DEVELOPMENT OF INTEGRATED PEST MANAGEMENT (IPM) CAPSULE FOR WHITE GRUB AND CUTWORM

ABSTRACT

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

Doctror of Philosophy

in

ZOOLOGY

(Entomology)

By

ZEWAR HUSSAIN BHAT

SECTION OF ENTOMOLOGY
DEPARTMENT OF ZOOLOGY
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

2007

ABSTRACT

The experiment on loss assessment studies due to cutworm infesting maize revealed that a maximum plant damage of 54.63% and a retrievable yield loss of 80.18% was recorded due to cutworm under a heavy infestation level of 6.05 larva/m^2.

The experiment on evaluation of various insecticides and biopesticides against cutworm infesting maize indicated that seed treatments with imidacloprid @ 0.8 g.a.i./kg seed and chlorpyriphos 20 EC @ 20.0 ml/kg seed were sound both in protection as well as production wise against cutworm infestation and resulted in maximum net returns.

The experiment on effect of seed rate in combination with seed treatment of imidacloprid against cutworm infestation in maize revealed that the highest seed rate S_3 (40 kg ha^{-1}) with seed treatment of imidacloprid proved significantly superior over all other treatments.

The experiment on loss assessment studies in potato due to cutworm revealed that a maximum plant damage of 17.39% and a retrievable yield loss of 62.01% was recorded due to cutworm under a heavy infestation level of 6.05 larva/m^2.

The results of the experiment on evaluation of various insecticides and biopesticides against white grub/cutworm infesting potato showed that post sown foliar sprays with chlorpyriphos 20 EC @ 0.04% a.i and quinalphos 25 EC @ 0.05% recorded a maximum Benefit: Cost (B/C) ratio followed by soil treatments with fenvalerate 0.4% dust @ 25 kg ha^{-1}, chlorpyriphos 1.5% dust @ 25 kg ha^{-1} and carbofuran 3G @ 30 kg ha^{-1}. The seed tuber treatments were not economically viable, despite being superior on production side.

The results of the experiment on effect of different dates of sowing and seed rates against black cutworm infesting potato revealed that the higher seed rate of 24 q ha^{-1} helped to compensate the cutworm damage and maintain optimum plant stand, which resulted in substantial better yields. The late sowing in first week of June asynchronised the susceptible crop stage and aggressive stage of pest, which resulted in evasion of cutworm infestation and resulted in significant net returns.

The results of the experiment on field evaluation of some insecticides as post sown soil application against cutworm/white grub infesting potato revealed that a highest B/C ratio was recorded in imidacloprid 200 SL @ 80 g.a.i ha^{-1} followed by chlorpyriphos 20 EC @ 800 g.a.i ha^{-1}. The highest mean grub population 8.80 per Sq.m was recorded in untreated control. Where as rest of all treatment applications recorded a significantly lowest grub population.

The faunastic study on white grub complex present in hill and mountain agro-ecosystem revealed that *Holotrichia longipennis* was predominant species followed by *Brahmina coriacea* and *Maladera* sp. at Shalimar (Srinagar). Where as, at high altitude location of Pahalgam *Maladera* sp. was predominant followed by *Holotrichia longipennis* and at Wadura Sopora *Brahmina flavosericea* was the predominant species followed by *Adoretus* sp., *Brahmina coriacea* and *Melolontha furcicauda* respectively.

The beetle emergence of different species started from late March with mass beetle emergence period in the month of July, the beetle emergence showed a declining trend up to month of September and no beetle emergence was recorded after September.

DEVELOPMENT OF INTEGRATED PEST MANAGEMENT (IPM) CAPSULE FOR WHITE GRUB AND CUTWORM

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

Doctor of Philosophy

in

ZOOLOGY

(Entomology)

By

ZEWAR HUSSAIN BHAT

SECTION OF ENTOMOLOGY
DEPARTMENT OF ZOOLOGY
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

2007

DEDICATED
TO MY

LATE FATHER

KH. GH. MOHIDIN PADDAR

Dr. FAROOQ A. ZAKI
Professor & Head

Division of Entomology
Sher-e- Kashmir University of Agricultural Sciences & Technology (K), Shalimar, SRINAGAR (J&K) 191121

Dr. SHUJAUDDIN
Prof. Entomology

Department of Zoology
Aligarh Muslim University, Aligarh 202002

CERTIFICATE

*This is to certify that the thesis entitled "**Development of Integrated Pest Management (IPM) capsule for white grub and cutworm** submitted by **Mr. Zewar Hussain Bhat** for the award of degree of **Doctor of Philosophy** in Zoology (Entomology) of the Aligarh Muslim University, Aligarh is his own work carried out in our Supervision and guidance. The work of Inter disciplinary nature was carried out both in Division of Entomology, SKUAST-(K) and Department of Zoology, AMU, Aligarh and is fit for submission.*

Dr. Farooq A. Zaki

Dr. Shujauddin

CONTENTS

Acknowledgement

All praises to Allah, the Cherisher and Sustainer of the world, billons of peace and blessings be upon our Prophet Hazrat MOHAMMAD (SAW), his family members and companions. I bow in gratitude to Almighty for giving me enough courage, patience and success in this venture.

*I deem it my great pleasure and privilege to express my profound sense of gratitude and sincere heart felt indebtness to my worthy supervisor, **Prof. Shujauddin,** Section of Entomology, Department of Zoology, Aligarh Muslim University, Aligarh. His experience in Entomological research as well as his willingness to share it with me was of great help in completing the present work.*

*Words fail to express my feelings of deep gratitude and indebt ness to my esteemed Co-Supervisor, **Dr. Farooq A. Zaki,** Professor & Head, Division of Entomology, SKUAST-(K) for his austere guidance, Constructive criticism, Keen interest and helpful advice throughout the course of this study. I shall always remember his painstaking interest, patience and constant encouragement despite all my lapses and short comings. It was an opportunity to work with him which I must not forget for ever.*

*I greatly owe to **Prof .A .M. Khan,** Chairman Department of Zoology, Aligarh Muslim University, Aligarh for helping me in various ways in submission of thesis.*

Thanks are due to Dr. (Mrs.) Asif Shuja, Reader Department of English, AMU Aligarh and Mrs. Mahjabeen Zaki for being constant source of moral support during the course of this work. My particular thanks are due to Dr. Zubair Ahmad, Department of Zoology, AMU

Aligarh for being constant source of inspiration, whose constant support and academic infusion led to the fruition of my present endeavors. My thanks are also due to my senior lab. colleagues Mr. Abdul Rouf Wani, Mr. Mohd Ayoub Mantoo and Mr. Manzoor Ahmad Parray for being of immense help during my research work. Encouraging guidance of Dr. A.Q. Rather is also felt with sense of deep gratitude. My particular thanks are due to Mr. Tariq Ahmad Bhat for his immense help throughout this endeavour.

I am also thankful to my colleagues and friends Mr. Muneer Ahmad Sofi, Mr. Malik Mukhtar, Mr. Sajad Mohiudin, Mr.Bilal Ahmad Bhat, Mr.Rifat Hussain Raina, Mr.Ab. Majid, Mr. Ashiq Hussain Bhat, Mr. Ab. Rashid. Dr. Mohd Aslam Khan and Mr. Mohd Samiullah, Mr. Shamim Ahmad, Miss. Anjum and Miss. Kavita Padey. Thanks are due to Mohd Tariq for composing manuscript with full dedication and skills.

Without the uninterrupted, untiring, selfless sacrifices and encouraging support given by my late father, the accomplishment of this arduous task would not have been possible for me. But he left for Heavens before I could accomplish this endeavor. After Almighty I owe to him the little success that I have achieved so far in my life.

With all sincerity and affection a deep sense of gratitude is expressed to my mother, Sara Bano sisters Vazira, Nuzhat, Afroza, brother Abid Hussain Bhat niece Khushboo jan and other family members for being ever generous in the upkeep of my high morale.

Zewar Hussain Bhat

Table 1 :	Loss assessment due to cutworm (*Agrotis ipsilon* Hüfnagel) infesting maize (*Zea mays* L.) under rainfed conditions in Kashmir.
Table 2 :	Evaluation of some insecticides and biopesticides against cutworm (*Agrotis ipsilon* Hüfnagel) infesting maize under rainfed condition in Kashmir.
Table 3 :	Effect of seed rate in combination with seed treatment of (Imidacloprid) against cutworm infestation in maize.
Table 4 :	Loss assessment due to cutworm (*Agrotis ipsilon* Hüfnagel) infesting potato (*Solanum tuberosum* L.) under rainfed conditions in Kashmir.
Table 5 :	Evaluation of some insecticides and bio-pesticides against cutworm/white grub infesting potato.
Table 6.1 :	Effect of different dates of sowing and seed rates on percent sprouting germination in potato infested with black cutworm (*Agrotis ipsilon*).
Table 6.2 :	Effect of different dates of sowing and seed rates on percent plant damage in potato infested with black cutworm (*Agrotis ipsilon*).
Table 6.3 :	Effect of different dates of sowing and seed rates on final plant stand in potato infested with black cutworm (*Agrotis ipsilon*).
Table 6.4 :	Effect of different dates of sowing and seed rates on tuber yield in potato infested with black cutworm (*Agrotis ipsilon*).

LIST OF GRAPHS

LIST OF FIGURES

CHAPTER-1

INTRODUCTION

INTRODUCTION

Maize (*Zea mays.* L.) and potato (*Solanum tuberosum* L.) are staple foods for millions of people all over the world and are cheap sources of carbohydrates and proteins. Apart from being a staple food for many sections of people, the maize provides an excellent fodder for the cattle. This is additionally significant for stall feeding during winter months in hill and mountain agro-ecosystem.

There is a great demand for maize as raw material for dairy, poultry feeds and other industrial purposes. Pop corn, corn flakes and roasted corn are becoming increasingly popular as snack and breakfast foods. Moreover, maize is one amongst the food grains that have very high food value and net energy, with low fibre content.

After wheat and rice, maize (*Zea mays* L.) is the most widely produced cereal crop in the world. Besides, serving as a staple food for more than 200 million people in developing countries of Latin America, Africa and Asia. It has assumed a greater significance for industrial utilization in recent years. In India the maize production is 14.72 million tonnes from 7.42 million hectares during 2004-2005 with a productivity of 1.98 tonnes per hectare (Anonymous, 2005)

Maize is cultivated in Jammu and Kashmir in varying edaphic and climatic conditions over a wide range of soil moisture regimes. The maize crop in the state is cultivated under rainfed conditions in about eighty per cent of area, especially on hilly slopes. The area planted under maize crop in the state is nearly 3.32 lakh hectares, and of this area 1.10 lakh hectares falls in Kashmir Division and 2.22 lakh hectares in Jammu Division (Anonymous, 2005), An analysis of statistics pertaining to production and productivity of maize suggests that despite occupying the highest acreage in state, Kashmir valley produced only 12.44 lakh quintals on an average as against 42.46 lakh quintals by Jammu region. Thus productivity in Kashmir valley is only about 11.31 q ha^{-1} in comparison to more than 19.13 q ha^{-1} in Jammu region (Anonymous, 2005).

Analysis of factors responsible for low production and productivity in comparison to available genetic potential of crop, among others include cultivation of crop under un-irrigated conditions, erratic rainfall, inadequate fertilization and poor cultural practices. The insect pests significantly contribute to reduction of yield. The common pests infesting maize crop under valley conditions include cutworms (*Agrotis ipsilon*), stem borer (*Chilo partellus*), army worm (*Mythimma separata*), white grubs (*Holotrichia, Brahmina* and *Adoretus* species), aphids (*Rhopolosiphum maidis* Fetch.) and wire worms (*Agriotes* spp.) The cutworms are the most important insects, which inflict a serious damage to crop by reducing the plant stand, whereas white grubs damage the roots resulting in stunted growth or death of the plants. The injury is seldom seen until harvest time and the withered plants can easily be pulled out from the ground.

Potato is another important food crop both in developed and developing countries. Due to its diversified uses in developed countries as food, feed and raw material for producing starch, it was generally regarded to be a crop suited for western world. The potato a native of South America was introduced to India through Europe during seventeenth century. At present, it is the most important food crop in the world after wheat, rice and maize. It ranks fourth in the world and third in India with respect to food production.

Potato is nourishing and wholesome food. Potato protein is superior to that of cereals and rich in essential amino acid 'lysine', vitamin C, other vitamins, minerals and trace elements. Over one billion people consume potatoes worldwide and taken as part of a diet by half a billion people living in the developing countries. It has been established as an important crop in many western countries, whereas in India, it still remains a vegetable. It is also used in preparation of starch, paste and dye etc.

India produced 23.16 million tonnes of potatoes from an area of 1.34 million hectares with an average yield of 17.32 tonnes ha^{-1} (Anonymous, 2004). This significant achievement has been made possible only with the development of high yielding, disease resistant and location specific varieties along with the development of advanced production technologies.

In Jammu and Kashmir state potato is grown from subtropical to extreme cold temperate conditions over an area of about 6.09 thousand hectares with a production of 11.74 thousand tonnes (Anonymous, 2005). The conditions under which potatoes are grown in Kashmir are very similar to those in Europe and North America and two crops can be grown (March-April and June-July). The first crop is used as a ware potato and the second crop utilized as seed potato for plains of Jammu, Punjab and Haryana.

The Jammu and Kashmir state on the whole and high hills in particular offer a great scope for increasing potato production for domestic consumption and also for export as seed to other parts of the Country. In Kashmir valley, the potatoes are grown on an area of 1720 hectares with a production of 34400 tonnes (Anonymous, 2005). The productivity however, is 20 t ha^{-1}, which is far below the productivity of some of the leading potato growing states of the country.

Pests and diseases is a major constraint in potato cultivation. Among diseases late blight, early blight and fusarial wilt are very serious. There are about 15 insect pests associated with potato in the state of which white grubs and cutworms are the major pests inflicting heavy losses. Grubs of several species of family scarabaeidae including *Holotrichia*, *Brahmina*, *Melolontha* and *Adoretus* damage the potato crop in Kashmir. The grubs feed on the tubers by making circular tunnels, thus render the tubers unfit for human consumption.

White grubs are polyphagous pests and are cosmopolitan in distribution. It is the immature stage of scarab beetle popularly known as Cock chafer, Chafer beetle, May beetles or June beetles. The grubs are subterranean and actively feed on living roots and underground stem of living plants.

White grub is one of the five national pests and a huge expenditure is incurred to control this pest at the national level. White grub is polyphagous and feeds on a wide variety of cultivated and wild plants. They have become devastating pest of various horticultural crops grown under rainfed conditions at the elevations ranging from 600 to 200 meters above sea level (Mishra *et al.*, 1998) covering the hill and mountain agro-ecological zone of India. High density apple plantation has become a soft target of these pests because of its dwarf nature. They feed on its foliage, roots and blossom and have become a limiting factor for popularization of high density apple.

In the state of Jammu and Kashmir, white grub has gained a tremendous importance in recent past, due to its attack on many agricultural and horticultural crops, golf courses, parks and lawns. Thus, the grubs snatch charm and beauty of these beautiful golf courses, lawns and parks and they wear a bald and ugly look. A number of species of white grubs have been reported in Jammu and Kashmir state and they include *Protecta neglecta* (Hope.), *Melolontha furcicauda, Hilyotrogus holoscericus* (Redt.), *Articaphia battalina* (Bates), *Adoretus ladakhansis, Adoretus* sp., *Brahmina* sp., *Hetronychus subhoeois* (Reshi *et al.,* 1967).

Considering the economic importance of this pest, it has become mandatory to evolve effective control strategies against this pest through economically viable, ecologically sound and socially acceptable integrated white grub management technology.

The black cutworms are larvae of several species of noctuid moths which bite through the stems at ground level and eat the leaves or entire seedlings. The majority of cutworms found in India fall under genus *Agrotis* and *Euxoa* among which, only four are widespread in plains and have considerable economic importance. *Agrotis ipsilon* (Hufnagel) is the commonest. Besides, *Agrotis segetum, Agrotis flamatra* (Schiffer) and *Euxoa spinifera* are quite common. The larvae of *Agrotis ipsilon* are popularly known as greasy cutworm or black cutworm in Asia and North America. Black cutworm is a cosmopolitan pest known to attack at least 49 species of cultivated plants besides feeding on many weed species (Odiyo, 1975).

The nocturnal larvae of this pest cut the haulms and stalks of young plants at the collar region and defoliate the plants in their early growth stage (Rajendra and Verma, 1989). They rarely consume the entire plant, but more commonly move to the next plant and damage in the row or to another row. Larvae spoil more than they consume and a severely infested field looks like as if it has been grazed (Johnson and Lewis, 1982 and Showers, 1997). The damage often goes unnoticed until after a significant number of plants have been damaged. Later stages of cutworm cut entirely through the plants or tunnel into the plants below or above the soil surface, whereas small stage cutworms climb plants and chew small holes in the leaves. Gholson and Showers (1979) indicated that a negative photo taxis is the primary factor governing nocturnal behavior of black cutworm larvae. Early instar larvae are photopositive, whereas later instars are photonegative. However, the hunger and presence of food could overcome this taxis (Archer and Musick, 1976).

Extremely dry or wet soil conditions may affect cutworm behavior and the location. Under dry soil conditions cutworms restrict their movement to underground tunneling and feeding. Under dry soil conditions cutworm feeds 5-8 cm below soil surface and all cuttings will be at or below growing point of corn seedlings (Showers *et al.,* 1979). Re-growth of cut seedlings is possible in some instances in corn depending on where the damage occurred. Maximum yield losses are reported in corn when 4^{th} to 6^{th} instar larvae feed on plants at coleoptile to four leaf stage (Showers *et al.,* 1983).The cutworm is most serious in weedy, late planted fields with poor drainage especially during cool and wet springs. Eggs are laid singly or a few together on leaves or stem of weeds, crop residues or bordering fields before the corn is planted. The young larvae feed on these plants until corn seedlings emerge.

In Kashmir valley, *Agrotis ipsilon* is a destructive pest on maize, potato, vegetable crops, flowers and fruit seedlings. Thus, reducing the plant stand and biological yields (Reshi, 1967).The extent of damage due to black cutworm in maize is 30-40 percent and 90 percent under moderately and heavily infested conditions respectively in Kashmir. The damage inflicted to maize seedlings is mainly from April to third week of June when saplings are two to six leaf stages and May sown crop is most severely damaged (Lone and Zaki, 1999). This period coincides with sowing and transplanting of most of the crops.

In Kashmir valley, five species of cutworms that have been recorded are *Agrotis ipsilon, Agrotis melafida, Agrotis exclamationsis, Peridorma saucia* and *Noctus pronubo* (Reshi, 1967). Some cultural practices and manipulations have shown promising effect in reducing the cutworm damage in maize (Lone and Zaki, 1999 and Zaki and Andrabi, 2001).The serious damage inflicted by this pest in Kashmir warrants to initiate control measures.

By and large, all the tactics employed for the control of cutworms or white grubs are the sole methods tested under different agro-ecosystems. Besides the control recommendations and options available against these pests are mainly soil application of granular /dust formulations of insecticides, which contribute to problems of contaminating soil ecosystem. Moreover, treating large areas for controlling soil borne pests with pesticides is undesirable, unwanted and unsafe for many non-target organisms. The heavy costs of pesticides, persistence, drift and adverse effects on useful soil predators and parasitoids have rendered them redundant in hill and mountain farming ecosystem. Low temperature reduces thermal and biodegradation rate of pesticides in soil and poison the useful and non-target organisms.

Considering the economic importance of these pests and that of crops in hill and mountain agro-ecosystem. It becomes mandatory to evolve an integrated pest management (IPM) module against these pests. The module should be ecologically sound, economically viable for small and marginal farmers and easy for adoption to fit in their agricultural production system.

With these premises the present studies were conducted with the following objectives:

i) to assess the avoidable loss caused by these pests in both maize and potato crops,

ii) to screen the eco-friendly insecticides for the management of these pests alone and in combination with bio-pesticides,

iii) to manipulate the cultural practices to mitigate the pest damage to potato crop,

iv) to evaluate the insecticides as seed treatment in maize against the cutworm,

v) to evaluate the natural plant products for their efficacy against the white grubs and cutworms,

vi) Faunastic study to record the white grub species complex present in hill and mountain agro-ecosystem of Kashmir,

vii) to combine the best treatments for developing IPM module against the key pests and analysis of cost benefit ratio for each IPM module, and

viii) to evaluate and demonstrate the IPM module on a farmer's field.

CHAPTER-2
REVIEW OF LITERATURE

REVIEW OF LITERATURE

I) WHITE GRUB (Family Scarabaeidae)

The literature pertaining to present study on management of white grub has been reviewed and categorized as under.

INCIDENCE AND ECOBIOLOGY:

White grub, *Holotrichia* spp. was first time reported in India on Jasminum and Nerium (Perumal *et al.,* 1971), six important species infesting eighteen crops were reported from Rajastan and twelve species from UP (Mathur *et al.,*1989 and Sharma,1989), one species from Kumaon (Arif and Joshi, 1994), 47 species from Himachal Pradesh (Tiwari *et al.,* 1991) and *Holotrichia consanguinea* infesting soybeans from sehore (Singh and singh, 1994). The grubs of *Rhinyptia maridionous* were reported to damage young rhizomes and roots of ramie, *Boehmeria nivea, Ziziphus juguba* and *Acacia arabica* (Pandit,1995); *Brahmina coriacea* to potato tubers in HP (Misra,1995) and *Lepidiota reuleauxi* to sugarcane in Papua New Guinea (Hartemink and Kuniata,1996).

White grub beetles caused heavy defoliation of neem tree (*Azardirachta indica*) in Tamil Nadu (Anamalai *et al.,*1996); sixty species of white grub complex were associated with sugarcane in Mexico among which *Phyllophaga lalanza* was the dominant species (Moron *et al.,* 1996), *Holotrichia consanguinea* and *H .serrata* were major nursery forest insect pests in North Bihar (Ali *et al.,*1996). The white grub species *Phyllophaga obsoleta* was the dominant species among seven species of white grubs complex infesting maize in Mexico (Gomez *et al.*, 1999), the preferred hosts of *Holotrichia longipennis* in Garhwal Himalayas were yellow rasp berry (*Rubus ellipticus* Sm) and sweet chestnut (*Castanea sativa* Mill) (Singh *et al.*, 1999), two species *Phyllophaga trichodes* and *P. misteca* were reported infesting corn in Mexico (Villalobos, 1999). The 6-7 month old plants of sugarcane variety CoC 6304 were found highly susceptible to white grub damage in Tamil Nadu (Rajendran, 1999). Ramirez- Salinas and Castro- Ramiraz (2000) reported that intense damage to corn in Mexico was caused by eight species of family Melolonthinae, six of these are in genus *Phyllophaga* and two in genus *Anomala* among which *P. menetriesi* caused greatest damage. The peak density of grubs 25.5/m^2 belonging to five species inhabiting top 20 cm soil, were reported to damage upland rice and maize in Philippines (Litsinger, 2002). Weed density was inversely related to rotation crop density and the grubs were most common in strawberry and oats, which were attractive to gravid females (Lamondia, 2002). *Holotrichia longipennis* was the predominant species among 33 species of white grub beetles on 51 host plants in Garhwal hills (Singh *et al.,* 2003).

Mating behavior and ecobiology was studied of *H. consanguinea* by (Bindra and Singh,1972; Mahal *et al.*,1991 and Kalra *et al.*,1991), *Cyclocephala immaculata* (Potter, 1980), *Holotrichia longipennis* (Mishra and Singh, 1991), *Anomala lineatopennis, Holotrichia covifrons* and *Melolontha melolontha* (Devi *et al.*, 1994) and *Popillia japonica* (Lacey *et al.*,1994). The larvae, pupae and adults of white grub *Holotrichia helleri* Brsk. in Indonesia were found in December-July, July-August and August-September respectively. The mass beetle emergence started at rainy season from November-December and life cycle was completed in one year (Suhartawan, 1997).

The two most attractive compounds for beetles of *P. japonica* were phenylacetonitrile and (Z) – Jasmone (Lougherin *et al.*,1998) Mishra *et* *al.* (1998) reported that beetles of *Anomala lineatopennis* emerged between 19.30 and 19.45 h from soil with peak emergence in first week of June. The mass beetle emergence of *Holotrichia longipennis* occurred during fourth week of June at dusk and mated on preferred host *Rubus ellipticus*. The longevity of females was greater and there was only one generation per year (Mishra *et al.,* 1998).

CHEMICAL CONTROL:

The literature available on chemical control has been arranged under following sub-headings.

1. **Seed treatment.**
2. **Soil treatment**
3. **Post sown foliar sprays.**

1. Seed Treatment:

Seed treatment is an effective and economical approach for pest control, as it minimizes the amount and cost of pesticide used and offers relative safety to natural enemies due to localization. Thus it can be adopted as an important component of Integrated Pest Management (IPM) programme. The method has been used with success against white grubs by Kumawat and Yadava (1990) with isofenphos and phorate; with carbosulfan 25 STD at 2g /Kg , monocrotophos and phosphomidon both @ 5 ml/kg seed against white grub infesting black gram (Thakur *et al.*,1990); with chlorpyriphos, quinalphos and lindane (Mishra and Singh, 1994) and with quinalphos in groundnut (Patel and Patel, 2000). Bareth *et al.* (2001) found entomogenous nematode *Steinernema glasseri* compatible with seed treatment of chlorpyriphos and quinalphos @ 25ml/kg. Choudhary and Dashad (2002) reported that high levels of organophosphates, chlorpyriphos and quinalphos hampered germination of pearl millet, where as all the concentrations of fenvalerate, cypermethrin, deltamethrin, alfamethrin and imidacloprid proved safer. Consistent reduction of root damage by white grub in corn is achieved by seed treatment, and the method is excellent to fit in integrated pest management (IPM) programme (Schwarz, 2003). The seed treatment with clothiandin is highly root systemic and enters transpiration stream through roots of germinating seedlings (Andersch and Schwarz, 2003).

The seed treatment with imidacloprid (42, 60 and 90 g ha^{-1}), fipronil (50g ha^{-1}), thiamethoxam (70g ha^{-1}) and thiodicarb (420g ha^{-1}) provided relative grain yields (RGY's) significantly higher than in control against white grub *P. cuyabana* infesting soybean in Brazil (Avila and Gomez, 2003). In an experiment Avila and Gomez (2003) reported that seed treatment of fipronil (10 & 20g ha^{-1}), clothiandin (36g ha^{-1}), imidacloprid (24 and 48g ha^{-1}) and thiamethoxam (28 & 56g ha^{-1}) increased grain yield significantly in corn. Rogers and Potter (2003) reported that natural parasitism of Japanese beetle by *Tiphia vernalis* (Hym: Tiphidae) was significantly lower in plots treated with imidacloprid in early May compared with the untreated turf. Koppenhofer *et al.* (2003) concluded that combined imidacloprid nematode application did not affect pathogenicity or infectivity of nematode progeny and thiamethoxam and nematodes showed a weaker interaction on scarab mortality. Jeuffrault *et al.* (2004) evaluated IPM programme launched twenty years before against white grub (*Hoplochelus marginalis*) on Reunion Island. The results revealed a reduction in damage to sugarcane crop coupled with active presence of *Beauveria brongniartii* in most sites, for which systemic insecticide application is to be halted immediately.

2. Soil Treatment (Granules / Dusts):

Heavy amounts of insecticides have been added to soil for the management of soil arthropods, various workers have reported effective /significant control of white grub species with aldrin and parathion (Pal *et al.,* 1972), with terracur P @ 3 Kg ha^{-1} against sugarcane white grub *Allisonotum impressicole* (Hsieh, 1974); with BHC against *Holotrichia consanguinea* (Bhardwaj *et al.*, 1976); with terbufos 15G against *Phyllophaga congrua* and *Phyllophaga implicata* infesting soybeans (Lentz, 1985); with BHC and fensulfothion (Singh and Dayal, 1986); with diazinon and ethoprop against oriental beetle, *Anomala orientals* and European chafer *Rhizotragus majalis* (Villani *et al.*, 1988); with heptachlor followed by bifenthrin against white grub *Maladera matrida* infesting sweet potato (Gol-berg *et al* .,1989); phorate 10 G, landrin 15 G and sevidol 4 G against white grub infesting ground nut (Kumawat and Yadava, 1990); phorate and carbofuran both @ 1 Kg a.i ha^{-1} against white grub on black gram (Thakur *et al.*, 1990). Kokate *et al.* (1991) concluded that quinalphos and phorate were effective against *Brahmina coriacea* infesting potatoes in H.P. Mishra and Singh (1995) reported that BHC (HCH) 10 percent dust, methyl parathion (folidol 2%), malathion 5 percent and phenthoate 2 percent were effective against *Holotrichia longipennis* damaging apple in Uttaranchal. Patil *et al.* (1991) reported that carbofuran or phorate @ 25 kg ha^{-1} applied to soil at transplanting or chlorpyriphos as a 0.6 percent seedling root dip @ 4 lit ha^{-1} were best treatments against white grub infesting chilies in Maharashtra. Saidi *et al.* (1992) got an effective control by a single treatment of controlled release granules containing 140 g chlorpyrifos a.i/kg for the control of sugarcane white grub *Cochliotis melolonthoids* (Geist) in Northern Tanzania. Meshram *et al.* (1993) concluded that folidol 2 percent dust applied @

300 g per 10 x 1 m bed was best against *Holotrichia insularis* in teak nursery. Mishra and Singh (1994) concluded that phorate treatment gave best control with grain yield of 14.50 q ha^{-1}, when compared with control (3.16 q ha^{-1}) against white grub infesting soybeans. Nielson and Cowles (1998) reported that pre-plant media incorporation of Talstar 0.2 G (bifenthrin) at 10 ppm or fireban 1.5 G (Tefluthrin) at 15 ppm based on dry weight of medium provided complete control of Japanese beetle, oriental beetle and European chafer in container nursery plants. Subaharan (2001) indicated that carbosulfan @ 10 g/palm caused > 60 percent reduction in grub population, whereas standard insecticide phorate @ 10 g/palm caused reduction of 36.43 and 44 percent respectively. Choudhary and Dashad (2002) reported that phorate application in standing crop was least effective against white grub infesting pearl millet. Cowles (2003) reported that > 95 percent larval mortality of Japanese beetle and oriental beetle can be expected upto three years following treatment of media with 10 ppm bifenthrin and > 99 percent larval mortality is expected for at least three years following treatment of media with 20 ppm bifenthrin.

3. Foliar Spray:

One of the important strategies for the management of white grubs is the control of adult chafer, which emerges out from cryptic habitat of soil after dusk to feed and mate on shelter belts, viz., shrubs and preferred host trees. Therefore, it is an imperative step to initiate control of adult chaffers. These can be collected mechanically through light traps or hunted from host trees and destroyed subsequently. Another method for chaffer control is by foliar spray and a lot of work has been carried out and many workers have reported effective control by foliar application with different insecticides against various species of white grubs with aldrin 0.1 percent against white grub infesting Jasminum and Nerium (Perumal *et al.*, 1971); 0.5 percent fenitrothion and 0.1 percent carbaryl against *Holotrichia consanguinea* (Bindra and Singh, 1972); phorate, ethyl parathion and BHC against *H. consanguinea* (Bhardwaj *et al.*, 1976); carbaryl 0.1 percent and DDT 0.5 percent against *Holotrichia serrata* Fabr beetles (Kaunsale, 1978); chlorpyriphos 20 EC and quinalphos 25EC both @ 4 lit ha^{-1} against *Holotrichia consanguinea* infesting ground nut (Gupta and Yadava, 1987); monocrotophos @ 0.05% and carbaryl @ 0.1 percent against *Holotrichia longipennis* damaging apple (Mishra and Singh, 1995); deltamethrin @ 0.005 percent and 0.01% against *Maladera insanabilis* infesting groundnut (Dwivedi and Awasthi, 1993); 50 percent parathion and parathion methyl @ 6.0 – 7.5 kg a.i ha^{-1} in 675 litters of water (Wang., 1994) chlorpyriphos 20 EC @ 40 kg a.i ha^{-1} against *Holotrichia longipennis* infesting upland rice (Singh *et al.*, 1999) and chlorpyriphos against white grub infesting potatoes (Mishra, 2001)

Kunkel *et al.* (1999) hypothesized that imidacloprid and halofenozide followed by irrigation was effective to control *P. Japonica* and *Cyclocephala* spp. grubs and had relatively little impact on beneficial invertebrates. An excellent control of white grub infesting turf in golf courses was achieved by June and August applications of imidacloprid and halofenozide (Zenger & Gibbs, 2001); by chlorpyriphos @ 8ml/palm and carbosulfan @ 10g /palm (Subaharan, 2001) and chlorpyriphos 20 EC and phorate 10G against white grub infesting potatoes (Mishra, 2003).

BIOCONTROL:

The literature available ion biocontrol has been reviewed under following sub heads:

1. **Entomopathogenic fungi**

2. **Entomopathogenic bacteria**

3. **Other method**

1. Entomopathogenic fungi:

Many entomopathogenic fungi have been found pathogenic on insects including white grub and these have been exploited for the management of white grubs. An excellent control of white grub *Holotrichia consanguinea* infesting pearl millet was achieved by fungal suspension of *Verticillum lacanii* 4 kg soil with 100 ml of fungal suspension (Gour and Dabi, 1988) with *Beauveria brongniartii* at the rate of 10^{15} conidia ha^{-1} against grubs of *Holotrichia serrate* and *H. consanguinea* (Vyas *et al.*, 1990). The adult life span of *Beauveria brongniartii* infected *Holotrichia serrata* grubs was significantly less than uninfected beetles (Nehru *et al.*, 1991). The entomopathogenic fungi *Beauveria brongniartii* and *Beauveria bassiana* were effective and caused a mortality of 40.3- 83.3 percent in white grub *Blitopertha pallidipennis* (Li-lz *et al.*, 1992), the effective application rate of *Metarhizium anisopliae* (B_{10} 1020) per plant is 0.5-1 gm against *Holotrichia disparilis*, how over contact of fungus with target organism be ensured (Vittarana *et.al.*, 1997).

Beauveria brongniartii and *Metarhizium anisopliae* were effective in comparison to carbofuran and fenamiphos against *Holotrichia consanguinea* (Vyas *et al.*, 1997). The temperatures of 28^0C and 20^0C were most suitable for growth, sporulation and conidial production in *M. anisopliae* and *Beauveria brongniartii* respectively (Sharma *et al.*, 1998); all the 30 strains of *Beauveria bassiana* were potential bio-pesticides on *Diatrea saccharalis* and distribution of contaminated dead larvae could significantly reduce insect populations (Lecuona and Lanteri, 1999). *Metarhizium anisopliae* was pathogenic to all three instars of grubs of

Holotrichia consanguinea and mortality in first instar grub after 16 days of exposure was 70% at the highest dose of $1x10^{11}$ spores 100 ml^{-1} soil (Yadav *et al.*, 2000).

All the strains of *Beauveria bassiana* and *Metarhizium anisopliae* were pathogenic to third instar *Phyllophaga* spp. resulting in mortality of 28.3-90.0% (Flores *et al.*, 2002); *Beauveria brongniartii* @10^9 spores/ml was effective against sugarcane white grub and showed only 2.5% crop damage (Chiramme *et al.*, 2003). *M. anisopliae* and *B. brongniartii* were effective against beetles of *H. consanguinea* in both the methods (insect and soil) inoculation (Sharma and Gupta, 2003); *B. brongniartii* against *Melolontha melolontha* (Enkerli *et al.*, 2004). The efficiency of *M. anisopliae* and *B. bassiana* increased, when applied with increasing rates of nicast / compost against third instar grub of *H. consanguinea* (Yadav *et al.*, 2004); the adult of *H. consanguinea* was most susceptible to both *M. anisopliae* and *B. bassiana* followed by eggs and pupa (Yadav *et al.*, 2004). Jeuffrault *et al.* (2004) monitored plant health plan implemented on Reunion Island particularly integrated pest management against white grub. They advocated that for long term sustainability of biological control, systemic insecticide application is to be halted immediately. Easwarmorthy *et al.* (2005) concluded that in laboratory bio-assays on eggs at a concentration of 10^4-10^9 spores/ml, *M. anisopliae* caused higher rate of infection than *B.brongniartii* and *B.bassiana*, whereas against second and third instar grubs, both *Beauveria* spp. at similar concentration were more infective than *M. anisopliae*.

2. Entomopathogenic bacteria:

The entomopathogenic bacteria have been successfully exploited by several workers for the management of white grubs. An excellent control of larvae of *Holotrichia serrata* inoculated with 1 millon spores of *Bacillus papillae* was achieved in 25-45 days after inoculation (David *et al.*, 1973) and with *B. popillae* var. *Holotrichae* at the rate of 5000,500 and 50 million spores/ m^2, mortality of 62.86, 44.98 and 39.23 was recorded respectively. *Bacillus papillae* could be used as a stressor on white grub *Cyclocephala hirta* to increase its susceptibility to *Haterorhabditis bacteriophora* (Thurston *et al.*, 1993). Vargas and Abarca (1998) reported that in 60-90% larvae of all *Phyllophaga* species studied, there were greater CFU concentrations of *P.agglomerans* than *B.cereus.*

3. Other methods:

Wrightman *et al.* (1994) concluded that phenological stage at which root damage occurred had a profound influence on subsequent recovery in root growth, biomass and ultimately on pod yield. Crutchfield *et al.* (1995) concluded that irrigation during autumn feeding, followed by remedial N fertilization may promote tolerance and recovery of white grub damaged turf of Kentucky blue grass (*Poa pratensis*) and tall fescue (*Festuca arundinacea*). Oliveira *et al.* (2000) reported that population fluctuation and extent of damage were similar under both no tillage and conventional tillage systems. However, population was reduced more in plots managed by heavier equipment such as mould board plough. Thus soil tillage could be one component within soil pest management system in soybeans.

II) CUTWORM (*Agrotis ipsilon* Hüfnagel)

The literature pertaining to present study on management of cutworm (*Agrotis ipsilon* Hüfnagel) has been reviewed and categorized as under:

INCIDENCE AND ECOBIOLOGY:

The incidence of *Agrotis ipsilon* (Hüfnagel) has been studied by various workers, the incidence of *Agrotis ipsilon* (Hüfnagel) in India is more during winter in plains and summer in hilly areas (Khanna, 1964).The first generation moth emergence occur between mid-March or beginning of April in Kashmir valley and its injurious stage is from April to third week of June (Reshi, 1967 and Anonymous, 1975). In laboratory conditions 93 percent of moths of *Agrotis ipsilon* emerged between sunset and sunrise (Nasr *et al.,* 1964); infestations in maize in Central United States are believed to originate from eggs oviposited during March – April (Sherrod *et al.,* 1979) and the annual infestations originate from immigrant females (Kaster and Showers, 1982). The moths disperse widely during a season (Odiyo, 1975) and fly normally between 1800 and 2400 hours and scarcely after mid night (Silveria *et al.,* 1977). The spring appearance of larvae in Northern Japan and Central Europe is thought to be due to migratory moths (Sugimoto and Kobayashi, 1978). The early season infestation in Lowa and Missouri is caused by immigrant moths from Central United States (Raymond *et al.,* 1983) and first generation adults emerge between 1830 and 0200 hours (Wang *et al.,* 1983). The peak period of moth emergence occurs during first week of March (Yadav *et al.,* 1984) and menace increases during moisture stress years (Garg and Mani, 1988)

The infestation in potato crop was first observed during third week of December and increased thereafter until second week of January (Das and Ram, 1988). Cabello and Salmeron (1989) reported that *Agrotis ipsilon* population originated exclusively from immigrating adults, with three flights being detected (January, February – March and June – July). Nag and Nath (1991) concluded that the aggregative nature of the larvae seemed to be mainly due to habitat heterogeneity and nocturnal behavior.

The pest population was more abundant in no tillage plots as compared to strip-cropping (Tonhasca and Stinner, 1991). Zaz (1999) hypothesized that moths of *Agrotis ipsilon* emerged from first week of March and reached its peak in first week of May in Kashmir. Verma and Verma (2002) reported that *Agrotis segetum* and *Agrotis ipsilon* are predominant species. Showers *et al.* (1995) concluded that near surface (100-300m) northerly winds may be responsible for autumnal southward migration of adults of *Agrotis ipsilon* in mid continental USA.

NATURE OF DAMAGE:

The black cutworm larvae are leaf feeders until they become half grown (4^{th} instar), then they cause serious injury by severing young corn seedlings, which are most susceptible from the emergence till 4^{th} leaf growth stage (Archer and Musick, 1977). Showers *et al.* (1979) indicated that regrowth of injured seedlings varied with location of growing tip. The seedlings cut above the growing tip survived and contributed to corn yield. Showers *et al.* (1983) reported maximum yield losses to corn, when 4^{th} to 6^{th} instars feed on plants at coleoptile to four leaf stage. Laboratory studies have shown that individual black cutworm larvae can cut and damage at least four young corn plants before pupation (Archer and Musick, 1977 and Clement and McCartney, 1982). However, field studies have consistently indicated lower estimates (Sechriest and York, 1967 and Showers *et al.*, 1983).

Gholson and Showers (1979) demonstrated that under green house conditions late instar larvae cut more seedling corn plants and fed on more baits under dark conditions than in light. Clement and McCartney (1982) concluded that a larvae of sixth instar will cut progressively fewer seedlings at each succeeding corn growth stage. Story *et al.* (1983) reported that black cutworm *Agrotis ipsilon* and clay backed cutworm *Agrotis gladiaria* (Morrison) were associated with stand cuttings, whereas dingy cutworm, *Feltia ducen* had no effect on plant stand.

ECONOMIC THRESHOLD:

The present treatment threshold of *Agrotis ipsilon* has been roughly given as 3 to 5 percent cuttings and presence of larvae (Anonymous, 1980). Troester (1982) has reported that economic injury levels were calculated and shown to be highly variable (0.7-4.5) larvae per 100 plants. Showers *et al.* (1983) found that corn plants suffered significant grain yield reduction after being manually infested with a single, fourth, fifth or sixth instar *Agrotis ipsilon* larva per meter row during coleoptile to one leaf stage of development. The damage was more severe during coleoptile and two leaf stage than in four leaf stage (Mulder and Showers, 1993)

SOWING DATES:

Showers *et al.* (1979) indicated that early corn plantings with considerable simulated black cutworm damage yielded more than late plantings without damage. The black cutworm damage was greatest for fifth instars inflicting one node cotton and decreased progressively with plant age to vital immunity at seven node cotton growth stage (Foster and Gaylor, 1986) Rodriguez-del-Bosque and Gallardo (1993) concluded that regardless of the planting date 81 percent of the attacks by *Agrotis ipsilon* occurred during the first three leaf stages and fields planted during March sustained the highest damage, in contrast to January and February plantings. Thakur *et al.* (1999) concluded that the pest inflicted a loss of 46.69 percent in Himachal Pradesh. Showers *et al.* (1979) indicated that regrowth of injured seedlings varied with location of growing tip. Lone and Zaki (1999) inferred from the studies under taken in Kashmir valley that maximum cutworm damage of 89.57 percent was recorded in normal sown crops and minimum 17.5 percent in late sown crop. Zaki *et al.* (2001) indicated that grain yield in maize was significantly higher in early sown crop, higher seed rate and insecticidal seed treatment in comparison to late sown, normal seed rate and untreated control plot respectively. Konar and Mohasin (2003) in West Bengal reported that plant damage appeared during third week of December and increased until second week of January.

HOST PREFERENCE:

Busching and Turpin (1976) demonstrated that larval survival was highest on blue grass, curled dock and wheat, while no larval survival occurred on giant fox tail or debris. Reese and Field (1986) reported that black cutworm grew more slowly on susceptible corn seedlings than on artificial diet. Uhan, (1989) concluded that larvae of *Agrotis ipsilon* showed preference to rice bran bait, while moths to blossom of Linden *Tilia* spp. (Wynne *et al.,* 1991). Darwish (1991) indicated that maize was the most preferred food. Karimullah *et al.* (1993) concluded that order of preference for *A. ipsilon* was local yellow > shaheen > local white. Paras-Nath *et al.* (1996) concluded that maize cultivars with greater sugar and protein contents were more preferred, whereas those with high phenolic contents and cholorophyll were less preferred. Amin and Abidin (1997) reported the host preference as bind weed *Convolvulus arvensis,* Egyptian clover *T. alexandrium* and cotton *Gassybium barbadcuse.* Williamson and Poter (1997) hypothesized that black cutworm densities could build up in areas of tall fescue or perennial rye grass surrounding golf course putting greens and tees.

YIELD LOSSES AND DAMAGES:

The much cover associated with reduced tillage provided an ideal environment for the survival of most insects that attack corn (Musick, 1970) and the infestation is more in reduced tillage system (Musick and Petty, 1974). Busching and Turpin (1976) reported 82. 6 percent damage in corn by black cutworm. Black cutworm damage to corn involved complex interaction among weed phenology and availability, corn development and larval development (Archer and Musick, 1977; Showers *et al.,* 1985 & Clement and McCartney, 1982).The maize plants are susceptible during the interval from plant emergence until several (Ca, five or six) leaves have fully emerged, fourth to seventh instars have high potential of inflicting damage (Archer and Musick, 1977).

The *Agrotis ipsilon* larval survival and development was greater on several species of weeds than on corn (Busching and Turpin, 1977). Sherrod *et al.* (1979) reported that ovipositing *Agrotis ipsilon* moths oviposit in weedy fields and larvae survive simulated tillage operations before corn planting and cause subsequent damage to corn seedlings (Levine *et al.,* 1983). The reduction in weed hosts force black cutworm larvae to feed on corn seedlings, a non preferred host (Mulder and Showers, 1993). The tillage operations and herbicide application be performed earlier for effective control (Showers *et al.,* 1985) and in presence of endemic soil predators under some circumstances, insecticidal sprays may not be necessary (Coaker and Williams, 1963; Frank, 1971 and Brust *et al.,* 1986).

Bhat (1986) concluded that besides irrigation, autumn ploughing reduced cutworm damage. The damage to maize crop was lowest in conventional tillage systems (Stinner *et al.*, 1988). Significant yield loss occurs if corn plants are cut below the soil surface (Whitford *et al.*, 1989). Drinkwater *et al.* (1992) found that bushy weeds with aerial parts were more inclined to accommodate larvae of *Agrotis segetum* than spindly and small weeds. Wilson and Eisley (1992) found that incidence of black cutworm was reduced especially in no tillage corn. Oloumi-Sadeghi *et al.* (1992) studied recovery of corn plants and reported that leaf feeding did not influence yield, but whorl feeding decreased yield by 20-30 percent. Parihar and Singh (1992) reported that larval population build up of *Agrotis ipsilon* was high in potato vegetable intercrop, intermediate in potato-maize intercrop and low in potato-sugarcane intercrop. Williamson and Potter (1997) reported that mowing of plots 48 h after oviposition removed 75-91 percent eggs. Shapiro *et al.* (1999) reported that the cutworm damage in nematode – treated plots was greater in plots with fresh manure than in plots without fertilizers.

CHEMICAL METHODS:

The literature available on chemical methods of control has been sub-divided under following sub headings:

1. ***In vitro* bioefficacy**
2. **Seed treatment**
3. **Seed treatment methods**
4. **Soil application and dusts**
5. **Foliar sprays**
6. **Other methods**

1. *In vitro* bioefficacy:

Sayed (1975) found that when 7 day old larvae of *Agrotis ipsilon* were fed on leaves of lettuce, lucern, spinach, castor and cabbage dipped in solutions of carbaryl, LC50 values obtained were 0.08, 0.35, 0.5, 0.6 and 0.82 percent, respectively. Pareek and Kushwaha (1976) studied relative toxicity of endrin, malathion, dieldrin and lindane against last instar larvae of *A. spinifera* (Hb). The LC50 values recorded were 0.07603, 0.17620, 0.24434 and 0.32434 respectively.

2. Seed treatment:

Seed treatment is a sound and rational approach of pest management. Several workers have evaluated seed treatments successfully against various insect pests infesting maize and other crops. Ivy *et al.* (1950) reported that much lower dosages are required for seed treatment than soil applications. An activated carbon carrier used for seed coating permits much higher dosages of the systemic compound to be tolerated by the seed (Ivy, 1952). Reynolds *et al.* (1953) treated seeds of alfalfa, cotton and sugar beets with the systemic insecticides demeton and phorate to control leaf feeding insects. Ivy *et al.* (1954) reported that several new systemic insecticides ammonium cyanamid 12008, 12009 and thimet were effective on a much wide range of insect pests in cotton. Parencia *et al.* (1957) reported that seed treatment in cotton proved effective against cotton aphid and secondary pests.

The seed treatment with thimet and bayer 16639 was effective against cutworm infesting corn (Reynolds *et al.*, 1957); wire worms (Apple *et al.*, 1958) and yellow stripped army worm and fall army worm on soybeans (Bowling, 1968). However the phytotoxicity by systemic insecticides has previously been reported in cotton (Hanna, 1958) and with dimethoate in cotton (Lindquist *et al.*, 1961). The same effect of seed treatment has been reported in case of seed corn maggots (*Hylemya platura*) on corn (Judge and McEwen, 1970 and Eckenrode *et al.,* 1973). Thompson *et al.* (1980) has reported that one third or less of the active ingredient required per hectare for soil treatments is used with seed treatments.

The coating and dressing of seeds of ground nut with some newer insecticides was found as effective as soil application of granuler pesticides (Yadava *et al.,* 1978 and Ram and Yadava, 1982). Sukhwani and Jotwani (1981) observed no adverse effect on germination in sorghum by seed treatment. The seed treatment with 1.5 percent carbofuran 35 ST, 1.5 percent carbosulfan 25 ST and 1 percent furathiocarb were effective in corn (Marwaha *et al.,* 1984 and Marwaha *et al.*, 1985). Raghuwanshi and Rawat (1985) revealed that the cost benefit ratio was maximum in seed treatment with dimethoate, chlorpyriphos, phosphomidon and monocrotophos.

Traditionally, the most common method of protecting corn and sorghum seeds has been the application of seed treatment with insecticides such as heptachlor, lindane and others against red fire ants (Parker, 1989). The seed treatment with carbofuran 50 SP and carbofuran 40 F was effective against shoot fly (*Atherigona soccata*) infestation (Balasubramanian *et al.,* 1987); with acephate against black cutworm in maize (Berry and Knake., 1988); with carbofuran 3.50g/100 g of seed against *Chilo partellus* on maize. (Sekhon *et al.*, 1989); with chlorpyriphos against red fire ants in corn (Drees *et al.*, 1992); with carbosulfan 25 ST at 70 and 90 g/kg seed against *Hylema antique* in onion (Markiewicz-Jodko, 1991); with pyrethroids and chlorpyriphos against black cutworm in potato (Islam *et al.*, 1991); with carbosulfan @

7.5 g/100 g seed against the stem borer in maize (Sekhon and Uma Kanta, 1992).

The seed treatment of imidacloprid 70 WS @ 224 g a. i. ha^{-1} proved effective against cutworm infesting maize (Sharma and Bhagat, 2000). Zaki *et al.* (2001) indicated that both the seed treatments of deltamethrin @ 0.1 ml and carbosulfan SD @ 7.5 g a.i. /kg seed recorded a significantly lower damage than control. Viji and Bhagat (2001) concluded that seed treatment with chlorpyriphos 20 EC @ 5 g.a.i/ kg seed, imidacloprid 70 WP @ 3.5 g a.i./kg seed attributed to higher yields against cutworm infesting maize. Sharma *et al.* (2002) indicated that application of chlorpyriphos after impregnation on sand and folidol dust was superior over other treatments against *Agrotis* spp. in wheat. Pons and Albajes (2002) demonstrated that seed treatment of maize with imidacloprid was effective in reducing incidence of cutworms (*Agrotis segetum*) in corn.

3. Seed treatment method:

Starks and Lilly (1955) used 5 ml of methyl cellulose solution as sticker sufficient for one pound of corn seed and 10.7 ml of acetone per pound of seed were used as a solvent for crystallized lindane. Adkisson - perry (1958) treated the seeds with thimet and bayer by means of a mechanically rotated barrel type treater, a small quantity of methyl cellulose plus 500 ml of water was applied and mixed until seeds were dampened. The insecticide was then added and mixing was continued until the seeds were evenly coated. Raghuwanshi and Rawat (1985) diluted emulsifiable concentrates with water in required concentrations into which the seeds were dipped for 12 hours. Kumawat and Yadava (1990) prepared a mixture of soil, water and seeds in the ratio of 1:3:6 and stirred for some time to form slurry, then dissolved granular insecticides were added to the slurry for some time till the slurry got evenly coated on seeds. The treated seeds were dried in shade for 12 hours prior to sowing and carbosulfan 25 ST was used dry for seed treatment. Drees (1992) reported that for treating a small quantity (0.23 kg) of seed the volume of each formulation required plus 2 ml of distilled water was added to the seed in a plastic bag, shaken for 3 minutes, and then allowed to air dry before use.

Zaki and Andrabi (2001) treated 100 g of corn seeds with about 10 ml of rice starch to act as sticker for homogenous distribution of insecticides after which measured quantities of insecticides were added. The seeds were tumbled in polyethylene bags to allow thorough coating of insecticide on seed surface and before sowing the treated seeds were dried in shade.

4. Soil application:

The literature available on soil treatments has been categorized under following sub heads.

a)Granules

b) Dusts

c) Foliar sprays

d) Other methods

a) Granules:

The soil treatment viz., spot/strip application of pesticide is an effective approach for pest management in cryptic habitat of soil. Various workers have reported significant control of cutworms infesting different crops. The soil treatment with granules of aldicarb, carbofuran, carbaryl, disulfotan and phorate were effective at 1 kg a.i. ha^{-1} (Gupta *et al.*, 1981);

with aldicarb granules 10G and carbofuran 3G at 20 and 37.5 kg ha^{-1}, respectively for the control of *Agrotis ipsilon* infesting maize in Kashmir valley (Bhat, 1986); with methosfolan followed by phorate, aldicarb and carbofuran against black cutworm infesting potato (Misra *et al.*, 1986); with parathion 2 percent dust or phorate granules in the soil at 20-25 kg ha^{-1} (Garg and Mani, 1988); with phorate and sevidol against white grubs in groundnut (Kumawat and Yadava., 1990); with diazinon 10G against *Agrotis ipsilon* attacking potato (Das *et al.*,1996) and with lindane granules followed by phorate and diazinon (Thakur *et al.*, 1997).

b) Dusts:

The dust formulations have been used by various workers to manage the menace of soil dwelling pests. An effective control of cutworm infesting potato has been achieved with insecticidal dusts of aldrin and heptachlor, when applied in split doses in potato crop at sowing and 45 days after sowing (Abraham *et al.*, 1972); with endosulfan at one kg a.i. ha^{-1} against cutworm infesting tobacco (Shahid and Khan, 1977); with pyrethroids against dark sided cutworm (Harris and Turnball, 1978). Thippeswamy *et al.* (1981) observed that percentage damage in cotton was 25.43, 29.03, 31.58 and 51.55 for endosulfan, quinalphos, carbaryl and the control respectively.

The insecticidal dust treatments with aldrin 5 percent, heptachlor 50 percent, DDT 5 percent @ 40 Kg/ ha gave excellent control of *Agrotis ipsilon* on wheat and gram crop (Vaishampayan and Veda, 1981); with heptachlor 10 percent against *Agrotis spinifera* infesting cucurbits (Pareek and Noor, 1982); with heptachlor 10 percent @ 20 kg/ ha against cutworm infesting maize (Bhat, 1986); with chlorpyriphos at 64 g ha^{-1}, heptenophos at 100 g ha^{-1}, triazophos at 100 g ha^{-1} against cutworm in maize (Biase *et al.*,1988); with parathion 2% against *Agrotis flemmatra*

Schiff in maize (Garg and Mani, 1988); with aldrin 5% @ 1.5 kg a.i. ha^{-1} against *Agrotis ipsilon* infesting gram (Nag and Nath, 1993); with lindane granules and dust (Thakur *et al.*, 1997); with chlorpyriphos 1.5 % dust against cutworm in maize (Sharma and Bhagat, 2000); with chlorpyriphos 1.5 % D @ 25 kg ha^{-1} (Viji and Bhagat.,2001) and with application of chlorpyriphos after impregnation on sand and folidol dust against cutworm in wheat (Sharma *et al.*, 2002)

c) Foliar sprays:

Various workers have achieved excellent control of cutworms infesting maize and other crops with foliar application of insecticides. The excellent control of cutworms infesting potatoes was achieved with foliar application of endrin, heptachlor and DDT (Shrivastava and Khan, 1962); with dieldrin against cutworm in cotton (Kamel and Shoeb, 1964); with 0.1% spray of quinalphos and chlorpyrifos for effective control of cutworm in gram crop (Kushawa *et al.*,1972); with chlorpyrifos and endosulfan against *Agrotis ipsilon* on tobacco (Thimmiah *et al.*, 1972); with acephate followed by endosulfan against cutworm in potato (Verma and Chandla, 1977) and with chlorpyriphos 0.1%, and quinalphos 0.5% against cutworm *Agrotis spinifera* (Hubner) on cucurbits (Pareek and Noor, 1982).

Pyrethroid insecticides comprise one promising new group of compounds. They are relatively stable and highly toxic to insects (Elliott, 1976) and have potential for control of agricultural insect pests (Davis *et al.*, 1975; Griffiths *et al.*, 1975; Harris and Svec, 1976; McDonald, 1976 and Schmidt *et al.*, 1976). Harris *et al.* (1978) reported that pyrethroid insecticides are effective against different instars of dark sided cutworm *Euxoa messoria,* white cutworm *Euxoa scandens* and black cutworm *Agrotis ipsilon* at application rates as low as 70 g a.i. ha^{-1}.

Misra *et al.* (1984) achieved an excellent control with four foliar contact insecticides viz. chlorpyriphos, aldrin, toxaphene + DDT and endosulfan against cutworm infesting potato; with carbaryl in climbing cutworm (Sinha and Verma, 1985); with quinalphos 0.15% against cutworm in maize (Bhat, 1986); with cyfluthrin, thiodicarb and carbaryl against black cutworm *Agrotis ipsilon* infesting tobacco seedlings (Link *et al.*,1988); with chlorpyriphos, quinalphos, phoxim and endosulfan in combating cutworm in potato (Rajendra and Verma, 1989); with pyrethroids viz. cyfluthrin 5 EC, fenvalerate 20 EC and fenpropathrin 10 EC against potato cutworm (Islam *et al.*, 1991); with permethrin, fenofos and terbufos against cutworm in maize (Oloumi-Sadeghi *et al.*, 1992).

The higher concentration of lambdacyhalothrin viz. 44 and 22 mg/litre against third to fourth instar larvae of *Agrotis segetum* had an antifeedant effect (Blair, 1991). El-ham and El-Sayed (1991) reported that chlorpyriphos was most toxic followed by triazophos and monocrotophos, when applied as treated leaves against the pest, carbamates were less effective. Addison *et al.* (1991) showed that lambdacyhalothrin 5% EC, at 10, 12.5 and 15.0 g.a.i. ha^{-1} and deltamethrin 2.5% EC at 12.5 g.a.i. ha^{-1} caused significant mortality of *Agrotis ipsilon* infesting maize in New Zealand.

The treatment with deltamethrin @ 0.025 percent, cypermethrin 0.005 percent and methyl parathion 2 D @ 25 kg ha^{-1} proved effective against *Agrotis ipsilon* on chickpea (Khurana and Kaushik, 1991); with carbaryl 40 WP @ 2 kg ha^{-1} against potato cutworm (Mohasin *et al.*, 1993) and with monocrotophos 36 EC @ 0.5 lit a.i. ha^{-1} against *Agrotis ipsilon* infesting gram (Nag and Nath, 1993). Iqbal *et al.* (1997) reported that edron, thioluxon, cyfluthrin and parathion methyl produced similar levels of control of tobacco cutworm in Pakistan. Zidan *et al.* (1998)

reported that fourth instar larva of *Agrotis ipsilon* was most sensitive to cyanophos. Thakur and Vaidya (2000) reported that chlorpyriphos treatment followed by root extract (0.75%) of *Rumex nepalensis* was effective on management of *Agrotis ipsilon.* Lopez and Hague (2003) reported that zeta-cypermethrin at 199.92 mg/m^2 was most effective treatment. Tripathi *et al.* (2003) concluded that chlorpyriphos 20 EC @ 2.0 kg ha^{-1} was most effective followed by quinalphos 25 EC (2.0 kg ha^{-1}) against black cutworm *Agrotis ipsilon* in Garhwal Himalayas.

BIOLOGICAL CONTROL:

Entomopathogenic bacteria and fungi:

Various workers have exploited entomopathogenic bacteria and fungi for the management of pests in cryptic habitat of soil. Salama *et al.* (1989) reported potentiation of *Bacillus thuringiensis* endotoxin against greasy cutworm *Agrotis ypsilon* (Rdf) in Egypt. Salama *et al.* (1990) concluded that addition of adjuvant potassium carbonate to the dipel bait caused a significant larval reduction of *Agrotis ypsilon* (Rdf). Ela *et al.* (1993) hypothesized that five cultures of *Bacillus thuringiensis* were potent against greasy cutworm *Agrotis ypsilon* (Rott), which belonged to sub-species *telworthi, thuringiensis* and *galleriae* respectively. Yang-Jianquan *et al.* (2000) reported that virulence to *Bacillus thuringiensis* decreased sharply during development. Konar and Mohasin (2003) reported that *Metarhizium anisopliae* @ 10^8 spores /ml was effective in reducing plant and tuber damage against cutworm *Agrotis ipsilon* infesting potato.

INTEGRATED MANAGEMENT/OTHER METHODS:

Johnson *et al.* (1984) concluded that both crop residue and weed presence influence black cutworm moth oviposition. Brust *et al.* (1985)

demonstrated that the endemic soil predator complex is a major factor in reducing black cutworm damage on corn especially in no tillage corn. Taraborrelli *et al.* (1989) have found that 0.25 per cent quinalphos bait gave good control of *Agrotis segetum*. El-ham and El-Sayed (1991) found that chlorpyriphos was most toxic against *Agrotis ipsilon* 5th instar larvae applied as poisoned bait and treated leaves. Edwards *et al.* (1992) reported that absolute populations of predators were 4-10 times higher in intercropping areas than in monoculture. Lopez and Potter (2000) reported that predation on cutworm eggs was lower in fair ways than in roughs, where ant population was reduced by insecticides. Mannan *et al.* (2004) reported that the plots treated with hand picking + 2 irrigation (30 and 45 days after planting) + one spray of Dursban (chlorpyrifos) + perching proved superior both protection as well as production wise against potato cutworm. Frank and Shrewsbury (2004) concluded that two species *Amara impuncticollis* and *Philonthus* sp. could consume all the instars of cutworms.

CHAPTER-3

MATERIALS & METHODS

MATERIALS AND METHODS

The studies entitled "Development of Integrated Pest Management (IPM) Capsule for White grub and Cutworm" was carried out at various research stations of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Farms of Agriculture Development Department, Government of Jammu and Kashmir, Srinagar, Farmer's fields located in various districts of the valley and in Department of Zoology, Aligarh Muslim University, Aligarh. The following sites were selected for experimental purposes:

i) High Altitude Maize Research Station, Pahalgam district Anantnag (Altitude : 7500 feet a.m.s.l),

ii) High Altitude Potato Development Farm, Gulmarg district Baramulla (Altitude : 8500 feet a.m.s.l),

iii) Potato and Fodder Development Farm, Yarikah, Tangmarg (Altitude : 7300 feet a.m.s.l)

iv) High Altitude Rice Research Station, Larnoo District Anantnag (Altitude : 7250 feet a.m.s.l),

v) Seed Multiplication Farm, Padgampora, District Pulwama (Altitude : 5200 feet a.m.s.l)

On farm demonstration trials were laid at the following sites:

a) Farmer's field Kuller Pahalgam District Anantnag (Altitude : 7500 feet a.m.s.l)

b) Farmer's field Yarikah Gulmarg District Baramulla (Altitude : 8000 feet a.m.s.l)

To achieve the objectives of the studies, the following experiments were carried out:

1) Loss assessment due to cutworm (*Agrotis ipsilon* Hüfnagel) infesting maize (*Zea mays* L.) under rainfed conditions in Kashmir,

2) Evaluation of some insecticides and biopesticides against cutworm (*Agrotis ipsilon* Hüfnagel) infesting maize under rainfed condition in Kashmir,

3) Effect of seed rate in combination with seed treatment of imidacloprid against cutworm (*Agrotis ipsilon* Hüfnagel) infestation in maize,

4) Loss assessment due to cutworm (*Agrotis ipsilon* Hüfnagel) infesting potato (*Solanum tuberosum* L.) under rainfed conditions in Kashmir,

5) Evaluation of some insecticides and biopesticides against white grub/ cutworm infesting potato under rainfed conditions,

6) Effect of different dates of sowing and seed rates on the infestation of cutworm (*Agrotis ipsilon* Hüfnagel) in potato,

7) Field evaluation of some insecticides as post sown foliar application against cutworm/ white grub infesting potato,

8) Faunastic study to record species of white grub complex present in hill and mountain agro-ecosystem of Kashmir.

To evaluate and validate the best treatments for IPM module against the key pests of white grub and cutworm infesting maize and potato crops, the following on farm demonstration trials were carried out:

a) On farm demonstration and validation of promising IPM components against cutworm/ white grub infestation in maize at Kuller, Pahalgam,

b) On farm demonstration and validation of promising IPM components against cutworm/white grub infestation in potato at Yarikah, Gulmarg.

EXPERIMENT NO. 1

Loss assessment due to cutworm (*Agrotis ipsilon* Hüfnagel) infesting maize (*Zea mays* L.) under rainfed conditions in Kashmir.

Field experimentation on yield loss studies due to cutworm in maize was carried out at High Altitude Maize Research Station, Pahalgam during the year 2004-2005 to work out the percent avoidable loss. Two treatments viz., seed treatment of imidacloprid @ 0.8 g.a.i./ kg seed and chlorpyriphos 20 EC @ 0.04% a.i. foliar spray were applied. Thus three treatments including control were designed as per the Randomized Block Design (RBD) with three replications in plots of 3×2 m^2 size. The spacing between rows was 60 cm and plant to plant 20 cm.

The maize C_{15} seeds were properly cleaned and 100 g of the seed was selected for each treatment. Rice starch obtained by boiling of rice was used as a sticker. Approximately 10 ml of rice starch was found sufficient to wet 100 g of seed precisely. The required quantity of liquid insecticide was measured with the help of a syringe and mixed with the sticker rice extract, for homogenous distribution of insecticide. The seeds were tumbled in polythene bags to allow thorough coating of insecticide on seed surface. The treated seeds were then dried under shade on a polythene sheet and finally kept in labeled polythene envelopes till sowing.

The post sown foliar spray was given as high volume spraying @ 600 lit ha^{-1} on both the plants as well as on soil surface in afternoon at four leaf stage of the crop followed by light earthing. Observations were recorded on the following parameters:

$$\text{Germination percentage} : \frac{\text{No. of seeds germinated}}{\text{No. of seeds sown}} \times 100$$

$$\text{Per cent damage} : \frac{\text{No. of plants cut}}{\text{No. of plants germinated}} \times 100$$

Plant stand : The no. of plants left after in each plot, when the cutworm damage stopped.

Cob yield : The cob yield of individual plots after drying were weighed separately and expressed in quintals per hectare.

Grain yield : The dried cobs from each plot were threshed and dried grain yield was recorded separately and expressed in quintals per hectare.

The initial plant population was recorded at germination stage in each plot. Percent plants damaged were recorded at two and four leaf stage of crop and were analyzed after taking the angular values. In the last grain yield was recorded in each plot after converting the values into quintals/hectare. Percent increase in yield over untreated control and percent avoidable loss was worked out for each treatment. Weekly sampling was done to know the efficacy of different treatments in reducing the black cutworm population. The average number of larvae per pit ($1 \times 1 \times 0.20$ m^3) was recorded to determine the infestation level.

The data for both the years were pooled and were statistically analyzed by Analysis of Variance and treatment means were compared by Duncan's Multiple Range Test (DMRT).

EXPERIMENT NO. 2

Evaluation of some insecticides and biopesticides against cutworm (*Agrotis ipsilon* Hüfnagel) infesting maize under rainfed condition in Kashmir.

To study the effect of different insecticides as seed treatment, soil treatment and as post sown foliar sprays. The experiment was carried out at two locations of Larnoo and Pahalgam during the year 2004-2005. The maize seed of the recommended variety for high altitudes C_{15} was obtained from Division of Plant Breeding and Genetics, SKUAST-K.

In this experiment eleven insecticides and biopesticides evaluated were T_1 (Multineem 0.03 EC), T_2 (Imidacloprid 200 SL) as seed treatment, T_3 (Deltamethrin 2.8 EC seed treatment) T_4 (Chlorpyriphos 20 EC) seed treatment, T_5 (Chlorpyriphos 20 EC) as foliar spray, T_6 (Chlorpyriphos 1.5% dust as soil treatment), T_7 (Fenvalerate 0.4% dust) as soil treatment, T_8 (*Beauveria bassiana*) as foliar spray, T_9 (Quinalphos 25 EC) as foliar spray, T_{10} (Carbofuran 3G) as soil treatment, T_{11} (Lambdacyhalothin 5EC as seed treatment) and T_{12} (Control). Thus, the experiment comprising of twelve treatments including control were designed as per the Randomized Block Design (RBD) with three replications in plots of 3 × 3 m size.

Method of seed treatment:

The method for seed treatment was cross referred from Experiment No.1

Soil treatment:

In case of soil treatments desired quantity of insecticidal dust/ granules were weighed separately with the help of a sensitive balance and mixed in thoroughly ploughed soil. These were dusted in furrows in respective plots at optimum moisture conditions just before sowing. The insecticides were properly mixed with the soil and then the seeds were manually placed in furrows.

Foliar spray:

The post sown foliar spray was given as high volume spraying @ 600 lit ha^{-1} on both the plants as well as on soil surface at four leaf stage of the crop followed by light earthing. Observations were recorded for germination percentage, percent plant damage by cutworm, final plant stand and grain yield as recorded in Experiment No. 1.

The data for both the years of two locations were pooled and were statistically analyzed by Analysis of Variance and means were compared by Duncan's Multiple Range Test (DMRT).

EXPERIMENT NO.3

Effect of seed rate in combination with seed treatment of imidacloprid against cutworm (*Agrotis ipsilon* Hüfnagel) infestation in maize.

This experiment was carried out at High Altitude Maize Research Station, Pahalgam during the year 2004-2005. The three different seed rates selected were as under:

S1 = 20 kg ha^{-1}

S2 = 30 kg ha^{-1}

S3 = 40 kg ha^{-1}

Among these seed rates S_1 (20 kg ha^{-1}) is the normal seed rate, which is being practiced at farmer's fields. Three different seed rates were treated with seed treatment of Imidacloprid and rest of three without any treatment. In all there were six treatment combinations S_1, S_2, S_3, S_1C, S_2C, S_3C (C= seed treatment of imidacloprid @ 0.8 g.a.i / kg seed). The experiment was laid out in a Randomized Block Design (RBD) with three replications in plots of 3×3 m^2 size. The data were recorded as per the method described in previous experiment. The procedure for statistical analysis was also the same as repeated in Experiment No. 1.

EXPERIMENT NO.4

Loss assessment due to cutworm (*Agrotis ipsilon* Hüfnagel) infesting potato (*Solanum tuberosum* L.) under rainfed conditions in Kashmir.

Field experimentation was carried out on yield loss studies due to cutworm in potato at High Altitude Maize Research Station, Pahalgam during the year 2004-2005. The treatment evaluated were carbofuran 3G @30 kg ha^{-1}, fenvalerate 0.4% dust @25 kg ha^{-1}, imidacloprid 200 SL tuber treatment, chlorpyriphos @ 0.04% a.i. foliar spray. Thus five treatments including control were designed as per Randomised Block Design (RBD) with three replications in plots of 3×2 m^2.

The initial plant population was recorded in each plot, at the sprouting stage. Percent plant mortality was recorded from the total plants cut and plants sprouted and were analyzed after taking the angular values. In the last tuber yield was recorded in each plot and converted into quintals/hectare. Percent increase in yield over untreated control and percent avoidable loss was worked out for each treatment. Weekly sampling was done to know the efficacy of different treatments in reducing the black cutworm population. The average number of larvae per pit (1 × 1 × 0.20 m^3) was recorded to determine the infestation level.

The data for both the year were pooled and analysed as repeated in Experiment No.1.

EXPERIMENT NO. 5

Evaluation of some insecticides and biopesticides against white grub/ cutworm infesting potato under rainfed conditions.

This experiment was conducted at two locations Larnoo (District, Anantnag) and Yarikah (Baramulla) during the year 2004-2005. In this experiment eleven insecticides and biopesticides evaluated were T_1 (Multineem 0.03 EC), T_2 (Imidacloprid 200 SL) as seed treatment, T_3 (Deltamethrin 2.8 EC seed treatment) T_4 (Chlorpyriphos 20 EC) seed treatment, T_5 (Chlorpyriphos 20 EC) as foliar spray, T_6 (Chlorpyriphos 1.5% dust as soil treatment), T_7 (Fenvalerate 0.4% dust) as soil treatment, T_8 (*Beauveria bassiana*) as foliar spray, T_9 (Quinalphos 25 EC) as foliar spray, T_{10} (Carbofuran 3G) as soil treatment, T_{11} (Lambdacyhalothin 5EC as seed treatment) and T_{12} (Control). Thus, the experiment comprising of twelve treatments including control were designed as per the Randomized Block Design (RBD), with three replications in plots of 2 × 3 m size.

The seed tubers were properly cleaned and 3.6 kg of tubers were selected for each treatment. Rice starch was used as sticker. The required quantity of insecticide was mixed with sticker for homogenous distribution of insecticide. The tubers were tumbled in polythene bags and then dried under shade. Finally these were kept in labeled polythene envelopes till sowing. The soil treatment was done by mixing desired quantity of insecticidal dust/granules in thoroughly ploughed soil, which was dusted in furrows at the time of sowing. The post sown foliar spray was given as high volume spray @ 600 lit ha^{-1} on both the plants as well as on soil surface after sprouting and with the appearance of first damage followed by light earthing.

The trials were conducted with potato variety (K-2500). The tubers were divided into lots of 1.2 kg each. The tubers were sown at the distance of 20 cm within the row, which were kept 60 cm apart. The crop was sown on last week of May. The seedlings started emerging from fifth day after sowing i.e. around first week of June. Observations on the number of plants damaged were taken at different seedling stages.

The field preparation, fertilizer application and other practices were followed as per recommended package of practices by SKUAST-K for raising a good crop. The observations were recorded for tuber sprouting, cutworm damage, final plant stand and tuber yield. The sprouting percentage was computed by counting the number of tubers sown and tubers sprouted. For plant damages, the number of plants cut by black cutworm was recorded from tuber sprouting till the cutworm damage actively stopped altogether. The percentage of plants cut (damaged) was calculated on the basis of number of plants germinated. The number of plants surviving at the last observation, when no more cut plants were recorded was taken as the final plant stand.

The extent of infestation in tubers by white grub was recorded by counting the healthy and damaged tubers in each plot at the time of harvesting and per cent damage in tubers was worked out for each treatment as well as in untreated control plots. The total yield of marketable healthy tubers (kg/plot) was recorded in each plot and yield data were analyzed after converting the values into quintals per hectare. The market rate of insecticides for the analysis of benefit: cost (B/C) ratio were taken from the State Agriculture Department, while the market rate of potato tubers was taken from the market on wholesale price basis. The data for these two locations were pooled and analysed by Analysis of

Variance. The treatment means were compared by Duncan's Multiple Range Test (DMRT).

EXPERIMENT NO. 6

Effect of different dates of sowing and seed rates on percent germination, percent damage, final plant stand and tuber yield in potato (*Solanum tuberosum* L) infested with black cutworm (*Agrotis ipsilon* Hüfnagel).

The experiment was carried out at Potato Development Farm, Gulmarg using potato cultivar K-2500 during the year 2004-2005. The experimental block was prepared as per the recommended package of practices by SKUAST-K.

A. Three dates of sowing of potato were

D_1 = 20th May

D_2 = 27th May

D_3 = 3rd June

B. Three seed rates selected were

S1 = 20 q ha^{-1}

S2 = 24 q ha^{-1}

S3 = 28 q ha^{-1}

Since 20 q ha^{-1} is the normal seed rate, therefore it was considered as control.

The treatment combinations of different dates of sowing with three seed rates were as under:

D_1S_1	D_2S_1	D_3S_1
D_1S_2	D_2S_2	D_3S_2
D_1S_3	D_2S_3	D_3S_3

The plot size for each treatment was 2×3 m with row to row distance of 60 cm. However, due to varying seed rates, the plant spacing varied. The fertilizers and other practices were followed as per SKUAST-(K) recommended package of practices.

Observations were recorded for seed germination, plant damage, plant stand and tuber yield. The germination percentage was computed by counting the number of tubers sown and tubers sprouted. For plant damage the number of plants cut by cutworm was recorded from seed germination till infestation stopped altogether. The number of plants surviving at last observation were taken as final plant stand. For tuber yield, the tubers of each plot were weighed separately and recorded.

Statistical analysis:

The pooled tabulated data of the three replications were first analyzed by the Analysis of Variance method of RBD to test for the treatment significance. Subsequently, two way tables were analyzed to find out interaction between the variables and test the significance due to each variable. The critical differences of different variables and their interaction effects were computed as under:

$$CD = \sqrt{\frac{2\ VE}{R}} \times t \text{ at error d.f.}$$

CD for D means $= \sqrt{\frac{2\ VE}{r \times c}} \times t$ at error d.f.

CD for S means $= \sqrt{\frac{2\ VE}{r \times D}} \times t$ at error d.f.

CD for interaction $= \sqrt{\frac{2\ VE}{r}} \times t$ at error d.f.

VE = Error mean sum of squares

r = Number of replications

D = Sowing dates

S = Seed rates

EXPERIMENT.NO.7

Field evaluation of some insecticides as post sown folair application in standing kharief crop against cutworm/ white grub infesting potato.

The trials were conducted with potato variety (K-2500) at Shalimar (District, Srinagar) and Gulmarg (District, Baramulla) during the year 2004-2005. The tubers were divided into lots of 1.2 kg each. The tubers were sown at the distance of 20 cm within the row, which were kept 60 cm apart. The crop was sown on last week of May. The seedlings started emerging from five days after sowing i.e. around first week of June. Observations on the number of plants damaged were taken at different seedling stages.

The field preparation, fertilizer application and other practices were followed as per recommended package of practices by SKUAST-K for raising a good crop. The observations were recorded for tuber sprouting, cutworm damage, final plant stand and tuber yield. The germination percentage was computed by counting the number of tubers sown and tubers sprouted. For plant damages, the number of plants cut by black cutworm were recorded from tuber sprouting till the cutworm damage actively stopped altogether. The percentage of plants cut (damaged) was calculated on the basis of number of plants germinated. The number of plants surviving at the last observation, when no more cut plants were recorded was taken as the final plant stand.

In this experiment five different insecticides viz., Chlorpyriphos 20 EC @ 800 g.a.i. ha^{-1}, Quinalphos 25 EC @ 800 g.a.i. ha^{-1}, Lindane 20 EC @ 800 g.a.i. ha^{-1}, Imidacloprid 200 SL @ 80 g.a.i. ha^{-1}, Lambdacyhalothrin 5 EC @ 0.01% foliar spray were applied as post sown foliar sprays. The spray was given as high volume spray @ 600 litres per hectare. The spray was given on both plants as well as ridges along the rows in optimum soil moisture conditions in standing crop after 20-22 days of mass beetle emergence (MBE).

The initial plant population was recorded before treatment application and after treatment application in each treatment. The per cent plant mortality data was transformed into angular values and then analyzed. The white grub infestation was recorded by counting the healthy and damaged tubers in each plot at the time of harvesting. The total yield of marketable healthy tubers (kg/plot) was recorded in each plot and yield data were analyzed after converting the values into quintals per hectare. Net return over control and B/C ratio was worked out for each treatment on the basis of cost of insecticides and rate of tubers. The average number of grubs per plot ($1 \times 1 \times 0.20$ m^3) of predominant species was recorded in each treatment and untreated control plots on the date of harvesting. The data for the two locations of both the years were pooled and analysed by Analysis of Variance. The treatment means were compared Duncan's Multiple Range Test (DMRT).

EXPERIMENT NO. 8

Faunastic study to record the white grub species complex present in hill and mountain agro-ecosystem of Kashmir

To record the white grub species complex present in Kashmir valley. The present light trap studies was carried out at Srinagar Golf Course (Altitude 5200 feet a.m.s.l), High Altitude Maize Research Station, Pahalgam (Altitude 7500 feet a.m.s.l), Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus, Srinagar (Altitude 5200 feet a.m.s.l), and Faculty of Agriculture, Wadura, Sopore (Altitude 5500 feet a.m.s.l) during the year 2004-2005. These were explored as severe endemic pockets and light traps were installed at all these locations from March to September.

The traps were befitted with 60 W fluorescent tubes and kept one meter above the ground level. The light traps were operated from 6.30 pm to 5.00 am. Daily collection of the trapped beetles was kept and number of beetles of each species was counted daily in the morning hours and recorded. The predominant species of white grub and peak emergence period of different species was worked out on the basis of light trap catch at each endemic pocket. The percentage of different species of beetles was calculated on the basis of total light trap catch. The predominant species of white grub was established on the basis of highest catch. The peak emergence period of different species of beetles at various locations was determined on the basis of month wise catch at that very location.

To evaluate and validate the best treatments for IPM module against the key pests and analysis of cost benefit ratio for each IPM components

Based on experimentation during the previous years, the sound treatments observed were combined to develop IPM module, against the cutworm/ white grub infestation in maize/ potato. The most suitable components thus obtained were integrated and tested at the farmer's fields for their validation, economical viability, ecological compatibility and social acceptability to fit in farmers Agricultural Production System. The B/C ratio was worked out for each module.

Two on farm demonstration trials were conducted for dissemination of technology and module developed. The demonstration trials were conducted for management of cutworm/ white grub both in maize and potato as follows:

a) On farm demonstration and validation of promising IPM components against cutworm/ white grub infestation in maize at Kuller, Pahalgam,

b) On farm demonstration and validation of promising IPM components against cutworm/white grub infestation in potato at Yarikah, Gulmarg.

a) On farm demonstration and validation of promising IPM components against cutworm/ white grub infestation in maize at Kuller, Pahalgam,

The demonstration was carried out in a farmers field at Kuller Pahalgam. The most effective and economically viable treatments were demonstrated for popularization of the integrated pest management (IPM) modules developed among common farmers, two treatments viz., imidacloprid 200 SL @ 0.8 g a.i/kg and fenvalerate 0.4 percent dust @ 25 kg ha^{-1} were demonstrated against cutworm *Agrotis ipsilon* infesting maize in High Altitude belts of Pahalgam.

The demonstration was conducted with maize seed C_{15}.The seeds were properly cleaned and 100 g of the seed was selected for each treatment. Rice starch obtained by boiling of rice was used as a sticker. Approximately 10 ml of rice starch was found sufficient to wet 100 g of seed precisely. The required quantity of liquid insecticide was measured with the help of a syringe and mixed with the sticker rice extract, for homogenous distribution of insecticide. The seeds were tumbled in polythene bags to allow thorough coating of insecticide on seed surface. The treated seeds were then dried under shade on a polythene sheet and finally kept in labeled polythene envelopes till sowing.

In case of soil treatments desired quantity of insecticidal dust/ granules were weighed separately with the help of a sensitive balance and mixed in pulverized soil (ten times). These were dusted in furrows in respective plots at optimum moisture conditions at the time of sowing. A thin layer of soil was placed over the insecticide so applied and then seed was sown in furrows. The observations were recorded for germination, cutworm damage, final plant stand and grain yield.The B/C ratio was worked out for each treatment.

b) On farm demonstration and validation of promising IPM components against cutworm/white grub infestation in potato at Yarikah, Gulmarg.

In the demonstration on management of cutworm infestation in potato at Yarikah, Gulmarg the treatments demonstrated were T_1 (carbofuran 3G @30 kg ha^{-1}), T_2 (fenvalerate 0.4% dust @ 25 kg ha^{-1}), T_3 (*Beauveria bassiana* @ 1.5 kg ha^{-1} soil treatment) and T_4(Control).

The demonstrations were conducted with potato variety (K-2500). The tubers were divided into lots of 1.2 kg each. The tubers were sown at the distance of 20 cm within the row, which were kept 60 cm apart. The crop was sown on last week of May. The seedlings started emerging from five days after sowing i.e. around first week of June. Observations on the number of plants damaged were taken at different seedling stages.

The field preparation, fertilizer application and other practices were followed as per recommended package of practices by SKUAST-K for raising a good crop. The observations were recorded for tuber sprouting, cutworm damage, final plant stand and tuber yield. The germination percentage was computed by counting the number of tubers sown and tubers sprouted. For plant damages, the number of plants cut by black cutworm was recorded from tuber sprouting till the cutworm damage actively stopped altogether. The percentage of plants cut (damaged) was calculated on the basis of number of plants germinated. The number of plants surviving at the last observation, when no more cut plants were recorded was taken as the final plant stand.

In case of soil treatments desired quantity of insecticidal dust/ granules were weighed separately with the help of a sensitive balance and mixed in pulverized soil (ten times). These were dusted in furrows in respective plots at optimum moisture conditions at the time of sowing. A thin layer of soil was placed over the insecticide so applied and then seed was sown in furrows. Finally the tuber yield was recorded in each treatment and expressed in quintals per hectare. The B/C ratio was worked out for each treatment. The procedure for statistical analysis was the same as repeated in Experiment No. 1.

CHAPTER-4

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

EXPERIMENT NO.1

Loss assessment due to cutworm (*Agrotis ipsilon* Hüfnagel) infesting maize (*Zea mays* L.) under rainfed conditions in Kashmir.

The data presented in Table 1 represents the germination percentage observed in various treatments. There was no significant impact on germination percentage of the seeds sown. Thus the germination percentage was recorded statistically at par in all of the treatments consequent of which the initial plant stand was also observed statistically at par in all the treatments.

The data on percent plant damage by cutworm revealed that a highest cutworm damage of 54.63 percent was recorded in control which however, was observed statistically at par with damage percentage of 30.39 recorded in chlorpyriphos 20 EC foliar spray. The perusal of data further revealed that a lowest cutworm damage of 11.71 percent was recorded in imidacloprid 200 SL seed treatment which however, did not differ significantly from chlorpyriphos 20 EC foliar spray.

The data also indicated a significant impact of cutworm infestation on final plant stand. The lowest plant stand of 15.66/ plot was recorded in control, which differed significantly from the other two treatments. However, the plant stand recorded in imidacloprid seed treatment and chlorpyriphos 20 EC foliar spray did not differ significantly from one another.

The data on grain yield revealed that highest grain yield of 3.29 kg/plot (54.83 quintals per hectare) was recorded in imidacloprid 200 SL

Table 1. Loss assessment due to cutworm (*Agrotis ipsilon* Hüfnagel) infesting maize (*Zea mays* L.) under rainfed conditions in Kashmir.

Treatment	*Dose ha^{-1}*	Cutworm Damage (%)*	Final Plant Stand (No /plot)	Grain Yield (Kg / m^2) (3×2m^2)	Retrievable loss %	Yield Q ha^{-1}	No of larvae (1×1× 0.20m^3) Post treatment
Imidacloprid 200 SL seed treatment	0.8 g. a.i/Kg seed (4.0ml/kg)	11.71 (19.04)^a	26.33^b	3.29^b	80.18	54.83	1.05
Chlorpyriphos 20 EC foliar spray	0.04% a.i.foliar spray (2 ml / litr)	30.39 (33.21)^{ab}	23.33^b	2.74^b	50.15	45.66	3.55
Control	--	54.63 (47.65)^b	15.66^a	1.82^a	-	30.33	6.05
C.D (P=0.05)	--	**16.70**	5.59	**0.872**			

* Figures in parenthesis are the Arcsine transformed values.
Figures superscripted by same letter do not differ significantly at (P=0.05)
Mean cutworm larvae per pit (1×1×0.20m^3) was 6.05 larvae.

seed treatment, which however, did not differ significantly from grain yield of 2.74 kg/plot (45.66 quintals per hectare) recorded in chlorpyriphos 20 EC foliar spray. The lowest grain yield of 1.82 kg/plot (30.33 quintals per hectare) was recorded in control, which varied significantly from the grain yield recorded in other treatments.

Comparative economics of the evaluated treatments envisaged that both the treatment applications were economically sound for their optimum net returns and consequently favourable B/C ratio. It is concluded that a maximum damage of 54.63 percent and a retrievable yield loss of 80.18 percent is caused due to cutworm under heavy infestation level of 6.05 larvae/m^2.

EXPERIMENT NO.2

Evaluation of some insecticides and biopesticides against cutworm (*Agrotis ipsilon* Hüfnagel) infesting maize under rainfed condition in Kashmir.

This experiment was also carried out to evaluate the bioefficacy of eleven different insecticides and biopesticides alone and in combination against cutworm infesting maize. The treatments were applied in three different patterns as seed treatment, soil treatment and as post sown foliar spray.

The results presented in Table 2 represent effect of various insecticidal treatments on germination percentage of seeds sown. The perusal of data revealed that imidacloprid 200 SL @ 0.8 g a.i./kg seed ranked superior by recording a germination percentage of 94.52 percent which differed significantly from all other treatments. The treatment of carbofuran 3 G ranked second by recording a germination percentage of 91.04 percent, which however, remained statistically at par with germination percentage of 89.05 percent in control. The lowest germination percentage of 59.20 was recorded in seed treatment of lambdacyhalothrin 5 EC.

The data on percent plant damage by cutworm infestation indicated that highest cutworm damage of 17.31 percent was recorded in control. All other insecticidal treatments proved significantly superior over control. The percent damage in *Beauveria bassiana,* chlorpyriphos 20 EC foliar spray and multineem 0.03 EC remained statistically at par with one another. All other treatments, however remained statistically protection-wise at par with each other.

The perusal of data revealed that final plant stand (No/Plot $3 \times 3m^2$) was significantly affected by cutworm infestation. The lowest plant stand was recorded in lambdacyhalothrin 5 EC seed treatment due to phytotoxicity, which remained statistically at par with chlorpyriphos 20 EC foliar spray. The highest plant stand was recorded in imidacloprid seed treatment, which did not differ significantly from carbofuran 3 G soil treatment.

The data presented in Table 2 represents grain yield recorded in various treatments. The data indicated that highest grain yield of 5.57 kg/plot (45.46 q ha^{-1}) was recorded in seed treatment of imidacloprid, followed by carbofuran 3G in which grain yield of 5.22 kg/plot (42.61 q ha^{-1}) was recorded. Both these treatments however remained statistically at par with one another. The treatment of fenvalerate 0.4 percent dust ranked third by recording a grain yield of 4.67 kg/plot (38.12 q ha^{-1}) and remained statistically at par with chlorpyriphos 20 EC seed treatment and chlorpyriphos 1.5 percent dust. The lowest grain yield of 3.29 kg/plot (26.85 q ha^{-1}) was recorded in control, which differed significantly from all other treatments.

Table 2. Evaluation of some insecticides and biopesticides against cutworm (*Agrotis ipsilon* Hüfnagel) infesting maize under rainfed condition in Kashmir.

Treatments	Dose / ha	Germina- tion (%) *	Cutworm damage (%) *	Final plant stand	Grain yield Kgs/plot ($3x3\ m^2$)	B/C ratio	Mean no. of larvae per pit ($1x1x0.20m^3$).
Multineem (0.03EC)	0.5% foliar spray	78.60 $(62.45)^{c}$	3.16 $(10.11)^{ab}$	51^{e}	3.93^{b}	5.33:1	1.50
Imidacloprid 200SL seed treatment	0.8g.a.i/Kg seed	94.52 $(76.67)^{g}$	1.57 $(7.2)^{a}$	62.33^{g}	5.57^{e}	53.13:1	0.50
Deltamethrin 2.8EC seed treatment	0.3g.a.i/Kg seed	67.65 $(55.34)^{b}$	1.45 $(5.83)^{a}$	44.66^{bc}	3.84^{ab}	22.75:1	0.50
Chlorpyriphos 20EC seed treatment	20.0ml/ kg seed	66.66 $(57.43)^{b}$	1.46 $(5.86)^{a}$	44^{b}	4.39^{bc}	70.84:1	0.50
Chlorpyriphos 20EC foliar spray	@0.04% a.i.	78.60 $(62.45)^{a}$	4.10 $(11.28)^{b}$	49^{de}	4.12^{b}	9.02:1	2.00
Chlorpyriphos 1.5% dust at sowing	25.0 kg	85.56 $(67.73)^{de}$	1.14 $(5.18)^{a}$	47^{cd}	4.39^{bc}	2.02:1	0.50
Fenvalerate 0.4% dust at sowing	25.0 kg	84.56 $(66.86)^{d}$	2.35 $(8.7)^{a}$	55^{f}	4.67^{cd}	5.01:1	0.50
Beauveria bassiana foliar spray	1.5kg	85.07 $(67.27)^{d}$	5.24 $(13.11)^{b}$	54^{f}	3.93^{b}	2.09:1	2.00
Quinalphos 25EC.foliar spray	@ 0.05% a.i.	83.57 $(66.13)^{c}$	3.63 $(9.19)^{a}$	54^{f}	4.30^{b}	17.33:1	1.50
Carbofuran 3G at sowing	30.0 kg	91.04 $(72.61)^{f}$	1.63 $(7.33)^{e}$	60^{g}	5.22^{de}	3.83:1	0.50
Lambdacyhalothrin 5EC seed treatment	5.0 ml/kg seed	59.20 $(50.29)^{a}$	1.67 $(6.25)^{a}$	49.33^{de}	4.12^{b}	16.44:1	0.50
Control	---	89.05 $(70.73)^{ef}$	17.31 $(24.57)^{c}$	39^{a}	3.29^{a}	--	5.50
C.D (P=0.05)	—	**2.83**	**6.06**	**2.37**	**0.608**	—	—

*Figures in parentheses are Arc sine transformed values.
Figures superscripted by same letter do not differ significantly at (P=0.05)

The comparative economics of the evaluated treatments indicated that highest B/C ratio was recorded in seed treatments of chlorpyriphos 20 EC followed by imidacloprid 200 SL. Thus, it is concluded that these treatments were best for management of cutworm infestation resulting in maximum net returns in maize crop.

EXPERIMENT NO.3

Effect of seed rate in combination with seed treatment of imidacloprid against cutworm (*Agrotis ipsilon* Hüfnagel) infestation in maize.

The data in Table 3 revealed that percentage damage differed significantly among the different seed rates ranging from 5.00 to 45.81 percent. The maximum cutworm damage of 45.81 percent was recorded in seed rate S_2 (30 kg ha^{-1}), which however was at par with percent damage recorded in seed rate S_3 (40 kg ha^{-1}). However, the lowest cutworm damage of 5.00 per cent was recorded in seed rate S_3C (40 kg ha^{-1}) treated with seed treatment of imidacloprid 200 SL, which also differed significantly from all other treatments. The percent damage in all other treatments did not differ significantly from one another.

The perusal of data on final plant stand revealed that the plant stand increased significantly over the normal seed rate S_1 (20 kg ha^{-1}) with the increasing seed rates. However, highest plant stand of 56.00/plot was recorded in S_3C (40 kg ha^{-1} treated with imidacloprid seed treatment), which differed significantly from all other treatments. The plant stand in S_3 (40 kg ha^{-1} without seed treatment) and S_2C (30 kg ha^{-1} with seed treatment of imidacloprid) was recorded as 51.33 and 41.00 per plot respectively. These two also differed significantly from one another. The plant stand in S_2 (30 kg ha^{-1} without seed treatment) and S_1C (20 kg ha^{-1} treated with seed treatment of imidacloprid) did not differ significantly

Table 3. Effect of seed rate in combination with seed treatment of (Imidacloprid) against cutworm infestation in maize.

Treatment	Cutworm Damage(%)*	Final Plant Stand (No/9m^2)	Grain Yield kg/plot (3x3m^2)	Grain yield Q. ha^{-1}	B/C ratio
S_1 (20 kg ha^{-1})	37.09 (36.89)^b	26.00^a	3.72^a	41.33	--
S_2 (30 kg ha^{-1})	45.81 (42.54)^c	33.00^b	4.80^b	53.33	19:1
S_3 (40 kg ha^{-1})	36.77 (37.28)^c	51.33^d	5.52^c	61.33	29:1
S_1C	27.97 (31.90)^b	33.33^b	5.04^b	56.00	41.67:1
S_2C	24.24 (29.38)^b	41.00^c	5.28^{bc}	58.66	37.99:1
S_3C	5.00 (10.16)^a	56.00^c	7.08^d	78.66	68.38:1
C. D(P=0.05)	**10.51**	**4.00**	**0.583**		

*Figures in parentheses are the Arcsine transformed values.
Figures superscripted by same letter do not differ significantly at (p=0.05)
C = Chemical treatment of Imidacloprid @ 0.8 g.a.i/kg seed.

from one another. However, the lowest plant stand of 26.00/plot was recorded in S_1 (20 kg ha^{-1} without seed treatment).

The data in Table 3 represents the grain yield recorded in various treatments. The data revealed that all the higher seed rates of maize were superior over normal seed rates in improving the grain yield. However, highest grain yield of 7.08 kg/plot (78.66 q ha^{-1}) was recorded in S_3C (40 kg ha^{-1} treated with seed treatment of imidacloprid), which differed significantly from all other treatments. The grain yield recorded in S_3 (40 kg ha^{-1}) and S_2C (30 kg ha^{-1} with seed treatment of imidacloprid) was at par with each other. The lowest grain yield of 3.72 kg/plot (41.33 q ha^{-1}) was recorded in S_1 (20 kg ha^{-1} without seed treatment), which varied significantly from all other treatments. Thus, the highest seed rate of 40 kg ha^{-1} with seed treatment of imidacloprid was suggested economically sound against cutworm infestation in maize under rain fed conditions of Kashmir.

EXPERIMENT NO. 4

Loss assessment due to cutworm (*Agrotis ipsilon* Hüfnagel) infesting potato (*Solanum tuberosum* L.) under rainfed conditions in Kashmir.

The data presented in Table 4 showed no effect of different insecticidal treatments on sprouting percentage of tubers. The germination percentage did not differ significantly amongst various treatments.

Regarding the cutworm damage, the perusal of data revealed that highest cutworm damage of 17.39 percent was recorded in control which differed significantly from all other treatments. The treatment of chlorpyriphos 20 EC foliar spray ranked second by recording a cutworm damage of 6.74 percent which also differed significantly from all other

Table 4. Loss assessment due to cutworm (*Agrotis ipsilon* Hüfnagel) infesting potato (*Solanum tuberosum* L.) under rainfed conditions in Kashmir.

Treatment	Dose per ha	Cut worm damage*	Final plant stand ($3x2\ m^2$)	Tuber Yield Kgs/plot ($3x2\ m^2$)	Tuber yield quintal/ha	Percent Retrievable loss	Mean no. of larvae per pit ($1\times1\times 0.20\ m^3$) 23-06-02
Carbofuran 3G	30.0 Kg ha^{-1}	2.59 $(9.17)^a$	65.75^b	10.37^b	172.83	16.91	2.02
Fenvalerate 0.4% dust	25.0 Kg ha^{-1}	3.56 $(9.31)^a$	64.25^b	11.12^b	185.33	25.36	1.52
Imidacloprid 200 SL seed treatment	0.8 g a.i Kg^{-1} 4.0 ml/Kg seed	3.36 $(8.90)^a$	66.00^b	14.37^c	239.50	62.01	0.5
Chlorpyriphos 20 EC	0.04% a.i. foliar spray	6.74 $(12.89)^b$	65.25^b	10.27^b	171.16	15.78	3.55
Control	-	17.39 $(21.09)^c$	55.75^a	8.87^a	147.83	--	6.05
C.D.(P=0.05)		**3.18**	**5.22**	**1.30**	--	--	

*Figures in parentheses are Arc sine transformed values
Figures superscripted by same letter do not differ significantly at (P=0.05)

treatments. However, cutworm damage in all other treatments remained statistically at par with each other.

The data on final plant stand indicated that plant stand was significantly affected by cutworm infestation. The lowest plant stand was recorded in control, which differed significantly from all other treatments. The plant stand in rest of the treatments did not differ significantly from each other.

The data depicted in Table 4 regarding tuber yield indicated that the highest tuber yield of 14.37 kg $plot^{-1}$ (239.50 q ha^{-1}) was recorded in imidacloprid 200 SL seed treatment, which differed significantly from all other treatments. The treatment of fenvalerate 0.4 percent dust ranked second by recording a tuber yield of 11.12 kg $plot^{-1}$ (185.33 q ha^{-1}) which however, did not differ significantly from other treatments.

It is concluded that a maximum plant damage of 17.39 percent and a retrievable yield loss of 62.01 percent is recorded due to cutworm under heavy infestation level of 6.05 larvae/m^2.

EXPERIMENT NO. 5

Evaluation of some insecticides and biopesticides against white grub/ cutworm infesting potato under rainfed conditions.

In this experiment eleven different insecticides and biopesticides were evaluated in three different patterns as seed treatment, soil treatment and as post sown foliar sprays and their efficacy against the pests were evaluated along the growth and yield parameters of the potato crop.

The results presented in Table 5 revealed that maximum sprouting percentage was recorded in the soil treatments of chlorpyriphos 1.5 percent dust, fenvalerate 0.4 percent dust, *Beauveria bassiana* and carbofuran 3G. The sprouting percentage in these treatments however, did not differ from one another and with multineem 0.5 percent foliar spray and control. The 'tuber sprouting in treatments of tuber treatment with imidacloprid 200 SL, chlorpyriphos 20 EC foliar spray and quinalphos 25 EC foliar spray remained statistically at par with one another. The least sprouting percentage was recorded in seed treatments of deltamethrin 2.8 EC and chlorpyriphos 20 EC.

The data depicted in Table 5 depicted that the percent plant damage by cutworm in all the insecticidal treatments was significantly lower than in untreated control, where the damage percentage of 14.73 was recorded. The lowest damage was recorded in soil treatments of fenvalerate 0.4 percent dust, carbofuran 3G and seed treatments of imidacloprid 200 SL, deltamethrin 2.8 EC, chlorpyriphos 20 EC and lambdacyhalothrin 5 EC. The damage percentage in rest of treatments remained statistically at par with one another.

The data displayed in Table 5 revealed that final plant stand was significantly affected by cutworm infestation. The maximum plant stand of 30.21 (No./plot) was recorded in soil treatments of chlorpyriphos 1.5 percent dust followed by 28.66, 28.22 and 29.88 in fenvalerate 0.4 percent dust, *Beauveria bassiana* and carbofuran 3G respectively. These all treatments were at par with one another. The plant stand in multineem 0.03 EC foliar spray and *Beauveria bassiana* furrow application remained statistically at par with one another. The plant stand in seed treatment of imidacloprid 200 SL, quinalphos 25 EC foliar spray and control remained statistically at par with one another. The lowest plant stand was recorded in rest of treatments in which sprouting of tubers was impaired due to phytotoxicity by seed treatments.

The number of clean tubers free from white grub damage at harvest time was significantly higher in all the treatment applications than in control treatment. Damage percentage in quinalphos 25 EC foliar spray, chlorpyriphos 20 EC foliar and multineem 0.03 EC foliar spray was significantly higher in comparison with other treatments. The seed tuber treatment with imidacloprid 200 SL, lambdacyhalothrin 5 EC and soil treatment with fenvalerate 0.4 percent dust recorded significantly lowest tuber damage. Besides the treatments in which phytotoxicity was recorded percent tuber damage by white grub was comparatively low.

The data regarding the marketable tuber yield is presented in Table 5. The data indicated that imidacloprid 200 SL recorded a significantly higher produce (213.55 q ha^{-1}) in comparison with rest of the treatments. The lowest tuber yield of 94.61 q ha^{-1} was recorded in control, excluding the treatments in which phytotoxicity was reported. The treatments of chlorpyriphos 1.5 percent dust, carbofuran 3G, fenvalerate 0.4 percent dust, quinalphos 25 EC foliar spray, *Beauveria bassiana* soil treatment and chlorpyriphos 20 EC foliar spray recorded a marketable yield of 178.72, 165.33, 154.55, 135.55, 125.16 and 120.60 q ha^{-1} respectively.

Comparative economics of the evaluated treatments revealed that the highest benefit/cost (B/C) ratio of 49.06:1 was recorded in quinalphos 25 EC foliar spray followed by chlorpyriphos 20 EC foliar spray in which B/C ratio of 42.32:1 was recorded. The treatments of fenvalerate 0.4 percent dust, chlorpyriphos 1.5 percent dust, carbofuran 3G, *Beauveria bassiana* and multineem 0.03 EC foliar spray recorded a B/C ratio of 18.97:1, 16.70:1, 12.54:1, 10.29:1 and 9.3:1 respectively.

Table 5. Evaluation of some insecticides and bio-pesticides against cutworm/white grub infesting potato.

Treatment	Dose ha^{-1}	Sprouting (%)*	Cutworm damage(%)*	Final plant stand (No/plot)	Tuber damage(%)* White grub	Marketable yield(Q ha^{-1})	B/C ratio
Multineem(0.03EC) foliar spray	0.5%	82.89 $(65.56)^{d}$	5.74 $(13.86)^{b}$	26.66^{e}	10.00 $(18.43)^{ef}$	108.22^{e}	9.30:1
Imidacloprid 200SL seed treatment	0.8g.a.i/Kg seed	71.41 $(57.67)^{c}$	1.01 $(5.76)^{a}$	25.11^{d}	1.66 $(7.40)^{b}$	213.55^{L}	1.24:1
Deltamethrin 2.8EC Seed treatment	0.3g.a.i/Kg seed	10.99 $(19.36)^{a}$	0.01 $(0.57)^{a}$	3.88^{b}	0.01 $(0.57)^{a}$	11.10^{b}	-
Chlorpyriphos 20 EC seed treatment	20.0ml/ kg seed	1.56 $(7.17)^{a}$	0.01 $(0.57)^{a}$	0.56^{a}	0.01 $(0.57)^{a}$	2.78^{a}	-
Chlorpyriphos 20 EC foliar spray	@0.04% a.i.	56.18 $(48.54)^{c}$	4.13 $(11.72)^{b}$	18.11^{c}	11.66 $(19.96)^{f}$	120.60^{f}	42.32:1
Chlorpyriphos 1.5% dust soil application	25.0 kg	85.63 $(67.72)^{d}$	2.94 $(9.87)^{b}$	30.21^{f}	6.66 $(14.95)^{de}$	178.72^{k}	16.70:1
Fenvalerate 0.4% dust soil application	25.0 kg	82.04 $(64.92)^{d}$	2.03 $(8.19)^{a}$	28.66^{f}	3.33 $(10.51)^{bc}$	154.55^{i}	18.97:1
Beauveria bassiana foliar spray	1.5kg	81.04 $(64.18)^{d}$	6.22 $(14.44)^{b}$	28.22^{ef}	6.66 $(14.95)^{de}$	125.16^{g}	10.29:1
Quinalphos 25EC foliar spray	@0.05% a.i.	73.70 $(59.14)^{cd}$	6.63 $(14.92)^{bc}$	22.88^{d}	13.33 $(21.41)^{f}$	135.55^{h}	49.06:1
Carbofuran 3G at sowing	30.0 kg	87.00 $(68.86)^{d}$	2.17 $(8.47)^{ab}$	29.88^{f}	5.00 $(12.92)^{c}$	165.33^{j}	12.54:1
Lambdacyhalothrin 5EC Seed treatment	5.0 ml/kg seed	18.58 $(25.53)^{b}$	0.74 $(4.93)^{a}$	6.55^{b}	1.60 $(7.26)^{b}$	57.33^{c}	-
Control	---	85.60 $(67.69)^{d}$	14.73 $(22.56)^{c}$	25.33^{de}	20.00 $(26.56)^{g}$	94.61^{d}	-
C.D (P=0.05)		**13.03**	**8.80**	**3.13**	**4.26**	**2.85**	-

*Figures in parentheses are Arc sine transformed values

Figures superscripted by same letter do not differ significantly at (P=0.05)

EXPERIMENT NO. 6

Effect of different dates of sowing and seed rates on percent germination, percent damage, final plant stand and tuber yield in potato (*Solanum tuberosum* L) infested with black cutworm *Agrotis ipsilon* Hüfnagel.

In this experiment, three sowing dates and three seed rates were combined in all permutations in order to find out their cumulative effect on the extent of damage to potato by black cutworm (*Agrotis ipsilon* Hüfnagel) and white grub.

The data presented in Table 6.1 represents the effect of different dates of sowing and seed rates on germination (tuber sprouting) percentage of tubers. The results revealed that sprouting percentage differed significantly amongst all treatments. Maximum sprouting percentage of 79.98 was recorded in D_1 sowing (20th May), which remained at par with sprouting percentage recorded in D_2 (27th May). Whereas lowest germination percentage was recorded in D_3 (3rd June) sowing, which however did not differ significantly from the sprouting recorded in D_2 (27th May). The sprouting percentage in seed rates did not differ significantly from one another.

The data on percent plant damage by cutworm infestation is presented in Table 6.2. The damage percentage differed significantly among all the treatments. The maximum cutworm damage of 13.55 percent was recorded in seed rate S_1 (20 q ha^{-1}), which remained at par with damage percentage recorded in seed rate S_3 (28 q ha^{-1}). Whereas lowest damage of 4.92 percent was recorded in seed rate S_2 (24 q ha^{-1}).

The data on final plant stand is presented in Table 6.3 which indicated that highest plant stand was recorded in seed rate S_3 (28 q ha^{-1}),

Table 6.1. Effect of different dates of sowing and seed rates on percent sprouting germination in potato infested with black cutworm (*Agrotis ipsilon*).

Dates of sowing	Seed rate q ha^{-1}			
	S1 (20 q ha^{-1})	S2 (24 q ha^{-1})	S3 (28 q ha^{-1})	Total
D1 (20th May)	253.45 (84.48)	235.38 (78.46)	231.04 (77.01)	719.87 $(79.98)^{b}$
D2 (27th May)	235.73 (78.57)	231.79 (77.26)	226.68 (75.56)	694.2 $(77.13)^{ab}$
D3 (3rd June)	208.16 (69.38)	202.99 (67.66)	227.18 (75.72)	638.33 $(70.92)^{a}$
Total	697.34 (77.48)	670.16 (74.46)	684.9 (76.1)	

C.D. for dates (P=0.05) = 6.74

Figures in Parentheses are mean values

Table 6.2. Effect of different dates of sowing and seed rates on percent plant damage in potato infested with black cutworm (*Agrotis ipsilon*).

Dates of sowing	Seed rate q ha^{-1}			
	S1 (20 q ha^{-1})	S2 (24 q ha^{-1})	S3 (28 q ha^{-1})	Total
D1(20[th] May)	48.39 (16.13)	14.07 (4.69)	16.45 (5.48)	78.91 (8.76)
D2(27[th] May)	44.33 (14.77)	15.18 (5.06)	54.89 (18.29)	114.4 (12.71)
D3(3[rd] June)	29.31 (9.77)	15.03 (5.01)	20.8 (6.93)	65.14 (7.23)
Total	122.03 (13.55)[b]	44.28 (4.92)[a]	92.14 10.23)[ab]	

C.D. for seed rates (P=0.05) = 6.51
Figures in Parentheses are mean values

Table 6.3. Effect of different dates of sowing and seed rates on final plant stand in potato infested with black cutworm (*Agrotis ipsilon*).

Dates of sowing	Seed rate q ha^{-1}			
	S1 (20 q ha^{-1})	S2 (24 q ha^{-1})	S3 (28 q ha^{-1})	Total
D1(20th May)	91.14 (30.38)	108.16 (36.05)	109.39 (36.46)	308.69 $(34.29)^{a}$
D2(27th May)	87.83 (29.27)	111.72 (37.24)	138.81 (46.27)	338.36 $(37.59)^{a}$
D3(3rd June)	109.31 36.43)	139.2 (46.4)	132.21 (44.07)	380.72 $(42.30)^{b}$
Total	288.28 $(32.03)^{a}$	359.08 $(39.89)^{b}$	380.41 $(42.26)^{b}$	

C.D. for seed rates (P=0.05) = 3.95
C.D for dates (P=0.05) = 3.95
Figures in Parentheses are mean values

Table 6.4. Effect of different dates of sowing and seed rates on tuber yield in potato infested with black cutworm (*Agrotis ipsilon*)

Dates of Sowing	Seed rate q ha^{-1}			
	S1 (20 q ha^{-1})	S2 (24 q ha^{-1})	S3 (28 q ha^{-1})	Total
D1(20th May)	30.50 $(10.16)^b$	25.50 $(8.5)^a$	29.75 $(9.91)^b$	85.75 (9.52)
D2(20th May)	31.50 $(10.5)^b$	27.50 $(9.16)^{ab}$	27.00 $(9.00)^a$	86.00 (9.55)
D3(3rd June)	23 $(7.66)^a$	40.00 $(13.33)^c$	30.50 $(10.16)^b$	93.50 (10.38)
Total	85 (9.44)	93 (10.33)	87.25 (9.69)	

C.D. for S x D (P=0.05) = 1.70
Figures in Parentheses are mean values

which however, did not differ significantly from S_2 (24 q ha^{-1}). The minimum plant stand was recorded in seed rate S_1 (20 q ha^{-1}). The plant stand among sowing dates was maximum in third date of sowing D_3 (3rd June), which differed significantly from D_1 (20th May), the normal date of sowing and D_2 (27th May) the second date of sowing.

The data presented in Table 6.4 depicts tuber yield recorded in various treatments. The perusal of the data revealed that among sowing dates maximum tuber yield was recorded in D_3 sowing (3rd June), which varied significantly from other treatments. Among seed rates the tuber yield was maximum (10.33 kg/plot) in seed rate S_2 (24 q ha^{-1}) followed by S_3 (28 q ha^{-1}) in which tuber yield recorded was 9.69 kg/plot, whereas minimum tuber yield of 9.44 kg/plot was recorded in seed rate S_1 (20 q ha^{-1}). Thus D_3S_2 was considered as best interaction to protect the cutworm damage and resulted in maximum net returns.

EXPERIMENT NO. 7

Field evaluation of some insecticides as post sown foliar application against cutworm/ white grub infesting potato.

This experiment was conducted to evaluate efficacy of various insecticides as post sown foliar application against cutworm/ white grub infesting potato.

The data presented in Table 7 revealed that percent cut damage differed significantly in various treatments. The highest cutworm damage of 20.02 percent was recorded in control, which varied significantly from rest of treatments. The treatment of lambdacyhalothrin 5 EC recorded a damage of 5.71 percent, which also varied significantly from all other all the treatments did not differ significantly from control.

The data regarding the per cent tuber damage by white grubs revealed that white grub damage on tubers was significantly higher in control which varied significantly from the rest of the treatments. The tuber damage in rest of the treatments was statistically at par with one another.

The data depicted in Table 7 represents marketable tuber yield recorded in various treatments. The perusal of data indicated that the maximum tuber yield of 133.83 q ha^{-1} was recorded in imidacloprid 200 SL foliar spray. The lowest tuber yield of 82.75 q ha^{-1} was recorded in control, which varied significantly from rest of the treatments. The treatments of lambdacyhalothrin 5 EC, chlorpyriphos 20 EC, quinalphos 25 EC and lindane 20 EC recorded a marketable yield of 119.33, 115.83, 108.24 and 99.41 quintals per hectare respectively.

The comparative economics of the evaluated treatments revealed that highest B/C ratio of 29.95:1 was recorded in imidacloprid 200 SL foliar spray, followed by chlorpyriphos 20 EC foliar spray in which B/C ratio recorded was 15.54:1. The treatments of quinalphos 25 EC, lindane 20 EC and lambdacyhalothrin 5 EC recorded a B/C ratio of 9.8:1, 2.97:1 and 1.22:1 respectively.

Table 7. Field evaluation of some insecticides as post sown foliar application against cutworm/white grub infesting potato.

Treatment	Dose/ha		Cutworm damage%*	Final plant stand(3x2 m^2)	Tuber damage %* (White grub)	Marketable tuber yield		B/C ratio	Mean no of grubs per pit(1x1x0.20 m^3)
	a.i	product				Kg's $plot^{-1}$	Quintal ha^{-1}		
Chlorpyriphos 20EC	800 g	4.0 lit	3.83 $(9.42)^a$	28.66	1.67 $(5.45)^a$	6.95^b	115.83	15.54:1	1.80
Quinalphos 25 EC	800 g	3.2 lit	7.02 $(15.04)^a$	27.83	0.01 $(0.57)^a$	6.49^b	108.24	9.8:1	1.30
Lindane 20 EC	800 g	4 lit	5.17 $(13.07)^a$	28.66	3.34 $(6.52)^a$	5.96^{ab}	99.41	2.97:1	2.80
Imidacloprid 200 SL	80g	0.4 lit	2.75 $(7.88)^a$	28.99	1.67 $(4.69)^a$	8.03^c	133.83	29.95:1	1.80
Lambdacyhalothrin 5 EC	0.01%	2 lit	5.71 $(13.82)^a$	33.33	-	7.16^{bc}	119.33	1.22:1	2.55
Control	-	-	20.02 $(26.57)^b$	27.66	13.34 $(21.15)^b$	4.96^a	82.75	--	8.80
C.D (P=0.05)			**9.06**	**N.S**	**12.50**	**1.50**	--	--	--

*Figures in parentheses are Arc sine transformed values.
Figures superscripted by same letter do not differ significantly at (P=0.05)

EXPERIMENT NO. 8

Faunastic study to record the white grub species complex present in hill and mountain agro-ecosystem of Kashmir.

8.1) Light trap catches of white grub beetles at Shalimar Srinagar during March to September.

The data presented in Table 8.1 revealed that more than 10 species of white grub beetles, trapped on the light traps were identified. Where as a minute fraction 9.91% of the trapped beetles could not be identified. Out of the total species identified *Holotrichia longipennis* Blanch (Coleoptera: Melolonthinae) was observed to be the predominant species (29.60% of the total light trap catch) followed by *Maladera* sp. (20.32% of the total light trap catch). *Brahmina coriacea* ranked third and recorded a light trap catch of 11.05% *Adoretus* sp.1, *Anomala rufiventris*, *Brahmina flavosericea* and *Adoretus* sp. 2 ranked fourth, fifth, sixth and seventh by recording a beetle catch of 8.00, 7.20, 7.13 and 6.34 percent respectively. Where as lowest number of beetles were trapped from *Melolontha furcicauda* (2.42% of the total catch).

The mass beetlė emergence i.e., 29.72% of the total catch was recorded in the month of June followed by July in which beetle catch recorded was 24.73%. The emergence of the beetles of predominant species *Holotrichia longipennis* started from March following light rains. The beetle emergence increased gradually and attained its peak in the month of June. Beyond which again declining trend was observed. In the months of August and September beetle catch recorded was 8.77 and 1.85 percent respectively.

8.2) Light trap catches of white grub beetles at Srinagar Golf Course.

The data presented in Table 8.2 revealed that among the eleven species of identified white grub beetles collected from light traps, *Holotrichia longipennis* was predominant species, which recorded a beetle catch of 30.92%. *Brahmina coriacea, Adoretus* sp.1 and *Brahmina floavosericea* ranked respectively second, third and fourth by recording a catch of 15.83, 14.89 and 9.94 percent respectively. The beetle catch recorded from *Amomala dimidata, Brahmina poonensis, Anomala rufiventris, Adoretus* sp. 2, *Melolontha furcicauda* and *Maladera* sp. was 9.74, 7.15, 4.84, 4.35, 4.05 and 4.00 percent respectively.

The beetle emergence started from the month of March (0.38%) and reached its peak in the month of June with a highest catch of 30.47%. Thereafter a declining trend in beetle emergence was observed. In the months of July, August and September the trapped beetles recorded were 23.47, 13.17 and 4.89% respectively. On the basis of emergence pattern of beetles, it may be concluded that the peak emergence period was in the month of June.

8.3) Light trap catches of white grub beetles at High Altitude Maize Research Station Pahalgam.

The results presented in Table 8.3 revealed that *Maladera* sp. was the predominant species (26.02% of the total beetles trapped) followed by *Holotrichia longipennis* which recorded a beetle catch of 25.81% of the total catch *Brahmina flovosericea Adoretus* sp.2, *Anomala rufiventris* and *Brahmina coriacea* recorded a catch of (13.16, 10.25, 8.97 and 7.55 percent) of the total catch respectively. The lowest number of beetles

2.44% of the total catch were recorded from *Adoretus* sp.1 and *Melolontha furcicauda* respectively.

The data on beetle emergence revealed that no beetle emergence was reported in the months of March and April. The beetle emergence started from the month of May (3.11% of total catch followed by June 26.28% of the total catch) and attained its peak in the month of July (45.14% of total catch). Beetle catch started declining from July onwards. In the months of August and September, the beetle catch recorded was 21.79% and 3.66% respectively.

8.4) Light trap catches of white grub beetles at Wadura Sopore.

The data on species wise catch presented in Table 8.4 revealed that a highest catch (27.61% of the total catch) was recorded of *Brahmina flavosericea* followed by *Adoretus* sp. and *Brahmina coriacea*, which recorded a catch of (23.82 and 21.66% of the total catch) respectively.

The beetle catch recorded from *Melolontha furcicauda*, *Holotrichia longipennis*, *Bolbocerus* species and *Brahmina poonensis* was 18.80, 10.83, 7.32 and 6.22 percent respectively.

The beetle emergence started from the month of May. Where as in the months of March and April no beetle emergence was reported. In the month of May (11.37% of the total catch) was reported, which gradually enhanced to 27.29% in the month of June. In the month of July highest beetle catch of 36.82% was reported. From August onwards a decreasing trend was observed up to month of September and the least number of beetles (4.87% of total catch) were recorded in the month of September.

Table 8.1. Light trap catches of white grub beetles at Shalimar Srinagar during March to September 2004–2005.

Total no. of beetles trapped											
S. No	**Species**	**Sub family**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**Total**	**% of Total**
01.	*Holotrichia longipennis* Blanch	Melolonthinae	9.00	37.00	56.00	66.5	28.00	11.00	0.00	207.5	**29.60**
02.	*Anomala dimidiate* Hope	Rutelinae	4.00	8.00	14.00	10.00	4.00	2.00	0.00	42.00	**5.99**
03.	*Anomala rufiventris* Redt	Rutelinae	0.00	0.00	0.00	18.00	27.00	5.5	0.00	50.5	**7.20**
04.	*Brahmina flavosericea* Brenske	Melolonthinae	0.00	4.50	14.50	22.00	8.00	1.00	0.00	50.00	**7.13**
05.	*Brahmina coriacea* Hope	Melolonthinae	0.00	4.00	16.00	18.50	26.5	9.5	3.00	77.5	**11.05**
06.	*Adoretus* sp.1	Rutelinae	2.00	4.00	15.00	16.00	7.5	0.00	0.00	44.50	**6.34**
07.	*Melolontha furcicauda* Anst	Melolonthinae	0.00	1.00	1.50	5.00	8.00	1.00	0.5	17.00	**2.42**
08.	*Maladera* sp.	Melolonthinae	0.00	10.00	26.50	44.00	26.00	26.5	9.5	142.5	**20.32**
09.	*Adoretus* sp.2	Rutelinae	0.00	0.00	0.00	4.00	15.00	35.00	7.00	61.00	**8.00**
10.	Unidentified spp.	-----------	0.00	0.00	3.50	22.50	38.50	5.00	0.00	69.5	**9.91**
	Total	————	15.00	68.50	147.00	226.50	188.50	96.50	20.00	762.00	
	% of Total	————	**1.96**	**8.98**	**19.29**	**29.72**	**24.73**	**12.66**	**2.62**		

Graph-1: Showing light trap catches of white grub beetles at Shalimar Srinagar during March to September 2004-2005.

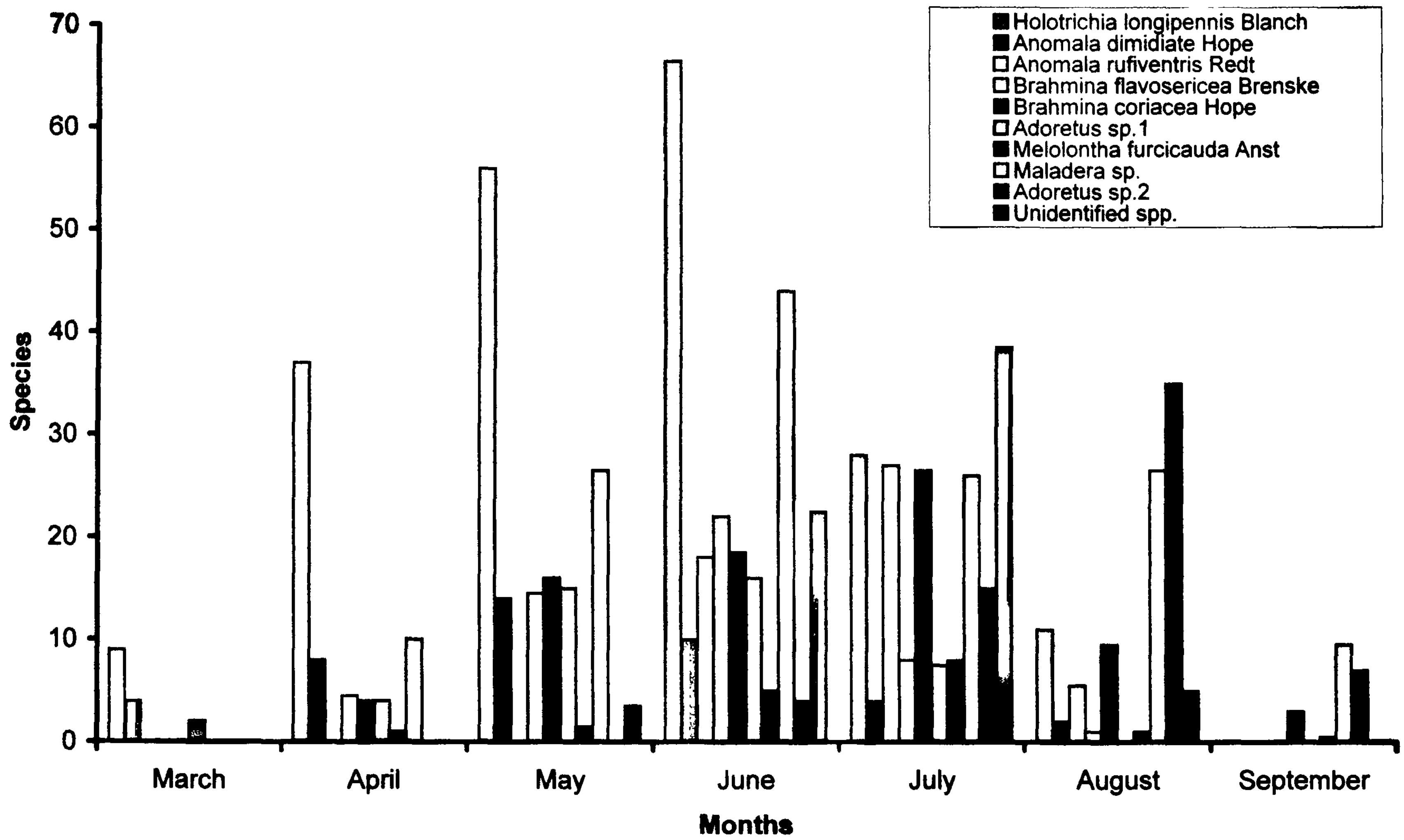

Table 8.2. Light trap catches of white grub beetles at Srinagar Golf course during March to September 2004-2005.

			Total no. of beetles trapped								
S.No	**Species**	**Sub family**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**Total**	**% of Total**
01.	*Holotrichia longipennis* Blanch	Melolonthinae	0.00	49.00	117.00	88.00	38.50	17.00	3.00	312.50	**30.92**
02.	*Anomala dimidiate* Hope	Rutelinae	0.00	3.50	16.50	27.50	36.00	13.50	1.50	98.50	**9.74**
03.	*Adoretus sp.*1	Rutelinae	0.00	2.50	36.50	17.00	28.00	31.00	35.50	150.50	**14.89**
04.	*Brahmina flavosericea* Brenske	Melolonthinae	0.00	0.00	3.50	37.50	50.50	9.00	0.00	100.50	**9.94**
05.	*Brahmina coriacea* Hope	Melolonthinae	0.00	2.50	33.00	72.50	30.50	20.50	1.00	160.00	**15.83**
06.	*Maladera sp.*	Melolonthinae	0.00	1.00	3.00	13.50	13.50	9.50	0.00	40.50	**4.00**
07.	*Melolontha furcicauda* Anst	Melolonthinae	0.00	0.00	3.00	17.50	15.00	4.00	1.50	41.00	**4.05**
08.	*Anomala rufiventris* Redt	Rutelinae	0.00	0.00	8.00	22.50	14.00	4.50	0.00	49.00	**4.84**
09	*Brahmina poonensis* Frey	Melolonthinae	5.00	15.00	18.00	25.00	17.00	9.00	3.00	92.00	**7.15**
10	*Allisonotum impressicole* Arrow	Dynastinae	0.00	10.00	30.00	45.00	21.00	15.00	7.00	128.00	**9.94**
11.	*Adoretus species* 2	Rutelinae	0.00	0.00	3.00	7.00	12.00	25.00	9.00	56.00	**4.35**
12.	Unidentified spp.	----------	0.00	0.00	0.00	19.00	26.00	11.50	1.50	58.00	**5.73**
	Total	----------	5.00	83.50	271.50	392.00	302.00	169.50	63.00	1286.50	
	% of Total	----------	**0.38**	**6.49**	**21.10**	**30.47**	**23.47**	**13.17**	**4.89**		

Graph-2: Showing light trap catches of white grub beetles at Srinagar Golf Course during March to September 2004-2005

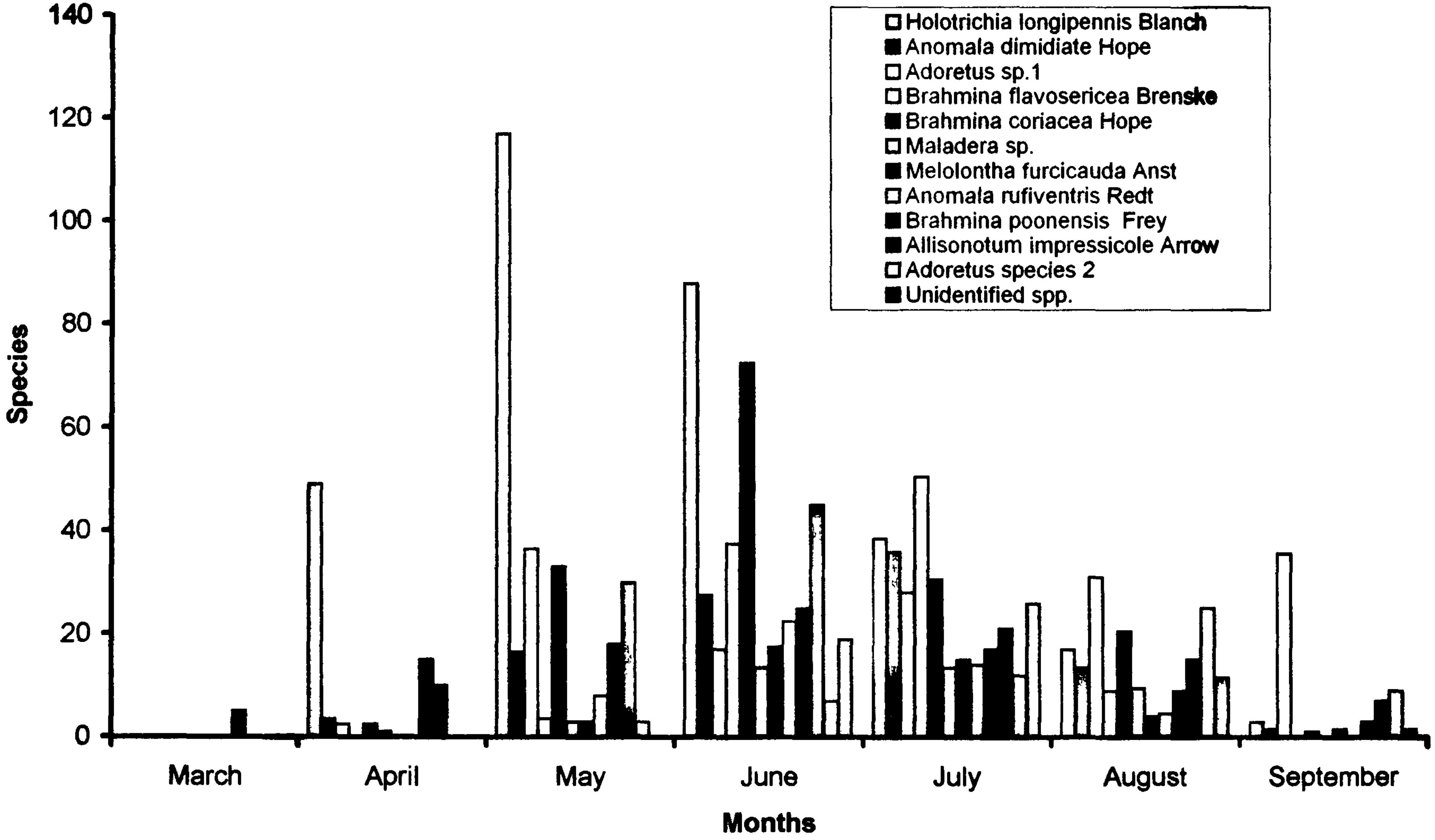

Table 8.3. Light trap catches of white grub beetles at High Altitude Maize Research Station Pahalgam during March to September 2004-2005.

Total no. of beetles trapped											
S. No	**Species**	**Sub family**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**Total**	**% of Total**
01.	*Holotrichia longipennis* Blanch	Melolonthinae	0.00	0.00	10.00	30.50	52.50	23.00	10.50	126.50	**25.81**
02.	*Anomala dimidata* Hope	Rutelinae	0.00	0.00	2.00	11.00	3.00	3.00	0.00	19.00	**3.87**
03.	*Anomala rufiventris* Redt	Rutelinae	0.00	0.00	0.00	9.50	23.00	11.50	0.00	44.00	**8.97**
04.	*Brahmina flavosericea* Brenske	Melolonthinae	0.00	0.00	1.00	16.50	30.50	15.00	1.50	64.50	**13.16**
05.	*Brahmina coriacea* Hope	Melolonthinae	0.00	0.00	0.00	10.00	22.00	5.00	0.00	37.00	**7.55**
06.	*Adoretus* sp.1	Rutelinae	0.00	0.00	0.00	6.00	4.00	2.00	0.00	12.00	**2.44**
07.	*Melolontha furcicauda* Anst	Melolonthinae	0.00	0.00	0.00	4.50	6.50	1.00	0.00	12.00	**2.44**
08.	*Maladera* sp.	Melolonthinae	0.00	0.00	0.00	34.00	66.00	27.50	0.00	127.50	**26.02**
09.	*Adoretus species 2*	Rutelinae	0.00	0.00	4.00	9.00	15.00	20.00	8.00	56.00	**10.25**
10.	Unidentified species	-----------	0.00	0.00	0.00	12.50	24.00	11.00	0.00	47.50	9.69
	Total	————	0.00	0.00	17.00	143.5 0	246.50	119.00	20.00	546.00	
	% of Total	————	**0.00**	**0.00**	**3.11**	**26.28**	**45.14**	**21.79**	**3.66**		

Graph-3: Showing light trap catches of white grub beetles at High Altitude Maize Research Station Pahalgam during March to September 2004-2005

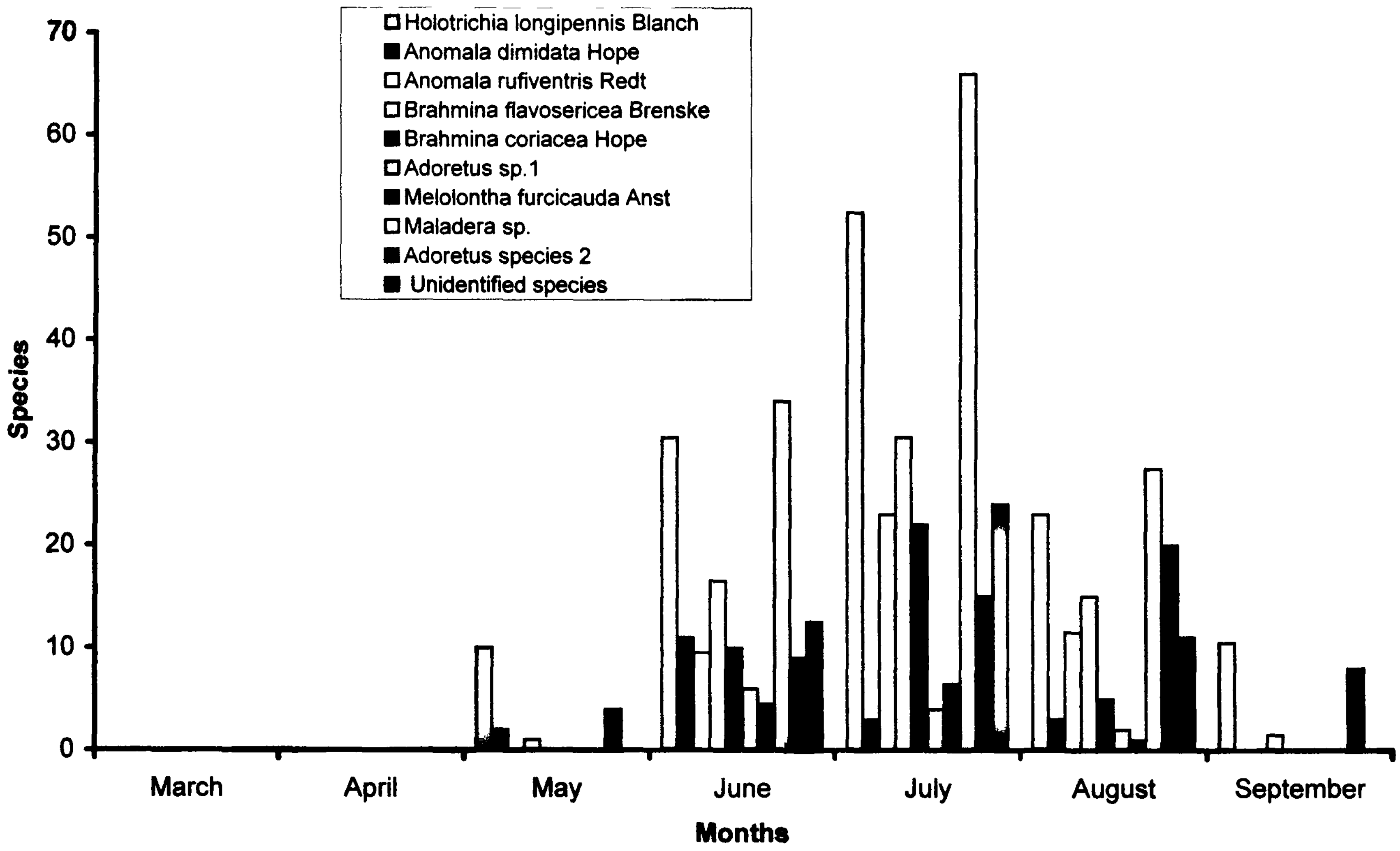

Table 8.4. Light Trap catches of white grub beetles at Wadoora (Sopore) during March to September 2004-2005.

Total no. of beetles trapped											
S.No	**Species**	**Sub family**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**Total**	**% of Total**
01.	*Holotrichia longipennis* Blanch	Melolonthinae	0.00	0.00	11.00	26.00	18.00	5.00	0.00	60.00	**10.83**
02.	*Brahmina flavosericea* Brenske	Melolonthinae	0.00	0.00	15.00	42.00	59.00	30.00	7.00	153.00	**27.61**
03.	*Melolontha furcicauda* Anst	Melolonthinae	0.00	7.00	19.00	35.00	55.00	30.00	8.00	154.00	**18.80**
04.	*Adoretus* sp.	Rutelinae	0.00	0.00	18.00	29.00	49.00	27.00	9.00	132.00	**23.82**
05.	*Brahmina coriacea Hope*	Melolonthinae	0.00	0.00	9.00	32.00	46.00	22.00	11.00	120.00	**21.66**
06.	*Brahmina poonensis* Frey	Melolonthinae	0.00	4.00	15.00	20.00	9.00	2.00	1.00	51.00	**6.22**
07.	*Bolbocerus* species	Geotrupidae	0.00	9.00	25.00	15.00	7.00	4.00	0.00	60.00	**7.32**
08.	Unidentified species	---------	0.00	0.00	10.00	25.00	32.00	22.00	0.00	89.00	**16.06**
	Total	---------	0.00	20.00	122.00	224.00	275.00	142.00	36.00	819.00	
	% of total	---------	**0.00**	**2.44**	**14.89**	**27.35**	**33.57**	**17.33**	**4.39**		

Graph-4: Showing light trap catches of white grub beetles at Wadoora (Sopore) during March to September 2004-2005.

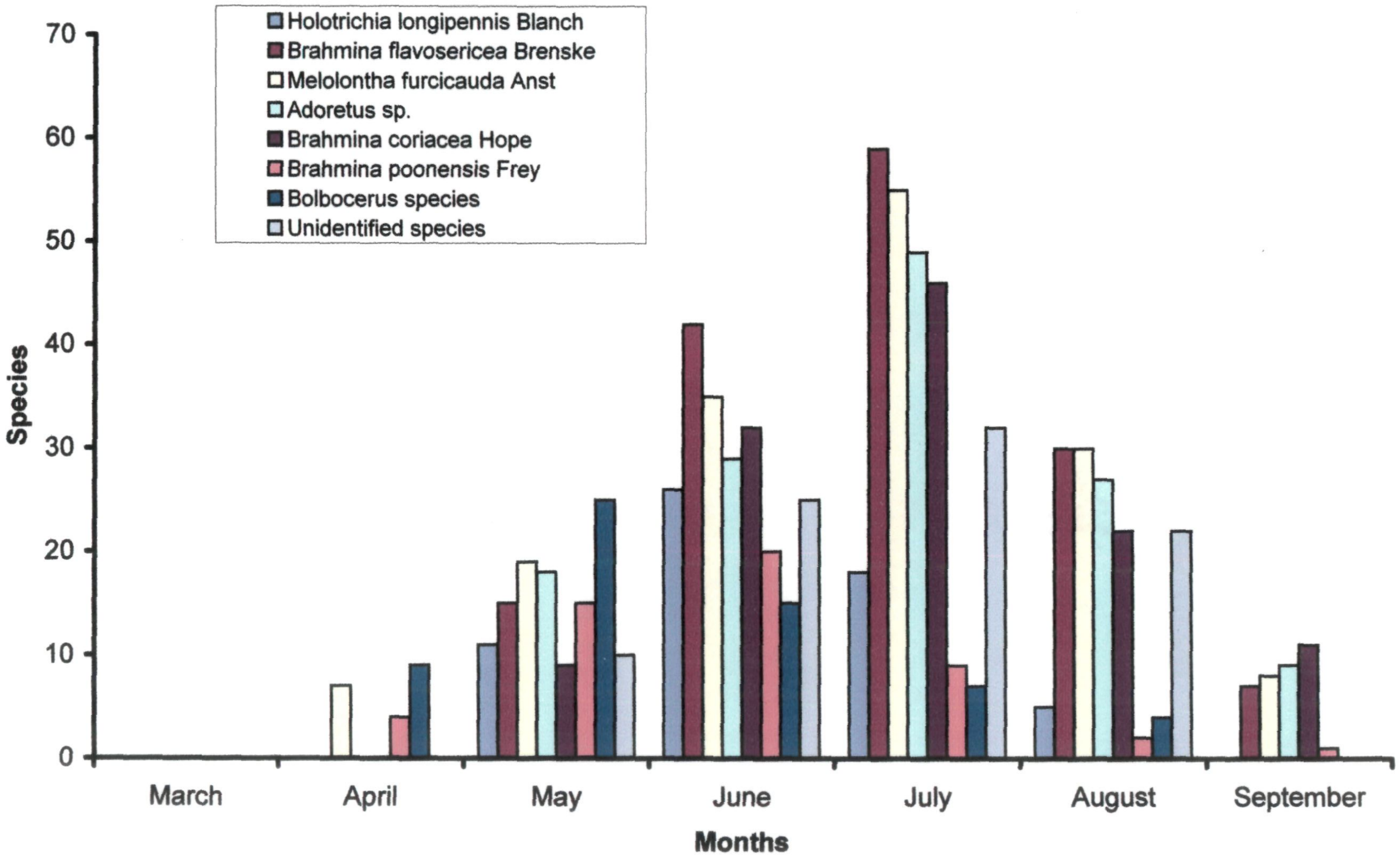

Table 8.5. Prevalence of different species of white grub beetles at four locations.

S.No.	Species	Shalimar	Sgr. Golf Course	Pahalgam	Wadura	Total	% of total
1.	*Holotrichia longipennis*	207.5	312.50	126.50	60.00	706.50	22.47
2.	*Anomala dimidata*	42.00	98.50	19.00	–	159.50	4.67
3.	*Anomala rufiventris*	50.50	49.00	44.00	–	143.50	4.20
4.	*Brahmina flovosericea*	50.00	100.50	64.50	153.00	368.00	10.78
5.	*Brahmina coriacea*	77.5	160.00	37.00	120.00	394.5	11.55
6.	*Maladera sp.*	142.5	40.50	127.50	–	310.50	9.09
7.	*Melolontha furcicauda*	17.00	41.00	12.00	154.00	224	6.56
8.	*Brahmina poonensis*	–	92.00	–	51.00	143.00	4.18
9.	*Allisonotum impressicole*	–	128.00	–	–	128.00	3.74
10.	*Adoretus* sp. 1	44.50	150.50	12.00	132.00	339.00	9.93
11.	*Adoretus* sp. 2	61.00	56.00	56.00	–	173.00	5.06
12.	*Bolbocerus* species	–	–	–	60.00	60.00	1.75
13.	Unidentified spp.	69.5	58.00	47.50	89.00	264.00	7.73
	Total	762.00	1286.50	546.00	819.00	3413.50	

Graph-5: Showing prevalence of different species of white grub beetles at four locations.

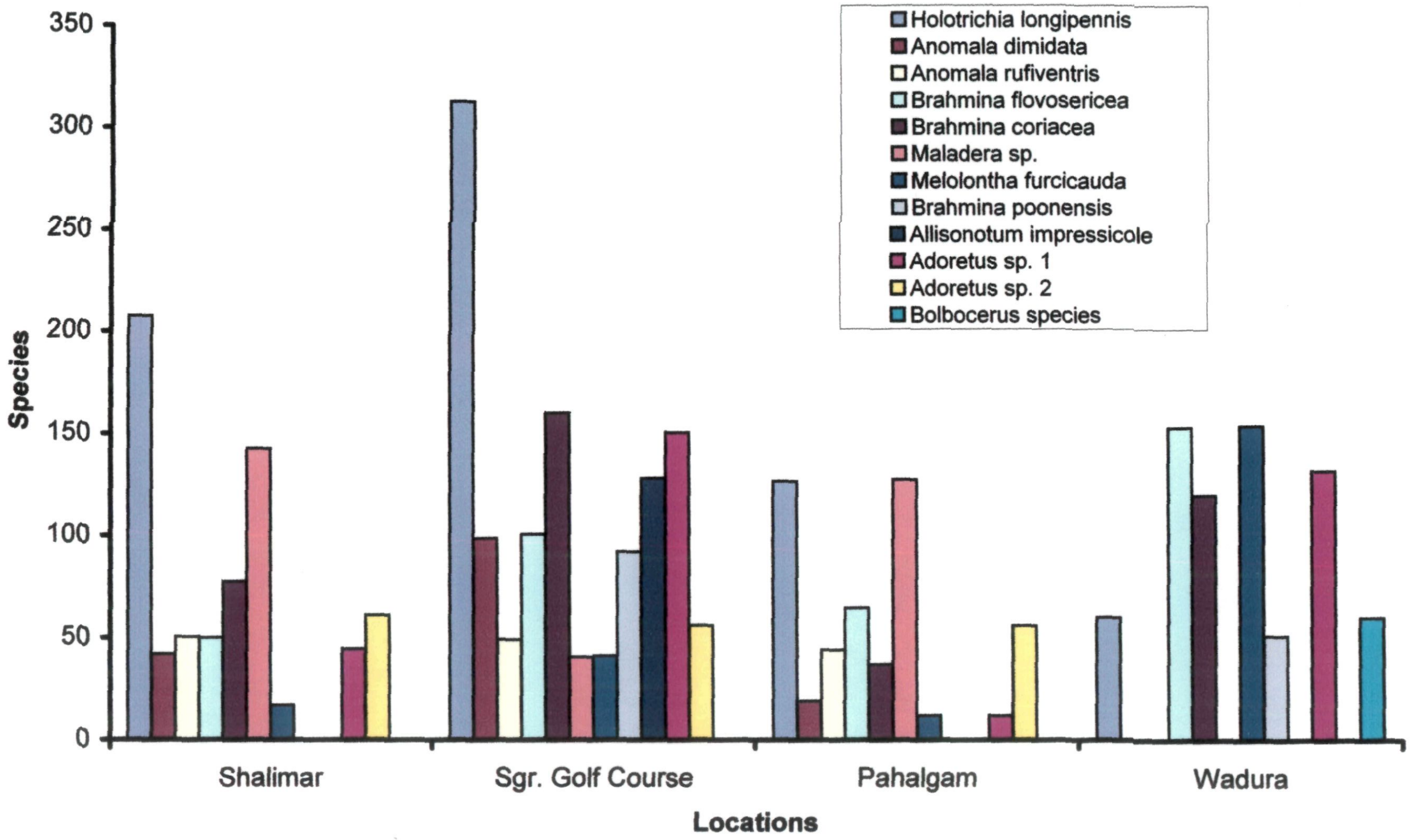

Table 8.6. Species of white grub beetles collected in light traps at four locations.

S.No	Species	Sub family	Prevalence at locations			
			Srinagar Golf course	Shalimar	Pahalgam	Wadura Sopore
01	*Holotrichia longipennis* Blanch	Melolonthinae	+	+	+	+
02	*Anomala dimidata* Hope	Rutelinae	+	+	+	-
03	*Anomala rufiventris* Redt	Rutelinae	+	+	+	-
04	*Brahmina flavosericea* Brenske	Melolonthinae	+	+	+	+
05	*Brahmina coriacea* Hope	Melolonthinae	+	+	+	-
06	*Maladera* sp	Melolonthinae	+	+	+	-
07	*Melolontha furcicauda*Anst	Melolonthinae	+	+	+	+
08	*Anomala rufiventris* Redt	Rutelinae	+	+	+	-
09	*Brahmina Poonensis* Frey	Melolonthinae	+	-	-	+
10	*Allisonotum impressicole* Arrow	Dynastinae	+	-	-	-
11	*Adoretus* sp 1	Rutelinae	+	+	+	+
12	*Adoretus* sp 2	Rutelinae	+	+	+	-
13	*Bolbocerus* spp.	Geotrupidae	-	-	-	+
14	Unidentified species	---------	+	+	+	+

\+ present
\- Absent

ON FARM DEMONSTRATION AND VALIDATION OF PROMISING, IPM COMPONENTS AGAINST CUTWORM/ WHITE GRUB INFESTATION IN MAIZE AT KULLER PAHALGAM.

The results presented in Table 9 revealed no significant impact on germination of grains. Thus, the germination percentage was observed statistically at par in all the treatments.

As there was no significant impact on germination. The initial plant stand was also observed to be statistically at par in all the treatments.

The data depicted in Table 9 revealed that both the insecticidal treatments proved significantly superior over untreated control where damage percentage recorded was 28.44. The treatment of imidacloprid 200 SL seed treatment and fenvalerate 0.4 per cent dust recorded a lowest damage of 7.55 and 8.19 respectively.

The cutworm infestation had a significant impact on final plant stand. The perusal of data revealed that a highest plant stand of 65.00 and 66.00 plants per plot was recorded in both the treatment applications which varied significantly from a plant stand of 51.00 plants per plot recorded in control.

Perusal of data revealed that a highest grain yield of 10.00 kg/plot was recorded in imidacloprid seed treatment followed by a grain yield of 9.66 kg/plot recorded in fenvalerate 0.4 per cent dust. These two were however, observed statistically at par with one another. The lowest grain yield of 7.66 kg/plot was recorded in control which varied significantly from the other two treatment applications.

The comparative economics of evaluated treatments showed that seed treatment of imidacloprid 200 SL and fenvalerate were economically reliable treatments for recording maximum net returns.

Table 9. On farm demonstration and validation of promising IPM components against cutworm/ white grub infestation in maize at Kuller, Pahalgam,

Treatment	Dose ha^{-1}	Germination (%)*	Initial plant stand	Damage (%)*	Final plant stand ($3x4\ m^{-2}$)	Grain yield Kg's / Plot	B/C Ratio
Imidacloprid 200 SL seed treatment	0.8 a.i./kg seed (4.0ml/Kg)	70.33 (56.99)	70.33	7.55 $(15.85)^a$	65.00^b	10.00^b	30.59:1
Fenvalerate 0.4% dust	25 kg ha^{-1} at sowing in furrow	73.00 (58.70)	73.00	8.19 $(16.6)^a$	66.00^b	9.66^b	10.85:1
CONTROL	-	71.33 (57.64)	71.33	28.44 $(32.21)^b$	51.00^a	7.66^a	--
C.D(P=0.05)		**N.S**	N.S	**4.46**	3.06	**1.51**	--

*Figures in parentheses are Arc sine transformed values
Figures superscripted by same letter do not differ significantly at (P=0.05)

ON FARM DEMONSTRATION AND VALIDATION OF PROMISING IPM COMPONENTS AGAINST CUTWORM/ WHITE GRUB INFESTATION IN POTATO AT YARIKAH GULMARG.

The results presented in Table 10 revealed that germination percentage did not differ significantly among various treatments.

Initial plant stand was also recorded to be at par in the various treatment applications.

The data depicted in Table 10 revealed that a highest damage percentage of 22.84 percent was recorded in control which differed significantly from all other treatments. The damage percentage in all other treatment applications was observed to be at par with one another.

The data depicted in Table 10 revealed that a lowest plant stand of 58.33 was recorded in control which differed significantly from all other treatments. The final plant stand in all other treatment applications was also observed to be at par with one another.

The data displayed in Table 10 revealed that all of the insecticidal treatments proved production-wise superior over untreated control in which a lowest tuber yield of 26.65 kg/plot was recorded which varied significantly from all other treatments. The tuber yield in all other treatment applications did not differ significantly among one another.

The comparative economics of the evaluated treatments revealed that highest B/C ratio of 14.80:1 was recorded in *Beauveria bassiana* followed by fenvalerate 0.4 per cent dust and carbofuran 3G with a B/C ratio of 12.53:1 and 6.16:1 respectively.

Table 10. On farm demonstration and validation of promising IPM components against cutworm/white grub infestation in potato at Yarikah, Gulmarg.

Treatment	Dose ha^{-1}	Damage (%) *	Final Plant *stand* (No /3x4 m^2)	Tuber yield kg/plot (3x4 m^{-2})	*Tuber yield* quintals/ha	B/C Ratio
Carbofuran 3G granules	30 Kg ha^{-1}	5.34 $(13.30)^a$	70.66^b	32.29^b	269.08	6.16:1
Fenvalerate 0.4% dust	25 Kg ha^{-1}	6.40 $(14.52)^a$	71.66^b	32.74^b	272.83	12.53:1
Beauveria bassiana with pulverized soil	1.5 Kg ha^{-1} at sowing in furrows	7.15 $(15.41)^a$	72.33^b	33.05^b	275.41	14.80:1
CONTROL	-	22.84 $(28.53)^b$	58.33^a	26.65^a	222.08	--
C.D (P=0.05)		**4.27**	**8.15**	**3.72**	--	--

*Figures in parenthesis are the Arcsine transformed values.
Figures superscripted by same letter do not differ significantly at (P=0.05)

Fig. 1: Depicting maize seedling infested with cutworm (*Agrotis ipsilon* Hüfnagel).

Fig. 2: Depicting cutworm damage on Coleoptile stage of maize.

Fig. 3: Depicting patches of cutworm infestation in maize.

Fig.4: Depicting cutworm damage on emerging seedlings of potato.

Fig. 5: Depicting cutworm damage at Coleoptile stage of maize.

Fig. 6: Depicting infested maize seedlings in untreated control.

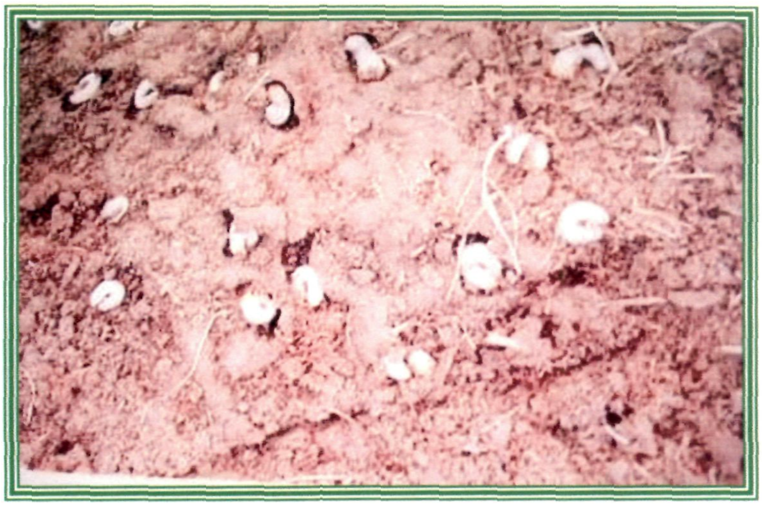

Fig. 7: Depicting heavy white grub infestation at Royal Springs Golf Course, Srinagar.

Fig. 8: Depicting wall nut as preferred host of chafer beetles.

Fig. 9: Depicting potato tubers infested with white grub in untreated control.

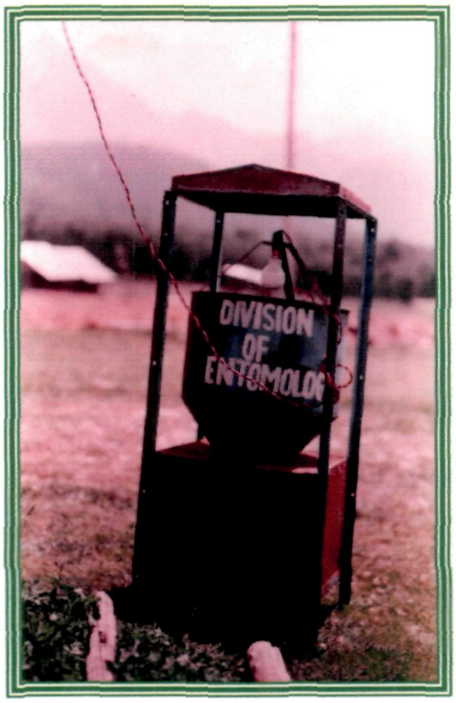

Fig. 10: Depicting installation of light traps to record the species of white grub complex.

Fig. 11: Depicting adult chafer beetles burrowing in soil.

Fig. 12: Depicting experiment on management of cutworm/white grub infesting potato at Gulmarg.

Fig. 13

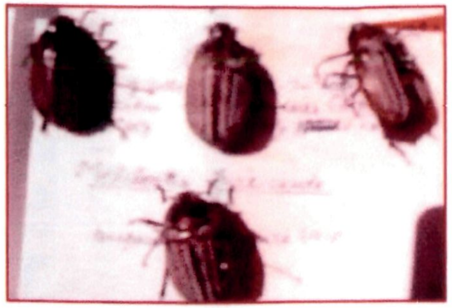

Fig. 14

Fig. 15

Fig. 16

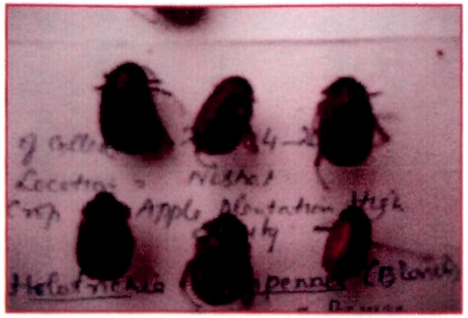

Fig. 17

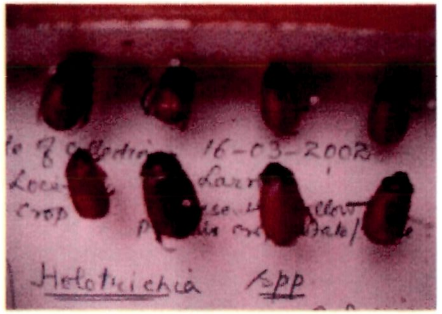

Fig. 18

Fig. 19

Fig. 20

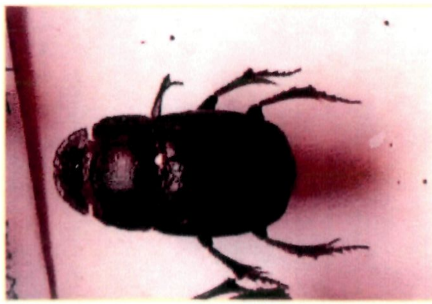

Fig. 21

Figs. 13-21: Depicting species of white grub complex in hill and mountain agro-ecosystem of Kashmir.

Fig. 22: Depicting protected maize seedlings with seed treatment of imidacloprid.

Fig. 23: Depicting on farm demonstration trial on management of cutworm/white grub infesting potato.

Fig. 24: Depicting on farm demonstration trial on management of cutworm/white grub infesting maize.

CHAPTER-5

DISCUSSION

DISCUSSION

Integrated pest management (IPM) is defined as a system approach of pest management that utilizes all pest control tactics in a compatible manner in order to reduce the pest population and maintain them below levels that cause economic or unacceptable aesthetic injury without posing a hazard to humans, domestic animals and other non target life forms. It does not aim to totally eliminate the pests, but to maintain pest populations at tolerable levels. Pesticides are often part of an IPM program, but are selected and applied responsibly to avoid health risks to other living organisms than those targeted.

Thus the judicious pesticide use by timely application, viz., seed treatment and spot/strip application seems to be sound and rational in alleviating the cutworm/white grub damage in both crops of maize and potato. The seed treatment minimizes the amount and cost of pesticide used and offers relative safety to natural enemies due to localization. Besides it provides a protection zone around germinating seedlings, which keeps most of the soil dwelling pests at bay. Thus it can be adopted as an economical and eco-friendly component of IPM program

By and large, all the tactics employed for control of cutworms/ white grubs are sole methods tested under different agro-ecosystems. The control recommendations against these pests are mainly soil application of granular/dust formulations of the insecticides. However, exorbitant costs of pesticides, persistence, drift and adverse effects on useful soil predators and parasitoids have rendered them redundant in hill and mountain farming ecosystem. Low temperature throughout the year reduces the rate of thermal and biodegradation of these soil pesticides and poison the beneficial and non target organisms.

Considering the status of these pests and their economic importance in hill and mountain agro-ecosystem of Kashmir. The studies undertaken would be of great value in developing an economically viable pest management program for white grub and cutworm in maize and potato. It would provide a long term complete management approach for white grub and cutworm in two major kharief crops of hill zone rather than short term approach to an individual pest problem. Hence the IPM capsule developed for the management of these pests will help to increase the production of these crops in hill and mountain agro-ecosystem of valley by reducing the losses and would considerably reduce the reliance on chemical control.

EXPERIMENT NO.1

The experiment on assessment of avoidable loss in maize to cutworm revealed that per cent cutworm damage was significantly higher in control (54.63%). Seed treatment of imidacloprid 200SL was significantly superior in prevention of cutworm damage by recording a percent damage of 11.71%. The percent cutworm damage in chlorpyriphos 20EC was, however, at par with seed treatment of imidacloprid.

The data on final plant stand (No/plot) indicated that the lowest plant stand was recorded in control, which differed significantly from the other two treatments. The plant stand in imidacloprid 200SL seed treatment and chlorpyriphos 20EC foliar spray did not differ significantly from each other.

The data on grain yield revealed that a highest yield of 54.83 quintals ha^{-1} was recorded in seed treatment of imidacloprid, which however was at par with grain yield of 45.66 quintals per hectare recorded in chlorpyriphos 20EC foliar spray. The lowest grain yield of

30.33 q ha^{-1} was recorded in untreated control, which varied significantly from the other two treatment applications.

The results pertaining to superior bioefficacy of imidacloprid seed treatment are comparable with the findings of Drink water (1994), who reported effective management of maize pests with seed treatment of imidacloprid. Viji and Bhagat (2001) also reported superior efficacy of imidacloprid against black cutworm *Agrotis ipsilon* infesting maize. Sharma and Bhagat (2000) reported that seed treatment of imidacloprid 70 WS @ 224g.a.i. ha^{-1} proved effective. Islam *et al.* (1991) reported that pyrethroid insecticides and chlorpyriphos gave > 80% reduction in cutworm (*Agrotis ipsilon*) infesting potatoes in Bangladesh. Superrior bioefficacy of chlorpyriphos has previously been reported by Gupta and Yadava (1987) against white grub infesting ground nut, Kushawa *et al.* (1972) against cutworm in gram crop and Mishra and Singh (1994) against white grub infesting soybeans.

Thus it is concluded that a maximum damage of 54.63% and a retrievable loss of 80.18% is caused due to cutworm in maize under an infestation level of 6.05 larvae /m^2.

EXPERIMENT NO.2

The experiment on efficacy of different insecticides and biopesticides as seed treatment, soil treatment and as post sown foliar spray against cutworm damaging maize revealed that all the insecticidal treatments proved significantly superior over untreated control that recorded a highest cutworm damage differing significantly from all other treatments followed by the damage in *Beauveria bassiana* foliar spray and chlorpyriphos 20EC foliar spray.

The highest plant stand in imidacloprid seed treatment and carbofuran 3G soil treatment is attributed to sound germination and maximum cutworm protection in these treatments. The lowest plant stand was recorded in seed treatments of lambdacyhalothrin 5EC, chlorpyriphos 20EC and deltamethrin 2.8 EC, which was attributed to impaired germination in these treatments due to phytotoxic effects on seedling emergence. The phytotoxicity by systemic insecticidal seed treatments has previously been reported by various workers such as Lindquist *et al.* (1961) in cotton, Reyonlds *et al.* (1957) in alfalfa, Hanna (1958) in cotton and Choudhary and Dashad (2002) in pearl millet.

The data on grain yield indicated that highest grain was recorded in seed treatment of imidacloprid, which however did not differ from grain yield recorded in carbofuran 3G. This is due to the reason that coating of insecticide provides a protection zone around the germinating seed by killing or keeping the pest off during the initial stage of crop growth at which the crop is more vulnerable to attack by wire worms and cutworms (Showers *et al.*, 1982). The present findings pertaining to effectiveness of imidacloprid are comparable to the results of Sharma and Bhagat (2000), who reported that seed treatment of imidacloprid 70 WS @ 224 g.a.i ha^{-1} proved effective in protection against cutworm infestation in maize and resulted in higher yields (Viji and Bhagat., 2001). Similar results @ 700 g.a.i/kg maize seed were reported by Drinkwater (1994). Pons and Albajes (2002) demonstrated that seed treatment of maize with imidacloprid was effective in reducing incidence of cutworms (*Agrotis segetum*) and other maize pests. Albajes *et al.* (2003) reported no adverse effect on predatory fauna in corn fields in response to imidacloprid seed treatment.

The results pertaining to effectiveness of chlorpyriphos are consistent with the findings of Gupta and Yadava (1987), who reported that spraying the foliage and drenching the ridges with chlorpyriphos 20EC was effective against white grub infesting groundnut in Rajasthan. Mishra and Singh (1994) reported superior bio efficacy of chlorpyriphos 20EC as seed treatment in soybean against white grub in Uttaranachal hills @ 25.0ml/kg seed. Pareek and Noor (1982) concluded that spray of chlorpyriphos 0.1% and quinalphos 0.5% can effectively control cutworm *Agrotis spinifera* (Hubner) on cucurbits. Thimmiah *et al.* (1972) have reported effective control of *Agrotis ipsilon* on tobacco crop by using non persistent insecticides chlorpyriphos and endosulfan. Kushawa *et al.*(1972) recommended 0.1% spray of chlorpyriphos and quinalphos for effective control of cutworm *Agrotis ipsilon* in gram crop. Elham and El-sayed (1991) also reported highest toxicity of chlorpyriphos against cutworm followed by triazophos and monocrotophos. Dress *et al.* (1992) reported that seed treatment with chlorpyriphos provided better protection than T-band application of chlorpyriphos against red fire ants (*Solenopsis incicta*) in corn.

The comparative economics of the evaluated treatments revealed that seed treatments of imidacloprid 200SL and chlorpyriphos 20EC resulted in maximum B/C ratio and highest net returns. The lowest larval population/m^2 was recorded in seed treatments of imidacloprid and chlorpyriphos 20EC. Therefore these two treatments can be suggested best for the management of cutworm infestation in maize.

EXPERIMENT NO.3

The experiment on integration of seed rate and seed treatment of imidacloprid revealed that a lowest percent cutworm damage of 5.00 was recorded in highest seed rate S_3C (40 kg ha^{-1}) treated with imidacloprid seed treatment. This is attributed to the reason that coating of insecticide provides a protection zone around the germinating seed, which keeps the pest inhabiting root zone away by killing younger larvae (Showers *et al.* 1982). The highest number of plants were cut in higher seed rate S_2 (30 kg ha^{-1}) without any treatment, which was at par with S_3 (40 kg ha^{-1}) without any treatment. This is attributed to either stronger attraction of moths for oviposition in dense vegetation and higher damage in higher plant stand as compared to lower plant density. The percent damage was lowest in normal seed rate S_1 (20 kg ha^{-1}). Though the number of plants cut in higher seed rate also increased gradually, but in spite of higher damage the net survival of seedlings was still better in higher seed rates. Which could maintain a better final plant stand and resulted in highest yield. Thus offering a higher seed rate is an important perspective of IPM, in which the pesticide can be replaced. This could be both ecologically as well as economically sound.

Final plant stand increased with the increase in seed rate and highest plant stand was recorded in highest rate S_3C (40 kg ha^{-1}) treated with imidacloprid seed treatment, which was attributed to maximum protection from cutworm infestation in this treatment. Next to it highest plant stand was recorded in seed rate S_3 (40 kg ha^{-1}) without seed treatment. The lowest plant stand was found in normal seed rate S_1 (20 kg ha^{-1}). The reduction in plant stand was due to least initial population of plants and the subsequent damage inflicted by cutworm.

The data on grain yield indicated that there was a significant increase in yield in all the seed rates over the normal seed rate S_1 (20 kg ha^{-1}) without any treatment. This increase in yield was due to better plant stand in higher seed rates even after allowing the damage by cutworm larvae. The maximum yield was recorded in highest seed rate S_3C (40 kg ha^{-1}) treated with chemical pesticide of imidacloprid. Which was due to maximum protection against cutworm damage and consequently a good plant stand. The grain yield in S_3(40kg ha^{-1}) was at par with S_2C (30 kg ha^{-1}) treated with imidacloprid seed treatment. The lowest yield of (41.33 q ha^{-1}) was recorded in seed rate S_1 (20 kg ha^{-1}) without any treatment.

Conclusively, higher seed rate of S_3C (40 kg ha^{-1}) treated with imidacloprid @ 0.8 g.a.i/kg seed was found to be good in protecting as well as compensating the plant damage caused by cutworm in maize, which resulted in lowest cutworm damage, highest plant stand and maximum grain yield. Since the experiment was carried under heavy cutworm population, plant thinning after the cutworm damage is ceased may be required during low cutworm infestation years.

EXPERIMENT NO.4

The experiment on loss assessment studies in potato due to cutworm showed no effect of different insecticidal treatments on sprouting percentage of tubers. Thus, the sprouting percentage did not differ significantly amongst various treatments.

The data on percent cutworm damage revealed that protection wise all the insecticidal treatments were significantly superior over untreated control, where the cutworm damage was considerably very high (17.39%). The application of carbofuran 3G, fenvalerate 0.4% dust and imidacloprid 200SL seed treatment proved equally effective by recording a lowest percent damage. These all did not differ significantly from one another. The treatment of chlorpyriphos 20 EC recorded a percent damage of 6.74% which also varied significantly from all other treatments.

The data on final plant stand (no/plant) indicated that the lowest plant stand was recorded in control, which differed significantly from all other treatments. The plant stand recorded in all other treatment applications did not differ significantly from one another. The data on tuber yield revealed that highest tuber yield was recorded in imidacloprid 200SL seed treatment, which differed significantly from all other treatments. The tuber yield recorded in other treatment applications, viz., carbofuran 3G, fenvalerate 0.4% dust and chlorpyriphos did not differ significantly from one another.

The comparative economics of the evaluated treatments revealed that chlorpyriphos 20 EC foliar spray and fenvalerate 0.4% dust resulted in maximum net returns and recorded a highest (Benefit: cost) B/C ratio of 37.88:1 and 11.5:1 respectivelly.

The lowest larval population i.e., 0.50 ($1\times1\times0.20m^3$) was recorded in the treatment of imidacloprid 200 SL where as it was highest $6.05/m^2$ in untreated control plots. Spraying the foliage and drenching the ridges with chlorpyriphos 20 EC was effective against white grubs infesting groundnut in Rajasthan (Gupta and Yadava, 1987). Rajendra and Verma (1989) reported that emulsion of chlorpyriphos, quinalphos, phoxin and endosulfan proved effective in reducing pest damage in potato in Nilgiris.

Hence it is concluded that a maximum damage of 17.39% and retrievable yield loss of 26.29% is recorded in potato due to cutworm under an infestation level of 6.05 larvae $/m^2$.

EXPERIMENT NO.5

The experiment on evaluation of insecticides and biopesticides in three different patterns, viz., seed tuber treatment, soil treatment and as post sown foliar sprays revealed that sprouting of tubers was significantly impaired in seed treatments with deltamethrin 2.8EC, chlorpyriphos 20 EC and lambdacyhalothrin 5 EC. There are numerous reports that systemic insecticidal seed treatments cause phytotoxicity. The phytotoxic effect by systemic insecticidal seed treatments has previously been reported by Lindquist *et al.* (1961) in cotton, in alfalfa (Reynolds *et al.*, 1957). Choudhary and Dashad (2002) also reported that higher levels of organophosphates, chlorpyriphos and quinalphos hampered germination. The phytotoxicity might have been due to rapid absorption of systemic insecticides, which damaged the germinating embryo's (Linquist *et al.*, 1961). Highest sprouting percentage of 97.78% was recorded in control, which varied significantly from all other treatments. The treatment of quinalphos 25 EC foliar spray ranked second and recorded a sprouting percentage of 92.23%. The percent sprouting in *Beauveria bassiana* and carbofuran 3G was at par with each other.

All the insecticidal treatments proved significantly superior over untreated control in protection against cutworm infestation. The maximum protection from cutworm damage was recorded in seed treatment with imidacloprid, fenvalerate 0.4% dust and carbofuran 3G soil treatments. The percent cutworm damage recorded in control was, however, at par with percent damage recorded in quinalphos 25EC foliar spray.

Hanna (1958) reported that seed treatment with systemic insecticides adequately protected young cotton plants for a period of 4.6 weeks after planting date. Berry and Knake (1988) found that acephate seed treatments effectively controlled black cutworm larvae in maize. Kumawat and Yadava (1990) found that seed coating with isofenphos, phorate and seed dressing with isofenphos EC were effective and economical than soil application of some promising insecticides against white grub infesting groundnut. Islam *et al.* (1991) reported that pyrethroids and chlorpyriphos gave >80% reduction in infestation level by *Agrotis ipsilon* in potato.

Plant stand is an important parameter, which in turn determines the yield. The perusal of data indicated that highest plant stand was recorded in chlorpyriphos 1.5% dust, Fenvalerate 0.4% dust, *Beauveria bassiana* and carbofuran 3G. These all, however did not differ significantly from one another. The plant stand recorded in control however did not differ significantly from quinalphos 25 EC foliar spray and imidacloprid seed treatment.

During tuberization stage grubs of several species of family Scarabaeidae including *Holotrichia*, *Brahmina*, *Adoretus* and *Anomala* spp. damage the tubers by tunneling through them, thus render the tubers unfit for human consumption. The percent tuber damage by white grubs revealed that all of the insecticidal treatments proved significantly superior over untreated control, in which maximum tuber damage was recorded. Next to control the maximum tuber damage was recorded in foliar sprays of multineem, chlorpyriphos 20 EC and quinalphos 25 EC but some workers have reported better efficacy of quinalphos (Tripathi *et al.*, 2003). Soil treatments of chlorpyriphos, fenvalerate and carbofuran also gave a better protection from white grub damage. These findings are in agreement with Gupta *et al.* (1981), who reported superior efficacy of granular treatment of Aldicarb, carbofuran, carbaryl, disulfoton and phorate at 1 kg.a.i ha^{-1} against *Agrotis ipsilon* infesting cauliflower.

The data on marketable tuber yield revealed significantly higher yields in all the insecticidal treatments over control and the treatments in which phytotoxicity was reported. The highest marketable yield was recorded in imidacloprid tuber treatment, which differed significantly from yield recorded in chlorpyriphos 1.5% dust. Next to these two treatments better yield was recorded in treatments of carbofuran 3G and fenvalerate 0.4% dust. These two also differed significantly from each other. The foliar sprays of chlorpyriphos 20 EC, *Beauveria bassiana* and quinalphos 25 EC recorded lowest marketable yield. These all differed significantly from one another.

The results obtained on superior efficacy of dust and granular formulations subscribe to the findings of Bhardwaj *et al.* (1976), who reported best efficacy of phorate (2.0 kg a.i) per hectare followed by ethyl parathion (2.0 kg a.i) and BHC (3.0 kg a.i) per hectare against white grub *Holotrichia consanguinea.* Lentz (1985) reported that Terbufos 15 G gave significant mortality of white grub *Phyllophaga congrua* and *Phyllophaga implicata* infesting soybeans. Singh and Dayal (1986) reported that application of 2.5 kg a.i per hectare of gamma BHC and fensulfothion 1.5 kg a.i per hectare gave 97.90 and 95.45 percent control of white grub in sugarcane Biase *et al.* (1988) concluded that dust formulation of chlorpyriphos @ 64g ha^{-1} was effective. Sharma and Bhagat (2000) reported that chlorpyriphos 1.5% dust was effective than chlorpyriphos 20 EC @ 400 g a.i ha^{-1}.

The comparative economics of the evaluated treatments revealed that chlorpyriphos 20EC foliar spray and quiualphos 25EC foliar spray resulted in maximum (Benefit: Cost) ratio followed by dust applications of chlorpyriphos 1.5%, fenvalerate 0.4% and carbofuran 3G. Rajendra and Verma (1989) reported that emulsion of chlorpyriphos, quinalphos, phoxin and endosulfan proved effective in reducing pest damage in potato in Nilgiris. Therefore, on economic front foliar sprays of chlorpyriphos 20 EC and quinalphos 25 EC can be suggested best resulting in maximum net returns. Although seed treatment of imidacloprid 200 SL proved significantly superior both protection as well as production wise, but was found uneconomical in potato due to high cost of pesticide.

EXPERIMENT NO.6

In the experiment conducted on manipulation of sowing dates and seed rates against cutworm infestation in potato at High altitude location of Gulmarg, the results of the experiment indicated that the percent tubers sprouted were maximum in D_1 sowing (20th May), which remained at par with sprouting percentage recorded in D_2 sowing (27th May). The maximum percent sprouting was recorded in last week of May probably due to conducive soil moisture and temperature. In D_3 sowing (3rd June), lowest per cent sprouting was recorded. The sprouting percentage among different seed rates did not differ significantly.

The data on per cent cutworm infestation calculated on the basis of total plants sprouted indicated that the highest infestation was recorded in seed rate S_1 (20 q ha^{-1}) which however, remained at par with per cent damage recorded in seed rate S_3 (28 q ha^{-1}) and S_2 (24 q ha^{-1}). The minimum damage was recorded in late sowing, which may be attributed to infestation evasion at that time. This subscribes to the findings of Whiteford *et al.* (1989) and Bangood *et al.* (2000). Thus, the late sowing was the best option to evade the aggressive stage of pest attack as the cutworm activity is low by that time. These findings are also in agreement with Showers *et al.* (1983), Story *et al.* (1983) in corn and Malgwi and Ajayi (2000) in sorghum.

Despite cutworm damage in higher seed rates, the net surviving plants were more in higher seed rates, which could sustain a better plant stand resulting in maximum net returns. Thus offering higher seed rate is an important perspective of IPM, in which pesticides could be replaced. This could be economically and ecologically sound in a crop like potato.

The plant stand increased significantly over normal seed rate S_1 (20 q ha^{-1}) with increasing seed rates. Highest plant stand was recorded in seed rate S_3 (28 q ha^{-1}), which however, did not differ significantly from S_2 (24 q ha^{-1}). Among sowing dates plant stand was maximum in D_3 (3rd June), which differed significantly from D_1 (20th May), the normal date of sowing and D_2 (27th May). The tuber yield increased in D_3 and D_2 over the normal date of sowing D_1. However, maximum tuber yield was recorded in D_3 sowing, which varied significantly from other treatments. Among seed rates the tuber yield was maximum in S_2 (24 q ha^{-1}) and lowest in S_1 (20 q ha^{-1}). Thus the reduction in tuber yield in normal seed rate and normal sowing date was due to maximum cutworm infestation resulting in poor plant stand despite sound germination. These findings subscribe to the results of Mannan (2004) against cutworm infesting potato. Levine *et al.* (1983) also found that corn grain yield reduction results from large number of young plants being cut than older plants.

Hence considering the economical and ecological perspective of IPM system, higher seed rate of 24 q ha^{-1} was found to be good in compensating the plant damage caused by cutworm. Likewise late sowing (1st week of June) resulted in substantial plant stand with best tuber yield. Thus, D_3S_2 yielding a benefit: cost ratio of 54:1 was considered as best interaction to protect cutworm damage in potato at Gulmarg and other high altitudes of Kashmir valley.

EXPERIMENT NO.7

The experiment on evaluation of insecticides as post sown soil application revealed that cutworm damage and tuber damage varied significantly in different treatments. Protection wise all the insecticidal treatments were found significantly superior over untreated control in which a cutworm damage of 20.02% was recorded. The rest of the all insecticidal treatments were found at par among one another. Similarly, all the insecticidal treatments gave superior protection to tubers against white grub damage in comparison to untreated control in which a tuber damage of 13.34% was recorded, which differed significantly from all other treatments. All of the insecticidal treatments were at par with one another in respect of tuber damage by white grubs. The maximum marketable tuber yield of 133.83 q.ha^{-1} was recorded in imidacloprid 200 SL @ 80 g.a.i ha^{-1}. This, however remained at par with marketable yield recorded in lambdacyhalothrin 5 EC. The marketable yield recorded in chlorpyriphos 20 EC, quinalphos 25 EC, lindane 20 EC and lambdacyhalothrin 5 EC was found at par with one another. The comparative economics of the different evaluated treatments revealed that a highest Benefit: Cost (B/C) ratio of 29.95:1 was recorded in imidacloprid 200SL foliar spray followed by chlorpyriphos in which B/C ratio of 15.54:1 was recorded. The treatments of quinalphos 25 EC, lindane 20 EC and lambdacyhalothrin 5 EC recorded a Benefit: Cost ratio of 9.8:1; 2.97:1 and 1.22:1 respectively.

The present findings pertaining to effectiveness of imidacloprid 200 SL (foliar spray) are comparable with the results of Viji and Bhagat (2001), who recorded the superior efficacy of imidacloprid against the black cutworm *Agrotis ipsilon* larvae infesting maize. The results also subscribe to the findings of Link *et al.* (2000) and Igrc-Barcic *et al.* (2000) for the management of cutworm by seed treatment with Imidacloprid. Sharma and Bhagat (2000) advocated that seed treatment of imidacloprid 70 WS @ 224g.a.i ha^{-1} was effective in management of cutworm. Pons and Albajes (2002) demonstrated that seed treatment of maize with imidacloprid was effective in reducing cutworm *Agrotis ipsilon* infestation in maize.

The results regarding efficacy of chlorpyriphos 20 EC draw their confirmation from the results of Gupta and Yadava (1987), who reported the superior efficacy of chlorpyriphos 20EC @ 4.0 lit ha^{-1} in standing crop of groundnut against the grubs of *Holotrichia consanguinea* in Rajasthan. Mishra and Singh (1994) recorded better bioefficacy of chlorpyriphos 20 EC as seed treatment in soybean against *Anomala dimidata* in Uttaranchal hills @ 25.0 ml /kg seed. Mishra *et al.* (1984) concluded all four foliar contact insecticides, viz., chlorpyriphos 20EC, aldrin toxaphene, DDT EC and endosulfan EC were superior in minimizing cutworm damage in potato. Tripathi *et al.* (2003) reported that chlorpyriphos 20EC @ 2.0 kg ha^{-1} was effective followed by quinalphos 25 EC @ 2.0 kg ha^{-1} against black cutworm infesting potato in Garhwal Himalayas. Mannan *et al.* (2004) integrated different cultural, biological and chemical management practices against potato cutworm and reported that hand picking + 2 irrigations (30 & 45 days after planting + one spray of chlorpyriphos + perching proved superior both protection as well as production wise. El-ham and El-sayed (1991) reported that chlorpyriphos was most toxic followed by triazophos and monocrotophos against cutworm under laboratory conditions.

Thus it may be concluded that among the various insecticides evaluated for their efficacy as post sown foliar spray, application of imidacloprid 200 SL (0.4 lit ha^{-1}) and chlorpyriphos 20 EC @ (4.0 lit ha^{-1}) in standing Kharief crop of potato were found to be the most effective and economically viable treatments both in terms of increasing the tuber yield as well as reducing the grub population under the rain fed conditions in hill and mountain regions of Kashmir valley.

EXPERIMENT NO.8

The present studies indicated that there are, more than 14 species of white grub beetles in Kashmir valley. It was observed that the beetles emerged between 1930 h and 2100 h. The maximum beetle activity was observed between 1940 h and 2015 h. The peak emergence period of beetles at high altitude areas of valley, viz., Pahalgam was during the month of July. Whereas at low lying areas of Shalimar Campus and Srinagar Golf Course, the mass beetle emergence was reported in the month of June. The beetles soon after emergence settled on nearby trees for mating and later on for feeding, if the host is preferred. In case of non hosts, the beetles were observed to move for the preferred hosts for feeding (Bindra and Singh, 1972). The adults fed in the night hours and entered in the soil near by the host plants at around 5.45-6.00 a.m. The results are in agreement with Mahal *et al.* (1991), who recorded peak activity of *Holotrichia consanguinea* Blanchard at 2000h.Bindra and Singh (1972) noticed that adults of white grub *Holotrichia consanguinea* became active after sunset and fed on various available hosts.

The freshly emerged beetles were light brown in colour with unchitinised soft elytra but turned gradually chestnut – brown in colour with dark brown legs. *Holotrichia longipennis* was observed to be the predominant species of which 706.5 beetles were trapped, which formed 22.47% of the total catch all around the valley. The results subscribe to the findings of (Mishra and Singh, 1997 and Mishra and Singh, 1999), who reported that *Holotrichia longipennis* was the predominant species in Garhwal region of Uttarannchal. *Brahmina coriacea* ranked second and recorded a beetle catch of 394.5 i.e. 11.55% of the total catch. Misra, (1995) also reported *Brahmina coriacea* as predominant species in north-western hills of H.P. *Brahmina flavosericea* ranked third and recorded a beetle catch of 10.78%. Present observations are comparable with Chander and Singh (1985), who recorded *Brahmina Coriacea* a common pest of apple and potato in Himachal Pradesh. *Adoretus* species ranked fourth and recorded a beetle catch of 14.99%. The percent beetle catch from *Maladera* sp. *Anomala dimidata* and *Anomala rufiventris* were 9.09, 4.67 and 4.20% respectively. Arif and Joshi (1994) reported for the first time *Anomala rufiventris* as a pest of brinjal in Kumaon hills. The least number of beetles 1.75% were reported from *Bolbocerus* species. Tiwari *et al.* (1991) has also reported that *Brahmina coriacea* caused 99.0% damage to apple leaves and potato crop in Himachal Pradesh.

The beetle emergence started from the month of March, when only a minute fraction of beetles were trapped, the emergence increased gradually and attained its peak in the month of July. Beyond July a declining trend was observed up to month of September in which only a few beetles were trapped. Beyond the month of September no beetle emergence was reported. Several workers such as Mishra and Singh (1991), reported that beetle emergence of *Holotrichia longipennis* began at end of May and peaked in the second week of June. The results obtained also draw their confirmation from the findings of Devi *et al.* (1994), who reported that in mid hill zone of Himachal Pradesh, *Anomala lineatopennis* was abundant in June, where as *Holotrichia covifrons* and *Melolontha melolontha* in July and July-August, respectively. Singh *et al.* (1999) studied host preference of *Holotrichia longipennis* and reported that yellow rasp berry (*Rubus ellipticus* Sm) and sweet chestnut (*Castanea sativa* Mill) were preferred hosts. The results are also in agreement with the findings of Singh *et al.* (2003), who reported *Holotrichia longipennis* as predominant species among 33 other species belonging to eight sub families in Garhwal Himalayas.

Based on findings of this study coupled with the work carried on the cultural aspects of cutworm management on maize previously at Srinagar. It is observed that a higher seed rate of 30-40 kg ha^{-1}, seed treatment with imidacloprid 200 SL @ 0.8 g.a.i/kg seed and late sowing of fourth week of May or early sowing of 20^{th} April, post sown foliar application of chlorpyriphos 20 EC @ 0.04 % a.i. and soil treatment of fenvalerate 0.4% dust @ 25 kg ha^{-1} and *Beauveria bassiana* with organic manure at planting time in maize crop have been found promising components of IPM module suggested for the management of black cutworm (*Agrotis ipsilon* Hüfnagel) and white grub *Holotrichia longipennis* in maize.

Similar, higher seed rate 24-28 q ha^{-1}, late sowing in first week of June and post sown foliar application of imidacloprid @ 80 g.a.i. ha^{-1}, soil treatments with carbofuran 3 G @ 30 kg ha^{-1}, fenvalerate 0.4% dust @ 25 kg ha^{-1} and *Beauveria bassiana* with pulverized soil/organic manure at planting time were observed to provide a sound control of cutworm/white grub infesting potato.

CHAPTER-6

SUMMARY

SUMMARY

Field experimentation on yield loss studies due to cutworm *Agrotis ipsilopn* Hüfnagel infesting maize revealed that a highest cutworm damage of 54.63% and a retrievable yield loss of 80.18% is inflicted by cutworm *Agrotis ipsilopn* in hill and mountain agro-ecosystem of Kashmir. The lowest plant damage of 11.71% was recorded in seed treatment of imidacloprid @ 0.8 g.a.i./kg seed.

The evaluation of various insecticides and biopesticides in three different patterns as seed treatment, soil treatment and as post sown foliar sprays against cutworm infesting maize revealed that seed treatments of imidacloprid @ 0.8 g.a.i./kg seed and chlorpyriphos 20 EC @ 20 ml/kg seed were sound in protection against cutworm infestation and resulted in maximum net returns.

Integration of different seed rates with seed treatment of imidacloprid @ 0.8 g.a.i./kg seed, indicated that the highest seed rate of 40 kg ha^{-1} treated with imidacloprid proved significantly superior over all other treatments.

Field experimentation on assessment of avoidable loss due to cutworm infesting potato revealed that a maximum plant damage of 17.39% and a retrievable yield loss of 62.01% was recorded due to cutworm under a heavy infestation level of 6.05 larva/m^2.

The results of the experiment on evaluation of various insecticides and biopesticides against white grub/cutworm infesting potato showed that post sown foliar sprays with chlorpyriphos 20 EC @ 0.04% a.i. and quinalphos 25 EC @ 0.05% recorded a maximum Benefit: Cost (B/C)

ratio followed by soil treatments with fenvalerate 0.4% dust @ 25 kg ha^{-1}, chlorpyriphos 1.5% dust @ 25 kg ha^{-1} and carbofuran 3G @ 30 kg ha^{-1}. The seed tuber treatments were not economically viable, despite being superior on production side.

The results of the experiment on effect of different dates of sowing and seed rates against black cutworm infesting potato revealed that the higher seed rate of 24 q ha^{-1} helped to compensate the cutworm damage and maintain optimum plant stand, which resulted in substantial better yields. The late sowing in first week of June asynchronised the susceptible crop stage and aggressive stage of pest, which resulted in evasion of cutworm infestation and resulted in significant net returns.

The results of the experiment on field evaluation of some insecticides as post sown soil application against cutworm/white grub infesting potato revealed that a highest B/C ratio was recorded in imidacloprid 200 SL @ 80 g.a.i ha^{-1} followed by chlorpyriphos 20 EC @ 800 g.a.i ha^{-1}. The highest mean grub population 8.80 per Sq.m was recorded in untreated control. Where as rest of all treatment applications recorded a significantly lowest grub population.

The faunastic study on white grub complex present in hill and mountain agro-ecosystem revealed that *Holotrichia longipennis* was predominant species followed by *Brahmina coriacea* and *Maladera* sp. at Shalimar (Srinagar). Where as, at high altitude location of Pahalgam *Maladera* sp. was predominant followed by *Holotrichia longipennis* and at Wadura Sopora *Brahmina flavosericea* was the predominant species followed by *Adoretus* sp., *Brahmina coriacea* and *Melolontha furcicauda* respectively.

The beetle emergence of different species started from late March with mass beetle emergence period in the month of July, the beetle emergence showed a declining trend up to month of September and no beetle emergence was recorded after the month of September. The *Holotrichia longipennis* was recorded as predominant species throughout the valley.

REFERENCES

REFERENCES

Abraham, E. V., Padmanaban, M. D. and Mohan-Dass, A. 1972. Control of potato cutworms. *Indian Journal of Agricultural Science,* **42** (5): 418-420.

Addison, P. J., Parker, G. M., Firth, A. C. and Brown, G. B. 1991. Evaluation of lambdacyhalothrin for the control of greasy cutworm in seedling maize. *Proceedings of the Forty Fourth New Zealand Weed and Pest Control Conference,* (edited by Popay, A. J.) **1991**: 310-311.

Adkisson-perry, L. 1958. Seed treatment of cotton with systemic insecticides alone and in combination with a fungicidal treatment. *Journal of Economic Entomology,* **51** (5):697-700.

Ali, M. S., Chaturvedi, O. P., Nair, K. S. S., Sharma, J. K. (ed.) and Verma, R. V. 1996. Impact of diseases and insect pests in tropical forests. **In**: *Proceedings of IUFRO symposium,* Peechi, India, 23-26 November 1993. 1996, 464-467.

Amin, A. A. H. and Abidin, M. I. 1997. Host preference and life table parameters of black cutworm, *Agrotis ipsilon* (Hufn.), (Lepidoptera: Noctuidae). **In**: *Proceedings Belt Wide Cotton Conference,* New Orleans, LA, USA, January 6-10, 1997, Vol.**2**: 1190-1192.

Andersch, W. and Schwarz, M. 2003. Clothianidin seed treatment (Poncho Reg.) – the new technology for control of corn root worms and secondary pests in US-corn production. *Pflanzenschutz Nachrichten Bayer,* **56** (1): 147-172.

Annamalai, R., Surendran, C., Thirumurthi, S., Gunasekharan, V., Nair, K.S. S., Sharma, J. K. (ed.) and Verma, R. V. 1996. Insect damage to Neem in Tamil Nadu, India. Impact of diseases and insect pests in tropical forests. **In**: *Proceedings of the IUFRO Symposium,* Peechi, India 23-26 November, 1993. 1996, 349-355.

*Anonymous, 1975. *Cutworm, agricultural information service,* Directorate of Agriculture, Jammu and Kashmir Government, Srinagar, pp 6.

Anonymous,. 1980. *Insect pest management guide* – field and forage crops III. Cooperative Extension Service Circular, pp. 399-423.

Anonymous, 2004. *Agricultural Statistics at a Glance,* 2004, Directorate of Economics and Statistics, Jammu and Kashmir, Government, Srinagar, pp 171.

Anonymous, 2005. *Data book I.C.A.R,* 2005 pp.171.

Anonymous, 2005. *Digest of Statistics,* Directorate of Economics and Statistics, Jammu and Kashmir, Government, Srinagar, pp 82.

*Apple, J. W., Strong, F. E. and Raffensparge, E. M. 1958. Efficacy of insecticidal seed treatments against wire worms on lima beans and corn. *Journal of Economic Entomology,* **60**: 690-692.

Archer, T. L. and Musick, G. J. 1977. Cutting potential of *Agrotis ipsilon* on corn. *Journal of Economic Entomology,* **70**: 745-747.

Arif- Mohammad and Joshi, M. C. 1994. White grub *Anomala rufiventris* (Coleoptera: Scarabaeidae) an unrecorded pest of Brinjal in Kumaon hills. *Karnataka Journal of Agricultural Science,* 7 (4): 484-485.

Avila, C. J. and Gomez, S. A. 2003. Effect of insecticides applied to seeds and sowing furrows on the presence of corn white grub, *Liogenys* species. *Documentos Embrapa Centro de Pesquisa Agropecuaria do Oeste,* **56** : 32.

Avila, C. J. and Gomez, S. A. 2003. Effect of insecticides applied on seeds and in sowing furrows in the presence of soybean white grub, *Phyllophaga cuyabana. Documentos Embrapa Centro de Pesquisa Agropecuaria do Oeste,* **55**: 27.

Balasubramanian, G., Balasubramanian, M., Gopalan, M. and Sivaprakasam, N. 1987. Seed treatment of sorghum for the control of shoot fly *Atherigona soccata* Rondani. *Madras Agricultural Journal,* **74** (4-5): 237-239.

Bareth, S. S., Ashok-Bhatnagar. and Gireesh-Sharma. 2001. Compatibility of entomogenous nematode, *Steinernema glasseri* (Steiner) with some insecticides used for white grub management. *Pest Management and Economic Zoology,* **9** (2): 123-128.

Berry, E. C. and Knake, R. P. 1988. Population suppression of black cutworm larvae with seed treatment on maize. *Journal of Economic Entomology,* **80** (14): 921-924.

*Bhardwaj, S. C., Yadava, C. P. S. and Yadava, S. R. S. 1976. Susceptibility of white grub, *Holotrichia consanguinea* Blanchard adults to various insecticides. *Indian Journal of Entomology,* **38** (3): 225-229.

Bhat, A. A. 1986. Control of cutworm, *Agotis ipsilon* (Hufn.) on *Zea mays* L. *Geobios,* **13**: 273-276.

Biase, L. M. D, Marullo, R., Palmieri, G. and De-Biase, L. M. 1988. Trials for chemical control of harmful moths in maize in the Caserta region. *Informatore Agrario,* **44**: 75-76.

*Bindra, O.S. and Singh, J. 1972. Biological observations on the white grub, *Holotrichia consanguinea* (Coleoptera: Scarabaeidae) and the relative efficacy of different insecticides against the adults. *Indian Journal of Entomology,* **33** (2): 225-227.

Blair, B. W. 1991. The concentration of lambdacyhalothrin and its effect on cutworm, *Agrotis segetum* (Lepidoptera: Noctuidae). *Bulletin of Entomological Research,* **81** (2): 143-145.

*Bowling, C. C. 1968. Systemic insecticide seed treatment tests on soybeans. *Journal of Economic Entomology,* **61**: 1224-1227.

Brust, G. E., Stinner, B. R. and McCartney, D. A. 1985. Tillage and soil insecticide effect on predator – black cutworms (Lepidoptera: Noctuidae) interaction in corn agro-ecosystem. *Journal of Economic Entomology,* **78**: 1389-1392.

Brust, G.E., Stinner, B. R. and McCartney, D. A. 1986. Predation by soil inhabiting arthopods in intercropped and monoculture agro-ecosystems. *Agriculture Ecosystem Environment,* **18**: 145-154.

Busching, M. K. and Turpin, F. T. 1977. Survival and development of black cutworm, *Agrotis ipsilon* larvae on various species of crop plants and weeds. *Environmental Entomology,* **6** (1): 63-65.

Busching, M. K. and Turpin, F. T.1976. Ovipositional preference of black cutworm moths among various crop plants, weeds and plant debris. *Journal of Economic Entomology,* **69** (5): 587-590.

*Cabello, T. and Salmeron, T. 1989. Phenological studies of three noctuid pests (Lepidoptera: Noctuidae) in South East Spain using sex pheromone and light traps. *Boletin de Sanidad Vegetal, Plagas* **15** (3): 225-232.

Chirame, B. B, Khadatare, R. M. and Bhoi, P. G. 2003. Control of white grub (*Holotrichia serrata* F.) in sugarcane with *Beauveria brongniartii. Journal of Maharashtra Agricultural University,* **28** (2): 208-209.

Choudhary, O. P. and Dashad, S.S. 2002. Effectiveness of insecticides against white grub and their deterious effects on germination in pearl millet. *Annals of Agricultural Research,* **23** (3): 391-397.

*Coaker, T. H. and Williams, D. H. 1963. The importance of some carabidae and staphylinidae as predators of cabbage root fly *Erosia brassicae* (Bouche). *Entomologia Experimentalis Et Applicata,* **6**: 156-164.

Cowles, R. S. 2003. Modeling the effectiveness of bifenthrin for reducing population of Japanese and oriental beetle larvae in nursery containers. *Journal of Environmental Horticulture,* **21** (2): 78-81.

Crutchfield, B. A., Potter, D. A. and Powell, A. J.1995. Irrigation and nitrogen fertilization effects on white grub injury to Kentucky blue grass and tall fescue turf. *Crop Science,* **35** (4): 1122-1126.

Darwish, Y. A. 1991. Effect of some host plants, as larval diets, on the biology of greasy cutworm, *Agrotis ipsilon* (Hufn.). *Assiut. Journal of Agricultural Science,* **22** (4): 3-14.

Das, B. B. and Ram, G. 1988. Incidence, damage and carry over of cutworm (*Agrotis ipsilon*) attacking potato (*Solanum tuberosum*) crop in Bihar. *Indian Journal of Agricultural Sciences,* **58** (8): 650-651.

Das, G. P., Elias, M., Hoque, M. A. and Miah, M. R. U. 1996. Field screening of insecticides in controlling the cutworm, *Agrotis ipsilon* (Hufnagel) attacking potato. *Bangladesh Journal of Zoology,* **24** (2): 133-136.

*David, H., Alexander, K. C. and Ananthanarayana, K. 1973. Milky disease bacterium for the control of sugarcane white grub. *Current Science,* **42** (19): 695-696.

*Davis, J. W., Harding, J. A. and Wolfenbarger, D. A. 1975. Activity of synthetic pyrethroids against cotton insects. *Journal of Economic Entomology,* **68**: 373-374.

Devi, N., Raj, D. and Kashyap, N. P. 1994. Relative abundance of some white grub beetles in mid hill zone of Himachal Pradesh (India). *Journal of Entomological Research,* **18** (2): 139-142.

Drees, B. M., Cavazos, R., Berger, L. and Vinson, S. B. 1992. Impact of seed protecting insecticides of sorghum and corn seed feeding by red imported fire ants (Hymenoptera: Formicidae). *Journal of Economic Entomology,* **85** (3): 993-997.

Drinkwater, T. W. and Van-Rensburg, J. B. J. 1992. Association of the common cutworm, *Agrotis segetum* (Lepidoptera: Noctuidae) with winter weeds and volunteer maize. *Phytophylactica,* **24** (1): 25-28.

Dwivedi, S. C. and Awasthi, C. J. 1993. Toxicity of synthetic pyrethroids to white grub *Maladera insanabilis* (Brenske) (Coleoptera:

Scarabaeidae). *Pest Management and Economic Zoology*, **1** (1): 64-65.

Easwaramoorthy, S., Srikanth, J., Santhalakshmi,G. and Gaetha, N. 2005. Laboratory and field studies on *Beauveria brongniartii* (Sacc.) Petch against *Holotrichia serrata* F (Coleoptera: Scarabaeidae) in sugarcane. *Cooperative Sugar*, **36** (6): 493-502.

*Eckenrode, C. J., Gantheir, N. L., Danielson, D. and Webb, D. R. 1973. Seed corn maggot seed treatment and granular furrow applications for protecting beans and sweet corn. *Journal of Economic Entomology*, **66**: 1191-1194.

Edwards, C. A., Brust, G. E., Stinner, B. R. and Cartney, D. A. 1992. Work in the United States on the use of cropping patterns to promote natural enemies of pests. *Aspects of Applied Biology*, **31**: 139-148.

Ela, R. A., Salama, H., Rogaei, M. and Aboul, E. R. 1993. Assay of *Bacillus thuringiensis* (Berl.) isolates against the greasy cutworm, *Agrotis ypsilon* (Rott.) (Lepidoptera: Noctuidae). *Journal of Applied Entomology*, **116** (2): 151-155.

El-ham, A. S. and El-Sayed, I. 1991. Laboratory studies on the effect of ten insecticides and two methods of application on the black cutworm (*Agrotis ipsilon* Hufnagel). *Bulletin of Faculty of Agriculture, University of Cairo*, **42** (3): 953-962.

*Elliott, M. 1976. Future use of natural and synthetic pyrethroids pp. 163-93. **In**: R. L. Metcalf and J. J. McKelvey Jr. (Eds.) *The future for insecticides, needs and prospects*, Wiley New York pp. 524.

Enkerli, J., Widmer, F. and Keller, S. 2004. Long term field persistence of *Beauveria brongniartii* strains applied as biocontrol agents against European cock chafer larvae in Switzerland. *Biological Control,* **29**: 115-123.

Flores, A. G., Rosa-W-de-la., Rojas, J. C., Castro-Ramirez, A.E. and De-la-Rosa, W. 2002. Evaluation of *Beauveria bassiana* and *Metarhizium anisopliae* (Mitosporic) against species of "white grub complex" in the South of Mexico. *South Western Entomologist,* **27** (1): 73-83.

Foster, M. A. and Gaylor, M. J. 1986. Feeding dynamics of the black cutworm, *Agrotis ipsilon* (Lepidoptera: Noctuidae) in cotton. *Journal of Economic Entomology,* **79**: 840-842.

*Frank, J. H. 1971. Carabidae (Coleoptera) as predators of red-backed cutworm (Lepidoptera: Noctuidae) in central Alberta. *Canadian Entomologist,* **71**: 416-418.

Frank, S. D. and Shrewsbury, P. M. 2004. Consumption of black cutworm, *Agrotis ipsilon* (Lepidoptera: Noctuidae) and alternative prey by common golf course predators. *Environmental Entomology,* **33** (6): 1681-1688.

Garg, D. K. and Mani, V. P. 1988. Control of insect pests of maize in Uttar Pradesh hills. *Indian Farming,* **38** (1): 37-39.

Gholson, L. E. and Showers, W. B. 1979. Feeding behaviour of black cutworms on seedling corn and organic baits in the green house. *Environmental Entomology,* **8**: 552-557.

Gol-berg, A. M., Avigdori-Avidov, H. and Nuriel, E. 1989. Insecticide control of a white grub, *Maladera matrida* on sweet potato. *Phytoparasitica,* **17** (3): 175-183.

Gomez, B., Villalobos, F. J., Ruiz, L., Castro, A. and Vale, J. 1999. The white grub complex (Coleoptera: Melolonthidae) in maize in Los Altos de Chiapas, Mexico. Its relation with the time of agricultural use and soil organic matter. *Folia Entomologica Mexicana,* **107**: 1-20.

Gour, M. N. and Dabi, R. K. 1988. Biological control of white grub using *Verticillium lecanii* (Zimmerm) Viegas. *Current Science,* **57** (1): 620-621.

*Griffiths, D. C., Scot, G. C., Jeffs, K. A., Maskell, F.E. and Roberts, P. F. 1975. Experimental insecticides as seed treatments for the control of wheat bulb fly in cereals. **In**: *Proceedings of Eighth British Insecticide and Fungicide Conference* pp. 213-221.

*Hanna, R. L. 1958. Insecticidal seed treatment for cotton. *Journal of Economic Entomology,* **51** (2): 160-163.

Harris, C. R. and Svec, H.J. 1976. Susceptibility of colarodo potato beetle in Ontario to insecticides. *Journal of Economic Entomology,* **69**: 625-629.

*Harris, C. R. and Turnbull, S. A. 1978. Laboratory studies on the contact toxicity and activity in soil of four pyrethroid insecticides. *Canadian Entomologist,* **110**: 285-288.

Harris, C. R., Svec, H. J. and Chapman, R. A. 1978. Potential of pyrethroid insecticides for cutworm control. *Journal of Economic Entomology,* **71**: 692-696.

Hartemink, A. E. and Kuniata, L. S. 1996. Some factors influencing yield trends of sugarcane in Papua New Guinea. *Outlook on Agriculture,* **25** (4): 227-234.

Hong, S. C. and Williamson, R. C. 2004. Comparison of sticky wing and cone pheromone traps for monitoring seasonal abundance of black cutworm adults and larvae on golf courses. *Journal of Economic Entomology*, **97** (5): 1666-1670.

*Hsieh, S. A. 1974. Control of sugarcane white grub, *Allisonotum impressicole* and wire worm *Melanotus tamsuyensis* with non-persistent insecticides. *Report of the Taiwan Sugar Research Institute*, **64**: 37-47.

Iqbal, J., Khan, I. A. and Saljoki, A. R. 1997. Control of tobacco cutworm, *Agrotis ipsilon,* Hufn. (Lepidoptera: Noctuidae) with synthetic pyrethroids and organophosphate insecticides. *Sarhad Journal of Agriculture*, **XIII** (5): 485-487.

Islam, M. N., Nessa, Z. and Karim, M. A. 1991. Management of the potato cutworm, *Agrotis ipsilon* (Hufn.) (Lepidoptera: Noctuidae) with insecticides other than the organochlorinated hydrocarbon insecticides. *Bangladesh Journal of Zoology,* **19** (2): 173-177.

*Ivy, E. E. 1952. Testing of systemic insecticides. *Agriculture Chemistry,* **7** (1): 121-123.

*Ivy, E. E., Scales, A. L. and Gorzychi, L. J. 1954. Three organophosphate insecticides for systemic control of cotton insects. *Journal of Economic Entomology,* **47** (6): 1148-1149.

*Ivy, E. E., Wm-Iglinsky Jr. and Rainwater, C. F. 1950. Translocation of octamethyl pyrophoramide by the cotton plant and toxicity of treated plants to cotton insects and a spider mite. *Journal of Economic Entomology*, **43** (5): 620-626.

Jeuffrault, E., Rolet, A., Reynaud, B., Manikom, R., Georger, S., Taye, T., Chiroleu, F., Fouillaud, M. and Vercambre, B. 2004. Twenty years of sugarcane white grub control on Reunion Island. *Phytoma*, **57**(3): 16-19.

Johnson, T. B. and Lewis, L.C. 1982. Pathogenicity of two nuclear polyhedrosis viruses in the black cutworm, *Agrotis ipsilon* (Lepidoptera: Noctuidae). *Canadian Entomologist*, **114**: 311-316.

Johnson, T.B., Turpin, F.T., Schreiber, M. M. and Griffith, D.R. 1984.Effect of crop rotation, tillage and weed management systems on black cutworm (Lepidoptera: Noctuidae) infestations in corn. *Journal of Economic Entomology*, **77**: 919-921.

Judge, F.D. and Mc Ewen, F. L. 1970. Field testing candidate insecticides as seed treatment for the control of seed corn maggot on lima beans in New York State. *Journal of Economic Entomology*, **63**: 1332-1333.

Kalra, V. K., Singh, H. and Rohilla, H. R. 1991. Population build up of white grub, *Holotrichia consanguinea* Blanch in Haryana. *Journal of Insect Science*, **4** (1): 73-75.

*Kamel, A. A. M. and Shoeb, A. 1964. Studies on the value of some chemical control measures as protective means against attack of cotton seedlings by certain pests. *Agriculture Research Revo Cairo*, **42** (3): 1-17.

*Karimullah; Ahmad, S. and Mashwani, M. A. 1993. Relative abundance of insect pests on maize cultivars at Kalam. *Sarhad Journal of Agriculture*, **9** (1): 15-19.

*Kaunsale, P. P., Deshpande, S.V. and Puri, S. N. 1978. Chemical control of white grub *Holotrichia serrata* Fabr. beetles. *Indian Journal of Entomology,* **40** (2): 134-135.

*Khanna, S. S. 1964. Pests of leguminous crops, gram cutworm. **In**: *Agricultural Entomology for Indian Students,* pp. 152-54. Adarsh Prakashan, Delhi.

Khurana, S. D. and Kaushik, H. D. 1991. Bioefficacy of insecticides against *Aphis Craccivora* Koch and *Agrotis ipsilon* (Hufn.) on chickpea. *Journal of Insect Science,* **4** (2): 193-194.

Kokate, K. D., Chandla, V. K., Nand, H. and Negi, K. S.1991. Management of white grub (*Lachnosterna coriacea*) in potato (*Solanum tuberosum*) fields of Shimla hills. *Indian Journal of Agricultural Sciences,* **61** (10): 787-788.

Konar, A. and Mohasin, M. 2003. Incidence of cutworm on potato in different locations of West Bengal. *Journal of the Indian Potato Association,* **30** (3/4): 329-330.

Koppenhofer, A. M., Cowles, R. S., Cowles, E.A., Fuzy, E. M. and Kaya, H. K. 2003. Effect of neonicotinoid synergists on entomopathogenic nematode fitness. *Entomologia Experimentalis et Applicata,* **106** (1): 7-18.

Kumawat, S. K. and Yadava, C. P. S. 1990. Effect of various insecticides applied as soil treatment, seed coating and seed dressing on groundnut against white grub. *Indian Journal of Entomology,* **52** (2): 187-190.

Kumawat, S. K. and Yadava, C.P. S. 1990. Effect of various insecticides applied as soil treatment, seed coating and seed dressing on groundnut against white grub. *Indian Journal of Entomology,* **52** (2): 187-190.

Kumawat, S. R. and Yadava, C. P. S. 1990. Comparative impact of white grub control through different strategies and methods in a bajra cropping system. *Indian Journal of Entomology,* **52** (3): 384-386.

Kunkel, B. A., Held, D.W. and Potter, D. A. 1999. Impact of Halofenozide, Imidacloprid and Bendiocarb on beneficial invertebrates and predatory activity in turf grass. *Journal of Economic Entomology,* **92** (4): 922-930.

*Kushawa, K. S., Noor, A. and Pareek, B. L. 1972. Cutworm damage and its control in Rajasthan. *Rajasthan University Research Journal,* **10**: 69-71.

Lacey, L. A., Amaral, J. J., Coupland, J. and Klein, M. G. 1994. The influence of climatic factors on the flight activity of the Japanese beetle (Coleoptera: Scarabaeidae) implications for use of a microbial control agent. *Biological Control,* **4**: 298-303.

La-Mondia, J. A., Elmer, W. H., Mervosh, T. L. and Cowles, R. S.2002. Integrated Management of strawberry pests by rotation and intercropping. *Crop Protection,* **21** (9): 837-846.

Lentz, G. L. 1985. Occurrence of *Phyllophaga congrua* (Leconte) and *Phyllophaga implicata* (Coleoptera: Scarabaeidae) on soybeans. *Journal of the Kansas Entomological Society,* **58** (2): 202-206.

Leucona, R. E. and Lanteri, A. A. 1999. Microbial control with entomopathogenic fungi in Argentina. **In**: *Proceedings of the IV Argentine Congress of Entomology,* Mar del Plata, Argentina, 8-12 March 1998. *Revista de la Sociedad Entomologica Argentina,* **58** (1/2): 301-306.

Levine, E. and Felsot, A. 1985. Effectiveness of acephate and carbofuran seed treatment to control the black cutworm, *Agrotis ipsilon* on field corn. *Indian Journal of Entomology,* **78** (6): 1415-1420.

Levine, E., Clement, S. L., Rubink, W. L. and McCartney, D. A. 1983. Re-growth of corn seedlings after injury at different growth stages by black cutworm, *Agrotis ipsilon* (Lepidoptera: Noctuidae) larvae. *Journal of Economic Entomology,* **76**: 389-391.

Li-lz., Zhou, X. S., Yan, J., Cui, Y. S., Yang, H.P., Zhao, M. G., Shi, J. L., Pan, H.Y. and Wang, Y. Y. 1992. Studies on the biological control technique for the white grub *Blitopertha pallidipennis* Reitter at the Bureau of Shangganling. *Collection of achievements on the technique cooperation project of P. R. China and F. R. Germany,* pp.136-140.

*Lindquist, D. A., Haiskaylo, J., Clark, J.C. and Davich, T. B. 1961. Systemic activity of dimethoate applied to cotton seeds. *Journal of Economic Entomology,* **54** (6): 1132-1135.

Link, D., Tarrago, M. F. S., Costa, E. C. and Sigaran-Tarrago, M. F. 1988. Efficiency of some organic synthetic insecticides in the control of black cutworm, *Agrotis ipsilon* (Hufnagel) on tobacco crop. Revista do Centro de Ciencias Rurais Universidade. *Faderal de Santa Maria,* **18** (2): 133-139.

Litsinger, J. A., Libetario, E. M. and Barrion, A. T. 2002. Population dynamics of white grubs in upland rice and maize environment of Northern Mindanao, Philippines. *International Journal of Pest Management,* **48** (3): 239-260.

Lone, J. I. and Zaki, F. A. 1999. Management of black cutworm (*Agrotis ipsilon* Hufnagel) in maize (*Zea mays* L.) through cultural manipulations. *SKUAST Journal of Research,* **1**: 64-70.

Lopez, R. and Potter, D. A. 2000. Ant predation on eggs and larvae of black cutworm (Lepidoptera: Noctuidae) and Japanese beetle (Coleoptera: Scarabaeidae) in turf grass. *Environmental Entomology,* **29** (1): 116-125.

Lopez, R. J. and Hague, N. G. M. 2003. Evaluation of insecticides and entomopathogenic nematodes for control of the cutworm, *Agrotis segetum* on endive. *Tests of Agrochemicals and Cultivars,* **24**: 22-23.

Loughrin, J. J., Potter, D. A. and Hamilton-Kemp, T. R. 1998. Attraction of Japanese beetles (Coleoptera: Scarabaeidae) to host plant volatiles in field trapping experiments. *Environmental Entomology,* **27** (2): 395-400.

Mahal, M. S., Singh, R. and Singh, B. 1991. Mating behaviour of white grub, *Holotrichia consanguinea* (Blanch) and its use as an index of population estimation. *Journal of Insect Science,* **4** (1): 27-31.

Mannan, M.A., Hossain, M. A., Ali, M. R. and Tasmin, R. 2004. Integrated pest management of potato cutworm, *Agrotis ipsilon* (Hufnagel). *Pakistan Journal of Scientific and Industrial Research,* **47** (1): 56-59.

Markiewicz-Jodko, J. 1991. Effect of marshal 25 ST and carbosulfan in control of onion fly *Hylema antique* Meig and carrot fly *Psila* *rosae* Fabr. *Mededelingen van de Faculteit Landbouww elens chappen Rijks universiteit Genl.* **56** (3b): 1143-1150.

Marwaha, K. K., Siddiqui, K. H. and Sarup, P. 1984. Newer carbofuran and carbosulfan formulations to control the maize stalk borer, *Chilo partellus* (Swinhoc). *Journal of Entomological Research,* **8** (1): 93-97.

Marwaha, K. K., Siddiqui, K. H. and Sarup, P. 1985. Evaluation of various insecticides against the shoot fly complex (*Atherigona soccata* Rond. and *Atherigona naqvii* Steystal) in spring sown maize. *Journal of Entomological Research,* **9** (1): 100-103.

Mathur, Y. K., Upadhyay, K. D., Srivastava, J. P., Anjor, R. and Agrawal, N. 1989. Survey of white grub beetles in plains of Uttar Pradesh. *Farm Science Journal,* **14** (12): 127-130.

*McDonald, S. 1976. Evaluation of several new insecticides for the control of Colorado potato beetle and the status of DDT resistance in southern Alberta. *Indian Journal of Entomology,* **69**: 659-664.

Meshram, P. B., Joshi, K. C. and Sarkar, A. K. 1993. Efficacy of some insecticides against the white grub, *Holotrichia insularis* Brenske in teak nursery. *Annals of Forestry,* **1** (2): 196-198.

Mishra, P. N. 2001. Management of white grub in potato under mid hill conditions of Uttranchal. *Annals of Plant Protection Sciences,* **9** (2): 329-330.

Mishra, P. N. and Singh, M. P. 1991. Field biology of white grub, *Holotrichia longipennis* on potatoes in Uttar Pradesh. *Journal of Indian Potato Association,* **20** (3/4): 249-251.

Mishra, P. N. and Singh, M. P. 1995. Efficacy of some insecticidal dusts against the white grub beetle, *Holotrichia longipennis* Blanch (Melolonthidae: Coleoptera) damaging apple leaves. *Annals of Plant Protection Science,* **3** (1): 83-85.

Mishra, P. N. and Singh, M.P. 1994. Control of white grub, *Anomala dimidata* Hope. (Coleoptera: Rutelinae) through insecticidal seed treatments in soybean: a new approach. *Annals of Agricultural Research,* **15** (2): 237-239.

Mishra, P. N. and Singh, M.P. 1999. Determination of predominant species of white grub in Garhwal region of Uttar Pradesh hills (India). *Journal of Entomological Research,* **23** (1): 65-69.

Mishra, P. N., Singh, M. P. and Yadava, C.P. S. 1998. Biological observations on white grub, *Holotrichia longipennis* in Garhwal hills of Uttar Pradesh. *Indian Journal of Entomology,* **60** (1): 79-83.

Mishra, P. N., Singh, M. P. and Yadava, C.P.S. 1998. Bionomics of white grub *Anomala lineatopennis* in Western Himalaya. *Indian Journal of Entomology,* **60** (1): 74-78.

Misra, S. S. 1995. White grub *Holotrichia (Lachnosterna) Coriacea* (Hope) – a key pest of potatoes in Himachal Pradesh, India. *Journal of Entomological Research,* **19** (2):181-182.

Misra, S. S. 2003. Assessment of avoidable losses in potato yield by managing white grubs, *Holotrichia* spp. at higher hills of Himachal Pradesh, India. *Journal of Applied Zoological Research,* **14** (1): 13-17.

Misra, S. S., Nagia, D. K. and Ram, G. 1986. Efficacy of granular systemic insecticides against potato cutworms, *Agrotis* spp. *Indian Journal of Entomology,* **48** (2): 144-147.

Misra, S. S., Nagia, D. K., Ram, G. and Bist, R. S. 1984. Evaluation of contact insecticides against potato cutworm, *Agrotis* spp. *Indian Journal of Entomology,* **46** (4): 460-466.

Moron, M. A., Hernandez-Rodriguez. S. and Ramirez-Campos, A. 1996. The white grub complex (Coleoptera: Melolonthidae) associated with sugarcane in Nayarit, Mexico. *Folia Entomologica Mexicana,* **98**: 1-44.

Mulder, P. G. and Showers, W. B. 1993. Feeding on corn by black cutworm (Lepidoptera: Noctuidae) larvae reared for one or multi-generations in the laboratory. *Environmental Entomology,* **12**: 340-344.

*Musick, G. J. 1970. Insect problems with no till crops. *Crops and Soil Magazine,* **23**: 18-19.

*Musick, G. J. and Petty, G.B. 1974. Insect control in conservation tillage systems. Conservation tillage. A hand book for farmers. *Soil Conservation Society of America,* pp. 52.

Nag, A. and Nath, P. 1991. Spatial distribution pattern of the cutworm, *Agrotis ipsilon* (Hufn.) (Lepidoptera: Noctuidae) in the maize field. *Giornale – Italiano di Entomologia,* **6** (28): 289-295.

Nag, A. and Nath, P. 1993. Biology of cutworm, *Agrotis ipsilon* (Hufn.), on some natural and artificial diet. *Naturalia-Sao-Paulo,* **18**: 57-66.

Nag, A. and Nath, P. 1993. Insecticidal control of greasy cutworm (*Agrotis ipsilon*) infesting gram (*Cicer arietinum*). *Indian Journal of Agricultural Sciences,* **63** (4): 248-250.

*Nasr, E. I., Syed, A. and Naguib, N. A. 1964. Contribution to the biology of greasy cutworm, *Agrotis ipsilon* (Rott.) (Lepidoptera: Noctuidae). *Bulletin of Entomological Society of Egypt,* **47**: 197-200.

Nehru, C. R., Jayarathnam, K. and Karnavar, G. K.1991. Application of entomopathogenic fungus *Beauveria brongniartii* for management of chafer beetle of the white grub *Holotrichia serrata* infesting rubber seedlings. *Indian Journal of Natural Rubber Research,* **4** (2): 123-125.

Nielson, D. G. and Cowles, R. S. 1998. Preventing white grub infestation in container grown nursery stock. *Journal of Environmental Horticulture,* **16** (4): 202-207.

*Odiyo, P. O. 1975. Seasonal distribution and migrations of *Agrotis ipsilon* (Hufnagel) (Lepidoptera: Noctuidae). *Central Overseas Pest Research Tropical Pest Bulletin,* **4**: 26.

Oliveira,L.J., Hoffmann-Campo, C. B. and Garcia, M. A. 2000. Effect of soil management on the white grub population and damage in soybean. *Pesquisa Agropecuaria Brasileira,* **35** (5): 887-894.

Oloumi-Sadeghi, H., Levine, E., Steffey, K. L. and Gray, M. E. 1992. Black cutworm damage and recovery of corn plants, influence of pyrethroid and organophosphate soil insecticide treatments. *Crop Protection,* **11** (4): 323-328.

*Pal, S. K. 1972. Efficacy of different insecticidal formulations on the control of white grub, *Aserica* sp. (Melolonthidae: Coleoptera) in desert area of Rajasthan. *Indian Journal of Agricultural Research,* **6** (3): 215-220.

Pandit, N.C. 1995. White grub, *Rhinyptia meridionous* Arrow (Scarabaeidae: Coleoptera). A serious pest of ramie, *Boehmeria nivea* Guad. *Environment and Ecology,* **13** (1): 245-246.

Paras-Nath; Abhijeet-Nag; Nath, P. and Nag, A. 1996. Relative preference of promising varieties of maize (*Zea mays*) to greasy cutworm (*Agrotis ipsilon*). *Bioved,* **7** (1): 23-28.

Pareek, B. L. and Kushwaha, K. S. 1976. Insecticidal trial against the cutworm *Agrotis spinifera* (Hb.). *Indian Journal of Entomology,* **38** (2): 198-199.

Pareek, P. L. and Noor, A. 1982. Efficacy of insecticides against cutworms, *Agrotis spinifera* (Hub.) infesting cucurbits. *Pesticides,* **16** (4): 8-9.

*Parencia, C. R. Jr., Davis, J. W. and Cowan, C. B. Jr. 1957. Further tests with systemic insecticides employed as seed treatments. *Journal of Economic Entomology,* **50** (5): 614-617.

Parihar, S. B. S. and Singh, O. P. 1992. Effect of cropping pattern on build up of *Agrotis ipsilon* and *Helicoverpa armigera* Hub. in potato. *National Academy Science Letters,* **15**: 257-258.

Parker, R. D. 1989. Heptachlor treated sorghum seed scarce. *South West Farm Press,* **16**: 11-17.

Patel, B. D. and Patel, G. M. 2000. Efficacy of new insecticidal formulations as seed treatment against white grub in groundnut. *Gujrat Agricultural University Research Journal,* **25** (2): 27-33.

Patil, S. M., Adsule, V. M. and Khaire, V. M. 1991. Efficacy of some insecticides against the white grub infesting chillies. *Journal of Maharashtra Agricultural University,* **16** (2): 276-277.

*Perumal, R. S., Lakshmanan, P., Subramanian, T. R. and Santhanaraman, T. 1971. Occurrence of the white grub *Holotrichia* sp. as a new pest of Jasmine and Nerium. *Madras Agricultural Journal,* **58** (6): 519.

Pons, X. and Albajes, R. 2002. Control of maize pests with imidacloprid seed dressing treatment in Catalonia (NE Iberian Peninsula) under traditional crop conditions. *Crop Protection,* **21**: 943-950.

Potter, D.A. 1980. Flight activity and sex attraction of Northern and Southern masked chafers in Kentucky turf grass. *Annals of Entomological Society of America,* **73**: 414-417.

Raghuwanshi, R. K. and Rawat, R.R. 1985. Chemical control of *Atherigona simplex* Thoms on kodo-millet with seed and furrow treatments. *Indian Journal of Agricultural Sciences,* **55** (7): 468-470.

Rajendra, T. P. and Verma, K. D. 1989. Chemical control of cutworms *Agrotis* spp. (Noctuidae: Lepidoptera) on potato in the Nilgiris. *Indian Journal of Entomology,* **51** (2): 177-180.

Rajendran, B. 1999. Sugarcane white grub incidence in Dharmapuri district of Tamil Nadu. *Cooperative Sugar,* **30** (7): 682.

Ram, G. and Yadava, C. P.S. 1982. Seed treatment of groundnut for control of white grub, *Holotrichia consanguinea* Blanch. *Indian Journal of Entomology,* **44**: 121-124.

Ramirez-Salinas, C. and Castro-Ramirez, A. E. 2000. The *Gallina Ciega* (Coleoptera: Melolonthidae) Complex in the cultivation of maize in El Madronal, the municipality of Chiapas Mexico. *Acta Zoologica Mexicana,* **8**(79): 17-41.

Raymond, P. D., Williams, B.S., Taylor, S. E. and Robert, H. S. 1983. Spring weather pattern associated with suspected black cutworm moth (Lepidoptera: Noctuidae) introduction to Lowa. *Environmental Entomology,* **12**: 1863-1872.

Reese, J. C. and Field, M. D. 1986. Defense against insect attack in susceptible plants. Black cutworm (Lepidoptera: Noctuidae) growth on corn seedlings and artificial diet. *Annals of Entomological Society of America,* **79**: 372-376.

*Reshi, N. D. 1967. Studies on insect pests of Kashmir. Part vegetables. Major pests with their life history and control measures. *Kashmir Science,* **IV** (1-2): 66-69.

*Reynolds, H. T., Anderson, L. D. and Swift, J. E. 1953. Tests with two systemic insecticides on vegetable and field crops in Southern California. *Journal of Economic Entomology,* **46** (4): 555-560.

Rodriguez-del-Bosque, L. A. and Loera-Gallardo, J. 1993. Influence of corn phenology and planting date on damage by the black cutworm (Lepidoptera: Noctuidae). *Florida Entomologist,* **76** (4): 599-602.

Rogers, M. E. and Potter, D. A. 2003. Effect of spring Imidacloprid application for white grub control on parasitism of Japanese beetle (Coleoptera: Scarabaeidae) by *Tiphia vernalis* (Hymenoptera: Tiphidae). *Journal of Economic Entomology,* **96** (5): 1412-1419.

Saidi, J. A., Ringo, D. F. P. and Owenya, F. S. 1992. Evaluation of controlled release chlorpyrifos for the control of sugarcane white grub *Cochliotis melolonthoides* (Gerst.) (Coleoptera: Scarabaeidae) in Northern Tanzania. *Tropical Pest Management,* **38** (4): 382-385.

Salama, H. S., Moawed, S., Saleh, R. and Ragei, M. 1990. Field tests on efficacy of baits used on *Bacillus thuringiensis* and chemical insecticides against the greasy cutworm, *Agrotis ypsilon* Rdf. in Egypt. *Anzeiger fur Schadling Skunde Pflanzenschutz, Unweltschutz,* **63** (2): 33-36.

Salama, H.S., Foda, M. S. and Sharaby, A. 1989. Potentiation of *Bacillus thuringiensis* endotoxin against the greasy cutworm, *Agrotis ipsilon. Journal of Applied Entomology,* **108** (4): 372-380.

*Sayed, E. I. 1975. Effect of different host plants on larval development and on response of the black cutworm, *Agrotis ipsilon* (Hufn.) to sevin. *Zeitschrift fur Angewandte Entomologia ,* **79** (4): 365-369.

Schmidt, C. D., Matter, J. J., Meurer, J. H., Reeves, R. E. and Shelley, B. K. 1976. Evaluation of a synthetic pyrethroid for control of stable flies and barren flies on cattle. *Journal of Economic Entomology,* **69**: 479-486.

Schwarz, M., Christie, D., Andersch, W., Kemper, K., Fellmann, K. and Altmann, R. 2003. Control of corn root worms (*Diabrotica* spp.) and of secondary pests of corn (*Zea mays*) using seed treatments of clothianidin. **In**: *The BCPC Conference: Pests and disease,* Volumes 1 and 2. Proceedings of an International Conference held at the Brighto, 2002. 59-64.

*Sechriest, R.E. and York, A. C. 1967. Evaluating artificial infestation of black cutworms. *Journal of Economic Entomology*, **60**: 923-25.

Sekhon, S. S., Umakanta. and Sajjan, S. S. 1989. Control of maize borer *Chilo partellus* (Swin) infesting maize with seed treatment formulations and other insecticides. *Journal of Insect Science*, **2** (1): 77-79.

*Shahid, M. and Khan, S. M. 1977. Biology and control of tobacco cutworm *Agrotis ipsilon* (Hufn.). *Journal of Science and Technology*, **1** (1): 27-30.

Shapiro-Di; Lewis, L. C., Obrycki, J. J. and Abbas, M. 1999. Effect of fertilizers on suppression of black cutworm (*Agrotis ipsilon*) damage with *Steinernema carpocapsae*. *Journal of Nematology*, **31** (4): 690-693.

Sharma, C. M. 1989. White grub and its management in Rajasthan. *Indian Farming*, **38** (11): 33-36.

Sharma, D.C., Katoch, K. K. and Kashyap, N. P. 2002. Relative efficacy of different insecticides to *odontotermes* spp. and *Agrotis* spp. in wheat. *Insect Environment*, **8** (1): 10-11.

Sharma, P. K. and Bhagat, R. M. 2000. Comparative efficacy of various insecticides used as seed and soil treatments against cutworm, *Agrotis ipsilon* (Rott.) infesting maize. *Journal of Entomological Research*, **24** (2): 163-165.

Sharma, S. and Gupta, R. B. L. 2003. Bioefficacy of three entomopathogenic fungi against beetles of *Holotrichia consanguinea* and *Maladera insanabilis*. *Plant Disease Research*, **18** : 190-192.

Sharma, S., Gupta, R.B. L. and Yadava, C. P. S. 1998. Effect of temperature on growth, sporulation and bioactivity of entomofungi against white grub (*Holotrichia consanguinea*). *Indian Journal of Entomology,* **60** (1): 1-7.

Sherrod, D. W., Shaw, J. T. and Luckmann, W. H. 1979. Concepts on black cutworm field biology in Illinois. *Environmental Entomology,* **8** (2): 191-195.

Showers, W. B. 1997. Migratory ecology of the black cutworm. *Annual Review of Entomology,* **42**: 393-425.

Showers, W. B., Kaster, L. V. and Mulder, P.G. 1983. Corn seedling growth stage and black cutworm (Lepidoptera: Noctuidae) damage. *Environmental Entomology,* **12**: 241-244.

Showers, W. B., Kaster, L. V., Sappington, T. W., Muldar, P. G. and Whitford, F. 1985. Development and behaviour of black cutworm (Lepidoptera: Noctuidae) population before and after corn emergence. *Journal of Economic Entomology,* **78**: 588-594.

Showers, W. B., Keaster, A. J., Raulston, J. R., Goodenough, J. L., Hendrix, W. H (iii)., Way, M. O. and Robinson, J. F. 1995. Seasonal migration of the black cutworm. *South Western Entomologist,* **8**: 119-134.

*Showers, W. B., Sechriest, R. E., Turpin, F. T., Mayo, Z. B. and Goodman Szatmari, G. 1979. Simulated black cutworm damage to seedling corn. *Journal of Economic Entomology,***72**: 432-436.

*Shrivastava, B. K. and Khan, R. M. 1962. Cutworm of potato and their control in Rajasthan. *Indian Journal of Horticulture,* **18** (2): 156-161.

*Silveria, N. S., Lara, F. M., Igue, T. and Carrao, C. A. B. 1977. Flight activity of some injurious noctuids determined by means of an automatic light trap. *Anais da Sociedade Entomologica do Brasil,* **4** (1): 3-11.

*Singh, B. P. and Dayal, R. 1986. Effect of insecticides on the control of white grubs (*Holotrichia serrata* Fab.) in sugarcane. *Indian Journal of Entomology,* **48** (4): 395-398.

Singh, M. P., Bisht, R.S. and Mishra, P. N. 1999. Field efficacy of some insecticides against white grub, *Holotrichia longipennis* infesting rice under rainfed conditions in Uttar Pradesh hills. *Indian Journal of Entomology,* **61** (2): 159-164.

Singh, M. P., Bisht, R.S. and Mishra, P. N. 1999. Preference of host plant by white grub beetle *Holotrichia longipennis* in Garhwal Himalaya. *Indian Journal of Entomology,* **61** (1): 7-10.

Singh, M. P., Bisht, R.S. and Mishra, P. N. 2003. Distribution of white grub fauna in Garhwal hills of Western Himalayas. *Indian Journal of Entomology,* **65** (2): 217-221.

Singh, O. P. and Singh, K. J. 1994. Record of white grub, *Holotrichia consanguinea* (Blanchard) infestation and its effect on yield of soybean in Madhya Pradesh. *Indian Journal of Insect Science,* **7** (1): 100-101.

Sinha, C. M. P. and Verma, G. D. 1985. Insecticidal control of climbing cutworm *Rhyacia herculae* (Corti. and Draudt) *Indian Journal of Entomology,* **47** (3): 346-348.

*Starks, K. J. and Lilly, J. H. 1955. Some effects of insecticide seed treatment on dent corn. *Journal of Economic Entomology,* **48**: 549-555.

Stinner, B.R., McCartney, D. A., Doren, D. M. Van Jr. 1988. Soil and foliage arthropod communities in conventional, reduced and no tillage corn (maize, *zea mays* L.) systems: a comparison after 20 year of continuous cropping. *Soil and Tillage Research,* **11** (2): 147-158.

Subaharan, K., Vidyasagar, P. S. P.V. and Basheer, B. M. M. 2001. Bioefficacy of insecticides against white grub *Leucophola lepidophora* Blanch infesting arecanut palm. *Indian Journal of Plant Protection,* **29** (1/2): 25-29.

Sugimoto, A. and Kobayashi, T. 1978. Seasonal prevalence and possibility of seasonal migration of the black cutworm (Hufn.) on Ishigaki Island, Okinawa. *Japan Journal of Applied Entomology and Zoology,* **22**: 40-43.

Suhartawan, 1997. Phenology and biology of *Holotrichia helleri.* Brsk., a sugarcane grub at Prajekan sugar estate. *Bulletin Pusat Penelitian Perkebunan Gula Indonesia,* **145**:21-37.

Sukhwani, T. R. and Jotwani, M. G. 1981. Control of sorghum shoot fly with insecticides applied as seed treatment in furrows. *Indian Journal of Agricultural Sciences,* **51** (11): 799-802.

Taraborrelli, L., Talami, M., Principe, P. and Corvi, F. 1989. Control of noctuids in Horticulture with a bait formulation based on quinalphos. *Difesa-delle-Piante,* **12** (1-2): 75-80.

Thakur, A. S., Vaishampayan, S. M., Abhishek-Shukla and Shukla, A. 1997. Evaluation of some soil insecticides against cutworm, *Agrotis ipsilon* (Hugnagel) in sunflower. *Crop Research Hisar*, **14** (3): 477-480.

Thakur, R. C., Verma, S. N., Nema, K. K. and Singh, O. P. 1990. Chemical control of white grub, on black gram in M.P. *Pesticides Bombay*, **24** (1): 25-26.

Thakur, S. S. and Vaidya, D. N. 2000. Management of cutworm, *Agrotis ypsilon* (Rottenburg) in maize. *Insect Environment*, **6** (2): 91-92.

Thakur, S. S., Jitender-Kumar and Kumar, J. 1999. Estimation of avoidable losses caused by various insect pests in maize. *Journal of Insect Science*, **12** (2): 154-155.

*Thimmiah, G., Panchbhari, K. S., Khan, A. R., Usman, S. and Kajjan, N. B. 1972. Insecticidal control of cutworms (*Agrotis ipsilon* Rot.) on tobacco (*Nicotiana tobacum* L.). *Indian Journal of Agricultural Science*, **42**: 925-927.

Thippeswamy, C., Thimmaiah,G., Govindan, R. and Devaish, M. C. 1981. Control of greasy cutworm, *Agrotis ipsilon* (Hufn.) on cotton. *Current Research*, **10** (1): 12-13.

*Thompson, A. R., Suett, D. L. and Percivall, A. L. 1980. Protection of radish from cabbage root fly damage by seed treatment with organophosphorous and carbamate insecticides. *Annals of Applied Biology*, **94**: 1-10.

Thurston, G. S., Kaya, H. K., Burlando, T. M. and Harrison, R. E. 1993. Milky disease bacterium as a stressor to increase susceptibility of scarabaeid larvae to an entomopathogenic nematode. *Journal of Invertebrate Pathology*, **61**: 167-172.

Tiwari, S. N., Kumar, A., Singh, M. and Kashyap, N. P. 1991. White grub species prevalent in Himachal Pradesh. *Journal of Entomological Research,* **15** (4): 301-306.

Tonhasca, A. Jr. and Stinner, B. R.1991. Effect of strip intercropping and no tillage on some pests and beneficial invertebrates of corn in ohio. *Environmental Entomology,* **20** (5): 1251-1258.

Tripathi, D. M., Bisht, R. S. and Mishra, P. N. 2003. Bio-efficacy of some synthetic insecticides and bio-pesticides against black cutworm, *Agrotis ipsilon* infesting potato (*Solanum tuberosum*) in Garhwal Himalaya. *Indian Journal of Entomology,* **65** (4): 468-473.

Troester, S. J. 1982. Damage and yield reduction in field corn due to black cutworm (Lepidoptera: Noctuidae) feeding results of a computer simulation study. *Journal of Economic Entomology,* **75**: 1125-1131.

Uhan, T. S. 1989. Effect of several kinds of poisonous baits on the black cutworm (*Agrotis ipsilon* Hufn., Lepidoptera: Noctuidae) and cabbage plant damage. *Bulletin Penelitian Horticultura,* **17** (3): 24-30.

Vaishampayan, S. M. and Veda, O. P. 1981. Chemical control of black cutworm, *Agrotis ipsilon* (Hufn.) a pest of wheat and gram at Jabalpur. *Indian Journal of Entomology,* **43** (1): 29-34.

Vargas, E. and Abarca, G. 1998. Relationship between stress and development of entomopathogenic bacteria *Pantoea (Erwinia) agglomerans (herbicola)* and *Bacillus cereus* in several species of white grub complex (Coleoptera: Melolonthidae)

(*Phyllophaga* spp. *Anomala* spp. and *Cyclocephala* spp.) in Costa Rica. *Agronomia – Meso Americana,* **9** (2): 25-30.

*Verma, K. D. and Chandla, V. K. 1977. Chemical control of *Agrotis segetum* D and S on potato. *Pesticides,* pp. 53.

Verma, K. S. and Verma, A. K. 2002. Cutworm species associated with different crops in Himachal Pradesh. *Insect Environment,* **8**: 1-23.

Viji, C. P. and Bhagat, R. M. 2001. Bio-efficacy of some plant products, synthetic insecticides and entomopathogenic fungi against black cutworm, *Agrotis ipsilon* larvae on maize. *Indian Journal of Entomology,* **63** (1): 26-32.

Villalobos, F. J. 1999. The sustainable management of white grubs (Coleoptera: Melolonthidae) pest of corn in "Elciclo" Biosphere Reserve. Tamaulipas, Mexico. *Journal of Sustainable Agriculture,* **14** (1): 5-29.

Villani, M. G., Wright, R. J. and Baker, P. B. 1988. Differential susceptibility of Japanese beetle, oriental beetle and European chafer (Coleoptera: Scarabaeidae) larvae to five soil insecticides. *Journal of Economic Entomology,* **81** (3): 785-788.

Vitarana, S. I., Nagahaulla, S. M., Abeysinghe, L. S. and Vitana, S. B. 1997. Environment friendly pest control agents: use of bio 1020 to control white grub damage on tea. *Sri Lanka Journal of Tea Science,* **65** (1/2): 34-45.

Vyas, R. V., Yadav, D. N. and Patel, R. J. 1990. Studies on the efficacy of *Beauveria brongniartii* against white grub. *Annals of Biology,* **6**: 123-128.

Wang, K. 1994. A new technique for controlling autumn white grubs in peanuts. *Bulletin of Agricultural Science and Technology,* **3**: 27.

Wang, Q., Haung, G. H. and Yang, Y. G. 1983. Preliminary studies on nocturnal activities of adult black cutworms. *Insect Knowledge,* **20** (3): 106-109.

Whitford, F., Showers, W. B. and Kaster, L. V. 1989. Influence of actual and manual black cutworm (Lepidoptera: Noctuidae) damage on recovery and grain yield of field corn. *Journal of Economic Entomology,* **82** (6): 1773-1778.

Williamson, R. C. and Potter, D. A. 1997. Oviposition of black cutworm (Lepidoptera: Noctuidae) on creeping bent grass putting greens and removal of eggs by mowing. *Journal of Economic Entomology,* **90** (2): 590-594.

Wilson, H. R. and Eisley, J. B. 1992. Effect of tillage and prior crop on the incidence of five key pests on ohio corn. *Journal of Economic Entomology,* **85** (3): 853-859.

Wrightman, J. A., Brier, H. B. and Wright, G. C. 1994. The effect of root damage caused by simulated white grub attack on the growth, yield and water use of groundnut plants. *Plant and Soil,* **160** (2): 267-275.

Wynne, J. W., Keaster, A. J., Gerhardt, K. O. and Krause, G. F. 1991. Plant species identified as food source for adult black cutworm (Lepidoptera: Noctuidae) in North Western Missouri. *Journal of Kansas Entomological Society,* **64** (4): 381-387.

Yadav, B. R., Trivedi, P. C. and Yadava, C. P. S. 2000. Biocontrol efficacy of entomogenous fungus, *Metarrhizium anisopliae* against white grub (*Holotrichia consanguinea* Blanch.). *Journal of Mycology and Plant Pathology,* **30**: 416-418.

*Yadav, L. S., Choudhary, J. P. and Yadav, P. R. 1984. Relative abundance of important noctuid moths on light trap infesting chickpea in Haryana. *Bulletin of Entomology,* **25** (2): 103-110.

Yadav,B. R., Trivedi, P. C. and Yadava, C. P. S. 2004. Application of entomopathogen, *Metarhizium anisopliae* and *Beauveria bassiana* against egg, pupa and adult of white grub (*Holotrichia consanguinea* Blanch.). *Annals of Agriculture Biological Research,* **9** (1): 67-69.

*Yadava, C. P. S., Saxena, R. C., Mishra, R. K., Dadheech, L. N. and Poonia, F. S. 1978. Integrated control of white grub. *News Letter,* **2** (2-3): 23-26.

Yang-Jianquan; Li-Fang; Chen-Jia Hua;Shi-Quanxiu; Zhang-Yuzhen; Yang, J. Q., Li, F., Chen, J. H., Shi, Q. X. and Zhang, Y. Z. 2000. Virulence test of *Bacillus thuringiensis* on black cutworm. *Journal of Fujian Agricultural University,* **29** (1): 65-68.

Zaki, F. A. and Andrabi, A. D. 2001. Seed treatment by cedar wood extract and insecticides on different sowing dates to control black cutworm (*Agrotis ipsilon* Hufn.) in maize. *Applied Biological Research,* **1** (2): 143-147.

Zaki, F. A., Keen, F. A., Wani, A. R. and Rather, B. A. 2001. An integrated management strategy for black cutworm, *Agrotis ipsilon* (Hufnagel) infesting maize. *Oriental Science,* pp. 69-75.

Zaz, G. M. 1999. Incidence and biology of black cutworm, *Agrotis ipsilon* (Hufn.). *Applied Biological Research,* **1** (1): 67-70.

Zenger, J. T. and Gibbs, T. J. 2001. Impact of four insecticides on Japanese beetle (Coleoptera: Scarabaeidae) egg predators and white grub in turf grass. *Journal of Economic Entomology*, **94** (1): 145-149.

Zidan, Z. H., Amin, A., Gadallah, A. I., El-Malki-Kh-Gh. and Eissa, M. A. 1998. Performance and efficacy of certain pesticides on the black cutworm under laboratory and field conditions. *Annals of Agricultural Science Cairo*, **3**: 1069-1084.

---

* References not seen in original.