the same year. Morphological and pathological variability has been studied in *Ascochyta rabiei* causing blight of chickpea. Seed treatment with Bavistin + Thiram @ (1.5+ 1.5 g) and spray of Indofil M-45/Kavach @ 360 g /acre in 100 liters of water has been recommended for effective disease control. The department gave genetic stock of promising lines of cowpea to the Department of Vegetable Science out of which Sel 263 variety of cowpea has been released.

Root rot and wilt are serious problems in early sown pea crop. Seed treatment with Bavistin has been suggested for its control. Pea lines/varieties having resistance to powdery mildew have been identified. A pathometry was devised for evaluating rust of pea based on infection types of leaves and stems due to uredia and telia. Six races of *Uromyces viciae fabae* occurring on pea were identified. *Lathyrus odoratus*, *L. aphaca*, *L. sativa* and *Vicia hirsuta* have been identified as collateral hosts for pea rust. Combined control measures against powdery mildew and rust by spraying Karathane and Dithane M-45 have been recommended. Triazole fungicides notably Bayleton (triadimefon) has been found highly effective against both powdery mildew and rust.

Meloidogyne incognita and *M. arenaria* are common nematodes associated with pulses in the Punjab. Losses due to root-knot nematode were found more in summer and *kharif* pulses. Interaction studies between *M. incognita* and *Rhizobium* spp. on pulses revealed that root-knot nematode besides adversely affecting the growth of plant also interferes with nitrogen fixation by *Rhizobium* spp. Summer ploughing during May-June decreases *M. incognita* population. Resistance against *M. incognita* has been found in different varieties of cowpea (Cowpea-88, C-152, 82-1B, Co-Pusa-1 and CG-28) and pigeonpea (AL-15, Prabhat, 4-64, 4-83, BDM-2, T-21, Sebore-197 and UG-300).

Maize

Incidence of crazy top downy mildew (*Sclerospora macrospora*) was reported for the first time in the State. Involvement of fungi, namely *Macrophomina phaseolina*, *Fusarium* spp., *Cephalosporium* spp., *Nigrospora* spp., *Drechslera halodes* and two nematodes, *Pratylenchus penetrans* and *Haplolaimus indicus* in causing post-flowering stalk rots has been established. The inoculation technique for post-flowering complex has been improved. Composite 'Kesri' has been improved for post flowering stalk rots particularly *M. phaseolina*. Phillipine downy mildew was observed as serious on seedlings up to 50 days age of the plant. Removal of *Kans* grass reduced the disease. Brown stripe downy mildew was identified causing serious damage to maize crop. *T* race of *Helminthosporium maydis* was identified for the first time in India. Rust on winter maize was observed as a serious disease in 1980s and the resistant sources were identified. Seed rot and seedling mortality in maize was controlled by seed treatment with Bavistin @ 3g/kg seed. Indofil M-45 @ 250g/100 litre of water has been recommended for the control of maydis leaf blight.

Pearlmillet

Stable sources of resistance to downy mildew, ergot and smut diseases have been located. A sick plot for screening against downy mildew has been created. Inoculation techniques for screening against ergot and smut have been standardized. Inheritance of downy mildew and ergot resistance has been studied and genotypes with stable resistance have been developed. Recurrent selection for resistance against ergot disease has resulted in the development of 123 ergot tolerant lines and five populations. Downy mildew of *bajra* has been successfully managed as all the varieties/hybrids recommended by the University are resistant to this disease. Rust (*Puccinia penniseti*) has been observed to cause significant damage at seedling stage and four races of the pathogen have been identified. Triazole compounds have been found highly effective against rust.

Groundnut

Pioneering work has been done on aflatoxin problem in groundnut. The afla-root disease of groundnut was reported for the first time and a bioassay technique for the detection of aflatoxin producer and non-producer strains of *Aspergillus flavus* was developed. Collar rot disease was effectively controlled by seed treatment with Thiram or Indofil M-45. Similarly, *Tikka* disease of groundnut was effectively controlled by spraying of Bavistin (50-60g/l water) with significant increase in yield. Score and Folicur have also been found effective. Carbendazim, apart from controlling 'tikka' disease of groundnut, was found to exhibit cytokinin like activities enhancing yield attributes. Clump disease of groundnut was noticed in Ludhiana and Sangrur districts. Bud necrosis acted as a deterrent for revival of groundnut cultivation in the State. As it resulted in necrosis of terminal buds. On the basis of symptom expression, biophysical properties and EM studies, the cause was identified as peanut bud necrosis virus.

Cotton

Delinting of cotton seed with commercial sulphuric acid was recommended for eradicating externally seed borne pathogens. Soaking period of such seed should be reduced to 2-4 hours from 6-8 hours as in case of non-delinted seed. For eradicating both externally and internally seed -borne pathogen, the soaking of seed in solution containing 10 g Ceresan wet and 2.5 g Streptocycline or 15g Agrimycin in 10 litres of water for 6-8 hours is recommended. For the control of secondary spread of bacterial blight and fungal leaf spots, three sprays of Blitox-50 (500g) + Agrimycin (20 g)/Streptocycline (3g) per acre at an interval of 15 -20 days starting just after rain shower of rain have been recommended.

Cotton Leaf Curl Virus (CLCV) has assumed significance and has spread in major cotton growing areas. Most of the Bt cotton hybrids are susceptible to this virus. Ambient conditions for the development of CLCV have been identified. Leaf curl resistant Bt hybrids i. e. MRC-7017 and MRC-7031 have been introduced for cultivation. Cotton lines EL-405, ISC-67E-3, ISC-33, ISC-77, BC-68-G-3, G-Cot-13, EL-192, EL-958, PK-558 and B-61-1862 have been found resistant to root knot nematode.

Sugarcane

Red rot caused by *Colletotrichum falcatum* is a serious disease of sugarcane. Epidemiological investigations on red rot have yielded useful information. Saprophytic survival of the fungus has been found up to 2 years. Infested soil acts as source of disease initiation. Variability in red rot pathogen was established and five distinct pathotypes have been identified in the State. The midrib isolates were found to be very weak as compared to stalk isolates. Pathogenic variability was also established in the pathogens of wilt, smut and pine apple disease. Set treatment with mercurials (Agallol 0.5%, Aretan 0.25%, Emisan 0.25%, Bagollol 0.25%), Tilt @ 0.25 per cent and moist hot air treatment at 54° C for 4 hours for the control of RSD, GSD and LSD have been recommended for raising healthy crop. Control of smut by sett treatment with Agallol 0.5 per cent as well as Vitavax 0.5 per cent, of red rot with Bavistin 0.5 per cent and damping-off in seedling nursery by sterilization of substrate soil with formaline 1 per cent are some other recommendations. Application of carbofuran @ 1 kg a.i./ha at planting was found to suppress nematode population up to 3 months resulting in enhanced cane yield.



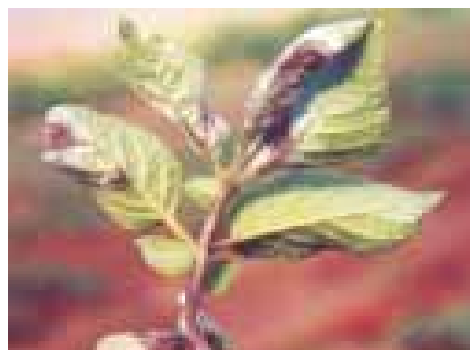
Red rot of sugarcane

Potato

Late blight: Late blight is a limiting factor in successful cultivation of potato crop in the State. Losses are more when the disease attacks before tuberization. It is a weather dependent disease and develops fast under high humidity and low temperature conditions with intermittent rainy spells. Based on disease survey data over the

past years, a late blight map has been prepared for the State. A detached leaf technique for evaluation and persistence of fungicides has been developed.

Eleven multigene races of the pathogen have been identified in the State. Infected seed tubers stored in cold stores have been found to serve as the main source of the disease carryover. Inter-relationship of potato and tomato isolates of *Phytophthora infestans* has been established. A minimum leaf wetness period of 6 hours is required for establishment of pathogen. A web based decision support system for the successful prediction and management of late blight of potato in Punjab has been developed for giving district wise advisory to the farmers. Prophylactic application of contact fungicides like mancozeb or chlorothalonil or propineb (500-700 g/acre) in first week of November is effective to check initial infection. Under more favourable weather conditions one or two applications of Ridomil Gold or Curzate M-8 or Sectin 60WG (700 g/acre) or Equation Pro (200ml/acre) have been recommended for managing disease development. Metalaxyl resistant strains of *P. infestans* have been observed in district Hoshiarpur and a need-based fungicide schedule with new fungicides worked out to manage resistance.



Late blight of potato

Common scab: Common scab affects the quality and marketability of tubers and is particularly more severe in light soils. Both superficial and pitted scab has been reported in the State. Green manuring with *dhaincha* before sowing and application of light weekly irrigations after tuberization have been found to reduce scab incidence. Tuber dip treatment with Emisan-6 (0.25%) for 10 minutes before sprouting has been recommended for effective control of the scab.

Black scurf: Black scurf has assumed significance in the State in the past few years. All the cultivated varieties in the State are susceptible. It adversely affects marketability of potatoes due to presence of black sclerotia of the fungus on tuber surface. Sowing of heavily infected tubers results into poor crop growth and patchy stand. Potato isolates of *Rhizoctonia solani* did not infect rice, while rice isolates proved weakly pathogenic on potato. Tuber dip treatment in solution of Monceren (0.25%) for 10 minutes has been recommended for control of scurf.

Pest risk analysis for brown rot and ring rot: To facilitate the export of potatoes, a plan of survey and monitoring protocols for establishment of pest free areas (PFAs) for brown rot/ring rot of potato was executed as per international protocols for PFAs (ISPM 4) under the guidance of Directorate of Plant Protection and Quarantine, Government of India. Survey of potato growing areas of Punjab state was done three times in the season i.e. re-cropping soil survey (10% of fields selected), cropping survey (20% fields/cropped area selected), post-harvest tuber survey (30% of tuber lots inspected). None of the soil samples yielded the colony of Brown rot pathogen (*Ralstonia solanacearum*) on SMSA medium. None of the plants showed brown rot symptoms and the crop was free from infection. During inspection of tuber lots, no tuber was found infected with brown rot (*Ralstonia solanacearum*) and bacterial ring rot (*Clavibacter michiganensis* sub.sp.*sepedonicum*) which was further confirmed serologically.

Tomato

Tomato germplasm was evaluated for resistance to diseases under field and artificial epiphytotic conditions. The tomato lines having resistance to early blight and multiple disease resistance have been identified. Root dip treatment of tomato nursery in vydate (1% for 30 min.) reduced the number of galls and egg masses of root knot nematode. Seed bed treatment with Basamid (40g/m²) gave its complete control. Spray application of Ridomil MZ in February followed by sprays of mancozeb have been found to be effective against late blight and also early blight on tomato. Tomato lines BT-117, LT-42, TH-21, IIIH-R-1, 58-11-1-1 were found to be moderately resistant to late blight under artificial inoculation conditions. Sel-12-1-17, Naveen Plus, CLN-2264(3) and TH-12 were found highly resistant with disease severity between 7-10 per cent.

Root knot nematode (*Meloidogyne incognita*) is an important pathogen of vegetable crops notably brinjal, tomato and cucurbits and in poly-net house grown tomato and capsicum. It infests nursery as well as transplanted crop and the spread to newer sites is mainly through infested nursery. Incorporation of 40 day old *Toria* or *Taramira* crop in nursery beds 10 days before sowing and turning the soil 3-4 times also decreased nematode infestation in seed beds and helped in raising nematode free and healthy nursery. Seedling dip with 0.03% Dimethoate (10 ml of Rogor 30 EC in 10 litres of water) for 6 hrs before transplanting decreased root galling index in tomato crop. Green manuring with American and French marigold reduced root knot infestation in field in the successive crop tomato. Growing of Garlic in rotation with other vegetable crops also decreased root knot infestation in field. Solarisation in net-house reduced root knot infestation in soil.



Root knot nematode on capsicum grown in poly-net house

Cucurbits

Downy mildew: Downy mildew is a devastating disease on muskmelon and in low tunnel grown cucumber. Resistance sources in wild melons and *phut* collections have been identified and being used in breeding programmes. Five muskmelon lines viz. IC274014, MCPS-11, MCPS-12, MCPS-17 were highly resistant against downy mildew. Four races of *Pseudoperonospora cubensis* (muskmelon downy mildew pathogen) have been identified. Overwintering vines of cucurbits such as *Luffa* that harbour the pathogen should be removed. Oospores of *P. cubensis* were observed in pumpkin and *Luffa aegyptiaca* during off season period indicating their possible role in disease perpetuation. A forecasting model based on secondary spread and humid thermal ratio has been developed for downy mildew of muskmelon. Prophylactic application of fungicides like mancozeb or chlorothalonil (600 g/acre) starting from second week of April have been recommended. Under high disease risk situation, one or two applications of Ridomil MZ or Aliette (500 g/acre) are recommended. New fungicides like Amistar (0.1%), Mefenoxam (0.2%) and Curzate M-8 (0.25%) have been found to be equally effective against downy mildew on cucumber under low tunnel system.

Powdery mildew: Resistant sources against powdery mildew were identified in some wild melons and *phut* collections. Pathotypes and their virulence patterns in *Sphaerotheca fuliginea* occurring on different cucurbits were identified. Ergosterol biosynthesis inhibitors (fenarimol, triadimefon, penconazole, flusilazole, propiconazole) were found to be highly effective against powdery mildew of summer squash.

Cucurbit viruses : New viruses (ZYMV, SqMV, WMV, CGMMV) were found to be associated along with CMV in cucurbit crops when analysed by DAS-ELISA.

Other Vegetables

Alternaria blight is a serious disease in all the cruciferous vegetables and its management technology has been worked out using dithiocarbamate fungicides. Iatrogenic effect of copper oxychloride on Alternaria blight in radish has been observed. Stalk rot of cauliflower can be controlled through farm yard manure amendment. The cause of radish mosaic has been identified as a member of poty virus group and three radish cultivars, namely S-white, S-24-29 and L-R Bombay were found resistant. Radish scab has been found to be more serious on off-season crops. For control of purple blotch of onion, sprays of Indofil M-45 in combination with malathion and sticker triton have been recommended. Folicur 25EC (0.1%) has given still better control of purple blotch. Onion thrips predisposed the plants to purple blotch. Downy mildew was recorded on seed crop from Bathinda and its management technology was given.

Ageratum conyzoides has been reported as an alternate host for yellow vein mosaic of okra for the first time from the State. The weed grows wild in diverse habitats served as primary source of infections. Cercospora leaf spot was managed by applications of Bordeaux mixture and Bavistin (0.1%). Chilli anthracnose could be

controlled by spray of Indofil M-45 or Blitox. The pathogens *Colletotrichum capsici* and *C. gloeosporioides* exhibited distinct morphological and pathological variability. Wet rot of chilli (*Chonephora avavenlitarum*) is assuming importance and can be managed by fungicide sprays recommended for anthracnose. Sudden wilt of chilli, which is favoured by heavy rains and stagnation of water has been effectively managed by planting chilli crop on raised beds. Chilli hybrids CH-1 and CH-3 have shown remarkable resistance to leaf curl virus and have helped in optimum yield output.

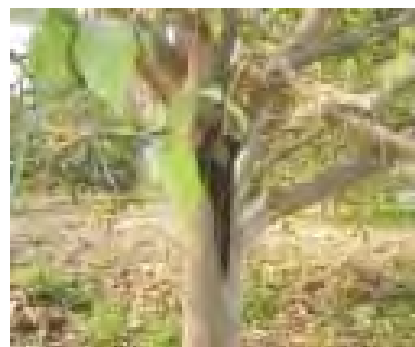
Phomopsis blight of brinjal (*Phomopsis vexans*) is a serious disease on this crop. Infected seed and plant debris have been found to play an important role in disease transmission to the new crop. Seed treatment with Captan or Thiram has been found to be highly effective in checking seed borne infection. Root knot nematode is the most important nematode pest of vegetable crops. Solarisation of nursery beds of brinjal in May-June reduced root galling index.

Citrus

The presence of four virus/virus like agents, namely citrus tristeza, exocortis, ring spot and greening with the trees showing symptoms of citrus decline has been established. A mother block of indicator plants has been created. Trunk injection under pressure with tetracycline HCL or Penicillin @ 500 µg/ml singly or in combination with zinc sulphate suppressed the greening symptoms. A large number of trees of different species of citrus have been indexed for the existing virus/virus like diseases. The bud wood from virus free promising trees has been used for producing virus free plants.

Foot rot has assumed significance as a serious disease of kinnow and other citrus cultivars. More than 60 per cent of kinnow orchards the State are infested to varying extent.

Infected nursery has been found as the main reason in spread of the disease to larger areas in the State. Low budding level, flood irrigation and mechanical injury to roots during intercultural farm operations have aggravated the problem further. Two species of *Phytophthora* (*P. parasitica*, *P. citrophthora*) are involved in causing infection. The disease can be kept under check by following an integrated approach. Apart from planting healthy nursery, bud union level may be kept sufficiently above ground and flood irrigation should be avoided. The roots should also be avoided from damage due to mechanical tractor-operated operations in the orchards. Soil drenching with Ridomil MZ/Gold or Curzate (25 g/10 l/tree) and trunk paint after removal of damaged skin (2g in 100 ml linseed oil) during February-March and July-August has been recommended. In addition, spray of Aliette (2.5%) has been recommended during April and September for better disease management.



Kinnow plant showing gummosis

For the control of fruit drop in Kinnow combined spray of Ziram 27 SC + 2,4-D (sodium salt of horticulture grade) or Propiconazole 25EC+2,4-D or Bavistin 50WP +2,4-D has been recommended. Screening of Government approved nurseries was done for certification. Methods for detection of *Phytophthora* propagules in soil using rough lemon leaf bait and for citrus greening and ring spot viruses using PCR were standardized .

Grapes

Anthrachnose and powdery mildew are serious disease problems in grapes. *Colletotrichum gloeosporioides* was also found to be associated with grape anthracnose after rainy season in Punjab. A minimum leaf wetness duration of 3h was necessary for establishment of anthracnose infection at 25°C. Severity was maximum during rainy season in Punjab. Effective management of anthracnose (*Gloeosporium ampelophagum*) has been obtained by alternate spray of Bordeaux mixture (2:2:250) and Bavistin (0.1%) during different months of growing season. This spray schedule also takes care of Cercospora leaf spot and downy mildew diseases. Bayleton (0.04%) was

found to be highly effective against powdery mildew of grapes followed by Topaz. Application of Score @ 0.1% or Bavistin @ 0.1% at 15 days interval particularly during rainy season period proved highly effective in controlling the disease.

Carbendazim resistant strains of *G. ampelophagum* were reported for the first time in India. These were equally pathogenic and highly competitive. Resistant strains possessed cross resistance to other benzimidazole fungicides like Topsin –M but were sensitive to fungicides like mancozeb, copper compounds, fluazinam and triazoles. A laboratory technique based on spore germination and germ tube length on fungicide treated leaf disc has been developed for evaluation of fungicides against *Uncinula necator*. Populations collected from various vine yards revealed presence of conidia with reduced level of sensitivity to triadimefon indicating development of resistance. Cleistothecia of *U. necator* were found for the first time under field conditions indicating their possibility in disease epidemiology. Cercospora leaf spot was found to be severe after rainy season in September-October whereas downy mildew incidence was reported more during October.

Peach

Root-knot nematode (*Meloidogyne incognita*) is a serious problem in peaches. Three to four applications of carbofuran @ 3kg a.i/ha in nursery beds in January, March, June and September reduced nematode galling index and increased plant vigour. In the affected orchards, application of Furadan 3G @ 100 g/ plant twice (February, June) in a year checked the nematode and increased plant growth. No carbofuran residues was detected in fruits after 60 days of Furadan application. Root dip treatment of infected peach nursery plants in 0.1 per cent solution of phenamiphos for 6 h was also effective in reducing galling index. Peach root-stock Flordaguard has been found resistant to *M. incognita* and recommended to the farmers.

Mango and Ber

Powdery mildew causes considerable losses of fruit yields both in mango and ber. Symptoms develop more conspicuously on young fruits than on leaves. Its mode of perpetuation as mycelium in the buds has been established. Karathane (0.1%) has been recommended for powdery mildew control in these fruit crops. Bayleton (0.1%) has also been recommended for the control of mango and ber powdery mildew.

Mushrooms

Nematode species such as *Aphelenchoides composticola*, *Ditylenchus myceliophagus*, *Evagrinorhabditis agaricus*, and *Rhabdibicauda jagdishii* were found associated with mushroom. Main sources of myceliophagus nematodes, *A. composticola* and *D. myceliophagus* were found to be cow dung, wooden boxes, spent-up compost and casing soil. Various other components like urea, superphosphate, muriate of potash and CAN proved toxic to these nematodes. Various hygienic conditions like surface sterilization with 2% formaldehyde, sodium hypochlorite, potassium permanganate and use of polythene sheets have been found effective in keeping *A. composticola* population under check.

Biocontrol of Plant Diseases

The mutants of *T. harzianum* have been obtained with UV irradiations. The mutant isolate showed better biocontrol potentiality against black scurf of potato and chickpea wilt both in green house as well as in field experiments. The amendment with FYM further enhanced biocontrol potentiality of both mutant and parent isolates against chickpea wilt. The mutant isolate has also better tolerance to Bavistin as compared to parent isolate. Dip treatment of potato seed lots in Trichoderma formulation (10 g formulation/litre water with 20 g molasses) for 10 minutes against Black scurf has been recommended.

For managing foot rot of rice, infected seed was dipped in Bavistin 0.05g + Streptocycline 0.01g /lit. of water for overnight and smeared with talc formulation of *T.harzianum* @ 15g/kg before sowing. In addition roots of plants were also dipped in *T. harzianum* @ 15g/liter of water for 6 hrs before transplanting. Treatments controlled the disease effectively. To manage pea wilt, treatment of Pea seed with talc based formulation of *Pseudomonas*

fluorescens @ 15g + 1 g Captan/Kg of seed provided excellent control. Both these recommendations have been included in the package of practices for the State farmers. An isolate of *Trichoderma viride* has been found effective in managing foot rot in citrus. Paste application of *T.viride* resulted in significant reduction in trunk lesion size and soil application also increased feeder root density.

Entomology

Insect Ecology

Work on Insect Ecology was started in 1969 under two PL-480 projects on 'Ecological studies on *Trogoderma granarium* Everts and methods of its control' and 'Ecological studies on the European corn borer and *Chilo partellus* in the Punjab' by the USDA Agricultural Research Service. Several new techniques/ methods have been developed such as (i) a trap to study sulphation as an index of atmospheric pollution, (ii) leaf disc area measuring photosensitive device to study antifeedant effects of plant products, (iii) non- enzymatic hydrolysis of flucosinolates using ion- exchangers, (iv) a mathematical model to predict the population fluctuations of sugarcane pyrilla and (v) an olfactometer to study the anemotactic response of mustard aphid. Population sampling techniques for different insect pests have been developed which is a primary tool for insect surveillance programmes. The department has also carried out pioneering work in the construction of life-tables of maize borer and other insect pests along with identification of key mortality factors.

Insect Physiology

Insect Physiology Laboratory was established in 1967 and studies on various aspects including insect nutrition, behaviour, insecticide-induced resurgence, insecticide resistance and biorational approaches in pest management were conducted. The laboratory has carried out pioneer research work on extraction and bioassay of female sex pheromones of rice moth and Angumois grain moth. Influence of biotic and abiotic factors on production of sex pheromones in the females and response of the males towards these pheromones was studied. The studies revealed that water stress in the host plant increased toxicity of the insecticides to *Lipaphis erysimi* whereas, increased supply of potassium to the host plant decreased fecundity of the aphid. It was established that sub-lethal concentrations of endosulfan, chlorpyrifos and several pyrethroids stimulate the reproduction and consequently resurgence of the aphid.

Toxic and developmental effects of several insect growth regulators, molecules with novel modes of action (neonicotinoids, cartap hydrochloride, diafenthiuron) and natural plant products have been studied on important insects. Studies showed high level of resistance by *B. tabaci* to various insecticides. Ethion, profenophos, triazophos, bifenthrin, imidacloprid and endosulfan did not exhibit any appreciable resistance and thus hold promise for effective control. Number and intensity of various esterase bands indicated variations in the population structure of the white fly collected from different hosts and locations in Punjab. Studies on food consumption, utilization and indices of growth have been carried out on a number of important lepidopteran pests. Based on these studies it was predicted in 1990 that *S. litura* may emerge as a pest of cotton in the state. This warning came true in the new millennium when outbreaks of the pest were recorded on cotton crop all over the state.

Insect Toxicology

Insect toxicology laboratory was established in 1968. A gas chromatograph was imported from U.S.A. and the work on pesticide residue analysis was initiated to find out safe waiting periods. The laboratory is engaged in the study on insecticide residues in various abiotic and biotic components of the environment, metabolism of insecticides in plants and insects and mechanism of insecticide resistance in major insect pests. The Pesticide Residue Analysis Laboratory (PRAL) which is a part of the Insect Toxicology section of the Department has been accredited by the National Accreditation Board for Testing and Calibration Laboratories (NABL). This is the first laboratory among State Agricultural Universities (SAU's) to get such recognition. The PRAL ensures timely services for testing pesticide residues in foods and agricultural products.

Since its establishment, the laboratory has developed cost effective, simple and sensitive methodologies for estimation of pesticide residues in different matrices. These methods have been adopted by various laboratories at national and international level. Suitable waiting periods were suggested for different crop/insecticide combinations. Analysis of 3146 samples of different food commodities during 1976-96 revealed invariable presence of DDT and HCH residues in vast majority of samples out of which 29 per cent samples had residues above the legal limit. However after 1996, the analysis of 3850 samples of food commodities revealed the presence of pesticide residues above the legal limit only in 3-4 per cent samples. This could be attributed to the ban on use of DDT and HCH in agriculture along with research and availability of chemicals with novel mode of action.



Pesticide residue analysis laboratory

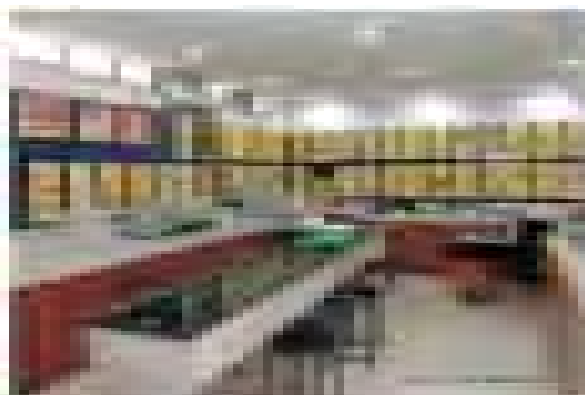
A method for the detection of insecticide resistance in diamondback moth, *Plutella xylostella* Linn, has been developed by the laboratory which was adopted by FAO as a standard method for resistance monitoring in this pest. The laboratory has detected variable degree of resistance in stored grain pests viz. red flour beetle and rice weevil to malathion and *Spodoptera litura* infesting different crops to fenvalerate. However, the diamond back moth infesting Cole crops exhibited resistance to a number of insecticides. Some new insecticides have been found effective against these resistant pests, which can be used to develop integrated pest management strategy against these pests.

Insect Molecular Biology

Work in the field of insect molecular biology was initiated in 2001. Since then, research in this field has resulted in number of achievements. Based upon B-biotype specific nucleotide sequences in white fly, a number of RAPD-PCR and SCAR markers have been developed. These markers have established B-biotype dominance in South India, complete absence in North India and a low level of contamination in Central Indian states. Additional SCAR markers holding plant host specificity in whitefly have been developed and validated. The markers have been useful in molecular analysis of whitefly population structures with respect to host specificity and in acquisition and transmittance of cotton leaf curl virus (CLCuV). CLCuV DNA from cotton has been characterized and molecular techniques developed for establishing CLCuV resistant/tolerant/ susceptible status of cotton genotypes. Restriction mapping of complete CLCuV DNA-A established that symptomatic differences amongst different diseased cotton plants could be due to different strains of CLCuV. A dot-blot ELISA kit has been developed for detection of Bt-protein (CryIAc) in Bt- cotton seeds and other plant tissues. PCR based techniques have been developed for molecular identification of cryIAc gene in cotton plants. These techniques have been extensively utilized for screening of cotton populations arising from various crosses. Chitinase and proteinase genes have been cloned from entomopathogenic fungus *Beauveria bassiana*. Holding significance in virulence of this fungus, these genes have been sequenced and are being studied for enzymes kinetics and recombinant protein expression. This will help the scientific community to understand and use microbials in a better way.

Taxonomy

Research in insect taxonomy using traditional methods has remained important aspect of entomological research. Six new genera, one new sub-genus and 81 new species of leafhoppers have been described and illustrated. Eleven species of Typhlocybinae leafhoppers have been recorded for the first time in India. Taxonomic keys have been prepared for 22 species under 12 genera of Indian Dikrancurini, 53 species under 16 genera of *Typhlocybini*, 07 species under 05 genera of *Zyginellini* and 86 species under 20 genera of *Empoascini*. The taxonomic status of 35 chrysomelid species was established. A checklist of Indian species of *Typhlocybinae* comprised of 568 species under 146 genera has been prepared. Ten species of leafhoppers, which act as vectors of different plant pathogens, have been identified. In aphids, 75 species from 150 host plants were recorded from northern India.



Taxonomy laboratory



Insect Museum

Survey-cum-collection tours were conducted at 376 localities in the states of Punjab, Himachal Pradesh, Haryana, Rajasthan, Uttarakhand and Delhi, covering an area of about 26350 hectares. This led to collection of 21,968 specimens of different insect orders, of which 18,472 insects belonging to 12 orders and 80 families have been processed which enriched the collection at Entomological Museum/Taxonomy Laboratory (Fig 2, 3). At present number of insects housed in this Museum has increased to 32,484. Taxonomy laboratory has collected more than 600 specimens of mealy bugs from Punjab and Rajasthan from 11 host plants and 150 specimens were deposited in the National PUSA Collection, IARI, New Delhi. A total of 227 species from Lepidoptera, Coleoptera and Hemiptera belonging to 33 Superfamilies, 53 families and 186 genera have been identified. Checklist of 29 species, synonymies of 24 species have been updated, 676 species have been studied for taxonomical/ morphological studies and 2429 illustrations have been prepared. Nineteen dichotomous keys have been prepared for 67 taxa of different ranks. The department is also catering the identification services to other institutes/ universities under which 167 specimens belonging to 68 species have been identified.

Biological Control

The work on bio-control of insect pests in Punjab was first initiated in 1960s by releasing 'Barbados strain' of tachinid fly, *Lixophaga diatraeae* Townsend, for the control of Gurdaspur borer on sugarcane, but it failed to establish. Later, over the years many species of *Trichogramma* were tried for the control of sugarcane borers. *Trichogramma chilonis* Ishii was found to effectively manage Tarai or stalk borer, *Chilo auricilius* Dudgeon and this technique is widely adopted by farmers. The laboratory has recorded 36 species of insects, 10 species of spiders, mite species from genus *Amblyseius* and 54 species of insectivorous birds preying on various insects. As many as 27 species of parasitoids belonging to 6 families were found parasitizing important agricultural insect pests. Nearly 30 species of entomopathogens including 20 species of baculoviruses caused disease in insect pests. NPV infections were recorded from some of most nefarious pests like *Helicoverpa armigera*, *Spodoptera litura*, *Plutella xylostella*, *Thysanoplusia orichalcea*, *Euproctis lunata*, *Spilosoma obliqua*, *Pieris brassicae* and *Hellula undalis* (Fabricius).



Release of Tricho cards for the management of sugarcane early shoot borer and stalk borer

Three species of egg parasitoids, *Trichogramma achaeae*, *T. brasiliensis* and *T. chilonis* (Taiwan strain) and three larval parasitoids, viz. *Allorhogas pyralophagus*, *Bracon kirkpatricki*, *Tetrastichus israeli* have been introduced in the state through Commonwealth Institute of Biological Control, Bangalore. Of these, *T. chilonis*, *A. pyralophagus* and *T. israeli* got established against sugarcane stem borer. An egg parasitoid, *T. chilonis* proved effective in controlling *Chilo infuscatellus* Snellon and *C. auricilius* in sugarcane. Experimental research trials followed by large scale demonstrations at farmer's fields during 1999 to 2009 in collaboration with

sugar mills proved the releases of *T. chilonis* @ 50,000 per ha at 7-10 days interval during July to October to be effective in reducing *C. auricilius* incidence. Similarly eight releases of *T. chilonis* @ 50,000/ha from mid-April to end-June at 10 day intervals have been recommended for the management of early shoot borer of sugarcane, *C. infuscatellus*. Eight releases of *T. japonicum* Ashmed @ 50,000/ha from mid-April to end-June at 10 day intervals were found effective for the management of top borer of sugarcane, *Scirpophaga excerptalis*.

Simultaneous releases of *T. chilonis* and *T. japonicum* @ 1,00,000 per ha at 7 day intervals, starting 30 days after transplanting, proved effective for the control of stem borer and leaf folder of rice. This has been recommended on organic rice for adoption. *T. chilonis* and *T. japonicum* are the major candidates for Bio Intensive Pest Management (BIPM); 7 weekly releases of *T. chilonis* and *T. japonicum* each @ 1,00,000 per ha along with one application of cartap hydrochloride (25kg/ha) were as good as cartap hydrochloride @ 25kg/ha, 30, 50 and 70 DAT for the management of leaf folder and stem borer in *basmati* rice. Similarly single release of *T. chilonis* @ 1,00,000 per ha after 10-15 days of sowing has been recommended for effective management of maize borer, *Chilo partellus*.

B. thuringiensis based biopesticides were found highly effective against the diamondback moth *P. xylostella* damaging Cole crops. Based on these studies, Dipel 8L @ 750ml/ha and Halt WP @ 750 gm/ha have been recommended by the university for DBM management. Weekly sprays of SI NPV @ 2.25×10^{12} OBs/ha were effective in controlling the attack of *S. litura* on Cole crops. A local isolate of *B. thuringiensis* (called PAU Bt) was isolated, multiplied and found promising for management of DBM on Cole crops. Its multiplication on a wheat bran based medium has also been standardized which costs less than Rs 100/- acre as compared to at least Rs 400/acre for the commercial Bt products.

Integrated Management of Insect Pests

Nearly 180 species of insect pests were established to cause damage to 53 species of crop plants grown in the state. A total of 1227 recommendations have been given by different sections of the department. These recommendations as part of package of practices are based on a variety of tactics including cultural and mechanical control practices, pest-tolerant varieties, biological control, pheromone traps, insect growth regulators and chemical pesticides. Economic threshold level (ETL) based application of insecticides have also been suggested for different crop/insecticide combinations to reduce health hazards.

Cotton : Studies on carryover of pink bollworm revealed that 82 per cent of the carryover was through cotton sticks. A number of cultural and mechanical control measures including grazing of cattle in fields after crop termination, shifting of cotton sticks to village premises from the field, stacking of sticks in vertical position, burning of sticks by the end of February, removal of seed from ginneries by end-April and sun drying or fumigation of left-over seed, etc. were recommended for minimizing the carryover population. ICAR-sponsored an ad-hoc project “Operational Research Project on the Integrated Control of Cotton Pests” under which the practicability and economics of above mentioned IPM technology was demonstrated at farmer’s fields (Fig. 9). During 1990s *H. armigera* emerged as a regular pest and whitefly *Bemisia tabaci* attained the status of a major pest. New molecules like spinosad, indoxacarb and thiodicarb proved very effective against *H. armigera*, while triazophos and ethion were recommended for whitefly management. Imidacloprid, thiomethoxam and acetamiprid became the molecules of choice for the management of cotton jassid. Among the new pyrethroids, beta cyfluthrin and lambda cyhalothrin were found effective against the pink and spotted bollworms. In the new millennium, large scale projects on IPM and insecticide resistance management (IRM) were initiated and Bt transgenic cotton was released for cultivation in the state during 2005. A website

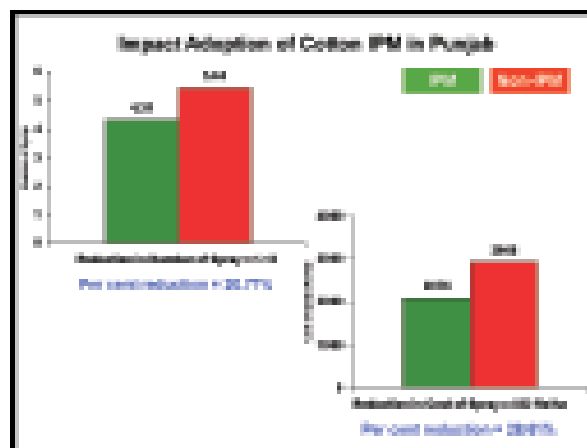


Fig. 9. Impact of adoption of IPM in cotton

www.pauipmcottondss.com has been developed for facilitating the cotton insect-pest management. PAU was first to evolve national level strategies for the management of mealy bug. IPM module of cotton developed by PAU was adopted by Sir Rattan Tata Trust and State Department of Agriculture in 300 villages.

The department is regularly monitoring the insect pests and diseases on six Bt cotton hybrids (RCH 134 Bt, RCH 317 Bt, MRC 6301 Bt, MRC 6304 Bt, Ankur 651 Bt and Ankur 2534 Bt) released for cultivation in Punjab during 2005. Studies on biodiversity revealed that 134 species of arthropods were associated with the cotton crop from seedling to harvest stage. Of these, 54 species were of herbivorous arthropods, 44 of natural enemies, 26 of casual visitors and 10 of pollinators. Diversity of total arthropods and predators was higher during the vegetative phase and non-target pests during reproductive phase of the crop. Diversity of all insect sub-communities, except Lepidoptera, was higher during the reproductive phase of crop. Monitoring of insecticides resistance showed high level of resistance in American bollworm to cypermethrin and fenvalerate, low to endosulfan and carbamates, negligible to chlorpyrifos and quinalphos, whereas it is not observed in case of spinosad. Monitoring for resistance in *Spodoptera* showed variable larval mortality of *S. litura* populations of Bathinda, Mansa and Ferozepur areas when exposed to different concentrations of recommended pesticides.

Rice : Rice root weevil, *Echinocnemus oryzae* (Marshall), brown planthopper, *Nilaparvata lugens* (Stal), termites (unusual pest for paddy fields) and small brown planthopper, *Loadelphax striatellus* (Fallen) were recorded as new pests. Timely sowing of rice has been recommended to check losses caused by stem borer. Lopping of the upper half crop canopy (Basmati 386 and Basmati 370) after 45 days of transplanting also reduces stem borer attack in tall basmati varieties, thereby, saving 1-2 insecticide applications. Among the cultural practices, it was recorded that conventional tillage in combination with shredding reduce the carryover of hibernating larvae of stem borer from December to February. Monitoring rice stem borer adult population using sex pheromone traps revealed number of egg masses in the field coincided with two peaks of trap catches. Overwintering of yellow stem borer larvae was higher in late June transplanted crop than in early and normal ones. Majority (98.7%) of larvae overwintered from the month of September in basal node in the root zone and only a single larva was found in each basal node. One dose of Padan + trichocard releases or fixing of 2-3 traps lowered the dead heart and white ear incidence in basmati.

Wheat : The department has given recommendations for the management of termites, grasshopper, armyworm, aphids and jassids on wheat. Similarly, pre-treatment of wheat seed with fipronil and chlorpyrifos was recommended. Economic threshold level of 5 aphids per earhead recorded from 10 randomly selected ear heads in each quarter of an acre was recommended for the control of aphids. Chemical control of wheat aphids with clothianidin, oxydemeton-methyl, dimethoate and monocrotophos was recommended.

Maize : Studies on the population dynamics and biology of maize borer were initiated and suitable methods for its control were recommended. Adjusting the time of sowing can be used for managing this pest. Biocontrol agents like *T. chilonis* released once @ 40,000 parasitized eggs/acre on 10-15 days old maize crop has been recommended for managing maize borer. Spring maize planted by January 25th suffered lesser damage than late sown crop. Shoot fly (*Atherigona* spp.) is another major pest which can be managed by applying furadan 3G @ 5 kg/acre at seedling emergence stage. Maize genotypes PMH 1, JH 3459, Sheetal and NK 6240 were recorded to be susceptible to shoot fly, whereas Parkash was the most susceptible hybrid. Among inbreds tested, CM 143 showed tolerance. Seed treatment with Sunato, imidacloprid and chlorpyrifos proved effective for the control of shoot fly on spring-sown maize.

Forage crops : Gram caterpillar *H. armigera* is the key pest of *rabi* forage legumes causing 55-75 per cent loss in seed yield of Egyptian clover (*berseem*), 40-45 per cent in alfalfa (*lucerne*) and 25-30 per cent in Persian clover (*shaftal*). The order of preference of genotypes in terms of host unsuitability for *H. armigera* was S69 (*shaftal*) > BL 10 (*berseem*) > BL 22 > LLC5 (*lucerne*) > BL 180 > BL 42 > BL 1. Cultural control practices have been recommended for raising the seed crop of berseem in a field away from other preferred hosts of gram caterpillar like gram, tomato, late sown wheat, sunflower, *sathe* moong and *sathe* mash. Spraying the seed crop at the initiation of flowers, with 125 ml of chlorantraniliprole 18.5 SL or 500 ml indoxacarb 15 EC or 150 ml spinosad 48 SC/ha, was recommended. Cultural control of Bihar hairy caterpillar, *Spilosoma obliqua* on berseem

was recommended by destroying weeds like cocklebur (*Xanthium strumarium*), Indian hemp (*Cannabis sativa*), Wild castor (*Ricinus communis*), Bathu (*Chenopodium album*) and Jangli palak (*Rumex aspara*) in adjoining areas before the sowing of berseem. To minimize its incidence on berseem, the following recommendations were made by the department i.e. sowing of crop away from fields of moong, mash, maize, groundnut and sesame which harbour this pest during *kharif*, avoiding growing of radish or turnip for vegetable purposes on bunds of *berseem* fields. Green semilooper, *Thysanoplusia orichalcea*, is another pest of berseem which thrives in the lodged crop. So, lodging must be prevented by timely cuttings at 30-35 days intervals and growing berseem crop in mixture with rye grass to avoid losses caused by this pest. Plant a row of sesame around cowpea field at the time of sowing to protect the fodder crop from the attack of hairy caterpillars.

Studies on management of shoot fly, *Atherigona* spp. revealed that its attack was relatively less on ridge-sown crop than on flat sown crop. Further, it was observed that timely sowing (June to mid-July) minimizes incidence of shoot fly in sorghum. If early and late sowing is to be done seed rate must be increased by 20 per cent. Alternatively, crop should be sprayed with 625 ml of Malathion 50EC or 250 g carbaryl/ha at four-leaf stage, followed by 2nd spray one week later. Studies on oviposition preference by stem borer, *Chilo partellus* female moths revealed that Napier millet genotype PBN233 was the most preferred for oviposition. Further, after hatching all the larvae died within a few days and none was able to pupate. Paired border rows of Napier-millet around maize fields were as effective as chemical control in protecting the fodder crop from damage by maize borer, *C. partellus*. For mechanical control maize borer infested plants should be uprooted and destroyed at early stage to prevent the pest build-up.

Oilseeds : The mustard aphid, *Lipaphis erysimi*, was the most damaging pest in rapeseed and mustard crops. The IPM technology for its management comprises: early sowing (up to 3rd week of October); application of recommended dose of nitrogen, spray the crop based on economic threshold level (50-60 aphids per 10 cm shoot or 0.5 to 1.0 cm terminal portion of shoot covered with aphids or 40-50 per cent plants infested with aphids).



Mustard aphid

Chickpea pod borer

Thiamethoxam, malathion, endosulfan, dimethoate, quinalphos, chlorpyrifos and oxydemeton methyl were found effective against the pest. IPM module was developed for the management of white grub on groundnut, which comprised: ploughing of field during May-June; sowing the crop early (between 10-20 June); killing beetles on preferred hosts by spraying carbaryl; treating the seed with chlorpyrifos or applying granular insecticides (carbofuran or phorate). The IPM module almost eliminated the white grub from groundnut. Sowing sunflower on ridges was recommended for avoiding damage to germinating seedlings due to cutworms. Head borer, *H. armigera*, that causes major damage, was controlled successfully by applying carbaryl, acephate, chlorpyrifos, endosulfan and monocrotophos starting from star bud initiation stage. Tobacco caterpillar, *S. litura* and Bihar hairy caterpillar, *S. obliqua* generally attack the crop in April-May and for their control, endosulfan and dichlorvos proved effective.

Pulses : In the germplasm screening programme, 785 entries of summer mungbean against bean thrips, 295 entries of summer urdbean against stem fly, 2654 entries of *kharif* mungbean against whitefly, 1603 entries of

kharif urdbean against whitefly, 1661 entries of pigeonpea against pod borer complex, 3723 entries of chickpea against gram pod borers, 2990 entries of lentil against lentil pod borer and 733 entries of field pea against pod borer were evaluated and resistant entries isolated. Sowing of sunflower as a trap crop in chickpea (1:7) reduces the incidence of pod borer. Intercropping 3 rows of mungbean in every 8 rows of pigeonpea reduces pod damage due to *H. armigera* and also facilitates spray operations in tall pigeonpea, besides giving higher net returns. Intercropping linseed in chickpea not only increased the per cent parasitization of *H. armigera* by *Campoletis chloridae*, but also reduced the pod damage.

Fruits : Among different fruit crops, *Citrus* spp. are being infested by 34 pests followed by pear (17); guava (15); ber (14); mango (13); grapes (12); peach (11); *jamun* and litchi (8 each); plum (7); sapota (6); banana and *aonla* (5 each); pomegranate (4) and papaya (2). To minimize the avoidable losses of these pests, 80 different tactics of management were developed. The major thrust was laid on cultural (18), mechanical (8) and chemical (54) technology in such a manner that there are minimum insecticide residues on the fruits. For control of mealybugs on citrus, guava and grapevine, regular monitoring for infestation of trees; maintaining the orchards neat and clean; not allowing the branches of trees to touch the ground; pruning or removing the infested branches and destroying the same; destroying the ant nests in the orchards, were recommended, along with applying drench spraying of 1875 ml chlorpyrifos in 500 litres of water, but spray in grapevines may be done after the harvest of crop in July to avoid residues of insecticides. For fruit fly control on peach, pear and guava, harvest the ripening fruits and do not allow the ripe fruits unplucked on the tree; regularly remove fallen fruits and bury the infested fruits at least at 60 cm depth; plant early maturing cultivars, adopt shallow ploughing with cultivator immediately after harvesting for exposing and killing the pupating larvae and pupae, and spray 1250 ml fenvalerate in end-June and repeat spray at weekly intervals, if required. Fruits should be harvested on third day after spray.

Vegetables : Studies revealed that brinjal cultivars *viz.* Punjab Barsati and Punjab Chamkila were resistant to shoot and fruit borer, tomato Punjab Chhuhara was comparatively resistant to fruit borer and Punjab-8 of okra resistant to jassid and fruit borer. Technique for the control of aphid vector, *Myzus persicae* of potato seed crop has been worked out and recommended for production of virus-free potato seed in the plains. Genetics of resistance in okra against jassid was determined for the first time in India. Okra lines HRB-55, HRB-9-2 and Varsha Bahar showed very low jassid injury and also were completely free from YMV symptoms in vegetative stage of the crop growth. For control of cotton jassid on seed crop of okra, initiate spray when jassid population exceeds 5 nymphs/leaf/plant, crop exposed to jassid infestation beyond 10 days after its appearance, early exposure of crop to jassid infestation up to 15 DAG, and leaves showed yellowing/ cupping at margins (second grade injury).

Biopesticides like Dipel/ Halt and reduced risk pesticides like indoxacarb, spinosad, flubendiamide and emamectin benzoate have been recommended for management of lepidopteran pests in Cole crops, tomato and okra.

Storage Pests

Bioecology, behaviour and interspecific competition of some important storage pests was studied under controlled conditions. Effect of chemosterilants like Tapa and Metapa on the male competitiveness of *Trogoderma granarium* was studied. Various fumigants, contact insecticides and botanicals were evaluated and effective seed protectants identified. Bag impregnation and prophylactic treatment of empty stores were recommended. Package recommendations for safe storage have been made to minimize the losses caused by different insect pests under stored conditions.

Insect Vectors

The department has undertaken work on virus vector relationship. Studies on cotton leaf curl virus (CLCuV) showed that *Sida* sp. and *Abutilon* sp. served as the most potent source of virus inoculum from where *B. tabaci* can acquire the virus. Spread of this disease can be checked by planting LD 327 variety of cotton as barrier crop. LHH 144 hybrid of cotton has been identified as resistant. Studies on various vectors showed that specificity in transmitting virus is dependent entirely upon its feeding character. In case of bell pepper first leaf stage was recorded to be most-susceptible to CMV transmitted by *M. persicae* which required only a brief visit of one

minute to acquire and transmit virus to plant. IPM strategies to check TLCV have also been evolved using virus free nursery raised as per recommended technique, planting maize as barrier and cucumber as trap crop and field spray with triazophos. The Insect Vector Laboratory of the department was the first to confirm rice tungro virus (RTV) through leafhopper transmission and electron microscopy in rice variety PR 106. Germplasm screening has also been carried out in cowpea against CpGMV which showed AC 7, IC5, IC8, IC9 and IC11 to be resistant. Similarly in tomato against TLCV line 58-11-1-1 was promising and can be used in resistant breeding programme.

Acarology

Surveillance reports revealed presence of 59 species of phytophagous mites belonging to families Tetranychidae, Tenuipalpidae, Eriophyidae, Tarsonemidae and Tuckerellidae and 35 species of predatory mites belonging to families Phytoseiidae, Stigmaeidae, Cunaxidae, Bdellidae, Cheyletidae, Tydeidae and Anystidae from different vegetable, fruit, cereal and ornamental crops from various localities of Punjab, Himachal Pradesh and Jammu region of J & K. Spider mite, *Tetranychus urticae* and yellow mite, *Polyphagotarsonemus latus* were identified as major pest mites on horticultural crops and brown wheat mite, *Petrobia latens* as minor pest on rainfed wheat. The avoidable crop losses vary from 13.7 - 18.14% in brinjal for *T. urticae*, 8.5 – 12.42% in rainfed wheat for *Petrobia latens* and 25.6% in chillies for *P. latus*. Based on LC₅₀ values and resistance ratios, mite populations from growers fields showed signs of resistance to dicofol but not to propargite, fenazaquin, wettable sulphur and profenofos. Fenazaquin (150ml/ha), spiromesifen (150ml/ha), abamectin (375ml/ha), diafenthiuron (300g.a.i./ha) and propargite (750ml/ha) were found to be effective against mites infesting vegetables under field conditions. Under nethouse conditions, abamectin @ 0.5ml/L, *Beauveria bassiana* @ 8ml/L, azadirachtin @ 15ml/L and sulphur @ 3g/L were effective in reducing the population of spider mites in brinjal, while fenazaquin @ 1ml/L and propargite @ 2ml/L caused > 80% reduction in mite population on citrus nursery. Studies on the feeding potential of predator *Chrysoperla* and anthocorid bug, *Blaptostethus pallescens* on adults of *T. urticae* revealed the voracious feeding ability of the 2nd and 3rd instar larvae of *Chrysoperla* as compared to 7-days old anthocorid bugs. Varietal response to mite infestation was studied in cucurbits, capsicum, chillies and brinjal. Different brinjal, frenchbean and bell pepper varieties/hybrids were heavily infested with spider mites, *T. urticae*, under net house conditions during April – May.

Apiculture

The department is pioneer in the successful introduction, multiplication and establishment of *Apis mellifera* in the State and its further dissemination throughout the country (Fig.10). *A. mellifera* was successfully introduced during 1962-64 through import of queen bees in the erstwhile Punjab (in Kullu valley, Nagrota Bagwan, now in H.P.). By the year 1972-73, some 45 colonies at Nagrota and 120 colonies of *A. mellifera* at Ludhiana campus were established. Sound management practices for *A. mellifera* in its new niche were developed which resulted in increased honey production.



Queen bee and worker bees

Fig. 10 Development of beekeeping in Punjab

Besides developing sound management techniques, the university is pioneer in mass queen bee rearing and breeding work, diagnosis of bacterial bee diseases, management of *Varroa destructor* and promoting use of honey bees as input in increasing crop productivity. The apiculture group in the department also played a lead role in promoting diversification in beekeeping through production of other hive products including pollen, propolis, royal jelly, bees wax, etc thereby making beekeeping more profitable. The department has executed an NATP sub-project in apiculture under 'Team of Excellence' mode. The department is the only one in the country to organize advance courses on various aspects of apiculture for progressive beekeepers, extension officers as well as apiculture scientists of SAUs. During the last ten years, the department has organized various advanced apicultural courses for apicultural scientists from various SAUs and ICAR Institutes. Besides research project under AICRP on Honey Bee, PAU is the pioneer to undertake National Bee Board funded project on 'Developing Quality Queen Bees of *Apis mellifera* for Nucleus Colonies'.

In a span of only three decades, Punjab has emerged as the leading state in beekeeping and hub of beekeeping activity in the country (Fig. 8b). The state is contributing nearly 37 per cent of the national apiary honey production, supplying *A. mellifera* colonies and apicultural equipment to other states, and has emerged as hub of commercial beekeeping in the country. Punjab has achieved the distinction of currently having more than 33,000 beekeepers, maintaining more than 3.5 lakh *A. mellifera* colonies with annual production of about 14,000 tonnes of honey, out of which more than 90 per cent is being exported. Honey trains run by railways during 2009 and 2011, carrying exclusively 2,000 and 4,000 tonnes of honey, respectively, from the Punjab is testimony to the impact of beekeeping research and development efforts of the university.

HORTICULTURE AND AGROFORESTRY

Fruits

The commercial cultivation of fruits in Punjab for more than 4 decades has been made possible due to extensive research on fruit growing done by the Department of Horticulture, at PAU and innovative, hardworking farming community of the state. At the first instance, PAU identified the fruit specific regions for the successful cultivation of major fruit plants. Consequently, to conduct crop specific research, PAU established regional research stations which strengthened the horticulture research in the state of Punjab. The vast germplasm collection of different fruit plants at PAU and its regional stations laid the foundation for development/ evaluation of improved varieties of different fruit plants for their commercial cultivation in the state. The horticultural scenario thus has changed substantially over the years due to (i) the release of high yielding varieties of peach, pear, mango, guava and grapes and (ii) the development of improved horticultural techniques and plant protection technologies for kinnow and other major fruits, which have resulted in increased fruit productivity and production in the state.

At present, in Punjab, fruit crops occupy an area of 69,813 hectares, with 13, 73,173 metric tonnes of annual production. Citrus, mango, guava, ber, pear, peach and grapes are the major fruits, while plum, aonla, pomegranate and phalsa are the minor fruits grown in the region. In citrus, kinnow mandarin has become the leading fruit crop (Occupying more than half of total area under fruit crops), which is giving the highest returns to the fruit growers. Area under kinnow is increasing rapidly and there is a high potential for its export. In other words, kinnow is the prime fruit of the state. Guava and ber are becoming increasingly popular with the farmers due to their wide adaptability in marginal soils and semi-arid conditions. The recently released pear cultivars- Punjab Gold, Punjab Nectar and Punjab Soft are replacing Patharnakh in the state, mainly because of their high yield and better quality of fruits. Parbhat variety of peach is likely to make an impact in peach cultivation. Likewise, Flame Seedless, a coloured variety of grapes and Punjab Purple a variety suitable for processing into juice, nectar and RTS may prove useful in breaking the monoculture of Perlette in the state. The salient achievements in fruit crops are briefly given below:

Recommended Varieties of Fruits

Over the past 5 decades with the prime aim to serve the farming community of the state, the University has recommended more than 135 varieties of fruit crops. The impact making varieties of different fruit crops such as of citrus, guava, mango, pear, peach, ber, grapes, litchi are discussed below:

Citrus

Mandarin

Kinnow : Trees are vigorous, large, tall, columnar with numerous long, slender, leaf ascending, virtually thornless branchlets and cold resistant; dense foliage consists of medium large; leaves broadly lanceolate; fruits medium, globose to oblate, skin golden orange when fully mature, acidity moderate with fine sugar/acid blend, flavour very rich, contains 12-25 seeds.

Sweet orange

Mosambi : Trees medium and upright; fruits small to medium, sub globose, surface smooth with longitudinal furrows, apex marked with circular ring, flesh pale yellow or whitish, juice with low acidity, contains 20-25 seeds.

Jaffa : Trees vigorous, upright, medium large, cold resistant and moderately productive; foliage dense; fruits medium to large, round to oblate, skin orange red, well blended acidity and sweetness, flavour rich with 8-10 seeds.

Blood Red : Trees medium and upright; fruits medium to large, roundish to slightly oblong, rind thin, deep orange, tight and glossy; flesh fully red when ripe, rich flavour with well blended sweetness and acidity, contains 8-10 seeds.



Kinnow in bearing

Grapefruit

Marsh Seedless : Trees vigorous, spreading, large and productive; fruits medium to large, oblate roundish, skin light yellow, smooth, medium in acidity and sweetness, contains 0-6 seeds..

Duncan : Trees vigorous, large, very productive and most cold resistant; fruits large, oblate, skin pale to light yellow or creamy, good acidity and 'sweetness' and well marked bitterness, contains about 50 seeds.

Lime and Lemon

Kagzi lime : Trees medium in vigour and size, spreading, bushy with numerous slender branchlets densely armed with small, slender spines; foliage dense consists of small, pale green, broadly lanceolate, blunt pointed leaves with definitely winged petioles; fruits small, round and thin skinned, pulp greenish white, juice strongly acidic.

Baramasi lemon : Trees spreading and vigorous, bears fruits round the year, most suitable for the agro-climate of the submontaneous areas of India Hoshiarpur, Gurdaspur and Ropar districts.

Guava

Allahabad Safeda : Trees somewhat dwarf with compact sub-globose, round crown; spreading branches and less dense foliage than *Sardar* guava; leaves large in size; fruits round, smooth, white flesh having pleasant flavour. TSS 10-12%.

L-49 (Sardar) : Trees dwarf with open rounded but flattened crown and dense foliage; spreading branches; leaves medium in size; fruits large with Allahabad rough surface and ribs on shoulders, flesh creamy white, smooth, juicy with excellent taste. TSS 10-12%.

Mango

Dushehri : Trees medium, spreading and moderate vigour; fruits small to medium, skin medium thick, smooth and yellow, flesh firm, fibreless, pleasantly sweet, stone small and thin with about 0.2 % acidity

Langra : Trees medium to large, moderately vigorous and spreading; fruits medium to large, skin medium thick, smooth and green, flesh fibreless, lemon yellow with fine taste and flavour, stone medium in thickness. TSS 15.7% and acidity 0.3%.

Pear

Patharnakh (hard pear) : Trees spreading and vigorous: fruits medium, round, green with prominent dots: flesh gritty, crisp and juicy.

Punjab Beauty (semi soft pear) : Trees upright, medium in vigour and regular in bearer; fruits medium, yellow (Fig. 5a) with red blush, flesh white, more juicy and sweet than LeConte and Baggugosha.

Peach

Shan-i-Punjab: Trees vigorous; fruits large, turns yellow with red blush at maturity, flesh firm and stone free at full ripe stage, good for canning. TSS 12% and acidity 0.74%.

Plum

Kala Amritsari : Self fruitful, high yielding, indigenous variety with vigorous tree; fruits medium sized, round oblate, depressed at both ends, turn dark purple on ripening, flesh yellowish with moderately juicy pulp: TSS 15% and acidity 1.2%.

Satluj Purple : A self unfruitful variety, trees medium irt vigour with upright growth habit; fruits medium large (average weight 25-30 gm), roundish, turn into crimson colour on ripening, thick skinned with yellow orange firm flesh, sweet taste. TSS 13-14% and. acidity 0.6-0.7%

Ber

Umran : Trees spreading and vigorous; fruits large, oval with a round apex; selection from skin smooth and glossy, golden yellow, turning to chocolate brown at maturity; pulp sweet with a pleasant flavour. TSS 19%.

Grapes

Perlette : Bunch medium to large and compact; berry seedless, firm, crisp, juicy and light amber, treated bunches have large round berries. TSS Marble 16-18%.

Litchi

Dehradun : An early, regular and heavy-bearing cultivar; fruits with an attractive colour but prone to splitting; pulp sweet, moderately juicy, medium soft in texture. TSS 17% and acidity 0.48%.

Calcuttia : Heavy bearing cultivar, excellent fruit quality; fruits large, attractive, less prone to cracking; pulp sweet and soft in texture, moderately juicy with good flavour. TSS 18% and acidity 0.49%.

Recently Recommended Varieties of Fruit Crops

Citrus

Star Ruby (grapefruit) : Trees are medium in size, fruit size small to medium, shape oblate-roundish. Peel

smooth, glossy yellow having distinctly bright red blush. Flesh colour is deep red (Fig. 2), fruits seedless (1-2 seeds), juicy, high TSS, acidic and rich in vitamin C. Ripens during last week of November and yield 53 kg/tree.



Grapefruit – Star Ruby

Mango – Gangian Sindhuri

Mango:

Alphonso : Fruit maturity takes place in the first week of July. Fruit medium in size, oval with prominent ventral shoulder, fruit colour greenish light yellow with light pinkish blush towards the proximal end, skin thin smooth, flesh cadmium yellow and firm, fibreless, superb taste, captivating flavour, juice abundant, TSS 17.5 per cent, acidity 0.35 per cent and stone is small. The tree yields 70 kg.

Gangian Sindhuri : It is a sucking type mango variety. Its fruits mature in 4th week of July, are fibrous and have pleasant colour and flavo.

Guava

Arka Amulya: It is a hybrid of Seedless x Allahabad Sufeda. Trees are dwarf with compact, round crown and drooping branches with dense foliage. The fruit is large, round, glossy with white flesh containing semi-soft seeds. T.S.S in fruit range from 9.3 to 10.1 % and acidity from 0.25 to 0.34 %. The average yield of rainy and winter season crop is 144 kg per tree.



Guava - Punjab Pink

Punjab Pink: A hybrid (Portugal x L 49) x Apple Colour, it has vigorous trees with drooping branches. The fruit is medium to large in size with attractive red coloured skin in summe and golden yellow in winter. The flesh is red having pleasant flavour. It is a prolific bearer with an average yield of 53 kg/tree.

Pear

Punjab Nectar: Trees are upright and medium in vigour. Its fruit is medium to large, with average fruit weight 138 g, ground colour yellow green, white fleshed,. T.S.S 13.6 %, acidity 0.21 %. Mature fruits less gritty, mellow when ripe and very juicy. Fruit matures in fourth week of July. Its average yield is 80 kg per tree. It is suitable for table and processing purposes.

Punjab Gold: Tree upright and medium in vigour. Fruit large with average weight of 166 g, ground colour golden yellow, and white fleshed. T.S.S 13.3 %, acidity 0.22 %. Mature fruit less gritty, mellow when ripe. Matures in end of July. Yield 80 kg per tree. It is suitable for processing and table purposes.

Punjab Soft: Its tree is upright and spreading, medium in vigour, leaf colour light green, fruit size medium, ground colour yellow green, flesh whitish, TSS 11.3 %, acidity 0.13 %, mature fruits very soft, very juicy (73 % juice),

matures in first week of July, yields 86 kg per tree. Fruits are suitable for processing like RTS, Nectar and Squash. Fruits can be cold stored for 4 weeks at 0-1°C and 95-95 % RH

Punjab Nakh- Trees are spreading and vigorous with average yield of 192 kg/ tree. Fruits are ovate, light yellowish green with prominent dots having average weight of 155g. Flesh is gritty, crisp and juicy. Keeping quality is good and can be stored for 60 days at 0-1°C temperature and 90-95 per cent relative humidity. It matures in last week of July.

Neijisseiki: Tree spreading, medium in vigour, leaf colour green, fruit size medium, ground colour golden brown, flesh whitish, T.S.S 12.9 %, mature fruits very soft, fruit firmness (11.17 lbs), very juicy (74.6 % juice), matures in end June to first week of July, fruit ripen on tree, yields 80.2 kg per tree. Suitable for processing like RTS, nectar and squash. Fruits have good storage potential and can be stored for 5 weeks at 0-1°C and 90-95 % RH.



Pear variety Punjab Beauty

Peach

Punjab Nectarine: Trees are vigorous and spreading. Fruits mature in 2nd week of May. The average yield is 39.2 kg/tree. Fruits are large weighing 90g, round, attractive with 90-100 per cent red blush over yellow ground colour at maturity, flesh is yellow at full ripe stage with TSS 11.5 per cent and acidity 0.8 per cent.

Prabhat: It is an early maturing (3rd week of April), white-fleshed peach cultivar. Fruits are medium sized, roundish with an attractive red blush (Fig. 6b), juicy and sweet, free stone when fully ripe. TSS 12% and acidity 0.37%. Average yield is 64 kg/tree.



Peach variety Prabhat

Grapes

Flame Seedless: Bunch is medium and well filled. Berry seedless, firm, crisp, light purple at maturity. It gives good response to quality improvement treatment.



Grape Variety Flame Seedless

Bunches have berries with T.S.S 18 %. It ripens during second week of June. For obtaining uniform colour treat bunches with 400 ppm ethephon at the colour break stage. Average yield per vine is 27 kg.

Punjab Purple: It is rich in anthocyanins, a source of antioxidants and is suitable for processing into juice, nectar and ready to serve beverage. It contains 60-65% juice with total soluble solids 17-18 % and acidity 0.50 %. It has medium and loose bunches. The berry is seeded, medium in size and purple at maturity. It matures in first week of June.

Ber

Sanaur-2 : Tree spreading and semi-vigorous. Fruit large, oblong, smooth and golden yellow. Pulp sweet with a typical flavour and 19 per cent TSS. Ripens in the second fortnight of March. Average yield is 150 kg per tree. It is fairly resistant to powdery mildew disease. Most suitable for *Kandi* area.

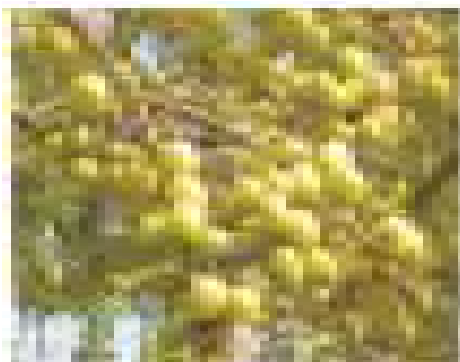
Wallaiti: Early variety. It ripens in 1st fortnight of March, yield 110-120 kg/tree, moderately susceptible to powdery mildew.

Aonla

Balwant (NA-10) : It is a chance seedling developed from cultivar Banarsi. Tree is semi-tall with semi-spreading growth habit and dense foliage. Fruit is flattened round and moderate in size. It is early season variety and matures in middle of November. Its average yield is 121 kg/tree.

Neelam (NA-7) : It is a seedling selection from open pollinated strain of cultivar Francis. Tree is tall with semi-spreading growth habit and dense foliage. Fruit is medium to large in size and conical in shape. It is mid season variety, which matures in end November. Its average yield is 121 kg/ tree.

Kanchan (NA-4) : It is a chance seedling from cultivar Chakaiya. Tree is tall with upright growth habit, sparse foliage. Fruit is flattened oblong in shape and small to medium in size. It is late in maturity and matures in mid December with average yield of 111 kg/tree.



Aonla variety Kanchan



Sapota variety Kalipatti

Sapota

Kalipatti : It is a table purpose variety having oval shaped fruits with sweet, mellow flesh of excellent quality. Fruits appear singly and contain 1-4 seeds per fruit. Average yield of mature plant is 166 kg/ tree.

Cricket Ball : This variety has fruits of large size, with round shape and contains 3-5 seeds per fruit. Pulp is gritty, granular with excellent taste and flavor. Average yield of mature plant is 157 kg/ tree.

Plant Propagation

Propagation techniques have been standardized in various fruit plants. Commercial methods of propagation recommended by PAU include T- budding in citrus and ber, side veneer grafting in mango, patch budding in guava, tongue grafting in pear, peach and air layering in litchi. In citrus rootstock, rough lemon, the foliar sprays of urea at periodic intervals has drastically reduced the time for production of nursery plants. Germination of Kainth, a rootstock of pear, seeds without stratification treatment saves time in nursery and has higher seed germination. Simultaneous grafting and rooting of peach with IBA (1000 ppm) saves one year in raising peach plants.

Likewise, rootstocks have been recommended based on extensive trials at Ludhiana and at regional research stations. In citrus, rough lemon is the commercially recommended rootstock. Likewise, L-49 for guava, root suckers for pear, Sharbati and Khurmani for peach, mango seedlings for mango and Kabul Green Gauze for plum have been recommended. In the recent years, improved rootstocks to overcome specific problems have been recommended. These include Flordaguard- a nematode tolerant rootstock for peach, Portugal- a wilt tolerant rootstock for guava and Kainth- sucker free rootstock for pear.

Production of Quality Planting Material

Disease free plants are the foundation for healthy fruit industry in the state. Keeping this in view, PAU has started production of virus free kinnow plants on commercial scale. During the foundation year, 2002-03, 2500 plants were supplied to progressive fruit growers of the state. Infrastructure has recently been strengthened to

produce 30,000 plants for supply to progressive farmers. Disease free bud wood is also being supplied to the State Department of Horticulture and many other nurseries in the state.

Production Technologies

The Production technologies including high density planting, training & pruning, manure, fertilizer and irrigation requirement has been standardized for commercial fruits of Punjab.

High density planting: In fruit crops like kinnow, guava, peach, plum and Baramasi lemon, the HDP has been developed. It results in 20-30 percent increase in yield and improved fruit quality.

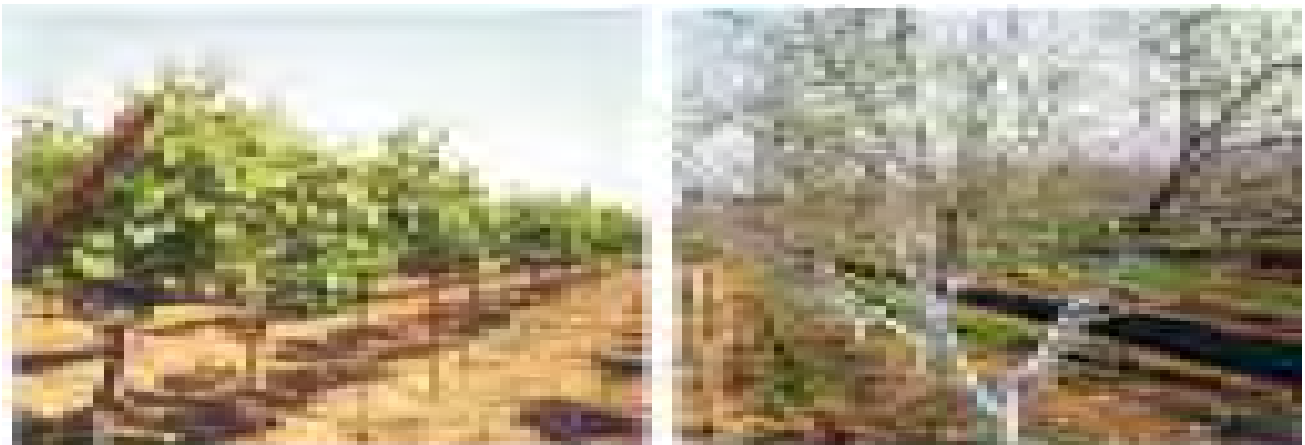


Virus free kinnow nursery production

In kinnow, high density planting ($20' \times 10'$) has been recommended for obtaining higher (34 %) yield. Guava planted at closer spacing (6×5 m) can accommodate 132 plants per acre, resulting in increased productivity per unit area. Planting peach at 6×1.5 m spacing in Y-system of training had superior quality fruits and with high productivity per unit area. In plum cv. Satluj Purple, the trees planted at 3×1.5 m spacing had highest fruit yield/ha as compared to 6×6 m, 6×3 m, 6×1.5 m and 3×3 m spacing. Planting baramasi lemon at 5×2.5 m spacing had maximum yield/ha compared to 6×3 m, 5×5 m and 6×6 m spacing.

Drip irrigation: Technology for drip irrigation in Kinnow (particularly month-wise daily water requirements) for judicious use of water and increased fruit yield has been standardized. Use of consumptive irrigation water has reduced requirement of water by $1/3^{\text{rd}}$. Thus three times area can be brought under fruit crops by using same quantity of water.

Training and pruning system : The training system and pruning as per the specific requirement of fruit plant has been standardized in all the commercial fruits. The commercial fruits such as mango, peach, pear, plum, and guava are trained as per modified leader system. While for grapes bower system has been recommended and is adopted on commercial scale. Improved training systems recently recommended for grapes and peaches include Y-system of training. The grape planted at 1.5×4 m spacing accommodates almost double the number of plants per acre, which produce superior quality fruits and lead to ease in cultural operations.



Y system of training in grapes and peach

Nutrition management: Balanced nutrition ensures health of plant as well as quality fruit production over the years. Keeping this in view, the requirement of organic (FYM) and inorganic fertilizers (N,P,K) as per age of the plant, in all the major fruit crops of the state has been standardized. Moreover, the time of fertilizer application has also been specified so as to obtain optimum returns from the crop. The recent recommendation of fertilizer application in kinnow will go a long way in sustaining kinnow cultivation in the state and avoid excessive use of

fertilizers by farmers. Three foliar applications of potassium nitrate (1% Multi-K i.e KNO₃ with 13 % N and 45 % K) each in the end of May, June and July should be applied to enhance yield (10 %) and quality of kinnow crop. The use of multi-K has been found beneficial to improve size of kinnow, especially in Hoshiarpur belt. The work on micro nutrient management has also been done extensively in different fruit crops. Zinc, iron, potassium and calcium are commonly observed micro nutrient deficiencies which can be effectively controlled by use of standardized micro nutrient doses.

Rejuvenation technology: The technology for rejuvenation in grapes, pear and ber has been standardized, so as to obtain fruiting from senile orchards. The old pear trees (> 20 years old) can be rejuvenated by heading back 3-4 main scaffolds to about 15 cm during December-January. The rest scaffolds should be completely removed. Paint the cut ends with Bordeaux paint. Many sprouts shall emerge on these stubs in March. In May retain only one to two outgoing shoots on each stub with a total of 6-8 shoots per tree. Rejuvenating trees start fruiting in third year and bear commercial crop in the fifth year. Ber trees can be rejuvenated after the age of 25 years. This can be done by heading back main limbs to 30 cm during second fortnight of May. The trees start giving commercial crop with higher yield of excellent fruit quality during the third fruiting season.

The old Perlette vines can be successfully rejuvenated by heading back the primary arms (2-3) leaving behind 1 foot stubs, in the month of December- January. Use Bordeaux paste or Bordeaux paint to protect the cut ends from infection. Train the newly emerged shoots from primary arms so as to have three pair of secondary arms and train them along each wire in opposite direction. Rejuvenated vines start fruiting in first year and bear commercial crop in the second year.



Rejuvenation of pear



Top working Flame Seedless on Perlette

Top working technology: To introduce new variety of fruit crop in a field in relatively shorter time, top working technology is ideal. Top working technology for grapes has been standardized. Flame Seedless, a coloured variety of grapes can be successfully top worked in situ on Perlette vines.

Quality Improvement

Crop regulation in guava : To have better quality fruits in winter crop of guava, there is a need to skip rainy season crop. The P.A.U recommendation of skipping rainy season crop with either urea sprays or by manipulating other cultural practices such as withholding irrigation in summer has been adopted on commercial scale.

Quality improvement in grapes : The optimum yield and quality in grapes can be obtained by flower bud thinning one week before flowering, followed by girdling at 4 mm berry size and 2 GA₃ dips of 40 ppm each at one week interval. Foliar spray of Potassium sulphate (1.5 %) one week after fruit set and again at colour break stage improves fruit quality of Perlette grapes.

Fruit thinning and girdling in peach: Peach is a heavy fruit bearer. To avoid over bearing and have superior quality fruits, fruit thinning is done in March, keeping fruit to fruit distance of 10-15 cm. Girdling further improves the fruit quality.



Girdling and fruit thinning in peach

Post Harvest Technologies

Ripening and quality improvement : The banana fruits harvested at green mature stage can be successfully ripened in four days by exposing to ethylene gas (100 ppm) for 24 hours in a ripening chamber maintained at 16-18°C and 90-95% RH. The fruits attained uniform colour, excellent quality with shelf-life of 4 days at 16-18°C and 2 days at 30-32°C.



Banana ripening using ethylene

The banana fruits at green mature stage can also be successfully ripened in four days by dipping in a solution of ethephon 500 ppm (1.25 ml per litre of water) for 2-3 minutes. The fruits should be air dried and kept at 16-18°C and 90-95% RH. The fruits attained uniform colour, excellent quality with shelf-life of 4 days at 16-18°C and 2 days at 30-32°C. Unripe pear fruits should be chilled for 3 days at 0°C and ripened at 20°C for 3 days and 4 days for Punjab Beauty and Patharnakh, respectively, to improve their quality during storage.

Storage studies in fruit plants : Kinnow fruits harvested at optimum maturity, packed in ventilated corrugated fibre board boxes should be stored at 5-6°C and 90-95% RH. The quality remains acceptable for 45 days. After harvesting, the kinnow fruits should be washed in clean water with wet foam followed by a dip in 0.01 per cent chlorinated water. The fruits are partially dried under shade and citrashine wax should be applied with foam. The waxed fruits are again dried in shade before drying. Flame Seedless grapes, harvested at optimum maturity with firm berries having light purple colour, packed in ventilated corrugated fiber board boxes (4 kg) lined with polythene film containing one sheet of grape guard, can be stored with acceptable quality upto 45 days at 0-2°C and 90-95% RH. The ber fruits of cultivar Umran harvested at colour break stage can be stored at 7.5 ± 1°C and 90-95% RH for two weeks with acceptable colour and quality. Likewise, Satluj Purple plum fruits, harvested at colour break stage, followed by post harvest treatment of calcium nitrate (2%) solution for five minutes, can be stored for four weeks in cold storage (0-1°C and 90% RH) with post storage shelf life of 2 days at ambient temperature. In case of pear, Punjab Beauty fruits can be cold stored at 0-1°C with RH of 90-95% for 60 days. These fruits have post-storage life of 1 to 2 days at room temperature and 4 days in refrigerator.

Processing technologies: Red wine with 10.5 percent (v/v) ethanol can be prepared from Punjab Purple grapes by alcoholic fermentation of must (juice + skin) using indigenous yeast *Saccharomyces cerevisiae* G with a fermentation efficiency of 90.0 percent. With this developed small scale technology, wine recovery of 62.0 percent (v/v) can be achieved with a cost of Rs 22 per 200 ml bottle.

Vinegar can be successfully prepared from Perlette grapes. It is a nutritious fermented beverage containing vitamins and minerals of grapes as well as vitamins from yeast. It possesses shelf life of upto 2 years. Technology for production of juice, nectar and ready to serve (RTS) beverage from grape variety Punjab Purple has been standardized. Technology for preparation of low alcoholic self carbonated carrot- amla beverage (1:1) with a shelf life of 3 months at refrigerated temperature has been developed. Non alcoholic naturally carbonated lemon beverage can be prepared with optimized concentration of clarifying agents and optimized heat treatment with a shelf life of four months. Pear variety Punjab Beauty can be processed in enameled cans with sugar syrup (400B) containing ascorbic acid (0.1%). This ensures value addition to pear crop.

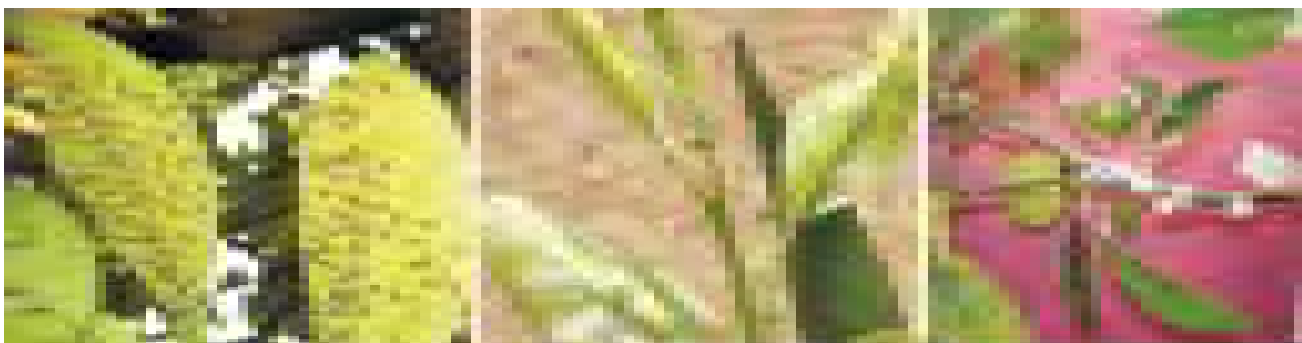
Plant Protection Technologies

Important insect-pests and diseases affecting quality production of fruits have been identified and effective control measures for the same have been provided by plant protection scientists of this department in collaboration with the parent departments.

Insect and mite pest management: Currently, 95 insect and mite species (constituting 170 pests) are active on 15 fruit crops grown in Punjab. *Citrus* spp. having the maximum number of 36 pests are followed by pear (17), mango (15), guava (15), *ber* (15), peach (12), grapes (12), *jamun* (9), litchi (9), plum (7), sapota (6), pomegranate (5), aonla (5), banana (5) and papaya (2). All these pest species belonged to 8 different orders, i.e. Hemiptera, Lepidoptera, Coleoptera, Thysanoptera, Hymenoptera, Diptera, Isoptera and Acarina. Aphids, mites, scales, mealy bugs, thrips, termites, American bollworm, tobacco caterpillar, *anar* butterfly, castor capsule borer, leaf webbers, hoppers, black fly, gall insect and shoot gall maker are among the emerging problems. Over the years it is found that insect and mite pests on fruit crops can cause 30-45 per cent damage as a whole.

Biology of *Phyllocnistis citrella* Stainton, *Dialeurodes citri* (Ashmead), *Diaphorina citri* Kuwayama, *Psorosticha zizyphi* Stainton, *Bactrocera dorsalis* (Hendel), *Sphenoptera dadkhani* Obenberger, *Amritodus atkinsoni* (Lethierry) and *Drosicha mangiferae* Green had been studied. Fluctuation of population in relation to abiotic factors such as temperature, relative humidity, total rainfall, number of cloudy days, sun shine, and evaporation had also been elucidated in case of *P.citrella*, *Diaphorina citri*, *Dialeurodes citri*, *A. woglumi* and *P.zizyphi*.

A large number of genotypes of citrus, pear, peach, plum, almond, guava, *ber*, grapes and date palm had been screened against different insect and mite pests. The sources of resistance are identified in some insects. Mechanism and basis of resistance in different fruit crops were also studied against different insect and mite pests. To minimize the avoidable losses of these pests, the entomologists persistently worked on the different tactics of management and a total of 75 management technologies were developed since 1962. The major thrust was laid on cultural (17), mechanical (7) and chemical (51) technologies in such a manner that there are minimum insecticide residues on the fruits. The application of these technologies in the field has reduced the avoidable losses from about 30-40 to 5-10 per cent.



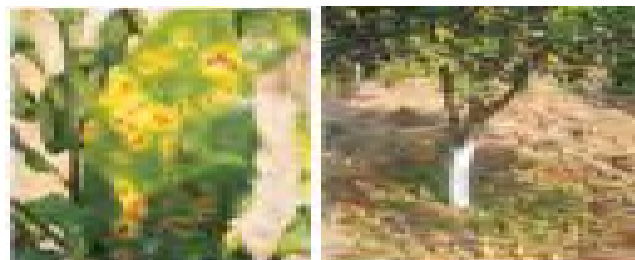
Citrus psylla

Citrus leaf miner

Mealy bug attack

Disease management : Two applications of Ridomil Gold MZ 68 WP or Curzet M 8 or Matco 8-64 @ 2g/100 ml of linseed oil as paint to the infected trunk portion and drench the soil with any of these fungicides (25g/10 litres of water per tree) at the base of tree in February-March and July-August have been recommended for management of citrus foot rot/gummosis. Two sprays of Aliette 80 WP (0.25%) in April and September in addition to soil drenching have been found effective for management of Phytophthora foot rot in citrus.

Pre-monsoon and post-monsoon applications of Bordeaux paste on trunk with soil application of *Trichoderma harzianum* (100g/plant) + *Trichoderma viride* (100 g/plant) + *Pseudomonas fluorescens* (100g/



Citrus canker

Fruit drop

plant) followed by spray of Fosetyl (Aliette 0.2%) have been found promising for management of Phytophthora foot rot/root rot in Kinnow mandarin. Management of citrus canker has been obtained by giving alternate spray of copper oxychloride (0.3%) + streptomycin (100ppm) and neem seed kernel extract (5%) starting from second fortnight of June up to second fortnight of October at 30 days interval. Likewise, spray of ziram 27 SC (0.25%) + 2,4-D (10ppm) or propiconazole 25 EC (0.1%) + 2,4-D (10ppm) or carbendazim 50 WP (0.1%) + 2,4-D (10ppm) in mid-April, mid-August and mid-September and two additional single sprays of ziram 27 SC (0.25%) or propiconazole 25 EC (0.1%) or carbendazim 50 WP (0.1%) in end-July and end-September have been recommended for management of pathological and physiological fruit drop in kinnow mandarin.

Clipping of scabby leaves during July and three sprays of ziram 27 SC (0.25%) or Dithane M-45 (0.25%) or Bordeaux mixture (2:2:250) or copper oxychloride (0.3%) during the last week of June to August at 20 days interval has been recommended for integrated management of citrus scab. Management of *Ber* powdery mildew has been achieved with four sprays of Bayleton 25 WP @ 50g/100 litres of water in mid-September, mid-October, mid-November and mid-December as an alternative to Karathane 40 EC and Sulphur.



Ber powdery mildew

Mango malformation

Spray of Score 25 EC (0.1%) in mid-July, mid-August and mid-September has been recommended as an alternative to Bavistin 50WP for the effective management of anthracnose of grapes. *Ber* black fruit spot disease could be managed with two sprays of Mancozeb 75 WP (0.25%) in end-January and mid-February. For management of mango malformation, it has been recommended to remove and destroy the affected shoots every month. Spraying of 200 ppm maphthalene acetic acid (NAA) has to be done prior to flower bud differentiation during the first week of October for reducing floral malformation. Three sprays of Topaz 10EC @ 40 ml/100 litres of water as an alternative to Bayleton in mid-March, last week of April and first week of May have been recommended for effective management of powdery mildew of grapes. Peach rootstock Flordaguard has been found highly resistant to root-knot nematodes. For management of guava wilt, the wilted trees should be uprooted and burnt. The healthy seedlings should be replanted after sterilizing the soil with 2 per cent formalin solution.

Vegetables

Vegetables are important cash crops and can play a significant role in diversifying agriculture. Most vegetables are short duration and can fit well in multiple cropping systems. There is an ample scope to double the productivity in the next 5-6 years through technological interventions. In Punjab, area and production of vegetable crops during 2010-11 was 69.8 thousand hectare and 1373.2 thousand ton, respectively. In last one decade production of vegetable pea, cabbage, tomato and potato has increased by 3.5, 2.02, 1.71 and 2.2 times, respectively. The challenges ahead are to have sustainability and competitiveness, and to achieve the targeted production to meet the fresh vegetable requirements and to meet the ever increasing demand of export and processing industry.

Tomato

Tomato is an important crop of the state and is grown both for fresh market and processing. At the time of the formation of the university indeterminate varieties Sioux, Best of All and Pusa Ruby were recommended by the State Department of Agriculture. The first tomato variety S-12 was developed by PAU in 1967 through mutation

breeding. To extend the availability of fruits, three varieties with different maturity groups namely Keckruth Ageti, Keckruth and Punjab Tropic were developed in 1971. Keckruth and Keckruth Ageti were selected from the segregating material received from Bulgaria. Both the varieties have round fruits with green shoulder. Punjab Tropic was selected from the segregating material received from the USA. Keckruth and Punjab Tropic by virtue of their good size and juicy fruits with deep red flesh were well accepted for fresh market and juice making.

In 1975, tomato production in the state received a tremendous boost with the development of Punjab Chhuhara from the cross Punjab Tropic X EC 55055. This variety became extremely popular among the growers. Within three years of its release, it replaced all existing varieties to the extent of about 80 per cent in the state and the adjoining areas. It is a pear shaped- prolific bearing variety with an average fruit yield of 80 tonnes per hectare. In the 1980s, Punjab tomatoes were transported to as distant places as Bombay owing to its superior shelf life and transportation qualities. The variety was subsequently recommended at the national level. It is noteworthy that even after 35 years of its release, it is still being used as a national check in AICRP trials. It was one of the few Indian vegetable varieties listed in the International Seed Catalogue during that period. Its sister line Punjab Kesri was released in 1978 for table purpose. It is an early maturing variety with oval, medium sized attractive fruits. It was also recommended at the national level.



Tomato variety Punjab Ratta

In the meantime, root knot nematodes were identified as a serious and widespread problem in vegetable growing areas of the state. Concerted efforts were made to develop tomato cultivars resistant to root knot nematodes. In 1985, Punjab NR-7, a first nematode resistant tomato variety in the country was developed from the cross S-12 X NMR-1. Subsequently, the variety was recommended at the national level. It performs well even under low water and high and low temperature stress conditions. Two varieties, Punjab Upma and Castle Rock were released in 2000. The fruits of Punjab Upma are deep red, oval, firm and pulpy with thick pericarp suitable both for fresh market and processing, whereas fruits of Castle Rock are oval, symmetrical round and very firm. A firm fruited, deep red variety Punjab Ratta suitable for processing was released in 2009. In the same year, two more varieties, Punjab Varkha Bahar 1 and Punjab Varkha Bahar 2, both resistant to leaf curl virus, were released. With the development of leaf curl virus resistant varieties, it has now become possible to grow tomatoes in the rainy season which otherwise was not possible due to the severity of the viruliferous whitefly (*Bemisia tabaci* Gennadius).

In 1990s, the emphasis was laid on heterosis breeding. The first tomato hybrid TH-2312 (VFN 8 X Punjab Chhuhara) was released in 1993. TH 2312 is resistant to root knot nematodes, leaf miner and high temperature stress. The fruits are medium firm and suitable for fresh market. Another hybrid TH-802 (Healani X Castle Rock) was released in 1997. It is resistant to root knot nematodes. The fruits are oval shaped, firm and suitable for processing. TH-1 (W 321 X I 181), a round fruited tomato hybrid moderately resistant to late blight, was released in 2003. Its fruits are attractive, firm and deep red with good shelf life. It is suitable both for fresh market and processing. Apart from cultivar development, genetic stocks of tomato possessing genes resistant to leaf curl virus, late blight, root knot nematodes; male sterile (both pollen abortive and functional) lines; and ripening inhibitor mutants have been developed. The current focus in tomato research is breeding for multiple disease resistance (leaf curl virus, late blight and root knot nematodes), abiotic especially high temperature stress tolerance, cultivation under protected conditions and development of cherry tomato cultivars.

Chilli Pepper

Chilli, an important spice and vegetable crop of India, is vulnerable to a number of viral and fungal diseases. A research project for the development of improved varieties of chilli was initiated by the University in 1962. In 1985, a multiple disease resistant variety Punjab Lal was developed from the cross Perennial X Long Red. The variety possesses multiple disease resistance to TMV, CMV PVY and leaf curl virus and tolerance to fruit rot. Its fruits are small, erect, dark red and extremely pungent with average capsaicin content of 0.96%. It is suitable for powder making and average yield is 120 quintals per hectare. In 1995, two more varieties Punjab Surkh and

Punjab Guchhedar were developed. Punjab Surkh is an early maturing variety developed by selection from the material introduced from UP. Its fruits are long, dark red with average capsaicin content of 0.8%. Average yield is 200 quintals per hectare. Punjab Guchhedar was developed by selection from the material introduced from Indonesia. Its fruits are medium long with pointed apex, deep red, erect, borne in clusters of 8- 12 and have destalking habit. Average capsaicin content is 0.98% and average fruit yield is 150 quintals per hectare.

Chilli production in the state received a tremendous boost with the development of MS-12, a genetic male sterile (GMS) line. The nuclear male sterility gene *ms10* was introduced from a French introduction ms509 through the conventional backcross method. Till today, only a few GMS lines in chilli pepper have been developed in the world; and MS-12 is one such line. Its erect fruit bearing habit is used as a morphological marker for F₁ hybrid purity test. The development of MS-12 has revolutionized the hybrid seed production of chilli in the country. The technology was well accepted by the seed growers of the country. By exploiting GMS, CH-1 (MS-12 X LLS) was developed in 1992. CH-1 is high yielding (250 quintals per hectare), with medium sized pungent fruits. It was quickly adopted by the farmers and area under chilli cultivation in the state increased three-fold within few years of its release. Another early maturing hybrid CH-3 (MS-12 X S-2530) was developed in 2000. Its fruits are dark green when immature and deep red when mature. It is mildly pungent with average capsaicin content of 0.51%. Average yield of red ripe fruits is 265 quintals per hectare.



Chilli hybrid CH-1

Brinjal hybrid BH-2

The current focus on chilli research is on development of molecular markers linked to the male sterility gene *ms 10* and its genetic mapping, development of new GMS & CMS lines and their utilization in hybrids development. In bell pepper, the focus will be to develop open pollinated cultivars suitable for cultivation under protected conditions and those can set fruits under tropical conditions. Another important activity will be to transfer heat tolerance from chilli pepper to bell pepper through conventional breeding techniques.

Brinjal

In brinjal, twelve true breeding varieties and two F₁ hybrids have been released since inception of PAU. Punjab -8, Punjab Bahar, Jamuni Gola and Punjab Neelam are round fruited, whereas, R-8, PH-4, Punjab Chamkila, Punjab Barsati, and Punjab Sadabahar are long fruited ones. Punjab Moti and Punjab Nagina are small round fruited varieties specifically developed for stuffing purpose. The F₁ hybrids BH-1 and BH-2 are oblong fruited and are meant for *Bhartha* making. Fruit yield up to 500 q/ha have been realized in true breeding varieties, while F₁ hybrids have the potential of 750 q/ha.

Garden Pea

Bonneville was the first pea variety recommended by PAU in 1971 for growing in the main season. It was capable of yielding up to 190q of large dark green and well filled pods per hectare. The variety was widely adapted and released at the national level. Later in 1971, Punjab-87 and Pb-88 showing superiority over Bonneville in pod yield and quality were released. Both the varieties were recommended at the national level. Punjab-87 was

also adjudged suitable for dehydration. Short duration early season varieties Hara Bona, Arkel and Mattar Ageta-6 were released in 1980, 1985 and 1989, respectively. Arkel and Mattar Ageta-6 had wide adaptability and both have been released at the national level. Mithi Phali, an edible podded variety yielding 120 q/hectare of edible pods, has been released in 1995. Punjab 89 variety was released in 2007. The plants of this variety are medium dwarf, vigorous, having more number of well filled pods (28-30 per plant). The pods are dark green, long, very attractive having 9-10 grains per pod. Pods are borne in doubles. It takes about 85-90 days for first picking. The shelled peas are very sweet and the shelling out turn is more than 55 percent. Average green pod yield is 150 q/ha.



Pea variety Punjab 89

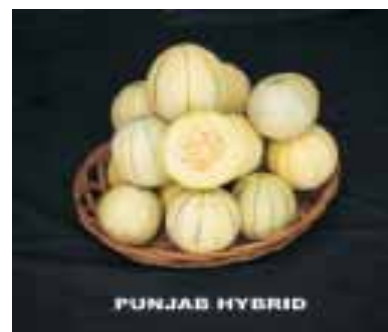
Okra

Okra is one of the major summer and rainy season vegetable crop. Research work on the development of improved varieties in okra was initiated in 1972. With the breakdown of resistance to yellow vein mosaic virus in Pusa Sawani, the main emphasis in okra was on the breeding for resistance against yellow vein mosaic virus. As a result, the variety Punjab Padmini was released in 1982, Punjab-7 in 1986 and Punjab-8 in 1995. The first two varieties have been developed as a result of interspecific crosses, *Abelmoschus esculentus* and *A. manihot* ssp. *manihot*, whereas Punjab-8 has been developed through mutation breeding of Pusa Sawani. All these varieties were widely accepted by the farmers because of their thin, long, green and tender fruits. All the three varieties were identified at the National level whereas, Punjab-7 was released at National level. The variety Punjab-8 has been found to be tolerant to fruit borer & jassid and good for processing.

Muskmelon

The first improved muskmelon variety Hara Madhu was released in 1967 in Punjab. This was the sweetest variety of its time with an average TSS of 13%. Its flesh is green, juicy, and flavoursome. However, it has poor shelf life and is susceptible to diseases like wilt, powdery and downy mildews. In 1974, variety Punjab Sunehri derived from a cross between Hara Madhu and Edisto was released. It gave average yield of about 165 q/ha and has excellent long distance transportation quality and very good orange flesh colour.

In 1981, first F_1 hybrid in the country Punjab Hybrid was released. It has salmon colored flesh with high TSS and yield of about 165 q/ha. It has been developed using MS-1, a genetic male sterile line as female parent and Hara Madhu as male parent. The F_1 hybrid seed production has been taken up extensively by National Seeds Corporation, private seed growers and progressive farmers for which technical guidance and seed of parental lines is being provided by the PAU. Variety Punjab Rasila was released in 1993 which carries resistance to powdery mildew and tolerance to downy mildew. Another hybrid MH-10 having excellent shelf life and very high yield (240 q/ha) was released in 1995. The hybrid was developed by using gynocious sex form of the female parent. In 2003, variety MM-28 having excellent shelf life and suitable for distant transportation was released. It gave marketable yield of 180 q/ha. It was seven days earlier than Punjab Sunehri. Its fruits are nearly round, non-sutured and intensely netted. Fruits develop 'full slip' stage at maturity. Average TSS content is 11.2%. In 2005, a muskmelon hybrid, Punjab Anmol was developed again utilizing the male sterility. It is an F_1 hybrid between a male sterile line MS-1 and Punjab Sunehri. It matured four days earlier than Punjab Hybrid. Average marketable yield is about 72q/ha. Its fruits are oval round, light brown, non-sutured and intensely netted. Its flesh is thick, orange coloured, medium in juiciness and flavoursome with TSS content of 11.5%. The average fruit weight is 710g. Its fruits have better shelf life and are suitable for distant transportation.



Muskmelon Punjab Hybrid

Bitter gourd

In bittergourd, variety C-96 was released in 1962 with medium, oblong, egg shaped and green fruits. Variety Punjab-14 was released in 1985 with medium sized, oblong and rough green fruits. Average yield of this variety is 125 quintals per hectare. Variety Punjab Kareli-1 was released in 2009. The fruits of this variety are long, thin, green and ridged. It is suitable for cooking by chopping. The average yield of this variety is 175 quintals per hectare.

Cucumber

Punjab Naveen variety of cucumber was released by this department in 2008. The plants have dark green leaves, uniform cylindrical fruit shape and attractive light green colour with smooth surface. The fruits are bitter free, soft seeds at edible maturity and are very crispy. It takes 68 days from transplanting to first harvest and its average yield is 175 quintals per hectare.

Pumpkin

Pumpkin, known as *Halwa Kaddu* is an important cucurbitaceous vegetable due to longer storage and nutritional value. Punjab Samrat released in 2008 is early in maturity, resistant to mosaic virus and high in vitamin-A. Fruit weight is 2-3 kg and average yield is 410 q/ha.

Watermelon

Three varieties, all exotic introductions from USA, were released in the year 1962. Charleston Gray has cylindrical fruits with light green rind, deep red flesh and 11-12% TSS. Sugarbaby has round fruits, deep red flesh and yellow belly with TSS content of 9-10%. Variety Special 1 is early maturing, round fruited with deep red flesh and 6% TSS content. Another variety Shipper was released in 1971. Its fruits are large, round and red fleshed with TSS content of about 8%.

Bottle gourd

Variety Punjab Round was developed in 1962, with medium round to spherical and slightly pubescent fruits. Another variety Punjab Komal was developed in 1988. It is an early maturing variety with oblong, medium sized and light green fruits. It is tolerant to cucumber mosaic virus with average yield of 500 quintals/hectare. Variety Punjab Long was developed in 1997. Its fruits are cylindrical, shining and light green in colour with average yield of 450 quintals per hectare. It is suitable for packaging and long distance transportation.

Summer squash

An early maturing variety of summer squash “Punjab Chappan Kadoo-1” was developed in 1982. This variety has field resistance to downy mildew and tolerance to virus, powdery mildew and red pumpkin beetle.

Squash melon

Tinda-48 was released in 1962 and is still popular among farmers. Its fruits are medium sized, flat round, light green and flesh is white.

Onion

In onion, six varieties for *rabi* and two for *kharif* season have been recommended. White onion varieties Punjab 48 and Punjab White are high in TSS and suitable for dehydration. Punjab Selection, Punjab Red Round and Punjab Naroya have been identified at the national level. PRO-6, another variety with deep red bulb colour and 390 q/ha yield, was released in 2003. All these varieties have very good storage qualities, whereas Punjab Naroya is also resistant to purple blotch. N-53 and Agrifound Dark Red were recommended for *kharif* season onion production in 1987 and 1997, respectively.

Garlic

Punjab Garlic-1 having dark green leaves, uniformly large sized bulbs with white cloves was released in 1993. It yields 95 quintals per hectare. In 2005 Punjab Garlic-17 was released. Its plants have dark green leaves. The bulbs are attractive and white. The cloves are bold, white and vary from 25-32 per bulb. It is early maturing and takes 165-170 days for maturity. Its average yield is 125q per hectare.

Cauliflower

Before formation of the University, three varieties of cauliflower were developed. Early Kanwari was recommended for early season, Giant Snowball for mid season and Snowball-16 for late season. Early Kumari is heat tolerant variety with small and yellowish curds; Giant Snowball has large sized white coloured curd with average yield of 250q/ha; Snowball-16 has white, compact curd with an average yield of 200q/ha. In 1978, two varieties of cauliflower, Punjab Giant-26 and Punjab Giant-35 were released for main season cultivation. Punjab Giant-26 yields about 275q/ha while Punjab Giant-35 has average yield of 300q/ha. For late season two varieties, Pusa Snowball K-1 and Pusa Snowball K-2 were released. Pusa Snowball-1 has compact, medium sized snow white curd. It was ready for harvest 100 days after planting and yielded 225q/ha.

Cabbage

In cabbage four varieties namely Golden Acre, Pride of India, Drumhead Early and Drumhead Late were introduced in 1962 for general cultivation under Punjab conditions. All varieties except Drumhead Late were early maturing with round heads.

Broccoli

Broccoli is a minor vegetable among cole crops. The work for its improvement was initiated in the year 1992 with the objective to develop compact, green headed variety of broccoli. A large germplasm was collected and evaluated. Out of this germplasm, a line BI 80167 was found to be promising under Punjab conditions. In 1998, the line was recommended for general cultivation in the state under the name Punjab Broccoli-1. Its leaves are smooth, wavy and dark green; and the main as well as the secondary sprouts are dark green. The leaves as well as sprouts have slightly bluish tinge. The sprouts are compact, attractive and succulent. The main sprouts are ready for harvest in about 65 days after transplanting. This variety is suitable for both salad as well as cooking purposes. Its average yield is 175 quintals per hectare.

Carrot

Carrot varieties Sel – 233 and Sel-21 with good root quality were released in 1974 and 1985, respectively. The varieties were derived from the cross involving subtropical and temperate types. Later, PC-34 with long roots (25cm), 13.3% DM, 8.8% TSS, 5.8% sugars content and with average root yield of 510q/ha was released in 2005. It is ready for harvesting 90 days after sowing.

Radish

In radish, varieties 5- White (Asiatic type), Japanese White and White Icicles (Temperate types) were released in 1962. 5- White has long white roots with green shoulder; Japanese White has pure white, smooth and cylindrical roots with bulbous lower end; while White Icicles has short, spindle shaped root and is quick growing. Punjab Safed was released in 1975 in Asiatic group. This variety has good root quality than other Asiatic types and retains edibility for longer periods. Punjab Ageti, having pink upper half and white lower half, and suitable for early sowing from April – August was released in 1988. Pusa Himani and Pusa Chetki were recommended for cultivation in Punjab for spring and summer seasons, in 1975 and 1988, respectively. Variety Punjab Pasand suitable for cultivation in main and early summer seasons was released in 1996. Its leaves are erect with entire lamina and roots are long, smooth, pure white and non pungent.

Turmeric

Turmeric, commonly known as *Haldi* is an important spice of daily use for colour and medicinal value. Two varieties namely Punjab Haldi-1 and Punjab Haldi-2 were released in 2008 for cultivation in the state. These varieties are high in curcumin content and give 275- 315 q/ha yield.

Cowpea

Like all other leguminous crops, cowpea is also consumed both as green pod and dry seed and is rich in nutritive value. It is rich and inexpensive source of vegetable protein. Hence, it deserves to get a place in every vegetable farm and kitchen garden. Cowpea-263, released in 1993 is suitable for both spring and rainy seasons. Its pods are medium green, thick, meaty, tender and about 20cm long. It is an early maturing variety. It is comparatively resistant to mosaic and free from golden mosaic. Average yield is 90 quintals per hectare.

Leafy vegetables

Two varieties of palak, Round Seeded Selection and Punjab Selection, were released in 1962. Later on variety Punjab Green was developed in 1990 having shining dark green, thick, long and succulent foliage. Kasuri Methi variety was released in 1962. Plants of this variety are trailing type, tender with good flavour and is still popular among farmers. Coriander is used to add flavor to our food. Punjab Sugandh, a dual purpose variety was developed in 2008. It gives 4-5 cuttings and is late in bolting. Its average green leaf yield is 375 q/hectare and dry seed yield of 8.75 q/hectare. The research on leafy type lettuce was initiated in 1987 – 88 with the introduction of fifty exotic lines from Horticulture Research International, Wallesbourn (UK). These were evaluated for horticultural traits viz, leaf yield, crispness and frillness. The non-heading type (leafy type) introductions produced seed in Punjab, whereas heading type and iceberg type did not produce seed under Punjab agro-climatic conditions. In 1993, a variety “Punjab Lettuce – 1” was released. Its leaves are light green, shining and crispy. It is non-heading type and bears loose leaves. It takes 45 days from sowing to first harvest of fully developed leaves and yield of green leaves is 90 quintals/hectare.

Production Technologies

The department has standardized the plant population density, seed rate and fertilizer requirements of various vegetable crops i.e. tomato, chilli, brinjal, garden pea, bulb crops, cabbage, cauliflower, leafy vegetables and cucurbits. The department has made recommendations for chemical weed control in vegetable crops such as potato, tomato, garden pea, okra, onion and garlic. Vegetable forcing techniques were standardized to produce off-season vegetables. Among various forcing techniques, raising nursery of muskmelon in polythene bags, *sarkanda*/ polythene cover in tomatoes and bulb-set technique in onion are the most popular ones. To advance maturity in cucurbit crops, a transplanting technique has been standardized by raising of seedlings in polythene bags and keeping them at a warm protected place during the month of January. Seedlings at two leaf stage are transplanted in the field when risk of frost occurrence is over. The transplanted crop is early in maturity and escapes the attack of red pumpkin beetle. For *kharif* crop of onion, bulbset technique is sure method for off season onion production where as nursery in summer months may fail due to intense heat. Bulbset size was optimized and sets of 1.5-2.5 cm size give highest marketable yield. Planting of 3-rows of bulb-sets on beds of 60 cm base, 40 cm flat-top and 10cm height improves the bulb size and saves the seed cost by 25%.

Seed-to-Seed method has been recommended in 2011 for commercial seed production of onion. In this method, seed is sown in nursery beds in last week of August to first week of September and seedlings are transplanted in last week of October to first week of November at 15cm spacing between rows and 10 cm between plants. This saves one year time required for bulb production and cost involved in storage of onion bulbs. Incidence of purple blotch and *Stemphyllium* blight on seed crop is less with this approach. It also avoids transmission of yellow dwarf virus from the bulbs to the seed crop.

Protected Cultivation

Net-house Cultivation

The net-house cultivation is an alternative and feasible option to produce vegetables with minimum use of pesticides. It also provides a better environment to improve yield and fruit quality. Net-house cultivation plays an important role in improving productivity, advancing maturity, increasing fruiting span and reducing pesticide application to produce safe vegetables. In 2005, net house cultivation of vegetable crops i.e. capsicum, tomato, and brinjal was recommended. Capsicum hybrid “Bharat’ (green) gives average yield of 400 q/hectare. In tomato, indeterminate hybrid ‘Naveen’ is recommended for cultivation in net house. In brinjal, BH-2 hybrid developed by PAU is recommended for net-house cultivation. Supplementary pollination is important for net-house grown brinjal to improve fruit yield and fruit shape. This is done by tapping the main stem of brinjal plant during noon hours. This increases the fruit setting and gives 93% higher yield than control. The rainy season crop of brinjal should be trained by keeping two main shoots to utilize vertical space, avoids overshadowing and to facilitate supplementary pollination. In autumn transplanted crop, mulching of beds with black polythene (25 micron thickness) from last week of November to first week of March gives early and 50% higher yield (650q/ha) under the net-house.



Net house cultivation of capsicum



Low poly tunnel for cucumber cultivation

Poly-house Cultivation

Poly-house provides a controlled and favourable environment which results in early harvest of superior quality fruits than that of the net house. PAU has recommended poly-house technology for cultivation of tomato and capsicum. Indeterminate hybrid “Naveen” has been recommended for cultivation in poly house due to its long flowering season. It gives an average yield of 660 q/ha with surface irrigation and 960 q/hectare with drip irrigation and fertigation. Capsicum Hybrid ‘Bharat’ is recommended for cultivation in polyhouse which gives yield of 455q/ha. The yield of drip fertigated crop is further enhanced to 630 q/ha in polyhouse. By adopting drip irrigation system in polyhouse, there is saving of 30-35% water as compared to conventional method. Among coloured capsicum hybrids, Bombay (red) and Orobelle (yellow) is recommended for cultivation under naturally ventilated polyhouses.

Low Poly-tunnel Technology

Low tunnel technology was recommended in cucumber and sweet pepper which helps raise these crops in early summer and capture premium for early marketing. Sweet pepper transplanted in 3rd week of November under low poly-tunnel was ready for picking in last week of March. The size of the fruit was also better and the yield higher than unprotected cultivation and normal planting in February. Likewise, cucumber also yielded higher when raised under tunnel in December over February planting. Covering tomato plants during winter months

helps raise early crop. Cultivation of brinjal under low tunnels using transparent non-perforated plastic sheet of 50 micron thickness from first week of December to second fortnight of February protects the crop from frost. This practice gives not only early and higher yield (680 q/hectare), but also makes brinjal available during the lean period of April-May.

Protection Technologies

Insect –Pest Management

Okra : Endosulfan @500g a.i./ha followed by three sprays of deltamethrin @ 10g a.i./ha or cypermethrin @ 50g a.i./ha has been recommended for the control of jassid and okra fruit borer in vegetable okra crop. Most suitable sowing period for okra crop was considered as 15th to 30th July when the crop suffered minimum and escaped insect pest attack. Four sprays of Lambda cyhalothrin (karate) 5 EC @ 15g a.i./ha and Sevin 50 WP (cabaryl) @ 800g a.i./ha are effective against okra fruit borer (2002). Seed treatments with imidacloprid 70 WG (Gaucho) @ 3g /kg for the control of cotton jassid on okra is recommended.

Brinjal : Application of carbufuran (Furadan 3G) @ 1 kg a.i./ha 10 days after transplanting followed by 3 sprays at 15 day intervals with cypermethrin (Ripcord 10 EC) @ 30g a.i./ ha starting one month after application of granules has been recommended for the control of aphid, jassid and brinjal shoot and fruit bore. Two sprays with dimethoate (Rogar 30 EC) @ 300g a.i. /ha followed by 3 sprays at 14 day intervals with cypermethrin (Ripcord 10 EC) @ 30g a.i./ha or deltamethrin (Decis 2.8 EC) @ 10g a.i./ha has been recommended for the control of sucking pests and fruit borer in brinjal (1988). Shoot clipping followed by destruction of larvae gave good control of brinjal shoot and fruit borer. Profenophos 50 EC 0.1% is effective against brinjal shoot and fruit borer. Application of FYM @10 t/ha and Azotobacter @1.25kg /ha along with NSKE 4% at 10 day intervals reduced the pest infestation and increased the marketable brinjal yield. Sex pheromone traps for brinjal shoot and fruit borer are effective for monitoring the activity of adult males.

Tomato : Three sprays of fenvalerate (Sumicidin 20 EC) and cypermethrin (Ripord 10EC) @ 30 g a.i./ha and deltamethrin (Decis 2.8 EC) @ 10g a.i./ha at 14 day intervals starting at flower initiation have been recommended for the control of tomato fruit borer. Action threshold for tomato fruit borer in tomato is on first sight of egg /larvae in the field. Five weekly releases of egg parasitoid, *Trichogramma pretiosum* @ 50,000 eggs /ha coupled with 3 sprays of HaNPV @ 1.5 x 10¹² P.O.Bs/ ha at 10 day intervals and 3 fortnightly sprays of Thiodan (endosulfan) 35 EC @ 700g ai/ha are effective against fruit borer of tomato (2003). Two sprays of imidacloprid 200 SL @ 0.3 ml/l first coincided with pest appearance followed by the second spray after 25 days for aphid management and four sprays of spinosad 45 SC @ 0.5 ml/l at 15 day intervals starting from flowering are recommended for the effective control of fruit borer in tomato.

Cauliflower : Action threshold for aphid on cauliflower is fixed as 30 aphids/plant (1987). Success 2.5 (Spinosad) @ 625 ml/acre at 10 day intervals is recommended for the control of diamond back moth (2009). Avaunt 15.8 EC (indoxacarb) @ 325 ml/hectare or Proclaim 05 SG (emamectin benzoate)@ 175g/hectare at 10 day intervals is recommended for the control of diamond back moth (2010).

Bottle gourd : Soil application of carbufuran 3 G @ 500g a.i./ha at the time of sowing gave effective control of red pumpkin beetle on bottle gourd (2010).

Management of soil-borne pathogens in net-/poly-net-house

Soil solarisation technique has given effective control of soil borne pathogens (fungal pathogens and nematodes) and weed flora. Solarization is done for a period of 45 days starting from 15th May to 30th June.

Screening of germplasm for nematode resistance

In tomato, 10 lines/cutivars viz. 8-2-1-2-5, 1-6-1-4, EC 631955, EC 631956, EC631957 and EC631958, EC119197, EC 531804, Hisar Lal and PNR-7 were found to have confirmed resistance following screening under

natural field conditions, sick plots, artificial inoculation and molecular marker techniques. In bitter gourd, out of 35 *Varh Karela (Momordica balsamina)* six lines viz. MB -3, MB-4, MB-5, MB-11, MB-13, and MB-16 were found resistant and six lines, MB-6, MB-10, MB-14, MB-15, MB-30 and MB-35 were found moderately resistant to root knot nematodes.

In chilli, out of 31 collections screened for root knot nematode resistance, Malagachi Yellow 12-3-3, Jalandhari, Laichi-2 were found resistant and lines MF-41-1-1-1-1, Bengal Green, Indonasia Selection, Shtal-51, ELS-1, ELS-3-3, Jalapeno, Punjab Lal, H-6 and Pickle were found moderately resistant to root knot nematodes. In brinjal, out of 219 lines/ varieties screened for resistance against root knot nematodes, *Solanum sisymbriifolium* (EC-305097), *S. khasianum* (K4489), *S. surattance* (IC11432), *S. indicum* (IC90016) and *S. torvum*, KG-219-1, IC-96630G-1, IC-909770G-20 were found resistant.

Floriculture and Landscaping

Rose

The department has a collection of 197 varieties of rose belonging to different groups. On the basis of evaluation, the most promising varieties were found to be Summer Snow, Arunima and Banjaran, in floribunda group. Varieties Summer Snow was found promising for flower production during hot summer months. A significant improvement was achieved in quick multiplication of rose by cottage-buddage method. Rose is conventionally propagated by T- budding and conventional method takes more than two years to produce budded plants. In the cuttage-buddage method, unrooted cuttings were made in December and simultaneously budded on the rootstock. The basal portions of these budded cuttings were treated with 2000 ppm of IBA for 30 seconds and planted in polybags containing garden soil and FYM in 1:1 ratio and sterilized with 2% formalin. Through this method, budded plants could be obtained in two months. Of the three rootstocks viz. *Rosa indica odorata*, *R. multiflora* and *R. bourboniana* evaluated, *Rosa multiflora* was found most suitable for producing budded plants. Studies also showed that the weeds in rose crop could be effectively controlled by mulching with black polythene (100 gauge thick).

Studies were also conducted to develop vase solutions for improving vase life of cut rose stems. The stems placed in vase solution containing aluminium sulphate (300 pm) or chlorine (50 ppm) prepared from bleaching powder showed significant improvement in vase life. Addition of sucrose (1.5%) slightly enhanced the effect of chlorine. Black leaf spot disease caused by *Diplocarpon rosae* is a major disease of rose. Spray of Dithane M-45 (0.2%) at fortnight interval has been recommended for control of this disease.

Gladiolus

A large collection of gladiolus is being maintained in the department. Nine varieties namely Sylvia, Snow Princess, Melody, Sancerre, Suchitra, Mayur, White Prosperity, Eurovision and Nova Lux have been recommended for cultivation in the state. The department has also developed and released four varieties namely Punjab Pink Elegance, Punjab Flame 2), Punjab Glance and Punjab Lemon Delight. Out of these, two hybrids namely Punjab Pink Elegance and Punjab Flame are suitable for cut spikes where as Punjab Glance and Punjab Lemon Delight for bedding purpose. The protocol for *in vitro* corm production was also developed.

Many gladiolus varieties are prone to iron deficiency which causes interveinal chlorosis of leaves ,thereby, adversely affecting the production of spikes and cormels. The iron deficiency was successfully recovered by spraying 0.3% ferrous sulphate twice at 10 day interval. Pre-emergence application of Stomp 30EC @ 650 ml/acre was recommended for the control of weeds in gladiolus.



**Gladiolus variety
Punjab Pink Elegance**

Vase solution containing sucrose (4 %) + $[Al_2(SO_4)_3 \cdot 16H_2O]$ @ 400 ppm was found to significantly enhance vase life of gladiolus spikes harvested at tight bud stage. The optimum harvesting stage of gladiolus for wet refrigerated storage was also standardized. The spikes of gladiolus should be harvested when 5-7 florets show colour. These spikes can be stored at 4°C for 9 days. Botrytis blight caused by *Botrytis gladiolorum* is a serious disease of gladiolus. Sprays of the fungicides Dithane M-45 (0.2%) and Kavach (0.2%) were found effective and recommended for effective control of this disease.

Carnation

Studies were conducted on the propagation of carnation through terminal cuttings. The rooting of cuttings was found to be higher in cooler months, i.e. October to February than in summer months i.e. April to June. The highest percentage of rooting was recorded (83%) in rooting medium containing sand and burnt rice husk in equal proportion. A technique for *in vitro* multiplication of carnation using shoot tip culture has also been developed. Extended light for 2-4 hours significantly increased the yield of flowers in cvs. Scania and Arthur Sim besides improving flower size and other growth parameters of the plant.

Chrysanthemum

Germplasm collection of about 200 varieties of chrysanthemum belonging to different categories is being maintained and evaluated for pot culture, cut flowers and garden decoration. Three varieties viz., Baggi, Birbal Sahni and Ratlam Selection have been released for loose flower production in the state. The department has also released five varieties namely Ajay, Kelvin Mandarin, Kelvin Tattoo, Reagan Emperor and Reagan White for cut flower production. Six varieties viz. Punjab Gold, Mother Teresa, Anmol, Royal Purple, Yellow Charm and Yellow Delight have been released for pot culture. Three varieties viz., Garden Beauty, Winter Queen and Autumn Joy have been released for garden decoration.



**Chrysanthemum variety
Regan White**

The department has also standardized a technique for propagation of chrysanthemum. Burnt rice husk was found highly suitable medium for rooting of terminal cuttings in propagation trays. The department has also developed technique for off season production of chrysanthemum using photoperiodic manipulation.

Marigold

Giant Double African Orange cultivar of marigold has been found suitable and recommended for commercial cultivation in Punjab. The seedlings should be planted 40x30 cm apart. The crop requires 100 kg nitrogen, 100 kg phosphorus and 50 kg potassium per hectare. The plants of marigold show high incidence of *Alternaria* leaf blight. Spraying the plants with Score (0.05%) or Dithane M-45 (0.2%) at fortnight intervals has been recommended for effective control of the disease.

Tuberose

The department has a collection of 12 tuberose cultivars. Cultivar Prajwal has been found most promising for loose flower production under Punjab conditions.

Seed Production of Flowering Annuals

Optimum time for transplanting and planting density was standardized for seed production of flowering annuals. The optimum time for transplanting of *Coreopsis lanceolata*, *Phlox drumondii* and *Helichrysum bracteatum* seedlings was found to be first week of November and for *Gaillardia aristata* and *Coreopsis tinctoria* third week of November. The optimum plant spacing recommended for *Coreopsis lanceolata*, *Coreopsis tinctoria*, *Helichrysum bracteatum* and *Gaillardia aristata* is 60 x 40 cm and for *Phlox drumondii* is 30 x 30 cm.

Pre emergence application of Stomp 30 EC @ 650ml/acre +two hand weeding after 50 and 80 days of transplanting was recommended for control of weeds in *Coreopsis lanceolata* and *Helichrysum bracteatum*. Treflan @ 625 ml/acre along with two hand weeding has also been recommended for control of weeds in *Helichrysum bracteatum*.

Studies were also conducted to develop methods for dehydration of flowers. Air drying in inverted position was recommended for laguras, statice, briza and bromus. However, for flowers of larkspur embedding in silica gel was recommended.

Evaluation of Planting Material for Landscape Use

In a survey of air polluted areas near sewerage and municipal waste waters in the sub-tropical region of Punjab, the ornamental trees tolerant to air, water and soil pollution, drought, water logging and salinity were identified. Studies were also conducted to evaluate the shrubs on landfill prepared using municipal solid waste. Out of 15 shrubs planted, *Ervatamia coronaria*, *Thevetia peruviana* and *Lantana depressa* and *Pedilanthus* showed luxurious growth. The department also provides landscape advice to the residential premises, public and private institutions.

Forestry

Silviculture

The department has developed package and practices for raising nursery of important tree species such as poplar, eucalypts, sisham, dek, kikar, subabul and teak. Poplar is the most widely planted exotic tree species in plains of North-West India, i.e., Western Uttar Pradesh, Punjab and Haryana. Due to concerted research and development efforts aiming at its genetic improvement, the area coverage and productivity of this species is bound to increase further in the State. Poplar cuttings with 15-20 cm length and 2.5-3.5 cm diameter produced good planting stock in respect of shoot growth. The cutting material for raising poplar nursery should be taken from one year old plants than from the branches of aged plants. Planting of poplar ETPs in 1 m³ pit had better above ground as well as below ground growth in comparison to traditional auger hole planting. Zinc deficiency in poplar nursery and plantation could be ameliorated by applying zinc sulphate. In nursery, it is recommended to add 40 kg zinc sulphate heptahydrate per acre at the planting time. In plantations, it is recommended to apply 100, 200 and 300 g/ plant zinc sulphate in Zn-deficient soils during 1st, 3rd and 5th year of growth in 1m dia basin, 2 m diameter basin or 3 m wide strip (1.5 m on each side of tree row), respectively. In poplar plantations, gaps created by dead plants could be successfully covered by planting of two years old plants.

Drupes of dek (*Melia azedarach*) treated with FYM for 15 days during February resulted in better germination, however, during summer months FYM treatment may be discouraged and cold water treatment is enough for higher seed germination. Growth performance of *D. sissoo* seedlings was significantly increased with application of inorganic and biofertilizers alone and in combination with each other. Dual inoculation with Rhizobium and VAM resulted in higher growth than their individual application. The growth and yield parameters of jatropha increased significantly with the increasing level of irrigation (7-8 irrigations/year) and nutrients (N₆₀P₂₀, N₇₅P₃₀, and N₉₀P₄₀ g/plant during 1st and 2nd, 3rd and 4th, 5th and 6th year, respectively). Pruning of jatropha plants should only be done to maintain shape of plants as the yield of unpruned plants was significantly higher than the pruned plants.

Re-vegetation of flyash dumping site has successfully been achieved. The survival and growth of *Dalbergia sissoo*, *Leucaena leucocephala* and *Eucalyptus tereticornis* was good on flyash. Local and standard timber volume and weight tables have been developed for *E. tereticornis*, *D. sissoo*, *Acacia nilotica* and *Populus deltoides* for estimation of timber volume and weight of standing trees. *Jatropha curcas* has been grown successfully with oil recovery of 14.5 per cent by weight under Punjab conditions.

Tree Improvement

The department has well established tree improvement programme on poplar, eucalypts, shisham, dek, kikar, willow etc. To broaden genetic base, a rich collection of germplasm of important forest tree viz. poplar (250 clones), eucalypts (96 progenies and 12 clones), dek (72 families), kikar (29 families), jatropha (35 seed sources, 30 progenies), shisham (25 progenies), Salix (16 sources) has been maintained and evaluated for different parameters. Eucalypts clones 413, 72, 405, 7 and 290 performed significantly better (> 30 per cent growth superiority) than seedlings. Elite genotypes of shisham and eucalypts have been identified for mass multiplication. *Leucaena* genotypes viz *Leucaena diversifolia* and its hybrid K-743-A (*Leucaena diversifolia* x *Leucaena leucocephala*) were identified as superior fodder varieties producing fodder with higher protein content and low mimosine content. Among the thirteen species of bamboo screened, *Bambusa vulgaris* and *Dendrocalamus strictus* performed better with respect to growth parameters after two years of their introduction.

With the strengthening of tree improvement programme in the Department of Forestry and Natural Resources, poplar clones introduced from U.P. were tested in nursery and under field conditions in central plain and semi-arid regions. On the basis of growth performance at the age of 6 years, five clones (PL-1 to PL-5) were released for commercial cultivation in central plain region and three clones, PL-3, PL-6 and PL-7 for semi-arid region. These clones had 35.3 and 223.6 per cent more wood production than the widely planted clone G-3 in central plain and semi-arid region, respectively. Recently poplar clones L-48/89 and L-47/88 were recommended for commercial cultivation in central-plain region and L-48/89 for semi-arid region. Clone L-48/89 recorded significantly superior volume (48.5 per cent) than the control (G-48) at age of eight years. Molecular characterization of 147 poplar clones using SSR markers has grouped the clones in 6 major clusters. It was helpful in detecting mislabeling of clones (L-253/87 and WSL-32) and proving identity of same clones (WSL-45) from different sources.

In progeny testing programme of *Eucalyptus tereticornis*. Sm, four progenies in height and one in collar diameter parameters performed better than the control. In case of *Dalbergia sissoo*, five progenies performed better in collar diameter and four in height over the control. Similarly, progeny No. 12 of 'Drek' performed tremendously better both for height and diameter than all other progenies both under irrigated and unirrigated conditions. *Acacia nilotica* ssp. *cupressiformis* recorded similar growth as *A. nilotica* ssp. *indica*. The former with its cupressiformis crown is more suitable for agroforestry. A number of straight growing *A. nilotica* phenotypes have been selected. *Dalbergia*, *Eucalyptus* and *Leucaena* performed better on flyash ponds. Madley, Punjab Local and S-146 varieties of mulberry performed better than others.

Agro-forestry

Poplar and dek are preferred trees by Punjab farmers. Being winter deciduous in nature, rabi crops such as wheat, potato, fenugreek and berseem can be grown successfully throughout the tree rotation. The grain yield of wheat varied from 24.5 q/ha in 6-year-old to 51.4 q/ha in 1-year-old poplar block plantation whereas in dek, the yield varied from 25.6 q/ha to 51.7 q/ha. In potato, yield up to 173 q/ha under poplar and 166 q/ha under dek can be obtained in 4 year old plantations compared to control yield of 218 q/ha. In kharif, it is economical to grow crops under poplar and dek only during first 4 years of their growth. Turmeric, moong and pearl millet have more production potential than other crops. Turmeric production varied from 66 % (62.7 q/ha) in 4 year old poplar to 87 % (79.1 q/ha) in one year old poplar to that of control yield. The yield reduction of intercrops can be decreased by manipulating spacing, cultural and management practices of trees. Recommended spacing for poplar block plantation is 8 x 2.5 m with wider tree rows in north-south direction. Out of the six wheat varieties (PBW-502, PBW-509, PDW-274, PBW-343, PBW-373 and WH-542) tested under poplar block plantation, the PBW 502 out yielded other varieties when sown in 2nd week of November as compared to the late sowings (end Nov and mid Dec). Among the new varieties, performance of PBW 621 and DBW 17 under poplar is better than PBW 550 and PBW 502. Additional (25 %) seed and N than recommended to sole wheat along with the recommended P significantly increased yield of wheat sown under poplar. In the present scenario, the farmers are getting more than Rs. 80,000/- per acre per year from poplar based agroforestry system under well-managed conditions. Intercropping of subabul with annual (maize + cowpea – berseem + rye grass) and perennial (napier bajra hybrid) grasses has positive interaction. The subabul-based silvi-pastoral system had high level of fodder and fuel output. One hectare of subabul intercropped with annual as well as perennial grass produced dry biomass (edible and non-edible) equivalent to 1.5 and 1.45 ha, respectively of sole fodder crops.

Studies have revealed that the boundary tree plantation should be in north-south row orientation to minimize the competition of trees with adjoining agricultural crops. In the poplar plantation, about 20 t/ha of litterfall was added in six years which returned about 176, 22, 133 and 368 kg/ha N, P, K and Ca, respectively. In a comparison of carbon content of five tree species (*Toona*, *Ailanthus*, *Melia*, Poplar and *Eucalyptus*) after seven year of planting, the aboveground, belowground and total carbon storage was highest in poplar (68.0, 16.8 and 84.7 t/ha, respectively) and lowest in *Toona* (25.0, 5.7 and 30.7 t/ha, respectively).



Poplar and wheat based agroforestry system



Poplar and turmeric based agroforestry system

Forest Protection

Bioecology and management of key leaf defoliators of poplar have been standardized in the department. A complete package for holistic integrated management of these defoliators has been recommended to the farmers. Management package for arjun gall psyllid, shisham leaf roller, toon fruit and shoot borer, bark eating caterpillar, pongamia leaf blotch miner and termite control in nursery and plantations have been worked out. Effect of burying of pupae, intercropping, tillage and irrigation on the adult emergence of *Clostera fulgurita* under field conditions was studied. The emergence was less in intercropped plots than fallow plots. Fungicides folicur and tilt @ 0.10 per cent were found effective to control foliar diseases of poplar caused by *Drechslera maydis*, *Myrothecium roridum*, *Pseudocercospora populina* and *Alternaria alternata*. In case of *Eucalyptus*, fungicides contaf and tilt were found effective @ 0.10 percent to control leaf spots caused by *Cylindrocladium* and *Cercospora*. Nursery and field screening of poplar clones against *Indarbela quadrinotata*, *Asphadastis cryphomycha*, termites and foliage diseases was worked out.

Seed Technology and Seed Production

Seed Technology

A separate unit of Seed Technology was established in the Department of Plant Breeding in 1978 and it was elevated as an independent Section in 1984 to promote seed research and quality seed production in different crops. The work on breeder seed production under the National Seed Project is mainly carried out carried out on different seed production farms of PAU. These farms are located at Faridkot (Distt. Faridkot), Nabha (Distt. Patiala), Naraingarh (Distt. Fatehgarh Sahib), Ladhawal (Distt. Ludhiana) and Kapurthala (Distt. Kapurthala). Likewise, the research component in seed technology encompasses three disciplines viz. seed production and certification, seed physiology, storage & testing and seed pathology. The achievements made in over the years in different domains of seed technology are as follows:

Seed Production and Certification

Major thrust areas under this domain include seed production technology, hybrid seed production technology, identification of stable diagnostic characters of seed, seedling and plant, micronutrient management of quality seed production, natural cross pollination in major crops, and standardization of spacing and fertilizers for enhancing seed yield and quality in various crops.

Seed Production Technology

Rice : Seed set on CMS lines was increased from 18.2 to 27.9% after spraying 20 ppm GA₃ at boot leaf stage, partial clipping of the flag leaf and shaking of the male parent at anthesis time. Sequential splitting *and* re-transplanting resulted in 39 times multiplication of seed over the control in cv. PR 109. Initial studies on drastically reducing the seed rate by tiller separation technique has given highly encouraging results. The technique will be of special significance in the cultivation of hybrid rice *and* to boost the initial seed multiplication of a variety.

Maize and Bajra : Row proportion studies in hybrid maize and bajra have indicated that 2:10 row proportion of male and female lines gives as good seed set as 2:6 for maize and 2:4 for bajra, the standard row proportion. The higher seed set will result in economical production of F1 seeds and the same would be available to the farmers at a reasonable cost.

Wheat : Certified seed produced higher grain yield as compared to the farmers' saved seed but the difference were not significant, but for the presence of off types, other crop seeds, weed seeds and higher incidence of loose smut in farmers' saved seed. Experimentally, it has been proved that the occurrence of barley plants in wheat fields is due to admixtures. Based on the above studies, "Seed Village Scheme" for the multiplication of wheat seed has been initiated from the current rabi season. The scheme will be extended to cover more crops. This/the firsts scheme of its kind to motivate and educate the farmers to produce good quality seed at their level to meet their requirements.

Seed multiplication ratio to the extent of 1:200 could be achieved as compared to 1:40 by lowering the seed rate upto 0kg/acre without any major significant loss in seed yield per unit area.

Onion : Bulbs of 5-6 cm diameter have been found to be economical for getting optimum seed yield. For planting one hectare, 28 q onion bulbs are sufficient.

Chemical weed control : Basalin *and* lasso were recommended for controlling weeds in okra.

Pest management : Application of thimmet 10-C at sowing followed by sprayings of Cymbush 25 EC or Somicidin 20 EC or Decis has been recommended for controlling jassid *and* fruit borer for okra seed production.

Hybrid rice seed production

Application of growth hormones and flag leaf clipping was found good for effective panicle exertion and seed set. On the basis of this, a package for successful hybrid seed production technology in rice has been given. Floral traits of parental lines were studied for selecting viable and better combinations for hybrid rice. CMS lines PMS 2A, PMS 6A, PMS 7A, PMS 10A and IR 58025A were found to be better than other CMS lines with respect to duration and angle of floret opening. Effect of times of nursery transplanting was studied on the flowering pattern of CMS and restorer lines of hybrid rice. Transplanting of seedlings of different ages revealed that old seedlings (more than 30 days) enhanced the panicle emergence while younger seedlings (20 days and 25 days old) delayed the panicle emergence in case of CMS as well as in restorer lines.

Farmers Participatory Seed Production Programme

Training camps for farmers were organized in different villages of Punjab for producing quality seed of various crops. Necessary guidelines for producing quality seed of wheat, paddy and moong were given in details. Quality seed was produced using recommended cultural practices and plant protection measures. Farmers were also educated regarding seed storage techniques to maintain quality and viability of the seed produced. Produced seed was distributed at village level among the farmers in the next season and was sown over larger area. As per the feedback, the farmers were very much positive and showed keen interest. The training camps helped in producing quality seed of different crops. To cite an example, from 10 acres of area planted with summer moong - SML 668 during 2004 season in Dharmgarh village in district Fatehgarh Sahib, about 40 qtl quality seed was produced and in the next season, the produced seed was sown over 26.6 acre giving net return of Rs. 3000/- per acre. Likewise, during 2008, foundation seed, certified Seed & TL seed of rice varieties PR 111, PR 114, PR 118,

PAU 201, Pusa 44, Pusa 1121 and Govinda were sown in an area of 42 ha in six villages in Patiala district. From this, 2150 qtl of quality seed was produced with net return of Rs. 10550/- per acre. During rabi 2008-09, certified seed of wheat PBW 343 was sown in an area of 114.40 ha in different villages of Faridkot and 5800 qtl of good quality seed was produced that helped in net return of Rs. 4500/- per acre.

Identification of Stable Diagnostic Characters

SSR marker based DNA fingerprinting and cultivar identification

Rice: Fourteen varieties of rice cultivated in Punjab were characterized using 80 Simple Sequence Repeats (SSR) primers. Sixty six primers showed polymorphism among the cultivars and identified the genotypes individually.

Maize: Twenty five cultivars of maize (4 composites, 14 inbreds and 7 hybrids) cultivated in Punjab were characterized using a set of seventy Simple Sequence Repeat (SSR) markers. Out of these, 67 markers produced polymorphic profiles, while only 3 were monomorphic. In all the genotypes, DNA fingerprints (unique DNA profiles) could be created by using the polymorphic SSR markers. Hence, all the genotypes could be differentiated individually

Okra: Ten varieties viz. G2, Parbhani Kranti, Pusa Makhmali, Punjab 7, Punjab Padmani, Pusa sawani, IIHR4, IIHR 10, HRB9-2 and EMS-8 were characterised w. r. t vegetative, floral and fruit characters along with their reactions towards diseases and pests.

Morphological characterization

Under varietal characterization of various crops, 19 varieties of rice, 18 of wheat, 11 of *Berseem*, 51 of sesamum, 7 of groundnut, 49 of cotton and 25 of maize were characterized to generate a complete database for finalizing National Test Guidelines for DUS testing. In rice, out of 65 characters studied, the varieties were grouped on the basis of time of heading, panicle number per plant, awn characters and grain characters viz. length, width and aroma. In wheat, out of 35 characters studied, time of ear emergence, ear and awn colour and grain characters viz. grain colour, grain crease and prominence of brush hair length were found to be important for grouping. In *Berseem*, out of 18 characters, the varieties could be grouped on the basis of leaflet characters viz. margin and hairiness and stipule pubescence. In sesamum, out of 20 characters studied, capsule characters viz. arrangement and hairiness and seed characters viz. Seed coat colour and 1000- seed weight were very helpful in grouping of the varieties. However, a lot of intra-varietal variation was observed. In groundnut, out of 20 characters studied, grouping could be done on the basis of four characters i.e. growth habit and pod characters viz. pod colour, prominence of beak and kernel weight. In cotton, out of 41 characters studied, the varieties could be grouped on the basis of leaf shape, flower petal colour, boll shape and fibre length. In maize out of 28 characters studied, the varieties could be grouped on the basis of time of anthesis, anthocyanin colouration of silks and type of grain.

Micronutrient management for quality seed production in paddy and wheat

The study revealed that basal application of zinc sulphate to wheat crop raised in Zn-deficient soil, resulted in better zinc uptake and higher Zn content but did not have any significant effect on seed quality parameters as compared to foliar application. In rice, seed analysis for micro-nutrients showed significant increase in zinc content and uptake with successive increases of zinc application up to 10kg Zn/ha (i.e. 50 Kg ZnSo₄/ha). There was also a significant increase in fresh weight of the seedlings and vigour index.

Natural cross pollination in wheat

The experiment was conducted with wheat variety K-23 (super dwarf strain; less than 75 cm) as a seed parent and K-39 (tall; about 1m) as a contaminator spaced at 3m isolation of the seed parent. The genetic contamination of 1.14% was recorded at 3m isolation which is, in fact, higher than the prescribed limit (0.5%).

Searching alternative area for hybrid seed production of major crops

Rice: No hybrid rice in Punjab has been released and almost the whole area is occupied with inbreds only as the varieties developed by PAU are very high yielding and are better yielders than most of the hybrids available in the market. The seed hybrid rice, however, can be successfully produced in the state and in fact a few farmers are engaged in hybrid rice seed production in the state, though not on a very large scale.

Cotton: On account of high pest incidence, high physiological loss of flower buds in case of seed parent and high labour cost incurred for hand emasculation and pollination, cotton hybrid seed production is uneconomical in Punjab.

Maize: Maize hybrid seed production is profitable proposition wherein the cost benefit ratio is 1.76. But as the isolation distance requirement is very high hence its seed production on a large scale is not possible in the state.

Standardizing spacing and fertilizers for enhanced seed yield and quality in sweet corn

The experiment was conducted with pearl popcorn as no released variety of sweet corn was available. Plant height, cob length, number of seed/cob and seed yield was more in flat sowing as compared to ridge sowing. Moreover, flat sowing took less days to 50% flowering. Significant differences were observed in plant height, days to 50% flowering and number of seed/cob.

Determination of optimum planting ratios in maize hybrid

A row ratio of 3:1 was found to be optimum for producing PMH-1 hybrid as it had more number of seeds per cob and higher 100-seed weight than the ratio of 4:1

Synchronization of flowering in inbred lines of maize

Spraying of urea (2%) 35 days after sowing was found to be the most effective treatment for inducing earliness in the female parent of maize hybrid Buland as compared to other treatments like hydration and a combination of urea spray with hydration.

Seed Physiology, Storage and Testing

Seed Storability

Storability of seed in different packaging materials for bulk seed storage

The study was conducted with maize, wheat, paddy and sunflower seeds under godown conditions. Polythene lined jute canvas were most suitable for seed storage under ambient godown conditions as all crops maintained MSCS standards for germination for one season in this type of packaging. Storability of seed in HDPE (high density polyethylene) interwoven non-laminated bags was at par with that in jute canvas/cloth bag

Seed storability of wheat and paddy in different packaging

Seed storability in HDPE (high density polyethylene) interwoven non-laminated bags was at par with that in jute canvas/cloth bags. Seed with good initial germination (>85%) and moisture level below 10 % can be stored well under a wide range of storage conditions when packed in HDPE or Jute canvas bags. Thus HDPE bags can be substituted for Jute canvas bags as these bags are economical.

On farm demonstration of safe seed storage technology in wheat

The on farm demonstrations revealed the wheat seeds having good initial germination (>85%) can be stored well under a wide range of on-farm storage conditions after drying to a safe moisture content (~10%) and then packing in HDPE/Jute-canvas bags.

Suitability of packaging materials for commercial seed storage of cowpea

Grain super bags as well as poly-lined cloth bags are safe for packaging material for storing seeds at ~9% moisture content for one planting season, maintaining seed quality above seed standards with minimum insect and pathogen incidence.

Conditioned storage and performance of hybrid sunflower and hybrid rice seed

Sunflower: In ambient storage, hybrid sunflower PSFH 118 and its parents 10A and P 61R maintained MSCS up to 12-months in both packagings i.e. cloth bags and poly-lined cloth bag. In cold storage, hybrid sunflower PSFH 118 and its parents 10A and P 61R can be stored up to 24-27 months.

Rice : In ambient storage, hybrid rice and its parental lines maintained MSCS up to 13 months in both the packagings. In cold storage, hybrid rice and its parental lines maintained MSCS up to 5 months of ambient storage subsequent to 3 months' cold storage.

Effect of thiram on germination on wheat during storage

The study was conducted with two wheat varieties PBW 550 and DBW 17 and packaging of cloth bag and poly-lined cloth bag. During storage thiram (@ 3g/kg) showed no deleterious effect on seed storability during one year storage. MSCS were maintained till 2 years of storage.

Vegetable seed viability under different packaging materials and cold storage

Radish, turnip and onion seed dried to 2.7-7.4% moisture content and packed in moisture impervious containers (poly bags 700 gauge and aluminium pouches), maintained the seed germination to the prescribed level for longer time at cold storage (10-15°C) conditions as compared to that under ambient storage conditions.

Screening of different varieties for seed storability

Screening of Pea varieties was studied for seed storability under ambient and accelerated ageing conditions. Pea varieties were grouped into three classes on the basis of their storability under ambient storage conditions viz. Good storer : Matar Ageta (6 - 18 months), Poor storer : Arkel (10 months) and Intermediate storers: Mithi Phali, Punjab 87 and Punjab 88 (12-14 months).

Seed Quality Enhancement

Standardisation of seed coating technology in soybean

Flowable Thiram 40 SC (Royal flow 40 SC) and Polymer + Vitavax 200 (containing Thiram (37.5% and Carboxyl 37.5%) were found effective in improving the seed quality of soybean in terms of germination (79 to 86% and 84%) and vigour index (37.58 to 44.98 and 44.99), respectively.

Development of pre-sowing seed treatments for invigoration

Pearl Millet (carry-over seed): Pre-sowing seed hydration treatment followed by air drying and thiram dressing @ 0.2 % was found to increase the germination, speed of germination and field emergence significantly.

Soybean (fresh and carry-over seed): Hydration for 2h and thiram dressing @ 0.2% was best as it significantly invigorated seed quality in terms of per cent germination (85% to 94%), speed of germination (11.87 to 19.95), emergence per cent, vigour index, plant stand in both the lots over control in both the lots followed by only hydration and CaCl₂ @ 2% for 2h.

Okra early sown (Feb sown): Pre-sowing seed treatment with GA₃ followed by air drying and thiram dressing @ 0.2 % was found to increase the germination, speed of germination, field emergence and final field stand. It also reduced post emergence plant mortality.

Chilli (Freshly harvested seed) : GA₃ seed treatment resulted in improved germination percentage, emergence percentage, speed of germination, seedling length and vigour index followed by KNO₃ treatment

Brinjal (freshly harvested seed) : The seeds of three varieties of brinjal were subjected to different seed treatments prior to seed storage. Treatment with hot water treatment, sodium hypochlorite and ammonium solution registered better seed quality in terms of per cent seed germination and seed vigour. Seed quality was improved by differential emasculating time and crossing period. Quantity and quality of seed (1000-seed weight, germination % and seed vigour) were increased in the plants emasculated in the afternoon (3.00-5.00 P.M.) and crossing period -3 (September 21-30) was the best in hybrid brinjal BH-1 and BH -2.

Variety Identification

PAGE studies for peroxidase activity were able to differentiate 8 out of 12 cultivars of rice under study i.e. PR115, Basmati 370, PR114, PR 106, Basmati 385, PR 116, PR103 and Basmati No.1. However, acid phosphatase and esterase did not show any polymorphism. Electrophoresis techniques were tried for variety identification in cluster bean. It was found that SDS PAGE of total proteins and globulins exhibited no polymorphism. PAGE studies in cluster bean indicated no polymorphism with respect to isozymes of peroxidase and esterase

Genetic Purity Testing

Developing techniques for genetic purity testing of muskmelon and chilli hybrid seed

Punjab Hybrid : PAGE studies for Isozymes of Esterase, Peroxidase, Phospho-gluco-mutase and Phospho-gluco-isomerase could not differentiate hybrid muskmelon (Pb hybrid) from its parents i.e. MS-1 and Hara Madhu, as all the bands were found to be at same Rf and same intensity in all three genotypes.

Hybrid Punjab Anmol: PAGE studies for isozymes of peroxidase and acid phosphatase could not differentiate hybrid Punjab Anmol and its parents (MS-1 and Punjab Sunehri) suggesting that some other isozymes (except above two) should be explored for variety characterization and for testing genetic purity of this hybrid of muskmelon.

Hybrid Chilli: CH 1 and its parents (MS 12 and LLS) and CH 3 and its parents (MS 12 female and S 2530) were taken. No isozyme polymorphism with respect to three isozymes (peroxidase, esterase and acid phosphatase) was observed. This suggested that some other isozymes (except these three) should be explored for testing genetic purity.

Maturity Indexing

Twenty five days after panicle emergence (DAPE) was found the optimum stage of maturity on case of *Panicum maximum* indicated by higher seed germination (23%). De-husking improves the seed quality in terms of per cent germination and seed recover. Truss and fruit position within a truss significantly affected seed quality in tomato cvs. Punjab Upma and Castle Rock. Seeds of the first truss and of the first fruit within a truss were of better quality in terms of germination and other seed quality parameters.

Seed Pathology

Paddy bunt

On the basis of data, zones of high disease incidence (S-W districts like Ferozepur, Faridkot, Bathinda and Sangrur), moderate incidence (central parts like Ludhiana and Kapurthala districts and parts of Amritsar and Jalandhar) and low incidence (N-E districts like Gurdaspur, Hoshiarpur, Ropar, Fatehgarh Sahib and parts of Amritsar, Jalandhar and Patiala) have been identified. Teliospores of *N. horrida* were found to be viable for 5 years under laboratory conditions, for 3 years at soil surface and for more than one year at different depths of soil. Teliospores remained dormant for 5-6 months. Optimum germination of the teliospores was obtained after 72h when incubated on a free film of water at $28\pm 1^{\circ}\text{C}$. While standardizing inoculation technique for the artificial creation of kernel smut, it was found that syringe inoculation at boot stage with inoculum load of 8×10^5 spores/ml (from 7-10 days old cultures) showed 100% probability of tiller infection with 15-42% grain infection. Evening inoculations proved better than the morning and mid-day inoculations

Paddy discolouration

Fusarium moniliforme, *Curvularia lunata*, *Dreschlera oryzae*, *D. tetramera*, and *Alternaria alternata* were predominantly associated with discoloured grains. On the basis of discolouration, the entire state was categorized into three zones. Dry seed treatment with Thiram in combination with Bavistin or soak treatment in Emisan improved the germination of discoloured seed. Prolonged spell of rains at the time of maturity of paddy, many a times, has resulted in deterioration of seeds affecting seed vigour and germination adversely. Treatment of such seed with Emisan (organo-mercurial), instead of upgrading the seed health, has resulted into phytotoxic action on seeds and seedlings. Therefore, precautions should be taken before treating such seed

Seed health status of farmer saved seed

The studies on evaluation of quality of farmer saved seed have shown that the quality of farmer saved seed has improved tremendously in terms of seed germination (90 % of the samples were found above MSCS), however, 5-10 % of the samples failed due to various diseases (Karnal bunt in wheat and paddy bunt). Further, physical purity has been the major impediment where 20-30 % of the samples have been failing marginally.

Standardization of tolerance limits for important seed borne diseases

Very low Karnal bunt incidence was recorded under all the treatments but it did not have any relationship with the intensity of seed infection. Probably, the spores after germination are carried away by the air currents from its centre of primary site and the infection depends upon the chance landing of the spores. Probably this is the reason that it did not have any relationship with the amount of inoculum load in the plot.

Grow Out Tests and Monitoring of Seed Quality

The purity of the varieties tested over the years was found within MSCS limits. The seed testing is a regular feature of the Seed Technology unit. The seed samples of different crops were tested for their germination and the seed lots with MSCS were offered for sale. During 2007-08 to 2009-10, 303 varieties of various crops have been tested for seed quality using grow out test during rabi and kharif seasons.

Salient Findings of Practical Significance

Seed Production & Certification

- In hybrids of maize (Paras and PMH-2) closer spacing of 45 cm between rows combined with the application of 120 N & 60 P₂O₅ kg/ha produces higher seed yield of both male and female parents.
- Sowing of parental lines for hybrid seed production of Paras in the first week of August and last week of July provides excellent seed setting and also escapes the damage due to pollen wash under Punjab conditions.
- Period of mid January to mid February is most suitable for seed production of sunflower in terms of maximum seed set and low disease incidence. Further, no supplementary pollination is required under north Indian conditions.
- On account of high pest incidence, high physiological loss of flowering buds in case of seed parent and high labour cost incurred on account of hand emasculation and pollination, hybrid seed production of cotton is unprofitable in Punjab, whereas, it is a profitable proposition in maize and pigeon pea.

Seed Physiology, Storage and Testing

- HDPE (high density polyethylene) interwoven non-laminated bags can be used in place of jute canvas bags for bulk seed storage. Care should be taken to dry the seed properly (within MSCS levels). Bags may be filled to 90 per cent capacity and stacked in alternate positions for better stability.

- For Pearl millet, the pre-sowing seed hydration for 16-18h and drying at room temperature to normal moisture content of seed followed by dry dressing with Thiram @ 0.2 per cent is effective for rapid and uniform field emergence and establishment.
- Twenty five days after panicle emergence (DAPE) is the optimum period for harvesting the seeds of *Panicum maximum* for better quality and storability.
- The polymer coating in combination with thiomethoxam with and without colourant is beneficial in improving the initial quality as well as storability of seeds of Soybean. The sequential coating with polymer-fungicide-insecticide is the most effective.
- Grain super bags are safe packaging material for storing seeds of different crops at 10 per cent for one planting season, maintaining seed quality above seed standards with minimum insect/pathogen incidence. The use of grain super bags would be useful for bulk storage at commercial level.

Seed Pathology

- For detection of BLB pathogen in rice seed, plating the kernel on sterilized moist blotter is the best method.
- On seed production plots, rice bunt can be effectively controlled by two spraying of Tilt @ 0.1 per cent or Contaf @ 0.2 per cent, first at boot stage and second 12 days thereafter.
- Vitavax treated wheat seed stored in polythene bags (400 gauge) can be carried over for one more season.
- Germination of parental lines of hybrid rice can be maintained for longer period, when stored in polythene bags (400 gauge) by treating the seed with Thiram or Captan (@ 0.2%)
- An inoculation technique for artificial creation of kernel smut of paddy (paddy bunt) has been standardized for screening of rice germplasm. Evening inoculations with secondary sporidia, injected at late boot to early heading stage, proved the best with inoculum load of 8×10^5 sporidia/ml.
- Embryo count method for detection of loose smut in wheat and sodium hydroxide soak method for paddy bunt has been standardized and recommended to Seed Testing Labs.

DUS Testing for Implementation of PVP Legislation

PAU, Ludhiana having been designated DUS test centre for cotton, barseem and wheat, the seed technology centre tested candidate varieties along with the respective reference varieties for their registration and protection. In cotton, most of varieties belonged to the Bt-cotton type. Data on 36 traits was also recorded including fibre quality traits. Among the quality traits, 2.5% span length was higher in tetraploid type candidate varieties (range 26.8 – 32.1 mm) than in the diploid type (19.6 mm).

Storage and Production of Vegetable Seeds

Seed priming with GA_3 @ 50ppm in okra, tinda, longmelon and cucumber enhanced seed germination in all the crops. Seed coating of tomato seeds with synthetic polymers and additive like fungicides thiram and plant growth regulators like GA_3 revealed increased percent germination and vigour with seed coated with polymers and GA_3 treatment. Standardization of fermentation period of seed extraction in tomato reveals that fermentation for 24 hr period led to decline in seed quality and its storability. Carrot seeds harvested in umbels after 40-55 DAF had maximum germination. In Radish, seeds attain maximum seed germination after 60 days of full of bloom. In tomato, seeds extracted from red firm tomatoes have seed germination. Different maturity groups of fruits based on fruit colour were used for the seed extraction of summer squash. The fruits of deep orange colour on wet seed extraction after surface drying gave maximum seed germination and vigour. In fenugreek, acid saccharification for different periods revealed that 15 minutes of acid treatment at the time of sowing removed hard-seededness and produced maximum germination.

Seed Production

The Directorate of Seed has the primary mandate of seed production of recommended crop varieties and its distribution so that the farmers get quality seed without any hassle for commercial crop production and the seed producers get foundation seed at appropriate time of sowing. The seed production is planned at various university seed farms and KVKs keeping in view the isolation and infrastructure available. About 3500 q breeder seed of field crops is produced annually and supplied to various agencies as per allocation from GOI. The production targets fixed by the ICAR for various crop varieties are fully met. The foundation seed is produced and supplied to different seed producing agencies both in public as well as in private sector. Currently, seed production is being carried out at 17 KVKs, 3 research stations and 5 seed production farms.

Planning of Seed Production Programme

The seed production programme is planned in the University level meeting where all the crop breeders, representatives of various seed producing organizations and officers of the State Department of Agriculture/Horticulture/Animal husbandry participate. The seed production programme is formulated for each crop variety on the basis of priorities fixed by the state government, seed demand received from various public and private seed producing agencies and seed growers. In addition, the seed demand during the previous crop season is also kept in view. The meeting of the committee is called twice a year during *kharif* and *rabi* seasons. After approval of the seed production programme, the copies of the plan are sent to seed producing farms for implementation.

Monitoring of the implementation of the formulated seed programme, its management and seed quality control is carried out during cropping season.

Sale Rate Fixation

The seed sale rates are fixed by a broad based committee. Two meetings of this committee are held for fixing sale rate for *kharif* and *rabi* seeds. The sale rate of the seed is fixed on the basis of the sale rates of different organizations like PSSC, NSC, SFCI and the minimum support price of grains fixed by the Central Government.

Seed Allocation and Sale

For this purpose, a comprehensive statement of the seed demand submitted by various agencies is prepared and thoroughly examined and depending upon the availability, the seed is allocated. The seed producing agencies are required to submit their foundation seed indent upto 15th March for *kharif* seed allocation and up to 15th September for *rabi* seed allocation. In addition, help is provided in the smooth conduct and sale of seed during Kisan Melas which is really a challenging job. The monitoring of the seed sale to the farmers from different outlets of the University is carried out to ensure that the farmers get the seed without any hassle and also that the University is in a position to sell the seed to the farmers.

Inspection of graded seed is carried out before sale during kisan melas to ensure that the seed being offered for sale meets the quality standards.

Notification of Varieties

Necessary arrangements are made for the notification of varieties released by the University. For this purpose the proposals received from the respective plant breeders are submitted to the office of The Director of Agriculture Punjab, Chandigarh. The required meetings are arranged and the information, as demanded from time to time by the Directorate of Agriculture is made available.

Facilities Developed

Under Mega Seed Project “Seed Production in Agriculture Crops and Fisheries” an amount of Rs. 7.33 crore was allocated by the ICAR for developing infrastructure and seed production facilities at the farms, horticulture

crops, microbiology, floriculture etc. The money allocated for the development of the farms has been utilized for the strengthening of irrigation, processing and storage facilities. This has greatly helped in improving seed quality as well as production.

Similarly, an amount of 2.40 crore was received from Ministry of Agriculture, GOI, New Delhi for upgrading seed processing and storage facilities at USF, Nabha, Naraingarh and Kapurthala. The funds have been utilized for the purpose of installing new processing plants (at USF, Nabha, Naraingarh, Kapurthala, Ladhawal and RHSSF Faridkot), construction of new seed stores (at at USF, Nabha, Naraingarh, Kapurthala and Ladhawal), construction of half covered sheds (at at USF, Faridkot, Ladhawal and Naraingarh), fencing of main farms and creation of underground irrigation facilities. This has greatly helped in improving seed quality.

Production of Seed

The university has been producing seeds of different varieties of important crops. The seeds of different classes viz. breeder, foundation and T/L are produced at five university seed farms situated at Ladhawal, Naraingarh, Nabha, Kapurthala and Faridkot, 16 KVKs and three regional research stations at Bathinda, Gurdaspur and Abohar. The quantity of seed to be produced every year and the crop season is linked with the seed demand received from various public and private seed producing agencies and seed growers. The quantity of total seed of different crop varieties produced during 1986-87 to 1990-91 was quite less and it ranged between 11254.11 and 14873.40 q. However, during the next 10 years, it increased from 20963.52 q in 1991-92 to 46159.45 q in 2000-01. The quantity of seed produced further increased during the next ten years where it varied between 46004.85 and 65549.74 q during 2001-02 and 2010-11 indicating substantial increase in demand for the seed of PAU developed varieties. Out of the total raw seed produced, the quantity of breeder seed and foundation seed produced during the past ten years is given in Table 14 below :

Table 14 : Breeder and foundation seed produced by PAU from 2001-02 to 2010-11

Year	Breeder Seed (q)	Foundation Seed (q)
2001-02	1489.61	14715.25
2002-03	1468.88	11440.68
2003-04	1561.21	17978.72
2004-05	1740.51	17988.21
2005-06	2729.33	18713.86
2006-07	2605.24	17418.82
2007-08	4207.4	12191.44
2008-09	4944.79	14778.48
2009-10	4908.14	14340.68
2010-11	5797.98	11271.50

POST-HARVEST TECHNOLOGY

Cereal Technology

Overcoming the adverse quality factors in wheat : Simple pearling technique has been developed to produce good quality baked products from rain damaged wheat. A ‘no time’ baking procedure using low pH, high salt concentration and a combination of reducing and oxidizing agents has been developed to produce good quality baked products from severely rain damaged wheat. Adverse effects of Karnal bunt infection on quality of wheat and its products and on living being have been extensively studied. A lye peeling and pearling technique has been developed to overcome these adverse effects.

Storage changes and improvement in the quality of sprouted flour : Changes in the quality of sound and sprouted flour, when stored (34.8°C, 66.7% RH) for 0, 45, 90 and 135 days were observed as protein, gluten, starch, free amino acids, proteolytic and amylolytic activity decreased with increase in storage period. Aging of sprouted flour for 45 days improved the cookie and cake making properties and further storage was of no value.

Addition of 4% vital gluten and 0.15% disodium phosphate was found to be beneficial for getting good quality flat breads from sprouted wheat. Good quality noodles could also be prepared from moderately sprouted wheats with the addition of 3% vital gluten and 0.15% disodium phosphate. However, highly sprouted wheat requires extra addition of gluten to the flour to produce quality noodles.

Improvement in bread making quality : Judicious application of amylolytic enzymes from fungal, bacterial and cereal sources have been found to improve the bread quality, productivity and economy. Low fat baked products like bread, biscuits and cakes have been developed using fat substitutes like guar gum, carboxymethyl-cellulose in combination with emulsifier such as stearyl-2-lactylate and glycerol mono-stearate. High fibre breads from high extraction rate flours or by adding a fibre source like *Psyllium mucilloid* husk (isabgol) have also been developed.

Emulsifiers and hydrocolloids as fat replacers in baked products : Two wheat varieties viz. PBW-138 and WH-542 were analysed for their physiochemical characteristics and milled into flour for preparation of bread, muffins and cookies. The emulsifiers viz. glycerol mono stearate(GMS) and sodium stearyl-2-lactylate (SSL) and hydrocolloids viz. guar gum(GG) and Carboxy methyl cellulose (CMC) at the levels of 0.25 and 0.50 % flour weight basis were included in the formulas to reduce the fat contents by 10 and 20% in muffins and cookies, respectively and omitting fat in bread. The qualities of products prepared after reduction of fat and addition of emulsifiers and hydrocolloids were better than their respective controls.

Composite flour and cereal brans for nutritious biscuits : Composite flours prepared from wheat, green gram, Bengal gram and black gram flour were studied for preparation of biscuits. Protein content of biscuits increased but top grain, color and texture were adversely affected. Quality scores showed that acceptable biscuits could be prepared from wheat flour supplemented with legume flour at level of 15%. Different cereal brans (wheat, rice, barley oat and corn), full fat and defatted were incorporated into wheat flour for biscuit making. After extensive trials, on the basis of acceptability rating and sensory evaluation 20% blending level for bran concluded to be best for quality biscuits. Storage studies revealed that product remained acceptable upto four months of storage at ambient conditions.

Variety bread formulations : With a view to fulfill the demand of urban segment for ready to eat convenience foods, variety breads were formulated under laboratory conditions. Such bread will suit the health of nutrition conscious population of our country. Formula of milk bread, Sour dough bread, soya flour bread, low sodium bread and breads prepared by utilizing sunflower kernel were given to local bakeries and milk bread and Soya bread formulas were adopted by few of them.

Isabgol husk in flour for chapatti making : A study was conducted with the aim of increasing fibre content after incorporation of isabgol (*Psyllium mucilloid*) husk at the levels of 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 in atta for use in chapatti making. Farinographic and pasting characteristics improved, as the level of fibre was increased. Mixing time of the flour decreased and dough became sticky in handling, as flour absorbed more of moisture with increase in level of fibre. Puffing of *chapattis* was partial but browning was even. *Chapattis* made with flour containing isabgol were found acceptable by the panelists at all the levels of supplementation.

Durum wheat processing and utilization : For proper milling of durum wheat into semolina, higher moisture (17-18%) was found to give better recovery of semolina. Similarly, higher tempering time (72 h) was more conducive for getting better results. Fresh flat bread prepared from durum wheat ranked first among breads and *chapattis*. The storage change, however, were fast in the durum wheat products. Bread wheat and durum wheat grains blended in different proportions (100:0, 80:20, 60:40, 40:60, 20:80, 0:100) were milled into flour and 'atta' for use in bread, cookies and chapatti making. Good quality bread and cookies could be prepared with wheat and durum flour in 60:40 ratios. Acceptable *chapattis* could be prepared from 'atta' or flour obtained from 40 percent bread wheat and 60 percent durum wheat blend. Such utilization will help to improve the nutrition in terms of protein content and β -carotene.

Egg free cakes : Whey protein concentrate 0-25 % (on egg weight basis) and whey powder at 0-100% (on egg weight basis)were used to replace eggs in the preparation of cakes. Replacement of eggs with whey protein concentrate and whey powder resulted in improved quality, acceptability and shelf life of muffins both at room

and refrigeration. Muffins with 15% level of whey protein concentrate (on egg weight basis) and 80% level of whey powder (on egg weight basis) were found best by the panelists. At this level values for firmness (texture analyzer) were also less.

Low sodium cookies : Low sodium cookies were prepared by replacing sodium salt with other mineral salts such as KCl, MgCl₂, CaCl₂, MgSO₄ and Na₂SO₄ and NaHCO₃ with K₂CO₃ and combination of NaHCO₃ and NH₄HCO₃ with K₂CO₃ and combination of NaHCO₃ and NH₄HCO₃ in ratio of 50:50 in the formula for cookie baking to study the effect of sodium replacement on cookie making quality from the three commercial flours (A, B, C) varying in composition. Residual sodium content decreased with the almost one-third with incorporation of all salt substitutes instead of NaCl. Further these levels decreased with the addition of K₂CO₃ as baking soda as compared to use of NaHCO₃ and NH₄HCO₃ (50:50). So, use of K₂CO₃ as leavening agent in baking powder is suggested to the bakers.

Improving bread making quality of wheat : Two types of gluten namely Indian (IG) at 3.0% level and German (GG) at 2.0% levels were incorporated along with additives namely SSL(0.5%) and GMS (0.25%) in flour from three Punjab wheat cultivars namely HD-2329, PBW-343 and PDW-233 to study the effects on rheological and bread making quality. Dough development time decreased and stability improved after the addition of gluten. There was significant improvement in baking performances of flour after the addition of glutes and further with additives, more so with GG. Fine wheat bran (10% flour weight basis) and different types of glutes (5%) namely IG and GG were added to flour from different wheat varieties viz. HD-2329, PBW-343, PDW-233, to study the effect on bread making characteristics. Addition of bran alone deteriorated the bread making quality, due to dilution of gluten protein. Dough handling properties and loaf volumes improved after addition of gluten along with bran. Addition of GMS & SSL further improved the quality as they improved the gas holding capacity of dough. Among the varieties HD-2329 was found best, where as comparing the glutes, GG was found best.

A study was conducted for preparation of brown bread from whole-wheat meal after the addition of glutes, with the objective of improving the nutrient content and acceptability of brown bread. Loaf volumes and specific volumes of bread improved considerably after the addition of glutes. Bread prepared was comparable with the white breads in loaf volumes and crumb structure.

Herbal extracts and their utilization in functional foods: From a study on some herbal food extraction (garlic, turmeric and stevia) and their functional foods it was observed that all herbal extracts (aqueous 25, 50, 75 percent could be added up to 2% without adversely affecting the quality. All the herbs are reported to possess potential biomedical benefits, so production of herbal baked products from these herbs will prove beneficial in the ailing people

Flax seed addition to increase the shelf life of whole wheat bread: A study was carried out to improve the nutritional value and shelf life of white and whole wheat bread by incorporating ungerminated and germinated flaxseed meal at 5,10,15 and 20 per cent levels. The quality and overall acceptability of flaxseed breads was found to be more than control breads. The whole wheat bread was acceptable up to 7 days under ambient and 10 days under refrigeration conditions.

Milling of whole wheat and barley into grits : Four varieties of wheat and two varieties of barley were processed to obtain the edible parts of the grain. Three types of mills (hammer mill, horizontal disc mill and vertical disc mill) were used to mill whole wheat and dehusked barley into grits. The milled products were subjected to particle size analysis. Hammer mill was found to be the best for milling of grains into grits. Durum wheat being hard, resulted in the higher yield of grits compared to the bread wheat.

Variety Pasta

Instant fresh noodles from durum and commercial wheat semolina: Investigation was carried out to find out the suitability of durum and commercial wheat semolina in the preparation of instant fresh noodles. Noodles were prepared using Italian Extruder (NAMAD) by the addition of 2.5% salt and 35 and 33 percent water to durum and commercial wheat semolina respectively. The overall acceptability of durum semolina noodles was found better than commercial semolina noodles in terms of color, flavour and taste.

Soy enriched pasta : Soybean, a miracle bean contains high quality protein with minimum saturated fat and makes an excellence substitute for animal foods. Soy flour (full fat and defatted) was incorporated in wheat semolina at different levels. Soy enriched pasta (macaroni, noodles, vermicelli) using full fat (9%) and defatted flour (12%) were best on the basis of cooking quality, organoleptic and nutritional quality.

High protein pasta : Legumes (chickpea, pigeon pea and mungbean) have better compatibility with wheat to yield nutritionally balanced products. Addition of these legumes in the form of flour added to wheat semolina at different levels and pasta of variable shapes were prepared. 20 per cent supplemented level yielded better quality product with the significant increase in protein content.

Vegetable enriched pasta : Instant nutritious noodles with vegetable powder/juice blends: To provide convenience and nutritious product to consumer, vegetable juices/pulps were added to semolina for preparation of pasta and noodles. Vegetables like beetroot, spinach, carrot and tomato can be successfully added in the form of juices/pulp/powders to increase the appeal, beta-carotene and mineral composition.



Vegetable juice/pulp incorporated pasta

Milling and cooking quality of pre-harvest flooding of paddy : Effect of pre-harvest flooding of paddy on milling and cooking of rice was studied. A significant reduction in grain weight and bulk density of paddy and rice in damaged samples were observed. Pre -harvest flooding adversely affected the milling and cooking quality of rice. The kernels became soft and developed fissures, which contributed to low head recoveries. The flood affected paddy shows lower cooking time and higher gruel solid loss and was rated poorer organoleptically.

Effective utilization of black-tip discolored rice by extended polishing : The problem of black tip discoloration is encountered in India at different times in different regions due to localized heavy rains at flowering and milk stage of the rice crop. This lowers the quality and creates the problem of disposal of rice. Commercially the rice in India is milled to 5-6 % degree of polish. Milling of rice to 10% degree of polish was very effective in decreasing the evidence of black tip discoloration in milled rice. Even 8% degree of polish was quite effective and losses in head rice yield and grain weight were much smaller.

Blending of wheat flour with broken rice flour for baked products : Better cookies were produced by replacing 10% wheat flour with that of rice flour. Cookies were equally acceptable even up to 30% level. Addition of rice flour changed the farinographic characteristic of dough, reduced the yeast requirements and fermentation time. It was found that rice flour at 10% level could be incorporated in bread, 20% in buns and 30% in pizza bases without altering the quality of products.

Incorporation of soybean as a functional ingredient in extruded snack : An effort has been made to incorporate soybean into the extruded snacks to add health benefits. Soybean was subjected to different treatments like boiling water, pressure-cooking and germination. Incorporation of soybean resulted in a decrease in expansion ratio and decrease in the acceptability of the extruded snacks. It has been studied that extrusion cooking of rice and soybean blends is possible at lower moisture content of the feed because of lubrication due to increase in fat content. Extrusion cooking of different combinations of soybean level (0-9%) and feed moisture (12-15%) has been carried out. Various quality parameters of the extrudates were studied. Soybean at a level of 6% and with feed moisture of 13% was found to be the best.

Edible films from Barley and oat β -glucans : Films for potential food uses were prepared from aqueous solutions of β -glucan extracted from hulled barley, hull-less barley, and oats. The oat β -glucan films showed higher tensile strength and water solubility, and lower colour, opacity, and deformation values than those of barley. Films prepared from hull-less barley cv. HLB 233 remained intact upon immersion in water for 24 hr.

Techno-economic development of malting indigenous grains : Application of gibberellic acid has been found to augment notably the enzyme system of the malts of indigenous barley, maize, triticale, wheat, ragi and

T.dicocum (Khapli wheat). Wheat grain extract-milk beverage (50:50) with excellent flavor and shelf life has been developed. The technology for the production of extract from different grains has also been developed. Malt concentrates from wheat, triticale, finger-millet and hull-less barley have been prepared and their characteristics studied. Concentrates from wheat and triticale showed high whip volume and good foam stability.

Noodles from barley flour : Noodles were prepared from hulled barley (VJM 210, PL 172) and hull-less barley (Geetanjali) flours supplemented with bread wheat semolina in the ratios of 0:100, 25:75, 50:50, 75:25 and 100:0. Significantly higher values for firmness of barley noodles than those of the semolina exhibited their integration worthiness during cooking and then handling later on.

Hull less barley for chapati making : The farinographic and amylographic characteristics of varieties Karan 16 and Karan 19 varieties of barley were studied. Functional and chapatti making properties of hull less barley supplemented wheat flour were studied. Replacement of whole wheat flour with up to 25% of barley flour did not affect the chapatti quality adversely. The farinographic and amylographic characteristics of varieties Karan 16 and Karan 19 varieties of barley were studied.

Extrusion Processing

Extruded snacks using waxy rice : Quality extruded snacks should have crispy bite. An attempt was thus made to incorporate waxy rice (samples collected from Assam) to improve the texture of extrudates and compared with basmati rice extrudates. Significant difference in texture was observed. The sensory attributes (appearance, color, texture) of extruded snacks improved by addition of waxy rice (50% level) to durum semolina.

Potato-cereal blends for snacks : Extrusion is world wide used technology for the production of variety products as it is more economical, primarily hygienic and ready to eat with good consumer acceptance. Potato is a wholesome food as it contains all essential dietary components. Wheat semolina, rice and maize grits along with two varieties of potato (white and red) were blended to obtain best processing conditions for snacks. Pre-cooked porridge and instant semolina was prepared using resultant extrudates by coarse and fine grinding

Snacks from potato chickpea blends: The blend of potato-rice and chickpea was extruded at different moisture content (14 -18%), screw speed (400 - 550 rpm) and barrel temperature (130 - 170°C). The final product was having 12.04% protein, 2.79% fibre, 0.86% fat, 1.79% ash.

Processing treatment to reduce aflatoxins in contaminated wheat: Different processing treatments (washing, dry milling, dry heating, wet heating or steaming, sand roasting, microwave heating, extrusion cooking, product preparation (*Chapatti* and extruded snacks) and treatments in combination at varying conditions were given to contaminated wheat. Most effective treatment for the destruction of aflatoxins was extrusion (170°C with 20% moisture content) which reduced 74.55% of aflatoxin content. About 54.32% decrease in aflatoxin content was noticed with microwave heating. Product prepared in combination with dry milling showed promising results in reduction of aflatoxin content.

Fruit and Vegetable Technology

Ready-to-serve canned products : A mechanized process for the production of ready-to-eat mustard saag has been developed in collaboration with Markfed and conditions for long shelf life established for export purpose. In addition, ready-to-serve canned products like lady's finger, tomato juice, baby corn, peach, plum and mushroom have been developed.

Dehydrated products : Conditions of dehydration for processing products like dehydrated *saag*, *methi*, spinach, lady's finger and bitter gourd have been standardized. The products have excellent consumer acceptability. Similarly, the technology was developed for preparation of dehydrated potato cubes.

Juices and concentrates : Ready-to-serve bottled juices with excellent color, flavor, texture and better shelf life have been prepared, viz. mixed vegetable juice (carrot: tomato: beet root), Perlette grape : apple juice, coloured grape juice (variety Punjab Purple) and sugarcane juice. Technology has been developed for preparing juice

from *patharnakh* with higher recovery and excellent consumer taste. The work was conducted for utilization of major fruits viz. kinnow, banana, guava, mango, pineapple, apple, litchi, pear and mandarin oranges. Blending of kinnow, pear and grapes with the other fruits of high palability like mango, guava and pineapple as carrier, ready-to-serve drinks of high organoleptic acceptability could be produced.



Grape juice and beverages Kinnow candy with peel

Preservation of pulps : Guava pulp has been successfully preserved. The flavor and color of the stored product were stable for use in the preparation of ready-to-serve beverages. Technology for the preparation of apricot and peach pulps and concentrates has been standardized to cope with the gluts. The preserved pulps and concentrate are suitable for ready-to-use beverage.

Storage and pre-treatments of potato for chip making : Among the three cultivars of potato tested, i.e. Kufri Chandramukhi, K. Badshah and K. Jyoti, K. Chandramukhi gave very good color quality of fried chips up to 10 weeks under ambient conditions while other varieties were assessed lower in color quality. None of these varieties were found suitable for chips after storage at $5 \pm 2^\circ\text{C}$ and $11 \pm 2^\circ\text{C}$. Dehydration of six potato cultivars was carried out by two methods (i) drying under ceiling fan in shade (ND) and (ii) Mechanical dehydration in cross flow cabinet drier at 90°C for 2 hr (MD). The yield of dehydrated slices was highest (19.70%) in K.Sindhuri, Rehydration ration was highest in K. Lalima with a slightly more value for MD than ND. Oil absorption decreased whereas non-enzymatic browning increased in stored slices.

Physico-chemical and organoleptic properties of kinnow juice : The physico-chemical and organoleptic properties of kinnow juice were affected by the method of extraction, pretreatment, incorporation of additive and storage period. The screw type extractor was found the best among all the extraction methods. Lye treatment of segments improved flavour scores of juice significantly while ethylene treatment and chilling of fruits and before extraction of juice had non-significant effect on organoleptic. Addition of sugar alone and in combination with 0.2% common salt and 0.2% *chatmasala* significantly improved the flavour scores of juice. The bottled kinnow juice had a shelf life of six months under ambient conditions and juice from screw type extractor retained better quality than superfine pulper during storage.

Processing of whole tomatoes : A process has been developed for canning of whole tomatoes under low pH conditions resulting in savings (about 30%) in energy requirements by the tomato canning industry. After a storage period of six months, the canned tomatoes had excellent sensory quality.

Quality of tomato juice and tomato ketchup : Earlier studies in the department showed that canning of tomato juice under low pH conditions resulted in darkened colour and slightly higher consistency. Study was planned to explain the mechanism responsible for the darker colour and increase in consistency of tomato juice. Tomato ketchup prepared with added hydrocolloid i.e. CMC at the levels of 0.3 –0.5% showed increase in yield by 22-25%, improved the colour, consistency and suspension.

Ready to eat canned and frozen saag from chinese mustard : A ready to eat canned as well as frozen mustard green leafy vegetable (saag) has been prepared from raya and Chinese mustard. The saag prepared from Chinese mustard had a smooth texture, good colour and flavour which were as much preferred by the consumers as the saag from raya mustard. Four Brassica varieties i.e. RLM-1359, GSL-1, Palam Dark Green and Palam Light Green were processed into canned curried sarson ka sag. Among varieties, Palam Light green was found to have the best acceptability by a panel of semi-trained judges on a nine point hedonic scale. Sample was also compared with Markfed sample of sag and was rated better in its taste, appearance and texture than Markfed sample.

Low cost technologies for preservation : Steeping preservation of button mushrooms (*Agaricus bisporus*) and baby corn in solutions containing sodium chloride and acetic acid were standardized for further use in processed products. Ready to serve vegetables and pickles were prepared from both fresh and steeped samples of baby

corn and were evaluated organoleptically. Baby corn stored for four months in steeping solution containing variable concentrations of soluble solids (7.0-9.2°B), sodium chloride (6-8%) and acetic acid (0.75-1.0%) could be utilized for preparation of vegetables (dried and curried) and pickles with acceptable organoleptic quality. Indigenous recipes for Mushroom *Biryani*, Mushroom *Pakaura*, *Dosa* were prepared from fresh and steeped mushrooms. These stored products were rated good to very good and had desirable physico-chemical and sensory characteristics at $-18^{\circ} \pm 1^{\circ} \text{C}$ upto 45 days and those at $4^{\circ} \pm 1^{\circ} \text{C}$ up to 15 days.

Watermelon flakes : Edible portion of two watermelon varieties Sugar baby and Shipper was scooped out after cutting the fruit into two halves. Results obtained in this study revealed salt and citric acid treatment for 7 min was essential for preparation of good quality dehydrated watermelon flakes.

Waste utilization : Processing of lemon (galgal) and kinnow peel waste for candy preparation and fruit juice waste of litchi and guava for leather making has been developed.

Effect of harvesting time on properties of juice and non-juice components of kinnow

Kinnow mandarin oranges were harvested in December, January and February to study the effect of harvesting time on the physico-chemical properties of juice, the composition and proportion of peel, pomace and seeds. The juice yield of kinnow decreased from 54 to 48.33% as the harvesting was delayed from December to February. The fruit harvested in January had the best quality characteristics i.e. ascorbic acid and viscosity. Different hydrocolloids were used to improve the quality of juice, squash and beverage and to reduce their browning and bitterness.

Carbonated RTS from peach and grapes: Carbonated beverage from peach and grape fruits was developed with 20% pulp, 13% TSS and 0.3% acidity by using post-mix and pre-mix methods. Carbonated grape juice drink from variety Punjab Purple was prepared with 15, 20, 30, 40 % juice and 12-15° B TSS by post-mix method. Organoleptically, drink containing 20% juice and 13% TSS was scored the highest. It contained maximum CO_2 gas pressure i.e. 30lb/in².

Cloud Stable juices and nectars from litchi and pear : Cloud Stable juices and nectars from litchi and Pear were developed using hydrocolloids. Sodium alginate and combination of CMC+ sodium alginate were selected for addition in litchi juice, pear juice, litchi nectar and pear nectar on the basis of cloud stability (transmittance at 540 nm), nephelometric turbidity units (Ntu), viscosity (cp), visual suspension (%) and sensory properties.

Osmotic dehydration : Blanched and unblanched cauliflower with or without the use of KMS was dipped in 5-25% salt solution for one, two, four, eight hour and over night and dried at 55°C in a cabinet drier. Cauliflower dehydrated by osmotic dehydration (20% salt solution) had good taste, appearance and shelf life than control. The effect of pretreatments i.e. blanching and potassium metabisulphite and two concentration of osmotic agents 50 and 70 ° B on the quality of osmotically dried apple slices was evaluated. Samples treated with potassium metabisulphite (700ppm) for 15 minutes gave extremely good colour, appearance and taste.

Canned curried Dal Makhani : Two black gram cultivars UG-414 and UG-218 were analyzed for their suitability for canned curried Dhal Makhani following best selected recipe. UG- 414 was liked better in its flavour than the UG-218 during storage, though significant difference was not found in the taste, texture and appearance of Dhal Makhani prepared from both the cultivars. Even storage had no significant effect on the sensory quality of dhal of both the varieties.

Standardization for carrot slices : Pre drying conditions like slice thickness, blanching time and temperature were standardized. It was found slice thickness of 4.5mm with blanching time of 4 min. in hot water at 95°C was found to give the best results during drying. The vacuum drying of carrot slices gave better results. So this method can be used for drying carrot slices in less time even under high relative humidity condition to give a better quality product which can fetch a better price in the market.

Dairy Technology

Technology for Indigenous Milk Products

Preservation of milk samples : Potassium dichromate (0.10 - 0.20%) and mercuric chloride (0.05% - 15%) are suitable for preserving time composite milk samples without affecting the accuracy of the fat test up to 5 – day period.

Fortification of milk with iron : Technology of fortification of milk with cheaply available iron salt has shown encouraging results. Buffalo milk containing 5 per cent fat can be fortified with 10 ppm of iron without having any adverse effect

Vegetable impregnated cheese : Coriander/mint leaves and sodium chloride concentration were standardized to yield cheese with improved nutritional value health benefits, sensory attributes and shelf-life.

Fruit flavored curd (dahi) : A study was undertaken to improve the quality characteristics of plain curd (dahi) with the incorporation of mango. The amount of ingredients and forms of mango were tested on the physico-chemical, sensory and storage quality of mango curd.

Technology for Frozen Products, Quality Improvement and Health Benefits

Use of stabilizers in ice-cream : Use of stabilizers like guar gum, gum ghatti, gum acacia, sodium alginate and gelatin has been found to increase the viscosity of ice-cream mixes. Guar gum even in low concentration was found to be particularly effective in increasing the viscosity. Ageing of the mixes prior to making ice-cream had beneficial effects. A good quality ice cream can be prepared by using any one of the blends of plant hydrocolloids (stabilizers) i.e. guar (50%) – isabgul (50%), Isabgul (25%) – acacia (37.5%) – guar (37.5%) and acacia (25%) – guar (25%) –isabgul (25%) – karaya (25%). However, the blends of guar (50%) – isabgul (50%) was found to be the best, when comparing among themselves.

Antioxidants rich ice-cream : Technology was developed for ice-cream incorporating kinnow peel (by product of kinnow juice processing) in different forms at 1-3 percent levels. Good quality ice-cream could be prepared which contained nutritional ingredients such as ascorbic acid, naringin, fiber, natural color, and flavour with health benefiting components having antioxidants, anticancer, antiviral and anti-inflammatory properties. Red grapes variety Punjab purple grapes were incorporated as whole and in crushed form at the levels of 10, 15 and 20 per cent each in the ice cream with the objective of incorporating important phyto-chemical i.e anthocyanins. Based on sensory evaluation, the best levels of grapes for addition in ice cream obtained were: crushed (15 per cent) and whole (15 per cent).

Studies on Frozen Yoghurt : Studies were carried out to improve the quality of frozen Yoghurt. Good quality frozen Yoghurt can be prepared using fat level of 5.0 per cent and any one of the stabilizers: gum acacia (0.5%), gum karaya (0.25%), sodium alginate (0.3%) and skim milk powder (1.0%). Frozen Yoghurt with gum karaya was found to be the best. However, superior quality product can be prepared by using gum karaya (0.25%) in combination with skim milk powder (1.0%).

Profitable Utilization of Dairy By-Products

Bread spread from butter milk : Butter milk concentrate obtained after removal of whey was used for preparation of bread spread. Fresh cream, channa, groundnut oil and common salt were used to improve the quality of the product.

Ghee residue : Ghee residue is an important by-product of dairy industry. It could successfully be utilized in cookie manufacture with some of additives like Glyceryl Mono-Stearate (GMS) or Sodium Stearoyl 2-Lactylate (SSL) for improved spread ratio and acceptability of cookies.

Butter milk : Butter milk is a highly nutritious by-product obtained during the manufacture of creamery butter and goes waste. A study on the effect of water replacement in dough with sweet cream buttermilk revealed that 25 to 100 per cent buttermilk could be satisfactorily incorporated in *chapatties*, 25-50 per cent water could be replaced with buttermilk during bread making and in cookies, buttermilk could be included up to 100% replacement level with water.

Naturally carbonated fermented whey/fruit juice beverage : Development of naturally carbonated fermented whey beverage blended with pineapple and strawberry juice was attempted. It was inoculated with yeast culture *Clavispora lucitaniae* @ 0.5 percent v/v and fermented at 30+5°C for 36 hours aerobically. Four types of beverages were prepared: paneer whey beverage blended with pineapple juice, paneer whey beverage blended with strawberry juice, cheese whey beverage blended with pineapple juice and cheese whey beverage blended with strawberry.

Milk Beverages and Variety Products

Milk based beverage using khaskhas, badam and magaz : Milk has long been recognized as the most wholesome and complete single food available in nature. It is healthy, nutritious, and rich in vitamins, minerals and trace elements and furthermore, it is the ideal basis for innovative and tasty soft drinks. Thus, the investigation was undertaken to develop milk based beverage using khaskhas, badam and magaz.

Development of low calorie functional milk : Low calorie functional milk drinks were developed using inulin and sucralose as fat and sugar substitutes, respectively. Cardamom and mango pulp were included as flavouring ingredients. The technology of pasteurized and sterilized cardamom flavoured milk drinks (CFD) and mango flavoured drinks (MFDs) was developed.

Cheese processing technology : Lactic acid has been found to successfully replace the traditionally used acidulant, citric acid for coagulation of milk in the process of cheese making. Aluminium foil was found to be better packaging material for paneer than polypropylene bags. The process of manufacture of processed cheese from mozzarella pre-cheese was standardized and shelf life of resultant cheese assessed. The cheese flavour was indianized by incorporation of different flavoring agents (cloves, black pepper, cumin, red chili, green chili, fennel, coriander and mint leaves). Investigation was carried out on development of mozzarella cheese sticks and its utilization as snack foods. Mozzarella cheese was prepared from buffalo milk and used for preparation of mozzarella cheese stick snacks using wheat flour and gram flour, alone as well as combination (1:1), with and without the addition of egg albumin to batter and bread crumbs coating on surface.

Soya Dairy Products

Development of low fat soy-paneer : Studies on the development of paneer-analog utilizing soybeans or soy flour indicated that tofu (soybean curd) could very well replace milk paneer as it resembled paneer in color, body and texture. Low-fat paneer could successfully be prepared by replacing part of milk with defatted soy slurry.

Soy milk quality improvement and utilization : Soymilk-dairy milk (60:40) blended beverage was found to be most acceptable. Beany flavor of soymilk was masked using fruit pulps (Mango, peach and guava). Quality sterilized soymilk and soymilk-dairy milk blended beverages can be prepared by blending with mango and peach pulp up to 5% and guava pulp up to 10%.

Soy yoghurt : Good quality yoghurt could be prepared by blending soy milk in dairy milk up to 50% along with 5% sugar and 1% SMP/WPC. Whey protein concentrates (WPC) could successfully replace skim milk powder (SMP) to supplement total solids and fermentable sugars to manufacture quality soy-yoghurt. Shelf life of resultant product was ten days at refrigeration temperature.

Meat, Fish and Poultry Technology

Use of culled hens : The meat from culled hens was used in the preparation of comminuted meat products like patties, sausages and pickle while the loaves along with residual meat were used for soup preparation. The recipes for various products from culled hens and broiler breeder males and by products have been standardized.

Extended meat products : Extended culled poultry meat with soy flour to produce good quality of sausage at 10 per cent replacement level was found to be quite acceptable. These sausages packed in 400 gauge polyethylene bags had a shelf life of 15 days at refrigeration temperature. The textured soy products were used for the preparation of loaves. Studies were conducted for the preparation of chicken patties using black gram flour (BGF) and corn flour (CF) in different ratios (3:0, 2:1, 1:2 and 0:3) as extenders. The organoleptic scores were found highest in patties containing BGF and CF in 2:1 ratio at 6% level of incorporation.

Buffalo meat : Process has been developed for the utilization of buffalo calf meat for the production of processed products like patties, sausages and meat balls. Cuttability characteristics of young buffalo calves reared up to 4 months of age were evaluated. Effects of ages on carcass characteristics of male buffalo calves were also determined.

Low fat meat product : Technology was standardized using hydrocolloids like sodium alginate, CMC, guar gum, gum acacia for preparing low fat meat products like patties, loaves and sausages.

Canned fish : Process for the canning of fresh water fish like Rohu, Katla and Mrigal in brine, in curry and as fried were developed.

Egg pickle : Process has been developed for the production of egg pickle with good consumer acceptability and shelf life. Efforts were made to preserve hard cooked eggs both at room temperature and at refrigeration temperature ($5 \pm 0^\circ\text{C}$) after treating them with wax and paraffin oil.

High fiber comminuted chicken meat products : Comminuted chicken meat products, patties, rolls and kebabs were prepared by adding wheat bran, corn bran, wheat germ and corn wheat and corn bran. The products were acceptable up to two months during frozen storage at $-18 \pm 2^\circ\text{C}$.

Fish based products : Successful technologies for local catla fish based products like patties, loaves, cutlets, momos, samosas were developed incorporating chicken meat, soya proteins, gluten, soya tofu, SMP for improving functional and nutritional characteristics. Commercial adoption of these can help revolutionize fresh water aquaculture in Punjab.

Storage of frozen catla fish mince : Catla fish mince with and without washing and cryoprotectants for the production of processed products. Higher organoleptic scores for appearance, colour, flavour and overall acceptability were obtained by sodium alginate treated washed mince. The fish could be stored up to two months at -20°C without significant decrease in organoleptic quality of products like patties and fingers prepared from it. The washed mince had better sensory acceptability than unwashed minced at the end of storage period of two months.

Tandoori chicken/tikka marinade/ barbecue sauce : Tandoori chicken/tikka marinade (TCM) was prepared and preserved in bottles and in retort pouches at ambient and refrigeration temperatures for three months. The product was found convenient to use both by the domestic and institutional consumers. Barbecue sauce was developed incorporating traditional ingredients to suit Indian palate. The Barbecue sauce after standardization of recipe and process was preserved in glass bottles and retortable pouches. The product was found highly acceptable at the end of three months storage.

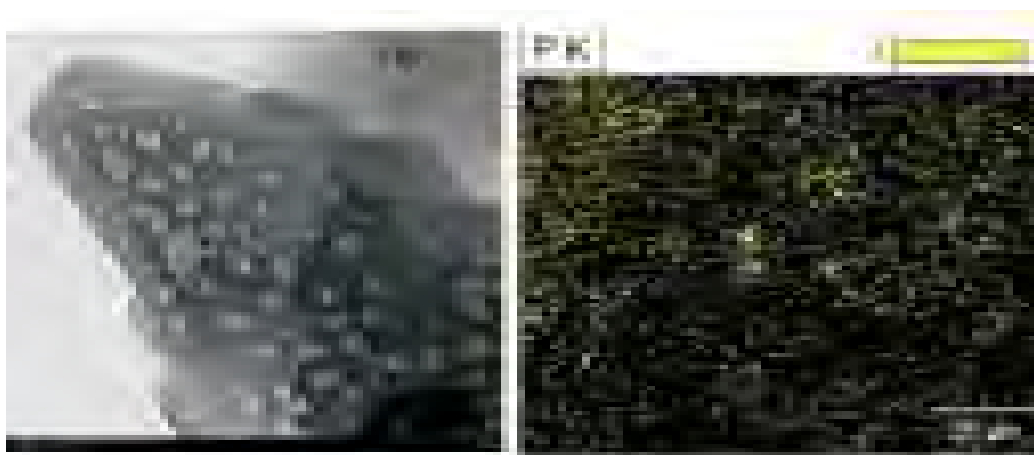
Antioxidant rich chicken patties : A study was conducted to improve the nutritional quality and shelf life of chicken patties by incorporating functional ingredients. The best levels of ginger paste (5%), aloe vera gel (3%) and tomato paste (4%) were incorporated in the final product. Vacuum packed chicken meat patties had significantly ($p < 0.05$) higher moisture, lower free fatty acid content, lower peroxide value and markedly higher scores for overall acceptability than LDPE packed at the end of two months of frozen storage period ($-20 \pm 2^\circ\text{C}$).

Nanotechnology

Electron Microscopy and Nanoscience Laboratory (EMN Lab) was established in 2005 with grant from ICAR. It is foremost state-of-art facility to boost nanoscience and nanotechnology research in agriculture. It hosts ultra modern models of Scanning Electron Microscope (SEM) with Energy Dispersive X-ray Spectroscopy (EDS), Transmission EM, Atomic Force Microscope (AFM), five variants of optical microscopes and a variety of equipments required for processing and preparation of samples for the above microscopies under one roof. The laboratory has been established for conduction of resident instruction, research and training and development of projects in the field of agricultural nanotechnology, to generate / synthesize nanomaterials for agricultural use and to share facilities and human resources with national and international organizations to complement research and education in agricultural nanotechnology.

The EMN Lab is providing high resolution imaging facilities to cater to the advance research goals of universities, institutions, and industries across the nation and abroad. The Laboratory has facilitated frontline research work on varietal distinctions of crops species, sex-signaling in insects, molecular prefixes in food processing and high resolution imaging of biological and material samples. It has provided pristine images and elemental distribution of nanowire, textile fibers, dental surfaces, nematodes, insects and their body parts, spermatozoa of rats and mammalian RBCs, critical components of rice (trichomes, seed, leaf, straw, husk), maize and black gram, bacteria, multicellular fungi and budding yeast as well as material samples (carbon nanotubes, nanowires, rice husk silica, and clay minerals).

The major research accomplishments include development of nanofabricated-P adsorbed on nanokaolinite as nutrient source to plants. This nanokalonitie adsorbed P would serve for better uptake of P by the plants thereby decreasing eutrophication. A novel methodology for separation of P-rich minerals free from heavy metal contaminants from very poor source of P i.e. Udaipur Rock Phosphate has also been developed. This P-beneficiation has led to P-rich mineral speiation with P content ranging from 10 to 24% (% atom). The Lab has also developed protocol for generation of nanomontmorillinte adsorbed Zinc for better uptake of zinc in the plant rhizosphere. The Lab has also characterized interfaces of clay-humus complex by electron microscopy and IR spectroscopy techniques.



TEM studies along with X-Ray mapping showing adsorption of phosphorous on the positively charged face of Kaolinite

The EMN Lab is also involved in conducting postgraduate courses on Electron Microscopy and Nanobiotechnology and two undergraduate courses on Nanobiotechnology. A total of 326 students took the benefit of these cutting edge courses. The Lab faculty has also imparted 24 one day/half-a-day trainings to PG and UG students of PAU and other institutes as well as delivered 14 one day/half-a-day Advance Faculty Training Programmes for faculty of sister departments of PAU, GADVASU and CIPHET (ICAR). The Lab faculty has also delivered fourteen invited lectures in national conferences and universities. EMN Lab has organized four national level advance faculty training programs of 1 to 2 weeks duration for agriculture (2008), engineering (2009), nutrient management (2010), and veterinary sciences (2011), which are highly lauded.

AGRICULTURAL ENGINEERING

Farm Machinery and Power Engineering

The Department of Farm Machinery and Power Engineering (previously Department of Farm Power and Machinery) was established in 1974. The department has a mandate of teaching undergraduate and postgraduate students in the area of Farm Machinery and Power Engineering, research and development of farm technologies in liaison with manufacturers for mechanizing farm operations and popularization of improved farm technologies amongst farmers through extension activities. The department was recognized as Centre for Advanced Studies in Farm Power and Machinery Engineering by the ICAR in year 1997. The Department has been engaged in design, development, evaluation and popularization of farm implements and machines to meet the challenges of farm mechanization. The last three decades witnessed the development and adoption of many farm tools and equipment for different farm operations, crops and crop rotations. A brief account of these technologies which have been commercially exploited and adopted by the farmers is given below:

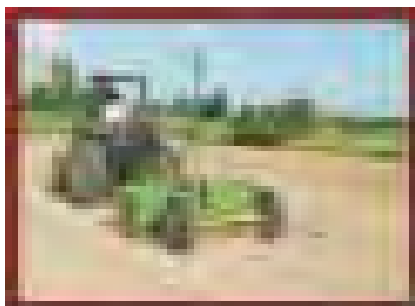
Seedbed Preparation and Sowing Equipment

Tractor-drawn Pulverizing Roller Attachment

Pulverizing roller is an attachment to the commercially available tine cultivators. It is suitable for puddling as well as dry seedbed preparation. The roller consists of 6 pulverizing members made of MS Steel flats. These members pass through the slots in the star wheels, which are fixed on the central axle at a distance of 37 cm each. The quality of puddle as well as dry seedbed preparation is much better and less number of operations are required. The performance of the equipment at higher speed (4-5 km/h) is better because of better churning action. The use of this machine can save 15-20 percent of irrigation water because of better quality of puddle. The machine can cover 2.5-3.0 ha/day both in dry land as well as wet land conditions.

Laser Land Leveler

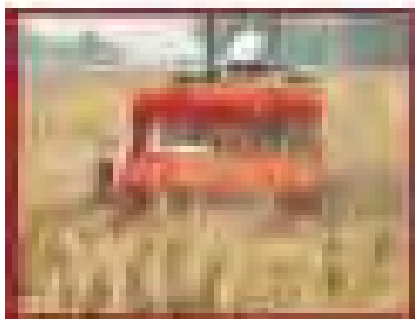
Declining water table and degrading soil health are the major concerns for the present Punjab agriculture. The enhancement of water use efficiency and farm productivity at field level is one of the best options to redress



Laser land leveler



Strip till drill



Happy Seeder



Multi-crop planter

the problem of water scarcity. Laser land levelling is one such technology which helped in using water efficiently, reduced irrigation time and enhanced productivity per unit input not only of water but also of other farm inputs. Laser leveler is trailed type equipment used for achieving precise levelling with desired grade. This two meter wide automatic leveling operation can be successfully carried with 50 hp or above tractor. It saves water to the tune of 25-30%, enhances efficacy of chemicals and fertilizers and improves productivity.

No Till Drill

The equipment is used for no-tillage system, requiring no previous seed-bed preparation after harvesting paddy and sowing of wheat crop effectively in one operation. This machine has inverted T-type furrow openers in place of shovel type furrow openers. The performance of the No-Till drill was found to be most effective when operated in the fields where the loose straw after the combine harvesting of paddy has been dealt with. It can be operated by a 35 hp or above tractor. Its effective output is about 0.35 to 0.4 ha/h. Its use saves 60-70 % diesel and time and cost of operation in comparison to traditional method.

Tractor-drawn-Strip-Till Drill

This machine is used for minimum tillage. It can sow wheat after paddy without any prior seedbed preparation. The machine consists of a standard seed drill with a rotary attachment mounted in the front of furrow openers. The rotary unit has C-type blades, which prepare a strip of 75 mm wide in the front of every furrow opener and hence only 40 percent of area is tilled. Tilling and sowing is done simultaneously. Machine capacity is about 0.25-0.40 ha/h. Diesel saving with the use of this machine is 50-60 percent as compared to conventional method where as the time saving is 65-75 %.

Happy Seeder

Happy seeder, combined the stubble mulching and seed drilling functions. The strip of stubble in front of the sowing tynes is cut, picked up and placed on the side of the drilled seed as mulch. The sowing tynes therefore engages bare soil. This pto driven machine can be operated with 45 hp tractor and covers 0.2-0.3 ha/h. Weed matter was nearly 50% lesser on happy seeder trial compared to conventionally sown plots. Happy seeder sows wheat directly in paddy residue in combine harvested field hence, prevents residue burning thus reduces air pollution. Mulched crops residue improved the soil hearth and added organic matter to the soil. This machine can also be used for sowing subsequent moong crop in wheat residue.

Tractor Operated Oil Seed Drill

Use of separate drilling machines for wheat and oil seed crops amounts to the increase in production cost per unit area. So the Department of Farm Machinery and Power Engineering has developed a tractor operated seed cum fertilizer drill with modified dual seed metering mechanism for sowing oil seed (small size) and wheat. The modified metering mechanism has two separate housing one each for each crop seed. Fluted roller for mustard was modified, while the fluted roller for wheat was kept as such.

Inclined Plate Multi Crop Planter

It is suitable for sowing bold grains like maize, soybean, groundnut, cotton etc. In this machine, planting attachment has been added to commercially available seed-cum-fertilizer drills. It can plant 6-rows of groundnut at a spacing of 30 cm in addition to number of other crops like maize, cotton, soybean, sunflower etc. Seed-metering mechanism in planting attachment is of inclined plate type with notched cells. Row to row spacing and plant to plant spacing is adjustable. It can cover 2.5-3.0 ha/day. It saves about 60% labour and time in comparison to manual planting.

Tractor-drawn Ridge Planter for Winter Maize

It is suitable for planting maize on ridges. The machine consists of a 3-bottom ridger; a hopper with 2 units of inclined plate metering mechanism, driving wheel and furrow openers. The performance of the machine for sowing maize was found to be highly satisfactory. It can sow 2 rows and has a capacity of 0.2-0.35 ha/h at a

forward speed of 2.0-2.5 km/h. Uniform plant to plant spacing can be achieved under good seedbed conditions. Machine saves about 80 percent labour as compared to the traditional method.

Tractor Operated Sugarcane Cutter Planter

It is used for sowing of sugarcane. It cuts the seed sets of desired size in addition to doing other operations of opening the furrows placing the sets in the furrows, application of fertilizer, treatment of sets and covering of sets simultaneously. Machine is operated by a 35-hp tractor and has two rows. In this machine, two persons sitting on the machine feed the complete sugarcane one by one into the set cutting unit by picking from the seed hopper. The rotating blades cut the sets automatically before dropping the furrows. Machine can cover 1.0-1.2 ha/day with the help of 5 persons. Thus, machine saves about 75 percent of labour in comparison to conventional method.

Trench Digger for Paired Row Sugarcane Planting

A two row trench digger is designed and developed by the department for paired row sugarcane planting. The bottom width of trench was 30 cm and top width of bed was 90 cm. Depth of trench was 25 to 30 cm. The capacity of the machine is 0.3 to 0.4 ha/h. About 8-10 percent water saving was observed in trench planting of sugarcane crop. There is a possibility of inter-row cropping of wheat, gram, gobi, sarson, mentha on the beds.



Trench digger for paired row planting



Bed planter



Four wheel riding rice transplanter

Semi Automatic Potato Planters

These are two types i.e. belt & cup type and revolving magazine type potato planters. In the first type the seed tubers were placed in a hopper with its two sides slanting. The planter utilizes two endless canvas belts with cups riveted onto them. Each cup picks up a tuber. Two persons, one for each row, sit on the planter and observe the seed metering belts to ensure that each cup contains a tuber, if not; then correction is made by removing/placing one of the tuber(s). Field capacity of the machine is 0.12-0.15 ha/h. The second type, of potato planter uses a revolving magazine having 10-12 compartments. Depending upon the number of rows (2/4) of the planter, one person is employed for each row to place (feed) the tubers into the seed compartments of each revolving magazine. A stationary plate is provided under the magazine with a slot directly over the delivery chute to drop the tuber. The output capacity of a two-row planter with revolving magazine varies from 0.12-0.15 ha/h.

Revolving Magazine Potato Planter

The second type of potato planter uses a revolving magazine having 10-12 compartments. Depending upon the number of rows (2/4) of the planter, one person is employed for each row to place (feed) the tubers into the seed compartments of each revolving magazine. A stationary plate is provided under the magazine with a slot directly over the delivery chute to drop the tuber. The output capacity of a two-row planter with revolving magazine varies from 0.12-0.15 ha/h.

Automatic Potato Planter

Automatic potato planter is used for planting potatoes without the help of manual labour. It consists of a hopper, two picker wheels for picking tubers, seed tube, furrow openers, three bottom ridgers, a fertilizer metering mechanism and a frame. At the bottom of the hopper, there are agitators to improve the delivery of potato tubers

to feeder. The metering mechanism is picker wheel type. The field capacity of the machine is 0.37 ha/h. Automatic potato planter saves about 70 % of labour in comparison to semi-automatic potato planter. The performance of the machine is highly satisfactory when uniform size of the potato tubers is used.

Bed Planter

This machine makes beds and sow crop simultaneously on the beds. The machine is operated with a 45 hp tractor. This machine makes two beds each of 67.5 cm base width, 35 cm of top width and slant height of 20 cm. Machine also has a bed shaper after seeding to give proper shape to beds. The well-pulverised soil and proper moisture content are required for making of proper shape of the beds. The machine can cover 0.3-0.4 ha/h and saves water to the tune of 15 – 20% for wheat crop. A single row one meter bed width bed planter was also developed for planting onions, garlic and other vegetables.

Mat Type Nursery Sowing Seeder

The mat type nursery sowing seeder is used for uniformly spreading of pre-germinated paddy seeds over the soil filled frames during sowing of mat types seedlings required for mechanical transplanting of paddy. Desired quantity of seed can be spread uniformly for sowing of seedlings. It saves about 80 per cent labour in comparison to manual spreading of seed.

Self-propelled Single Wheel Riding Type Paddy Transplanter

It is suitable for transplanting paddy seedlings in puddled soil. The machine consists of a 3.9 hp light weight diesel engine, power transmission system, main frame and mat type rice nursery tray, float and transplanting unit. It has a lugged wheel and the weight of the machine rests on the lugged wheel and float at the time of transplanting. Machine uses mat type seedlings and it can transplant 1.2-1.6 ha/day with the help of 4 persons. Hill population of 33 hills per square meter can be achieved with 2-4 seedlings per hill. It saves about 80% labour as compared to manual transplanting.

Self-propelled Walk Behind Type Paddy Transplanter

It is a 4 row walk behind type machine operated by a 4.3 hp petrol engine. It has only two lugged wheels and the weight of the machine rests on the lugged wheel and float at the time of transplanting. The same lugged wheels were used for transportation. Row to row spacing is 30.0 cm and four settings are provided for plant to plant spacing i.e. 12, 14, 18 and 21 cm. There is a provision for adjusting the number of hills transplanted per square meter and depth of transplanting. Machine uses mat type seedlings and it can transplant 0.8-1.2 ha/day with the help of three persons. It saves about 78% labour as compared to manual transplanting.

Self-propelled Four Wheel Riding Type Paddy Transplanter

Self propelled four wheel type paddy transplanter is a 6 row riding type machine operated by a 16.75 hp petrol engine. It has four lugged wheels and the weight of the machine rests on the lugged wheels. The same lugged wheels are used for transportation. The machine has five forward speeds. Row to row spacing is 30.0 cm and five settings are provided for plant to plant spacing i.e. 12, 14, 16, 18 and 21 cm. Five settings are provided for adjusting the number of hills transplanted per square meter. Transplanting depth is also adjustable. Machine uses mat type seedlings and it can transplant 4.0-4.8 ha/day with the help of five persons. It saves about 87% labour as compared to manual transplanting.

Vegetable Transplanter

A vegetable transplanter has been developed for transplanting seedlings of brinjal, cauliflower, cabbage, tomato and other crops like winter maize, african sarson etc. The machine consist of a frame, two lugged ground wheels, seedling tray, seat for the operator, furrow opener, compaction wheels, finger guide tunnel, picker wheel type metering mechanism, a water tank and a bed forming attachment. Picking forks has a spring mounted rubber flappers which opens before passing through the tunnel and close during its passage. Again the flappers open at the bottom end of the tunnel to release the seedlings in a furrow. The wheel compact the soil around the seedlings.

The plant spacing in the machine is adjustable. Two persons one for each row sitting on the machine is required to place the seedlings in the flappers. The machine can transplant seedlings both on the beds and on flat surface. Machine can cover about 0.7-0.8 ha/day. Plant missing varies from 3-7 per cent. There is saving of labour up to 75-80 percent in comparison to manual transplanting.

Tractor Operated Post Hole Digger

This equipment is used for digging pits of size ranging from 15 to 75 cm diameter and up to 90 cm depth. This machine is operated by the tractor pto through gear box and is mounted on the 3-point linkage of the tractor. The field capacity of this machine depends on the type of soil and its moisture content. Under average conditions, it is capable of digging 60-70 pits/h of 90 cm depth.

Manually Operated Seed Drill

Manually operated seed drill is used for seeding wheat and oilseed crops like rapeseed and mustard. The machine consists of seed hopper and fluted seed metering device. The power to metering mechanism is provided by chain and sprocket through a ground wheel. Shovel type furrow opener is used for opening the furrows. Machine is operated by one person. Machine is widely used for inter-row sowing of rape seed and mustard in wheat crop or moong in sugarcane crop. It can plant 0.3 to 0.4 ha/day.

Manually Operated Garlic Planter/Multicrop Planter

It is useful for sowing garlic and other bold seeds. In this machine, the planting mechanism has been mounted over the existing wheel hand hoe, which is used for inter-culture purposes and is already commercialized. The planting mechanism consists of a vertical plate with spoons. The capacity of the hopper is about 3.0 kg and two persons operate the machine. Plant spacing can be varied by varying the number of spoons on the periphery of vertical plate. Planting spoons are also available for sowing different crops like peas, sunflower, cotton, bhindi, maize, and soybean. It can plant 0.3 to 0.4 ha/day. Missing is only 4-5 percent. Machine is getting popularity because of very simple design.

Inter Culture and Spraying Equipment

Rotary Power Weeder

It is a self-propelled engine operated power weeder for inter culture operation in horticulture and wider row crops. The depth of operation ranged from 4-7 cm. The machine can be operated at an average forward speed of 1.5 to 2.0 km/h having average width of coverage 62.2 cm (in two pass). The weeding efficiency of the machine varies from 80-94 % depending upon the type of crop. The field capacity ranged from 0.6 to 1.0 ha/day. The performance of the machine for weeding is found satisfactory on cotton, sugarcane, sunflower and gram.

Tractor operated Rotary Weeder

This machine is suitable for weeding in wider row crops like cotton, sugarcane etc. The machine consists of three rotary weeding blade assemblies. Power to these assemblies is provided from tractor pto transmitted to main square shaft through gearbox mounted on main frame with the help of set of sprockets and chain. The machine has provision for adjustment of row to row spacing. Field capacity of the machine is 0.3-0.4 ha/h. Weeding efficiency varies from 75-85 %.



Tractor operated rotary weeder

Manually Operated PAU Wheel Hand Hoe

It is suitable for inter culture in row crops except paddy. For wider row crops, "Trifali" with 3 blades can also be used. It can cover 0.3-0.4 ha/day and one person can easily operate this equipment. The work rate of this equipment is about 4-5 times faster as compared to "Khurpa" without any additional load on the operator. Weed control with wheel hand hoe is only in the rows.

Tractor Operated Sprayer

It is suitable for spraying on cotton crop or any other wider row crops. It consists of a centrifugal pump, a tank, pressure regulator valve and a boom with nozzles and spray gun fitted on a frame. The sprayer is mounted on the 3-point linkage of the tractor and drive is given through from tractor pto through a set of gears. Boom height can be adjusted from 10 to 225 cm from ground to suit different crop height. It can cover up to 1200 cm width and has a capacity of about 2.0 ha/h at a field speed of 3.0 km/h.

Self-propelled High Clearance Sprayer

It is most suitable for spraying on tall crop like cotton or wider row crops. The machine has a chassis with 120 cm ground clearance, four wheels, and 20 hp diesel engine, gearbox, water tank, seats for the operator, spray pump and boom with 18 nozzles. The boom height can be adjusted from 31.5 to 168.5 cm to suit different crops and can be folded during transport. The field speed is up to 5 km/h and the road speed is up to 25 km/h. The width of coverage is 1350 cm and it has a capacity of about 2.0 ha/h at a field speed of 3.0-4.0 km/h. Mechanical damage caused by the movement of high clearance sprayer in cotton crop is less in comparison to tractor operated sprayer.

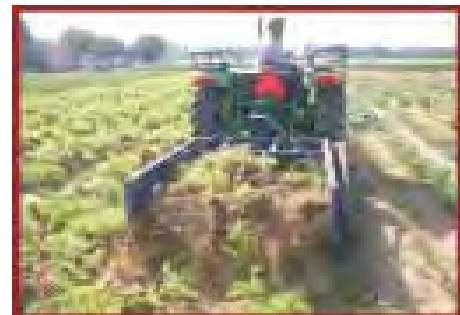
Harvesting and Threshing Equipment

Tractor Front Mounted Vertical Conveyor Reaper Windrower

It is suitable for harvesting and windrowing of wheat and paddy crops. The machine is mounted in front of the tractor and the power to the machine is provided through tractor PTO with the help of intermediate shaft running beneath the body of the tractor and a coupling shaft. Height of the machine above ground is controlled by tractor hydraulic with the help of pulleys and steel ropes. After the crop is cut by the cutter bar, it is held in a vertical position and delivered to one side of the machine by lugged belt conveyors and fall on the ground in the form of a windrow perpendicular to the direction of movement of machine. The machine is operated at a speed of 2.5-3.5 km/h and has a field capacity of about 0.4 ha/h. The use of this machine for harvesting can save about 60-70% labour and about 40-50% cost in comparison to manual harvesting.

Vegetable Digger

This machine is used for digging various root crops like carrot, potato, garlic and onion. It consists of a digger blade made from carbon wear resistant steel. An elevator chain conveyor has been attached behind the blade. Two oval agitators are provided in the conveying system for separation of soil particles from the crop. The power to the elevator conveyor has been provided through a gear box. Two coulter discs are provided in front of the blade at the outer ends which help in easy slicing and lifting of soil by the blade. A roller behind the conveyor belt is provided for easy collection of dug material as it presses the soil before fall. The capacity of the machine varies from 0.21-0.28 ha/h with harvesting efficiency ranging between 96-99 %. Labour saving is about 60-70 %.



Vegetable Digger

Groundnut Digger Elevator

The machine is suitable for harvesting groundnut crop. It digs the groundnut vines below the pod zone and simultaneously elevates them by an elevator-picker reel (conveyor) for dropping on the ground. The soil attached to the vines is shaken off in the process and a window is formed with the help of deflector rods. The vines are dropped in such a manner that the pods get exposed to the sun for speedy drying. The field capacity of the machine varies from 0.3 to 0.4 ha/h at tractor forward speed of about 2.5 km/h with the help of three persons. Digging efficiency is around 97-98 %. Percent detachment of pods is about 3-4 %. Machine saves up to 80-85%

labour and 35-40% cost in comparison to tractor operated digger blade.

Haramba (High Capacity) Thresher

Haramba thresher is suitable for threshing wheat crop and is highly popular. Threshing material pass through the concave. Light materials like chopped straw (Bhusa) is blown away with aspirator blower while the heavier materials like grains, nodes etc. fall on a set of reciprocating sieves. The sieves clean the grain and there is an optional attachment of an auger to elevate the grains and conveys directly on to a trolley. Feeding of crop is manual by standing on a platform provided with the thresher. Generally 3-4 persons are required for continuously feeding of the crop. Capacity of the thresher varies from 15-20 q/h. The labour required for threshing with haramba thresher including the transportation of crop varies from 30 to 35 man-h/ha.

Axial Flow Paddy Thresher

The paddy thresher had axial flow beater type threshing cylinder. The paddy thresher consists of feeding hopper, threshing cylinder, concave, cylinder casing, two sieves and screen for cleaning and blowers/aspirators. The crop is fed into the hopper and it is received by the threshing cylinder tangentially and then moves along the cylinder axially. For cleaning purpose, the thresher has two aspirators, one blower and one thrower. Threshing efficiency varies from 97-99 %, cleaning efficiency varies from 90-97 % and cylinder loss varies from 0.7 to 3.6 %. It saves about 70% of labour as compared to conventional method of manual threshing by beating.

Maize Dehusker cum Sheller

This machine comprises of an axial threshing cylinder with a suitable concave and a thrower mechanism to eject empty stalk and husk. Grains fall on the cleaning sieves for cleaning. The machine can be operated by 25 to 35 hp tractor or 10 to 15 kW motor. The thresher can thresh the dehusked maize cobs having moisture content in the range of 12-24 % successfully. The output capacity of the machine varies from 1200 -2400 kg/h. The threshing and cleaning efficiency of the thresher is in the range of 96-98 % and 94-98 % respectively. Broken grains vary from 1-3%.

Groundnut Thresher

The machine can detach the groundnut pods from the vines. The capacity of the thresher is about 200 kg/h at moisture content of 35% (pods). The cleaning efficiency was found to be 94.2-97.0% whereas the threshing efficiency was of the order of 99%. Broken grains were observed to be 0.2-0.5%. There is a saving of about 31% in cost of operation and about 83% in labour requirement per hectare as compared to traditional methods of threshing.

Sunflower Thresher

Machine is suitable for threshing sunflower crop and has a capacity of 600-900 kg/h of clean grain. Threshing efficiency of the machine is 100 % where as cleaning efficiency is about 90%. Grain losses vary from 0.65 to 2.94 % depending upon crop moisture content. Machine requires 4-5 persons for crop feeding. It saves about 70% labour in comparison to traditional threshing.

Multi Crop Thresher

Commercially available spike tooth type thresher has been used for threshing moong and mash after incorporating few modifications. The threshing cylinder has thirty six spikes placed six in each row. For threshing pulses, six spikes were retained on cylinder in six rows i.e. 1 in each row. The arrangement of spikes on cylinder periphery was axial. Threshing efficiency of the thresher is around 99% and cleaning efficiency is around 98-99%. The output capacity is around 250 kg/h.

Vegetable Seed Extraction Machine

This machine is developed for extracting seeds from different vegetables and fruits like tomato, brinjal, chilli, watermelon, summer squash, cucumber, tinda etc. It consists of frame, feeding chute, a primary chopping chamber,

a crushing chamber, seed collecting chamber, rotor, concave screen, a seed out let, a waste (pulp) outlet, water pump, sprinkler and power transmission system. The fruits or vegetables are cut into small pieces in the primary chamber. Thereafter, these are further crushed by means of axially arranged blades attached to a rotor shaft. The shaft rotates at a speed of 250-300 rpm. Different concave screens for separating different seed sizes are used. Sufficient water should be available at the site of the machine. Three persons are required to operate the machine. The machine can extract seeds at the rate of 5.49, 3.78, 9.42, 4.68, 3.60, 6.60 and 1.42 kg/h respectively of brinjal, tomato, chilli, summer squash, watermelon, squash melon and cucumber. Maximum seed loss of 5.0-5.8 % is observed.

Fodder Harvesting Machinery

Tractor-operated Cutter Bar Type Forage Harvester and Chaffer cum Loader

The system consists of two separate units. First one is a mower and the second one is a chaff cutter cum loader. The mower has a working width of 196 cm and so designed that it can be folded easily during transportation. The chaffer cum loader has two powered feed roller and one compressing roller. It has two chaffing blades for chaffing of fodder and six thrower attachments are mounted on the periphery of the cutter. A reversing mechanism has also been provided for safety. The fodder is cut with mower and is collected in the field. The chaffer cum loader, chaff the fodder at site and the throwers mounted on the periphery of the cutter throws the fodder directly into the trailer. The field capacity of the side mower varies from 0.20-0.25 ha/h and fuel consumption from 3.5-4.0 l/h when operated at a speed of 1.5-2.0 km/h. The throughput capacity of the chaffer cum loader varies from 12.0-18.0 t/h and fuel consumption from 4.0-4.5 l/h respectively. Three persons are required for feeding the crop to the chaffer. The chaffer cut the fodder pieces of uniform size of 18-20 mm. There is a saving of about 50 percent in cost of operation and 65 percent in labour cost.

Manually Operated Long Handle Scythe

It is suitable for harvesting barseem fodder. It has a long handle made of hollow pipe and a curved blade. One person in standing posture holds the handle from two points to operate the scythe. In one stroke a person cuts an area of about 1.2 m wide and 0.6 m long. In 2nd stroke, cut crop is swept with blade itself to make a sort of windrow. It has a higher work output in comparison to sickle as it has a better working posture. It saves about 50 % labour.

Residue Management Machinery

Paddy Straw Chopper

This machine chops the paddy straw left in the field after combine harvesting into small pieces and spreads the chopped straw evenly in the field. This straw then can be incorporated into the soil and subsequent drilling of wheat can be done. This is an environment friendly technology as farmers do not need to burn the paddy straw left in the field and also improves the soil health. Paddy straw chopper consists of a rotary shaft mounted with blades named as flails for harvesting and chopping the paddy straw. Two counter rows having serrated blades are mounted on the concave of front portion of straw bruising which further assists in chopping the straw. The rotary shaft has two rows of flails. Each row consist of 20 number of flails. The shape of the flail is inverted gamma type. One counter row each having 21 serrated knives is fixed on the inside of the concave. Machine is operated by a 45-50 hp tractor. Field capacity of the machine is 0.3 ha/h and approx. 70 % straw is chopped in the size less than 10 cm.

Straw Baler

The straw baler is used for collecting and baling straw in the combine-harvested field. Before baling, first stubble shaver is operated to harvest the stubbles from base level. It can form bales of varying length from 40 to 110 cm. The height and width of bales are generally fixed at 46 cm. The weight of bales varies from 15 to 45 kg depending on moisture content of straw and length of bales. The capacity of the baler varied from 0.34-0.38

ha/h.

Straw Combine

Straw combine is used to recover wheat straw after combine operation and is operated by a 35-40 hp tractor. Straw collected by straw combine is chopped into small size and collected in the trolley having a net to remove the dust. Also some grains are collected along with straw. The capacity of machine on an average is 0.5 ha/h and straw recovery is about 55-60%. Machine is highly popular.

Ergonomics and Safety

Slow Moving Vehicles Emblem

Slow moving vehicle emblem (SMVE) was made sticker base rather than plastic base, which helps in simple fabrication and pasting on tractor trailer to avoid accidents during night.

Safety Cage for Tubewells

It is a ring shaped cage having a window type entry and is used for covering the wells and tubewells at farms and in villages to avoid accidents and saving human and animal from falling in tubewell. The height of the ring is 75 cm and diameter is 210 cm.

Poisonous Gas Aspirator for Tubewells

It is a simple aspirator and is operated by 35 hp or above tractor. Power to the aspirator is provided by tractor PTO and size of aspirator fan is 50 cm. The aspirator is connected to a flexible plastic pipe that can reach up to 30 ft deep well. The aspirator with the help of flexible plastic pipe sucks the poisonous gases produced in the tubewells and saves human lives especially during monsoon season.

The above mentioned technologies developed by the department have resulted in impact on the economy of the state through reduction in the cost of cultivation, reduction in the losses, increase in the cropping intensity, decrease in labour requirement, increase in production and productivity because of timeliness of operations and reduction in drudgery of operator/worker.

Soil and Water Engineering

Tubewells and Pumps

Safety device for diesel engines: The diesel engines coupled with centrifugal pumps are usually water cooled. As soon as the centrifugal pump fails to lift water due to one reason or the other, the diesel engines continue to operate and get overheated resulting into ceasing of engine. Therefore, a low cost safety device was developed



Safety device



Propeller Pump

to protect the engine from over-heating. The device stops the engine automatically when the centrifugal pump fails to lift water. The device is available in the market and has been adopted by a large number of farmers.

Efficient reflux valve: The reflux valve is a non-return valve and is used with every shallow tubewell. It was found that significant head loss takes place in the reflux valve. Therefore, an energy efficient reflux valve was developed. The valve is being commercially manufactured under BIS certificate and has been widely adopted by the farmers in the State.

Propeller pump: To pump water from open water bodies like irrigation canals, drains, farm ponds where the water level is within two metres from the ground surface, propeller pumps are more efficient than centrifugal pumps. Inclined as well as vertical propeller pumps were developed which can deliver medium to high discharge at low head. This pump has special application in south west part of the state where farmers can use it for lifting water from water courses to irrigate the fields which are at higher level than water course.

Animal drawn lift irrigation pump: To overcome the problem of electricity and diesel shortage, a pump operated by animal power and with a very high efficiency of 70 percent giving discharge equal to small shallow tubewell has been developed to lift water from 6m depth. About one million hectares area in this state has conditions conducive for such sets. It can be connected to a tubewell along with the existing electric/diesel pump. This is a very effective standby arrangement and is of special use to small and marginal farmers in bet areas.

Improving operational efficiency of agricultural pumpsets: Field and lab studies were conducted to measure operational efficiency of centrifugal pumps and it varies from 25 -58 %. Technologies were developed to improve efficiency of electric and diesel pumpsets for conservation of energy in pumping system.

Gas problem in tubewell pits: In some areas of the Punjab State, accumulation of harmful gases has been found in tubewell pits during monsoon. Once a person goes into these pits for repair of pumpset, he feels difficulty in respiration and becomes unconscious after a few minutes and dies of asphyxia. Techniques for detection and removal of these gases have been developed. Necessary precautionary measures were also recommended.

Ground Water Management

Water balance studies: In order to study the behaviour of groundwater table in different conditions of recharge and extraction, computer models have been developed for Bist Doab tract, Upper Bari Doab Canal (UBDC) command area and area lying west of Sirhind Canal Feeder. These models are useful in predicting the position of water table in an area under different operating conditions. Thus, declining of water table with increasing number of tubewells or rise of water table due to rainfall or from seepage, can be predicted. Water balance studies carried out for these areas indicate that further development of ground water is not possible as utilizable ground water potential in these areas has already been fully exploited. The water resources management expert system was developed for optimum utilization of water resources for Bist Doab Canal Tract of Punjab state. The system can be used to suggest optimal cropping pattern for efficient planning and management of available water resources with different levels of surface and ground water availability. It can be used by the decision makers to explore the wide range of crop management alternatives.

Artificial recharge of Ground water: An analytical model has been developed to simulate the artificial recharge to ground water through cavity wells. The model predicts the effect of concentration of clay in recharge water on aquifer properties and rate of recharge. Filtration technologies to remove suspended matter from runoff water before putting into cavity well has been developed. The technology has been

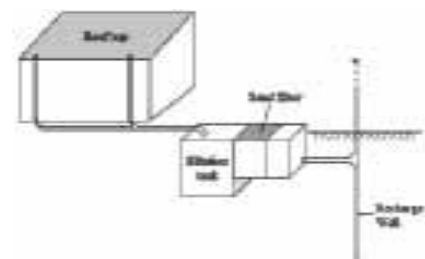


Fig.11. Roof top rainwater harvesting

tested in the field and found useful for adoption under actual field conditions.

Roof top water harvesting: The technology for rooftop rainwater harvesting has been developed (Fig.11). Rainwater harvesting through roof top is one of the simple, economical and eco-friendly techniques which can be used for artificial recharge of groundwater at mass level. This will check the declining of water table problem to some extent. Besides it will help in decreasing the stagnation of water on roads during rainy season.

Irrigation Water Management

Canal water management: The strategies for modernization of canal regulation system, keeping in view the shift in cropping pattern and increased use of ground water, have been developed for Upper Bari Doab Canal Command Areas. The water allowance and the capacity factors were revised which resulted into minimizing the gap between the supply and demand for irrigation water. The recommendations have already been accepted and adopted by the Irrigation Department of the state.

Optimum dike height: To conserve rainwater in paddy fields, the optimum dyke height should be kept as 17.5, 22.5 and 27.5 cm for light, medium and heavy soils respectively, under average rainfall conditions of major paddy grown areas in Punjab.

Proper sizes and grade of border/check basins: Too large/small size of borders/check basins using flood irrigation method leads to poor water use efficiency. Likewise, low distribution efficiency results if these are not properly leveled. Furrow method of irrigation is suitable for crops like cotton, maize, soybean, sunflower and sugarcane etc. on all types of soils. Information has been generated on the size of plots along with different grades to be adopted on different soils corresponding to different discharge of water available from the source. In case of paddy, the field should be leveled and one acre should be divided into 2 equal parts.

Simulation of soil moisture profiles : A two dimensional finite difference mathematical model has been developed to simulate the soil moisture profiles under wheat crop, considering soil, climatic and crop parameters. The model can successfully be used for scheduling of irrigations for wheat crop.

Micro irrigation: Studies on sprinkler irrigation losses and pattern parameters as affected by operating conditions were carried out with a view to find out the possibility of adoption of sprinkler irrigation system in the State. It was found that the high wind and high temperature prevailing during the summer month resulted in poor distribution efficiency and high evaporation losses. Thus, the sprinkler system should be operated preferably during morning and the evening.

It is beneficial to grow sugarcane with drip irrigation paired row plantation with 0.8 IW/CPE drip irrigation treatment and 75% of recommended dose of fertilizer (N) produced maximum Yield (93.31 t/ha) as compared with other treatments. This will give 24.95% increase in yield with saving of irrigation water (34.4 %) and 25% saving of fertilizer (N) as compared with conventional method (74.69 t/ha).

Study on sugarcane using sprinkler method and found that it saved 38.3 cm (20.6%) of total water used consequently increasing the WUE by 24.7 percent. The sugar yield increased by 1.62 per cent under sprinkler method as compared to surface method of irrigation. The experiments on sugarcane with drip irrigation revealed that water use efficiency was 9.5 % more than sprinkler system.

Developed irrigation and fertigation schedules for chilli, potatoes, tomato, brinjal, early cauliflower and sugarcane . The increase in yield and saving in water ranges from 15-56% and 17-63 % respectively.

Use of mulches along with drip irrigation has improved the processing quality of potato along with



Chilli crop under drip irrigation

increase in yield by 30-35% as compared to no mulch condition

Use of saline water using drip irrigation system: The irrigation of tomato crop resulted a maximum yield of 63.41 t/ha by applying canal water with discharge rate of 1.2 lph at IW/CPE ratio of 0.8. There was a yield reduction of 10 %, 23% and 28% by applying irrigation by mixing canal water and ground water in the ratio of 3:1, 1:1 and 1:3 respectively. Even if we apply 100 % saline water through drip irrigation having EC19.5 dS/m we can get 60% of the maximum yield which otherwise was not possible by flood irrigation. More over as the salinity ratio increases, the quality parameters like TSS, acidity and ascorbic acid increases. Thus it is recommended that drip irrigation system can be safely used in areas having saline underground water to get better quality produce with slight reduction in yield.

Construction of plastic lined storage reservoir: The procedure for the construction of plastic lined storage reservoir for the storage of canal water in canal command area or rain fed areas have been standardised .Two Water storage reservoirs have also been constructed at the research farm for demonstration purposes Viz. Brick lined (Size 10m x 10m x 2.8m) and Lime Lined ((Size 10m x 10 m x 2.8m)

Use of solar photo voltaic pumping system for micro irrigation system: The department is promoting use of SPV pumping system to be used with micro irrigation system . The department has installed 2 HP and 10 HP submersible SPV pumping system at the research farm.



Design of net house

Protected Cultivation

Design of net house : A 500 m² net house has been designed and constructed at the vegetable research farm and at farmers fields. Provision has been made to fix the plastics sheet or shade net as and when required at the top of the net. Vertical stitching of the net is recommended instead of horizontal one. This reduces extra pressure on stitched section & avoids tearing of net. The net house can withstand to wind speed up to 100 km/ hr. The approved design can be adopted by the farmers of the state. This technology will be of immense use to the small & marginal farmers

Design of green house : The summer temperature inside the green house is high and it is not possible to grow the crops in May- July. A modified greenhouse has been constructed by increasing side ventilation area and providing top ventilations (windows at the top). This will help in optimizing environmental parameters viz. Temperature, relative humidity, and solar radiation for favourable plant growth and the farmers will be able to use the poly house for crop production throughout the year. A complete package of practices for Tomato and capsicum cultivation under naturally ventilated green house has been developed for the adoption of the farmers.

Height of low tunnels : Effect of low tunnel environment on growth and yield of capsicum using drip irrigation system was evaluated and found that, it is beneficial to grow sweet pepper in low tunnel with 60 cm tunnel height which is drip irrigated with IW/CPE ratio of 0.75 as it gives highest yield (45% higher than conventional irrigated), highest water use efficiency and highest B/C ratio(2.93 without subsidy and 3.05 with subsidy) .

Drainage Engineering

Skimming wells /multiple well point system : In south west Punjab, at several places, relatively good quality ground water floats over poor quality ground water. Battery of skimming wells/multiple well point system has been developed for skimming of relatively better quality water layer floating over the poor quality of ground water. The technique prevents the hazards of salts which are likely to occur due to the installation of single irrigation well of higher capacity.The technology has been adopted by a large number of farmers in the state.

Bio drainage system: Technology to establish the eucalyptus (bio-drainage) in waterlogged sodic soils was developed. The eucalyptus plantation on ridges covered with polythene sheet has been recommended in severely waterlogged salt affected soils. It was further observed that the application of amendments decreased mortality and increased the plant height and girth as compared to the control treatments but their effectiveness varied with the type of amendment and dose of application. The cost of eucalyptus establishment is very nominal about Rs. 250 per plant. The farmers of surrounding villages adopted this technology and raised this plant at the ridges of the field plot for controlling water table.

Development of solute transport model: A two dimensional solute transport model was developed and validated. The model was calibrated with the field data and predictions of salt distribution in the soil ground water and drainage effluent for 10 years period were made. Application of this model was also made to study the long term effects of different drain spacing depth combinations, size of drain, ground water salinity and layering of aquifer on salinity of soil and ground water effluent. These results are very useful for solving drainage and salinity problems of the Punjab State.

Soil and Water Conservation Engineering

Runoff /soil loss model : Mathematical models have been developed to stimulate the runoff process and predict the erosion loss under different land management conservation practices both in arable and non arable lands. These models are useful in predicting the runoff rates, soil loss/sedimentation loss and evaluate different soil conservation measures and arrive at the optimum combination of these practices for minimizing the soil loss.

Runoff and Sediment Yield Modelling: Mathematical models are useful analysis tools to understand the watershed problems associated with runoff and soil erosion and to find solutions through land use changes and best management practices. A two-dimensional physically based distributed numerical model has been developed to simulate runoff and sediment yield from small agricultural watersheds on event basis. The model was applied on a 1.45 ha agricultural watershed located in Shiwalik foothills for simulating runoff and sediment yield. The results indicated that the model has the potential to simulate runoff and sediment yield from small agricultural watersheds for individual storm events with reasonable accuracy.

Mathematical modeling: The department has calibrated and validated various models such as HYDRUS, LEACHN, APSIM, MODFLOW, DRAINMOD, and SALTMED.

Civil Engineering

Research in Civil Engineering is being carried under the thrust areas of biogas technology, optimization of structures and water resources engineering. The major emphasis of the research work carried out in the department is in the area of biogas development and cost reduction aspects of biogas plant by modifying the existing designs of the plants. A lot of work was carried out on the engineering aspects of the biogas technology to make it cheaper and economically viable.

Inexpensive Biogas Plants

The conventional biogas plants (KVIC, Janta and Deenbandhu models) are very costly, because of constantly increasing cost of steel, cement and bricks. Therefore, it is absolutely necessary to dispense with the costly construction material altogether or to reduce their quantity to bring down cost. Based on this principle PAU developed inexpensive model both of drum type and dome type biogas plants and cost of the plants was brought down to 25 percent to 40 percent of the conventional models, as the digester was not lined with bricks but was an ordinary dug pit. The underlying principle involved is in the formation of a bacterial lining in the pit dug into the soil. The bacterial organisms are present in the colloidal form in the dung slurry when constantly fed to any porous medium and they form an impervious layer like a mat by completely choking the porous medium. In this way, a thick protective lining is formed in the pit. This acts as impervious layer and prevents seepage of water from the slurry to the ground water. Therefore, it is possible to completely or partially do away with the masonry construction

around the pit, thereby reducing the cost of the plant.

Spent Slurry Management

The digested or spent slurry coming out from the outlet of a biogas plant, being run on animal excreta, has a high manorial value due to its high N, P and K content. The digested slurry is also a rich source of macro and micro nutrients essential for plant growth and metabolism. However, the handling of the spent slurry is difficult due to its fluid nature *i.e.* its moisture content is around 93-95 percent. In bigger sized plants such as Institutional biogas plants and Community biogas plants, management of the spent slurry is practically a big problem. Different methods were tried to find a solution for the disposal of spent slurry. The spent slurry can be effectively dried in a drying bed. This method removes the moisture and preserves the nitrogen content of the slurry. Other methods like construction of simple pits, compost pit, and transporting slurry to fields via pipe can also be used depending upon the local conditions. The method of drying digested slurry under sun requires a large space in the vicinity of the biogas plant. Also there is formation of semi impervious layer on top of slurry after some time and this prevents further evaporation. So this layer needs to be removed periodically. As such, this method is labour intensive and time consuming. In a method of filtration using sludge drying beds, the choking of the filter media takes place. Due to which, there is no more filtration of water from slurry after some time. A method of filtration using stationary sieve can also be used, which has advantage over drying beds. The stationary sieve is easy to clean and is comparatively economical. However, it cannot be used for large sized biogas plants as the process of filtration is very slow.

Slurry Handling for Large Biogas Plants

A slurry handling machine (vibration type) has been developed for large biogas plants and it was modified through long duration trials. The evaluation consisted of dry and wet running of machine. The efficiency of machine was found to be 38% and total solid concentration was around 15%. There was no surplus water as whole of liquid goes back to biogas plant. The frequent breakdown and high noise level has almost been controlled. A prototype of the slurry handling machine was fabricated and installed at 85 m³ capacity biogas plant at Himachal Pradesh Krishi Vishva Vidyalaya, Palampur. The initial results of the machine have been encouraging and the suggestions made by Palampur centre were incorporated after trials at users' site. Slurry handling machines of PAU, Ludhiana and HPKVV, Palampur centres were also comparatively evaluated at user's site having a biogas plant of size 45 m³ (Kanganwal village, Ludhiana).



Slurry handling machine

Both machines were fabricated and installed at farmer's field. Machine developed by Palampur centre was not only costly but also there was frequent problems of clogging of liquid outlet of the machine, when the machine stops after rotating, around 50 to 60 liters of slurry comes out as such which gets mixed with solid fraction. It is very difficult to clean machine from inside. The problems in machines were rectified at the field only. Trials conducted with PAU machine showed that the total solids in the solid fraction obtained from upper sieve is 13% where as from the lower sieve it is around 6.5%. The filtered water has around 3% of total solids in it. The filtered water can be used for mixing in the cattle dung during feeding of biogas plant. The solid fraction from the upper sieve can be dried in the sun and can be handled easily. The solid fraction obtained from the lower sieve which is around 20% of the total volume of the slurry has to be handled separately. The slurry handling machine developed and modified by PAU centre can be used to handle large volumes of slurry.

Development of Hybrid Anaerobic Baffled Reactor

The anaerobic baffled reactor is one of the latest technologies in the field of waste treatment and has been described as one of the most efficient wastewater treatment process. It consists of a series of compartments in which water flows in up and down direction and gets treated during its passage. Advantages of the treatment include production of biogas as a byproduct, minimal sludge handling, low hydraulic retention time and low construction, operation and maintenance cost. The biogas generated can be used for heating, lighting and cooking purposes. Three reactors namely, anaerobic baffled reactor (ABR), hybrid anaerobic baffled reactor (HABR) and anaerobic baffled filter were developed for anaerobic treatment of wastewater of an agro-industry. Based upon the performance, the design procedure was recommended for the design of HABR. The design of the HABR plant was given to the industry for installation at the industrial unit in Raikot to treat waste of parboiling of rice. The successful running of HABR plant will not only be helpful in curtailing environmental pollution but also decreasing the running cost of industrial waste treatment.

Standardization of Operation Parameters for Biogas Plants

Six biogas plants were installed in different villages under ORP and performance was studied. The plant was better in terms of biogas production and slurry handling. However, the farmers were facing problems of choking with the feeding of solid feed without any water and they were adding water in different quantities in the biogas plant. ORP trials conducted on a number of solid state Janta biogas plants and solid state (HAU model) in Punjab revealed the problem of choking after feeding cattle dung as such, without addition of water. Experiments were carried out on solid state biogas plants to standardize their operation parameters.



Solid State Janta biogas plant

Modified Janta biogas plant (Fig. 2) and Deenbandhu plant of one m³ capacity were constructed and evaluated in the biogas field laboratory of the university. In the field plant also, there was frequent problem of choking when cattle dung was added as such. Daily feeding of 25 kg feed with 5-6 litre of water was started in July 2004. Daily gas production from the biogas plants were measured by water displacement method. TS, VS and pH of the inlet and outlet slurry were measured at monthly intervals. Daily gas production from the biogas plants varied from 0.3m³ to 1.2m³ in different months of the year. This variation is due to the difference in atmospheric temperature in different months ranging from 14.8°C to 34° C. The average TS content of the inlet in different months varied from 13.5% to 15.8% whereas TS of the outlet was 9.5% to 11%. An average of 11 % VS was degraded for production of an average of 0.88 m³ gas/day.

The solid state biogas plants are working well with the addition of 20-30 % water to the fresh cattle dung without any choking problem and compromising biogas production for the last 5 years.

Design and Evaluation of Fixed Dome Solid State Biogas Plant

Plants of capacity greater than 6 cubic meter were designed. Plant of higher capacity is run with 1:1 cattle dung and water. These plants are now so designed that water required is less than 1:1 ratio. Also dual fuel engines are available which runs on biogas and diesel. An attempt has been made to run diesel engine purely on biogas by fitting a kit from Gas Technology India. A 20 m³ fixed dome biogas plant was designed and installed at user's site costing Rs 56,000/-. The plant was installed and diesel engine was converted to run on 100% biogas. The 6 hp diesel engine available with the department has been converted to run fully on biogas. The quantity of gas needs to be controlled as engine is put to load. However, efficiency of the engine is poor at variable load and it consumes too much of biogas as compared to dual fuel engine thus warranting further modifications.

Adoption of Biogas Plant for Operation on Poultry Droppings

A number of farmers of different villages were contacted for the construction of biogas plants and demonstrations were carried out at different places. Based on the interest shown and the availability of poultry droppings with the farmers, 10 farmers of different villages were selected to carry out the ORP trials. The users started its working as per standard practice i.e. on cattle dung and water in the ratio of 1:1 and then were shifted to the usage on poultry droppings after stabilization of bacteria. All the users were satisfied with the working of the biogas plants.

Demonstrations on Solid State Deenbandhu Biogas Plant

An extensive survey was carried out for the installation of biogas plants in various districts of Punjab through KVKs and the users were motivated for installation of 6m³ capacity biogas plant. Performance of these biogas plants was monitored and all the users were satisfied with its usage. An extensive survey of interested users was done for the construction of biogas plants. The design of fixed dome type biogas plants was carried out as per user's requirements. Three large capacity fixed dome type biogas (two plants of 45 m³ capacity and one of 60 m³ capacity) have been installed and commissioned at farmer's fields. All the users were satisfied with its usage. They are very happy with its working especially in summer days as there is acute shortage of power in summer days. Thirteen more users have got installed these types of biogas plants of capacity ranging from 20-70 m³ based on this design recently.

Monitoring Status of Low Cost PAU Biogas Plants

In Punjab state, about 5000 low cost PAU biogas plants ((Katcha Pucca model) have been installed. Five districts namely Sangrur, Patiala, Ludhiana, Barnala and Faridkot were selected for this study under ORP and 125 users were selected in these districts. Data revealed that there is no leakage problem in these biogas plants and thus there is no failure on its construction part. There is no pollution problem to the surrounding areas from these biogas plants. All the users are very much satisfied with its working. It was found that for all the capacity varying from 1m³ to 6m³, the cost of installation of PAU model biogas plants is lowest than that of KVIC, Janta and Deenbandhu models of biogas plants. Moreover it has been seen that payback period of PAU model biogas plants is almost negligible (i.e. in the range of 0.6 – 1.4 years) as compared to that of other models of biogas plants w

MECHANICAL ENGINEERING

The thrust areas of research in mechanical engineering include solar energy, noise & vibration and greenhouse technology. Many solar devices such as solar cookers, solar dryers, solar air heaters, solar ovens have been developed in the thermal area. Work has also been done for the development of low cost heating and cooling technologies for green houses, optimization of greenhouse space for nursery raising applications and micro-climatic modification of greenhouses for summer and winter use. The specific technologies that emerged are as follows:

Water Heaters

PAU Solar Water Heater

Natural circulation type Solar Water Heater of PAU design



PAU solar water heater

with high efficiency and lower cost was developed. The feature of this design is that it is scale-free. It has been made possible by installing plate-type heat exchanger in its tank. Besides, it has more insulation to reduce heat losses. One solar collector of 1m² aperture area gives 50 liters of hot water per day. On an average, hot water at a temperature between 55-60°C is available from this solar water heater. This solar water heater was commercialized.

Integrated Solar Water Heater

A compact integrated solar water heater of 50 liters per day capacity was developed. In the conventional Solar Water Heater, solar collector and storage tank are separate units. Besides, due to back circulation during night, the overnight temperature of water in storage tank drops considerably. This problem was also addressed in this design. It is a single unit, housing a collector and a storage tank. There is thermostatically controlled solenoid valve, which stops back circulation during night. There is also a heat exchanger in the storage tank, which prevents scale formation in the pipes of collector. The average overall heat loss coefficient of solar collector and storage tank are 5.7 W/m²-K and 1.2 W/m²-K respectively. The three efficiencies viz. system efficiency during day time, storage efficiency during off-sunshine hours and overall efficiency during 24 hour period were 51.8%, 73.1% and 35.7% respectively.

Dryers

PAU Portable Farm Solar Dryer

A solar dryer for drying agricultural produce at farm level was developed. It is natural convection type and it does not require electricity for its operation. It is named PAU Portable Farm Solar Dryer. The solar interception area of one unit is 3.35 sq. m. About 20-30 kg of product is loaded at one time and it gets dried in 3-4 sunny days. In order to increase the capacity any number of such units can be placed side-by-side. The special feature of this dryer is that it is portable design so it can be dismantled and stored inside during off season. The amount invested in the dryer can be recovered in about 135 drying days.

PAU Domestic Solar Dryer

A small sized natural circulation solar dryer was developed for use at domestic level. It is named as PAU Domestic Solar Dryer. It does not require electric energy or any other fuel. It works on all sunny or partly cloudy days during summer as well as winter. It can be used to dry various products (fruits, vegetables, spices etc.) for domestic use at home under hygienic conditions. Its aperture area is 0.36 m². Loading capacity of the dryer is 1-3 kg per batch depending upon the product. The quality of the dried product is comparable to that of commercially available branded products with self guarantee of unadulterated product. The shelf life of dried product is about one year. The cost of one dryer can be recovered in about 80 drying days.

Solar Operated Desiccant Seed Dryer

The dryer is 35 x 31cm in cross-section and 55 cm high. It can dry 1 kg of seed from initial moisture content of 40% to 5% in 6 hours. It uses silica gel as a desiccant, which can be regenerated with solar energy after one use. There is an electric heater (of 200W power) for supplementary heating and an electric blower (of 330W power) for re-circulation of air. It can supply dry and hot air at any desired temperature, higher than ambient temperature. The dryer was tested in the lab and was able to dry onion and brinjal seeds without impairing their germination. It was latter field tested.

Development of Large Capacity Natural Circulation Solar Dryer

This solar dryer has separate solar air heater and drying chamber. The aperture area of solar air heater is 2.25 m². The duct spacing is 10 cm and the duct is made of fiberglass sheet at the bottom & sides and glazing of transparent polycarbonate sheet at the top. The drying chamber has two trays of different sizes. The size of lower

and upper tray is 108 x 48.5 x 19.5 cm high and 106.5 x 47 x 6.5 cm high. A fan (50W) is provided at the top of the chamber. The fan is switched ON if the air temperature at inlet to dehydration chamber is more than 60°C. The laboratory trials were conducted for drying of methi. The experiment was continued for four drying days with efficiency of 62%, 29%, 32% and 18% on successive drying days. It is very useful for drying vegetables and fruits.

Solar Heaters

Low Cost Solar Air Heater

A low cost solar air heater made of thermocol with UV stabilized plastic sheet as glazing was developed. The thermocol acts as insulation, vapour barrier and supporting structure thereby eliminating the need to use GI sheet for support structure and vapour barrier. Also there is no need of glass wool insulation since thermocol itself acts as an insulator. The duct has fiberglass on bottom and sides which acts as absorber of solar radiation. The total cost of low cost solar air heater (Single glazing) is about one fourth as compared to that of packed bed solar air heater. Thermal efficiencies of the low cost solar air heater with single and double glazing at flow rate of 0.017 m³/s-m² are 37.4% and 24.0% respectively while the corresponding value is 64.5% for the packed bed solar air heater.

Packed Bed Solar Air Heater

Hot air is required for agricultural applications such as drying of produce/seed, regeneration of desiccant etc. Traditionally electrical heater, furnace oil etc. were used to heat the air. Solar air heater can also be used for this purpose. Packed bed solar air heater was designed, fabricated and tested for this purpose. Blackened iron chips (waste of machine shop) were used to act as an absorber of solar radiation. Even at low air flow rates, this heater gives high efficiency because of better heat transfer due to turbulence created by iron chips and volumetric absorption of solar radiation. An electric blower is required for supplying the hot air for the given application. One solar air heater is of 1.25m² aperture area. Its payback period is 260 days of use when electric energy is replaced and 310 days of use when LDO/furnace oil is replaced. Number of solar collectors to be used is worked out depending upon temperature rise and air flow rate requirements of given application.

Cookers

Development of FTAR Solar Cooker

An efficient design of solar cooker called FTAR Solar Cooker was developed at PAU quite a few years back. It had three pots. But experience from its use showed that most of the time only two pots were used. Sometimes only single pot was used. The frequency of using three pots was almost negligible. Keeping in view the above feedback from the users, a FTAR solar cooker of smaller size for two pots was fabricated. The aperture area of FTAR Solar Cooker (2 pots) is 0.15 sq. m as compared to 0.25 sq. m of the cooker with three pots. The length of glass cover of this cooker is 53.5 cm as compared to 78 cm with three pots. The weight has reduced to 22 kg from 37 kg. Electrical backup was also provided for use during cloudy days. Hence, FTAR Solar Cooker (2 pots) is easier to handle. Its output matched with the food requirements and it can cook food on cloudy days also.

Folding two-step Asymmetric Reflector Solar Cooker

This new type of solar cooker retains most of the desirable features of the single reflector solar cooker. The folding 2-step asymmetric reflector enhances the solar input into the hot box appreciably as compared to the single reflector box cooker. Its concentration ratio is much higher as compared to that of the single reflector box cooker.



Stationary concentrator of SPV panel

Its stagnation temperature as measured in winter has been found to be 40 to 45°C higher than the single reflector box cooker.

Improvements in Rural Cooking Devices

The work was undertaken for the improvement of the efficiency of cook stoves (smokeless chullahs and angithies) for biomass combustion including wood of varying sizes. One to two pot smokeless chullahs were developed and found to be 15% more efficient than the conventional chullah. Agro-waste water heater was also designed in which all kinds of fuel available at the farm could be burnt conveniently. The heater had a thermal efficiency of the order of 37%.

Concentrators

Development of Concentrator for Solar Photovoltaic Panel

To increase solar energy incident on SPV panel, two solar concentrators were developed viz. Stationary Solar Concentrator for SPV panel and Tracking Solar Concentrator for SPV panel. The Stationary Solar Concentrator for SPV panel is front lit type with its axis along East-West direction. It does not require diurnal tracking but periodic adjustments in tilt are required. The results showed that the output of SPV panel with stationary concentrator was 1.56 times the output without concentrator. A single axis tracking solar concentrator for SPV panel has its axis horizontal and along east-west direction. Its reflector area was 3.3 times that of receiver (SPV panel). Its theoretical concentration ratio was 3.1. The output with concentrator was 1.8 times the output without concentrator.

Greenhouses Design and Microclimatic Control

Development of Multi-Rack Tray System for Greenhouse Nursery Raising

The upper space of the greenhouse where the microclimate is also under control is not used at all. Therefore, lesser number of seedlings is produced. If the small greenhouse is used in such a way that all its upper space is also used for raising nursery plants without affecting the light interception (photosynthesis of the plants), then a small greenhouse can produce much more number of seedlings at a lower price per plant. Keeping this in mind, upper space inside an east-west oriented greenhouse (where the micro-climate is also under control) is optimized for producing maximum number of nursery plants by developing a multi-rack tray system (MRTS). The MRTS is designed in such a way that the vertical distance between the two consecutive trays (H) and width of the tray (W) is optimized for different months of the year at different latitudes so that the shadow of the upper tray does not fall on the lower one. Nursery of many vegetables and ornamental plants was successfully raised using the MRTS inside a 3m high greenhouse having three stacks. Almost uniform growth of plants in all the three trays was observed.

Development of Dual Purpose Greenhouse

A dual purpose greenhouse is designed and developed for simultaneously producing full crop on the greenhouse ground and nursery plants on the existing north wall (in optimized stacks) for higher economic gains. North wall of the greenhouse does not contribute any solar radiation inside the greenhouse. Instead during winter months, due to smaller altitude angle of the sun, significant fraction of solar radiation transmitted through south roof and south wall of the greenhouse (incident on the transparent north wall) passes through it and lost to the ambient. Using solar geometry, nursery trays were optimally designed and mounted in two stacks on the north wall in such a way that at solar noon no fraction of solar radiation leaves through it and also does not cast any shadow of the upper stack onto the lower stack and on the plants grown on the floor. It was computed that for four winter months (November to February), the maximum altitude angle of the sun with horizontal (at solar noon) at 30°N latitude is always less than 47°. The optimum ratio between the height of two consecutive stacks (H) and width of the tray (W) is 1.07 (for four months). Computations show that in a greenhouse having 210 cm high north wall

with two stacks on it, the optimum values of H and W are 72 cm and 67 cm. Optimum heights of the upper and lower stacks are 192 cm and 112 cm above the ground. Nursery plants of tomato crop were raised on these two stacks having three trays of 160 cm × 67 cm size each. About 4500 nursery plants per stack (three trays) were produced in one cycle. In this way about 9000 nursery plants were produced in each cycle. This can be done in addition to the normal crop raised on the greenhouse floor.

Dynamic Performance of Agricultural Implements

Thresher

Spike-Tooth Type Thresher: Theoretical and experimental studies have been carried out to study the dynamic performance of the spike-tooth type thresher. Equations governing the free response of the thresher rotor were solved and find the first set of mode shapes were studied which corresponded to the natural frequencies of 62.8, 108.3 and 165.3 Hz. It was found that none of these frequencies matched with the excitation frequencies of 41 and 208 Hz associated with the aspirator fan and cylinder respectively. Transferring of half of the mass moment of inertia of the flywheel to that of the pulley indicated that this modification would avoid torsional resonance that might otherwise occur due to higher harmonics of excitation frequencies. First critical speed of the existing rotor of the Sherpur thresher was found to be 1685 rpm which is significantly above the operating frequency. Shaft diameter of 4.5 cm instead of 5 cm was found to lower the critical speed to 1365 rpm. Further reduction in diameter below 4.5 cm will bring the critical speed of the shaft close to the operating speed of the thresher rotor.

Effect of the balancing of the thresher rotor was studied. Static balancing of the rotor did not give the satisfactory results. But the rotor unbalance of 387.5 gm-mm / kg body weight was brought down to 76.48 gm-mm/kg body weight by means of dynamic balancing which is well below the accepted limit of 160 gm-mm/kg body weight as per ISO Standard. The response peaks were lowered by 78-80 %. It is recommended that the thresher rotor must be dynamically balanced after mounting the flywheel, threshing drum, fan and the pulley and also fixing the bearing and the bearing brackets. The vibration levels were brought down by 59.2% in the longitudinal direction. Balancing of both reciprocating and rotating masses brought down the vibration levels by 75-90%. Stiffening of the supporting member of the thresher rotor was also reduced the vibration level considerably. Actual field studies on the improved version of the thresher showed marked effect on the reduction of vibration levels and also lowered the noise level by 2dB.

Chaff-Cutter or Toka Type Thresher: Most of the work on this type of thresher involved experimental of vibration levels under various operating conditions in the field. The main rotor which consists of closely mounted flywheel cum pulley and the threshing cylinder and the other individual rotor consisting of fan had an unbalance of 1040 and 325 gm-mm/kg body weight of the concerned rotor respectively. Rotor was balanced only statically and the unbalances were reduced close down to the permissible limit of 160gm-mm/kg body weight. 60% of the reciprocating inertia forces associated with sieve were also balanced. Provision of a small flywheel on the shaft driving the sieve smoothed the jerky motion and then reduced the vibration levels.

Potato Digger-Shaker

The design improvement which have been theoretically worked out and then incorporated consisted of altogether removal of the upper mass and replacement of the bar supporting it by a lighter one, replacement of the oscillatory blade by a lighter one, provision of flywheel on the crank shaft and provision of a modified frame to accommodate the flywheel. These modifications in the existing model were the major improvement which reduced the vibration levels considerably. Partial balancing of the reciprocating parts, however, did not much reduce the vibration levels. The overall vibration levels were reduced to 49% of the vibration levels in the existing model. Experimental studies under the actual field condition indicated the reduction in vibration to 33%. Prolonged operation of the digger-shaker to harvest many acres of potato crop was quite successful. No breakage due to mal-functioning or

fatigue failure of the component occurred. The implement may thus be said to have survived the fatigue loading.

Powered Knap-Sack Sprayer

This study relates to the dynamic performance and vibration control of powered knap-sack sprayer which is finding wide application among the small farmers. Severe vibration generated by the high speed reciprocating engine that are transmitted to the back and shoulders of the operator, caused discomfort and fatigue, and can also be a source of damage to the spinal column of the operator. A test rig was first designed fabricated and fixed in a wall and it has different provision of mounting / attaching the powered knap-sack sprayer on the mechanical shoulder with back plate and split clamps. Since the human body is most sensitive to vibration in the vertical direction, attempt has been mainly made to reduce the excitation and transmission of vibration in the vertical direction.

Vibration at the source has been reduced by fully balancing the reciprocating engine in the vertical direction. Transmission of vibration has been reduced by providing shoulder spring isolation and also by replacing the existing rubber blocks between the engine-sprayer unit and the frame, with the springs having low stiffness in the vertical direction. Field studies by actually mounting the sprayer on the back and shoulder of various subjects was conducted both before and after adopting the vibration control measures. The vibration levels in the vertical direction have been found to come down by 62.88% to 75.52% at the shoulder and by 48.72% to 68.04% in the longitudinal direction at the chest. Limited study on the heart rate of the sprayer operator has also revealed that the heart rate of the operators is low when they operate the improved sprayer as compared to the existing one.

Acoustic performance of Exhaust Mufflers of Tractor Engines

Acoustic performance studies of some existing tractor mufflers/silencers have been conducted in terms of insertion loss and noise reduction. All the sources of engine noise other than its exhaust noise were isolated while conducting the performance studies. The insertion losses provided by the mufflers of Massey Ferguson, Swaraj, International and Ford tractors have been recorded as 7.5 dB(A), 4dB(A), 12dB(A) and 8.5 dB(A) respectively, while the corresponding back pressure exerted by these mufflers have also been recorded as 15.6, 15.7, 24.3, and 12.9 cms of water. A muffler has been designed and fabricated for Massey Ferguson tractor and compared its acoustic performance in terms of insertion loss and noise reduction with the existing one. The insertion loss provided by the new muffler is 3dB(A) higher than that of the existing muffler and the back pressure exerted by the new muffler is 3.3 cms of water which is much less than as compared with the existing muffler.

Processing and Food Engineering

The research work carried out in the area of processing and food engineering has led to the development of several technologies that have proved useful to the farming community. The salient research achievements and important technologies developed are given below :



Mechanical grain handling unit

Agro-Processing Complexes

Agro-processing models/complexes consist of two or more machines for processing at farm/village level. The machines are Mini rice mill (2.5qph), Baby oil expeller (60kg/h), Small atta chakkies and Large atta chakkies with scouring machine (50kg-500kg/h), Masala grinder, Cotton ginning machine, Penja, Cleaner, Dal Mill and Feed mill (4.5 q/h). More than 400 agro-processing complexes have been established in Punjab till now out of which 25 agro-processing complexes were established under PAU guidance. Economic analysis of these agro-processing complexes indicate that with an initial investment varying from Rs 80000 to Rs 800000, an agro

processing complex gives a monthly profit of Rs 5000-43000, apart from providing employment to 1-5 persons.

Machines/Equipments/Lines/Systems/Structures

Air tight metal bin :The concept of air tightness in metal bins was recommended by PAU in the early 70s and these bins are suitable for domestic storage of food grains and seeds. Air tightness in metal bins in different forms is now a household phenomenon in Punjab covering rural as well as urban household. These metal bins are available in sizes of 1.6 to 16 quintals.

Mechanical grain handling units for markets: Mechanical grain handling units were designed and established in some markets of Punjab. The system includes unloading devices, bucket elevator, a high capacity cleaner, automatic weighing and bagging machine, a slat conveyor and bag stitching machine. Punjab Mandi Board has installed 88 such Mechanical Handling Units in 34 grain markets in Punjab. These units require only 35 min for wheat and 50 min for paddy to handle 100 bags, in comparison to traditional system of 300 min per 100 bags of wheat and 350 min per 100 bags of paddy.

Rotary screen grain pre-cleaner: Rotary screen grain pre-cleaners of single screen as well as double screen were designed and developed. The machine output is approximately 10 to 15 qph at a cleaning efficiency of 90% with a 4 HP motor. The cleaner is under commercial production.

PAU moisture meter: A low cost moisture meter (Rs 650/-) was designed and developed to cater the needs of farmers and grain processors. It can measure moisture content of wheat, rice, sorghum, millets, etc. within 12-35% on wet weight basis. The accuracy of the meter is comparable with existing commercial meters.

Briquetting machine: A low cost briquetting machine was designed and developed, based on optimum design principles. It can produce 100 kg/h. The average energy consumption is 20% compared to 10% for existing machines. It can process cow dung, molasses, and developed, based on optimum design principles. It has a capacity of 100 kg/h. The average energy consumption for producing 100 kg of briquettes is 20% as compared to 10% for existing machines. This is a viable technology.

Radial honey extractor :The power-cum-hand operated eight frame radial honey extractor made up of stainless steel (food-grade) was designed and developed. This works efficiently at 165 rpm with the honey recovery of 192 kg/h. The initial investment is Rs. 30,000 and the running cost is Rs. 11/ q of honey.

Trolley-cum-batch dryer : A tractor trolley available with farmer has been converted into a multi-crop dryer which can hold about 3-4 q of chillies and 1-1.5 ton of paddy per batch. The dryer can dry 10 quintals per batch of paddy in 100 min for 5% moisture reduction and it can dry 2 quintals of red chillies from 80% to 10 % moisture in 28 hours. The unit cost (per machine) is Rs.1, 50,000 – 2, 00,0,00/- including the cost of hydraulic trolley. The unit cost of operation for paddy is Rs 20/q and for chillies is Rs 90/q.

Honey-cum-wax separator : On the principle of squeezing action, both manually-operated and hydraulic-operated wax separators have been designed, developed and field evaluated on honey uncapping wastes. The machine can separate approximately 42 % of honey per batch from fresh uncapping waste. The cost of honey separation is Rs. 42/q with an initial equipment investment of Rs. 9000/- only.



Honey-cum-wax separator

Vegetable washing machine

Electric-cum-battery heated uncapping knife: In order to make the uncapping process more effective an electric-cum-battery heated uncapping knife working both on AC as well as 12 V DC was designed and developed. This can uncap one frame in 20-22 seconds. Its performance is better than that of the conventional knife in comparison to the ease of operation and time.

Evaporative cooling unit: A simple structure of double wall of bricks, sand and cement of size 1.9 m x 1.3 m and a height of 0.6 m have been developed for domestic storage of fruits and vegetables. This structure has sand between two walls which is kept wet by adding water periodically which is allowed to evaporate causing cooling in the interior chamber. The structure is covered from the top with a wire mesh and a wet jute bag is placed over it. Capacity of the structure is approx. 30 to 40 kg and temperature reduction up to 10-15°C can be achieved. The economic feasibility of the similar structure with (5.49m x 5.49m x 3.36m external dimensions) to store 100 bags of potatoes was evaluated.

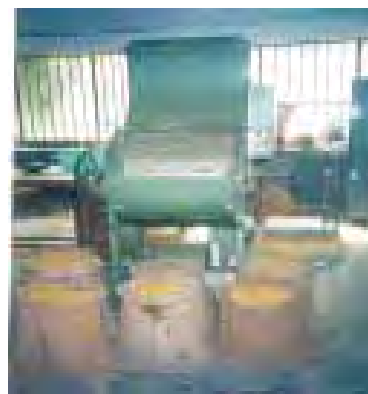
Farm level fruit and vegetable washing machine: Stainless steel, portable, electric power (1 hp) operated horticulture produce washing machine was designed, developed and tested. A wide range of fruit and vegetables (carrot, potato, raddish, turnip, ginger, okra, tomato, spinach, turnip, kinnow and pears) can be mechanically washed. Unit cost of the machine (prototype) with prime mover accessory (e.g. motor, compressor, etc.) is Rs. 70,000- 10,0000/- (for different capacity models). Unit cost of operation is Rs. 1 –10/q. Ten prototypes have now been sold to various centers and other institutes.

Turmeric washing and polishing machine: Turmeric rhizomes can be mechanically washed and polished in a portable, electric power (1 hp) operated, rotary drum type turmeric washing and polishing machine. The machine when operated at optimum rotational speed for optimum time can wash 2.5-3.0 q/h of turmeric rhizomes. The same machine can be used for polishing turmeric with some modifications. The capacity of turmeric polishing machine is 1 q/h. Only one person is required to operate the machine.

Honey heating-cum-filtration system: The fully mechanized honey heating cum filtration unit was designed and developed. It has a separate heating and filtration section with an optimum capacity of 50 kg. It can filter 2q/day honey with the processing cost of Rs.200/q. The honey processed through this unit at both 50°C and 60°C heating temperature with holding time of 20 min and 40 min were superior in microbiological and biochemical quality attributes when compared with raw and commercially processed honey.

Technologies for Storage Shelf life

Use of biogas for the control of grain pests : Biogas was successfully used to control stored grain insect-pests infesting moong and paddy. The moong grains were stored in 1, 5 & 10 q capacity PVC bins whereas paddy (basmati) was stored in 1 q PVC bins which were specially designed for the purpose of passing gas through them. Biogas showed no adverse effects on germination of stored grains. The alcoholic acidity, FFA & the uric acid content were found to increase with increase in the insect population in the untreated control samples of moong and paddy (basmati), however, with the biogas treatment; acidity as well as uric acid content of the grains was under control. The crude protein content of the moong grains in the treated samples remained constant during the storage. The cooking quality of grains was unaffected by the biogas application.



Turmeric washing and polishing machine

Effect of edible coatings on shelf-life and quality of perishables: Enhancement of shelf life of kinnow, okra and tomato was done by edible coatings. Two types of edible coatings were used for kinnows i.e. carboxy methyl cellulose (CMC) 0.5, 1.0 and 1.5% and casein 8%. It was found that 0.5% CMC coating and HDPE bags were found to be the most suitable combination for extending the shelf-life of kinnows upto 40 days without adversely affecting the juice quality. Under ambient conditions, the CMC 0.5% coating and high density polyethylene bags 200 gauge were found to be very effective for extending the shelf-life of okra upto twelve days under the desired level of quality. Three types of edible coatings viz. cellulose, pectin and starch coatings were formulated and tested for its application on tomatoes for increasing shelf life of tomatoes. Based on quality parameters observed at regular intervals it was found that tomatoes coated with pectin (3%) and packed in LDPE bags with 4 perforations increased the shelf life of tomatoes by 7 days under ambient condition and by 28 days under refrigerated condition.

Post harvest management of high moisture paddy : Monitoring of the paddy samples from production (farmers) to marketing i.e. grain markets showed that the maximum number of samples (62.7%) was in the range of 12-18 % which are suitable for various purposes. Over dried paddy samples (< 12%) were only 9.1%. The samples with more than 18% moisture content (28.2%) would have dried to safe levels till procurement and processing, because the maximum moisture content observed in any of the samples was 23.4 % at the trader's level.

Effect of dried neem leaf smoke against pulse beetle : Equipment for giving smoking treatment to the stored grains (0.5-1.0 q capacity bins) was developed to evaluate the technology suggested by Jabalpur centre. Bengal gram (stored in 50 kg capacity PVC bins), artificially infested with pulse beetle, was exposed to neem leaf smoke treatment with the developed smoking unit successfully. Percent infestation, germination, moisture content, protein, carbohydrates and off-colour seeds were observed monthly. The total infestation was restricted to only 6.76% in neem leaf smoke treated samples as against 87.5% in untreated control over a period of six months of storage. The total water soluble sugars increased from 6.6 to 14.5% in untreated control samples, whereas this increase was only upto 9.2% in treated samples thus showing the significance of neem leaf treatment in controlling pulse beetle and maintaining the quality of grains without any adverse effects.

Improvement in rice milling through enzymatic pre-treatment: Cellulase (695.45IU), xylanase (931.25IU) and protease (521.74 IU) were obtained using Basal medium as substrate. The brown rice (Basmati 370) and Pusa 44 were treated with all three enzymes produced in the laboratory under optimized conditions. Enzyme was found to be active at all selected pretreatment conditions. All independent variables i.e. temperature, concentration and time had statistically significant effect on percentage broken, polishing time and optimal cooking time. The enzyme required for pretreatment of brown rice from 1 kg of paddy is 25mg. For large scale production of microbial enzymes, a solid state fermenter has been designed, fabricated and evaluated. This fermenter can ferment 10kg of rice straw (wet wt.) to produce 250g of enzymes in one batch, which is sufficient to treat brown rice obtained from 10 tonnes of paddy.

Hook system for minimizing pilferage losses in grain markets : It was found that practically there is no substitute of hooks (kundis) being used by the labour for the lifting of bags in mandis/ warehouses. As compared to the hook size of 8 mm (commonly used), hooks of size 6mm gave better results in terms of pilferage losses. The hooks of size below 4mm did not work properly. After theoretical design it was felt that hooks made of MS having size of 6mm can be further tested for lifting the bags.

Techniques for control of stored grain insects/mycoflora in Bengal gram : Experiments to evaluate the effect of turmeric powder, neem leaf powder and thermal treatments as grain protectants against Pulse beetle on Bengal gram were carried out in the laboratory and observations were recorded. The thermal effect was thoroughly studied against all the life stages (egg, larva, pupa and adult) of pulse beetle and it was established that 60°C temperature was most effective and a complete mortality was achieved when grains were exposed for 20 minutes at 60°C. Thus no adult emergence took place at these temperatures and time combinations. These temperatures effectively killed all the life stages of pulse beetle when exposed separately. Preliminary observations reveal that

mustard oil with neem powder is more effective in controlling mycoflora in Bengal gram as compared to other plant products.

Modified atmosphere packaging of perishables : Packaging and storage studies were conducted for various agricultural crops to extend the shelf life of the crop keeping in view the responses of significant quality parameters for each crop. Modified atmosphere packaging of guava fruits using LDPE 100 gauge film can extend the shelf life up to 42 days under refrigerated conditions ($8\pm 1^\circ\text{C}$) and 27 day under room temperature conditions ($14-17^\circ\text{C}$) as compared to 10 days for control. For ber fruits, the LDPE-200 non-perforated film was identified as the best storage treatment for shelf life of 15 days at ambient conditions while for low temperature storage conditions the best three identified films for shelf life of 25 days are LDPE-100, HDPE-100 and the HDPE-200. Considering all the storage aspects, the non-perforated HDPE-100 gauge film showed the best results. In case of bell pepper, shelf life of 12 days for flush storage samples packaged in PE bags; 24 days for samples in jute bags, open trays (control) and samples stored in evaporative cool chamber irrespective of packaging materials and 32 days for samples kept in refrigerator without any packaging materials (open) and 40 days for product packaged in jute bags and PE bags. The quality of fenugreek leaves stored in 150 gauge PP non perforated film stored at 15°C and 75 % relative humidity was superior to either combination of 1, 2 perforation (0.3 mm dia.) and control samples.



Thin layer convective drying of red chillies

For a study on French beans and mushrooms, 150 gauge PP film bags (surface area: 0.17 m^2) and 200 gauge LDPE film bags (surface area 0.1 m^2) were selected depending upon the type of vegetable. Different quantity of the produce was packaged in the selected packages and stored at 15°C and 75% relative humidity. The results showed that the packaging treatments resulted in the creation of MA having 2.6 – 12.7 % O_2 and 4.5 – 13% CO_2 concentration. The acceptable level of green colour of French bean could be maintained for 3 days; and the surface colour of mushroom, was well-retained for 4 days under the MAP conditions studied. Minimally processed carrots packaged in 150 gauge PP films could be stored safely for 15 days at 15°C and 75% RH. For lettuce it was observed that package fill density had considerable effect on the steady state in-pack gas concentrations. Most desirable in-pack gaseous environment (O_2 : 1-5% and CO_2 : 10-15%) observed for package fill density of 0.25g/cc in 150 gauge PP bags could extend the shelf life of fresh-cut lettuce till 18 days.

A mathematical model for shelf-life prediction was developed for packaging and storage of fresh-cut vegetables under macro-perforated modified atmosphere. Packaging of minimally processed spinach in LDPE pack ($40\ \mu\text{m}$ thickness) showed maximum retention of chlorophyll (74.35%) and ascorbic acid (13.33%) along with considerable retention of b-carotene. The storage of spinach at 15°C temperature and 75% RH can enhance shelf life to 11 days without any adverse effect on biochemical and sensory quality parameters. Baby corn could be stored for 10 days at 10°C and 75% RH in $50\ \mu\text{m}$ LDPE film packages, The shelf life of shelled peas packaged in LDPE were found as 4, 7, 17 and 45 days when stored at ambient, 15°C , 5°C and -11°C , respectively. The shelf life of peas was 20 days when packaged in LDPE with 5% CO_2 and stored at temperature of 5°C .

Drying of agricultural produce : Drying studies for various agricultural commodities have been carried out for obtaining best quality dried products with extended shelf life. A study on spray drying of *Aloe vera* gel and tomato juice was conducted. The inlet temperature of 150°C and 60% malto-dextrin concentration is advisable for best quality *Aloe vera* powder. Best quality tomato powder can be obtained by spray drying of tomato juice at inlet temperature of 140°C with 40:60 maltodextrin with juice blend. Drying of cauliflower was best at 60°C , 60 m/min air velocity for size of (4.5 x 3) cm on the basis of drying kinetics and quality. In another study, on the basis of quality. In an experiment on Marigold flowers

(variety: Jafri) the optimum drying conditions were found to be drying temperature of 60-65°C at an air velocity of 2 m/s and a pretreatment of KMS (0.9 %) for 15 minutes.

Thin layer convective drying of red chillies was tried at five different temperatures i.e. 45, 50, 55, 60 and 65°C. The variety Punjab Lal in pricked form was found to be of the best quality when dried at 55°C. A study was conducted to evaluate the performance of low-cost drying methods for preparation of tomato powder from blanched and unblanched tomato slices of 'Punjab Chhuhara' cultivar. On the basis of overall quality, drying time and cost of drying, aeration sun drying was found to be the most efficient method followed by room air fan drying, open air sun drying & solar drying. Turmeric (both mother and finger rhizomes), boiled in open pan for 45 min at 100°C, was dried using different methods. Multi-rack solar dryer with trapezoidal cross-section yielded best quality turmeric powder with highest curcumin content and oleoresin content. The dehydration of 1 kg of fresh turmeric yields 170 g turmeric powder.

Energy for Agriculture

The School of Energy Studies for Agriculture has been actively involved in development of renewable energy technologies in area of biogas, solar energy, biomass gasification and bio diesel. Some of the technologies developed are given below:

Biogas

In Biogas technology, work was carried out on PAU Katcha -Pacca models of cattle dung based biogas plants, effect of low temperature on biogas production, poultry droppings based biogas plants, dry fermentation, spent slurry management, mathematical modelling of biogas plant operations, operation parameters for the solid state Janta biogas plants and solid state Deenbandhu plants for Punjab region. Work was also carried out for high capacity modified PAU fixed dome type biogas plants.

The PAU center, through extensive research, has developed inexpensive models of moving drum type and fix dome type plants. These are called PAU Katcha-Pacca model. The drum type inexpensive model costs 50-60% less than the conventional KVIC plant. More than 1200 such plants (both KVIC and Janta models) have been installed in the districts of Sangrur, Faridkot, Patiala, Amritsar and Ludhiana and are working satisfactorily for the past 20 years. The fixed dome Janta biogas plant, PAU Model, inexpensive Katcha Pacca Model costs approx. 1/3rd the price of the conventional Janta biogas plant. In both these models the digester pit remains unlined i.e. Katcha and above the pit either a steel gas holder or pacca pit is constructed. The gas yield of these plants is comparable to conventional model and is highly stable as far as structural parts are concerned and is economical.

Studies were conducted to assess the extent of pollution to ground water, if any, from the PAU Katcha-Pacca Plants. No loss of moisture was observed due to seepage after a period of 20-30 days in the katcha pit of plant. Ammonical nitrogen, taken as index of pollution was never found below the depth of 30 cm. Studies also revealed that the sandy soil is as good as sandy loam and clayey soil for installing PAU model Katcha-Pacca plants. Labotaratoty, pilot and field level studies were conducted to study the feasibility of using poultry litter as an alternate substrate to cattle dung for biogas generation without modifying the existing design of the biogas plants. Bench scale studies revealed that poultry litter and water in the ratio of 1:3 (w:w) make a suitable influent to the biogas plant.

To meet the increasing demand of dairy farmers, large capacity biogas plant for power Generation has been designed, developed and demonstrated by PAU centre with the help of ICAR, which is basically of Janta biogas plant type but its gas holder is fixed, of hemispherical shape. The design is approved by ICAR and a manual is published by ICAR about engineering and construction drawings of fixed dome biogas plants (20 to 500 m³ capacity).

Solar Energy

PAU Solar Water Heater: Solar Water Heater of PAU design with high efficiency and lower cost was developed. It is natural circulation type. Its absorber is fin and tube type and it has a storage tank. Additional feature of this design is that it is scale-free. This has been made possible by installing plate-type heat exchanger in its tank. Besides, it has more insulation to reduce heat losses. One solar collector of 1m² aperture area is required to give 50 litres of hot water per day. So the design is modular. On an average, hot water at a temperature between 55-60°C is available from this solar water heater. This solar water heater was commercialized. It was manufactured and marketed by M/s Vishwakarma Solar Energy Corp. Phillaur.

PAU Portable Farm Solar Dryer: A solar dryer for drying agricultural produce at farm level was developed. It is natural convection-type so it does not require electricity for its operation. It is named 'PAU Portable Farm Solar Dryer'. It is a modular design. The solar interception area of one unit is 3.35 sq.m. About 20-30 kg of product is loaded at one time and it gets dried in 3-4 sunny days. It may be noted that any number of such units can be placed side-by-side to get higher capacity. The special feature of this dryer is that it is portable so it can be dismantled and stored inside during off-season.

Low Cost Solar Air Heater : A low cost solar air heater made of thermocol with UV stabilized plastic sheet as glazing was developed. The thermocol acts as insulation, vapour barrier and supporting structure thereby, eliminating the need to use GI sheet for support structure and vapour barrier. Also there is no need of glasswool insulation since thermocol itself acts as insulator. The duct has Fiberglass on bottom and sides which acts as absorber of solar radiation. The total cost of low cost solar air heater (Single glazing) is about one fourth as compared to that of packed bed solar air heater.

Biomass

Development of rice husk based gasifier for engine application: This gasifier has been successfully operated in laboratory and field conditions. It was used in the field situation to run engine of 10 KW for water lifting operation for irrigation of farmers fields.

Development of engineered prototype gasifier for thermal applications: PAU gasifier of 50,000 kCal/h capacity has been successfully designed and tested for thermal applications. This gasifier has been successfully run for 400 hrs in thermal mode and 50 hours in electricity generation mode without any adverse effect on its components. In this engineering prototype there is provision for replacement of all parts and interchangeability of component for manufacturing ease.

Evaluation of cotton sticks as gasifier fuel : The evaluation of cotton sticks as a fuel in gasifier was carried out. It was observed that cotton sticks did not flow properly through the grate. Modifications in the cotton sticks also did not solve the problem.

Development of wood based gasifier : An imbert type gasifier of 50,000 kCal/h capacity based on PAU design has been successfully installed in an industry in Jalandhar. It has been used for drying the product with the hot gases obtained from the burning of producer gas.

Performance commercially available rice husk based gasifier: A rice husk based gasifier was procured from M/s Associated Engineering Works (AEW), Tanuku, (A.P.). The gasifier system is designed to gasify 50 - 100 kg rice husk per hour and to deliver more than 500 MJ/h heat energy. The gasifier performance was evaluated .and It was found that gasifier did not produce combustible gas continuously. Therefore it can not be recommended for industrial application as such.

Evaluation of PDKV Akola cook stove: The PDKV Akola portable stove has been tested in laboratory and field conditions. This stove had efficiency in the range of 22-23 % in the laboratory conditions.

Comparative evaluation of producer gas cleaning systems: Three producer gas cleaning systems developed by PAU, SPRERI and CIAE Centers were operated with 10 kW throat less rice husk gasifier system. Maintenance schedules were worked out for all systems. All the systems provided clean gas within the MNRE specified range of < 150 mg/Nm³ when these systems were run according to the maintenance schedule.

Biodiesel

Biodiesel was prepared from thirteen different kinds of plans and it was tested in diesel engine for short duration. A tractor engine was operated successfully for 500 hours on biodiesel

Preparation of biodiesel using ethyl ester: The ethyl esters were prepared from non-edible *Jatropha curcas* L. seed oil using hydrated alcohol containing 85%, 90% and 95% ethanol and anhydrous (200 proof) ethanol and trans-etherification reaction condition were optimized for maximum recovery of biodiesel with anhydrous ethanol. The prepared biodiesel was characterized for different fuel properties.

Engine testing of biodiesel prepared from ethyl ester: A variable compression engine was used to study the properties of various blends of this biodiesel with diesel. The engine performance was better on various aspects with the blends of this biodiesel as compared to diesel engine.

Information Technology

The School of Electrical Engineering and Information Technology is setup with a vision to change the computer culture to Information Technology at PAU and to develop world class agricultural informatics at PAU and bridge the digital divide among the agricultural scientists and farmers. The use of methods of mass communication using information technology will be very effective in transfer of technologies developed at PAU to farmers and farmers will be empowered to take informed and quality decisions which will have positive impact on the way agriculture and allied activities are conducted.

The School is becoming essential ingredient in the development of agriculture informatics and playing a catalytic role for the interdisciplinary research in the development of Web based Decision Support System, providing weather forecasting information to farmers. Collaborative effect of Information Technology and Molecular biology is producing Bioinformatics for wheat genome sequences at PAU and many more.

The information about package of practice in multimedia format can be supplied through information KIOSK at block level.

The school is also providing the technological strength to PAU administration and digitization of the records with the development of Information Superhighway within the campus. The following IT services are developed and managed by the school:

- Management of Campus Network
- Management of PAU Website
- Management of PAU Mail
- Management of Online Circular System (CAMPUS ONE)
- Online Examination System
- Technical Support to PAU Balance Sheet and other PAU softwares
- Video Conferencing

Memorandum of understanding has been signed with IBM for help in above programs and services. The IBM has supplied softwares regarding e-learning, network management. IBM has certified SEEIT as Centre of Excellence in Agriculture ICT.

School of Information Technology is redefining the internal communication at PAU in the paradigm of ~~Information Technology~~ ~~Compendium of 150 Types of Achievements~~ for the ICT enabled services such as PAU Email, Campus Portals and Video Streaming. PAU officers can make use of PAU Portals for posting circulars and notices. Infrastructure has been developed to provide facilities such as Internet Computing Laboratory and Video Conference Room. New Campus Wide Network has been developed with Wi-Fi facility.

BASIC SCIENCES

Microbiology

Mushroom Research and Technology

A low cost, rural oriented, labour-intensive mushroom cultivation technology has been successfully developed, transferred and is being practiced by the growers of the Punjab state and adjoining areas producing about 50% of the total mushroom produce of the country. The R&D efforts has led to recommendation of a round the year seasonal cultivation technology for five varieties of mushrooms namely, *Agaricus bisporus* (White button mushroom), *Pleurotus* spp. (Oyster mushroom) and *Lentinus edodes* (Shiitake mushroom) during the winter season and *Volvariella* spp. (Paddy straw mushroom) and *Calocybe indica* (Milky mushroom) during the summer season. A new composting schedule of 24 days duration for preparation of long method compost has been developed (replacing the 28 day schedule) giving optimum yield of white button mushroom. Similarly new compost formulations based on the use of wheat straw with paddy straw (1:2, w/w) and with digested wet biogas slurry have been recommended. New casing soil mixtures utilizing biogas slurry and burnt rice husk along with farmyard manure (1:3, v/v) have been developed as alternatives to the use of farmyard manure and sandy soil (4:1, v/v). Use of carbendazim for the effective control of competitors of mushrooms and dichlorophos for insect pests have been recommended.



Low cost technology for year round cultivation of recommended varieties of mushrooms

High yielding strains of different varieties of *A. bisporus* (PAU S-11), *Pleurotus* spp. (PAU-2, PAU-3, PAU-5), *L. edodes* (PAU-LeS), *V. diplasia* (PAU-Vd) and *C. indica* (PAU-Mm3) have been recommended for cultivation under Punjab conditions. High quality spawn of these strains supplied to the growers of the region has resulted in a staggering increase in mushroom production in the State. A germplasm bank of mushroom cultures consisting of 103 strains belonging to 17 spp. of 7 edible taxa has been raised over the years and is being successfully maintained. Most of these cultivars have been accessioned with ATCC and NRRL (USA), CMI (UK), INRA (France), IMTECH (Chandigarh) and DMR (Solan).

A systematic breeding programme for the development of mushroom hybrids especially among incompatible lines of desired genetic variability has been undertaken employing both conventional and non conventional strategies. Molecular profiling of the selected lines is being undertaken using RAPD analysis.

Successful cultivation technologies for growing several specialty mushrooms including *Auricularia polytricha*, *Hypsizygus ulmarius*, *Flammulina velutipes*, *Agrocybe aegerita* and *Ganoderma lucidum* using locally available

substrates have been developed. Nutritional composition of mushroom varieties and their biomedical significance have been documented. The inclusion of *A. bisporus* or *P. florida* in hypercholesterolemic diet of rats decreased blood and tissue cholesterol/lipid levels, the effect being more pronounced with the feeding of *P. florida*. Characterization of allergens of *Pleurotus* by SDS-PAGE immunoelectrophoresis has been achieved. Rapid DOT-EIA, a diagnostic test for the detection of spore specific antibodies has also been standardized. The extraction, purification and characterization of biomolecules including glucans and terpenes from medicinal mushrooms including *Lentinus edodes* and *Ganoderma lucidum* has identified molecules of medicinal importance from these mushrooms. *Pleurotus* harvested spent straw has been found to be equally good as original wheat straw in the rations of buffaloes.

Soil Microbiology

Efficient *Rhizobium* cultures for mungbean, soybean, lentil, pea, gram, lucerne and berseem have been developed along with their bulk multiplication for field use. The use of these cultures by Punjab farmers has enhanced legume yield by 10-15 per cent and the initial recommended dose of nitrogen can also be saved. Moreover, *Rhizobium* inoculation to mungbean has shown residual effect equivalent to 30 kg N/ha to the subsequent wheat crop. The survey of Punjab soils has indicated poor and ineffective nodulation, suggesting the need to inoculate legume crop each time. Competitive ability of introduced and native rhizobia was shown using serological and antibiotic marker techniques. The role of micronutrients such as iron, zinc and molybdenum in enhancing symbiotic nitrogen fixation in legumes has been highlighted. The technology has been transferred to the Directorate of Agriculture, Punjab. These cultures are being supplied to the farmers of Punjab and adjacent states.

Azotobacter biofertilizer @ 10kg/hectare is recommended for enhancing cane yield of sugarcane crop by 5-6% and is being supplied to the farmers of Punjab. Fungicides like Captan, Thiram and Ceresan and insecticides like Rogor, Hemithion and Malathion were found harmless for legume-*Rhizobium* symbiosis and could be safely used for killing seed-borne pathogens and the insects eating germinating seedlings along with *Rhizobium* inoculant. The use of blue green algae cultures under field conditions has shown a saving potential of 30 kg N/ha in basmati rice. The herbicides recommended for rice showed no deleterious effect on blue green algae. The use of *Azorhizobium* + VAM + formononetin resulted in an increase of 22.1 per cent yield of maize (*Zea mays* L.).



***Rhizobium* culture**

Biotization technology for micropropagated plants (sugarcane, Aloe vera, poplar, safed musli) has been developed which increases 10-12% survival rate upon their transfer to soil. Biotization with *Piriformospora indica* increased the cane yield in micropropagated sugarcane crop. Diazotrophic diversity analysis was performed in Punjab soils. The diazotrophic count was found to be negatively affected with the soil nitrogen particularly ammonical nitrogen while positively affected with soil organic C-content. Highest diazotrophic population was observed in Submontane undulating region whereas lowest population was found in flood plain region. The diazotrophic potential of the isolates at the molecular level was ascertained by performing *Nif H* analysis using two different *Nif H* primers (*Nif H* 1 and *Nif H* 2) from different agroclimatic regions of Punjab. Diverse groups of diazotrophs were found in different agroclimatic regions of Punjab and *Nif H* positive isolates were amplified for 16S r DNA. These diazotrophs were characterized upto species level and submitted to NBAIM, Mau. One *Pseudomonas* isolate was found to tolerate 150ppm atrazine as sole C source.

Impact of application of various pesticides on soil biota and non-target organisms on rice-wheat cropping system indicated a decreased population dynamics in the pesticide treated plots with respect to control. In wheat seasons application of chloropyriphos and Bavistan decreased the population of all groups of microorganisms studied while 2,4-D posed no negative impact on population dynamics of nitrogen fixers. Leader showed no negative impact on phosphorus solubilising microorganisms and nitrogen fixer population. Application of combination of these pesticides decreased fungi, phosphorus solubilising microorganisms and N-fixers populations. In rice season a negative impact of application of quinalphos was studied in all microorganisms while phorate and butachlor

exhibited negative impact on all microorganisms except N-fixer and actinomycetes population respectively. No specific trend could be ascertained on microflora when these pesticides were used in combination.

Endophytic actinomycetes from wheat, rice and medicinal plants and actinomycetes from rhizospheric soil of medicinal plants were characterized for their functional potentialities and it has been found that a few isolates of *Streptomyces* sp. could be used as plant growth promoting and biocontrol agents. Endophytic bacteria were isolated from endorhizosphere of sugarcane and ryegrass and identified upto genus level. Studies of their functional potentialities revealed that they can be used as PGPR.

Industrial Microbiology

Microbial strains particularly species of *Pseudomonas*, *Achromobacter*, *Alcaligenes* and *Bacillus* have been found to degrade isoproturon, lindane, different isomers of chlorobenzoic acid and 2,4 dichlorophenoxyacetic acid. Immobilized cells of *P. putida* on sodium alginate revealed faster degradation of 2,4-D and lindane. Plasmids coding for degradation of 2-chlorobenzoic acid and 3-chlorobenzoic acid have been identified and transferred to *E. coli* rec mutants. A consortium of aerobic bacteria isolated from polluted waters of *Buddah Nallah* is found to tolerate and degrade as high as 5000 ppm of 3-chlorobenzoic acid. A strain of *P. pickettii* has excellent potential for detoxification and elimination of chemical pollutants from agricultural soils.

A number of fluorescent *Pseudomonas* strains showing antagonism against fungi have been identified and are being tested for control of *Rhizoctonia* and *Fusarium*. Isolated strains of *B. subtilis* have been tested for their antagonistic action on emergence of juveniles from egg masses of root-knot nematodes in crop plants.

Extensive studies have been conducted on pathogenic and toxigenic strains of bacteria occurring in milk, dairy products and various foods. Besides *E. coli*, enterotoxin production by other bacteria including *Streptococcus faecalis*, *Clostridium perfringens* and *B. cereus* and their incidence in various foods have been investigated. The occurrence of an emerging pathogen, *Listeria monocytogenes*, in milk, dairy products, meat and meat products and its survival in the vegetables, ice cream mix and the effect of low temperature storage have been monitored.

Nutritional value of wheat and rice straw has been improved by solid state fermentation, thereby enhancing their digestibility and protein content by 9-15 folds. The study concluded that *Sporotrichum thermophile* and *Myrothecium verucaria* have potential to upgrade agricultural residues into protein rich biomass for cattle feed. *Chaetomium globosum* and *Sporotrichum pulverulenum* gave six-fold increase in the crude protein of kinnow-mandarin residue. Sugarcane bagasse and sawdust have been enzymatically saccharified and fermented to ethanol. Strain improvement through mutation and protoplast formation to produce higher amounts of extracellular cellulase has been carried out. Potential production of microbial enzymes, alkaline proteases, amylases and thermostable α -amylase has been achieved.

Wheat bran, rice bran and *paneer* whey have been utilized for production of gibberellic acid and citric acid. Mutants of *Fusarium moniliformae* had the potential for enhanced gibberellic acid production. Macerated mycelium and fungal impregnated grains were better inocula for fermenting wheat bran into citric acid. Production of bioethanol through saccharification and fermentation of agri-residues revealed formation of absolute alcohol @ 0.031 g g⁻¹ of rice straw. Sunflower wastes in the form of sunflower stalk and hulls were used for bioethanol production. Ethanol yield of 4.052 and 4.032 kg ethanol/ quintal of sugarcane juice was recorded. Different waste materials including those of crops, animals and agro-industry have been successfully exploited for biogas production. Pre-treated rice husk has been found suitable for higher biogas generation.

Inulin, a polymer of fructose in roots of Chicory plant, has been fermented into ethanol by *Kluyveromyces fragilis* with fermentation efficiency of 65%. Sorghum malt has been found to be the best source of amylolytic enzymes for maximum saccharification of starch into simple sugars which have been fermented to yield upto 8.2% ethanol. Two fast flocculating yeast isolates of *Saccharomyces cerevisiae* have been improved by UV irradiation, possessing higher ethanol production capacity.

Technology for production of wine (grapes, guava and tea), and vinegar (sugarcane, grape, rice, malt and tea) has been developed. Technology for concentrated sugarcane vinegar production has been submitted for grant of patent. Natural vinegars produced from grapes and sugarcane have been analysed for their organoleptic and antioxidant properties. Dry and sweet wines from fruits including grapes, mango, pear, peach, plum, guava and rose have been produced. Wines of medicinal value have been prepared from ginger, mint and bitter-gourd. Dry yeast tablets have been produced. Technology for production of low alcoholic carbonated beverages from fruits (plum, citrus and lemon) and vegetables (amla and carrot) has been developed and submitted for grant of patent.



Production of natural vinegars

Bacteriological water testing kit

Regular paid service of bacteriological analysis of water samples (potability) and food samples is being rendered to assess their quality. A dye based, bacteriological analysis kit has been developed to determine suitability of water for drinking at end user's place and the same is offered on sale. Similarly, sugarcane vinegar and its starter cultures are being sold by the department and trainings are imparted to the farmers/entrepreneurs.

Biochemistry

Biochemistry of Crop productivity

For studying *in vivo* regulatory role of enzymes during grain/seed filling in cereals and legumes, techniques have been developed for successful culturing of inflorescence. Mechanisms of carrier-mediated transport of sucrose in meristems and its transformation to galactomannan in guar have been elucidated. By manipulating the levels of sucrose and amino nitrogen in the sap entering the grain, an enhanced synthesis of protein in the cereal seed has been demonstrated.

Higher activities of isocitrate dehydrogenase and malic enzyme in the seed at the time of rapid seed filling in mungbean and lentil were effectively linked to the deposition of protein reserves in developing seeds of lentil. By identifying sucrose synthase as the major enzyme responsible for sink filling, it may be possible to increase the yield as well size of the seeds by increasing the copy number of sucrose synthase in the developing seeds. A direct correlation between the activity of acetyl CoA carboxylase and fatty acid synthesis in the maturing sunflower seed has been established.

Abiotic Stress Biochemistry

Use of antioxidant enzymes for depicting drought tolerance in wheat has been established. Variable sowing times and irrigation practices can be used for inducing variation in different wheat quality characteristics. Wheat grown under rain-fed conditions has low trypsin inhibitor activity. Out of eleven late embryogenesis abundant (LEA) genes in wheat only, six LEA genes were induced in C-306, a drought tolerant genotype, under water deficit conditions.

Gibberellic acid and kinetin have been found to reverse the effects of water deficit and salt stresses on growth of chickpea seedlings by enhancing amylase activity and mobilization of starch from cotyledons. Higher

activities of superoxide dismutase, ascorbate, catalase and acid phosphatase as well as lower content of phytic acid in cold stress tolerant chickpea genotypes as compared to cold stress susceptible genotypes are the biochemical markers for cold tolerance in chickpea.

Biotic Stress Biochemistry

Citric acid, oxalic acid, salicylic acid were strong inhibitors of *Rhizopertha dominica* amylase. Feeding trials with these eco-friendly chemicals and wheat α -amylase inhibitor in wheat showed effectiveness in controlling the multiplication of *R. dominica*.

Role of polyphenol metabolism in disease resistance, particularly in relation to mungbean yellow mosaic virus (MYMV) infection in mungbean has been brought out. Uniconazole, a growth retardant, was shown to impart resistance to susceptible varieties of mungbean against MYMV by increasing the activity of enzymes involved in polyphenol metabolism.

Industrial Biochemistry

Chemicals preventing dextran formation in sugarcane milled juice have been identified for improving sugar recovery. Enzymes involved in fructan and sucrose metabolism have been characterized. Utilization of chicory fructans for producing fructose using high inulinase yielding strains of *Kluyveromyces* and *Aspergillus* has been shown.

Ruminant Biochemistry

Ruminants fed on paddy straw or hybrid napier showed a negative balance of calcium due to its binding with oxalic acid present in these feeds. Oxalate-rich diets should, therefore, be supplemented with feed grade limestone. Supplementation of live yeast (*Saccharomyces cerevisiae*, strain 1026) culture to the diet of lactating buffaloes increased the average milk yield by 13.5 per cent and increased the growth rate of the calves.

Animal and Nutritional Biochemistry

Dietary fibres from wheat, maize, soybean and chicory root not fructans resulted in lowering the cholesterol level of plasma in experimental animals. Histopathological and biochemical studies of aorta, liver and heart indicate retardative effect of garlic on the development of arteriosclerosis.

Zoology

The Department of Zoology, since its inception in 1971, is engaged in pursuing research and teaching in the areas of rodentology, agricultural ornithology, fisheries, animal physiology and faunal diversity.

Rodentology

Rodents cause significant damage to field crops. Package of practices for management of rodent pests were developed, modified and updated with changing agronomic practices on the basis of regular data and testing of new and safer chemicals and other methods. Relative abundance and distribution pattern of different species of rodents have undergone tremendous changes as population of some species (lesser bandicoot rat) have increased whereas that of others have declined (soft furred field rat, Indian gerbil and India bush rat). Some species have also changed their distribution pattern. Lesser bandicoot has started commensalizing and short tailed mole rat has not been trapped for long time in Punjab. In addition to monitoring, developments and modifications in the technology for their management, educative materials were developed to educate the farmers about rodent pest management. Based on testing of about 25 chemicals for their rodenticidal, antifertility and repellent/attractant properties, suitable chemicals, their bait carriers, formulations and timings of application in different crops and seasons have been recommended. Cultural and mechanical methods for intercrop periods have also been recommended. To overcome the problem of bait shyness caused due to the repeated use of zinc phosphide bait, method of pre-

baiting has been developed. For trapping more than one rat at a time, a double chambered multi-catch trap with tunnel type entrance has been developed. A complete package of technologies for controlling rodents in poultry farms and other premises has also been developed.



Rodent damage to groundnut crop



A bandicoot rat in wheat field

Agricultural Ornithology

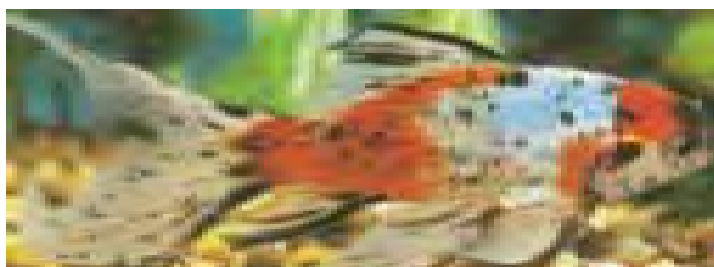
Several bird species have been observed to cause serious damage to the agricultural crops in the State. Package of practices for protection of crops from bird damage were developed and modified with changing cropping pattern and wildlife acts. A check list of the birds of Punjab and Chandigarh was compiled which comprised of a total of 240 species and sub-species recorded from the state. Population of some birds (granivorous) have increased whereas of others have declined (house sparrow, insectivorous and birds of prey). Rose ringed parakeet has been found to be the predominant depredatory species in Punjab. Ecofriendly bird management methods like the use of reflective ribbon to protect cereal crops and fruits, wrapping of maize cobs by leaves of the plant, cultivation of sunflower crop in large blocks to reduce damage, use of prerecorded warning distress calls of birds and planting of screen/lure crops have been developed. For scaring away the birds from crops, a CD containing warning/distress calls of birds has been developed for use by farmers. In view of utilizing the feeding habit of insect eating birds for control of insect pests, method of installing artificial T-perches in crops was developed. Installation of 30 T-perches per acre has helped in attracting 20 beneficial birds in cotton, melon, bitter gourd and berseem crop fields. Artificial wooden nest boxes were developed and tested in field to increase population of beneficial bird species. Eight species of birds have adopted wooden nest boxes and three have utilized earthen pots for nesting successfully.



Spotted owlet inhabiting artificial nest box

Fisheries

Recommendations have been developed for fresh water fish farming to increase fish production. Computer aided regression models to estimate desired ration size have been prepared. Feeding according to the model based feeding table resulted in 83% higher fish yield compared to that by traditional feeding practice. Optimum temperature required for breeding of ornamental fish has been worked out to be 20-25°C. Improved technology for culturing fresh



Gold fish Shubunkin bred for the first time in Punjab

water carp species in waters with low to medium salinity (up to 4 ppt) and high alkalinity (up to 675 mg l⁻¹) has been developed for South-western districts of Punjab. Methods have been explored for enhancing productivity of reservoirs (from 48 Kg ha⁻¹ to 160 Kg ha⁻¹) and to bring more waste land area under fish production. Recipes for seven value added products namely fish patty, fish mince pakora, fish loaf, fish finger, fish balls, fish samosa and fish salad have been developed after de-boning the flesh of common carp and Indian major carps. All these products have good consumer acceptability. The shelf life of these products is 120 days at -25 °C storage. Successful rearing technology of freshwater prawn for North western India has also been developed.

Animal Physiology

Contributions in the field of animal reproductive biology pertaining to comparative aspects of follicular growth and maturation, spermatogenesis and spermatozoa in different species of fish, lizards, birds, rodents, buffalo, goat, sheep, helminthes parasites and insects have led to better understanding of their complex reproductive mechanisms and their population in relation to environmental factors. Significant qualitative and quantitative variations in the mast cell population in the ovaries during different stages of reproductive cycle, lactation and pregnancy were revealed. Biopesticidal properties of egg white proteins (particularly protein fraction rich in avidin) against red flour beetle, a stored grain pest were evaluated. Effects of various chemicals and pesticides on reproduction have been evaluated. Technique for *in vitro* fertility appraisal of buffalo semen has also been developed along with standardization of methodology for preserving buffalo semen.

Faunal Diversity

Studies on animal diversity, distribution and taxonomy have revealed many new species of helminthes parasites, crustaceans, earthworms, fruit flies, predatory and phytophagous mites, spiders and molluscs. Faunal description, systematics and identification keys have been prepared which are being used throughout the country. Relationship and significance of these animals to agriculture and that of parasitic helminthes with that of human health have been determined.

Botany

Abiotic Stress Tolerance

The mechanism of abiotic stress tolerance has been elucidated having far-reaching implications in crop improvement. The drought-tolerant genotypes of wheat, durum and triticale were shown to possess a superior capacity for osmotic adjustment achieved by increased accumulation of osmolytes. pretreatment sustained it to certain extent. Cytosolutes viz. total soluble sugars, amino acids, proline and specific proteins accumulated more under moderate stress. The increased activities of hydrolase's pointed out that osmoprotection mechanism was critical for survival. Stress induced at tillering and anthesis stages adversely affected photosynthetic activities. Foliar application of calcium helped to sustain photosynthetic activity whereas ABA was inhibitory. The cell wall-bound calcium has been shown to be critical for the acquisition of thermotolerance, possibly by acting as a secondary messenger for modification of plant metabolism and protection of membrane integrity. Drought susceptibility index was found good criterion for screening of germplasm. Polyacrylamide gel electrophoresis (PAGE) revealed accumulation of dehydrins under stress.

The focus in the field of plant reproductive biology has been on regulation of pollen germination and tube growth, pollen-stigma interaction and incompatibility barriers, embryogenesis and seed development in crop plants. Reproductive processes during flowering and early seed-filling in cereals were found to be especially vulnerable to drought and heat stresses resulting in significant reduction in yield and grain quality.

Developmental Physiology

Studies conducted for understanding the mechanism of cotton fiber initiation, elongation and the transition to secondary wall deposition in *Gossypium hirsutum* and *G. arboreum* have helped in identifying the physiological

and biochemical traits determining fiber quality. The key role of hormonal balance in terms of auxins, gibberellins and abscisic acid has been established. This has opened new avenues for achieving improved fiber production under *in vitro* and *in vivo* conditions. Chemicals affecting Ca-metabolism viz. CaCl₂, Nifedipine (calcium channel broker), Chlorpromazine (Ca-calmodulin antagonist), Brassinolide (promoter of cell division and elongation), KNO₃ and NAA were tested *in vitro* for fiber production from fertilized ovules/seeds of *Gossypium hirsutum* and *G. arboreum*. Positive role of K in fiber elongation when available during and after elongation phase became evident.

A concept of non-photosynthetic fixation of carbon dioxide has emerged from studies with several non-photosynthetic plant tissues which has created a new awareness concerning its role in plant metabolism, growth and development. An efficient operation of this pathway, mediated by PEP carboxylase and associated enzymes, has been linked to higher productivity of C₃ plants e.g. cotton, ground nut and wheat. The role of PEP carboxylase for recapturing respired carbon dioxide is a major discovery with many spin-offs, especially for oil or protein crops, which have large respiratory costs for reducing and rearranging molecules from carbohydrates for synthesis of oil and protein end-products.

Plant Growth Regulation

Efforts have been made for enhancing the efficiency of crop production using plant growth regulators. Exogenous applications of a number of phenolic compounds, previously thought to be of secondary importance, have shown promising results in achieving improved productivity of several field crops, e.g. mungbean (salicylic acid, caffeic acid), chickpea, groundnut, Indian mustard and lentil (1,2,4- acid, H-acid). In pigeonpea and groundnut, the applications of monophenols caused synchronized pod development, increased translocation of photoassimilates and reduction of flower abscission. At least, 15 different phenols (mono-, di-, and polyphenols) were identified to possess anti-transpirant activity, acting via suppression of hydrolytic enzymic activities and membrane permeability changes in stomatal guard cells. Paclobutrazol, a close analogue of the fungicidal triazole family, was found to impart lodging resistance and improve seed yield of Indian mustard.

In groundnut, aliphatic alcohols improved yield by leaf longevity by delaying senescence. Seeds of pre-harvest sprouting tolerant wheat genotypes were characterized to possess greater ABA insensitivity. Seed treatment with plant growth regulators and priming in organic and inorganic osmotica have shown promising results in achieving improved seed performance under normal and stressing regimes, and invigoration of aged seed lots.

Agro-biodiversity

Biochemical evaluation of monocotyledons taxa in terms of flavonoid patterns, proteins and isozymes patterns has proved to be useful not only in the identification of taxa but also in providing data which when utilized in conjunction with cytological information is of immense value in selection of genotypes, detection of hybridization, and establishing interrelationships amongst them. With a view to promote agro-biodiversity, the studies on some crops like Kalmegh, *Aloe vera*, *Plantago*, resin and latex producing plants have been conducted along with their anatomical as well as biochemical characterization.

The morphological, physiological, biochemical and anatomical features of the siliquae of shattering susceptible cultivars of *B. napus* (GSL-1, GSL-2 and GSC-5) and shattering resistant cultivars of *B. juncea* (PBR-210) and *B. carinata* (PC-5) were compared. The siliquae of shattering susceptible cultivars had distinct wide valve margins at the apical, middle and basal positions. Structurally, a separation layer characterized by thin walled cells between valve margins and main vascular bundles represented the dehiscence zone. In susceptible cultivars the activities of cellulose and polygalacturonase in the dehiscence zones were greater in siliquae walls nearing maturity than the resistant cultivars. Localized applications of IAA (100 µg ml⁻¹), kinetin (50 µg ml⁻¹) and salicylic acid (50 µg ml⁻¹) decreased the shattering percentage of siliquae, IAA being the most effective. PGR-induced resistance to shattering in susceptible cultivars was the result of enhanced lignifications of cells walls in dehiscence zones.

Morpho-Physiology of Disease Resistance

Studies were conducted to identify morpho-physiological and biochemical markers for various field and vegetative crops with respect to disease resistance.

The morpho-anatomical characteristics of leaf, stem and fruit of Brassica species in relation to resistance to downy mildew (*Peronospora parasitica*) and white rust (*Albugo candida*) were investigated. The thickness of epidermis-cum-cuticle on both the adaxial and abaxial surfaces was found more in the resistant genotypes of *B. juncea* as compared to susceptible genotypes. The size, frequency and index of stomata on both the leaf surfaces were significantly higher in the susceptible than in the resistant genotypes. The average palisade index, thickness and number of palisade layers were more in resistant genotypes. The thickness of the epidermis-cum-cuticle layer of the stem as well as total thickness of the fruit wall were also more in the resistant genotypes.

Likewise, it was observed in case of groundnut that the stomatal density and the length of guard cells were significantly higher in the genotypes showing susceptible reaction to *Cercospora arachidicola*, the causal organism of tikka disease in groundnut, while the resistant varieties had higher palisade index. The highly resistant genotype PI 250747 also had higher frequency of trichomes and calcium oxalate crystals. Among the biochemical factors, the higher concentration of starch and free amino acids, particularly alanine and glutamine, and more post-infectious accumulation of phenols were observed to be the important factors determining the resistance of groundnut varieties against this fungal pathogen of groundnut.

Among anatomical features, minimum stomatal size, stomatal frequency index, maximum trichome size and frequency in resistant genotypes of chilli to *Alternaria solani* helped in resistance acquisition. The phytoanticipins viz. total phenols, flavonoids and ascorbic acid content were significantly higher in *A. solani* resistant chilli genotypes. Higher palisade index with lesser spongy parenchyma in resistant chilli genotypes appeared to be useful in avoiding the entries of fungal spores inside the tissue.

Chemistry

Synthesis and Biological Activity of Schiff Bases and Metal Complexes

Some novel and convenient methods were developed for the synthesis of α -cyanoamines, α -ketoacids and α -amino acids by carrying out the reaction of cyanogen bromide with benzalanilines, cinnamalanilines and ketimines and 1,4-benzothiazines and 1,2,5-benzoxathiazepine with sulphenes and benzalanilines. 2, 3-Dihydrobenzofuran derivatives were synthesized by the addition of cyanogen bromide to 2-hydroxy substituted ketimines through a novel rearrangement of anticipated N-bromo- α -cyanoamines. Condensation of 2-hydroxyphenyl ethylidenebenzylamines with cyanoacetic acid, cyanoacetamide, malononitrile and ethyl cyanoacetate in the presence of a base resulted in the formation of coumarinimide derivatives as a result of cyclization due to interaction between 2-hydroxy and nitrile group of adducts or addition-elimination products.

Eco-friendly techniques utilizing microwave were adopted for the synthesis of Schiff bases and their derivatives. The advantages of using these techniques include minimum use of solvent and very short reaction time. A number of series of Schiff bases with different substituents in C-phenyl and N-phenyl rings, different extent of conjugation in the molecule and various rings attached to carbon or nitrogen atom of the azomethine linkage were synthesized by microwave technique. Schiff bases have also been synthesized from 1-naphthylamine and 2-chloro, 3-chloro and 4-chlorobenzaldehyde by traditional and microwave irradiation methods.

A new contribution in the field of chemistry has been made in terms of chemo selective reaction with azomethine linkage leaving a more reactive ketonic moiety intact, during the reaction of ethyl cyanoacetate with benzal-4-acetylanilines. Chemo selectivity of reaction of malononitrile, cyanoacetic acid, cyanoacetamide, methyl cyanoacetate, nitro methane, acetyl acetone, diethyl malonate, dimethyl malonate, ethyl acetoacetate *etc.* with benzal-4-acetylanilines as well as with benzal-3-acetylanilines was also studied. Cyano active methylene compounds reacted with 2-hydroxybenzal-4-acetylaniline to yield 2-imino-2H-chromene derivatives due to cyclization of the addition-elimination products because of interaction between hydroxy and cyano group, a useful reaction for the

synthesis of systemic heterocyclics. Conjugated heteronoid compounds were synthesized by condensing benzalanilines and cinnamalanilines with active methylene compounds in presence of a base.

Screening of 4-thiazolidinones, the heterocyclic compounds having nitrogen and sulphur in a five membered ring for their fungi toxicity revealed that these compounds possessed promising antifungal activity with ED_{50} values of less than 10 ppm against *Alternaria alternata* and between 10-20 $\mu\text{g mL}^{-1}$ against *C.lunata* and *F.oxysporum*. Two Schiff bases namely cinnamal-4-chloroaniline and cinnamalaniline when tested at 2000 $\mu\text{g mL}^{-1}$ against late blight of potato caused by *Phytophthora infestans* in replicated trials in the field reduce the disease intensity to 61.6 and 80.0 % respectively from 91.6 % observed in control treatment where only water was sprayed

One of the thio substituted Schiff bases namely α -methyl- β -chlorobenzal-(2-thioaniline) when evaluated against *Alternaria brassicae* on toria crop and against *Alternaria solani* on tomato crop in the field was found to be effective at 2500 $\mu\text{g mL}^{-1}$ as compared to control where no treatment was applied and also found to be just at par with standard fungicide Indofil M-45. This compound also showed better antifungal potential against *Anthracoise sp.* of chillies at 2500 $\mu\text{g mL}^{-1}$ as compared to Indofil M-45 in field trials.

A quantitative structure activity relationship has been developed among Schiff bases. The spacer between two phenyl rings plays a pivotal role in determining the biological activity as systemic fungicides. Thus, the Schiff bases of 2-phenylethylamine showed better activity than those of benzyl amine followed by aniline. The same trend was observed for the nematocidal activity of Schiff bases against *Ditylenchus myceliophagus* and *Caenorhabditis elegans*. Complexes of 2-hydroxybenzal aniline and 2-hydroxynaphthalaniline and their N-phenyl derivatives with Fe (III), Zn (II), Cd (II), Ni (II) and Co (II) were synthesized. Complexes of transition metals with dithiocarbamates were prepared.

The screening of Co (II), Ni(II), Fe(II), Cu(II) and Cd(II) complexes of 1-(2'-hydroxyphenyl) ethylideneaniline and its N-phenyl derivatives for antifungal activity has shown that complexation of parent compounds enhanced the antifungal activity. Two heteronoids namely ethyl 4-hydroxybenzalchloroacetate and ethyl 3,4-dimethoxybenzalchloroacetate when tested in field at 0.25% concentration against fruit rot of chillies caused by *Colletotrichum capisci* reduced disease intensity considerably as compared to control.

Chemistry and Potential of Natural Products as Agrochemicals

The sesquiterpene lactones namely dehydrocostus lactone, isoalantolactone, alantolactone, parthenin and some of their derivatives were treated with diazoethane and diazoester. In case of diazoethane the desired substituted pyrazolines have been prepared and characterized by spectral studies whereas the diazoester yielded the cyclopropyl derivatives. Microwave induced reactions *viz.* Knoevengeal condensation of aromatic aldehydes with dimedone and Meldrum's acid, allylic oxidation using urea-hydrogen peroxide complex and isomerisation of double bonds in natural products were carried out. New eudesmanolides were isolated from the roots of *Inula racemosa*. The stereo structures of our compounds were established by chemical and spectroscopic methods. An allylic oxidation reagent for sesquiterpene lactones was developed.

An extensive use of microwave energy has been made to develop and modify new and existing chemical methodologies. These include isomerisation of exo double bond to endo position in sesquiterpenoids, Hoffmann elimination, pyrolysis of alkyl pyrazolines of sesquiterpenoids, synthesis of heterocyclics like 4-thiazolidinones, oxazolones etc. Various reactions like reduction, oxidation and dehydrogenation were carried out on thin layer chromatography plates using different reagents to save time and chemicals. Separation of different terpenoids, pesticides, amino acids, steroids and plant growth regulators was done using different adsorbents and also impregnated silica gel. TLC procedure using arsenic trichloride/perchloric acid as a chromogenic spray reagent was developed for the identification and detection of insecticides. The sensitivity of the techniques was 0.5-2 μg . Considering the simplicity and low cost, this standardized TLC procedure is comparable to other available methods.

Three compounds namely Thymol (Ajwain oil), Isopalchoulenone (Nagar motha) and Santonin were tested for their efficacy on germination of sugarcane var. CoJ88 and CoJ89 with fairly good results. These three compounds when applied as such or in combination with IBA, to grape wine cuttings caused an increase both in number and length of root and also early emergence of shoot were observed. The essential oils from eucalyptus, bottle brush, lemon grass, ginger, garlic, turmeric, mentha, bay leaves and marigold flowers were isolated and their chemistry and protection potential were studied by exposing three week old adults of *T. castaneum* to wheat grain treated with essential oils mentioned at different concentrations of oil. Bioefficacy studies of all the oils and their fractions showed that the percent mortality increased with increase in number of treatment days and concentration.

The protection potential of lemon grass *Cymbopogon citratus* was assessed by exposing three week old adults of *T. castaneum* to wheat grain treated with lemon grass oil dissolved in acetone at six different concentrations ranging from 50-2000 $\mu\text{g mL}^{-1}$. Complete mortality was observed after 2, 17, 37, 43, 50 and 55 days of treatment for the concentrations tested. The results reveal that lemon grass oil provided protection to wheat grains from *T. castaneum* infestation. Maximum protection was observed at 2000 ppm concentration. Polar fraction was found to be more active than the non-polar fraction. Yellow coloured, pungent smelling essential oil of garlic having pH 5.5 and refractive index of 1.54 was isolated in 0.06 percent yield from the bulbs of *Allium sativum* by steam distillation method. Thin layer chromatography of oil revealed seven spots having R_f values of 0.12, 0.30, 0.43, 0.51, 0.69, 0.85 and 0.89 respectively. IR spectrum indicated the presence of diallyl disulphide, allyl propyl disulphide, diallyl thiosulfinate, Z-Ajoene and E-Ajoene. The protection potential of the essential oil was assessed by exposing three week old adults of *T. castaneum* to wheat grains treated with garlic oil dissolved in acetone at five different concentrations ranging from 100-500 $\mu\text{g mL}^{-1}$ respectively. Complete mortality was observed after 4 days of treatment at 500 $\mu\text{g mL}^{-1}$. The percent mortality was found to increase with increase in number of treatment days and concentration. The results revealed that garlic oil was effective in providing protection to wheat grains against *T. castaneum* infestation. Maximum protection was observed at 400 and 500 $\mu\text{g mL}^{-1}$ concentrations.

Sesquiterpenoids from vetiver oil (*Vetiveria zizanoides*) and their transformation products were tested as antifungal agents. Khusinoldiolmonobrosylate effectively inhibited spore germination in *Alternaria alternata* and *Fusarium oxysporum*. N-Khusilidene-p-methoxy aniline inhibited spore germination only in *Alternaria alternata*. Epikhusinol, N-Khusilidene-p-fluoroaniline and N-Khusilidene-p-bromoaniline inhibited spore germination only in *Fusarium oxysporum*. Parthenin and its derivatives prepared were tested for their bioefficacy against adults of *Tribolium castaneum*. All the compounds exhibited complete mortality at the spiking level of 10,000 $\mu\text{g g}^{-1}$. Reduction product was found to be most potent followed by parthenin, diethanolamine adduct, methanol adduct and diazomethane adduct. Neem oil, extracted from kernels of neem plant on column chromatography yielded hexane, ethanol and chloroform extracts. Bioefficacy studies showed that ethanol and chloroform extracts had similar insecticidal activity against *Tribolium castaneum* which was more than the hexane extract.

New pyrazoline derivatives of alantolactone and isoalantolactone were synthesised. The carbon chain at C-13 was extended by treating alantolactone and isoalantolactone with diazomethane, diazoethane and diazopropane to form substituted pyrazolines. The structures of all the compounds were elucidated by IR, and $^1\text{H NMR}$ spectral techniques. The isolated compounds and their derivatives were screened *in vitro* for their antifungal potential at various concentrations against *Alternaria brassicae*, *Penicilium italicum* using spore germination inhibition technique and *Rhizoctonia solani* by poisoned food technique. The percent spore germination inhibition for *Alternaria brassicae*, *Penicilium italicum* and percent mycelia growth inhibition for *Rhizoctonia solani* was calculated. All the compounds showed fairly good fungitoxicity against the test fungi with ED_{50} values of less than 500 $\mu\text{g mL}^{-1}$. Isoalantolactone was found to be more fungitoxic than alantolactone. Diazomethane derivatives were more fungitoxic than diazoethane and diazopropane derivatives; there by showing that increased chain length at C_{13} decreased the fungitoxic effect. Interestingly the compounds were more fungitoxic to spores than mycelian growth.

Synthesis and Growth Retardant Activity of Quaternary Salts

A number of quaternary salts were prepared and tested as plant growth retardants. The tertiary amines required for the synthesis of these salts with ether, ester, cinnamic acids, glycidyl ether, glycidyl ester functionalities

having aliphatic, aromatic, terpenic and alicyclic moieties were prepared by using different reactions. Convenient and inexpensive methods were developed for chemoselective reactions. Aldehydes were chemo selectively reduced in the presence of other carbonyl moieties using thiourea dioxide (TUDO) in aqueous ethanolic system. A new methodology of great synthetic importance involving the use of triacetoxyborohydride and diacetoxyborohydride to reduce the triple bond in the presence of double bond was developed. Quaternary salts as well as ammonium salts have been tested for their biological activity on *Phaseolous aureus* on turnip seeds or/on *Orzya sativa*. Some of the compounds have shown comparable plant growth retardant activity to that of CCC or ABA on the laboratory scale. In some cases it has been observed that substituents which enhanced the positive character on the quaternary nitrogen showed more retardant effects.

Analysis of Samples for Heavy Metals

Validated methods for the analysis of heavy metals in water, wheat flour, milk and tomato using Atomic absorption Spectrophotometer. A method for estimation of nine elements, namely; lead, potassium, copper, iron, calcium, magnesium, manganese, sodium and zinc in deionised water, using AAS flame technique is reported. Fresh deionised water prepared from Millipore water purification system with Biocell and Milli Q was acidified at 0.2 percent level using Suprapur nitric acid. The acidified deionised water was spiked at $2 \mu\text{g mL}^{-1}$ (Pb, K, Cu, Ca, Mn, and Zn), 1ppm (Fe) and $0.3 \mu\text{g mL}^{-1}$ (Mg and Na) levels with standard solutions of each element and the graph was plotted separately for each element. The correlation coefficient was close to 0.999. Characteristic mass for all the standards used in plotting the graph, for each element were in the range of $\pm 20\%$ of the recommended characteristic mass. The recoveries for lead, potassium, iron, copper, calcium, magnesium, manganese, sodium and zinc were found to be more than 90 percent, respectively. The method detection limit and limit of determination for all nine elements were determined.

The study was planned to standardize method for the estimation of five elements i.e., cadmium, chromium, lead, arsenic and zinc at $100 \mu\text{g L}^{-1}$, $500 \mu\text{g L}^{-1}$, $1 \mu\text{g mL}^{-1}$, $6 \mu\text{g mL}^{-1}$ and $20 \mu\text{g mL}^{-1}$ respectively in wheat flour using micro-wave sample preparation system (MSPS) and atomic absorption spectrophotometer (AAS). The samples were digested in MSPS using supra pure nitric acid. A five-point graph for standard of each element was plotted separately. The correlation coefficient was close to 0.999. The characteristic mass for all the standards used in plotting the graph, for each element were in the range of ± 20 percent of the recommended characteristic mass. The recoveries for cadmium, chromium, lead, arsenic and zinc were found to be more than 90 percent respectively. The method detection limit and limit of determination for all five elements were determined. Efforts were made to standardize method for the estimation of five elements i.e., copper, cadmium, iron, lead and zinc at 5,4,5,25 and $2 \mu\text{g mL}^{-1}$ respectively in tomato using micro-wave sample preparation system (MSPS) and atomic absorption spectrophotometer (AAS). The samples were digested in MSPS using supra pure nitric acid. A five-point graph for standard of each element was plotted separately. The correlation coefficient was close to 0.999. The characteristic mass for all the standards used in plotting the graph, for each element were in the range of ± 20 percent of the recommended characteristic mass. The recoveries for copper, cadmium, iron, lead and zinc were found to be more than 90 percent respectively. The method detection limit and limit of determination for all five elements were determined.

The method for the estimation of five elements i.e., copper, cadmium, iron, lead and zinc at 6, 4,5,20 and $2 \mu\text{g mL}^{-1}$ respectively in milk using micro-wave sample preparation system (MSPS) and atomic absorption spectrophotometer (AAS) is reported. The samples were digested in MSPS using supra pure nitric acid. A five-point graph for standard of each element was plotted separately. The correlation coefficient was close to 0.999. The characteristic mass for all the standards used in plotting the graph, for each element were in the range of ± 20 percent of the recommended characteristic mass. The recoveries for copper, cadmium, iron, lead and zinc were found to be more than 85 percent respectively. The method detection limit and limit of determination for all five elements were determined. Analyzed heavy metals in 301 samples of drinking, effluent and irrigation water, milk, cheese, paneer, cereals, pulses, rice, oil, wheat and gram flour, vegetables, fruits, turmeric powder, herbal powder, biofertilizers, bioinsecticides, organic manures, urine and processed foods. Analysis helps the clients to export their products and the laboratory to generate funds.

Twenty two samples of turmeric powder samples were collected from different markets of Ludhiana to assess the extent of heavy metal contamination. All the samples of turmeric were found to be contaminated with one or more toxic metals. However, none of the samples were found to contain arsenic. The study revealed that 4.5, 27.3, 31.8 and 63.6 % of the samples were found to contain cadmium, lead, zinc and copper above their respective permissible limits of 0.1, 10, 25 and 5 mg kg⁻¹ respectively prescribed by PFA.

Adsorption of Heavy Metals

Adsorption of manganese by soils was found to be affected by pH, organic matter, and concentration of adsorbate, time of exposure, temperature of incubation and nature of supporting electrolyte. Adsorption of copper by soils has been found to be influenced markedly by concentration of adsorbate, pH, and time of exposure and temperature of incubation. The effect of temperature was not uniform for the test soils and adsorption of copper was more at high pH. The adsorption isotherms of copper by soils, clay minerals and carbon were L-shaped and obeyed first order rate equation. The magnitude of adsorption has been found to be enhanced by combined oxygen.

Chemistry of Drugs

Kinetic studies on the interaction of drugs namely paracetamol, ibuprofen, caffeine and sulphamethazole with picric acid revealed that the reaction took place in two steps. The specific rate constants were also determined. The complexes of sulphamethoxazole, trimethoprim and 5-chloro-7-iodo-8-quinolol with some metal ion acceptors were synthesized and characterized. Chemical and spectroscopic studies on molecular complexes of antibacterial and antiameobic drugs as donors with picric acid and silver picrate as acceptors were carried out. The potentiometric studies of the complex formation of nimosulide with various transition metal ions in different aqueous organic mixtures were carried out to determine the metal-ligand stability constants.

Chemistry of Nanoparticles

XRD, TEM and VSM techniques were employed to study cadmium doped magnesium ferrite nanoparticles. Mg_{0.6}Cd_{0.4}Fe₂O₄ displayed maximum saturation magnetization and particle diameter was approximately 34nm. XRD results displayed line broadening. Synthesized pure magnesium ferrite was used as adsorbent and lead adsorption study on synthesized ferrite and activated charcoal is in progress.

Economics and Sociology

Migrant Agriculture Labour

An analysis of the dynamics of migrant agricultural labour in Punjab revealed that 98 per cent of the migrants started coming to the State after 1975. About 93 per cent of them belonged to Bihar and Uttar Pradesh and five per cent came from Nepal. The major factors determining migration were poverty, unemployment and low wages in the native areas of the migrants. The total number of migrants during the year 1995 was estimated at about 3.87 lakh during the lean period and about 7.74 lakh during the peak period of work load. It is estimated that the number of migrants increased by 35.31 per cent in 1995-96 as compared to that in 1983-84. The total earnings of the entire migrant agricultural labour force were estimated at Rs 534.35 crore in 1995-96, out of which the remittances to their native places amounted to Rs 354.75 crore and the remaining amount of Rs 179.59 crore was spent in the Punjab state itself.

Income and Expenditure Pattern of Farms

Income, employment and expenditure patterns vary considerably among different farm size categories and different regions of the state. There is 17 per cent increase in the average operational size from 3.18 hectares in 2001 to 3.73 hectares in 2009. On an average, a farm family is employed to the extent of 136 man days out of 294 man days in a year. About 46 per cent of the family labour remains unutilized in Punjab. The use of tractor is just

171 hours in a year out of which 130 hours is in crop farming, 29 hours are hired out and 12 hours are used for social purpose. On the whole, the utilization capacity in case of tractor and diesel engine is very low at 16.14 and 17.88 per cent respectively. The investment on machinery is highest (37%) followed by livestock (25%). Average investment is Rs. 77000/ hectare. An average farm family in the state earned Rs. 2, 41,975 as a total farm family income in the year 2008-09, contributed mainly by crops followed by dairying. The dairying enterprise was more popular amongst the marginal farms where its contribution towards gross farm family income was 35.5 per cent. The average farm business income both on per farm and per hectare basis was Rs. 2, 83, 010 and Rs. 76,000 in the State. The per capita and per earner farm business income in the state was estimated at Rs 19,981 and Rs. 72,572, respectively. Average farm expenditure per household was Rs.89, 248 in the state.

About 9.60 per cent of the farm families are living below the poverty line in the state. These families were earning less than Rs. 5550 per head in year 2008-2009. The number of operational holdings in the state decreased from 11.17 lakh in 1990-91 to 9.97 lakh in 2000-01. The maximum decline was observed in case of marginal and small farmers i.e. by about 2 lakh. Every 6th farmer in Doaba (16%), every 9th in Malwa (11.8%) and every 19th in Majha (5.3%) have left farming. Likewise, 1/5th of the farmers left farming in Sub-mountainous region as compared with about 1/10th in the Central and South-Western regions. The important reasons for leaving farming were identified to be low income from farming, division of land and repayment of old debt. About 22 per cent of the small and marginal farmers of the state who left farming joined labour market. Another 21 per cent adopted some low-investment low-earning self-employment ventures like flourmill, repair shop, construction work, grocery shop, etc. This is topped by another 10 per cent as dairy/milkmen. Another 10 per cent are sort of distress-rentier class, who do nothing but live on meagre earnings of land rent or interest on deposits from sale of the tiny piece of their holdings, perform no useful economic activity and therefore, some of them either indulge in bad habits or start taking intoxicants. About 7 per cent have emigrated elsewhere/abroad and 6 per cent are working as truck/taxi/auto drivers or van operators.

Ground Water and Fertilizers Use

Judicious use of groundwater resource is must for sustainability and can enhance incomes to the farmers. A three pronged approach i.e. promoting water saving technologies such as Tensiometers and Direct Seeding in rice, crop diversification towards basmati, baby corn, sweet corn and some other vegetables and exploring the role of insurance products in agriculture and building a viable sup.

Fertilizer use varies substantially across different regions of the country. The use is low in rainfed areas like Rajasthan while it is very high in irrigated areas like Punjab state. There is little scope to increase the fertilizer use in high fertilizer using areas. The best route to increase the fertilizer use is to increase the area under irrigation. In order to rationalize the nutrient ratio (NPK ratio), which currently is highly tilted towards nitrogenous fertilizers, there is need to encourage fertilizer application after soil testing. There is need to build up a strong infrastructure for soil-testing in the state. The value marginal productivities of fertilizers are much higher than their marginal costs in the states using medium to low levels of fertilizers. This fact points towards the need to refocus the efforts in promoting the fertilizer use. Marginal increase in fertilizer use in West Bengal, Tamil Nadu and Assam and other medium to low fertilizer using states will generate much higher returns by increasing yield and profits. Further, there was need to emphasize the importance of micronutrients in crop production in the states of very high use of macro nutrients such as Punjab and Haryana as the marginal returns to the micronutrients usage are higher than their marginal costs. Fall in relative price of fertilizers, increase in yield and greater availability of institutional agricultural credit helped increasing use of chemical fertilizers in rice and wheat crops in the state of Punjab. The impact of increase in area under high yielding varieties on fertilizers use was also significant. The farm yard manure and micro nutrients were significant determinants of productivity of wheat and rice warranting their application for improving soil fertility and availability of minor elements.

Agricultural Credit

The agricultural institutional credit has increased tremendously in Punjab during the last one and half decade with the growth rate of 14.1 per cent per annum at current prices and 6.1 per cent per annum at 1990-91 (input)

prices. The highest growth was observed during the years 2000-01 to 2004-05. Per hectare credit increased from Rs. 3883 during the year 1990-91 to Rs. 13476 crores at constant input prices. The commercial banks dominated for institutional finance to farmers in Punjab and reached a share of 74.4 % in 1990-91. Thereafter, it declined to a low of 53.8 % in 1997-98 and increased again to 71.6 % in 2004-05.

Farm Indebtedness

About 89 per cent of farm households in Punjab agriculture were under debt with an average amount of debt of Rs. 201427 per household in the year 2005-06. The whole farming community in the state was estimated to be under total debt of Rs. 21064 crores during this year out of which institutional loan was approximately 62 per cent and the remaining 38 per cent came from non-institutional sources namely commission agents. The rate of interest charged by the commission agents varied from 24 to 36 per cent per annum in most of the cases. The number of indebted farmers was the highest in case of semi-medium farmers and the lowest in case of large farmers. However, the small farmers had the highest per acre debt. Debt was highest in the cotton belt of the state due to failure of cotton crop during the decade of nineties. The tractor owning farmers were more heavily indebted than other farmers but they had a higher share of the institutional loan. The expenditure on social festivities, particularly when it exceeds Rs.50, 000 caused higher indebtedness.

To solve the problems of persistent indebtedness in the farming community there is a need to monitor the functioning of the non-institutional sources of finance and the causes of indebtedness at regular intervals. There is an urgent need to strengthen the cooperative sector so that individual farmer need not make heavy fixed investments in machinery and equipment. Agricultural service centers with village cooperative societies should be encouraged so that the farmers can hire in the machinery on payment basis. Loans to the farmers for heavy machinery should be provided taking into consideration the three R's i.e. Returns, Repaying capacity and Risk bearing ability of the farmer. Non-farm employment and dairy business can provide ample opportunities for employment to the rural poor and supplement their income. Implementation of crop insurance scheme in Punjab will help the farmer to fight against natural disasters. Mass campaign against use of intoxicants and extravagant expenditure on social festivities will definitely help the Punjab farmer get out of indebtedness.

Suicides by Farmers and Agricultural Labourers

A census survey on farmers and agricultural labourers' suicides, it was estimated that 2890 farmers and agricultural labourers committed suicide during the period of 2000 to 2008 in the districts of Bathinda and Sangrur. Out of 1757 suicides by farmers about 80 per cent were small and marginal farmers. The main reason for committing suicides was the economic distress. About two-thirds of the victims committed suicide due to heavy debt, which was beyond their capacity to repay. Very large proportion of the debt was owned to the non-institutional sources. The average debt-income ratio was as high as 7.75 in Bathinda and 4.57 in Sangrur districts. More than 50 per cent of the suicide victims belonged to the productive age group of 30-50 years. Loss of status due to selling off land for repaying the debt was also one of the important reasons for suicides in non-debt related suicide cases.

Mathematics, Statistics and Physics

Mathematics

One, two and three dimensional mathematical models have been developed to investigate the effects of environmental conditions, blood flow and metabolic heat generation on the temperature distribution in skin and subcutaneous tissues (SST). The solutions provide inter-relationships between interface temperatures, thermal conductivities, metabolic heat generation, blood perfusion, thicknesses of various layers of SST and ambient temperature. The trend of temperature profiles in SST reflects the dependence of temperature distribution not only on the environmental conditions and biophysical variables but also on the geometry of SST. The temperature of nodes of tumour region crosses the body core temperature at low environmental temperature.

Parallel algorithms has been developed for the solution of tridiagonal and quasi pentadiagonal system of linear systems on hypercube and Josephus cube. The speed up and efficiency for the algorithms are calculated both theoretically and numerically. A parallel algorithm for computing N point Lagrange Interpolation on a n-dimensional hypercube (where N is exactly divisible by 2^n) is also developed. The speed up and efficiency of the algorithm is calculated both theoretically and by simulating it over a network of PC's.

Mathematical developments in electrochemical techniques for accurate measurement of low concentration of electroactive ions in soil and water samples as well as in the prediction of chemical reaction rates have been widely acclaimed in scientific circles as 'Singh and Dutt' approximation.

Statistics

The estimator was developed for the estimation of multi-characters like production of milk/ eggs /honey and the population parameter on socially disapproved items like drug addiction for which the individuals are reluctant to respond. The estimate for milk production in zone-II was maximum (6,002,488,399 Ltrs.) followed by Zone-III (1,746,994,779 Ltrs.) and Zone-I (1,356,680,814.31 Ltrs.). The figures for honey were estimated to be 8,383,009 Kg in Zone II followed by 1,293,582 Kg. in Zone III and 1,183,154 Kg. in Zone I. The estimates for the production of eggs were maximum in Zone II (1,654,970,671) followed by Zone-III (895,630,259) and Zone-I (570,442,938). The study revealed that in zone-II, the number of drug addicts were maximum (3,252,692) followed by Zone-III (896,074) and Zone-I (647,032). The study was also extended to the socio-economic characteristics vis-à-vis extent of drug dependence and prevention / intervention of drug abuse and their relationship. The major reason for taking drugs was curiosity, while dealing with psychological problem. Among emotional problems lack of love was the major cause of taking drug irrespective to land holdings. Under miscellaneous; inadequate education, unemployment and bad company were the reasons for taking drugs.

The study of growth performance, variability and instability of pulses and food grains in Punjab state was conducted for the years 1960-61 to 2009-10. The study had shown that growth rate of pulses production decreased significantly during this period. It was -8.09 percent per annum during sixties and decreased to -9.16 percent per annum during 2000-01 to 2009-10. This happened due to significant decrease in area i.e. -7.17 percent for whole period under pulses, whereas production of food grains increased at the rate of 4.62 percent per annum i.e. five times because of significant increase in area and yield of food grains. The instability in production of pulses is much higher i.e. up to 35.74 percent. Variability and Instability increased in pulses but decreased in food grains.

For the first time an estimator of the proportion and mean of a stigmatized character of a hidden group (G) in a finite population was developed.. An estimator of population total using Optional Randomized Response Technique corresponding to PPSWR and PPSWOR sampling designs was developed. This method was used to collect information on the sensitive character thereby trying to minimize respondent's hesitancy in disclosing their answer.

The cumulative cube root method developed was used in sample surveys in the areas of Economics and Sociology, Extension Education and Business Management, etc. New randomized response models using efficient devices was developed which were useful in sample surveys to collect information on sensitive issues like income tax, drug abuse, sex-related diseases, etc. A survey study of the factors influencing milk production of cross-bred and indigenous milch animals has helped to answer many complex questions on the profitability of keeping cross-bred Holstein-Friesian cows. Software have been developed for data management in wheat germplasm to retrieve stocks with desired traits for hybridization programme and for predictive modelling in soil sciences and agrometeorological studies.

Physics

Two Experiments were carried out to study the effect of magnetic field on germination and vigour of soybean seeds (SL-295). In first experiment, Seeds were exposed to varying strength of magnetic field and for fixed duration. In second Experiment, seeds were exposed for constant strength of magnetic field and for varying time

duration. It was concluded that the exposure of magnetic fields of 50 and 100 gauss for period nearly 40 hours to 48 hours increased the percent seed germination and vigour in soybean (SL-295).

Moisture sorption and desorption studies of seeds of Gram [GPF2 (irrigated), PDG4 (rainfed)] and Mustard [RL1359(irrigated), PBR97(rainfed)] were carried out at 30°C and 25-85% relative humidity (RH). It was observed that varieties recommended for rainfed cultivation have smaller area under their moisture hysteresis loops as compared to the seeds classified for irrigated cultivation for gram, while no such trend was observed for mustard seeds.

Many pharmaceutical products are obtained by leaching of plant roots, leaves and stems. In the present era, extraction or leaching is extensively used as a unit operation to obtain many important food components, for example sugar from beets with hot water, lipid from oil seeds and animal tissue, vegetable meal from defatted meals, extracts from tea leaves and coffee grounds, hydrocolloid from algae and plant tissue and oleoresins and pigment from plant.

The electrical conductivity of orange and tomato juices were experimentally measured for determining their dependence upon temperature and pulp present in juice. The contribution to electrical conductivity due to pulp was evaluated on the basis of a theory developed for this study. It was observed that around 0.03 Kg/liter of pulp, produces maximum contribution for electrical conductivity for both the juices.

School of Business Studies

During the period under report, the research in the School of Business Studies focused on the areas of agribusiness management, marketing management, human resource management, financial management, entrepreneurship, and SMEs (small and medium enterprises). The significant research findings are as follows:

Agribusiness Management

In agri-business area, some of the major research contributions include studies on procurement system of fruits and vegetables in retail, consumer satisfaction towards retail milk selling agencies, consumer attitude towards organic food, integrated value chain management, application of critical path analysis in agriculture for multiple crop planning in various agro-climate zones of Punjab, economics and management of poultry and dairy farming, export potential of cut flowers, basmati rice and mushrooms from Punjab, marketing of fruits and vegetables and cost structure of cotton yarn. Export Orientation of food processing industry in Punjab was studied and it was found that export orientation is still in its nascent stage in this industry. Research on consumer preferences regarding organized fresh fruits and vegetables retail outlets revealed that the most important attributes influencing the consumers to buy fruits and vegetables from these stores were product quality, location and variety. A study on examining awareness and adoption of bio-fertilizers among farmers revealed that majority of the farmers were aware of bio-fertilizers. A study undertaken to find out the factors influencing the tractor purchase decision of farmers highlighted that majority of farmers had their own tractors and four major reasons given by the farmers for buying a tractor were - timeliness of operation, reduced availability during peak season, faster work and status symbol.

Marketing Management

In this area, the major research contributions pertain to advertising and marketing strategies of different industries/companies, management of sales force, point-of-purchase and in-store display strategies, brand equity and consumer complaints. The faculty of the school made an attempt to understand the influence of large organized retailers on small unorganized retailers. Also, research was undertaken on market orientation and service quality, brand equity, understanding purchase behaviour towards select branded commodity products. Another research study on understanding the youth market with special reference to purchase behaviour highlighted that youth preferred to purchase national brands for durables and local brands for non-durables.

Human Resource Management

In the area of human resource management, studies were related to occupational role stress, employment in organized retail and other sectors. Research was conducted to study the association of Human Resource Development (HRD) climate with job satisfaction in selected organizations. It was found that HRD climate and job satisfaction had a positive relationship.

Financial Management

Research in the field of financial management includes studies on effectiveness of equity portfolio protection strategies, performance of MACD Indicator, naïve versus mean variance framework of diversification, management of inventories and working capital, profitability and export financing practices. The research contributions are also made in the areas of computerization of MIS and management control systems in selected companies. Another study found that the survival and growth of the corporate sector depend to a large extent on its financial performance. Also, the research was undertaken pertaining to adoption of micro insurance, role of self-help groups by the faculty of this school.

Entrepreneurship

Entrepreneurship development related studies are on enterprise social responsibility, export orientation and cluster development, growth of entrepreneurship in Punjab, especially in the rural areas, techno-economic feasibility of setting up small units and the role of government agencies in promoting entrepreneurship culture.

Small and Medium Enterprises

In the current business scenario, ensuring that the SMEs in manufacturing and service sectors grow at a healthy rate, is crucial for the overall growth of the Indian economy. For this to happen, the small and medium enterprises have to become competitive. The faculty members of the school have undertaken research studies to analyze the competitiveness, existing business practices, and constraints in textile and clothing industry, auto components sector, sports goods industry, floriculture and other emerging sectors of Punjab.

Some of these studies have helped the agri-business companies/entrepreneurs to improve the effectiveness and efficiency of resources used thus improving their competitiveness. In future, there would be a renewed emphasis on agri-business strategies and policies with special focus on fruit/food processing industry, supply chain management and the management of rural development and entrepreneurship. Organized retailing in India is no more restricted to the metros and major cities. With consumption in metros already being exploited, manufacturers and retailers of products such as personal computers, mobile phones, automobiles, consumer durables, financial services etc. are increasingly targeting consumers in Tier II cities and towns. Further, the rural market is booming beyond everyone's expectation. The future areas of research in rural retailing include rural retail strategies and practices, rural retail formats, information gathering and processing in rural retailing, operations management in rural retail outlets. The specific areas of research in Agricultural marketing information systems may be marketing research and information network, agricultural marketing reforms, market infrastructure schemes and subsidies, contract farming.

HOME SCIENCE

Research achievements in the various disciplines of Home Science *i.e.* Food and Nutrition, Family Resource Management, Human Development, Clothing and Textiles and Home Science Extension and Communication Management are summarized below.

Food and Nutrition

Community Nutrition

Nutritional status of children and adolescents belonging to various income groups in different agro climatic zones of Punjab indicated dietary inadequacies of cereals, pulses and leafy vegetables that lead to the prevalence of malnutrition, B-complex deficiency diseases and anaemia among vulnerable groups. The high prevalence of anaemia among adolescents girls (90%) and children (96%) as observed. The prevalence of malnutrition in children was recorded as underweight (43%), stunting (40%) and wasting (27%). There was a significant association between the level of malnutrition and anaemia with academic and physical performance. Nutrition intervention studies based on supplementation and programmes based on information, education and communication (IEC) were conducted to prevent malnutrition and anaemia. A large number of value added products using cereals, pulses incorporated with underutilized greens (cauliflower greens, colocasia, Bengal gram leaves, amaranth and drumstick leaves) have been formulated after nutritional and organoleptic trials. Weekly iron supplementation along with natural source of Vitamin C was more beneficial than synthetic Vitamin C to restore normal levels of red blood cells, haemoglobin and iron.

The results of studies on impact of energy and iron status on physical fitness of college girls and young women indicated that energy deficiency and moderate degree of anaemia significantly reduced the physical work efficiency. The intake of heavy metals such as lead, cadmium, nickel, copper and iron was found to be higher than provisional tolerable limits/ recommended levels among children and women living in the sewage irrigated areas.

The studies on evaluation of Mid Day Meal Scheme, a school feeding programme indicated the contribution of one-fourth of energy and half of protein with negligible contribution of micronutrients towards the daily nutrient intake of children. The mid day meal was found to be a substitute rather than supplement for the home meal.

Nutritional Evaluation of Foods/ Diets

Nutritional value of cereals improved significantly with supplementation of legumes, green leafy vegetables, milk and milk products. Cereal –pulse combination in 80:20 ratio along with small quantities of green leafy vegetables and milk helps in reducing the nutrient deficiencies. Oat flour supplementation in wheat flour in the ratio 1:3 is more beneficial than 1:4 to maintain body weight, blood pressure and lipid profile. Oat supplemented idli, salty biscuits, and *namak pare* were highly acceptable at 15% level, *dalia* and *khichdi* at 25% while *panjiri*, *missi roti*, vegetable rolls, pancake and poha at 30% level of oat supplementation. The pearl millet based recipes prepared from PHB-2168 variety had nutritive value comparable to wheat recipes. Maize flour based recipes when supplemented with pulses and milk and milk products improved their protein quality. Maize and pearl millet can be substituted for wheat/rice-based diets satisfactorily.

Amla powder prepared from five different cultivars was used as a substitute to mango powder in selected food preparations which were evaluated organoleptically on the basis of physico-chemical analysis of amla powders at the end of three months, TSS increased from 1.21 to 2.46%, acidity 0.14-0.45% and total sugars 0.09-0.15%. For ascorbic acid percent loss was found to be 14.16-19.07%. Organoleptic evaluation of different amla baked products *i.e.* fresh amla cake, amla date cake, amla apple pie, amla jam cookies and amla powder cake and amla salty biscuits which were prepared using fresh amla pieces, pulp and amla powder was found to be highly acceptable.

Bengal gram whole, *curry*, green gram *dal*, *kabuli channa* and *missi roti* were supplemented with cauliflower leaf powder (5% and 7.5%) and lemon juice (15%). Supplementation reduced the level of phytates (5.5 to 8.6%) and polyphenols (2.06 to 5.5%) in cooked value added products, which further increased their *in vitro* protein and

starch digestibility. For vegetable usage of cowpea variety CL-367 developed by PAU the optimum time of pod picking is 9th day after flowering to obtain maximum sensory and nutritional attributes. To improve protein digestibility and mineral retention, the optimum time of cooking of cowpea seeds is 2-3 minutes by pressure cooking and 10-15 minutes by boiling and microwave cooking.

Nutrient Availability and Their Interactions

Pressure-cooking, roasting, dehusking, sprouting and fermentation destroyed the anti nutritional factors and enhanced the nutrient availability. Fermentation brings the body zinc balance to positive from negative in unfermented wheat diet fed group. Additional vitamin C in the diet significantly improved iron absorption from cereal based diet, whereas addition of egg reduced the absorption. Addition of small quantity of milk (150 ml/d) to cereal-based diets improved the absorption and retention of iron, copper and zinc compared to addition of equal quantity of legumes. High dietary fiber resulted in low availability of micronutrients. Dietary zinc deficiency reduced protein utilization of wheat and rice diets and also decreased mobilization of Vitamin A from liver. Available lysine was linearly related to nitrogen balance and protein quality at low levels of energy consumption. Fermentation and autoclaving of pulses resulted in the increased availability of zinc. Absorption of b- carotene from basal diets increased when supplemented with spinach, mustard leaves and carrots. Wheat diet supplemented with milk showed a protective effect against lead retention damage compared to only wheat and wheat legume diets. Blood levels of copper, zinc and iron were negatively correlated with lead and cadmium intake in children. Growth efficiency of rats with radish oil at 10 and 20 % was better than the mustard and turnip oil.

Therapeutic Nutrition

Diabetes, hypertension and coronary heart disease has been on the rise among the community. Although the development of any disease involves the complex interplay of several factors, lifestyle choices as well as healthy diet have a significant role in the prevention of disease. Supplementation of bitter melon, jamba and fenugreek seeds (2g/d), amla powder (5g/d) and sprouted fenugreek seeds (25g/d) and flaxseeds (5g/d) for a period of three months was found to be an effective measure to control blood glucose and lipid levels. Supplementation of flaxseeds at the level of 5g and 10g were supplemented for a period of two months to the Coronary Heart Disease patients. It revealed significant reduction ($p < 0.01$) reduction in blood pressure, total cholesterol and triglycerides and significant ($p < 0.01$) increase in HDL-C due to presence of soluble fibre in flaxseed, which decrease the incidence of Coronary heart disease. An imperative increase in HDL-C with amla powder (5g/d) along with nutrition counseling was also observed.

Spirulina in the form capsules were given to the Non Insulin Dependent Diabetics Mellitus male subjects for a period of 60 days. There was improvement in the fasting blood glucose, post prandial levels and lipid profile. It could be inferred that 2g of spirulina supplementation is effective measure to bring favourable and significant improvement in diabetic state as compared to 1g dosage. Supplementation of 100 mg and 200 mg of Aloe Vera L gel powder along with nutrition counselling significantly reduced blood glucose levels and blood pressure along with improvement in lipid profile of the non insulin dependent diabetes. Probiotic yoghurt supplementation containing strains of *Lactobacillus acidophilus* alone and *Lactobacillus acidophilus* along with *Streptococcus thermophilus* had a significant effect in the improvement of lipid profile of cardiovascular disease patients.

Kidney stones among males were found to be associated with the consumption of foods rich in oxalates, calcium, refined carbohydrates and animal proteins. Incidence of goitre was associated with low iodine consumption from natural diets in goitre prone areas. Most of the iodized salt available in the market did not have added iodine. Toxicity effects of fluorine were more common among men in the areas where drinking water contained more than 2 ppm of fluorine.

Food Safety

Sanitation and food hygiene in hotels, army langars, police constable messes and *dhabas* were very poor. The findings of the survey of home food preparers from rural and urban areas of Ludhiana District about the

awareness towards food safety revealed that all the respondents were considerably aware about the food safety issues (9.25/15). A significantly negative correlation was found between food safety awareness and incidence of food borne diseases thus emphasizing that with a better food safety awareness, the incidence of food borne diseases decreased.

The microbial estimation of the food samples revealed that 40 percent of the samples of kneaded dough were found to be contaminated with *E coli*, 53 % of the samples of cooked dal were found to be contaminated with *Aeromonas*, 66.7% of the boiled potato samples were found to be contaminated with *Aeromonas*, *Salmonella*, *Staphylococcus*, 60 % of the cheese and *kheer* samples were found to be contaminated with *Aeromonas*, *Salmonella*, *Staphylococcus* and *E coli*. The respondents whose food samples were free from microbial contamination were having a significantly higher food safety awareness score than the respondents with microbial contamination in the food samples ($p < 0.01$). Thus, a higher food safety awareness can be instrumental in reducing the microbial contamination in food.

Samples of cauliflower, cabbage and brinjal were procured from local market as well as farm gate from different locations of Punjab for residue analysis. Simulated trials of endosulphan and quinalphos were conducted and the samples were processed with different selected household processing methods i.e. washing, blanching, cooking, sodium chloride and acetic acid. It was found that in sample treated with quinalphos, cooking showed maximum reduction (76.6%) in pesticide residue followed by blanching (70.3%). Similar percent residue reduction was observed in washing and acetic acid i.e. 66.9% and least reduction was with the treatment of sodium chloride (92.9%). The results revealed that in sample treated with endosulphan, cooking (79.1%) and washing (61.8%) showed maximum reduction. Least percent residue reduction was observed in case of acetic acid (23.6%). The samples of all the vegetables were containing the majority of the pesticide residues which were not present in the recommended official list given by Codex Alimentarius Commission. This may be attributed to the spraying of non recommended pesticides on the vegetable crops and is thus, an area of concern in context of food safety.

Clothing and Textiles

Development of Textile Technologies for Functional Utility

The conditions for dyeing cotton, wool, silk and terycot with natural dyes were optimized. The natural dyes used were maddar, annatto, kachnar, walnut, *Aloe vera*, chob chini, revindchini, chereta, spinach, henna, onion, tea, etc. Both natural and synthetic mordants were used for mordanting. The optimum pH for extraction of dyes ranged between 7-8, extraction time 30-75 minutes. The dyeing pH was 3-6, while the material concentration varied between 0.5-3.0 g/ g of fabric at dyeing time 60-105 minutes. Mordanting conditions for each dye were also optimized. It was found that the optimized dyeing and mordanting conditions improved light, rubbing and washing fastness. Enzymatic pretreatment of cotton, wool and silk using cellulose and protolytic enzymes led to increase in CIE Lab values, depicting an increase in dye absorption and improved the fastness ratings of dyes.

Clothing for agricultural pesticide applicators was designed using a water repellent finish on cotton and polyester/cotton blend. This gave outstanding water and oil repellency that was found to be good, even after 30 launderings. The finish performed better on polyester/ cotton that was recommended to make seven protective garments. A partial cover for face and gloves in combination with *kurta* and *pyjama* gave the maximum protection against pesticides.

Starch applied as a finish on cotton clothing of pesticide users was helpful in reducing the amount of pesticide residue. Conditions for washing the treated fabrics were optimized. These included – concentration of heavy duty detergent - 2%, temperature - 80°C and time - one hour. Masks of various kinds were designed and developed for the pesticide applicators and the workers harvesting wheat. Protective gloves for okra pluckers were developed that led to improvement in productivity.

Aromatherapeutic products - gloves, kneecaps, pillow covers and handkerchieves, for use by persons having joint pains or asthma were developed by finishing cotton with microcapsules of lemon, jasmine, eucalyptus and

pine oils. Use of these products for two months by the respondents led to a decrease in medicine intake among 82.50 per cent of the respondents, changed the sleeping pattern of 50 per cent and increased the outdoor activities of 67.50 percent of the respondents.

Mulberry silk waste / wool and oak tussar waste / wool fabrics were developed by optimizing the blending proportions. Yarns having 65 silk waste: 35 wool had significantly higher ($p < .05$) strength, lesser hairiness, improved evenness and moisture regain. Blended and union fabrics developed from these exhibited excellent crease recovery, drapability, significantly lesser ($p < .05$) bending length and flexural rigidity, higher abrasion resistance, strength, moisture regain and dimensional stability. Hand values of developed fabrics showed these were suitable for women's thin winter dress materials and men's winter suitings. Value addition of the mulberry silk/wool blended fabric was done by optimizing cold reactive, hot reactive, leveling acid and milling acid dyes.

Investigations were conducted on cleansing efficiency of different natural, synthetic and home made detergents, dry cleaning solvents, effect of different stains on different fabrics like cotton, silk, polyester/cotton, wool and blends. Optimum conditions for washing with natural detergents - neem, potato, papaya, reetha, bael, siris, tuma and latzira on wool were - 10% concentration, 35°C temperature and washing time of 20 minutes. Neam was found to possess the maximum cleansing efficiency and was the most cost-effective natural detergent. Recipes for two home made detergents were standardized by washing the artificially soiled samples of white cotton fabric with ten home made detergents at 50°C temperature, for 30 min and 3% concentration. Cleansing efficiency of these detergent powders was 95 per cent. Small - scale enterprises could be established using these recipes.

Value Addition of Traditional Crafts for Entrepreneurship Development

Studies were conducted to develop products based on consumers' preferences, using various printing techniques such as screen, stencil, transfer and non conventional block printing. The substrates used were cotton and polyester/ jute. An entrepreneur could earn 13 - 31 per cent profit by making household articles using screen printing. Non conventional printing techniques were used to develop designs for suits and *dupattas* that could generate 20.8- 48 per cent profit.

Studies were conducted on to diversify the use of traditional embroideries - *sindhi*, *kantha*, *kasuti*, *phulkari* and traditional crafts - macramé, finger weaving, card weaving, *durrie* weaving etc. Innovative products such as wrist and neck bands, belts, lamp shades etc. were developed on the basis of consumers preferences. Depending upon the type of article, an entrepreneur can earn profit per cent ranging between 18 - 150 per cent through such innovations.

Designing, Pattern Making and Functional Clothing for Physically Challenged

Anthropometric measurements were standardized for different garments and age groups - infants, toddlers, school and college going girls and boys and basic blocks in three sizes were prepared. Paper patterns of designed shirts, trousers, jackets, frocks, knickers, tops were developed using these basic blocks.

Functional garments were designed and constructed for physically challenged persons having limb handicap; quadriplegics; boys and girls afflicted with poliomyelitis and cerebral palsy; arthritic and orthopedically handicapped men and women as well as mastectomised women. The special features incorporated in the garments included shoulder seam opening, elasticated side openings, change in front and back length, sleeves with openings. The lower garments were elasticated, had larger crotch of side opening at knee level and were reinforced at the points of maximum wear and tear. Easy to manipulate fasteners such as press buttons, velcro, zippers and elastics were used in full front and side opening for ease of donning and doffing.

Practices of Textile Industry and Consumers

Adoption of automation and CAD/CAM systems by knitwear industry of Ludhiana showed that 83.1 percent units used automatic machines, 72.3 percent units used CAD systems and 36.9 percent units used manual sketching for fabric designing. In garment designing, 91.9 percent units used manual sketching and 75.6 percent units used CAD system.

Documentation of rural textile micro-enterprises of Punjab revealed Malwa region had highest concentration of enterprises. Maximum number of Textile Micro Enterprises (TMEs) were self managed and started with an initial investment of Rs.5 lakh. In Malwa, acrylic yarn was mostly used as raw material followed by cotton, viscose rayon and blends for weaving shawls and blankets. In Majha, nylon was mainly used for net making and carpet weaving, followed by wool and cotton. Majority of the units used credit sale method to attract retailers for sales promotion.

In a study on the impact of marketing forces on apparel usages of adolescent girls in Punjab, a significant association was observed between the income of the parents of the respondents and the style of apparel use. The level of satisfaction of respondents with their wardrobe and parental income, age of respondents and use of different types of apparel were significant at (pd"0.05%) level. Price and new style were ranked as the most important determinants of apparel while purchases of rural and urban respondents, respectively.

Human Development

Bio-Physical Development

The overall growth profile of rural children with respect to weight and height across varying age groups and different agro climatic zones depicted that both males and females from central plain region were the tallest of all, whereas, males from central plain region and females from sub-mountain region were the heaviest than all other zones. The undernourished children were found to be considerably lagging behind their normal counterparts in both motor and mental abilities, at all age levels. The children from 'Neurotoxicant Polluted Eco-Settings' (NPS) were far below the children of 'Neurotoxicant Free Eco-Settings' (NFS) in all the parameters investigated viz. physical, psychological and social development.

Cognitive Development

Time use pattern of migrant children affected their cognitive abilities. Involvement in academics, play activities and market work improved their cognitive abilities. Quality of home environment plays an important role in the acquisition of cognitive functions and learning abilities of children. Intelligence and Emotional intelligence were found to have a positive correlation with problem solving ability.

Psycho-Social Development

Despite living in conditions of socio-economic hardship, majority of rural adolescents perceived high degree of happiness. Female adolescents perceived significantly more happiness in their life as compared to their male counterparts. Males manifested significantly higher psychoticism in their personality, greater self esteem and more independence, whereas, females were significantly more extravert and expressive. among adolescents, accepting and caring family environment and social support were significantly positively correlated with happiness. Psychotic personality pattern emerged as a strongest risk factor, whereas, Self-esteem, social support and parental acceptance emerged as the strongest protective factors.

Self concept of adolescents of working mothers was better in comparison with adolescents on non working mothers. Good home environment, positive parent child relationship, good socio-emotional climate of the school and higher level of intelligence played a vital role in the development of positive moral values. Significant positive correlation was found between corporal punishment and anxiety. Psychological problems were significantly more frequent in migrant labourers as compared to their local counterparts in industrial sector. Self- esteem was significantly higher among industrial labourers than among agricultural labourers. Self- esteem was significantly higher in local labourers as compared to migrant labourers.

Adolescent girls had significantly closer and more intimate friendship patterns as compared to boys and they confided in their friends at a higher degree and had better self concept. Few respondents in the 1st generation (MILs) showed a favourable attitude towards female foeticide whereas not even a single respondent in the 2nd generation (DILs) was in favour of the same.

Parenting Strategies

Rural parent-adolescent conflicts had their roots in parental interference and socio-economic constraints of families. Parents' education and children achievement positively affected parent-child relationship. Rural parents favoured physical and social development, whereas, urban parents favoured intellectual and emotional development of their daughters.

On the basis of situational analysis of rural adolescent girls among six agro climatic zones of Punjab, gender discrimination was quite evident. Girls were considered inferior to boys in terms of household work, educational opportunities and rituals. Girls did not know anything about legal aspects. Their low sense of self worth and self esteem comes in the way of accessing avenues for enrolling in skill training programmes. In case of school dropout girls, her world view becomes limited, her skills stagnate, her confidence levels go down making her all the more vulnerable and diffident.

Care provided by grandparents and adults other than grandparents showed very little difference in the development outcomes when compared among themselves. Grandparents were found to be major support available to rural mothers for the care of children and 'supervision' was the main task delegated to the other caregivers. Better emotional adjustment, higher social maturity and good marital relations of the parents were found to have positive correlation with positive parenting whereas, Stress deteriorated the quality of parent child relationship.

Early Childhood Education

The quality of child care services available were not of very high order. Indoor space was inadequate, outdoor space was not properly utilized, attendance was poor and limited time was spent for educational activities. Teacher-child interaction was also observed to be inadequate. Physical environment and staff-children interactions were satisfactory only in few centers.

Implementation of 'teaching values' programme had the potential of diminishing the differences in learning values which occur due to disparities in parental education. Parents' education and occupation were not associated with learning values of children. Girls required more time to adjust (1.5 weeks) as compared to boys (1.25 weeks) in early childhood care centers. The parents and care providers of the early adjusting children adopted better strategies to make their children adjust better.

Status and Management of Elderly

It was found that very few elderly females as compared to the males were enjoying Very Good Quality of Life (QOL) and that was true across all support systems. The elderly males and females experienced social isolation in comparable proportions and degrees across various dimensions of social isolation (family, friends, neighbours and coping mechanisms) and at all socio economic levels (high, middle and low). The elderly parents living with their children possessed better physical and psychological health as compared to those living in emptiness. Elderly mothers were more vulnerable to physical and psychological health problems as a result of children leaving home.

Intergenerational exchange had a varied impact on physical and psychological health of elderly in both the settings. Child to parent support reduced anxiety and anger but it increased feeling of inadequacy and sensitivity among parents. Urban adolescents had more favourable attitudes towards grandparents as compared to the rural adolescents. In aged death anxiety and religiosity was non-significantly and negatively correlated among males but significantly and positively associated with each other among females.

Children with Special Needs

Rural and urban children differed significantly in behavioural problems. Better the home environment, lesser the behavioural problems in school age children. Sibling rivalry, faulty parent child relationship, parental disharmony and broken homes were strongly perceived as causes of behavioural problems among adolescents. Auditory discrimination disability was the leading problem among primary school children, followed by the disabilities related

to coping and visual perception. Learning disabled children displayed higher degree of attention-deficit-disorders. They were more impulsive, hyperactive, day dreamers and were having poor concentration. Children receiving low quality of total home environment displayed significantly poor performance in all the learning skills.

Parental knowledge, economic condition and the resources available affected the quantity and quality of care provided to the disabled child in a family. Prevalence of learning disability was found to be 11.90 percent among school children and there is a need to sensitize teachers towards behavioral signs of hidden problems of vision and learning disability thereby helping teachers to identify these problems as early as possible.

Impact of Media and Advances in Information and Communication Technology

The majority of rural adolescents spend their leisure time by viewing television, doing household chores and personal care. Frequency and degree of internet use was significantly higher among males as compared to females. High internet use was linked with low social cognition, higher psychological inadequacy and depression. TV viewing for long hours declined perceptual and motor skills of children.

Home Science Extension and Communication Management

Designing of Instructional Media/Deliverables/Modules

Instructional media/deliverables such as printed modules, web based modules, multimedia modules, slide tape series, demonstration kits, booklets, folders, flash card sets, CDRs, etc. on different Home Science topics under different projects were developed and tested for knowledge and skill empowerment of extension functionaries, beneficiaries and formal sets of learners. In this direction, an Instructional package of 17 hypermedia and print based modules along with criterion reference mastery tests have been developed and validated for individualized and on line training of trainers. The strategy proved to be very effective in promoting cognitive learning of users in terms of gain in scores at different hierarchical levels of learning viz. knowledge, comprehension, application, analysis, synthesis and evaluation.

Adoption and Diffusion of Technology

Research was focused on adoption/ popularization/ promotion of homestead and other allied technologies. It was found that for dissemination of Home Science practices the farm women should be provided with opportunities to pass through various stages of Innovation-Decision process i.e. Awareness, Interest, Knowledge, Motivation, Action and Evaluation to enhance adoption status of Home Science Technologies.

Women in Agriculture

The multi dimensional role complexities of women in agriculture along with their receptivity towards agricultural technologies was studied in order to suggest strategies for extension training, farm women oriented extension programmes in KVKs and in the University. Study revealed that women perceived harvesting to be the most drudgery prone agricultural task followed by transplanting, carrying load on head, weeding, winnowing whereas chaffing, feeding, cleaning of cattle shed were considered to be the most drudgery prone animal husbandry tasks. Women participation was as high as 100% in activities such as offering water to animals, cutting, collection, chaffing and transportation of fodder, feeding the animals, cleaning of cattle shed and boiling of milk. The mean time spent per day for performing different agricultural activities was observed to be 2.84 hour per day over the year and the mean hours spent per day per animal for performing animal related activities were 0.65 hours per day per animal. The results also revealed that each improved implement introduced in the experimental area was perceived to be useful in reducing drudgery and improving work efficiency.

Quantitative and qualitative data base on women in agriculture from all the agro climatic zones of Punjab which is the part of All India Coordinated Research Project (AICRP) was also generated. The data consists of women profile in agriculture in Punjab, zone wise and landholding wise analysis of participation and decision making pattern of farm women in farm, livestock management, post harvest and household activities. Two books

titled 'Data Book on Women in Agriculture' and 'Qualitative Data Base on Rural Women-Ecological Friendly Empowerment' were compiled by the Technical Coordinator at National Level and Published by ICAR. The data generated by AICRP, PAU, Ludhiana was part of this document.

Capacity Building and Women Empowerment

The SHG strategy adopted for building capacities of rural women proved effective in providing opportunities to farm women for learning, sharing, consensus building on local issues, sustainable use of technologies, awareness generation and mobilizing community opinion for resolving local problems. Studies also revealed that agricultural and animal husbandry operations requiring huge inputs of time and labour were performed by women. However, the activities requiring management skills but least inputs of time and labour are still performed by men. For developing entrepreneurship skill in rural women, knowledge was perceived to be the top most requirements (59.20%), followed by technical skill (51.70%), money (43.30%), machine (40.00%) and market (27.5%). The suitability analysis of enterprises revealed dairy to be the most preferred enterprise (29.2%) followed by bakery (27.5%), preservation of fruits & vegetables (26.4%), ban making (25.8%), vermicelli (20.8%), mushroom cultivation (20.8%), floor mill (20.0%) and beekeeping (20.0%).

The women as beneficiaries of agriculture related training or units of human resource in development programmes are still being over looked in a male dominated rural sector. For mainstreaming rural women in agriculture, it was recommended that first hand information through capacity building programmes must be delivered to them. Besides, gender sensitization programmes must become important component of training of extension personnel & functionaries.

ANIMAL PRODUCTION AND HEALTH

Animal Genetics and Breeding

Buffalo breeding

The genetic improvement of buffaloes has been taken up under a Network Project on Buffalo Improvement of ICAR in 1993 which was earlier (1970) started as All India Co-ordinated Project on Buffalo Improvement. The major thrust of this project is the improvement of Murrah breed of buffaloes by undertaking the progeny testing of buffalo bulls at institutional farms and field area and then to disseminate superior germplasm to field areas. The project jointly taken up at the four participating centers viz. PAU, Ludhiana, National Dairy Research Institute, Karnal, Chaudhary Charan Singh Haryana Agricultural University, Hisar and Central Institute for Research on Buffaloes, Hisar made a significant contribution during this period.

The milk yield of buffalo herd has increased from 1671 kg in early seventies to the present level of 2389 kg with peak yield of 12.4 kg and fat percentage of 7.6 %. With the systematic selection and optimum management, it has been possible to produce buffaloes with peak yield as high as 24.6 kg day and lactation yield of 4430 kg. An elite herd of buffaloes has been established having average milk yield above 3000 kg is mated with the proven bulls for the production of bull calves, whose semen is supplied to the field areas and dairy development agencies. The remaining bull calves from the elite buffaloes are given to the buffalo breeders to use as bulls for the genetic improvement of their buffaloes. Under ten sets, eighty bulls have been evaluated by ICAR on the basis of performance of their daughters' record and among them, 21 top ranked bulls have been identified which were 42% superior over their contemporaries. To date, the university has supplied 554 bull calves/bulls and 2.2 lac doses of liquid and frozen semen to the dairy farmers and other dairy development agencies.

Cattle breeding

Crossbreeding of dairy cattle was initiated with Red Dane breed from Denmark and later on Holstein Friesian breed was introduced. The major objectives of the Cattle Improvement Projects are to compare the performance of different genetic groups of crossbred cattle and to evaluate the crossbred bulls through progeny testing, to supply the semen of genetically superior bulls to the farmers and other dairy development agencies.

Evaluation of the body weights of the calves/heifers belonging to different genetic groups revealed that the crossbreds having 75% or above HF inheritance had the maximum body weight (312 kg) at 18 months of age resulting in decline in age at first calving from 31.2 to 28.2 months. For the optimum exploitation of the genetic potential of crossbreds, it was felt necessary to provide higher levels of feeding and management. The feeding experiments conducted at the university have shown that for the proper growth and early sexual maturity, the crossbred animals should be fed at 120-130% N.R.C. standards.



HS Crossbred Bull



HS Crossbred Cow

The average 305-day milk yield of crossbred cows has increased from 2835 kg in 1974-75 to 4499 kg in 2005-06. The milk yield of crossbred cows with 50% exotic germplasm increased from 3168 to 3759 kg and that of 75% exotic germplasm increased from 2932 to 4499 kg indicating the better exploitation of the genetic potential of crossbreds with higher exotic inheritance. Crossbred cows with peak yield upto 52.5 kg a day and 305-day milk yield of 7847 kg have been produced and the bull calves retained from such cows are evaluated through progeny testing.

Evaluation of purebred HF and crossbred Bulls

The breeding values of the bulls estimated from the first lactation 305 day milk yield of the daughters by different methods. The breeding values of the purebred HF bulls ranged from 3029 to 5155, 3098 to 4663 and 3382 to 3881 kg. Bull No. HF1792 ranked on top and bull no. HF1325 on second position performed exceedingly well & semen of these bulls were supplied extensively in the field area. Bull No.11H1528 topped the ranking with BLUP method.

These studies also indicated that out of American, Danish, Israeli, Australian, French Holstein Friesian bulls, the Israeli bulls topped the ranking, followed by the Danish bulls. These studies further revealed that the ranking of the American bulls on the basis of their daughter's milk yield in U.S.A. was considerably changed under Indian conditions indicating Genotype x Environment interaction. This necessitates preliminary evaluation of bulls under Indian conditions before making any large scale import of frozen semen from U.S.A. or any other country. This will help in formulating a long term policy for the import of Friesian germplasm.

Field progeny testing

The field progeny testing project a network programme of ICAR with collaborative units of PAU, Ludhiana, Kerala Agricultural University, Mannuthy and Bhartiya Agro Industries Foundation, Pune got started in 1979. The area of operation is served by 21 A.I. centers in Ludhiana district, which are operated by State Animal Husbandry Department and some by trained inseminators. The average 305-day first lactation milk yield of crossbred progenies in the adopted villages was 1698 kg in the year 1979 which as a result of supply of high quality semen of test bulls has increased to 2961 kg in the year 2006. This has been achieved by providing technical guidance to the farmers about the breeding, feeding and management of crossbred animals.

Some progressive dairy farmers after getting training and superior germplasm from the project have established crossbred herds with lactation milk yield of more than 4000 kg and peak yield of more than 40 kg a day. Field Progeny Testing Project has major contribution in changing the scenario of dairy farming in the adopted villages by providing technical know how, germplasm and motivation of farmers.

Services given to farmers and other agencies

The University supplies bull calves/bulls and semen of purebred exotic and crossbred bulls to the farmers and other dairy development agencies. Since the inception of the project, about 80 male calves/bulls and 7.0 lac doses of liquid and frozen semen have been sold so far. The changing pattern of livestock population in Punjab state over the years indicates pragmatic shift from livestock farming as a way of life to economic dairy farming. The total milk production of the State, which was 1.92 million tonnes in the year 1965-66, has increased to 9.16 million tonnes in the year 2006-07 which comes out to be 477% increase during this period and the University played a vital role in augmenting the milk production in the state. But during this period the population of cattle has declined from 31.6 lac to 17.6 lac, a decrease of 44.3%. However, buffalo population has increased from 29.8 lac to 50.0 lac, an increase of 67.8% during this period. The average milk yield of cows in the state has increased from 750 kg in 1970 to 2700 kg, which is highest as compared to cattle milk yield average of other states of India. Some institutions and many progressive dairy farmers of the Punjab state have established herds of crossbred cows and buffaloes producing more than 4000 kg and 2300 kg milk yield per lactation, respectively. The intervention with breeding, nutritional, health cover, marketing and processing technologies at this stage as recommended by University Scientists, made Punjab a dairy developed state comparable to any dairy developed country in the world.

Embryo transfer technology

Twin calves were produced through embryo transfer in buffaloes in 1988. Pure Holstein-Friesian calves have also been produced through ETT by using frozen embryos imported from U.S.A. Calves from outstanding cows which had developed reproductive failure (chronic repeaters) have been produced successfully by *in vitro* fertilization.

Cattle and buffalo embryos have been successfully deep-frozen for long term preservation. Calves have also been successfully produced through embryo transfer in the farmers herd. Subsequently, the state Animal Husbandry Directorate imported Holstein Friesian embryos and produced bull calves with technical assistance from the university. These bulls have started donating semen and are being used to improve the cattle population.

Layer chicken breeding

Development and Improvement of White Leghorn Pure-bred Stocks: Two pure strains of White Leghorn (PL1 & PL2), synthesized from divergent genetic sources in early seventies, have been improved through selection for the various traits related to productive and reproductive performance. The annual egg production of these pure strains now is around 290 eggs per pullet per year with average egg weight of 57-58 g (68 70 weeks) representing a cumulative improvement of over 35 and 12 % for the two most important components of layer productivity.

Development and Release of the Commercial Stock (Satluj Layer): The reciprocal crosses of the two purebred stocks (PL 1 and PL2), in addition to testing at the University farm, have also been tested under field conditions in Punjab and simultaneously in the national level Random Sample Laying Tests held under varied agro-climatic conditions of the country. Based on performance evaluation, the cross line stock was released by the 'Varietal Release Committees of the state for commercial use under the patent name of 'Satluj layer'.

Rhode Island Red and Other Colored Stocks: In order to meet the demand of a specialized market and to cater to the demand of small farmers, the layer genetic improvement program of the university has been re-oriented for developing suitable coloured plumage stocks. The University has developed two strains of Rhode Island Red (RIR-B and RIR-C), a stock of Dahlem Red and a synthetic stock designated as 'Punjab Red'. The stocks have undergone genetic selection for egg production and egg weight for the last 5-6 generations. At the onset, the coloured plumage stocks were inferior to the White Leghorn long-term selected strain but these had all the other desirable attributes viz. tinted eggs, hardiness and high body weight. The selection program has resulted in significant genetic improvement in both egg production and egg weight though the traits are genetically antagonistic to each other.



White Leghorn



IBL-80 Broiler

Japanese quail breeding

Development and Genetic Improvement of Pure Lines: Two strains had been developed and genetically improved through intra-population selection for over 40 generations for 4-5 week body weight. These strains have achieved 75-85% genetic improvement over the contemporarily reared control line. Direct selection for body weight has

resulted in deterioration of their egg production and reproduction. In order to overcome the undesirable side effects of body weight selection, a dam line (PQ4) has also been developed and improved for early sexual maturity and higher egg production.

Development of Punjab White Quail: A strain of quails with white plumage has been developed and genetically improved over generations. Based on its growth performance, the strain was released for commercial production under the name “Punjab White Quail”. The white plumage favourably compares with coloured strains for growth. The average egg weight is about 13g and the eggs are used for preparation of pickles.

Poultry breeding (Meat-type)

Development and Improvement of Pure strains: Under the All India Co-ordinated Research Project, two strains viz. PB1 and PB2 have been developed from synthetic base populations constituted through inter-se mating of commercial stocks. These strains have undergone 33 and 27 generations of selection, respectively. As a consequence of selection, the age at marketing has decreased wherein the broilers can now be marketed at 5 weeks of age. In the dam line, the egg weight has remained more or less static but egg production to 52 weeks of age has significantly improved from 117 to 133 eggs. The pure line broiler strains developed at the University have been selected for the National Poultry Breeding Programme. These have been supplied to the Project Directorate on Poultry, Hyderabad and other Universities and Institutes for replication.

Development, Release and Improvement of Commercial Broiler Stock IBL 80: Based on performance evaluation of the cross of the pure strains (PB1 and PB2) in national level Random Sample Tests, a commercial stock, designated as IBL80, was released at the national level by the Variety Release Committee constituted jointly by the Indian Council of Agricultural Research and the Ministry of Agriculture and Animal Husbandry. The IBL - 80 was the first indigenous broiler released at the national level. Among the public sector stocks, IBL-80 held 1st position in 9 national level Random Sample Tests. In addition to live weight, it excelled other entries in feed conversion, dressing percentage and margin of receipts over feed and chick costs. In the recently conducted Random Sample Test, 7-week body weight of 2.0 Kg has been attained with the feed conversion ratio of 1.91 which is the best performance from amongst the Public sector entries. Since it's release for commercial production, IBL 80 has been improved as a result of continuous selection practiced in its parental strains.

Supply of poultry germplasm

The broiler chicken germplasm has been supplied in the form of hatching eggs, day-old commercial as well parent chicks to the farmers, hatchery persons, educational and research institutes, and to the Project Directorate on Poultry, Hyderabad. The University has also supplied over 5 lakh parent stocks and commercial day old chicks of layer chickens to farmers and the State Department of Animal Husbandry. The state department has in turn multiplied and supplied several-fold more number of commercial chicks to farmers which has been instrumental in expansion of the commercial farming in the state. In addition to the state of Punjab, the parent stock chicks had also been supplied to the adjoining states i.e. J & K and Himachal Pradesh.

Livestock Management

Development of a package for management practices through research activities is very necessary for exploiting the maximum production potential of livestock, some of which are as under:

Calf management

Feeding of raw milk, boiled milk (cooled to body temp.) and diluted milk (3 parts of milk and 1 part of hot water) to newly born weaned buffalo calves upto 4 months of age, resulted in a daily weight gain of 225, 196 and 204, respectively. The incidence of diarrhea was significantly higher in calves fed diluted milk. Disbudding of calves with anesthesia is a humane technique can help reducing undue stress and enhancing growth among the calves. Buffalo calves can be slaughtered before eighteen months preferably at the age of 14 months to achieve maximum daily gain at minimum cost of production.

Calf age determination

The eruption of first to fourth pair of milk teeth in buffalo calves was observed to take place by first, second, 6th and 24th weeks of age, respectively. Similarly, the permanent incisors erupted at the mean age of 34.3, 42.2, 51.7 and 59.6 months, respectively.

Challenge feeding of pregnant cows

Challenge feeding of high yielding cows (3500 to 4000 lit/lact) at the rate of 4 kg concentrate feed per day from 8th to 3rd week prior to calving and 5 kg from 3rd week before calving, produced 36.9 kg more milk and showed lesser body weight losses during the first 150 days of their ensuing lactation.



Bucket milking machine for buffalo

Lactating buffalo behavior

Ingestive behavior of lactating buffaloes was the most intense immediately after the morning and evening milkings. Early weaning significantly increased the milking time in buffaloes. Docile animals had significantly higher daily milk yield and shorter milking time as compared to aggressive, restless and nervous animals. The bedding material of depth 20 and 30 cm can improve the udder health, milk quality and quantity especially during the winter season thus can increase the net profit from the dairy enterprise.

Machine milking

Machine milking had increased the average milk flow rate to 0.81 kg/min. resulting in more yield per milking (4.1 kg) and improvement in quality (8.2×10^4 /ml bacterial count). The study showed that the buffaloes are amenable to machine milking after initial adaptability period of 15 days. 450 mm Hg vacuum and 65 cycles per minute pulsation rate can give better results with respect to milk yield, milk quality, completeness of milking and udder health and hence can be put into practice for machine milking of buffaloes. Somatic cell count can effectively be used as management tool to evaluate the quality of milk at dairy farm.

Standardization of buffalo milk

A formula has been developed for computing fat corrected milk (FCM) yield of buffaloes adjusted to 6 per cent fat i.e. $FCM(6\%) = 0.4 M + 0.1F$, where FCM is the fat corrected milk, M is the weight of milk and F is the fat in Kg.

Rabbit rearing

Three breeds of rabbits i.e. German Angora (GA) for wool and Soviet Chinchilla (SC) and New Zealand White (NZW) for meat for being maintained and multiplied for supplying superior germplasm to the farmers. Studies on replacement of fish meal with extruded hatchery waste (EHW) indicated that fish meal can be completely replaced by EHW. Weaning of rabbit kits may be done at 35 days of age which would result in at least one additional crop of rabbits in a year. The Feed cost can substantially be reduced to produce more body weight in Soviet Chinchilla (Broiler Rabbit) by supplementing whole wheat grains at 75% level. Evaporative cooling method in broiler rabbit rearing is able to fetch 65% more profit in terms of net returns as compared to those reared without cooling.

Poultry housing

As compared to the use of foggers, and exhaust fans, the evaporative cooling proved to be the most efficient method for lowering the temperature inside the broiler house during the dry-hot season. The chicken broilers because of higher dressing percentage, less protein and ME utilization and production of meat at low cost than the rabbit broilers thus are more efficient and economical producer of meat in Punjab. Modified cage floors using plastic mats can help reduce the egg breakage to 3.98% thus able to save 9 hatching eggs per breeding hen. Total

18 light hours provided to the broiler chicks can increase live body weight, reduce the cost of production and improve the welfare of the birds in comparison to conventional continuous lighting regime.

Poultry ration and growth performance

MAGACAL supplementation to the poultry ration can help in combating marginal deficiencies of Calcium and available Phosphorus thus can help reducing the huge mortality especially during the heat stress period. Beak trimming at 4-12 weeks of age in White Leghorn pullets can reduce feed consumption and better FCR thus can be economical management practice. Phase feeding (either following BIS or NRC standards) among broiler chicks can result in lowering the feed cost without sacrificing growth performance thus can result in better returns. Canola meal at 20% replacement of soybean meal protein can have better feeding value for broiler chicks with increased gross return and margin of profit over feed cost. 70-80 sq.cm/bird and 150 sq.cm/bird of floor space during growing and laying stage, yellow light for better feed efficiency and fertility and Vitamin E and herbal CE supplementation can be adopted as management practices for maximum economic return from the Japanese quail rearing. Separate sex rearing and segregation of male broiler chicks on day- old body weight basis can improve the growth performance and uniformity of the flock in turn can lead to considerable economic return.

Animal Nutrition

Ruminant nutrition

Novel feed resources

- Paddy: The low nutritive value of paddy is due to the husk portion which affects the digestibility of other nutrients.
- Corn steep fluid: A byproduct of starch industry, It contains 40 percent CP and 22 per cent soluble sugars can be used in diets of ruminants.
- Spent brewer's grains: The fresh spent brewer's grains (DM=24%) contain 18.8 per cent CP, 14.6 DCP and 54.6 per cent TDN on dry matter basis, can replace 50 per cent of concentrate in growing calves and milch buffaloes.
- Potato waste: About 5-7 percent of the stored waste potatoes (PW), which can act as a good energy source for the efficient utilization of urea in the ruminants.
- Spent coffee waste: Spent coffee waste is a good energy source, but has poor digestibility.
- Pleurotus harvested spent wheat straw: It had low nutritive value but good acceptability. If supplemented with cheap energy source it can form basal roughage for ruminants.
- *Agaricus* harvested spent wheat straw: *Agaricus* harvested spent wheat straw can replace 20 percent concentrate mixture on nitrogen basis.
- *Volvariella* harvested spent paddy straw: The spent paddy straw had high crude protein, cell soluble and lignin, whereas the crude fibre, cellulose and hemicelluloses contents were depressed.
- *Phalaris minor* (Gulli danda) seeds: Gulli danda seeds contain comparable CP to wheat grains. The digestibility was between wheat and maize grain. It can replace conventional cereal grains up to 100 per cent in the concentrate mixture of ruminants.
- Sarson saag waste (SSW): A cannery waste comprising of sarson-palak-methi in the ratio of 95: 4:1 contains 14.5% crude protein. An adult animal can consume 40-50 kg day and serve as basal maintenance ration when supplemented with mineral mixture.
- Vegetable residues: Feeding trials revealed that cauliflower leaves, cabbage leaves and pea pods could serve as an excellent nutritious fodder for ruminants.

- Forest grasses and tree leaves: Leaves of tut, chall, biul, chamror and leucaena were recommended for feeding to livestock. Similarly, Barua and Sanchrus were the best wild grasses for feeding to livestock.

Energy and protein requirements of buffaloes

The DCP requirement was found to be 2.34 and 2.03 g/w^{0.75}kg/day and the ME requirement for maintenance as 99.5 and 111.3 Kcal/W^{0.75}kg/day in winter and summer, respectively. DCP requirement of 2-year old buffalo heifers, was found to be 1.6 per cent lower than the recommended NRC levels. One Kg concentrate mixture with as lib green fodder was sufficient for growth and development of reproductive organs in buffalo heifers.

Uromol and Uromin lick

Uromol is prepared by heating a mixture of urea and molasses in the ratio of 1:3. Binding of urea with sugars present in molasses, helps in slow release of ammonia in the rumen, can replace oilseed cakes. A brick-shaped uromin lick containing urea as a source of crude protein and all the essential minerals for ruminants has been prepared. Fields trails have shown that it cured many reproductive problems of cows and buffaloes and increased their milk production from 5 to 10%.

Nutrition-reproduction inter-relationships

Results indicated that buffalo heifers can calve at about 3 years of age with scientific feeding and management. This age is about 8 months less than average calving age reported from some organized dairy farms. Trials in cows indicated that 20 per cent higher DCP and TDN than as recommended by NRC shortens age at puberty and age at conception, thereby them in milk at an early age.

Protected proteins

Using formaldehyde, GNC protein helped to increase growth rate of buffalo calves (700g/head/day). Recently, a new and simple method has been developed by heating cane molasses with groundnut cake and soybean proteins.

Improvement of low-grade roughages

Fermentation of straw: A microbiological process for enriching wheat straw with urea (96.5:3 at 70% moisture) results in both physical and chemical treatment besides enrichment of straw by microbial protein. It can be fed as a maintenance ration to the ruminants. Fungal treatment of groundnut shells: Cleven fungi grown on the groundnut shells (GNS) to improve its nutritive value, Only *Corprinus* sp. *Sclerotium* sp. and *Sporafrichum pulvurentum* increased the true protein content (7.91 to 10.0%).

Paddy straw and selenosis

Paddy straw obtained from some parts of Ludhiana district contained high amount of selenium (2.11 ppm) and buffalo calves showed symptoms of selenosis. It is recommended that straw should always be fed in limited amounts along with green fodders and concentrates.

Total mixed rations/Complete feed

Complete feeds with metabolizable energy (ME) 110% of NRC requirement and undegradable protein (UDP) 25% of crude protein (CP) gave best response in transition cows. Supplementation of niacin in these feeds improved the nutrient utilization and the cows achieved 1st postpartum estrus at a much earlier age. Feeding rations in the form of total mixed ration (TMR) which is blend of concentrate, green fodder and crop residue improved digestibility of organic matter and neutral detergent fibre with marginally higher daily live weight gain and reduced the cost of labor.

Poultry Nutrition

Improving feed efficiency

Heat Stress: Heat stress in broilers can be reduced by supplementing the diets with either 0.3% sodium bicarbonate or 0.3% potassium chloride or a mixture of 0.1% sodium bicarbonate and 0.1% potassium chloride in terms of growth and FCR.

Probiotic supplementation: Supplementation of *Lactobacillus*, *Streptococcus* and *Saccharomyces* in the broiler diets improve weight gain and dressing percentage.

Enzyme supplementation: Supplementation of fibrolytic enzymes in the broiler diets improves weight gain, feed conversion, protein efficiency ratio and digestibility of nutrients. Similarly supplementation of Non starch polysaccharide enzymes to wheat based diet improved growth rates. In rice kani based diets both growth and feed conversion improved. Supplementation of Avizyme -1500 and vegpro in layer diets increased the feed consumption, increase in egg production, egg weight and egg mass.

Phytase enzyme: Supplementation of 600 units of enzyme phytase and vitamin D₃ alone or in combination reduced the dietary requirement of both calcium and phosphorus from organic source in the diets of commercial broilers, thereby saved the expensive dietary DCP by 1-1.3 kg per quintal of ration.

Novel feed resources for poultry

Maize: In chickens, both wheat and triticale can replace 100 per cent of maize, whereas, rice kani can replace only 30 percent. In broiler, mashes bajra and ice cream cone waste, can respectively replace 50 and 25 per cent of maize.

Rice bran (RB): In egg type chicken, extracted rice bran can be substituted with 50 per cent of RB. Salseed meal, wheat bran (except in starters) or crushed paddy can also replace RB up to 10, 15 and 60 per cent, respectively.

Decorticated cotton seed cake: In growers and layers, it can replace GNC completely, compared to only up to 20 per cent in starters. In broiler mashes it can be used only up to 50 per cent of GNC.

Mustard cake: In starters, growers and layers and broiler mashes, mustard cake can be used respectively up to 100, 50, 20 and 50 per cent in place of GNC.

Toasted guar meal: It can replace 50 percent GNC only in grower/layer mashes.

Maize gluten and sunflower cake: These can be used up to 25 per cent and 50 per cent, respectively in place of GNC in starter, grower and layer mashes. In broiler mashes, sunflower and til cake can be incorporates up to 25 per cent in place of GNC.

Fish meal: 100 percent fish meal with male chick maize or 0.3 per cent lysine and 0.2 per cent methionine together had no adverse effect on the performance of both egg and meat type chicken. Meat meal, liver meal or silk worm pupae meal can be used between 40 to 50 per cent in place of fish meal.

Alternate phosphorus sources: Deflorinated rock phosphate and superphosphate can be used as an alternate to dicalcium phosphate.

Combination of protein supplements: Dietary levels of fish meal can be reduced by 2% by using vegetable protein combinations viz. CB: CS: SB or GN: MC: SB (2:1:1) in place of groundnut extraction without affecting growth and productive performance.

Brewer's spent grains: Dried sorghum and rice brewer's grain can be incorporated @ 5 % and 10 %, respectively in the broilers diet.

Detoxification of antiquality factors

Detoxification of guar meal was made possible by solid substrate fermentation technique. Similarly recycling of cage broiler droppings (BD) in broiler mash was made possible by solid substrate fermentation. This reduced uric acid and crude fibre. It can be used in poultry rations upto a maximum of 20 percent in diets. Combinations of different vegetable protein supplements e.g. groundnut cake (GNC): mustard cake (MSC), cotton seed cake (CSC), soybean meal (SBM), and sunflower meal (SFN) were found more efficient than using groundnut cake alone due to better assortment of amino acids. Use of two protein sources if used in poultry mashes have complementary effect and can also reduce dependence of fishmeal. Sodium chloride when used 1 percent or more in broilers diets caused demineralization of bones thereby affecting Ca and P balances adversely. The safe level of sodium chloride in poultry mash is 0.5 per cent. Free service is provided to farmers and Govt. agencies for analysis of their dairy/poultry rations (300-400 samples/annum).

Veterinary Medicine

Mineral imbalances

Baseline surveys conducted in dairy animals of three agro climatic zones of state have shown deficiencies of calcium, phosphorus, copper and iodine. Low blood levels of manganese and zinc were recorded in sub mountainous and central zones of Punjab. Molybdenosis induced hypocuprosis was found in dairy animals, endemic in many parts of the state. Copper deficient dairy animals depicted depressed humoral and cellular immune response to hemorrhagic septicemia infection. Organic copper preparations are recommended for effective treatment. Hypophosphatemia resulting in pica was prevalent in dairy animals of all the regions of the state. Oral phosphorus supplements (bone meal and dicalcium phosphate) were effective in correcting hypophosphatemia. Chronic fluorosis identified in Sangrur, Mansa, Bhatinda and parts of Ferozepur districts results in dental mottling, lameness in livestock. Oral supplementation of calcium chloride @ 50gm daily is recommended for the treatment. Efforts are being made to provide deflourinated water to the dairy animals of flourtic areas of Punjab.

Pockets of seleniferous soils were found in Nawan Shahhar, Hoshiarpur and Jalandhar districts. Major clinical effects were abnormalities of hooves and horns, emaciation and poor reproductive performance. Oral administration of sulphates and/or arsenical preparations checks the disease. Subclinical iodine deficiency was widely prevalent in dairy animals of Punjab. It has been observed that single injection of iodized oil was effective in improving iodine status of deficient dairy animals.

Mastitis

Mastitis, the inflammation of mammary glands causes huge economic losses to the dairy industry. Current annual losses being Rs. 7165 crore/annum for India and Rs. 503 crore for Punjab. The average prevalence of subclinical mastitis in state was found up to 50% in cows and 30% in buffaloes. The occurrence of clinical mastitis was reported to be 4-7% of animals. The bacteria constituted major etiologic agents of mastitis are staphylococci, streptococci and *E. coli* being the major isolates. The drug sensitivity pattern of mastitis pathogens goes on changing and hence needs constant monitoring. At present, ceftriaxone-tazobactam, cefquinore, amoxicillin-sulbactam, enrofloxacin and gentamicin were found *in vitro* to be the most suitable drugs in mastitis therapy. The Bromothymol blue (BTB), Sodium Lauryl Sulphate (SLS) paddle and Electrical conductivity tests were adjudged as the best and easy tests for diagnosis of subclinical mastitis. Therapy trials showed that by about 60-70 percent of clinical mastitis could be treated with different intramammary preparations. The regular post-milking teat dipping in 0.5% iodine plus glycerine and dry therapy proved very much effective in preventing mastitis. Recommendations for managing mastitis include pre-milking washing and drying of udder, regular checking of animals for subclinical mastitis by SLS test and taking prompt therapy of advance cases, post-milking teat dipping in iodine-glycerine/chlorhexidine teat dip and dry therapy at the end of lactation.

Impaction syndrome

Recent changes in the agricultural, animal production and feeding practices have led to increased incidence of gastrointestinal disorders particularly ruminal impaction syndrome in dairy animals. The common causes of impaction have been identified as peritonitis, omasal impaction, reticular abscess, abomasal ulceration and caecal dilatation. Feeding of excess coarse roughages, poor quality fodder, inflammatory processes like fever/pain, advanced pregnancy and metabolic disturbances also act as predisposing factors for forestomach impaction. These disorders are presented with clinical signs of scanty pasty faeces or absence of defecation, abdominal distention, abdominal pain and tympany. The diagnosis requires complete blood cell count, peritoneal fluid analysis, X-ray, ultrasound and rumenotomy. The impactive disorders can be prevented by feeding good quality feed and fodder. If animal shows signs of fever or tympany or does not pass faeces for 24 hours, early treatment should be initiated.

Primary ruminal dysfunctions

Indirect qualitative microbial activity tests on rumen liquor were found to be very sensitive for detecting the severity of ruminal disorders viz. acidic and alkaline indigestion. Dairy animals affected by acute lactic acidosis and ammonia toxicity develop lateral recumbancy. Medicinal treatment was not effective in such cases. To save the life of such animals immediate evacuation of rumen contents by rumenotomy is recommended. Efficacy of monensin was established in the treatment of subacute lactic acidosis. Exclusive feeding of paddy straw caused chronic indigestion and deficiencies of zinc, iron and copper. Supplementation of protein and mineral mixture is essential for rapid recovery.

Fresh rumen liquor could be safely stored for 12 to 16 hours at 37°C for effective rumen cud transplantation. Interspecies rumen fluid such as from sheep/ goat can be used for transplantation in cattle and buffaloes.

Production diseases

Administration of vasopressin followed by oral glucose therapy in treatment of pregnancy toxemia of sheep was found more effective than the intravenous administration of glucose therapy. Inadequate energy status of diet was found as major cause of subclinical ketosis which was prevalent in 12 to 18% of crossbred cows at commercial dairy farms during first month of the lactation. Prevalence was highest in cows of 7 to 9 years age group. Studies on Downer Cow Syndrome (DCS) showed that deficiencies of calcium, potassium, phosphorus and mastitis- metritis syndrome were the most common etiological factors for precipitation of this disease. A combined therapy with calcium, phosphorus, potassium and vitamin supplementation along with slinging of recumbant animals were found helpful in clinical recovery.

Calf diarrhea

Diarrhea was found a leading cause of mortality in buffalo calves. Parental copper supplementation to new born buffalo calves (75 mg /calf) and their dams (150 mg/animal) reduced severity and mortality due to diarrhea. Fluids containing bicarbonate were found better than fluids with lactate in reversing metabolic acidosis.

Foot lameness

Lameness is a herd problem with serious implications on production and reproduction of dairy animals. Though clinical lameness is apparent in 9 % and 2 % of cattle and buffaloes respectively but the subclinical lesions can be present in 40-50 % of animals at any dairy farm. Sole ulcers and white line fissures are the lesions commonly responsible for clinical lameness. Formalin foot bath/spray (4%) and supplementation of biotin and zinc have been found effective measures for prevention and treatment of foot lesions causing lameness.

Chlamydiosis in buffaloes

Chlamydia psittaci has been isolated from lung tissue of buffalo calves. Clinical signs, pathophysiology and

diagnostic tests were evaluated. Long acting tetracycline was found most effective antibiotic in treatment of Chlamydiosis.

Lantana toxicity

Lanata camara contained high concentration of toxic principles viz. Lanatadene A and B. Toxic principles caused pathological damaged to liver, kidneys, lungs, rumen and jejunum. Activated charcoal and supportive therapy with liver tonics was found completely effective in managing the toxicity.

Trypanosomiasis in equines

Clinico biochemical and chemotherapeutic studies have been conducted in trypanosomiasis caused by *Trypanosoma evansi* in equines. Combination of Quinapyramine sulphate and Quinapyramine chloride was most effective drug for clinical cure and provided complete protection for 70 days against *Trypanosoma evansi*.

Anemia in cattle

Chronic anaemia in crossbred cattle was due to idiopathic hematuria and intestinal infection with acid fast bacilli. Iron deficiency was the cause of anaemia in 28 percent of calves. Four intramuscular injections @ 250mg of nandrolone propionate improves hemoglobin and PCV values of cows with idiopathic anemia.

Canine diseases

- Bacterial dermatitis, scabies and demodicoses were the most common skin diseases. *Microsporum gypseum* was the most common cause of dermatophytosis and well managed with miconazole with or without ketoconazole.
- Canine parvovirus was a major cause of diarrhea in young dogs. Hemagglutination and ELISA tests were found to be reliable tests for confirming diagnosis.
- Ancylostomiasis was most common intestinal parasite in young dogs and effectively treated with ivermectin followed by albendazole.
- Liver dysfunction profile and its epidemiology has been determined. Primary hepatitis diseases affected 74 percent dogs and reactive hepatitis was diagnosed in 26 percent of dogs.
- In geriatric dogs, renal failure is very common manifestation.
- There is a growing incidence of hypothyroidism in dogs.
- Endoscopy and echocardiography are important tools for diagnosis of various GIT and heart problems.

Veterinary Gynaecology and Obstetrics

Ultrasonography of buffalo genitalia

Ultrasonographic biometrics and echotexture of reproductive organs in comparison with the rectal palpation was established in buffaloes for different stages of the estrous cycle as well as for repeat breeder buffaloes.

Seasonal trend of reproductive activity in buffaloes

Breeding season of buffaloes starts in rainy period and winter is the most favorable period, while summer remains the most unfavorable period. In rural Punjab, the proportion of buffaloes exhibiting anoestrus (no ovulatory activity) during summer is appreciably greater (74-86%) compared to winter (22-26%). Also, calving interval is longer for buffaloes calving in February-June due to delayed resumption of post-calving ovarian activity compared to those calving in July-December (from 38-64 to 116-148 days).

Induction of ovarian cyclicity in anestrus buffaloes

Use of a sustained release internal progesterone device for 12 days along with administration of Pregnant Mare Serum Gonadotropin (PMSG @ 700 IU, im) successfully induced estrus in 80 percent anestrus buffaloes. The estrus inducing efficacy of this treatment was further improved by supplementation of energy-rich Urea Molasses Multinutrient Blocks (UMMB). A Prostaglandin-F_{2α} based protocol was also established for induction of estrus in buffaloes.

Early onset of postpartum ovarian activity in buffaloes

The winter season favors early involution of uterus and resumption of ovarian activity in buffaloes. Use of Vitamin E + Selenium during late gestation is ideal for early expulsion of the fetal membranes and better postpartum luteal activity leading to an improvement in conception rate. The supplementation of UMB leads to early resumption of postpartum ovarian activity and higher milk production.

Repeat breeding in bovines

Non-infectious causes of repeat breeding were associated with mistimed insemination, suprabasal progesterone at estrus and luteal malfunctioning. Repeat breeding due to endocrine aberrations was best treated by PGF_{2α} administration on day 7-9 post-ovulation, double injections of GnRH (on day 0 and 12 post-ovulation), polyunsaturated fatty acid (soybean oil) infusion on day 14 -16 post-AI or progesterone supplementation on day 5th, 8th and 12th post-AI.

Uterine Immunomodulation of endometritic cattle

Bacterial endometritis in repeat breeding dairy cattle was treated by intrauterine infusion of immunomodulators viz *E. coli* LPS and Oyster Glycogen, alternative for the conventional antibiotic and hormonal therapy. Intrauterine Iodine (0.5 %) administration is another substitute with high success rate to clear uterine infections.

Fetotomy operation in cattle, buffalo and mare

The procedures of fetotomy were standardized for per-vaginal delivery of fetus having different monstrosities and anomalies needing 1-4 cuts to deliver the fetus. Fetotomy has distinct advantage over cesarean section in terms of survival in 80 percent cases, quick recovery, less cost of treatment and maintenance of post-treatment reproductive efficiency.

Sharma's modified Schaffer's method of uterine detorsion in buffaloes

Uterine torsion constitutes 70 per cent of dystocia cases presented at university hospital. The weak broad ligaments were the important etiological factor. Sharma's modified Schaffer's method was developed for detorsion of uterus in buffaloes with a success rate of 90 percent in fresh cases without affecting post-delivery reproductive efficiency.

Clinical landmarks for treatment strategy of uterine torsion

Subjecting only suitable animals to procedure of uterine detorsion prevents the dam from undue stress associated with unsuccessful attempts. Buffaloes having passed <36 h since event of torsion, with complete milk let down and relaxed pelvic ligaments are fit for detorsion irrespective of degree of torsion. Buffaloes presented between 36-72 h of occurrence of uterine torsion, degree of torsion <180, partial let down of milk and partially tightened pelvic ligaments can be detorted successfully. Buffaloes with >180 degree uterine torsion and presented in similar clinical condition are unfit for detorsion. Buffaloes having passed >72 h since onset of the torsion, having reabsorbed udder, tightened pelvic ligaments are unfit for detorsion and can be directly subjected to caesarean operation.

Survivability of dystocia affected buffaloes

The degree of stress of dystocia in buffaloes was assessed through measurement of adrenal stimulation and metabolic dysfunctions. As indicated by circulating cortisol, the dystocia affected buffaloes are under immense stress. Excessive degree and duration of stress poses threat to life of dam as well as fetus. The process of relieving uterine torsion by detorsion method further potentiates existing stress. Complete detorsion of uterus should be achieved within 1-2 rolls as employing two additional rolls decreases dam survival by 40 percent. The prognostic importance of blood indices in relation to survivability of dystocia suffering buffaloes was established.

Treatment of retention of placenta

Incidence of retention of placenta in cows and buffaloes was 18 and 5 per cent, respectively. The treatment with broad-spectrum antibiotics, prostaglandin and oxytocin immediately after calving reduced the time of shedding the fetal membranes and had fast uterine involution.

Breeding bull soundness

Biometrics of scrotum, consistency of testes and bodyweight is a good criterion for selection of breeding bull at an early age. Bacterial and fungal load of semen could be significantly reduced by regular pre-collection preputial washings and by adding antifungal (Nystatin) drugs. Crossbred bulls had higher incidence of infertility as compared to purebred bulls. Following parenteral administration of enrofloxacin, tetracycline and paracetamol in breeding bulls, the semen should not be used for a month. The vaccination (FMD) in breeding bulls affects the semen quality for a month.

Cryopreservation of bovine semen

Quality of cryopreserved semen could be improved by addition of antioxidants, membrane stabilizers and sugars in the extenders. Cryopreservation of buffalo bull semen with TRIS was better than EYC and CAW extenders. Supplementation of TRIS-Egg Yolk extender with chloroquin diphosphate and ascorbic acid reduced cryoinjury and improved post-thaw sperm viability. Sperm penetration distance (SPD) in 2 percent polyacrylamide gel (PAG) was established as an indicator of bull fertility. Hypo-osmotic swelling test (HOST) and sperm penetration tests were standardized for semen evaluation.

Improving semen quality and fertility

Sephadex filtration removes the dead and abnormal sperm from the semen. Fresh / extended / post-thaw bovine semen can be gently placed over the sephadex column (G 15, 20% w/v) prepared in sterilized glass syringe and filtration process is completed in 2-3 minutes. Carrying out artificial insemination using filtered semen improves the conception rate by 20-25 percent.

Reproductive disorders in bitches

Vaginal cytological examination procedure was used for diagnosing the stages of estrous cycle and optimum mating period in bitches. Chemotherapy of venereal granulomas using i.v. administration of vincristine sulfate, an anti-neoplastic drug, had distinct advantages over surgical excision of tumors. Pyometra was treated in female canines through careful administration of PGF_{2α} in divided doses along with the antibiotics.

Veterinary Surgery and Radiology

Anaesthesia

Safer and economical anaesthetic protocol for long term anaesthesia in bovines using pre-anaesthetic drugs Diazepam, Midazolam, Butorphanol, along with thiopental sodium and Propofol as induction agent and halothane and isoflurane as maintenance agents bovines were developed. Safer and economical anaesthetic protocol for

long term anaesthesia in equines using Xylazine and Ketamine as induction agent and isoflurane as maintenance agents were developed. In small animals various anaesthetic combinations using ketamine, xylazine, acepromazine, butorphanol, midazolam, glycopyrrolate, halothane and isoflurane were found safe and satisfactory.

Surgery

A surgical technique for successful treatment of diaphragmatic hernia in buffaloes and crossbred cows through abdominal approach made it possible to save heavy economic losses to the farmers with an overall survival rate of over 80%. Surgical management of ruptured urinary bladder, uremia and surgical and dissolution protocols have been developed for urolithiasis in canines. Thoracic surgeries like lung evisceration, rib fractures, thoracic trauma and repair of Persistent Right Aortic Arch (PRAA) are being managed successfully using positive pressure ventilation. The technique of successful surgical repair of ventral hernia and prepubic tendon rupture was developed by using synthetic nylon mesh.

Open teat surgery in buffaloes has been developed and routine surgical management of teat fistulas and lacerations is being done. Tendon grafting of traumatised tendon in equines and canines by means of preserved homologous tendon grafts from cadavers has been successfully carried out. The technique of intramedullary interlock nailing was found most suitable for the repair of long bone fractures in bovines and canines. Bone plating was used successfully for management of long bone fractures in dogs. Ultrasound therapy has been found to be beneficial in healing of fracture, wound, muscle and tendon and treatment of acute and chronic arthritis. Surgical management of colic, perineal affections and uterine torsion in equines is being developed with encouraging results.

Diagnostics

The department is well equipped with latest diagnostic facilities like computerised radiography, ultrasonography, colour Doppler, and echocardiography. Radiological factors for adult buffalo, bulls and bullocks were standardised in this department. Ultrasonography was used to diagnose the cases of foreign body syndrome, rumen impaction, omasal impaction, abomasal impaction, reticular abscess, liver abscess, reticular adhesions, and intestinal obstruction due to fecolith, intussusception, mesenteric torsion and peritonitis in bovines. Computerised radiography is being used for diagnosis of small and large animal affections. Ultrasound guided biopsy is being done in small and large animals. Echocardiography is being done in the cases of dogs suffering from cardiac diseases.

Veterinary Public Health and Epidemiology

Residue analysis

Insecticide residues in pork

DDT was found to be the most predominant insecticide in pig tissue samples which was detected in 93.3, 100.0 and 90.0 per cent of samples in liver, fat and muscle of pig, respectively. The mean residue levels of DDT were found to be 0.339, 0.417 and 0.313 mg kg⁻¹ in liver, fat and muscle tissue, respectively. o, p'-DDE were the more predominant metabolites of DDT detected in pork samples.

Organochlorine residues in lamb, buffalo meat and human population

Mean total DDT, HCH, endosulphan, dieldrin in lamb were 0.696, 0.151, 0.607 and 0.053 mg kg⁻¹, respectively while respective values for DDT, HCH, endosulphan, dieldrin in buffalo meat were 0.308, 0.095, 0.043 and 0.013 mg kg⁻¹. Highest amount of endosulphan was found in sheep patties (1.022 mg kg⁻¹).

Insecticide residues in goat meat

DDT was found to be the most predominant insecticide in goat tissue samples with an average of 0.573, 0.156, 0.208 and 0.060 mg kg⁻¹ in fat, muscle, liver and kidney, respectively. Average levels of HCH in fat, muscle, liver and kidney were 0.441, 0.137, 0.126 and 0.092 mg kg⁻¹, respectively.

Food safety

Listeria monocytogenes

Fifty samples each of sheep, goat and poultry raw meat were screened for the presence of *Listeria monocytogenes* and the incidence was 4%, 2% and 8% in sheep, goat, and poultry meat, respectively, with an overall incidence of 4.6%.

Salmonella from meat of different food animals

Sixteen strains (9 from meat and 7 from excretions) of *Salmonella* were isolated from 423 samples examined from meat of different food animals (chicken, goat and pig) and their excretions indicating an overall prevalence of 3.78 per cent. The isolated strains were serotyped as: *S. Typhimurium* (13) and *S. Enteritidis* (3).

Zoonoses

Immunodiagnosis of *Sarcocystis sp.* and *Cysticercus cellulosae*

A total of 211 samples were examined between July 2000 to June 2001 to know the prevalence of *Sarcocystis* sp. of which 128 (60.66%) were found positive for *Sarcocystis* sp. using digestion method. A total of 116 (54.32%) samples were found positive by rapid isolation of intact micro- *Sarcocystis* cysts from muscular tissues. The prevalence rate of *Cysticercus cellulosae* was found to be 6.35 per cent.

Disease investigation

- The department provided “fire brigade” like services to the farmers in the face of outbreaks of animal disease. The basic data on the morbidity and mortality pattern, seasonal prevalence and other ancillary information is given below.
- Outbreaks of equine viral rhinopneumonitis (in 15 mares) suspected for glanders involving eight mules and two foals were recorded.
- FMD remained prevalent in exotic and crossbred cattle and pigs, sheep and goats. The incidence of mortality was very high in young calves, kids and piglets.
- More than 28 outbreaks of H.S. were recorded alone during 1989 and 1990 and 53 during 1991-96 with significantly high fatality rate.
- High incidence of brucellosis was recorded in organized farms and private breeders herds. Out of 312 serum samples from veterinarians and dairy workers, 22.1 per cent were found positive for brucellosis.
- Out of 8899 animals tested for Johne’s disease and 7935 for tuberculosis, 118 and 840 animals were found positive for these diseases, respectively.

Veterinary Microbiology

Bacterial diseases

***Pasteurella multocida* (Haemorrhagic Septicemia)**

During the period up to 1996, out of a total of 2488 samples from different animals and free flying birds processed for *P. multocida*, 112 isolates were obtained which belonged to type A, type B and type E. While during the period of 1996-2006, out of a total of 2188 samples processed, 60 isolates of *P. multocida* were obtained. The antibiotic sensitivity pattern revealed them to be sensitive to enrofloxacin, chloramphenicol and gentamicin but resistant to co-trimoxazole, streptomycin and oxytetracycline. The isolates were confirmed by PCR.

Outer membrane protein (OMP) profiles of 17 *P. multocida* (B:2) isolates revealed 23 proteins ranging from 13 kDa to 94 kDa. The results of SDS-PAGE and Western blotting indicated that 32 kDa protein was present in all the isolates and may prove to be a candidate antigen for a subunit HS vaccine. The genomic characterization was done by ribotyping using labeled probe derived from 16S rRNA gene of *P. multocida* P52. Studies were conducted in mice to know the protective efficacy of OMPs (esp. 32kDa and 25kDa) after extraction from *P. multocida* (strain P52) organisms grown under normal and iron regulated conditions.

Brucellosis

Samples (90) were tested against brucellosis by RBPT followed by TAT. The significant titres were obtained in 9 samples. Eleven (11) isolates of *B. abortus* were identified. Isolates were mostly sensitive to Gentamicin followed by curofloxacin. The sensitivity in decreasing order was Pefloxacin (80%), Ciprofloxacin(78.6%), Cotrimaxazole (73%), Chloramphenicol (66%), Tetracycline (64.3%), Neomycin (60.1%), Oxytetracycline (59.7%), Lincomycin (46.2%) and Ampicillin (17.6%).

***Campylobacter fetus* infections**

Preputial washings and semen samples of the 37 breeding bulls and 27 buffalo breeding bulls were screened for *C. fetus* and 7 and 3 bulls were found positive, respectively. None of the semen sample was found positive. All the isolates were found sensitive to Gentamicin and Enrofloxacin and resistant to Ampicillin. In an another study, out of a total of 61 samples comprising of vaginal mucus, fetal membranes and foetal contents from the cases of aborted cattle and buffaloes, *C. fetus* subsp. *venerealis* (1) and *C. fetus* subsp. *fetus* (6) was isolated. Preputial washings from breeding bulls (n=62) were compared for detection of *C. fetus* by isolation and PCR. Eighteen (18) were found positive by isolation and 4 by PCR.

Calf diarrhoea

A total of 78 diarrhoeic cow and buffalo calves were screened for the presence of rotavirus infection by RNA-PAGE, ELISA and Discontinuous Counter-immunoelectrophoresis (DCIE). Twenty one (21) samples were found positive by RNA-PAGE, 18 by ELISA and 16 by DCIE. Five (5) distinct electropherotypes were found. In another study, 52 faecal samples from diarrhoeic buffalo and cow calves revealed *E. coli* and *Salmonella* Newport.

Chlamydiosis in domestic animals

During the period up to 1996, a total of 1992 sera from apparently healthy sheep, buffalo and cattle and 113 goats experiencing chlamydial abortions were screened for measuring chlamydial antibodies. Three strains of *Chlamydia*, one each from faeces of sheep, aborted foetus and brain of cow were isolated from Punjab and confirmed by standard criterion.

***Salmonella gallinarum* infections**

OMPs from 10 strains of *Salmonella gallinarum* showed a common major protein band of 35-37 KDa besides minor bands of 33 KDa, 30 KDa and 18 KDa. The Western blot analysis revealed major band of 35-37 KDa to be immunogenic and cross reactive. A comparative study on competitive exclusion with 'Aviguard' (commercial product of Bayer) and oral vaccination against *S. Gallinarum* in chicks revealed Aviguard to offer better protection.

Bacterial load of semen

Seventy two (72) frozen semen samples (straws) from bulls were tested for total bacteriological load as per the method set by International Animal Health Code 1999 in the OIE manual of standards.

Viral Diseases

Bovine Herpes Virus 1 (IBR) infection

Fifty-one (51) breeding bulls from a Govt. organized farm were screened for BHV-1 (IBR) infection by virus isolation and PCR but none was found positive. Out of 40 samples from different organized dairy farms of Punjab, 4 were found positive by PCR technique. Twelve positive hybridoma clones were detected. Indirect ELISA was standardized for the detection of BHV-1 antibodies in the Balb/c mice.

Foot and Mouth disease (FMD)

The immunogenic response to FMD virus aluminium hydroxide gel tetravalent vaccine was evaluated in cross breeds. Majority of the animals showed a poor immune response revealed by liquid phase blocking ELISA.

Avian adenovirus (AAV) infection

Inclusion body hepatitis (IBH) was recorded in broiler chicks of 3-5 weeks of age. The maximum number of outbreaks was recorded in the months of October to December and aflatoxicosis appeared to be the most common concurrent condition. Histopathologically confirmed outbreaks of IBH (47) revealed 31 avian adenovirus (AAV) isolates.

Egg drop syndrome (EDS) in poultry

Average drop of 24.53 % in egg production during the five year period (1984-88) was observed with maximum drop being recorded during summer months in 6-9 months old birds. Out of a 114 tissue samples processed for virus isolation, 16 isolates resembling IB virus, one resembling CELO virus and one resembling EDS-76 virus were found.

Fowl pox infection

Nineteen (19) isolates of fowl pox virus (13 from skin lesions and 6 from respiratory tract) were obtained from the field outbreaks and confirmed by standard criterion. Comparative immunity of four fowl pox virus vaccines and one local strain was studied in chickens.

Infectious Bursal Disease Virus (IBDV) infection

Polyclonal anti-idiotypic antibodies (anti-Id Abs) were raised in rabbits directed against IBDV. Purified anti-Id Abs significantly inhibited the binding of Ab1 to IBDV in competitive ELISA. Anti-Id conferred marginal protection in broiler chicks. Nine isolates were obtained from field outbreaks of IBD. Out of these, five were completely neutralized by antibodies against vaccine and variant strains, whereas two isolates were not completely neutralized and were considered as pathogenic variant strains of IBDV. Characterization of IBDV isolates by RT-PCR and RFLP was done.

Marek's disease (MD) in domestic fowl

During a 5 year period, out of a total of 36,654 necropsies performed in domestic fowl, 1884 cases of MD were diagnosed with highest incidence in 13-18 weeks old birds in Punjab.

Newcastle disease virus (NCDV) infection

A total of 15 outbreaks of Newcastle disease in organized farms in Punjab were attended and the Newcastle disease virus was isolated from 12 farms and analyzed by molecular techniques viz., PCR and Restriction analysis. All the isolates were found to be lentogenic.

Fowl adenovirus (FAV) infection

FAV isolates were propagated in CEL cell culture and further characterized by PCR and RFLP. Sequences and phylogenetic analysis of the fibre genes revealed almost 100 per cent homology with sequence of FAV-4 and FAV-1 fibre gene.

Mycotoxins

Screening of poultry feed samples and raw materials (332) revealed 66.8% of the samples positive for different mycotoxins ranging from 50-1000 ppb. Mycotoxins detected in decreasing order were aflatoxins, ochratoxins, citrinin and sterigmatocystine. Aflatoxins in the feed/ingredients were found ranging from 75 ± 25 to 400 ± 25 ppb. Aluminium silicate in concentration of 0.5% to 1.0% in poultry feed acts as adsorbent for aflatoxins. *In vitro* studies revealed that propionic acid (0.5%) can be effectively used to inhibit the mold growth in feed/ingredients. Sodium bisulfite (0.5%) and sodium hydroxide (2%), each at 20% moisture level for 24 hours was found to detoxify the aflatoxins.

Veterinary Pathology

Poultry Diseases

The poultry diseases recorded for the first times were Cystic Pancreas in broiler chicks and multiple tarso-metatarsals spur. Various genital affections recorded were oophoritis, salpingitis, egg peritonitis, atrophied ovary and oviduct, egg bound, tumors of ovary, impaction of the oviduct, uterine inertia, persistent right cystic oviduct and ovarian cysts. Biochemical studies on combined effects of aflatoxin and malathion in broiler chicks showed that they had a synergistic effect on suppression of humoral immune response in chicks. Chicks experimentally fed AFB₁ revealed increase in the activities of AST, ALT, AKP, LDH and decreased total proteins and albumin indicating hepatic dysfunction. Experimental chronic toxicity of quinalphos in broiler chicks suggested that cumulative insecticide toxicity was immunosuppressive and may predispose birds to various other diseases. Antioxidant status and hepatic function studies in chicks suggested protective role of herbal vitamin C in alleviating heat stress. Studies on naturally occurring infectious coryza in chickens revealed swelling of face, nasal discharge and conjunctivitis as main clinical signs. The major diseases affecting the lymphoid system of poultry observed were IBD, IBH, HPS, ascites syndrome, lymphoproliferative diseases and aflatoxicosis.

Rabies

Effect of temperature treatments on the virulence of street rabies virus in mammary secretion was studied and it was found that milk of a rabid animal even after being heated up to 37°C for one hour was infective through contact with abraded skin, mucous membranes or by consumption. Histopathological alterations in nervous tissue of rabid buffaloes and cattle revealed Negri bodies in cerebellum both in cattle and buffaloes. Clinico-pathological approaches for ante-mortem detection of rabies antigen in buffalo calves experimentally infected with street rabies virus could be explored further as a clinico-pathological indicator of the presence of rabies infection before onset of clinical signs. Comparison of ELISA, FAT, Seller's stain and mice inoculation test on early detection of rabies antigen in buffalo calves experimentally infected with street rabies virus showed that ELISA was found most sensitive. During a 5 year epidemiological study on Rabies in Punjab in dogs buffaloes, cows and wild animals revealed 53.22% positive for rabies. Effect of environmental factors on Street Rabies Virus in saliva revealed that the virus in saliva retained virulence up to 60 minutes. Sensitivity of direct immuno-fluorescence test (FAT), Counter-immuno electrophoresis test (CIEP) histopathology and Impression smears stained with Seller's staining in the diagnosis of rabies revealed that CIEP was more sensitive than histopathology.

Diseases of small and large animals

Naturally occurring cardiovascular lesions in pigs, buffaloes, cattle, sheep, goats, chicken and reindeer were studied and genesis of these lesions were compared with the lesions in human cardiovascular system. During late eighties, a peculiar disease (gangrenous syndrome) was observed in buffaloes in various districts of Punjab. Disease was characterized by necrosis of tips of tail, ears, extremities and tongue. Patho-anatomical studies on female reproductive system of buffaloes revealed lesions in ovaries, cervix and vagina mainly. Pathology and pathogenesis of experimental mycoplasmosis, chlamydiosis, yersinosis and mycoses in ruminants, rabbits and mice was studied. Mastitigenic potential of *Mycoplasma* in caprine mammary gland revealed that *Mycoplasma* was quite pathogenic. Experimental infections with *Absidia corymbifera* and *Candida albicans* in buffalo-calves and goats resulted in self limiting pathological alterations. Prevalence of *Cryptosporidium* in Punjab was

found to be 50% and 25.68% in diarrheic and non diarrheic calves, respectively. Hyperplasia of rumen epithelium, mild abomasitis and chronic enteritis, pleuritis along with degeneration of primary laminar necrosis of laminar corium was revealed alongwith hoof lesions in experimentally induced chronic selenosis in buffalo calves.

Diagnostic cytology

Diagnostic cytology was found to be highly sensitive and specific in the diagnosis and differentiation of cutaneous neoplasia from non-neoplastic conditions, besides canine mammary neoplasia. Ultrasound guided cytology of visceral organs/masses of dogs and that of poultry diseases resulted in rapid and improved diagnosis of diseases, particularly neoplasms.

Veterinary Parasitology

Helminthology

A thorough survey on helminthic fauna of livestock revealed forty-eight species of helminthes. Most effective drugs: Zani against mature and immature paramphistomiasis; Panacur and Nilzan against round worms and Niclosamide and Panacur against tapeworms. Nine species of helminthes of pigs reported in Punjab. Four nematodes species viz, *Ascaridia galli*, *Heterakis. gallinarum*, *Gonoploneuma sumani* and *Subulura minetti* were encountered in birds. The foci of snails have been identified and mapped out for forecasting the outbreak of trematode diseases. *Indoplanorbis exustus* and *Gyraulus* Studies the *convexiusculus* snails were the predominant snails. Studies for the control of vector snails have led to the conclusion that popular trees like *Calatropis procer* (AKK), *Encalypticus lanceplata* (Safeda) and *Azadirachts indicis* (Neem), if grown, at the bank of water bodies can impose a very effective snail control. The dry fruits of *sapindus emarginatus* (Ritha) and *Acacia cancinna* (Shikakai) were found effective against *Lymnea luteola*. Biological agents like predacious insects, fishes, duck, etc. have been experimentally evaluated to be quite good for control of vector snails.

Epidemiology of paramphistomosis in ruminants in different agro-climatic zones of Punjab was recorded. A total of 3757 faecal samples (1949 buffaloes, 926 cattle, 618 sheep and 264 goats) were collected from different village(s) / area(s). Out of the total, 157 samples (116 buffaloes, 28 cattle, 2 goat and 11 sheep) were found positive for paramphistome eggs with an incidence rate of 4.18%. The highest incidence was found in buffaloes (6.08%) followed by cattle (3.02%), sheep (1.78%) and goats (0.76%) in different agro-climatic zones of Punjab and other adjoining states. Standardization and evaluation of a diagnostic test (Indirect plate-ELISA) is useful for the early detection of immature paramphistomosis was done by using somatic whole adult antigen. Dot-ELISA as an immunodiagnostic test for early possible detection of the paramphistomosis in ruminants was standardized using somatic and excretory-secretory antigens *Paramphistomosis epiclitum* and was able to detect infection from 26% of the clinical cases as compared to 10% cases detected by coprological examination.

Protozoology

Studies on the effects of Levamisole as an immunomodulator against *Trypanosoma evansi* infection in cow calves revealed increase in immunoglobulin decrease in albumin to Ig ratio and increase in Ig levels in CST in all the groups, while increase in circulating immune complexes was observed in simultaneous Levamisole treatment with *T. evansi* infection. The role of host cell sialic acid in *Trypanosoma evansi* infection in buffalo calves was investigated before and after chemotherapy. The trypanosome showed sialidase activity. Circulatory antigen detection in *T. evansi* was done. Based on pharmacokinetics study of antitrypanocidal diminazene diaceturate in combination with anti-pyrine and procaine in experimental *T. evansi* infection in buffalo calves, the dosage regimen recommended was at a dose of 3.90 mg/kg followed by 2.70 mg/kg body weight repeated at 7 days interval. In cow calves, it is recommended @ 4.04 mg/kg followed by 3.12 mg/kg body weight at 14 days intervals. *Trypanosoma evansi* is responsible for producing immuno suppression in buffalo calves, leading to poor immune response to hemorrhagic septicemia vaccination.

Anticoccidial activity of six compounds used as prophylactics viz. PANacoxin (amprolium + sulphaquinoxaline + ethopabate), Amprol plus (amprolium + ethopabate), Embamin (nitrofurazone + furanzolidone) was found to give full protection against the lower levels of the monospecific infections with *E. tenella*, *E. necatrix*, *E. acervulina* and *E. maxima*. Ayurvedic drug AV/PPP/22 (Ayurvet Limited), @ 0.4% in feed broke the life cycle of *Eimeria tenella* by destroying primarily the second-generation schizonts. Better results were achieved when coccidiostat and immunomodulator @ 1 ml/ 10 chicks/ day) were given alone in caecal coccidiosis in broilers. Clinico-haemtochemical changes in cattle naturally infected with *Theileria annulata* revealed normochromic hypochromic anaemia, neutrophilia, lymphopenia and leucocytosis. BUN and circulating immune complexes were increased. Treatment with buparvaquone resulted in restoration of normal biochemical parameters.

Ectoparasites

Comparative study on therapeutic efficacy of flumethrin, delamethrin and amitraz for tick control in buffaloes revealed that Flumethrin provided protection from ticks up to 42 days; where as, amitraz and delamethrin provide protection upto 21 and 14 days respectively. Knock down effect of ticks in case of flumethrin, delamethrin and amitraz was 24, 48, and 24 hours respectively. Live attenuated schizont lymphoblast culture vaccine for tropical theileriosis has been evaluated for calfhoo immunization in laboratory trials also field trials at village level in the Punjab State.

Adaptive trials of theileriosis vaccine

In 40 vaccination camps at village level, 4000 young calves have been vaccinated. These field vaccination trails have involved more than 3000 farmers from 400 villages in the districts of Faridkot, Bathinda and Ferozepur in coordination with Civil Veterinary Hospital staff of the Punjab State. In these successful trails over 500 vaccinations were done in newborn calves of few days age. *Theileria Count Down Zero – 2000 A.D.*, a field level programme, co-sponsored by Punjab State Council for Science and Technology and State Department of Animal Husbandry, Punjab, Chandigarh. It aims at developing Model Plan with effective village level network for calfhoo immunization in crossbred dairy cattle for control of tropical theileriosis, a killer disease of newborn crossbred calves. The vaccine induces immunity within 3 weeks of inoculation. Under tick infested field conditions repeat exposure to tick infestation provide booster and thus only one vaccine injection can provide life long immunity. The development of an effective vaccine for young calves provides an effective substitute for the very expensive anti-theileria drug Butalex, and also helps in sustenance of intensive artificial insemination based animals breeding programme for high milk productivity using exotic germplasm or even in future, using exotic embryos of high milk yielding disease susceptible breeds. Anti-tick vaccine offers a better alternative for control of vector ticks than chemical acaricides. An immuno-dominant tick salivary gland protein of 66 KD has been identified which may be useful for development of anti-tick vaccine for control of *Hyalomma a anatolicum*. The vector tick of tropical theileriosis.

The genes for the immunogenic proteins of salivary glands of the vector tick of tropical theileriosis have been cloned. This will lead to further work on genetically engineered tick salivary proteins as vaccines. Ascaris helminth extract, as an immuno-modulator or IgE immune responses, was found successful in enhancing anti-tick immunity in crossbred cow-calves for control of ticks.

Veterinary Pharmacology and Toxicology

Antibacterial dosage

The dosage of antibacterials in buffaloes, cattle and other livestock used previously were based on the dose established in their western counterparts, which was unsatisfactory. Studies undertaken in this department have established proper dosage of several groups of antibacterials such as amphenicols, tetracyclines, cephalosporins, aminoglycosides, penicillins, fluoroquinolones and sulphonamides with some other therapeutic agents in Indian cattle and buffaloes. Among sulfonamides, the detailed pharmacokinetics (PK) of sulfadimidine, sulfapyridine, sulfamethoxypridazine. Sulfadimethoxine, sulfanilamide, sulfadiazine and suflamethoxazole were investigated in

cow and buffalo calves. Among cephalosporins, detailed distribution and elimination pattern of cephaloridine, cefoperazone, cefalexin, cefatoxime, ceftriaxone, ceftizoxime, cefuroxime, cefpirome and cefepime have been investigated in cow calves and buffalo calves.

Disposition of various fluoroquinolones was investigated in bovines including enrofloxacin, ciprofloxacin, pefloxacin, ofloxacin, levofloxacin, gatifloxacin and danofloxacin under healthy/diseased condition. The effect of fever on dosage regimen of several antibiotics was also determined in febrile animals. Extensive disposition studies on diacetyl monoxime (DAM) and pyridine aldoxime methiodide (2-PAM) were investigated in buffalo calves, heifers and sheep. The biochemical alterations induced by these oxime reactivators at various dosage levels were also investigated. The suitable dosage regimen of DAM in buffalo species was found to be 30 mg/kg i/v followed by 15 mg/kg i/m at 12 h intervals. For 2-PAM, the appropriate dosage regimen would be 20 mg/kg followed by 12 mg/kg at 6 h intervals. To maintain the therapeutic plasma concentration in sheep, the dose of 13 mg/kg should be repeated at 8 h for DAM and 4h for 2-PAM in sheep. The PK study of DAM and 2-PAM conducted in diseased model showed significant elongation of elimination half life and marked alterations in all other PK parameters. Oxime reactivators increased the plasma level of carboxyl esterase, transferases and blood glucose but depressed the levels of plasma phosphates.

Insecticide toxicology

Toxicological and biochemical studies of various insecticides were conducted in bovines to evaluate their toxicity potential and in livestock including dichlorvos, monocrotophos, phorate chlorpyrifos, ethion, acephate, cypermethrin, deltamethrin, alphasmethrin, fenvalerate, amitraz, malathion, sumithion, phosphamidon, phosalone, triazophos, oxydemeton-methyl and imidacloprid. Monocrotophos is one of the hazardous OPI for buffalo species. Administration of DAM (30 mg.kg⁻¹, ¼ iv, ¾ im) constituted the most effective therapy for organophosphorous insecticide toxicity as it protected all the animals against OPI-induced toxicity. Although DAM or atropine alone afforded protection against OPI induced lethality to some extent, a combination of DAM plus atropine was found to be most effective therapy against OPI poisoning in bovine calves. No therapeutic treatment was found successful in case of phorate poisoning.

Antidotal therapy of acutely chlorpyrifos-poisoned buffalo calves with atropine and DAM failed to protect animals against lethality and it was ineffective in reversing the chlorpyrifos-induced alterations in biochemical parameters. Atropine and DAM plus atropine prolonged the time of death following intoxication by ethion. Cypermethrin and deltamethrin in the recommended dosage were not harmful to buffalo species, so can safely be used as ectoparasiticides in this species. In case of cypermethrin intoxication in buffalo species, use of chloral hydrate may protect the intoxicated animals. Alphasmethrin and fenvalerate in recommended dosage or concentration are not much harmful to cattle, so can safely be used for insect pest control in and around animal farms, and as ectoparasiticide in this species. The repeated oral and dermal toxicity studies on amitraz suggested that it can be used safely in recommended concentrations as an ectoparasiticide in crossbred cattle, but should not be exposed to animals for longer duration by oral route. Methyl parathion and malathion when administered for prolonged periods even in low doses were found to affect the immune status of rabbits.

Mineral toxicology

Toxic effect of various minerals including molybdenum, fluoride and selenium was studied in cow and buffalo calves. Sodium sulphate was found to be the best antidote for molybdenosis and could be used in poultry at a dose twice that of Mo ingested. A concentration of e" 121.0 ng/ml of fluoride may be considered as a threshold level for fluoride toxicity and CaCO₃ and Al₂O₃ may be effectively used in the treatment of subacute toxicity of fluoride in buffalo calves. Elevated blood selenium levels produced both negative as well as positive effect on the immune system. Oxidative stress was thought to be one of the important mechanisms involved in selenium toxicity.

Veterinary Physiology and Biochemistry

Cardiovascular physiology

Hemorrhagic or endotoxic shock decreased haematocrit, haemoglobin (Hb), leukocyte, erythrocyte and neutrophil count with overall lymphocytosis. Endotoxic shock (Infusion of *Eschrechia coli* endotoxin @ 5mg/kg BW/h for 3h) in buffalo calves lead to initial tachycardia followed by bradycardia, hypotension, fall in Central Venous pressure (CVP), hypovolemia, hypotemmemia, hypoalbuminemia, hypoglycaemia, fall in BUN, GPT, Cl and K, lactic acidosis, hypoxia and death. Treatment of endotoxmic buffalo calves with various combinations of Hypertonic Saline Solution, flunixin meglumine, Plasmex-D (Dextran-40), Blood and 5% BSA normalized systolic/diastolic pressure, pulse pressure, Mean Arterial Pressure (MAP) and CVP along hematocrit and Hb.

Digestive physiology

Highest concentration of rumen metabolites and maximum growth rate of microbial population was observed with a diet containing chaffed wheat straw, green fodder, concentrate and mineral mixture. Thus, feeding of wheat bhoosa to livestock during lean period should always be incorporated with concentrate and/or green fodder with mineral supplements to maintain proper health and production of animals. Profile of rumen bacteria in buffalo calves when maintained on Subbul diet lead to significant gain in their body weight. Exclusive feeding of rice straw to buffaloes decreased the frequency and increased amplitude of rumen movements, increased ruminal pH, total bacterial and protozoal counts as well as copper, iron and zinc in rumen liquor were declined.

Reproductive physiology

Increased level of testosterone with corresponding decrease in androstenedione in male buffalo calves indicated the approaching age of puberty. First estrus appeared around 56 days after parturition. During pregnancy, plasma thyroid hormones increase, whereas, T3 levels decrease progressively in later half of pregnancy.

Mineral physiology

Hypophosphataemia affecting legs of buffaloes was widely prevalent in Ludhiana, Sangrur, Patiala, Ferozpur and Gurdaspur. Exclusive feeding of paddy straw to buffalo calves resulted in alkaline indigestion. Plasma copper, zinc and iron were higher in brown swiss as compared to other breeds of cattle and also higher in Murrah than Nili-Ravi buffaloes. Copper was higher in goats followed by cattle, sheep and buffaloes whereas iron and magnesium were highest in buffaloes. In normal cycling buffaloes, a rise in plasma sodium, chloride and inorganic phosphorus and a fall in plasma calcium level was the pattern observed during estrus phase.

Physiological chemistry

Observations revealed that CSF is closed to venous blood in respect of pCO₂, and oxygen saturation. Induced hyperkalaemia initiated respiratory alkalosis. Plasma K above 10.08±1.02 mmol/litre led to metabolic acidosis, which may potentiate the cardiotoxic effects and may prove fatal. Decreased O₂ uptake by peripheral tissue and drastic desaturation during acidotic phase may also be contributing for predisposition to Downer's Cow Syndrome. Induced metabolic alkalosis following hypercalcaemia at 12 and 24 h intervals was preceded by combined metabolic and respiratory acidosis. Hypocalcaemia led to biphasic changes in acid base variables. The decrease in ionized plasma Ca²⁺ concentration upto 0.82±0.06 mmol/litre associated with a metabolic alkalosis. Further decrease in plasma Ca²⁺ concentration to 0.61±0.09 mmol/ litre led to metabolic acidosis. There was a significant oxygen desaturation as well as impaired uptake of oxygen by peripheral tissues and pulmonary blood. Highest amounts of colostral Ig and IgG were available on the day of parturition and thus the calves should receive colostrum as early after birth as possible. Antioxidant effects of vitamin E and Se prevented the liver against oxidative stress during endotoxic shock.

Biochemical studies on reticulo-ruminal impaction (RRI) in buffaloes showed abnormalities in plasma lipid profile, a significant increase in the activities of liver specific enzymes, viz. AST, SDH, GGT and arginase in plasma and creatinine and bilirubin concentrations. This pointed towards hepatic and renal dysfunctions during RRI in buffaloes. Less activities of antioxidant enzymes in buffalo bull spermatozoa was due to higher lipid peroxidation that indicated that they were more prone to oxidative stress as compared to cattle bull spermatozoa when stored at refrigeration temperature. Vitamin E in EYC diluent significantly reduced the leakage of antioxidant enzymes viz. SOD, GPx and G6PD from spermatozoa and also protected against decline in sperm motility under refrigerated conditions up to 72 h of storage. Vitamin E+C combination also had the same effects but these were less pronounced than vitamin E alone. Biochemical Studies on Blood in Acute and subacute bovine Mastitis revealed altered oxidant/antioxidant status in these animals. The affected animals had a significantly higher plasma albumin, globulins and fibrinogen indicating an increase in the acute phase protein in plasma.

Veterinary Anatomy

Gross/Gerontological anatomical studies

Important gross anatomical points were observed in the thyroid gland of ageing goat, nasal meatuses of buffalo, bones of buffalo skull, biometry of liver and gall bladder of sheep and intrahepatic biliary system in buffalo. Besides this, age related histomorphochemical changes have been described in arteries, heart, ovary, fallopian tube, uterus, vagina, hypophysis cerebri, thyroid gland and brain stem nuclei of goat

Emblaming technique

On the basis of trials with various embalming fluids, a fluid containing – phenol 11.5 per cent, ethanol 10.7 percent, thymol 1.5 per cent, formalin 7 per cent in water was recommended for the routine dissection in tropical climate.

Histomorphological, histochemical and histoenzymic studies

Histomorphological studies on diaphragm in relation to diaphragmatic hernia in buffalo revealed that there was no inherent structural weak point in diaphragm. A lamina muscularis mucosae, was reported for the first time in buffalo. Islets of Langerhans in goat pancreas showed high percentage of immuno reactive cells in females. Mucopolysaccharides, lipids, phosphatases and oxidoreductases were localized in the glandular epithelia of accessory sex glands of ram. The fimbriae in oviduct of buffalo were not prominent and the transition of ampulla into isthmus was gradual. The ampulla formed nontortuous ‘hair pin loop’. The uterotubal junction presented a ‘S’ shaped configuration. The cyclic corpus luteum of buffalo comprised of non steroidogenic and steroidogenic cells. Immunohistochemically and ultrastructurally the FSH, LH, TSH, PRL, and GH cells were demonstrated in hypophysis cerebri of goat and buffalo. The Rathke’s pouch and the infundibulum appeared before 30 mm CR length stage. The somatotrophs were first recognized at 60 mm CRL, Somatotrophs at 185 mm CRL foetus. The thyrotroph, FSH- and LH- gonadotrophs were first recognized in 60 mm, 120 mm and 482 mm CRL stages respectively.

Surgical anatomy

The trephining of frontal sinus in buffalo can be done on the line joining the middle of temporal regions about midway between the median plane and the lateral margin of the head and that of maxillary sinus at about the mid point between the infra orbital margin and facial tuberosity.

Developmental anatomy

Majority of structures of buffalo stomach developed at 11.20 cm CVRL (79 days). The papilla appeared in rumen at 19.60 cm CVRL and in reticulum at 14.70 cm CVRL (95 days). The pyloric and fundic glands were observed in abomasum at 14.70 cm CVRL (95 days). The buffalo lungs were distinct by 10.1 cm CVRL (74 days). Bronchial cartilage plates appeared at 5.50 cm CVRL (53 days). The female genitalia was first observed

at 10.0 cm (73 days). The Uterine caruncles appeared at 35.0 cm CVRL (152 days). Development of female genitalia proceeded in caudocranial direction. Both the cranial and caudal parts of mesonephros in buffalo were differentiated at 3.0 cm CRL (42 days). The mesonephros started degenerating at 4.1 cm CRL (47 days) and complete degeneration observed at 10.3 cm CRL (75 days), which occurred in a cranio-caudal direction.

Other studies

The prolonged administration of cypermethrin even in minute quantity caused degenerative changes in respiratory, digestive and urogenital organs of rabbits. It was observed in testis that exogenous dihydroandrosterone rendered the leydig cells physiologically inactive. A study on folliculogenesis in buffalo revealed that the ovarian follicles were minimum during mid luteal phase and maximum in the follicular phase. The follicular atresia was significantly higher in mid luteal phase, which decreased during late luteal, follicular and early luteal phase. The radiological study in buffalo revealed that hepatic artery divided into dorsal and ventral interlobar arteries before entering the liver hilus.

REGIONAL RESEARCH STATIONS

Regional Research Station, Gurdaspur

An Agricultural Experimental Station at Gurdaspur was established in 1910 for catering to the agricultural technology needs of the sub-mountain region extending from Gujrat district in Pakistan to Ambala district in India. Located at 32.02°N and 75.24°E, Gurdaspur is characterized by high rainfall and high humidity which are very congenial for the development and spread of fungal diseases of crops. A new era in the history of the Research Station, Gurdaspur began under the patronage of Dr. M.S. Randhawa, Vice- Chancellor, Punjab Agricultural University, Ludhiana, who upgraded the status of this centre to that of a research station in 1972.

The National Agricultural Research Project (NARP) funded by the ICAR (from 1983-1993) provided much needed strengthening of the Regional Research Station to concentrate on zone/region specific problems through inter-disciplinary research. A PL-480 research project on 'Collection, maintenance and evaluation of wheat germplasm and its related species and utilization of useful variability' sanctioned by the USDA during 1983-88, and adhoc projects on Fusarium head scab of wheat further strengthened the research programs.

A number of promising, high yielding and disease - resistant varieties of different crops have been developed/ tested at the station and released for cultivation in the zone/state.

Wheat

The outstanding varieties of wheat developed at Gurdaspur include WG 357 (1971), WG 377 (1972), PBW 54 (1983), PBW 120 (1985), PBW 138 (1985), PBW 175 (1987), PBW 222 (1990), PBW 226 (1989) and PBW 299 (1991). In all, 53 improved varieties of wheat were developed/tested at Gurdaspur in collaboration with PAU, Ludhiana, since its inception in 1962. The semi dwarf wheat vars. WG 357 and WG 377 having bold, hard lustrous grains with excellent chapatti making properties became quite popular among the farmers. Dr. A.S. Minhas was awarded a cash Prize of Rs. 5000/- by PAU for developing these varieties in 1972.

Rice

The research on improvement of rice was initiated in 1949. The rice varieties Jhona 349, Palman 246, Basmati 370, Jhona 227, Jhona 20, Basmati 217 and 14 other rice varieties were developed at this station.

Pulses

In pulses, Mash 48 (1948), Mash 1-1 (for kharif season), Mash 218 and Mash 414 (for summer season) and gram varieties C 235, G 130 (highly resistant to blight) and G 543, Lentil 9-12, Moong G 65 and PG3 of Field Pea were developed at the station.

Oilseeds

The work on oilseeds was initiated in 1965 and Gurdaspur station was a centre for conducting research on sesamum and linseed crops and a number of improved varieties of sesamum were developed here viz., TC 289 and TC 25. Similarly, TL 15 and Gsp. Comp.2 (TGC-2) of Toria and Gobhi Sarson Ludhiana 1 (GSL-1) were also developed.

Cotton

In cotton, an outstanding early maturing and high yielding variety of desi cotton G 27, was developed at this station which occupied a major area under desi cotton in the state, during those days. The work on desi cotton was later shifted to Ludhiana.

Maize

The research on maize was taken up in 1970 to develop improved varieties, particularly with early maturity and 10 promising varieties/composites/hybrids were developed in close collaboration with PAU, Ludhiana.

Fruits

The fruit section was established in 1928-29 to study the adaptability of fruit plants grown in the sub-mountainous region and the mango varieties Aman Dusehri was found to be the most promising followed by Langra and Samar Bahisht. In litchi, the outstanding varieties Dehradun, Calcuttia late, Seedless late, Seedless No.2 and Rose Scented were recommended for cultivation in the region. An excellent fruit nursery was established in 1973 for supplying pedigreed fruit plants of mango, pear, plum and litchi to the growers. Recommendations on fertilizer applications, propagation techniques, reducing post-harvest losses and plant protection such as litchi nut borer have been made from this station.

Soil Science

In soil science, the chemical laboratory at Gurdaspur was established in 1936. The findings of this laboratory on classification of soils and their characteristics, determination of fertilizer and micronutrient requirements of various crops and providing soil and water testing services to farmers, since the establishment of 'Soil Testing Laboratory' in 1967, have greatly helped the farmers to make judicious use of fertilizers for their crops. A total of 3,24,790 soil samples and 2287 water samples have been analyzed. Out of these, 2,46,593 samples were tested for fertilizer recommendation, 27,670 for Kallar reclamation, 50,527 for orchard plantation and 175 soil samples for micronutrients.

Disease Management

Gurdaspur is considered as hot spot for several diseases affecting different crops. The work relating to plant pathology at Gurdaspur was started in early 1940s. A number of crop varieties/germplasm lines especially of wheat, rice, pulses and oilseeds resistant to various diseases have been identified and utilized in breeding programs. Wild germplasm of wheat and its related species viz., wild *Triticum* species, *Aegilops* and *Agropyron* species resistant to rusts, Karnal bunt, loose smut, head scab and foliar blights have been identified. Effective control measures have been developed for controlling Karnal bunt and head scab of wheat, brown spot of rice, foot-rot of basmati rice, Rhizoctonia blight of moong etc. A root-rot and wilt sick plot, developed around 1945, has been regularly used for identifying resistance to the wilt complex disease in gram and resistant germplasm varieties/lines were identified.

Agromet Field Unit

An 'Automatic Weather Station' was established at the station in 2009 by the IMD, New Delhi which provides information on different weather parameters. Weather related advisories, based on weather forecasts, are issued to the farmers/extension agencies of Gurdaspur and Hoshiarpur districts, twice a week. This has helped the farmers to minimize crop losses and curtail expenditure on irrigation, fertilizers and pesticides.

Research Recommendations

The scientists working at the research station have contributed 38 research recommendations in different areas of agriculture that have been included in the Package of Practices of PAU. These have been adopted by the farmers in the region leading to enhanced agricultural production.

New Research Projects and Laboratories

A new collaborative research project on evaluation, cultivation and processing of aromatic and medicinal plants for Dhar block (now in Dist. Pathankot) has been sanctioned by the Dept. of Biotechnology, Govt. India to improve the economic status of farmers in the region. Recently, three new research laboratories viz. Biocontrol Lab., Leaf/Tissue Analysis Lab. and Plant Health Clinic have been established at this research station..

Regional Research Station, Faridkot

The Regional Research Station, Faridkot, located in the agriculturally most potential region - Zone IV (South-Western Zone) of Punjab, was established in April 1970. It has 45 acre of rich fertile, leveled and well laid out farm area for experimentation. The altitude of the zone varies between 200 to 300 m amsl. The soil are largely of alluvial origin and coarse to fine in texture. Mostly the soils are alkaline in reaction having pH more than 7.5. The water table in the region varies from 2 m to 10m below the ground level. The sub-soil water is brackish and salty, which is not fit for irrigation to crops. The average annual rainfall and potential evapo-transpiration of the zone is 419 mm and 1424 mm, respectively. The principal *kharif* crops of the zone are rice, cotton, sugarcane and mung bean. The important *rabi* crops are wheat, chickpea, rapeseed and mustard. In addition, horticulture and vegetable crops also cover a considerable area in this zone. The research is being carried out under All India Coordinated Crop Improvement Project sanctioned by the ICAR on cotton (main centre) and sugarcane (sub centre). The multilocation research trials are also being conducted on pulse crops, bajra, sorghum, sunflower, rapeseed and mustard, and soybean.



American cotton variety F1861



Cotton hybrid PAU 626H

The research priorities of the research station include development of high yielding, early maturing varieties and hybrids of cotton having superior fibre quality and resistance/tolerance to various biotic and abiotic stresses, development of region / location specific improved cane varieties having higher yield, quality, and tolerance to biotic and abiotic stresses, undertaking basic, strategic and applied research for developing location specific crop production and protection technologies for optimization of production of cotton and sugarcane, production of nucleus and breeder seed of improved varieties and multi location evaluation of advanced genotypes of chickpea, mungbean, pigeonpea, paddy, bajra, sunflower, rapeseed and mustard, and linseed for yield and other characters.

Crop Improvement

The following varieties of cotton and pulses have been developed and released at the station:

Sr.	Name	Year	Important features
Cotton			
1	F 414	1977	Early maturity (180-190 days), seed cotton yield is 760 kg/acre, mean fibre length is 23.2mm.
2	F 286	1983	Early maturing, medium staple with 2.5% span length of 23.9 mm, suitable for spinning at 30s counts. Average seed cotton yield is 840 kg/acre.
3	F 505	1986	Possesses bigger bolls, dark green leaves with maximum yield potential of 1440 Kg per acre. Its ginning outturn is 35.3% and fibre length at 2.5% span length is 25.1 mm.
4	F 846	1992	Dark green, broad lobed leaves with big round bolls, average seed cotton yield is 1100 kg per acre with ginning outturn of 35.3% and 2.5% fibre span length of 26.8 mm.
5	F 1054	1992	Early maturing, high yielding variety suitable for late sown conditions, average yield is 1150 kg kapas per acre with ginning outturn 34.6% and fibre length at 2.5% span length is 26.8 mm.
6	F 1378	1997	Early maturing, high yielding variety, having medium staple with 2.5% span length of 26.2 mm. Average seed cotton yield is 985 kg/acre.
7	F 1861	2002	Matures in 180 days, average seed cotton yield is 804 kg/ acre, ginning outturn is 33.5% and fibre length is 26.3 mm.
8	PAU 626H	2007	It matures in 180 days. Its average seed cotton yield is 804 kg/ acre in research trials. Its ginning outturn is 33.5%. Its fibre length is 26.3 mm. cotton leaf curl virus resistant.
9	FDK 124	2011	Takes about 160 days to mature, short staple, coarse fibre variety with 2.5 span length of 21.0 mm and ginning outturn of 36.45%, average seed cotton yield of 928 kg per acre, resistant to jassid and whitefly.
10	F 2164	2012	Identified for North zone, matures in 180 days, average seed cotton yield is 1050kg/ acre with ginning outturn of 33.6% and 2.5% span length of 27.7 mm and is spinnable at 40s counts
11	FHH 141	2012	Identified for North zone, matures in 180 days, average seed cotton yield is 1000 kg/ acre with ginning outturn of 34.1% and 2.5% span length of 26.4 mm
12	FMDH 9	2012	Identified for North zone, matures in 160 days, average seed cotton yield is 1100 kg/ acre with ginning outturn of 36.6%
13	FMDH 8	2012	Identified for South zone, average seed cotton yield is 615 kg/acre with ginning outturn of 39.0%
Chickpea			
1	GPF2	1994	The plants are semi-erect with lush green leaves and long fruiting branches with two seeds per pod. It has bold seeds and matures in about 170 days. Its average yield is 7.6 quintal per acre.
2	PDG3	1997	Recommended for sowing under rainfed conditions. It is semi-erect with dark green leaves and long fruiting branches. It has bold seeds and matures in about 160 days. Its average yield is 7.2 quintal per acre.
3	PDG4	2000	Recommended for sowing under rainfed conditions. Its plants are erect with dark green foliage. It bears long fruiting branches arising from the base. It has bold seeds and matures in about 160 days. It is fairly resistant to wilt, foot rot, root rot and blight. Its average yield is 7.8 quintal per acre.

The station has also contributed in the evaluation and release of the following 73 varieties of different crops:

Crop	No. of varieties	Variety/hybrid
American cotton	17	LH 886, LH 900, LH 1134, LH 1556, LH 2076, LHH 144, Ankur 651, Whitegold; RCH 134 Bt, RCH 308 Bt, RCH 314 Bt, RCH 317 Bt, MRC 6301 Bt, MRC 6304 Bt, MRC 7017 BG-II, MRC 7031 BG-II, Ankur 3028 BG-II
Arboreum cotton	5	LD 327, LD 491, LDH 11, LD 694, Moti
Sugarcane	5	CoS 8436, CoH 119, CoJ 85, CoJ 88, CoJ 89
Chickpea	4	L 550, PBG 1, BG 1053, GLK 25104
Pigeon Pea	4	AL 15, AL 201, PPH 4, PAU 881
Mungbean	9	SLM 32, SML 134, ML 131, ML 267, ML 613, PBM 1, SML 668, ML 818, PAU 911
Urd bean	1	Mash 114
Soyabean	1	SL 744
Sunhemp	2	Crota L1, PAU 1691
Bajra	6	PHB 10, PHB 47, PBC 15, PBC 138, PBC 164, PHB 2168
Wheat	6	WL 711, HD 2329, PBW 154, PBW 154, PBW 222, PBW 226
Rapeseed & Mustard	5	RL 514, RLM 619, Gobhi Sarson, Ludhiana-1, PBR 210
Sunflower	6	SH 3322, PAC 302, DK 3890, SH 88, PSFH 118, PSFH 569
Vegetable	2	Sponge gourd (PSG 9), Garlic (PG 17)

Crop Production Technologies

The following crop production technologies have been developed at the research station :

- Wider intra-row spacing of 75 cm instead of 60 cm for American cotton hybrids, 60 cm instead of 45 cm for *desi* cotton hybrids and American cotton varieties, and 45 cm instead of 30 cm for *desi* cotton varieties.
- Nitrogen dose of 150 kg/ha found to be suitable for hybrids of both *American* and *Desi* Cotton and 75 kg N/ha for varieties of both kinds.
- Four sprays of 2% potassium nitrate at weekly interval starting at flower initiation in addition to soil applied fertilizers resulted in higher seed cotton yield.
- Seed rate of 750 g/acre and spacing of 67.5 × 75.0 cm for Bt cotton hybrids, RCH 317Bt, MRC 6301Bt, MRC 6304Bt, RCH 308Bt, RCH 314Bt; and seed rate of 750 g/acre and spacing of 67.5 × 90 cm for Bt cotton hybrids, RCH 134Bt have been recommended.
- Fertilizer application, i.e., 150 kg N/ha and 30 kg P₂O₅/ha for Bt cotton hybrids have been recommended.
- For gap filling, 3 week old nursery grown in 4" x 6" polythene bags, filled with 1:1 mixture of soil and FYM can be transplanted.
- Gram (Chickpea) as an intercrop in autumn planted sugarcane in 2003
- CoJ 89 variety of sugarcane for late planting conditions in 2005 CoJ 88 variety of sugarcane for saline water conditions in 2005
- Paired row trench planting method of sugarcane in 2009
- Application of *Azotobacter* biofertilizer @ 10kg/ha in 2009
- Planting of sugarcane in standing wheat using Furrow Irrigated Raised Bed (FIRB) system in 2012

Crop Protection Technologies

- The new insecticide NNI 0001 480SC @ 100 g/ha was recommended for the control of pink, spotted and young larvae of American bollworm.
- The foliar application of Acetamiprid 20SP @ 50g/ha and Thiomethoxam 25WG @ 100 g/ha were recommended for the control of cotton jassid.
- Spinosad 48SC @ 150 ml/ha, Indoxacarb 15SC and 15EC @ 500 ml/ha were recommended for the management of grown up larvae of American bollworms.
- Fenpropathrin 10EC (Mestthrin) @ 300ml/acre was recommended for control of pink and spotted bollworm larvae.
- Emisan 6 @ 0.5 g/kg seed as seed treatment against seed borne diseases was recommended.
- Use of Confidor 200 SL (imidacloprid) and Hostathion 40 EC (triazophos) for control of sugarcane whitefly *Aleurolobus barodensis* (Maskell) was recommended in 2004

Regional Research Station, Bathinda

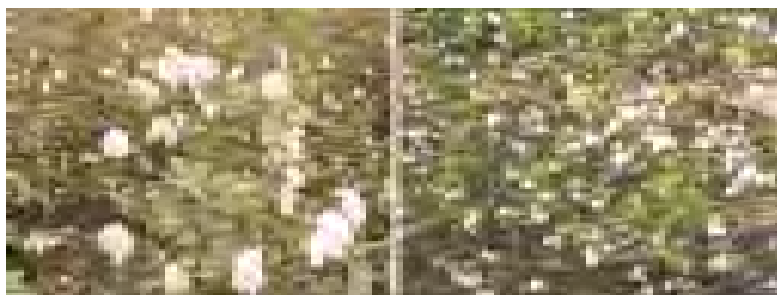
The PAU had established its Fruit Research Station at Bathinda in 1972 to cater to the research needs of horticulture (mainly citrus and grapes) of the state. This region of Punjab differs from other parts of the state with respect to low rainfall (less than 400 mm/year), low and erratic canal water supply, saline-sodic underground poor quality water, high temperature coupled with strong stormy winds during summer months. The Fruit Research Station was elevated to Regional Research Station in 1987 under the aegis of National Agricultural Research Projects (NARP). This station has an area of 325 acres and the research is conducted in the disciplines of Plant Breeding, Water Management, Agronomy, Soils, Entomology, Plant Pathology, Horticulture, Vegetables and Agrometeorology. The research station is involved in the development of 8 varieties of cotton, 4 of wheat, 3 of barley, 6 of raya, 3 of onion, 3 of popular and one each of toria, bajra, mungbean, grape, baramasi lemon and lettuce. In addition to this, 36 varieties of different crop plants have been tested and 29 production/protection technologies from this station have been included in the Package of Practices of PAU.

This station is well equipped with laboratories, library and computer facilities. It produces more than 1000 quintals of seed of improved crop varieties annually along with quality nursery plants of fruits for distribution to various agencies, farmers and fruit growers. Soil samples brought by the farmers of the region are tested for their macro and micronutrients status for judicious use of fertilizers. As the underground water in most of this region is of poor quality, water samples of the region are analyzed in the laboratory for their quality and suitability for specific crops. Field days on different crops, front line and live demonstrations, *rabi* and *kharif Kisan Melas* organized in September and March every year have played a key role for transfer of technology to the farmers. The farmers of south-western districts of Punjab and adjoining areas of Rajasthan and Haryana have been greatly benefitted through such programmes

Development of varieties

Cotton

LH 2076: It is a high yielding cotton leaf curl resistant variety with an average seed cotton yield of 7.8 q/acre, plant height of 153 cm, 2.5% span length of 27.1 mm and ginning out turn of 33.4%.



Americal cotton var. LH 2076

Cotton var. FDK 124

FDK 124 : FDK 124 is a *desi* cotton variety recommended for cultivation in the state. Average seed cotton yield of FDK 124 is 9.28 q/acre and takes about 160 days to mature. It is a coarse fibre variety with 2.5 per cent staple length of 21.0 mm and ginning out turn of 36.4%.

LH 2108: LH 2108 variety of American cotton has been identified for North zone comprising Punjab, Haryana and Rajasthan by Varietal Identification Committee of All India Coordinated Cotton Improvement Project. This variety has seed cotton yield of 2700 kg/ha with good boll bearing, 2.5 per cent staple length of 28.2 mm and fibre strength of 22.2 g/tex.

F 2164: Identified for North zone comprising Punjab, Haryana and Rajasthan by Varietal Identification Committee of AICCIP. This variety has seed cotton yield of 2839 kg/ha and has good boll weight, seed index and lint index than the check varieties. F 2164 has superior fibre quality and is spinnable at 40s counts.

FHH 141: Identified for North zone by Varietal Identification Committee of AICCIP. FHH 141 recorded seed cotton yield of 2511 kg/ha against 2159 kg/ha of local check, LHH 144 giving an increase 16.32% in seed cotton yield.

FMDH 8: FMDH 8 is a hybrid of *desi* cotton which is identified for North zone by Varietal Identification Committee of AICCIP. It gave 99.71% and 31.77% higher seed cotton yield than the zonal check and local checks, respectively.

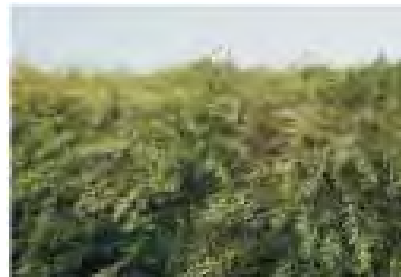
FMDH 9: This hybrid of *desi* cotton was identified for North zone by Varietal Identification Committee of AICCIP. It gave 16.83% and 16.98% higher seed cotton yield than the zonal and local checks, respectively.

Raya

PBR 210: Recommended for timely sown irrigated conditions in south-western districts of Punjab. Its average yield potential is 6.6 quintals per acre and oil content 37.8%. Tolerant to white rust disease and matures in 150 days.

PBR 91: Recommended for timely sown irrigated as well as rainfed conditions in south-western districts of Punjab. Its average yield potential is 8.1 quintals per acre and oil content is 37.6%. Tolerant to white rust disease and matures in 145 days.

PBR 97: It is recommended for rainfed conditions in the state. It is bold seeded and oil content is 39.8%. It matures in 136 days and average yield potential is 5.2 quintals per acre.



Raya variety PBR 91

Toria

PBT 37: This variety is recommended for irrigated conditions in the state. It is early maturing cultivar and takes about 91 days to mature, and suitable for toria- wheat rotation. It has oil content of 41.7% and yield potential of 5.4 quintal per acre.

Wheat

PBW 550: It is recommended for timely sown and irrigated conditions in the state. Its plant height is about 86 cm, resistant to yellow and brown rust, but susceptible to karnal bunt. It matures in about 146 days and average yield potential is 20.8 quintal per acre.

PBW 590: It is recommended for late sown and irrigated conditions in the state. Its plant height is about 80 cm, resistant to yellow and brown rust, but susceptible to karnal bunt. It matures in about 128 days and average yield potential is 16.4 quintal per acre.

PBW 373: It is recommended for late sown and irrigated conditions in the state. Its plant height is about 90 cm, susceptible to yellow and brown rust, but resistant to smut. It matures in about 140 days and average yield potential of 16.5 quintal per acre.

Barley

PL 419: This variety has been recommended for timely sown and rainfed conditions in the state. It is short stature (80 cm) and stem resistant to lodging. It is resistant to yellow rust, loose smut and covered smut. It matures in 130 days and average yield potential is 14 quintal per acre. It is suitable to prepare malt.

PL 426: It has been recommended for timely sown and irrigated conditions in the state. It is short stature (80 cm) and stem resistant to lodging. It is resistant to yellow rust, loose smut and covered smut. It matures in 124 days and average yield potential is 14 quintal per acre.

PL 807: This variety is recommended for timely sown and irrigated conditions in the state. It is short stature (80 cm) and stem resistant to lodging. It is resistant to yellow rust, loose smut and covered smut. Matures in 137 days and average yield potential is 17.2 quintal per acre.

Bajra

PHBF-1: It is a multi-cut forage hybrid of bajra. It flowers in 150 days and attain plant height of 198 cm. It has succulent stem and multicut nature. The average yield of this hybrid is 256 q/acre.

Mungbean

PBM 1: This variety is recommended for south-western districts of Punjab for *kharif* season. Its plants are erect, determinate and medium statured (67 cm). It matures in 75 days and has good cooking quality. Its average grain yield is 4.2 q/acre.

Grapes

Beauty Seedless: Apart from Perlette variety, Beauty Seedless has been recommended for cultivation in the arid-irrigated region of the state.

Baramasi lemon

PAU selection: This variety has been recommended for cultivation throughout the state.

Lettuce

Punjab Lettuce-1: This variety has been recommended for cultivation in the state for kitchen gardening. It gives first cutting 45 days after transplanting. Its green leafy yield is 35 q/acre.

Onion

Punjab Naroya: This variety is recommended for cultivation at the national level in *rabi* season. It is tolerant to purple blotch. Its average yield is 150 q/acre.

Punjab White: This variety of white onion is recommended for cultivation in *rabi* season in the state. It is suitable for powder making. Its average yield is 135 q/acre.

Agrifound Dark Red: This is a variety of red onion recommended for cultivation in *kharif* season in the state. Its average yield is 120 q/acre.

Poplar

PL 3, PL 6 and PL 7 clones of poplar are recommended for cultivation in the state.

Production Technologies

Cotton : Some of the production technologies recommended for cotton include dDate of sowing of cotton up to mid-May, reduction of nitrogen dose from 100 kg/ha to 75 kg/ha for American cotton varieties, spacing of 67.5 x 15 cm has been recommended in *desi* cotton for higher seed cotton yield, application of drop (thidiazuron)@ 150 g/ha for advancing boll opening and thus allowing the early sowing of wheat, ridge sowing and irrigation in furrows that saves 30-35% irrigation water applied without reduction in seed cotton yield, application of first irrigation to American cotton 6 weeks after sowing instead of 4 weeks after sowing resulting into significant increase in seed cotton yield and helping in deep penetration of root system, inter and intra row spacing of 67.5 x 75 cm for *Bt* cotton hybrids but for RCH 134 *Bt* spacing of 67.5 x 90 cm, pre emergence spray of stomp 30 EC (pendimethalin) @ 1.0 litre/ acre for weed control in American cotton, for poor quality underground water pre sowing irrigation with canal water followed by subsequent irrigations with poor quality water to cotton grown on ridges in alternate furrows, fertilizer requirement for *Bt* cotton hybrids @ 150 kg N and 30 kg P₂O₅/ hectare, and for gap filling, transplanting of 3 weeks old nursery grown in 4" x 6" polythene bags filled with 1:1 mixture of soil and FYM.

Chickpea : Pre emergence application of linuron (0.9 kg /ha) for the weed control in chickpea has been recommended. Likewise, pre-emergence application of Stomp 30 EC (pendimethlin) @ 1.0 litre/ acre and pre plant application of Treflan (trifluralin) @ 1.0 litre/acre has been found effective and recommended for the control of annual weeds.

Guara :Pre-emergence application of Stomp 30 EC (pendimethalin) @ 750 ml/acre has been recommended for fodder as well as seed crop. It has been advised to apply 25 percent less nitrogen to *rabi* crops sown after leguminous crop (guar, soybean and mungbean).

Mungbean: Pre - emergence application of Treflan 48 EC (trifluralin) @ 800 ml/acre has been found effective for control of annual weeds in main season mungbean and recommended to the farmers.

Raya: Pre-emergence application of Treflan 48 EC (trifluralin) @ 625 ml/acre or 400 ml/acre + one hoeing has been recommended for control of annual weeds.

Grapes : In Perlette grapes, pre-bloom thinning with plastic brush retaining only 100-125 flower buds, stem girdling by removing 4mm wide bark ring followed by dipping of berries in 40 ppm solution of GA 3 improved quality and enhanced ripening in grapes. With this technique heavier berries with more TSS (up to 22%) and reduced juice-acidity can be obtained. Pruning technique by retaining 3-4 buds/.cane has been recommended as it ensures bigger bunches with heavier berries. Foliar application of 1.5% Potassium sulphate has been recommended for quality improvement in perlette grapes.

Rejuvenation technology and top working of Perlette grapevines: The old perlette vines trained on bower system can be successfully rejuvenated by heading back the primary arms leaving behind one foot stub in the month of December-January. Perlette vines of grapes can be successfully replaced by top working with Flame Seedless by tongue grafting in the last week of February. This technology advances the maturity of Flame Seedless by 4-5 days and improve fruit quality.

Kinnow : For control of fruit drop in kinnow, 0.3% copper oxychloride + 2,4-D (sodium salt) (10 ppm) has been found effective and recommended at national level. Four fortnightly sprays of Bavistan @ 0.1% starting from July for control of pathological fruit drop and rot in *kinnow*. Physiological and pathological fruit drop in kinnow with spray of Ziram 27 SC (1250 ml) + 5 g 2,4-D (Sodium salt of horticulture grade) or propiconazole 25 EC (500 ml) + 5 g 2,4-D or Bavistin 50WP (500g) + 5 g 2,4-D in 500 liters of water in mid-April, August and September has been recommended. Besides, additional spray of only Ziram 27 SC (1250 ml) or Propiconazole 25 EC (500 ml) or Bavistin 50 WP in end July and September is recommended.

Sweet Orange: Spacing of 6 x 6m in sweet orange variety *Jaffa* has been found better and recommended to the farmers. Intercropping wheat crop in Sweet Orange has been found economical only up to 7-8 years.

Onion : A technique for better seed production in onion by keeping a spacing of 30 cm x 45 cm has been recommended.

Protection Technologies

Seed treatment with imidachloprid (Gaucho) @ 5g/kg in American cotton has been shown to reduce the attack of jassid and help in reducing environmental pollution. Integrated control of aphid and painted bug in rapessed mustard has been recommended. Eco-friendly measures as early sowing, application of only recommended fertilizers and first irrigation after three weeks of sowing have tended to reduce the expenditure incurred in pesticide spray operations. For controlling termite, seed treatment with 4 ml Chloropyriphos/ 7 ml Thiodan/ 6 ml Regent/kg of seed has been recommended. An effective control of powdery mildew of grapes using three sprays of Bayleton (40g/100 litre water) during March-May has been recommended.

Regional Research Station for Kandi Area, Ballawal Saunkhri

Kandi Area Development Project (KWADP) was initiated in April 1980 with World Bank assistance as a pilot project for integrated development of watersheds in Punjab. The Punjab Agricultural University was entrusted with research component to carry out the research on micro watershed hydrology in Kandi watersheds. Soon after, Regional Research Station Ballawal Saunkhri was established in August 1982 under National Agricultural Research Project (NARP) to cater to the research needs of Kandi region. The research station is located in the foot hills of Shiwaliks at 31° 6' 5" N latitude and 76° 23' 26" E longitude, at a height of 355 m above mean sea level, about 14 km from Tehsil Balachaur, District S.B.S. Nagar. It has a total area of 135 ha that includes area under buildings & roads, cultivation, forests, and hills (hilly forest area).

This region is characterized by the erratic distribution of rainfall, small and scattered land holdings, severe soil erosion on sloppy lands, poor soil fertility, low moisture retention capacity, loss of rainwater as runoff, deforestation because of heavy biotic pressure, crop failure/low and uncertain yields, poor quality of livestock, shortage of fuel and fodder and lack of infrastructure facilities. However, the region is the main source of natural forests rich in flora and fauna biodiversity. The region is popularly called *Kandi* area. In a sub-humid type of climate, the mean annual rainfall is 1100 mm. About, 80 per cent of the rains coincide with the *kharif* season and rest 20 per cent occur in the *Rabi* season. Mean maximum temperature of 41°C is recorded during the first fortnight of June whereas the mean minimum temperature of 6°C during January. Soils of the area are generally light in texture with loamy sand and sandy loam as the dominant textural classes.

The main objectives of the station are to generate location specific and need based technologies in the field of land and water Management, arable cropping, horticulture & agro-horticulture, forestry & agro-forestry for the sustainable development of the region.

Rainwater Management

Makkowal is base flow water harvesting system, very efficient and economical as it requires no external energy. The discharge from Makkowal type water harvesting system was maximum (approx 68.9 lps) during monsoon season and 6.7 lps post monsoon season. Summer ploughing enhanced rain water intake and resulted in 33 and 25 % increase in yield of maize and wheat respectively and adopted by 80% farmers of the region.

Minor land configuration conserve *in situ* soil moisture that increases efficacy of applied inputs, results in 25 to 57 % increase in different crop yields. Among different vegetative barriers, Kanna (*Sachharum munja*) proved best in terms of yield, water-use-efficiency and economic returns. It was followed by Napier Hybrid Bajra (*Pennisetum purpureum*), Subabul (*Leucaena leucocephala*) and Vetivar (*Vetiver zizanooides*) in maize, sesamum and blackgram.

The V-ditch and crescent bund methods of planting for horticultural and forestry plants on sloppy land harvested maximum rain-water in-situ as compared to the traditional pit method. On an average 240.8 ha cm water was available for supplemental irrigation from water harvesting structure at village Karoran. Pre-sowing and Pre-sowing + one supplemental irrigation to wheat increased yield by 73 and 83 % over control respectively. Additional income of Rs. 18000/- (approx.) per year by pisciculture (species: Rohu (*Labeo rohita*), Katla (*Hypophthalmichthys*), Mrigla (*Carrhinus mrigala*). Sowing across the slope increased grain yield by 22% & 18% in maize and wheat respectively over round about sowing method (farmer's practice).



Makkowal type water harvesting system



Raya intercropping in wheat

Cropping Systems

Gram-*raya* and blackgram-chickpea cropping sequences were more profitable than the traditional Maize-Wheat sequence giving additional income of 16000/- and 9000/-, respectively. *Raya* intercropping in wheat and lentil increased yield by 12-15%, adopted by 90% farmers in the Kandi region

Integrated Nutrient Management

In maize/*mash*- wheat/lentil cropping systems, yield obtained with 15 kg N through compost/ green leaves + 20 kg N through urea was statistically at par with 40 kg N/ha (urea). N through inorganic source in maize recorded max grain yield of 2483 kg/ha with B:C of 1.99 which is at par with grain yield obtained with 50 % inorganic N + 50 % org N.

Energy Management

In maize-wheat rotation, the yield of both crops recorded with 50 % conventional tillage (CT) + interculture (IC) + chemical weed control was at par with CT + IC, thus saving two tillage operations.

Participatory Varietal Selection

The station has recommended maize hybrids (PMH-2, JH-3459 and Parkash) which are medium in height and cob placement, tolerant to mid and late season drought, less prone to lodging, gave on an average 50 % higher yield as compared to local cultivars.

Horticulture & Agro-horticulture

A number of fruit plants including guava (*Psidium guajava*), Amla (*Emblica officinalis*), Galgal (*Citrus limon*), Ber (*Zizyphus mauritiana*), Kinnow, mango (*Mangifera indica*), olive, and pomegranate (*Punica granatum*) were tested under rainfed conditions. Out of these, Amla, Ber, guava and Galgal performed better.

Amla : Among five varieties of Amla, Chakiya cultivar yielded heavy bearing (90.44 kg/tree) and larger fruit size. Highest TSS (10.8%) and acidity (2.5%) were observed in Banarsi Seedling and followed by Chakiya in TSS

(10.7%) and by Banarsi grafted in acidity (2.5%). The amount of vitamin C content was found highest in cultivar Chakiya (643 mg/100 g pulp)

while minimum in Banarsi Seedling (584 mg/100 g pulp).



Amla cultivar Chakiya



Galgal cultivar GS-6

Guava : In guava, the higher plant height (360 cm) and stem girth (38.2 cm) were recorded in Allahabad Safeda as compared to Sardar (Lucknow-49). Both cultivars of guava were almost same yielder but Lucknow-49 recorded heavier (236.1 g/fruit) & larger (58.2 cm²) fruits with higher TSS (13.5%), total sugars (9.2%) and vitamin C content (353 mg/100 g pulp) than Allahabad Safeda.

Ber : Sanaur No. 2 cultivar of ber was found vigorous in growth with heavy bearing and fairly tolerant to powdery mildew as compared to Umran and ZG-2. *In-situ* grafting of wild ber (mallah) with Sanaur No. 2 is a successful practice. The fruit yield, fruit weight, fruit size and fruit pulp of wild ber (mallah) after top working with Sanour No.2 were similar to recommended cultivar Sanaur No.2. Highest TSS (18%) was recorded in Sanaur No. 2 followed by the Umran (15.6%) and ZG 2 (12.8%).

Galgal : In case of Galgal, cultivar GS-6 attained maximum plant height (430 cm), stem girth (43.3 cm) and plant spread (460 cm) followed by K-1 and these were found most suitable for cultivation in Kandi area. The highest fruit yield (13.0 kg/tree), fruit size, TSS and acid content were obtained from spacing of 20 x 20 and was followed by 16 x 16 and 12 x 12 feet under rainfed conditions of *Kandi* area.

Forestry and Agro-forestry

Guinea grass (*Panicum maximum*) under Khair (*Acacia catechu*) trees yielded 576 q/ha yr protein rich green fodder during lean period and is good for silvipasture development beside rehabilitation of degraded land. *Grewia optiva* (Biul) a winter fodder tree, yielded 52 q/ha protein rich fodder (19%) than local fodder tree *Butea monosperma* (Dhak) (19 q/ha) with less protein (15%) and more fiber contents. The biomass produced was in the ratio of 2:1 leaf and sticks.

Leucaena leucocephala (Subabul) leaves feeding at the rate of 30% of total forage to milch animals increased the milk production by 10-25% with no adverse effect on the health of animals. Subabul has potential as a source for bio-energy and also an excellent source of raw material for charcoal making (charcoal yield 16-20% of total wood). *Bambusa vulgaris* and *Dendrocalamus strictus* (Lathi Bans) were found promising species in terms of growth and yield.

The regional research station has also played a key role in capacity building of field functionaries of different departments in major areas (soil & water conservation, water resource development, agriculture, horticulture, forestry, agro-forestry, medicinal & aromatic plant, watershed management as well as of farmers by organising field days, *kisan melas* and *kisan goshti*.

Regional Research Station, Abohar

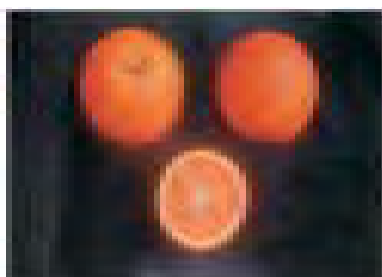
The Regional Fruit Station, Abohar came into existence in 1961. Initially, a citrus progeny- cum - nursery was started by the Department of Agriculture, Punjab in 1946 on an area of 25 acres. Later in 1954, the ICAR launched a Coordinated Date - Palm Improvement Scheme with its main centre at Abohar. In the year 1961, the Regional Fruit Research Station was established at Abohar for undertaking research on the improvement of fruit crops grown in the arid- irrigated region of North India namely Citrus, Grapes and Dates. In December 1962, with the formation of Punjab Agricultural University, Ludhiana, the Research Station came under its control. In 2006, the name of Regional Fruit Research Station, Abohar was changed to Regional Research Station, Abohar. The research station is located at 74.12° E, 30.08° N with an altitude of 185.78 meter and receiving annual precipitation of 75-300 mm. At present, it is spread over an area of 232 acres where an extensive research on citrus, grapes, date palm, peach, pear, plum, apricot, ber, guava, mango, aonla, wheat and cotton is being carried out.

The research station was established with the objective to introduce, collect, characterize, conserve and evaluate the biodiversity of horticultural crops under arid irrigated region; to utilize the available biodiversity and improve the target crops for the development of high quality and productive types having tolerance to biotic and abiotic stresses; and to develop integrated pest and disease management technologies for horticultural crops under arid irrigated conditions.

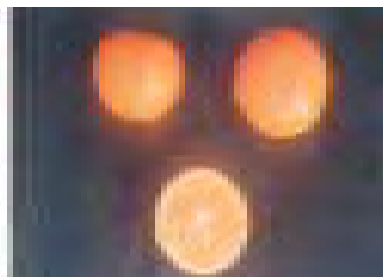
Investigations are being carried out on the conservation of genetic resources of these crops, improvement of fruit crops and development of varieties suitable for arid irrigated region. Work on agro- horticulture techniques such as propagation, planting systems, pruning, training, rootstock selection, plant protection and post-harvest handling is carried out at this station. The station is committed to take up the basic and strategic research programmes for enhanced production and productivity of fruit crops. Since its establishment, this research station has made several recommendations on citrus, grapes and other fruit crops which have benefitted the farmers.

Germplasm Collection

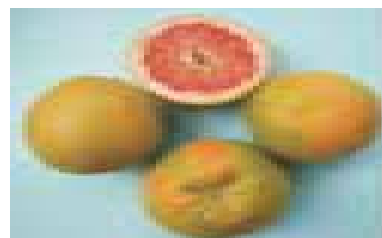
One hundred and ten citrus species/ varieties have been collected from India and abroad and are being maintained at this research station. Besides these edible varieties, a rich collection of rootstock species has also been made. The citrus germplasm including mandarin (25), sweet orange (26), rootstocks (30), grapefruit (8), pummelo (4), tangelos (4), lemons & lime (8), and navels (5) are being maintained for use in crop improvement programmes. Apart from citrus, diverse collection of varieties of other fruit crops such as grape (44), guava (8), mango (6), peach (6), pear (7), pomegranate (6), aonla (7), ber (8), plum (2) and date palm (34) are also being maintained.



Kinnow (Mandarin)



Blood Red (Sweet Orange)



Red Blush (Grapefruit)



Duncan (Grapefruit)

Nursery Production

A well organized nursery is being maintained using virus- free budwood on improved rootstocks. Quality citrus plants are being multiplied and distributed to the fruit growers.

Introduction, evaluation and recommendation of new varieties:

Citrus : Several varieties and root stocks of citrus and other fruits were evaluated at the research station and the following varieties/ root stocks have been recommended for cultivation in the Punjab state :

Citrus varieties evaluated and recommended for plantation

Citrus species	Varieties released
Mandarins	Kinnow
Sweet oranges	Jaffa, Blood Red, Mosambi, Hamlin , Pineapple, Valencia late
Lemons	Eureka, Baramasi, Italian Round, Galgal
Grapefruit	Marsh seedless, Duncan, Foster, Redblush, Star Ruby
Limes	Kagzi
Sweet lime	Local

Rootstocks recommended for different citrus species

Citrus Species	Rootstock recommended
Mandarins	
Kinnow mandarin	Rough lemon (<i>Citrus jambhiri</i>)
Sweet Oranges	
Jaffa	Rough Lemon (<i>Citrus jambhiri</i>)
Valencia late	Rough Lemon (<i>Citrus jambhiri</i>)
Mosambi	Pectinifera (<i>Citrus depressa</i>)
Blood Red	Cleopatra (<i>Citrus reshni</i>)

Grape : Perlette has been found to be the best grape variety for commercial cultivation in the region.

Guava : Commercial cultivation of guava under arid – irrigated zone of Punjab has been recommended

Aonla : Cultivation of Aonla varieties viz., Balwant (NA-10), Neelam (NA-7) and Kanchan (NA-4) under Punjab conditions has been recommended.

Production Technologies

Plant spacing : In order to obtain higher fruit yield and better economic returns in kinnow mandarin, high density plantation (20' X 10') was found most productive and has been recommended to the growers. The trees should be widened at the 15th year of tree age by removing alternate trees (keeping 20' X 20' spacing) to prolong the life expectancy of kinnow orchards.



Zinc deficiency in kinnow

Nutritional requirements : Fertilizer requirement for kinnow mandarin has been worked out for correcting nitrogen and phosphorous deficiencies so as to obtain higher fruit yield with better fruit quality.

Age (years)	Farmyard manure (kg / plant)	Nutrients Basis (g/ Plant)		Fertilizer Basis (g/ Plant)	
		N	P	Urea (46 %)	Super Phosphate (16%)
1-3	10-30	110-330	-	240-720	-
4-7	40-80	440-770	220-385	960-1680	1375-2400
8 & above	100	880	440	1900	2750

Entire farmyard manure is applied during December. The N doses are split into two parts and the first half is applied in February/March (before flowering) and second half in April-May (after fruit set). Phosphorous is applied along with first dose of nitrogen. In case of sweet orange, nitrogen application @ 900 g per tree has been found to be the optimum dose for higher fruit yield and good quality of sweet orange cv. Jaffa.

Micronutrient requirement: Foliar application of 1000 ppm Zn + 1000 ppm Mn during the months of April and August is found to be effective for better fruit yield and quality in Kinnow mandarin. To correct the Zn deficiency, foliar application of 0.3% ZnSO₄ during April, June and August is recommended for citrus.

Weed control : Glyphosate @ 2.51 l/ha was found an effective herbicide and it kills both the monocot as well as dicot weeds without any adverse effect on growth of seedlings.

Crop Physiology

Crop regulation: Application of Ethrel (600 ppm) and NAA (400 ppm) sprays at full bloom stage were effective in thinning the flowers / fruitlets in order to regulate bearing behavior of Kinnow mandarin. A technique was developed to improve the quality of grapes cv. Perlette, by a combination of girdling of the main trunk, brushing of panicles and dipping in 40 ppm gibberellic acid.

Physiological fruit drop: Foliar application of 2,4 - D (20 ppm) or Gibberellic acid (20 ppm) during end – March, end – April, mid – August and mid- September was found highly effective to check physiological fruit drop in Kinnow mandarin. A positive correlation of fruit drop with temperatures while negative correlation with relative humidity and rainfall has been observed

Fruit Development: Fruit growth followed double sigmoid pattern and fruits took about 50 days to develop from full bloom to maturity under the arid - irrigated conditions of Punjab in apricot cv. Benazeer.

Post- harvest Storage

Post-harvest storage studies indicated that Kinnow fruits can be stored for 28 days under ambient conditions and up to 45 days under cold storage conditions with the post harvest treatment of 2,4-D (250 ppm) + waxing without affecting fruit quality. Foliar application of 2,4-D (20 ppm) during mid-October and mid-September was found effective for extending the harvesting period of Kinnow up till end March for the commercial benefit of citrus growers.

Plant Protection Technologies

Insect Pests Management

Citrus Whitefly and Blackfly: For the control of citrus whitefly and blackfly, spraying with 1000 ml Fosmite 50EC (ethion) or 1250 ml Hostathion 40EC (triazophos) or 1140 ml Thiodan 35 EC (endosulfan) in 500 litres of water per acre during April-May and September - October has been found effective and recommended to the growers.

Citrus Psylla : Spraying with 1250 ml Rogor 30EC (dimethoate) or 1000 ml Metasystox 25 EC (oxydemeton-S-methyl) in 500 litres of water per acre has proved effective for psylla control and recommended to the growers.

Aphids: Aphids (*Toxoptera aurantii*, *Aphis gossypii* and *Myzus persicae*) are the regular pest of citrus. *T. aurantii* and *M. persicae* are active from first week of February to first week of May with their critical period of infestation from first week of March to first week of April. These two species along with *A. gossypii* are also causing damage to citrus plants from last week of August to second week of November with their critical period of infestation from second week of September to first week of October. The nymphs and adults suck the cell sap from young leaves and tender twigs. This impairs the vitality of the tree and causes severe curling and deformation of young leaves resulting into stunted growth. The honeydew excreted by the aphids also provides a good substrate for the growth of sooty mould, which affects the photosynthetic activity of the plant. Spray of 1250 ml Rogor 30 EC (dimethoate) or 1000 ml Metasystox (oxydemeton-S-methyl) in 500 litres of water per acre has been recommended for the control of aphids on Kinnow mandarin.

Citrus Leaf-miner : Spraying with 1000 ml Ripcord 10 EC (cypermethrin) or 500 ml Sumicidin 20 EC (fenvalerate) or 1250 ml Hostathion 40 EC (triazophos) or 1875 ml Durmet 20 EC (chlorpyrifos) in 500 litres of water per acre during April-May and August- September has been recommended.

Citrus Thrips : Spraying with 1000 ml Fosmite 50 EC (ethion) or 1250 ml Hostathion 40 EC (triazophos) or 1140 ml Thiodan 35 EC (endosulfan) or 1000 ml Metasystox 25 EC (oxydemeton-S-methyl) in 500 litres of water per acre has been recommended.

Mealy Bug on Citrus / Guava / Grapevine : For effective management of mealy bug, regular monitoring of the infestation of trees by observing the underside of leaves, young shoots, fruits and branches has been advocated. The orchards sanitation needs to be maintained. The branches of trees should not be allowed to touch the ground. Prune or remove the infested branches and destroy the same. Drench spraying of insecticides like 1875 ml Durmet/Dursban/Coroban 20 EC (chlorpyrifos) in 500 litres of water first on the appearance of pest has been recommended. In case of grapevine, spray may be done after the harvest of the crop in July to avoid the residues of insecticides.

Pear Aphids: For the control of pear aphids, spray of 1000 ml Metasystox 25 EC (oxydemeton-S-methyl) or 200 ml Imidacloprid 200 SL or 160g Thiamethoxam 25 WSG in 500 litres of water at initiation of foliage (3rd-4th week of February), full bloom (1st -2nd week of March) and fruit set (3rd-4th week of March) has been recommended on Semi-soft pear. On Patharnakh, single spray of any of these insecticides at full bloom (2nd - 3rd week of February) was found effective.

Pear Mite: Spray 1000 ml Fosmite 30 EC (ethion) or 1000 ml Metasystox 25 EC (oxydemeton-s-methyl) in 500 litres of water per acre as soon as mite population appears on underside of leaves. Repeat the spray if needed.

Residue Analysis

Citrus: Following application of quinalphos (Ekalux 25EC) at 10.0 and 20.0 ml per tree (per 5 litres of water) the initial deposits of quinalphos on Kinnow mandarin pulp at both these dosages were found to be 0.05 and 0.16 mg/kg, respectively. The results clearly show that quinalphos does not penetrate into the pulp of the Kinnow mandarin and the fruit is safe for consumption even after one day of the application at both these dosages. Following application of imidacloprid at the rate of 0.008 and 0.016% a.i. on Kinnow mandarin plants, the average initial deposits at both these dosages on the rind of Kinnow mandarin fruits were found to be 2.40 and 3.90 mg/kg, respectively. Residues of imidacloprid were below its maximum residue limits (MRL) of 1.0 mg/kg in whole citrus fruits at 0 day sampling.

Following application of triazophos at 0.10% a.i. and 0.20% a.i. on Kinnow mandarin plants, the initial deposits at both these dosages on the rind were found to be 14.66 and 22.20mg/kg, respectively. Residues of triazophos degraded to below its maximum residue limit (MRL) of 0.2 mg/kg, in pulp on seventh day after its application at the recommended dosage.

Grapes: Residues of imidacloprid were estimated in grape leaves, grape berries and soil following four applications of Confidor 200SL at 400 and 800 ml per hac. Residues of imidacloprid in grape berries at harvest time were observed to be below determination limit of 0.05 mg/kg at single dose and 0.06 mg/ kg at double dose. However, acceptable daily intake (ADI) of imidacloprid is 0.06 mg/ kg body weight/ day, which means an adult of 60 kg and a child of 10 kg can safely tolerate intake of 3,600 and 600 µg imidacloprid, respectively, without any appreciable risk to their life. Assuming consumption of 200 g grape berries contaminated at 0.06 mg/ kg, it will lead to an intake of only 12 µg of imidacloprid, which is quite safe for a child as well as for an adult. Hence, the use of imidacloprid on grape crop seems to be toxicologically acceptable.

Residues of carbaryl were estimated in grape berries by Gas Liquid Chromatography (GLC) following single application of Sevin 50 WDP @ 0.15 and 0.30 a.i. %. An assessment of intake of carbaryl residues 1 day after application and its comparison with acceptable daily intake (ADI) reveal its safe intake both the child of 10 kg and an adult of 60 kg. Therefore, a waiting period of one day has been suggested for the safe consumption of carbaryl treated grapes to avoid any health hazards.

Following four foliar applications of Nativo 75 WG (trifloxystrobin 25% +tebuconazole 50%) on grapes @ 175 and 350 g/ha, Ripe grape berries and soil samples collected at harvest which happened to be 34 days after the last application, did not show the presence of residues of trifloxystrobin and tebuconazole at their determination limit of 0.01 and 0.02 mg/kg, respectively.

Pear: Following application of ethion at recommended dosage @ 1.0 ml per litre (0.05% a.i.) on pear, the initial deposit of ethion was observed to be less than its maximum residue limit of 2.0 mg per kg. However, based on acceptable daily intake (ADI) of ethion at 0.002 mg per kg, a waiting period of 10 days is recommended for safe consumption of pear fruits following application at recommended dosage.

Disease Management

Citrus Foot rot/Gummosis : Ridomil MZ 72 WP has been recommended as trunk paint (2 g Ridomil MZ in 100 ml linseed oil) on the affected trunk/bark portion and as soil drench (25 g Ridomil MZ per tree in 10 litres of water) of root zone areas of the infected trees twice in February -March and July - August. Among trunk paint, soil drench and paint + soil drench, trunk paint in combination with soil drench of Ridomil MZ were found most effective. For overall disease management, Ridomil MZ soil drenching in root zone area of the affected trees in February - March and July - August and two sprays of Aliette in April and September have been recommended. In addition, two applications of Curzate M 8 during February - March and July- August @ 25g/ litre as soil drench using 10 litres of water and trunk painting (2g/100 ml linseed oil) on infected portions also control foot rot effectively.

Citrus Ring Spot Virus : Citrus Ring Spot Virus (CRSV) has been reported for the first time on Kinnow mandrain and Sweet orange. Use of healthy bud-wood/ saplings free of CRSV is recommended for raising healthy orchards.

Citrus scab: An integrated approach comprising of clipping of scabby leaves during July and three sprays of ziram (0.25%) or mancozeb (0.25%) from end June to August at 25 days interval were found effective and have been recommended.

Fruit Drop: Spraying with Ziram 27SC (0.25%) + 2,4-D (10ppm) or Propiconazole 25 EC (0.1%) + 2,4-D (10 ppm) or Bavistin (0.1%) +2,4-D (10 ppm) in mid April, August and September and two single sprays of these fungicides in July and end September have been recommended for the control of fruit drop in Kinnow.

Sooty Mould : An integrated approach comprising of three sprays of Ziram 27 SC (0.25%) in combination with Fosmite 50 EC (0.2%) at three week interval during August - September were found promising for the control of sooty mould in citrus.

Grapes Anthracnose and Powdery Mildew : Thiophanate methyl 70 WP @ 0.1% as spray application was found effective for the control of grape anthracnose. For powdery mildew control, three sprays of Bayleton or Topas (0.05%) at monthly interval starting from mid March to May have been recommended.

Ber Powdery Mildew : Foliar application of four sprays of Bayleton (0.05 %) in mid - September, mid- October, mid- November and mid-December have been found effective and economical for the control of ber powdery mildew.

Date Palm

The Regional Research Station, Abohar is the only research centre in India which has a comprehensive collection of 34 date varieties of commercial importance, procured from leading date growing countries with great expense and efforts. The material was propagated, multiplied and supplied to different research centres for their establishment. The major findings are mentioned below :

- Cultivars Hilalwi and Barhee were found best for raw eating, whereas, cultivar Medjool was best for *chhuhara* making and the same has been recommended at the AICRP level.
- Method for the preparation of soft dates and dry dates (*chhuharas*) has been developed.
- Nutritional requirement of date palm has been standardized to obtain maximum fruit yield.
- Turmeric (Punjab Haldi -2) performed better under the shade of date-palm and its average yield recorded was 85.33q/ha.
- The varieties Ganesh, Mridula, Phule Arakta, Bhagawa cultivars introduced from M.P.K.V. Rahuri, Maharashtra i.e. Bhagwa and Mridula are performing better under Abohar conditions.



Turmeric under the shade of date-palm

Fruit Research Station, Bahadurgarh

Regional Fruit Research Substation, Bahadurgarh is situated at 76.4°N and 30.3°S near Bahadurgarh Fort, Patiala. The station was established in December 1960. In the original scheme, which was financed by the State Government and the ICAR on 50:50 basis, it formed a part of the main station at Abohar. The other sub-station under this scheme was located at Kandaghat (Shimla Hills). Research work was mainly conducted on citrus (under humid conditions) and on ber which were planted under the ICAR scheme of “Improvement of Fruit Trees”. On merger of Pepsu State into Punjab, this research station was transferred to Punjab Agriculture Department on 1st November 1956. The Regional Fruit Research Station was transferred to the Punjab Agricultural University, Ludhiana on 1st April 1963. At present, the station is spread over an area of 51.4 acres where research on guava, ber and minor fruits is being carried out.

This research station was established with the objective of introduction, collection, evaluation and conservation of the germplasm of regional horticultural crops under irrigated eco-system of Punjab. The station is committed to carry out applied research on fruit crops for the welfare of the fruit growers with emphasis on agro-techniques such as propagation, canopy management and nutritional aspects. The extension services are regularly provided to the fruit growers. The research station is mainly involved in work on guava (*Psidium guajava L*) and ber (*Ziziphus mauritiana L*). In addition to these crops, work on mango (*Mangifera indica*) and aonla (*Emblica officinalis*) is also being carried out. The elite germplasm of these crops was collected from various research institutes for evaluation. Standardization of the agro techniques like propagation, training, pruning, and nutrient management is also carried out.

Guava improvement through hybridization is in progress to develop coloured guava hybrids. There has been a clear cut impact of research, nursery production and extension activities on development of horticulture in the districts of Patiala, Sangrur, Mohali, Fatehgarh. The area under fruit crops like guava and ber is maximum in the region indicating positive impact of the research on these fruit crops.

Salient achievements of the research station are mentioned below :

- Three varieties of ber i.e. Umran, Sanaur-2 and Wallaiti have been recommended for commercial cultivation.
- Development of Punjab Pink, a new guava hybrid is in advance stage.
- Pruning of ber cv Sanaur-2 at 8 buds level in the month of April-May has been recommended
- Crop regulation of guava by 15% urea spray has been recommended.
- Pear varieties Pathar Nakh, LeConte and Smith have been recommended for cultivation.
- Ber propagation technique by T-budding has been standardized.
- Guava propagation technique by patch budding has been standardized.
- Ber varieties Katha Phul, Gular, Illaichi, Nazuk and ZG-2 were found resistant to powdery mildew.
- Collection and maintenance of germplasm of various major and minor fruit crops such as Ber (*Ziziphus mauritiana*) (48), Guava (*Psidium guajava* L) (33), Aonla (*Embllica officinalis*) (8), Bael (*Aegle marmelos*) (6), Karonda (*Carissa congesta*) (4), Mango (*Mangifera indica*) (20), Pear (*Pyrus communis*) (6), Plum (*Prunus salicina*) (2), Grape (6), Jamun (*Syzygium cuminii*) (4), and Sapota (*Manilkara achras*) (17) are being efficiently carried out for their use in fruit improvement programmes.

Fruit Research Station, Gangian

Introduction (to be added five lines)

The Fruit Research Station, Gangian was established in 1973 with the objective to conserve the elite sucking seedling type of mangoes found in the sub-mountainous zone of Punjab and also to provide the technical know how to the farmers of Kandi area for the improvement of their socio-economic status. It is situated near Dasuya in district Hoshiarpur and has an area of 47.6 acres. At present, it has more than 114 varieties of mangoes for their evaluation, conservation and maintenance. Eight sucking type varieties have been released for cultivation in Punjab with the prefix GN (Gangian). Evaluation of citrus as well as litchi varieties is also carried out at the station to develop and refine technologies for their cultivation in the sub-mountainous and Kandi area of the Punjab. Quality plants of mango, litchi and citrus are produced in the nursery of the station to boost fruit production in this area.

Salient achievements of the research station are mentioned below :

- Sucking mango varieties viz. GN1 (Gurmel da Amb), GN2 (Samrali), GN3 (Kukian de Chhalli), GN4 (Bijrore di Bud), GN5 (Hariana Kanghi), GN6 (Punjab Beauty), GN7 (Mallian wali Chhalli) and Gangian Sindhuri (GN19) have been released for general cultivation in Punjab.
- Alphonso table purpose mango variety has been recommended for cultivation.
- SB Rampur and Amrapalli mango varieties were found promising under sub- mountaneous region of Punjab.
- Punjab Galgal (Hill lemon) variety of lemon has been released for cultivation in sub- mountaneous region of Punjab.
- Application of one kg N, two kg P₂O₅ and one kg K₂O per tree fertilizer significantly improved fruit yield in Dusehri mango.
- Alphonso mango can be ripened with in 4 days by dipping in Ethephon (600 ppm) for 4 minutes and kept in wooden boxes lined and covered with newspaper.
- Mango seedlings grafted during July-September gave the highest percentage of success rate under sub mountaneous region.

- Air layering in litchi during July-August gave highest survival percentage under sub- mountaneous region.
- Fruit yield/acre and net returns were appreciably higher in closely planted orchards. On the basis of above findings, Kinnow mandarin plantation at spacing of 20'x10' has been recommended under sub-mountane zone of Punjab.
- Soil application of K_2O @ 600 g/plant significantly increased fruit size, weight, juice content and fruit yield.
- Three alternate sprays of 750 ml Sumicidin/Fenval 20EC (Fenvalerate) or 1000 ml Ekalux 25 EC (Quinalphos) in 500 litres of water at fruit set, 20 days thereafter and at colour break stage were effective against litchi nut borer. Removal of fallen fruits (mummies) from the orchards and ploughing the field also decreased the incidence of the pests in next cropping season.
- Calcuttia litchi fruit can be stored at 2-3°C and 90-95 % RH up to 3 weeks with the post harvest fumigation of SO_2 (6 g/kg of fruit) for 15-20 min followed by dip with 1 N HCL for 2 minutes.
- The vegetative and growth data revealed that mango (Dusehri) plants headed back at a distance of 3 to 4m from the ground level gave good performance. Rejuvenated trees came into bearing after three years.
- Amla cultivars, NA-7, Krishna, Chakiya and Kanchan have been evaluated under sub-mountaneous zone of Punjab. Kanchan and Chakiaya are performing better.
- Survey was conducted to identify the elite sucking mango strains in the sub mountaneous region of Punjab with the collaboration of Biodiversity Board (Punjab). Twenty nine strains were found promising and were evaluated for various physic- chemical attributes.

TRANSFER OF TECHNOLOGY

The Directorate of Extension Education of PAU is vested with the responsibility to disseminate improved agricultural knowledge among the farmers through its activities including training programmes, *Kisan Melas*, workshops, method demonstrations, front line demonstrations, campaigns, exhibitions, field days, farmers' group discussions etc. In addition, diagnostic and advisory services are also imparted in the Plant Health Clinic at Ludhiana campus and at 12 Farm Advisory Service Scheme (FASS) centres at erstwhile district headquarters. Apart, there are 17 Krishi Vigyan Kendras (KVKs) which are also addressing the problems of visiting farmers and providing the facility of diagnosis of plant samples and soil and water testing. The on-farm trials and adaptive research trials are also conducted at farmers' fields. The diagnostic-cum-exhibition mobile van is also being used for spreading the information among rural masses about subsidiary occupations like mushroom growing, apiculture, hybrid seed production, poultry, dairy farming, fisheries, etc. alongwith production and protection technologies for the crops, vegetables, fruits and flowers using CDs, audio visual aids and documentaries for the better understanding about the technology for obtaining higher yield per unit area and time.

The role of extension education is not merely the diffusion of the improved practices and technologies among the farmers but also the assessment and refinement of the technologies at the cultivators' fields. This feedback brings more perfection in the technology for its large scale adoption. Such ways and means adopted by the PAU enabled farmers to harvest very high yield of wheat (4.7 t/ha) and paddy (6.0 t/ha). The average productivity of vegetables and fruits in Punjab has risen to 16.0 and 20.0 t/ha, respectively.

The PAU has been a trend setter in quick transfer of technology. The key factor is the sound research base whereby the recommendations are made only after thorough experimentation at main campus and at research stations followed by their testing in collaboration with extension scientists of the PAU and the State Department of Agriculture at cultivators' fields. The soundness of the recommendations has helped the extension functionaries to imbibe confidence in the University and farmers visit the University in large numbers. Another very significant sign of development is inculcating scientific temper among the Punjab peasantry by the university which is being considered as important as the increase in farm production. This change in farmers' outlook will surely sustain progress.

Farm Advisory Service Scheme

Farm Advisory Service Scheme (FASS) was started in the University since its inception during 1962 primarily with the objective of the quick transfer of improved agricultural technology among the farmers of the Punjab and getting first hand feedback of their field problems. FASS was initially started with extension specialists in the disciplines of Agronomy, Soil Science, Horticulture, Plant Protection and Farm Management. It has been further strengthened by appointing separate specialists in the discipline of Plant Pathology, Entomology, Fruit Science and Vegetable Science. The specialists in the field of Agricultural Engineering and Soil & Water Engineering have also been posted in some districts of the State. At present, twelve FASS are functioning at district headquarters of Amritsar, Bathinda Chandigarh, Faridkot, Ferozepur, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Patiala, Ropar and Sangrur. The newly created districts of Fatehgarh Sahib, Fazilka, Mansa, Muktsar, Moga, Pathankot, Shaheed Bhagat Singh Nagar and Tarantaran, yet do not have the FASS and are being served by the staff of the district from which these districts have been carried out. FASS centres conduct adaptive research trials at farmers' fields to test the technology generated in research system under different agroclimatic conditions. The scientists also organize training camps, field days, exhibitions, campaigns, surveillances and crop surveys. On an average, 300-400 adaptive research trials on different varieties/cultivar evaluation, production and protection technologies are conducted every year.

During 1962 to 2011, the FASS centers conducted 18096 adaptive research trials, 33,041 demonstrations, organized 1262 campaigns, 1891 field days and 1733 exhibitions. As a resource persons participated 10020 times in district and block level training camps. The total number of farmers visited FASS offices for advice were 4, 77,944. Such close interaction with a large number of farmers by the FASS scientists is the unique way of

transfer of technology and a source of feedback. It is thus clear that assessment of technologies can be made on the basis of close contact with the farming community. It resulted in the fast adoption of technology leading to high yield realization. It is further to note that FASS advised 15, 15,294 farmers at their field. Besides these, 1,434 feed backs, 1,323 T.V./Radio talks, 2,048 crop surveillance visits, 2,178 publications and 81,725 plant diagnostic services were also provided.

At the University level, various departments in the disciplines of Agronomy, Entomology, Extension Education, Plant Breeding and Genetics, Soils Science, Farm Management, Plant Pathology, Fruit Science, Vegetable Science, Floriculture & Landscaping, Food Science & Technology, Food & Nutrition, Clothing & Textiles, Human Development, Family Resources & Management, Processing & Food Engineering, Farm Machinery & Power Engineering, Soil & Water Engineering are having Subject Matter Specialists which are exclusively associated with the transfer of technology and actually involved in the monitoring of programmes organized at farmers' fields. The subject matter specialists also work as resource persons in the farmers' training camps organized by the State Department of Agriculture.

Krishi Vigyan Kendras

Seventeen Krishi Vigyan Kendras (KVKs) have been established in the State with the financial assistance from the ICAR and are functional at district headquarters. These KVKs have been established in the different agro-climatic zones of the State and are working under the control of PAU. The first KVK was started at Gurdaspur in 1987. Five KVKs namely Bathinda, Kapurthala, Bahawal (Hoshiarpur), Rauni (Patiala) and Malewal (Ferozepur) were started in the 7th five year plan during 1991-92. KVK at Langroya (SBS Nagar), Kheri (Sangrur) and Faridkot were started in the 8th five year plan during 1994-95. KVK at Ropar, Nagkalan and Jahangir (Amritsar), Fatehgarh Sahib, Samrala (Ludhiana), Nurmahal (Jalandhur), Budh Singhwala (Moga) and Mansa were started in the 10th five year plan in 2004-05 and 2006-07.

The KVKs are imparting vocational trainings for developing entrepreneurship skill, short duration trainings to increase productivity per unit area and time, and refresher trainings of the extension functionaries to update their knowledge with the latest developments in the field of agriculture science. Every KVK organizes 100-110 trainings in a year. All the KVKs have established a Plant Health Clinic which is equipped with required infrastructure. Ten KVKs are having Soil and Water testing laboratories. A polyhouse at every KVK is being developed to organize the farmer's training on protected cultivation. At four KVKs viz., Bathinda, Faridkot, Ropar and Fatehgarh Sahib a project sponsored by ICAR entitled National Initiative on Climate Resilient Agriculture has been launched wherein focus is given to work in a farmer participatory mode to increase and sustain the productivity of crops under changing climate and to develop harmonious practices to counteract the effect of the weather vagaries.

The total number of vocational, short duration and refresher trainings organised were 4,075, 12,874 and 1,352 during 1982 to 2011, respectively. The total numbers of frontline demonstrations and on farm trials conducted were 10,510 and 1,135, respectively during this period. The number of field days organized was 1,309. In addition, 2,023 exhibitions, 8,690 lectures, 1,699 TV/Radio talks, 2,010 publications, 378 Scientific Advisory Committee meetings and 444 campaigns were also organized. The State Level Training and Planning Workshops are organised to finalise the training schedule to be followed round the year at PAU and KVKs during the month of February every year. The State level officials are invited to participate in the discussion while finalizing the training schedules for the farmers, farm women, vocational and refresher training courses. Thereafter, the schedule is strictly followed.

At present, in the Punjab, there are about 33,000 apiary honey Beekeepers and about 14,000 MT/year of honey is produced which is about 37 percent of the total production of the country. Likewise, the mushroom production has touched another milestone by producing 52,000 MT annually. To popularize the production of oilseeds and pulses among the farmers, frontline demonstrations are arranged by every KVKs. Every KVK conducts 100 frontline demonstrations every year at cultivators' fields. On the basis of the results, yield gap analysis is done. To solve the location specific problems, on-farm experiments are conducted. The KVKs celebrate technological week wherein technology developed at PAU is demonstrated and the knowledge is passed on to the

farmers, farmwomen and students. Campaigns like congress grass eradication, seed treatment, safe storage of grains, soil testing week, rat control etc. are also organized. The field days on frontline demonstrations are proving as an asset to maintain credibility among farmers. The KVK farms produce certified seeds of different crops in their respective areas to cater to the need for improved seed.

Plant Clinic

A Plant Disease Clinic was established in 1978 under the Department of Plant Pathology with the main objective of providing diagnostic service about plant diseases. In 1993, it was re-designated as Central Plant Clinic under the control of Director of Extension Education to cover all aspects of plant health. After realizing its importance, the name was changed to as Farmers Service Centre in a separate building during 1999 and presently it is known as Agricultural Technology Information Centre (ATIC). ATIC has been established with the objective to deliver technology and input under Single Window Delivery System. Various technologies have been exhibited in the form of blow-ups, touch screen 'Kiosk' and preserved live samples in transparent pots.

ATIC addresses the field problems of visiting farmers. On an average, 10,000 farmers visit the centre every year for redressal of their field problems and about 2,500 farmers bring plant samples for diagnosis. Proper remedial measures are advised to the farmers after thorough examination of the plant samples by a team of scientists. The visiting farmers are also acquainted about the successful cultivation of crops particularly with reference to the integrated pest management/nutrient management. Apart from diagnostic and advisory service, the farmers can also buy quality seed, farm literature, and microbial culture and plant saplings under one window. In turn, the university gets feedback about new problems. So far, a total of 1,26,212 farmers have visited ATIC and 34,524 plant samples have been diagnosed for different disorders. In addition, 27,732 queries have been answered on phone. ATIC also imparts practical training for final year agricultural students. It also provides a platform for student farmer interactions.



Plant sample being examined in Plant Clinic

Training Programmes

Centre for Training of Extension Personnel and Farmers

In July 2003, four schemes namely Farmers' Training Programme in Agricultural Extension, Advanced Centre for Training in Wheat Production Technology under NAEP-III, Provision of an Extension Specialist in Home Management and three Assistant Extension Specialists in Food & Nutrition, Child Development and Clothing & Textiles were merged and renamed as 'Centre for Training for In-service Extension Personnel, Farmers and Farm Women'. The main objectives of the centre are (i) to disseminate latest agricultural technologies among farmers/farm women through training camps, courses, field days, campaigns and kisan melas, (ii) to organize refresher training courses/seminars/workshops for the field officers and master trainers concerned directly or indirectly with agricultural development in the State, (iii) to organize skill oriented entrepreneurial trainings for the farmers/farm women, (iv) to identify field problems for the scientific analysis and providing solution to the farmers/farm women and (v) to develop technology dissemination kits including booklets/pamphlets, audio and video cassettes, etc. for the farmers as well as for the master trainers.

This Centre organizes 30-35 training courses throughout the year for the farmers and farm women of Punjab and around 30 refresher training courses for the extension personnel. Besides, 3-4 research and extension specialist workshop, two young farmers training classes, 150-200 exposure visits, monthly meetings of PAU Punjab Kisan Club, quarterly meetings of Punjab Bee-Keepers Association and Tree Growers Association and sponsored training courses are organized every year. During the last 10 years, the number of short, vocational

and refresher trainings organized is 203, 19 and 178, respectively. The number of farmers participated in monthly meetings of PAU Kisan Club varied from 2,914 to 3,853 every year. Likewise, up till 2007-08, monthly meetings of beekeepers association were organized but now meetings are organized quarterly. The number of beekeepers having participated in these meeting varied from 211 to 243 every year. Likewise, the Tree Growers Association was formed during 2007-08 and its quarterly meetings are organized since then, wherein the number of participants varied from 74-109.

The centre for training is also attending to the visits of farmers and extension functionaries from the adjoining States. The total number of farmers from the neighbouring States that visited PAU during 2004-12 has 16,332. The corresponding number of extension personnel was 7,899 thus clearly elucidating the impact of the PAU and its services rendered towards farming community and extension personnel involved in agriculture.

Practical Training Course in Agriculture for Young Farmers

Practical education in scientific agriculture is being imparted regularly to the young farmers in the age group of 20-25 years through three months training course. PAU is one of the pioneer institutions to start such a practical oriented special course in agriculture for the young farmers. The first course was started in January, 1965 with the objective of providing integrated system of training embracing all important fields of agriculture i.e. field crops, horticultural crops, animal science, farm management, farm power & machinery and allied enterprises. The purpose is to provide young farmer trainees with theoretical background and practical skills as to operate the farming on scientific lines and sound proposition. Two training courses commencing in the month of January and August are organized every year. After getting training through these courses, quite a good number of farmers have started cultivation by adopting scientific means and also undertaken secondary agriculture thus proving role models for others.

Gardeners/Horticulture Training Course

The Gardeners' Training Course was started in 1962 to provide training on growing of fruits, vegetable crops and flowers to meet the growing demand in public as well as private sector. Training in this course particularly relating to plant protection measures and pruning and training of fruit trees is helpful in creating self-employment opportunities for rural youth in developing their own orchards/nurseries. To date, 993 students have completed the course at PAU, Ludhiana. This course was started in 2008-09 and is financed by the National Horticulture Mission (NHM), through State Department of Horticulture and every student gets stipend of Rs.1000/- per month. At present, the training of this course is being conducted at KVK,s at Gurdaspur and Bathinda. Another programme of one year called 'Horticulture Training Course' for Horticulture Supervisors was started in the year 2008-09 at PAU, Ludhiana with the financial assistance of NHM and to date 73 trainees have completed the course. In the year 2011-12, the Horticulture Supervisor Training Course has also been started at KVK, Gurdaspur and KVK, Bathinda with 25 seats at each centre.

Farm Women Training

Training for farm women is conducted by the Department of Home Science Education & Communication which was established in 1976. The main objective of the training is to disseminate home science technology among the farm families to improve the quality of rural life. The major thrust areas of home science activities include women as entrepreneurs and development of their knowledge and skill, household decision-making and access to resource as influenced by changing technologies and information sources and farms as productive firms, households as consumers and women as liaison between farm and home in relation to food production, processing, consumption, preservation, storage and management, fuel, fodder and livestock management.

Correspondence Course

The PAU is the first among agricultural universities of the country to start a non-degree training programme for educated, busy farmers who can not remain away from their farms and homes for a long period to attend formal training classes at the University. The first correspondence course of one year duration was started in April, 1971. Since then, the lessons were being mailed to farmers. After completion of course, nine question papers are used to be sent to farmers/respondents. After passing correspondence course, farmers were provided certificates. In the year 2003, this scheme of correspondence courses was discontinued because KVKs were started at district level, which were easily approachable/ for farmers and farmwomen.

Training Programmes in Engineering

The training centre is in operation since 1984 in the College of Agricultural Engineering and Technology where trainings are organized throughout the year and a large number of participants attend the trainings. The total number of trainings organized so far are 302 for a total of 4,804 participants. These trainings have a focus on the use of farm power machinery, improved method of irrigation (sprinkler, drip) and recharging of the ground water aquifers, processing of food and value addition, installation of gobar gas plants and bio-energy generation.

Model Training Courses

Three training courses on precision farming, conservation agriculture and wheat production technology were sanctioned to the PAU by the Ministry of Agriculture, Govt. of India. These were organised during 18-25th July, 2011, 9-16th January, 2012 and 6-13th February, 2012, with the corresponding number of participants as 29, 18 and 20, respectively. The main objectives of the model raining courses was to impart latest knowledge to enhance input use efficiency, reduce the cost of production, recycling of resources, adoption of improved technology, and application of inputs. Also the knowledge for developing zone management approach was given to the trainees. The second generation machinery (happy seeder, strip till drill, laser land leveler, etc.) was demonstrated to the trainees for their use, least disturbance to the soil, retention of crop residue on the surface, less compaction to the soil and adoption of most efficient cropping systems for enhancing the productivity, profitability and sustainability over time. It is worth mentioning that in the first two training courses on precision farming and conservation agriculture, the trainees were exclusively from the neighbouring states while in wheat production technology, the trainees from the Punjab were also included because the wheat is the major *Rabi* crop of the State.

Trainings on Agricultural Market Intelligence

The Department of Economics & Sociology is conducting trainings on the marketing intelligence since 2009-10. The total number of trainings organized in the last three years were 17 for the farmers and 14 for the agricultural officials.

The university is regularly holding training classes for the interested house-wives, farmers, farmwomen and other interested persons in the art of fruit and vegetables preservation at the home as well as at commercial scale. These classes are being run primarily to prevent and reduce wastage of fruits and vegetables otherwise highly perishable in nature.

Soil and Water Testing

On account of the appearance of multi-nutrient deficiency in crops, vegetables, fruit trees, etc., the farmers have become curious to know the kind and level of deficiency of different macro and micro nutrients. Similarly, quality of water has to be tested for its suitability for irrigation to crops and orchards. The PAU has established soil testing laboratories at Ludhiana, Bathinda and Gurdaspur. All these laboratories are providing service to the farmers for knowing their soil status in terms of both macro and micro nutrients. Likewise, 10 Krishi Vigyan Kendras (Bathinda, Ferozepur, Faridkot, Hoshiarpur, SBS Nagar, Kapurthala, Gurdaspur, Muktsar, Jalandhar and Patiala) are also having soil and water testing facility to analyze farmers' samples and a total number of 10,556 samples have been tested.

Weather Forecasting

A regular weekly feature, entitled Crop and Weather Outlook for the Farmers is released on every Friday which appear in all the newspapers and radio and television stations. It also contains important information regarding crops/dairy/poultry operations for the farmers.

Dissemination of Technology Products

A seed shop has been established at the ATIC from where the quality seeds of various crops, vegetables, fodders and *Rhizobium* culture (biofertilizers) are sold to the visiting farmers. This centre has sold 92,686 and 64,695 quintals of seed of *Rabi* and *Kharif* crops, respectively along with 12,118 units of biofertilizers (*Rhizobium* culture) since its inception (1999 to 2011).

Farm Literature

The visiting farmers are encouraged to have access to the latest farm literature available in the shop provided at ATIC. In addition, package of practices for *Rabi* and *Kharif* crops, small bulletins/books pertaining to subsidiary occupation such as dairy, beekeeping, mushroom growing, farm machinery, etc. are also sold to the farmers. Two popular monthly magazines namely *Changi Kheti* (Punjabi) and Progressive Farming (English) are reaching each and every corner of the State, which deliver timely information on current topics every month to the farmers.

The farmers from adjoining states such as Haryana, Rajasthan, Uttar Pradesh, Uttara khand, Himachal Pradesh and Jammu & Kashmir also visit regularly to this centre in groups during their exposure visits. The scientists of the centre explain the role of the ATIC towards farming community and knowledge is passed on to them about Punjab Agriculture as well as about the improved practices.

Help Line

The University has provided helpline facility to help farmers who are unable to visit the university. For this purpose, a phone number 0161-2401960-70 (Ext. 417) has been installed in the ATIC. Beside, other help-lines Ext. 301 (Marketing), Ext. 400 (Farm Power & Machinery), Ext. 401 (Crop Production), Ext. 404 (Entomology), Ext. 419 (Seed Shop), Ext. 435 (Plant Breeding), Ext. 452 (Vegetables Cultivation), Ext. 458 (Fruit Cultivation), Ext. 461 (Economics), Ext. 505 (Plant Pathology) and Ext. 506 (Soil Science) have also been provided with the concerned extension specialists of the Departments so that the farmers may get relevant information instantly.

Research and Extension Specialists Workshops

Research and Extension Specialists Workshops are a regular feature of the University. In these workshops, besides highlighting the field problems and their remedial measures, new findings are finalised in the presence of the officers of the State development departments and thereafter promoted for their large scale adoption by the farmers. The first workshop for officers of the State Department of Agriculture was held for three days during February 1965 and since then these are being organised regularly. All extension functionaries in the rank of Agricultural Officers participate in these workshops. The system worked so efficiently that the University expanded the sphere to other development areas to have a separate workshop on Horticultural Crops in 1980, Soil & Water Conservation in 1984, Animal Husbandry in 1989 and Agricultural Engineering in 1991. The name of the workshops was changed to 'Research and Extension Specialists Workshop' during March, 2007. Different technical sessions are organised and thorough discussions are held for finalization of any new technology which is later on published in the form of Package of Practice for *Kharif* and *Rabi* crops, Vegetable crops and Horticultural crops.

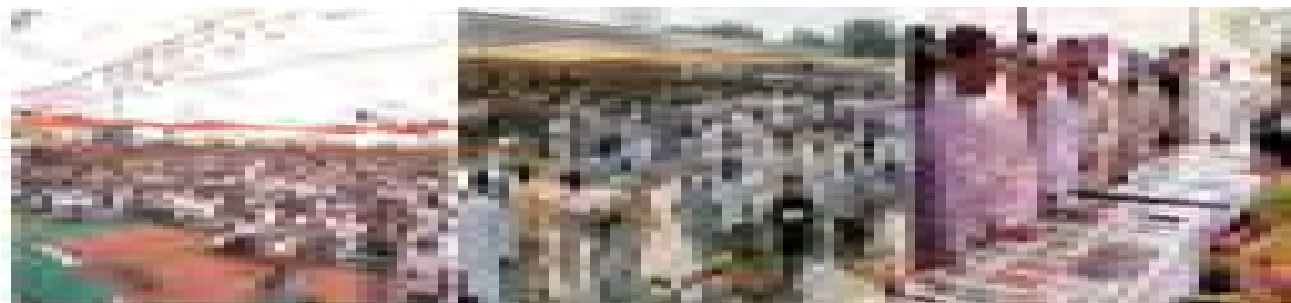
A special National Workshop on Machinery for Horticulture Crops sponsored by the National Horticulture Board, was organised at PAU during 10th -12th March, 2011 in which about 2000 farmers participated. The Research and Extension Specialists Workshops for *Kharif* and *Rabi* crops are held regularly during February and August every year respectively. While the workshops on vegetables, fruits and flower crops and soil and water

conservation are held once a year. The total number of Research and Extension Specialists Workshop for Agricultural Crops organised so far is 95 while the corresponding number for Horticultural Crops, Soil & Water Conservation and Animal Husbandry workshops is 32, 28 and 15, respectively.

Apart from this, a national level Honey Festival-cum-Workshop was organised for the first time at PAU during February 22-23, 2011 in which about 2,000 farmers participated. It was organised to promote honey bee entrepreneurship and to get feed back from the beekeepers for making it a flourishing venture. It was sponsored by National Horticulture Mission.

Kisan Melas

The PAU is pioneer in organising *Kisan Melas* to acquaint the farmers with the latest advances in agriculture and allied fields. In 1967, first *Kisan Mela* was organized at PAU in which a large number of farmers participated. By seeing the overwhelming response, the *Kisan Mela* at main campus was made a regular feature. Thereafter, regional *Kisan Melas* were started to ensure maximum contact with the farmers, to supply them the improved seed of crops, vegetables and fruit plant saplings complemented with the production and protection technology transfer. The first regional *Kisan Mela* was started at Gurdaspur in 1975. Again the response was highly encouraging which further motivated the University authorities to start *Kisan Melas* at all the Regional Research Stations. Thereafter, the *Kisan Melas* were started at Ballowal Saunkhri in 1983, at Bathinda in 1985, at Patiala in 1995 and at Faridkot in 2011. These *Kisan Melas* are being organized twice a year in the months of March and September before the start of *Kharif* and *Rabi* crops. Due to consistent demand of farmers of district Amritsar, the first *Kisan Mela in this district* at Amritsar was held at Khalsa College, Amritsar in March 2012. Technical sessions are organized to transfer the latest knowledge to the farmers. The question-answer session further satisfies the farmers in which their queries are addressed properly. The farmers gain knowledge while visiting the live demonstrations of crops/vegetables/fruits related to production, protection and value addition. The seeds of improved cultivars and farm literature are also displayed and sold to the farmers.



A view of *Kisan Mela* at Ludhiana

Farmers getting seeds during *Kisan Mela*

Farmers purchasing PAU farm literature during *Kisan Mela*

The farmers are also acquainted about the allied enterprises such as beekeeping, mushroom cultivation, hybrid seed production, livestock and poultry management, vermi-compost, protected cultivation, tie & dying of clothes, interior home decorations, preparation of domestic recipes for preservation of vegetables, fruits, etc. Likewise, knowledge driven technical aspects viz., spraying techniques, following of integrated nutrient management (INM), integrated pest management (IPM), conjunctive use of water, making choice of cultivars (varying in duration, time of sowing) under irrigated and rainfed situations, identification of non-monetary inputs, improved methods and kind of inputs for their high use efficiency are motivating the rural masses to come forward to participate in the technological fairs. The farmers also purchase the farm literature published by the University. To encourage the farmers in quality production, produce competition is arranged on the eve of *Kisan Mela*. So far, 331 *Kisan Melas* have been organized. The *Kisan Melas* are being considered the best tool of technology transfer. As a result, the other State Agricultural Universities have also started to organize *Kisan Fairs* on the pattern of PAU.

To create innovative aptitude amongst farmers, the University has instituted awards for outstanding adoption of agriculture technology. A total of ten awards are given every year to the progressive farmers of the Punjab during the Kisan Melas at PAU, Ludhiana during months of March and September. The names of the awards are Chief Minister's Award in Agriculture and Chief Minister's Award in Horticulture, S. Dalip Singh Dhaliwal Memorial Award, Parwasi Bharti Award, S. Ujagar Singh Dhaliwal Award, S. Surjit Singh Dhillon Award, and Sardarni Jagbir Kaur Memorial Innovative Women Farmer Award. The corresponding award value is Rs. 25000, 5000, 8000, 3100, 5000 and 3100 along with a plaque and citation, respectively. Three new awards are sponsored by CRI Pumps for Improved Water Management, Organic Farming and Utilization of Farm Mechanization in Agriculture. Each award carries an amount of Rs. 10,000 along with a plaque and citation.

Feedback Mechanism

The technology evolved at PAU may not be applicable as such in the field and it needs assessment and refinement which is being done at cultivators' fields. The problems observed by the extension staff at the time of field visits and during discussions with the development staff and farmers are passed on to the Directorate of Research of PAU. Feedbacks are also received from the field staff of the state development departments during the Research and Extension Specialists' Workshops. The other mechanisms of getting farmers feedback are mentioned below:

PAU Farmers Committees: Progressive farmers representing various districts of the State are nominated as the members of this Committee. The first PAU Farmers' Committee was constituted during 1970 and is in operation since then. Nominations to the Committee are invited from the staff of Farm Advisory Service Scheme and Krishi Vigyan Kendras and the membership is renewed after every two years and one-third members are replaced with the new ones. The meetings of this committee are held twice a year under the chairmanship of the Vice-Chancellor. This forum provides an opportunity to the farmers to come in direct contact with the experts of the University to provide feedback on the technologies evolved by the University and the emerging problems being faced by them are brought to the notice of the university scientists for their solution. At the same time, the members assist the PAU in quick dissemination of new information. Now its scope has been extended to other specialized areas.

During 1989, the PAU Fruit and Vegetable Growers' Committee was constituted with a view to provide a forum for the fruit and vegetable growers to have direct contact with the experts of the PAU for solving their problems. In 1991, Animal Husbandry Farmers' Committee was formed comprising of progressive dairy, poultry and other livestock farmers. The objective of this committee is to provide a forum for the dairy/poultry farmers to come in direct contact with the experts of the University and to bring Animal Husbandry problems to the notice of the experts for their solutions. Now this Committee is operational in Guru Angad Dev Veterinary and Animal Science University. Another committee called Agricultural Equipment Manufacturers' Advisory Committee was constituted in 1995 keeping in view the problems of farm machinery manufacturers of the State. Many a times, the manufacturers also have genuine problems like lack of technical know-how, non-availability of required raw material, ignorance about latest design and testing facilities for the farm machinery. All such discussions held in the meeting with the experts help in the improvement of agricultural machinery.

Punjab Farmers Club: For harnessing hidden energies and potentials of farmers towards socio-economic and agricultural development, an attempt was made to form a Kisan Club on 15th June, 1966 in village Barewal Awana-Fatehpur of Ludhiana district which later rose to a district club in 1969 and state club called Punjab Kisan Club in 1984. Farmers' Club with the membership of 650 farmers is functioning following the principle of mutual cooperation and self confidence under the patronage of the University. The members hold meeting every month to discuss their current problems relating to agriculture. An endeavour is made to find their solution through discussion with scientists. The members of this club also serve as a useful medium in spreading new techniques developed by the University amongst their fellow farmers. The Club often visit successful ventures of the fellow farmers for learning purposes. The club has a motto of 'Scientific Farming' and it publishes its own farm bulletin called "*Kheti Sanjhan*" since 1987, which is spread scientific information to the members. In 2006, Punjab Kisan Club was registered and its name changed to PAU Kisan Club. At present, about 6,700 male and 450 female

members are registered members of the Club. Of these, 400 male and 50 female members are actively participating in the monthly meetings organized on first Thursday of every month. A Souvenir is published at the annual function of the club to highlight its activities.

Keeping in view the role of farm women in agriculture, a new wing '*Istri Wing/ Women Wing*' has been constituted in 1983. The members of the club are imparted training on the technologies related to improving home life of farm-women and farming families as a whole. Its members also serve as change agents for bringing about improvements in the family life of the farmers.

Punjab Young Farmers Association: PAU organized Rural Youth Volunteer Corps for young and progressive farmers of the Punjab for adoption and dissemination of latest farming techniques during the year 1976, on the pattern of Peace Corps volunteers of USA. During 1983, the organization was re-designated as the Punjab Naujawan Kisan Sanstha. The members of the association are the young farmers from all parts of the Punjab. Young farmers who are given regular and formal short duration training in the University are enrolled as members of this *sanstha*. At the district level, members remain in constant touch with extension scientists of the Farm Advisory Service Scheme located in their respective districts. Adaptive research trials and demonstrations are mainly conducted at the farms of young farmers and this mechanism helps in transmitting the latest technology to the remotest areas of the State in the shortest time. Generally, two state-level meetings are held in a year at the main campus of the University at the time of farmers' fair. The members display their innovative activities and interact with each other and bring into the notice of the research scientists the problems being faced by the farmers in their respective areas in the adoption of agricultural technology. A quarterly news bulletin entitled, "*Sanket Pattar*" in regional language containing hints on important agricultural practices is being published for the benefit of the members since 1977.

Diagnostic Survey Teams: To tackle the newly emerging problems in the field of agriculture and horticulture, diagnostic survey teams of experts depending upon the nature of the problems are constituted from time to time. These teams make detailed field surveys of the problem for its proper diagnosis and feedback to the farm scientists. On the basis of these surveys, strategies are developed to tackle emerging problems. Every year, a number of teams are constituted for monitoring the performance of crops, to study the incidence of crop diseases, surveillance and monitoring of insect-pests, to study the performance of new farm machines and to assess the crop prospects. Through the surveillance of field problems, the deficiencies in the technologies are passed on to the research system for further refinement.

Zonal Research Extension Advisory Committees: Under the National Agricultural Research Project (NARP), Zonal research stations were established to meet the research needs of the particular zone. In order to improve and finalize the research programmes of the research stations, this committee was constituted. While organising meetings, research scientists, Associate Directors of Krishi Vigyan Kendras, District Extension Specialists of FASS centres, district level officers of agriculture, animal husbandry, fisheries, forestry and horticulture departments and selected farmers of zone are invited. Two meetings are arranged in a year by Associate Director of Research of every zone. These meetings are held under the chairmanship of Director of Research of the PAU. In these meetings, feedback from extension staff, development staff and farmers of the respective zones proves very helpful in planning the research programmes for the zone.

Impact of Extension Activities

Impact on crop residue management: The rice-wheat cropping system is being adopted on about 60 per cent of the cultivated area. The rice crop residue (4-5 MT/ha) is generally burnt by the farmers which causes environmental pollution and loss of macro and micro nutrients. The farmers do it to complete the wheat sowing in time. Otherwise if incorporated in the soil, it delays the sowing of wheat. Therefore, a technology of zero till wheat sowing in combine harvested rice field using happy seeder was developed by PAU. It can sow 2.0 ha wheat in one day without burning. During 2006-07, only 8 acres were sown as demonstrations. The impact was good and the area increased over time. During 2007-08, 2008-09, 2009-10, 2010-11 and 2011-12, the wheat area sown using happy seeders was 100, 280, 752, 2000 and 4000 acres, respectively. The corresponding number of

happy seeders increased to 11, 60, 91, 271 and 500, respectively, clearly indicating that the farmers are coming forward to adopt this resource efficient technology.

Enhancement of cotton productivity : The IPM/IRM technology in cotton developed by PAU was demonstrated and disseminated in five districts of Punjab viz., Mansa, Bathinda, Barnala, Ferozpur and Muktsar under the project 'Enhancement of Cotton Productivity' during 2002 to 2010. The Information Centres were set up in the adopted villages and one scout was appointed in every village. Similarly, one supervisor was appointed for each of the five villages. A four days training for the scouts and supervisors was arranged at PAU to upgrade their knowledge about the IPM technology. Similarly, training was also given to the scouts and supervisors employed by the State Department of Agriculture because they had also adopted villages separately under this Project. The technology on IPM/IRM in cotton was explained to the farmers in the villages by arranging training programmes. Likewise, the knowledge of the farmers was upgraded during farmers' group discussion at demonstration sites by the scouts. The supervisors were primarily responsible for implementation of the technical programme and to record data on the prescribed proforma. The technology comprised of growing recommended varieties, time of sowing, seed treatment against insect pests and diseases, judicious use of fertilizers, regular surveillance of insect pests and natural enemies and use of IPM following economic thresh-hold level. Almost entire belt of cotton was covered under IPM by the PAU, State Agriculture Department and Markfed. The total number of farmers who adopted IPM package was 78,850 during eight years. The area covered under IPM every year varied from 1,152 to 35,182 ha. The IPM resulted in substantial reduction in the number of insecticide sprays. Now the farmers are using only 3-5 sprays. As a result of IPM, the additional profit margin varied from Rs.5, 371 to Rs.15,699 /ha and simultaneously enabled to control the insect-pests damage discernibly.

Adoption of laser land levelers: The water use efficiency always relies on the uniformity index. More uniformity in the field leads to less irrigation water application. The second generation machinery viz., laser land leveller has proved as a water wise device. Its system is computerized and automatic based on the signal released by the emitter and received by the hydraulic system installed at the tractor itself. The scraper is adjusted based on the signal received from the emitter. Interestingly, it is being adopted by the farmers at extensive scale because substantial saving of irrigation water (25-30%) has been made where this implement was used. There has been a consistent increase in the number of laser land levellers starting from eight in 2005 and it rose to 6,000 in 2011. The area covered by laser land leveller in Punjab during 2005, 2006, 2007, 2008, 2009 and 2010 was 1312, 25900, 116150, 280172, 608165 and 1320134 ha, respectively.

Control of foot rot disease in *basmati*: *Basmati* rice is considered as a viable option of diversification for paddy and it requires less irrigation water as its growing season coincides with the rainy season. The high yielding cultivar of *basmati*, Pusa Basmati 1121 was adopted by a large number of farmers but it was highly affected with foot rot disease during 2009. The PAU has developed a very effective control measure using *Trichoderma* (bio-pesticide) for treating the seed as well as the nursery plants before planting. Awareness was created among the farmers to make use of this bio-pesticide for the control of foot rot and as a result the farmers controlled this disease effectively. The sale of the bio-pesticide (*Trichoderma*) by the PAU was worth Rs.55,000/- and Rs.80,000/- during 2010 and 2011, respectively, clearly showing the adoption of the technology by the farmers.

Adoption of tensiometer and leaf colour chart: Since paddy is a water guzzling crop, it was highlighted at several different fora that measures should be taken to reduce the irrigation water application. As a result, tensiometer device was developed by the Department of Soil Science, which helped to save 20-25 per cent irrigation water. This technology was passed on to the farmers and the total number of tensiometers sold or given for demonstrations at the cultivators' fields were 5,105 in a span of six year. The farmers have, however, not adopted this technology to the desired level. Likewise, the farmers are applying high level of nitrogenous fertilizers to rice, wheat and maize. A very simple device known as 'leaf colour chart' has been standardised for the need based nitrogen requirement of these crops.

Mushroom as a subsidiary occupation: The mushroom cultivation is being promoted at extensive scale and a large number of farmers are coming forward to get the training from the KVKs as well as from the Department of Microbiology at PAU. The farmers of Punjab are producing about 50 per cent of the total mushroom production of the country. The University is promoting mushroom cultivation by supplying spawn to the farmers. About 4,000 bottles of spawn are supplied every year. The private spawn producers have also established a large number of units. The KVKs and Department of Microbiology are playing a crucial role by imparting training to the youth and the number of mushroom growers is increasing.

Promotion of bio-fertilizer: The use of *Rhizobium* culture is a very useful practice in pulses. Its cost is very nominal and is used as seed treatment. It enables to increase the productivity varying from 10 to 15 per cent. The Department of Microbiology, PAU, Ludhiana is supplying the culture to the farmers. The promotion of this culture is being made by the Directorate of Extension Education. During the last one and a half decade, its use has increased substantially.

Adoption of net-house technology: The protected cultivation is considered as one of the useful option to produce off-season vegetables and to fetch price premium in the market. It has been realized that the technology is proving as an asset particularly for the small and marginal farmers. The favourable policy of the State Govt. has helped the farmers to establish net-houses with technical back up provided by the KVKs, FASS, Department of Vegetable Science as well as the Department of Soil & Water Engineering which have made this technology successful. During 2006-07, in the first phase, only 90 farmers had established the structure for growing vegetables or high value crops under net-houses. It is astonishing to see the progress and presently the total number of net-houses in the State is 954. The major crops being grown are *Capsicum* (Shimla mirch), cucumber and tomato. The unique feature of this protected cultivation structure is that vertical space up to eight feet can be utilized and the preference is always given to the vegetables which are having trailing habit. The technology developed by the PAU for these crops has been accepted by the farmers and from 500 m² protected area, one can produce equivalent to 3,000 m² in the open area. Being a profitable venture, the farmers are showing more interest and the special trainings are being organized at all the KVKs.

Adoption of mechanical rice transplanter : The rice cultivation is being practiced on about 28 lakh ha, and labour cost and availability are becoming critical input over time. The mechanical transplanting is being promoted to overcome labour scarcity. Cost effective paddy transplanters are being developed and modified by the Department of Farm Machinery & Power Engineering. Presently, about 6,000 acres of land area is being sown by using the mechanical transplanter. This is playing a very good role as demonstration to the adjoining farmers. Recently, four wheeler mechanical paddy transplanter has been developed and its efficiency is very high and can cover about 10 acres of land per day. The KVKs are conducting campaigns in their respective districts to create awareness amongst farmers for raising mat type nursery and it is presumed that area under mat type nursery will further increase many fold in the coming years. Even the custom-hiring system is being promoted (transplanter along with rice nursery) so that the small and marginal farmers may also avail the benefit of this new technology.

Promotion of technology through self help groups: The self help group is considered the way out for fast dissemination of knowledge among the large chunk of rural masses. An effort is being made at all the KVKs with the sister line departments to formulate self help groups. This effort shows the ray of hope to the matriculates, school drop outs, small and marginal farmers who can establish their entrepreneur units by availing the benefit extended by the State Govt. Numerous schemes have been formulated by the NABARD and are being implemented through the State machinery. During 2000, total number of self help groups registered through KVKs was 32. After 5 years, the number has risen to 78 and during 2010, the number of self help groups which are functional and registered with the various banks is 162.

Centre for Communication and International Linkages

The Centre was established as 'Communication Centre' in 1972 by strengthening the 'Farm Information Service' of the University. It was renamed as 'Centre for Communication, Languages and Culture' in 2003 and as the 'Centre for Communication and International Linkages (CCIL)' in 2008. The mandate of the CCIL is to

disseminate the latest farm technologies to the farmers of Punjab through print and electronic media. The activities and achievements of the CCIL are given as under:

Publications

This CCIL publishes farm bulletins on a wide variety of subjects related to agriculture and allied fields. It also publishes Package of Practices for Crops of Punjab- *Kharif* and *Rabi*, Package of Practices for Cultivation of Vegetables, Package of Practices for Cultivation of Fruits, Journal of Research, university reports, Punjab Agricultural Handbook, calendars, *etc.* Besides, two monthly farm magazines *viz.* *Changi Kheti* (in Punjabi) and *Progressive Farming* (in English) are published by the CCIL. Currently, 119 publications of the centre are available including 34 farm bulletins, 9 packages of practices, 2 farm magazines. Sixteen bulletins in English and 20 in Punjabi were published during 2011-12. PAU farm literature published by the CCIL has developed temperament for scientific farming among farmers of the state.

Audio-Visual Aids

The CCIL has assist in the preparation of audio cassettes/CDs on wheat, rice, cotton, sugarcane, mushroom, bee-keeping, balanced nutrition, distress calls of birds. In many of these cassettes/CDs, farming tips have been combined with folk songs related to the crop or the subject. The cassettes are in great demand. The Centre has provided services in the preparation of a number of video cassettes namely *River of Honey*, *Cultivation of Wheat*, *Nutrition of Wheat*, *Loose Smut in Wheat*, *Fish Culture*, *Watershed Management* for the benefit of farmers.

Circulation and Sale of Farm Literature

The CCIL contends sale and circulation of PAU farm literature. It sells PAU publications through counters at the CCIL and in the Directorate of Extension Education, at *Kisan melas*, *etc.* The CCIL also procures advertisements for PAU publications.

The publications have become very popular among farmers and their demand is ever increasing. It is evident from the fact that the sale of literature has increased from just Rs.5,200/- in 1965-66 to Rs.1.38 crore in 2011-12. During this year, a total of 4447 subscribers were enrolled. To promote the sale of farm literature, 24 exhibitions/ displays were organized during 2011-12. Details of the sale are given in the Table 15 below:



A collection of PAU farm literature

Print and Electronic Media

The CCIL facilitates quick dissemination of news, features, photographs and articles to print and electronic media through e-mail/ fax. The centre releases news about the University work and various events for publication in the leading newspapers of the country. These releases are well received by almost all newspapers published from the region. Since Punjabi language papers have wide circulation in Punjab villages, these are used for spreading farm information to farmers and extension workers.

A close liaison has been established with *Doordarshan Kendra (DDK)*, Jalandhar for agriculture based programmes *Viz.* '*Mera Pind Mere Khet*' and '*Saavi Dharti*', and with All India Radio (AIR), Jalandhar for '*Dehati*', *Unnat Kheti*, and *Kheti-Baadi* programmes. The CCIL also makes documentaries on PAU activities and functions. A quarterly list of TV programmes is prepared in advance and sent to *DDK*, Jalandhar. This list is finalized by a committee of experts from different disciplines. The centre prepares PAU resource personnel for AIR and *DDK* talks, group discussions and even 'live' programmes. It records interviews of scientists for telecast and broadcast. In addition, the CCIL conveys the *DDK* and AIR, Jalandhar flash messages to keep the farmers

Table 15. Sale of farm literature published by PAU from 1965-66 to 2011-12.

Year	No. of farm magazines/ bulletins sold	Revenue earned (Rs.in lac)
1965-66	472	0.052
1995-96	66,584	22.00
1996-97	59,441	19.64
1997-98	65,170	28.11
1998-99	89,128	29.97
1999-2000	1,05,400	29.97
2000-01	1,16,800	34.67
2001-02	1,32,200	36.00
2002-03	1,25,100	46.05
2003-04	1,29,700	36.11
2004-05	1,06,400	46.72
2005-06	1,11,750	55.36
2006-07	1,25,700	57.15
2007-08	1,41,000	59.23
2008-09	1,33,600	62.39
2009-10	1,05,500	80.12
2010-11	1,01,500	114.15
2011-12	1,06,750	138.36

alert about various outbreaks of diseases, pests or other maladies and their control measures as suggested by the farm experts for telecast/broadcast. AIR covers special activities of the University like *Kisan Melas*, field days, etc. It assisted PAU scientists to deliver 141 TV talks at *DDK*, Jalandhar on different subjects during 2011-12. It also assisted for 151 radio talks on various topics in the '*Dehati*' programme of AIR, Jalandhar, AIR, Bathinda and AIR, Patiala during the same year.

The Centre also works out schedules for press conferences, individual interviews and 'shoots' with the Vice-Chancellor and other functionaries of PAU. The section issues on an average 750 press releases every year to the print and electronic media. It also provides material such as PAU publications, photo gallery, etc. for posting on the PAU website as Information for the farmers and development functionaries.

Public Relations and International Linkages

PAU being the torch-bearer of Green Revolution in the country, and front runner in developing and rapid dissemination of agriculture technologies, is visited by eminent personalities from all over the world. The CCIL conducts visits of national and international delegations to PAU farms and laboratories, organizes meetings with officials and scientists, of national and international visitors and arranges presentation of farm literature to the visiting dignitaries. On an average 120 foreign dignitaries visit the University from 20-25 countries every year. The Centre also coordinates signing of Memoranda of Understanding (MOUs) with various national and international institutions. During the last five years (2008-2012) the University has signed 43 MoUs, (27 national and 16 international)

Desk Top Publishing and PAU Printing Press

The CCIL is responsible for design and layout of all PAU publications. It looks after all pre-press preparations. It also archives digital files of designed and published works in CDs and other storage media. PAU printing press looks after the printing needs of the University. During 2011-12, a large number of printing jobs were undertaken that included 1,215 degree certificates, 159 merit certificates, 1,443 and 743 copies (duplicate and triplicate, respectively) cash receipt books, 380 fee collection books, 48,000 diesel coupons and 7,300 petrol coupons.

Photography

Photography services are provided to various departments/ offices to meet their academic, research, extension needs. The CCIL provides video coverage to various university activities/ events and maintains photo-bank for use in PAU publications.

Museum of Rural Life of Punjab

The CCIL maintains the Museum of Rural Life of Punjab, which mirrors the social and cultural life of rural Punjab. The interior of the museum is a repository of rural household and farm articles giving a picture-postcard view of vanishing art and craft or daily use articles. It has plaster of Paris dummies posing to perform different household activities like churning milk, grinding grains, knitting trouser cords, etc.

M. S. Randhawa Art Gallery

A new air conditioned gallery named as M.S. Randhawa Art Gallery dedicated to the connoisseur of art and promoter of culture, Dr. Randhawa, has been established recently in the University, which is under the control of CCIL. The 1800 sq. feet gallery is fitted with halogen spot light and wooden flooring. It is ideal for exhibitions of painting, photographs, sculptures and other art works. The Gallery was formally inaugurated by PAU Vice-Chancellor Dr. M.S. Kang on February 28, 2009. Since then, several exhibitions by eminent artists have been held in the gallery.

Kulwant Singh Virk Auditorium

This 70-seat auditorium is housed on the second floor of the CCIL Building and is dedicated to an eminent Punjabi writer, Sh. Kulwant Singh Virk. The auditorium is being used for organizing, lectures, film shows and other academic events.

AWARDS AND HONOURS

Punjab Agricultural University has the distinction of producing eminent scientists who have excelled in their respective fields both at the national and international level. Contributions of the university in meeting food requirements of the country have been recognized several times in the form of following awards :

- First to get Best State Agricultural University Award by the Indian Council of Agricultural Research, Govt. of India in the year 1995.
- Agricultural University of the Year Award 2011 (Krishi Shiksha Samman) by Mahindra & Mahindra.
- First International Potash Institute (Switzerland) and Fertilizer Association of India (IPI-FAI) Award for transfer of technology in balanced use of fertilizers in the year 2010.
- First to get Special Grant of Rs. 100 Crore by the Govt. of India, in recognition of the contributions towards Green Revolution, for promoting excellence in basic and strategic research

Besides, the University has received best ICAR Team Research Awards several times and National Zonal Award for KVK, Faridkot.

The scientists of PAU have brought laurels to the university by getting several awards and honours such as Padma Bhushan (7), Padma Shri (13), World Food Prize (1), Rafi Ahmed Kidwai Award (24), Shanti Swarup Bhatnagar Prize (2), Om Praksh Bhasin Award (2), Arjuna Award (3), Sahitya Academy Award (1), Jawahar Lal Nehru Award (17). Three alumni have received coveted honours in the defense services, viz. Ati Vashisht Seva Medal, Vir Chakra and Ashok Chakra.

Several scientists of the University have been honoured with prestigious fellowships such as Fellows of Indian National Science Academy (15), Fellows of National Academy of Sciences (2) and National Academy of Agricultural Sciences (67).

The University has produced one Chancellor, 39 Vice Chancellors (7 currently serving), one Director General of ICAR, Deputy Director Generals of ICAR/Directors of Institutes (18), Chairman Agricultural Scientists Recruitment Board (4), Chief Executive, National Rainfed Area Authority, Chairman, Commission for Agricultural Costs & Prices, Govt. of India (3), Commissioners of Agriculture/Horticulture/Animal Husbandry of India (6), National Professors/National Fellows of ICAR (13), Asstt. Director Generals of ICAR (9) and Project Directors of ICAR. Eight of the University alumni also served as Directors/DDG of international organisations. Several of its scientists have also been elected as Presidents of the prestigious professional societies. Besides, several alumni of PAU served as distinguished administrators, defense personnel, litterateurs, and luminaries as a result of its excellent education and skill-imparting capacity.



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