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ALL INDIA NETWORK PROJECT ON SOIL ARTHROPOD PESTS

ICAR

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2020-21

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NETWORK UNIT
SKN AGRICULTURE UNVIERSITY
RAJASTHAN AGRICULTURAL RESEARCH INSTITUTE
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CONTENTS

TECHNICAL PROGRAMME ALLOTTED TO VARIOUS CENTRES FOR THE YEAR 2020-21

WHITE GRUB

I. TRAP TECHNOLOGY

A. Species profiling of soil arthropods through light trap:

The light trap of NCIPM (with timer) will be installed for few months to monitor "scarabaied beetles" activity (according to agro-ecological region of each centre) and the light sources will be switched on for few hours every day during evening to catch the adults. Daily collection of beetles be sorted species wise and correlated with corresponding weather data pertaining to Temperature, Relative Humidity, Rainfall etc. The GPS will be used to record the geographical details with respect to distribution pattern of species restricted by altitude/latitude/longitude. LED will be included in the light trap. Beside this, data on species abundance and species richness are to be mentioned in the results. There is need for correlating the luminance values (Lux) of the light sources in light traps to beetle catches.

(All centres will do this experiment)

B. Population Monitoring of soil arthropods on host trees:

Survey will be carried out during peak outbreak of beetle, once in a month for monitoring of soil arthropod pest species in different host trees.

(All centres will do this experiment)

C. Population monitoring of damaging stage of soil arthropod pests and their extent of damage in different crops:

Visual monitoring of soil arthropod pest species and their extent of damage in different crops will be recorded. Survey will be carried out once in a month and extent of damage to different crops by soil arthropod pest species be reported periodically in MPR. All information should be supported by GPS locations.

(All centres will do this experiment)

D. Pheromone:

The concerned centre will isolate pheromone gland of the relevant species and solvent extract of glands as well as whole body; isolation of pheromone by confinement and rinse method and trapping of volatiles/pheromones by using suitable adsorbents. The extracts containing the pheromone will be analysed in GCMS to identify the compounds. Bioassay will be carried out with relevant species to establish the efficacy of identified compound.

Centres:

Durgapura: Use of pheromone nanotechnology to develop slow-release pheromone for the control of *Holotrichia consanguinea* in collaboration with NBAIR, Bangaluru.

Jorhat: *L. mansueta* (Already identified the two pheromonal compounds of both male and female of *L. Mansueta* and further will be tested in field.

Bangalore: *H. Serrata* (To be isolated)

Palampur: Extraction and identification of pheromones of *B. coriacea.*

Almora: The pheromone extracted from the white grub species like *Anomala bengalensis* and *Sophrophs sp.* will be tested for its attraction in the laboratory (Y maze olfactometer/wind tunnel olfactometer) and if found effective, will be tested in field using pheromone traps. Fresh extraction of the pheromones of *A. bengalensis* and *Sophrops sp.* will be made using air entrainment technique.

E. Monitoring of natural enemies of soil arthropods:

To monitor the prevalence of natural enemies (parasitoids, predators & pathogens) of major soil arthropods, seasonal soil sampling be done in the endemic pockets. Each centre will undertake the sampling method of each organism according to the cropping system. Natural enemies should be sent to **NBAIR, Bangalore, IARI**, **New Delhi** who will act as Nodal Officer on behalf of this group and will facilitated its identification and culturing and providing necessary details regarding receipt No. and code numbers.

(All centres will do this experiment).

F. Surveillance of white grub

For white grub surveillance by use of drone for monitoring and survey of white grub beetle and other soil arthropod pests on hire basis.

Methodology:

Drone camera can be operated in crop field during survey programme. The auto captured images and video clips can be downloaded and assessed for the incidence of soil insect pests. The technology can also be used for recording behavioral study to of insect/attraction of beetle to pheromonal lures and light traps/congregation of beetles in host trees.

Methodology: Drone camera (Model: DJI Phantom 4 with a flying capacity upto 2 KM upto 120 m height or any other available models) can be operated in crop field (sugarcane, ground nut, Potato field etc.) during survey programme. The auto captured images and video clips can be downloaded and assessed for the incidence of soil insect pests. The technology can also be used for recording behavioural study of insects /attraction of beetles to pheromonal lures and light traps/congregation of beetles in host trees especially in high altitude areas / detection of diseases etc.

(All centres will do this experiment).

II. MANAGEMENT OF WHITEGRUBS THROUGH CHEMICALS:

Insecticides are applied in soil, seed, and furrows/ through seed treatment if the sowing time coincides with the emergence of beetles. If the crops are sown much earlier than beetle emergence, the insecticides are applied by soil drenching method in standing crops at the time of occurrence of eggs and neonate first instar grubs. In areas where both the situations occur (crops sown earlier than monsoon and crops sown with the onset of monsoon coinciding with beetle emergence) trials should be laid out separately for both the situations. In all the cases the critical timing of pesticide application should be according to the presence of eggs and first instar grubs for targeting the key species of each region. Pesticides residues analysis and B:C should also be given. Correlation of grub population with damage needs to be established. Name of species should be mention in the title of the trial as there is different response of different species against each insecticide.

A. Evaluation of granular insecticides against white grub:

S.N.	Treatments	Hills	Plains
1.	Carbofuran 3G	750 g *a.i.*/ha	750 g *a.i.*/ha
2.	Clothianidin 50 WDG	120 g *a.i.*/ha	120 g *a.i.*/ha
3.	Fipronil 0.3G	-	50 g *a.i.*/ha
4.	Thiamethoxam 25WG	80 g *a.i.*/ha	80 g *a.i.*/ha
5.	Imidacloprid 70 WG	300 g *a.i.*/ha	300 g *a.i.*/ha
6.	Chlorantraniliprole 0.4% GR*	-	100 g *a.i.*/ha
7.	Fifronil40%+Imidacloprid 40%WG*	300 g/ha	300 g/ha
8.	Untreated check		

Crops

Potato : Jorhat (pre-sowing), Palampur (post-sowing), Pantnagar
Soyabean : Pantnagar (pre-sowing as well as post-sowing)
Groundnut : Durgapura
Sugarcane : Kolhapur, Ghaziabad, Pantnagar

B. Evaluation of some insecticides against white grub:

S.N.	Treatment	Hill		Plain	
		Seed/soil furrow application (At sowing)	Drenching in standing crop (Post sowing)	Seed/soil furrow application (At sowing)	Drenching in standing crop (Post sowing)
1.	Imidacloprid 17.8 SL	48 g *a.i.*/ha	60 g *a.i.*/ha	-	-
2.	Thiamethoxam 30 FS	80 g *a.i.*/ha	150 g *a.i.*/ha	80 g *a.i.*/ha	150 g *a.i.*/ha
3.	Fipronil 5SC	-	-	100 g *a.i.*/ha	150 g *a.i.*/ha
4.	Clothianidin 50 WDG	80 g *a.i.*/ha	125 g *a.i.*/ha	80 g *a.i.*/ha	125 g *a.i.*/ha
5.	Imidacloprid 600 FS	500 g *a.i.*/ ml/ ha	1000 g *a.i.*/ ml/ha	500 g *a.i.*/ ml/ha	1000 g *a.i.*/ ml/ ha
6.	Chlorantraniliprole 18.5 SC*	-	-	500 ml/ha	500 ml/ha
7.	Fifronil 40%+Imidacloprid 40%WG*	3 g per kg seed	300 g/ha	3 g per kg seed	300 g/ha
8	Untreated check				

Crops

Potato, Rajmash : Palampur (both), Pantnagar
Arecanut : Bangalore (Entire Garden covering)
Soyabean : Pantnagar, Kolhapur
Groundnut : Durgapura, Kolhapur
Colocasia : Jorhat
Sugarcane : Kolhapur, Ghaziabad, Pantnagar (Sett treatment)

III. MICROBIAL CONTROL OF WHITE GRUBS

A. Management of White grubs through Bio-control Agents

Treatments:

S. N.	Name of bioagent	Dose
1.	*Heterorhabditis indica*	0.5g/m^2
2.	*Steinernema glassari*	0.5g/m^2
3.	*Metarhizium anisopliae**	0.5g/m^2
4.	*Beauveria bassiana**	0.5g/m^2
5.	*H. indica + M. anisopliae**	0.5g/m^2
6.	*H. indica + B. bassiana**	0.5g/m^2
7.	*S. glassari + M. anisopliae**	0.5g/m^2
8.	*S. glassari + B. bassiana**	0.5g/m^2
9.	EPN *(H. indica)* infected galleria larvae supplied by FARMER	3 galleria/m^2
10.	EPN*(S.glassari)*infected galleria larvae supplied by FARMER	3 galleria/m^2
11.	Local isolates at centre	-
12.	Check	

***Requirement should submit at least one month in advance**

Crops

Potato : Palampur, Almora and Pantnagar
Sugarcane : Bangalore
Arecanut : Bangalore
Soyabean : Pantnagar
Groundnut : Durgapura
Green gram : Jorhat
Sugarcane : Kolhapur, Ghaziabad, Pantnagar

The material will be supplied by Dr. D. Ramanujam, NBAIR, Bengaluru and Dr. J. P Singh, FARMER (Ghaziabad) along with detailed protocol and detailed methodology. Application of biopesticides should coincide with mass emergence of beetles after first shower of monsoon. Almora centre send VLBA-1, 2, 3 &4 Last year. In microbial trial “CFU” may be used in place of number of spores for quantity of treatment.

IV. Management of soil arthropods through IPM

S.N.	Treatments	Dose
IPM-I	Application of *Beauveria bassiana* (mix with FYM and apply in furrow before sowing)	0.5 g/m^2
	Seed treatment with imidacloprid 600 FS	5.0 g/kg seed
	*Placing of earthen pots in the field with shelled cobs of maize (4-5 days after sowing)	50/ha
	Drenching of Imidacloprid 17.8SL (50 days after sowing)	600 ml/ha
IPM-II	Application of *Metarhizium anisopliae* (mix with FYM and apply in furrow before sowing)	0.5 g/m^2
	Seed treatment with imidacloprid 600 FS	5.0 g/kg seed
	*Placing of earthen pots in the field with fresh cow dung (4-5	50/ha

	days after sowing)	
	Drenching of Fifronil 5 SC (50 days after sowing)	3.0 lit./ha
IPM-III	Application of *Heterorhabditis indica* (mix with FYM and apply in furrow before sowing)	0.5 g/m^2
	Seed treatment with imidacloprid 600 FS	5.0 g/kg seed
	*Placing of earthen pots in the field with wooden pieces (4-5 days after sowing)	50/ha
	Drenching of Fifronil 40%+Imidacloprid 40% WG (50 days after sowing)	500ml/ha
IPM-IV	Untreated check	-

* Only for termite attraction

(All centres will do this experiment)

Crops

Potato : Palampur, Almora and Pantnagar
Sugarcane : Bangalore
Soybean : Pantnagar
Groundnut : Durgapura
Green gram : Jorhat
Sugarcane : Kolhapur, Ghaziabad, Pantnagar

B. Study of local isolates of Entomopathogenic microbes for their Infectivity against soil arthropod pests:

The existing isolates would be screened against concern species and the active isolates will be identified. These would be further tested as many times as possible to identify the most consistently pertaining (relatively high activity isolates). Two to three such isolates would be field tested.

IV. WHITE GRUB TAXONOMY (NBAIR, Bangalore and UAS, GKVK, Bengaluru):

A. Compilation of literature on Scarabs of India- Continued

B. Development of Taxonomic keys for Scarabs of India

C. Description of White grubs of Karnataka, Tamil Nadu, Telangana, Kerala, Himachal Pradesh, Eastern states, Uttarakhand, Utter Pradesh and Rajasthan in phased manner

V. Development of Distribution maps of white grub and termite pests of India

Following centre will develop distribution map of different white grub species of different states as mentioned against their centre:

(A) Durgapura: Rajasthan, Gujarat and MP
(B) Palampur: HP, JK, Punjab and Haryana
(C) Pantnagar: Uttrakh and Delhi
(D) Kolhapur: Maharashtra, Goa and Odessa
(E) Bangalore: Karnataka, AP, Telangana, Tamil Nadu and Kerala

(F) Jorhat: Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura
(G) Almora: Uttrakhand

All the centres should complete the work in the supervision of Dr. Sreedevi, NBAIR, Bengaluru (Nodal Officer) and submit the map detail within six months to her.

Dr. Mahapatro, IARI and Dr. Badal AAU, Jorhat, will develop distribution map of different termite species of India within three months and submit to Network Coordinator.

VI. SOCIAL ENGINEERING

A. For beetle management all centres will survey and suggest endemic areas of white grub infested districts.

The prominent tehsils with respect to prevalence of white grubs will be sort listed and further 4-5 villages will be selected on the basis of cropping pattern and host trees. Campaigns will be organized to educate the people about the adult management with light and/or pheromones. Emphasis will be on pre-monsoon training to the villagers including children as well as women. Constitution village task forces to tackle the beetle management programme. With onset of monsoon message will be delivered to the villagers through mobile SMS involving local KVKs/department of Agriculture about the importance of spraying of host trees and installation of lures.

TERMITE

I. MANAGEMENT OF TERMITES THROUGH CHEMICALS

A. Through seed treatment

S.N.	Treatments	Dose (per kg seed)
1.	Thiamethoxam 25 WG	3.0 g
2.	Imidacloprid 17.8 SL	3.0 ml
3.	Acephate 50% + imidacloprid 1.8%	4.0 g
4.	Fifronil 5 SC	10.00 ml
5.	Thiamethoxam 30 FS	3.0 ml
6.	Imidacloprid 600 FS	6.5 ml
7.	Clothianidin 50 WDG	2 g
8.	Fifronil 40%+Imidacloprid 40%WG*	3.0 g
9.	Chlorantraniliprole 18.5 SC*	2.0 ml
10.	Untreated check	-

Crops

Wheat : Palampur, Pantnagar
Wheat, Chickpea, Groundnut : Durgapura
Groundnut : Bengaluru

***New entry**

B. Through drenching

S.N.	Treatments	Dose per ha
1.	Thiamethoxam 25 WG	600 g
2.	Imidacloprid 17.8 SL	360 ml
3.	Acephate 50% + imidacloprid 1%	1250 g
4.	Fifronil 5 SC	3.0 lit.
5.	Thiamethoxam 30 FS	600 ml
6.	Imidacloprid 600 FS	1042 ml
7.	Clothianidin 50 WDG	300 g
8.	Fifronil 40%+Imidacloprid 40%WG*	500 g
9.	Chlorantraniliprole 18.5 SC*	500 ml
10.	Untreated check	-

Crops

Wheat : Palampur, Pantnagar

Wheat, Chickpea, Groundnut : Durgapura

C. Through sett treatment in sugarcane crop

S.N.	Treatments	Dose (per litre water)
1.	Thiamethoxam 25 WG	1 g
2.	Imidacloprid 17.8 SL	1ml
3.	Acephate 50% + imidacloprid 1%	1 g
5.	Fipronil 5 SC	1 ml
6.	Thiamethoxam 35 FS	1 ml
7.	Imidacloprid 600 FS	1 ml
8.	Clothianidin 50 WDG	1 g
9.	Fifronil 40%+Imidacloprid 40%WG	1 g
10.	Chlorantraniliprole 18.5 SC	0.5ml
12.	Untreated check	-

Centre: Jorhat, Kolhapur, Ghaziabad, Bengaluru and Pantnagar

D. **Drenching in standing sugarcane crop through water**

S.N.	Treatments	Dose(per ha)
1.	Imidacloprid 600 FS	800 ml
2.	Imidacloprid 17.8 SL	350 ml
3.	Fipronil 5 SC	2 litre
4.	Imidacloprid 70 WS	160 ml
5.	Clothianidin 50 WDG	250 g
6.	Chlorpyriphos 20EC	4 litters
7.	Chlorantraniliprole 18.5 SC	500 ml
8.	Untreated check	-

Centre: Jorhat, Kolhapur, Ghaziabad, Bengaluru and Pantnagar

CUTWORM

I. Monitoring of Cutworm

Palampur and Pantnagar centres will monitor the population of the cutworm through light trap and pheromone traps.

II. Management of cutworms:

(A) Field evaluation of pre-sown application of different granular insecticides against cutworm

S.N.	Treatments	Dose
1.	Imidacloprid 17.8.SL	60 g *a.i.*/ha
2.	Carbofuran 3G	750 g *a.i.*/ha
3.	Clothianidin 50 WDG	120 g *a.i.*/ha
4.	Fipronil 0.3G	50 g *a.i.*/ha
5.	Thiamethoxam 25WG	80 g *a.i.*/ha
6.	Untreated check	-

Crop

Cabbage: Palampur

Potato: Pantnagar

(B) Field evaluation of post-sown application of different granular insecticides against cutworm

S.N.	Treatments	Dose
1.	Imidacloprid 17.8.SL	60 g a. i./ha
2.	Carbofuran 3G	750 g a.i./ha
3.	Clothianidin 50 WDG	120 g a.i./ha
4.	Fipronil 0.3G	50 g a.i./ha
5.	Thiamethoxam 25WG	80 g a.i./ha
6.	Untreated check	-

Crop

Cabbage: Palampur

Potato: Pantnagar

(C) Field evaluation of post planting application of different liquid insecticides against cutworm.

S.N.	Treatments	Dose
1.	Imidacloprid 17.8.SL	60 g a. i./ha
2.	Carbofuran 3G	750 g a.i./ha
3.	Clothianidin 50 WDG	120 g a.i./ha
4.	Fipronil 0.3G	50 g a.i./ha
5.	Thiamethoxam 25WG	80 g a.i./ha
6.	Untreated check	-

Crop

Cabbage: Palampur

Potato: Pantnagar

LOCATION SPECIFIC TRIALS

Each centre will conduct experiments of local importance based on the feedback received from different sources.

Durgapura Centre

A. To explore the use of nanotechnology to develop slow-release pheromone for the control of *Holotrichia consanguinea* in collaboration with NBAIR, Bangaluru.

B. Biological suppuration of termite in groundnut crop.

C. Management of termite through some chemicals applied as seed dresser and standing crop of chick pea/wheat.

Jorhat Centre

Experiment No.1: Designing and field testing of few promising attractants against red ant, *Dorylus orientalis* in potato

Experimental Layout:

Design: Randomized Block Design
Number of treatments: 6
Replication: 4
Individual plot size: 4×3 sq.m
Variety: "*Kufri Jyoti*"

Details of the treatments:

T_1: Rice bran oil + Boric Acid based attractants
T_2: Sugarcane trash + Boric Acid based attractants
T_3: Honey + Boric Acid based attractants
T_4: Dog biscuits + Boric Acid based attractants
T_5: Chlorpyriphos 20 EC @ 3ml/ lit as insecticidal check
T_6: Control

Methodology:

Potato crop (variety: *Kufri Jyoti*) will be grown by following recommended agronomic package of practices of Assam. The four individual bait materials (T_1-T_4) @ 25 ml/bait or g/bait will be loaded in locally available cheap bait stations. The bait stations will be randomly placed at 15 cm depth and diagonally at a distance of 2 meter before the 1st and 2nd earthing up operation in the plots. Chlorpyriphos 20 EC @ 3 ml/lit will also be treated in furrows as an insecticidal check before sowing of potato tubers and one control plot will also be kept.

Observations to be recorded:

Red ant populations will be monitored by counting the number of ants attracted to each bait stations and the data will be analysed through ANOVA.

Experiment No. 2: Nutritional profiling of some edible soil dwelling insects of Northeast India

The following soil dwelling insects will be collected through light trap and scouting from the diverse habitats. Collected specimens will be sorted out, sundried and powdered form of the samples will be used for analysing different parameters by following standard protocols.

Field cricket (*Brachytrupes portentosus*), Mole cricket (*Gryllotalpa africana*), Grasshopper (*Ruspolia* sp.) and Grasshopper (*Oxia* sp.)

Parameters to be studied:

S. No.	Parameters	Methodologies to be followed
1.	Proximate composition	Carbohydrate (A.O.A.C, 1984), Fat, Protein (A.O.A.C, 2000) Fibre and Ash (A.O.A.C. 2000)
2.	Elemental composition	Na, K, Ca, Mg, P, Fe, Zn, Cu and Mn (John C. and Van, L., 1980**).**
3.	Fatty acid profiling	Both essential and non-essential fatty acids (AOAC 20thEdn, 2016)
4.	Amino acid profiling	Both essential and non-essential amino acids (Bidlingmeyer*et al.*, 1987)
5.	Antioxidant properties	Phenol content (Singleton and Rossi, 1965), Flavonoid content (Yanping*et al.* 2004)
6.	Antinutritional properties	Tannin (AOAC, 1975)

Palampur Centre

1. Management of adults of white grubs

A. Evaluation of insecticides against beetles of *Brahmina coriacea*

S. No	Name of chemical
1.	Chlorantraniliprole 18.5 SC
2.	Bifenthrin10EC
3.	Clothianidin 50 WDG
4.	Thiamethoxam 25 WG
5.	Imidacloprid 17.8 SL
6.	Chloropyriphos 20 EC

B. Interaction effects of entomopathogenic fungi with insecticides

Biocontrol agents	Insecticides
1. *Beauveria bassiana*	1. Imidacloprid 17.8 SL
2. *Metarhizium anisopliae*	2. Chlorpyriphos 20 EC
	3. Clothianidin 50 WDG

2. Molecular characterization of *Melolontha* sp.

For phylogenetic analysis mitochondrial and nuclear gene will be amplified and sequenced using different primers. Amplified PCR products will be cloned and sequenced using standard molecular biology tools. Sequences thus obtained will be examined for sequence homology with the sequences at NCBI database employing BLAST N (https://blast.ncbi.nih.gov/Blast.cgi?PAGE-TYPE=BlastSearch).

3. Characterization of pheromone of *B. coriacea* beetles

The pheromone glands from female beetles of *B. coriacea*will be removed. For dissection of pheromone glands, the beetles will be collected at night from their host trees in the first week of June. After dissection, the glands will be put into glass ampoules in solvent (Dichloromethane) and then the glass ampoules will be sealed, labeled and kept in deep freezer. The extract will be further characterized.

Bangalore Centre:

A. Development of Distribution maps of white grub pests of crops in Karnataka

B. Evaluation of bio-agents against white grubs

1. Evaluation of *Beauveria bassiana* isolates maintained at Bengaluru centre against sugarcane and arecanut white grubs.

2. Evaluation of NBAIR, Bengaluru isolates of *Beauveria bassiana* and *Metarhizium anisopliae* against sugarcane and arecanut white grubs and termites in sugaracane.

C. Demonstration and popularization of insecticide free management option for arecanut white grubs such as digging and removal of grown-up larvae.

D. Digital documentation of species of scarabs available at Bengaluru centre repository.

Pantnagar Centre

A. Organic methods for the management of white grubs in crops grown in hills of Uttarakhand (Soyabean, Sugarcane and Potato)

B. Organic methods for the management of cut worms in crops grown in hills of Uttarakhand (Soyabean, Sugarcane and Potato)

Kolhapur Centre

1. Distribution of the white grub species in Western Maharashtra
2. Biology of *Leucopholis lipidophora* and *Holotrichia serrata* under the changing climatic conditions
3. Bio efficacy of Entomopathogenic fungi against *L. lipidophora* infesting Sugarcane
4. Efficacy of new molecules of insecticides against the *H. serrata* infesting Soya been/ Groundnut
5. Bio-efficacy of EPN against the *H. serrata*

Ghaziabad Centre

1. Scaling up of effective dose of EPN infected *Galleria* Cadaver for the control of White Grub on Sugarcane and other crops.
2. Comparative study of *Beauveria bassiana*, *Metarhizium anisopliae* using alone and in combination of both bioagents mixed with compost/FYM at the time of sowing and in standing crop by drenching for control of White Grub on Sugarcane.
3. Isolation and identification of EPN and EPF from local soils.
4. Comparative assessment of efficacy of *Heterorhabditis indica* for control of major species of White Grub on Sugarcane and other crops.
5. Study of Biology of major species of White Grub prevailing in Western U.P.
6. Isolation of Phenomenal Compounds based on Air Entrainment Technology

Almora centre

1. Molecular phylogeny of major Melolonthinae and Rutelinae whitegrubs using mitochondrial genes

Target genes: Mitochondrial gens of evolutionary importance viz., Cytochrome oxidase I (COI) and Cytochrome b (Cytb). Sequence variation, molecular phylogeny and evolutionary divergence of major species of Rutelinae and Melolonthinae white grubs native to Uttarakhand will be studied.

2. Studies of gut micro flora of major white grub species of Uttarakhand

Identification of midgut micro flora diversity of major whitegrub species of Uttarakhand viz., *Anomala dimidiata*, *A.bengalenesis* and *Holotrichia setticollis*.
Characterization of chitinolytic and cellulolytic bacteria from isolated micro flora and identification of bioactivity.

WHITE GRUBS

TRAP TECHNOLOGY

A. Species Profiling of Soil Arthropods through Light trap

RARI, Durgapura

The light trap of known light range was operated for fixed few months of scarabaeid activity (from March to September) and during the active adult period. Daily collection of beetles was sorted out species wise and correlated with corresponding weather data pertaining to temperature Relative Humidity Rainfall etc. The GPS will be used to record the date pertaining to geographical details to find the distribution pattern of species restricted by altitude/latitude/longitude.

Methodology: The light trap of known light range was operated for fixed few months of scarabaeid activity (from March to September) and during the active adult period. Daily collection of beetles was sorted out species wise and correlated with corresponding weather data pertaining to temperature, Relative Humidity & Rainfall etc. The GPS will be used to record the date pertaining to geographical details to find the distribution pattern of species restricted by altitude/latitude/longitude.

For the monitoring of soil arthropods, the light traps were installed at different locations in Research farm of Rajasthan Agricultural Research Institute, Durgapura, Jaipur. During the season from March to September the light trap catches of soil arthropods were recorded separately for each light trap installed. On perusal of the data it was observed that this year again species composition of the soil arthropods trapped in light trap was similar as compared to previous seasons. No new species was observed in the light trap catches. Among the coleopteran the species belonged to families, six from melolonthnae, three from rutelinae and one from eateridae. Among the lepidopterians one species belonged to family noctuidae was trapped during the season. **Table 1** showed that maximum numbers (2805) of beetles of ***Maladera insanabillis*** were caught during this period. However, the peak emergence was in the month of July where maximum ***Maladera insanabillis*** beetles were trapped 809. Then after July the emergence decline and only 128 beetles were caught in trap. Next in sequence of higher emergence of beetles was whitegrub species ***H. consanguinea***. The total number of beetles collected during entire period was 2400. The emergence of ***H. consanguinea*** started in the month of June and continued till August. The peak emergence was noticed in the month of July where 1733 beetles were trapped.

The relative abundance of predominant species, *H. consanguinea* was 32.62 and 32.39 per cent and that of *M. insanabilis* was 42.80. In the light traps the catches were low in number for the other species like *Maladera carinata* (940 ra. 14.34%) followed by *H. serrata and Maladera* species with 212, ra., 3.23%, & 51, ra. 0.77% respectively9 (Fig 1).

Out of six malolonthids, the two species, *Maladera* species and *Schizonycha* species were emerged in low population level. Their relative abundance was 0.77 and 0.10 % only at respectively.

The species *Anomala bengalensis, Pachyrrhinadoratus frontatus* and *Anomala dimidiata* belonging to family Rutelinae were caught in small numbers in the light traps. The population of *A. bengalensis* was 150 with relative abundance 2.28% in light traps. The peak emergence was in the month of July. The population of *A. dimidiata* was 33 (r.a. 0.50%) beetles with peak emergence in the month of July.

In the light trap specimens of wireworm belonging to family elateridae and *Agrotis* sp., of cutworm belonging to family noctuidae of Lepidoptera were also observed to be attracting in low numbers.

The maximum emergence of predominant species *H. consangunea* of the area was in the month of July due to monsoon rains begun in this month only.

Conclusion: Light trap monitoring of whitegrub beetles was done at two locations at Research farm of RARI, Durgapura. It was noted that cumulative count of both the traps during the entire period from March to September was maximum in case of ***Maladera insanabillis*** (2805 beetles) and it was predominant species during the season. It was followed by ***H. consanguinea*** with 2400 catches. Rest of the species was low in number such as *Holotrichia serrata, Maladera carinata, Anamola bengalensis, Anolala dimidiata,* and *Schizonica*. This year maximum catches of ***H. consanguinea*** were recorded in the month of July and then the population decline. This was because the good monsoon rains begun in the first week of July. The same trend was also recorded in rest of the species.

Table 1: Beetles of different species of white grub trapped in the light trap during March to September 2020-21 at RARI, Durgapura.

Sr. No.	Name of species	Number of beetle collected								Relative abundance (%)
		March	April	May	June	July	Aug.	Sept.	Total	
	A Melolonthinae (6)									
1	***H. consanguinea***	**-**	**-**	-	502	1733	165	-	2400	**36.62**
2	***H. serrata***	-	-	-	09	203	0	-	212	3.23
3	***Maladera carninata***	-	52	179	267	354	63	25	940	14.34
4	***Maladera insanabillis***	19	199	436	611	809	603	128	2805	**42.80**
5	***M. species***	**-**	**-**	-	06	33	10	02	51	0.77
6	***Schizonicha sp***	**-**	**-**	-	-	4	02	-	06	0.10
	B Rutelinae (3)									
1	***Anomala bengalensis***	**-**	**-**	-	29	95	25	01	150	2.28
2	***A. dimidiata***	**-**	**-**	-	05	22	06	-	33	0.50
3	***Pachyrrhinadoretus frontatus***	**-**	**-**	-	-	06	01	-	07	0.10
	C Elateridae (1)		**Total**	-	-	-	-	-	6553	-
1	**Wireworm**	**-**	**-**	-	06	23	03	02	34	-
	D Noctuidae (Lepidoptera (1)									
1	***Agrotis* sp.**	-	04	08	17	14	05	01	49	**-**
	Rainfall (mm)	-	-	-	37.3	230.5	31.1	65.4	-	-

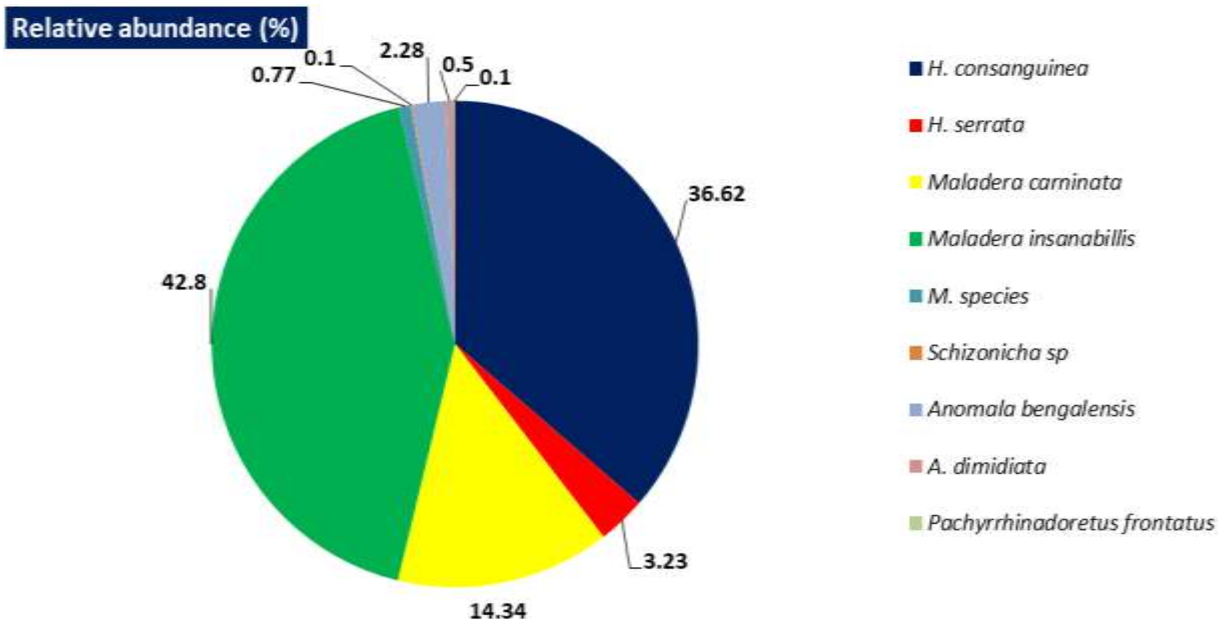


Fig: 1 Relative abundance of beetles throughout season (kharif, 2020-21)

AAU, Jorhat

The progress on species profiling of scarab beetles through light trap during 2020 is highlighted below:

A.1. Light trap studies for the collection of scarab beetles:

A light trap was set up at the Instructional Livestock Farm, Assam Agricultural University, Jorhat (26.7227° N, 94.1957° E) for the collection of scarab beetles from May to September, 2020 (Fig. 2). The number of beetles trapped were recorded and subsequently species wise sorting was carried out. Maximum numbers of beetles (1360 nos.) were recorded during the month of June, 2020 (Table 2) and afterwards the beetles showed a decreasing trend and reached the lowest population during September (159 nos.).

A.2. Correlation of scarab beetle population with different meteorological parameters:

Different meteorological parameters *viz.*, temperature (maximum and minimum), relative humidity (morning and evening), total rainfall, number of rainy days, bright sunshine hours and wind speed were correlated with the monthly population of scarab beetles. All the parameters exhibited non-significant correlation with the monthly population of the beetles during the study period (Table 3, Fig. 3).

A.3. Species profiling of scarab beetles:

The study on relative abundance of light trapped catches of scarab beetles indicated that *Apogonia ferruginea* was the most predominant species and contributed 42.42 per cent out of the total number of beetles trapped during the period of investigation. The second most abundant species was *Heteronychus sp.* (27.26%) followed by *Anomala chlorosoma* (14.40%) (Fig. 4). The other phytophagous scarab beetles which were found in lower numbers were

Anomala chloropus, Sophrops irridipennis, Maladera insanabilis, Adoretus aerial, Holotrichia serrata etc.

Table 2. Light trap catches of scarab beetles along with the meteorological parameters during active season from May to September, 2020

Months	Beetles collected	Temperature (°C)		Relative Humidity (%)		Total Rainfall (mm)	Rainy days	Total BSSH (hr.)	Wind Speed (Km/h)
		Max^{m}	Min^{m}	Morn.	Even.				
May	443	29.8	21	92	72	236.4	13	128.5	2
June	**1360**	31.5	24.3	95	78	410.3	19	112.5	2.2
July	925	31.5	25	97	81	370.1	19	57.7	1.9
August	315	33.6	25.6	93	75	325.7	14	148.3	1.6
Sept.	**159**	32.4	24.8	95	77	210.3	17	105.1	1.3

March-April: Collection could not be done due to COVID-19 pandemic

Table 3. Correlation of scarab beetle population with different meteorological parameters during 2020

Meteorological parameters	Correlation coefficient (r)
Maximum temperature (°C)	0.741 NS
Minimum temperature (°C)	0.533 NS
Morning relative humidity (%)	0.029 NS
Evening relative humidity (%)	0.036 NS
Total rainfall (mm)	0.527 NS
Rainy days	0.236 NS
Total bright sunshine hour (hr.)	0.199 NS
Wind speed (km/hr)	0.429 NS

NS: Non-Significant

Fig. 2. Collection of scarab beetles by operating light trap

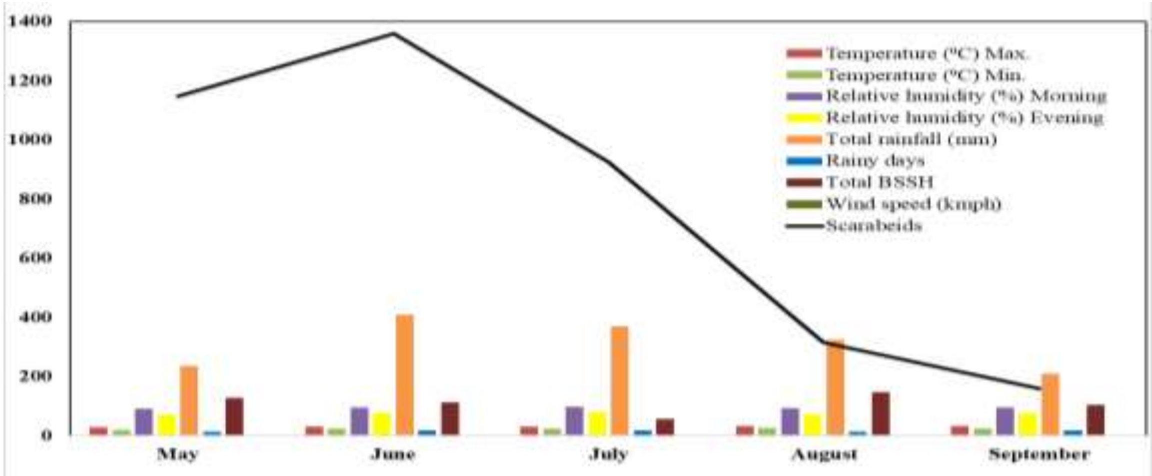


Fig. 3. Light trap catches of scarab beetles along with the meteorological parameters during May to September, 2020

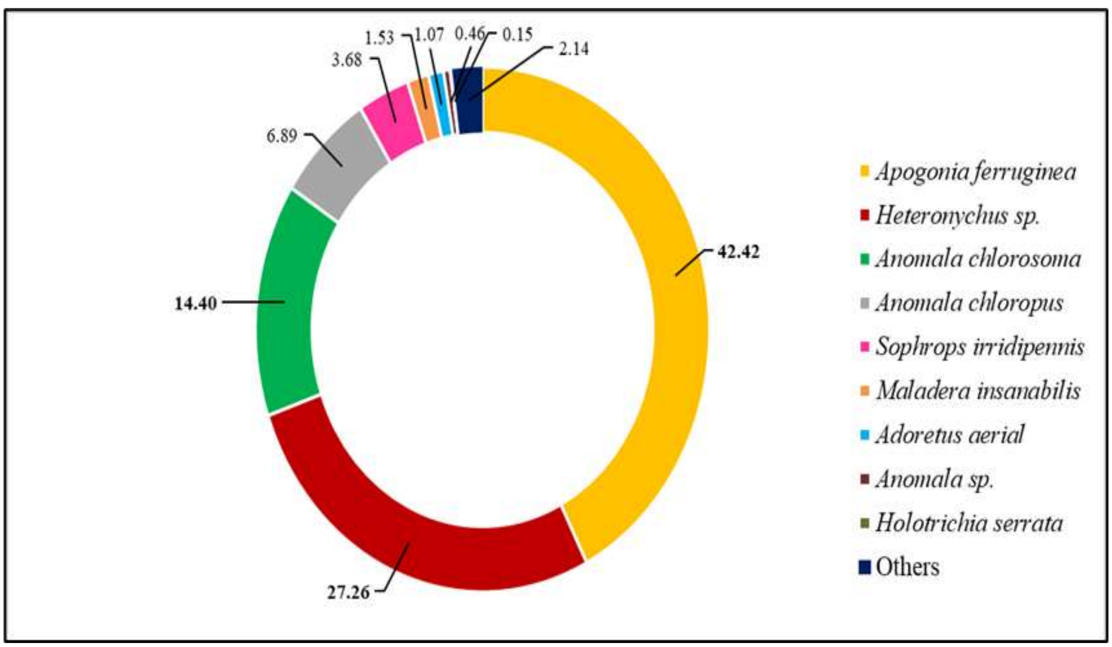


Fig. 4. Species profiling of scarab beetles during 2020

CSK-HPKV, Palampur

i) Monitoring of scarab beetles on light traps during 2020: During 2020, beetle collection on light trap was done at Palampur, Kullu, Badagaon and Chailchowk. The data pertaining to these locations are presented here under.

a) Palampur: At Palampur, 12 species were identified on light trap during May-September, 2020. During May, the population of scarab beetles was comparatively very low. In June, *A. varicolor* showed peak activity on light trap (197 beetles) followed by *M. thomsoni* (140 beetles). The population of *A. lineatopennis, A. dimidiata, B. coriacea, H. longipennis, H. sikkimensis, M. furcicauda*, *M. indica*, *M. insanabilis*, *M. cotesi*, and *Onthophagous* spp, ranged from 0-98 beetles during June. The total beetles catch was highest in case of *A. varicolor* (306 beetles) followed by *M. thomsoni* (175 beetles). There was gradual decline in beetle catch during July for most of the species, whereas in case of *M. furcicauda* and *M. indica*, the catch was maximum in July (70 beetles) and Aug (55 beetles), respectively. Overall beetles catch was maximum in June (59.76%) followed by July (28.63%). *A. varicolor* showed maximum dominance (27.20 %), followed by *M. thomsoni* (15.56%) (Table 4). The frequency of occurrence was highest in case of *H. longipennis* (100 %).

Table 4. Abundance and frequency of beetles on light trap at Palampur during 2020

Species	**Number of beetles collected in 2020**					**Total catch**	**Dominance (%)**	**Frequency (%)**
	May	Jun	Jul	Aug	Sept			
A. lineatopennis	2	98	23	4	0	127	11.29	80
A. varicolor	1	197	87	21	0	306	27.20	80
A. dimidiata	0	5	2	1	0	8	0.71	60
B. coriacea	0	4	3	1	0	8	0.71	60
H. longipennis	2	62	15	2	1	82	7.29	100
H. sikkimensis	0	33	26	1	0	60	5.33	60
M. furcicauda	0	25	70	4	2	101	8.98	60
M. indica	0	0	8	55	21	84	7.47	60
M. insanabilis	2	87	54	9	0	152	13.51	80
M. thomsoni	2	140	32	1	0	175	15.56	80
M. cotesi	1	36	11	1	0	49	4.36	80
Onthophagous spp.	0	8	2	1	0	11	0.98	60
Total	10	695	333	101	24	1163		

Table 5. Alpha diversity of scarab beetles on light trap at Palampur

Diversity indices	Values of diversity indices
Shannon index (H')	2.13
Simpson's index of diversity (D)	0.86
Simpson's reciprocal index (1/D)	1.17
Pielou's evenness index (J')	0.86

The value of Simpson's index of diversity (D= 0.86) was high, whereas the value of Simpson's reciprocal index was low (1/D= 1.17). These values indicate high species diversity. The Shannon index (H') was calculated to be 2.13. At Palampur, only 12 species were collected, but there was no dominance of a single species. The Pielou's evenness index (J') was calculated to be 0.86 which showed reasonable evenness and moderate variation in community between different species of scarab beetles in Palampur area (Table 5.).

b) Kullu: At Kullu, total 09 species were collected on light trap. *A. linneatipennis* (12), *B. coriacea* (19), *B. flavosericea* (11), *H. longipennis* (17), *M. insanabilis* (32) and *M. thomsoni* (65) showed peak activity during June, whereas *M. cuprescens* (34), *M. furcicauda* (09) and *A. rufiventris* (11) showed their peak activity in July. During August, only *M. cuprescens* (18 beetles) registered higher catch. The leading species at Kullu was *M. thomsoni* constituting 28.44 per cent of total beetle catch. The frequency of occurrence was 100 per cent for *A. linneatipennis* and *M. cuprescens*. The overall beetle catch was maximum in June (54.44 %), followed by July (36.88 %), and August (9.06 %) (Table 6).

Table 6. Abundance and frequency of Scarabaeid beetles on light trap at Kullu during 2020

Species	Number of beetles collected during 2019				Total catch	Dominance (%)	Frequency (%)
	Jun	Jul	Aug	Sept			
A.linneatipennis	12	7	1	1	21	6.56	100
A. rufuventris	5	11	1	0	17	5.31	75
B. coriacea	19	11	1	0	31	9.69	75
B. flavosericea	11	8	2	0	21	6.56	75
H. longipennis	17	3	1	0	21	6.56	75
M. insanabilis	32	10	1	0	43	13.44	75
M. thomsoni	65	25	1	0	91	28.44	75
M. cuprescens	10	34	18	1	63	19.69	100
M. furcicauda	0	9	3	0	12	3.75	50
Total	171	118	29	2	320		

Table 7. Alpha diversity of scarab beetles on light trap at Kullu

Diversity indices	Values of diversity indices
Shannon index (H')	1.46
Simpson’s index of diversity (D)	0.95
Simpson's reciprocal index (1/D)	1.05
Pielou’s evenness index (J')	0.66

The Shannon index (H') was computed to be 1.46. The Simpson’s index of diversity (D) and Simpson’s reciprocal index (1/D) were calculated as 0.95 and 1.13, respectively, indicating low dominance of single of scarab beetles in Kullu area. The Pielou’s evenness index (J') was calculated to be J' = 0.66 indicating higher evenness with less variation in community between collected species of scarab beetles in Kullu (Table 7).

c) Badagaon: Total six species were recorded on light trap at Badagaon and *P. fullo* was the most predominant species comprising 29.27 per cent of total beetle catch. Maximum numbers of 19 were collected in August and the frequency of its occurrence was recorded to be 100 per cent. The frequency of occurrence of *H. sikkimensis, M. insanabilis* and *M. passerinii* was observed to be 100 per cent. Overall catch of beetles was maximum in July (45.53 %) and June (32.52 %) as shown in (Table 8).

Table 8. Abundance and frequency of beetles on light trap at Badagaon during 2020

Species	Number of beetles collected in 2019			Total catch	Dominance (%)	Frequency (%)
	Jun	Jul	Aug			
A. rufuventris	1	11	0	12	9.76	66.66
A. dimidiata	2	2	0	4	3.25	66.66
H. sikkimensis	10	11	2	23	18.70	100
M. insanabilis	17	12	2	31	25.20	100
M. passerinii	5	8	4	17	13.82	100
P. fullo	5	12	19	36	29.27	100
Total	40	56	27	123		

Table 9. Alpha diversity of scarab beetles on light trap at Badagaon

Diversity indices	Values of diversity indices
Shannon index (H')	1.63
Simpson’s index of diversity (D)	0.79
Simpson's reciprocal index (1/D)	1.27
Pielou’s evenness index (J')	0.91

The Shannon index (H') was calculated to be 1.63, indicating low species richness. The Simpson’s index of diversity (D) and Simpson’s reciprocal index (1/D) were calculated to be 0.79 and 1.27. The Pielou's evenness index (J') indicates high evenness (J'= 0.91) with between collected species of scarabaeid beetles at Badagaon (Table 9).

d) Chailchowk: A total of six species were recorded and *H. longipennis* was found to be predominant species constituting 43.22 per cent of total catch and frequency of occurrence of *H. longipennis* was recorded to be 75 per cent. The maximum frequency of occurrence (100 %) was recorded in case of *H. sikkimensis. A. rufiventris* was found to be least dominant (1.10 %). Overall catch of beetles was maximum in June (59.34 %) followed by July (29.67 %) as shown in (Table 10).

Table 10. Abundance and frequency of beetles on light trap at Chailchowk during 2020

Species	Number of beetles collected in 2019				Total catch	Dominance (%)	Frequency (%)
	June	July	August	Sept			
A. lineatopennis	19	8	1	0	28	10.26	75
A. rufiventris	0	1	1	1	3	1.10	75
H. longipennis	70	40	8	0	118	43.22	75
H. sikkimensis	14	9	8	4	35	12.82	100
M. insanabilis	40	19	4	0	63	23.08	75
M. cotesi	19	4	3	0	26	9.52	75
Total	162	81	25	5	273		

Table 11. Alpha diversityAlpha diversity of scarab beetles on light trap at Chailchowk

Diversity indices	Values of diversity indices
Shannon index (H')	1.03
Simpson's index of diversity (D)	0.94
Simpson's reciprocal index (1/D)	1.06
Pielou's evenness index (J')	0.57

The Shannon index (H') was computed to be 1.03. The Simpson's index of diversity (D) and Simpson's reciprocal index (1/D) were calculated as 0.94 and 1.06, respectively, indicating very low dominance of single species of scarab beetles in Chailchowk area. The Pielou's evenness index (J') was calculated to be J' = 0.57 indicating moderate evenness between collected species of scarab beetles in Chailchowk (Table 11).

ii) Similarity indices in relation to scarab fauna in different areas of Himachal Pradesh

The species richness and abundance revealed that Palampur and Chailchowk exhibited maximum similarity as indicated by the values of Sorensen's similarity index (SI=0.43), Jaccard similarity index (JCI= 0.22) and Bray-Curtis index (0.33) (Table 12). Maximum dissimilarity was recorded between scarab assemblages from Palampur and Badagaon as indicated by highest value of Bray-Curtis distance index (BCDI= 0.91) (Table 13).

Table 12. Beta diversity showing similarity among scarab species in different locations of HP in 2020

Locations → / Locations ↓	Kullu			Badagaon			Chailchowk		
	SI	JI	BCI	SI	JI	BCI	SI	JI	BCI
Palampur	0.38	0.19	0.25	0.29	0.14	0.09	0.43	0.22	0.33
Kullu				0.24	0.12	0.19	0.42	0.21	0.30
Badagaon							0.40	0.20	0.29

SI=Sorenson's index; JI=Jaccard's index; BCI=Bray Curtis index

Table 13. Bray Curtis distance index of scarab fauna in locations of HP in 2020

Locations → / Locations ↓	Kullu	Badagaon	Chailchowk
	BCI	BCI	BCI
Palampur	0.75	0.91	0.67
Kullu		0.81	0.70
Badagaon			0.71

Plate 1 Light trap used for monitoring of beetles

GKVK, Bengaluru

Modified Robinson's light traps with 165 W mercury vapour lamp were set up in different locations – GKVK campus (12° 58'N; 77°35'E; 930 M above sea level). Light traps were operated at weekly intervals from 6 pm to 6.00 am. Collections were also opportunistically made from host plants. The traps were run at regular intervals and beetles were sorted out and labeled as morpho species. The number of each morpho species was recorded per catch. The identifications of each morpho species was done up to the genus level. Corresponding weather data pertaining to Temperature, Relative Humidity, Rainfall, etc. were also recorded and tabulated. Beside this, data on species abundance and species richness were also recorded. Adult beetles were also

Results: Twenty species belonging to four subfamilies were collected using light trap in the GKVK campus (Table.14). No new species have been collected from the GKVK onsite.

Table 14: Scarab beetles collected using light trap Scarab beetles collected using light trap at GKVK.

Taxa	Scarab beetles collected using light trap				
	2017	2018	2019	2020	2021
Subfamily	4	6	5	4	4
No. of specimens	583	773	970	650	312
No. of species	13	7	14	11	9

GPBUA &T, Pantnagar

Monitoring of scarab beetles was done with the help of light trap at Pantnagar. The light trap was installed at Pantnagar in the month of March 2020-21 for monitoring of the white grub by collection and identification. The light traps were kept switch on from 7.00 pm to 11.00pm. Whatever beetles were trapped in light trap funnel were brought in laboratory for identification and shorted out species wise. Data presented in table 15 indicated that beetle emergence was recorded from the month of March, 2020 and remained continued up to September, 2020.

First appearance of beetle's species which was recorded in the month of March was *Holotrichia serrata, Anomala xanthoptera, Heteronychus liioderes, Anomala rugosa, Holotrichia rosettae* and *Holotrichia serrata.* In the month of March, *Anomala xanthoptera* was predominating specie of white grub followed by *Heteronychus liioderes*. However, in month of April, the predominating species was *Holotrichia serrata, Heteronychus liioderes* followed by *Anomala rugosa*, *Anomala bengalensis*. Average data of white grub collected on light trap indicated that *Holotrichia serrata* was predominating species of Pantnagar followed by *Adoretus simplex* and *Anomala bengalensis* by recording 16.91 and 10.33 percent of total population collected on light trap. Lowest population was *Mimela* sp followed by *Anomala dimidiate*. Highest population was recorded in the month of May followed by June. Last appearance of beetle was recorded in the month of September, 2020 and thereafter no beetle was\ recorded on light trap (table 15).

Table 15: Scarab beetles trapped on light trap at Pantnagar during active season (April to September, 2020-21).

Sl. No.	Name of species	March	April	May	June	July	August	Sept.	Total	% Abund
1	*Anomala xanthoptera*	16	9	0	0	0	0	0	25	1.18
2	*Heteronychus liioderes*	2	11	26	5	0	0	0	44	2.08
3	*Holotrichia rosettae*	9	52	40	12	0	0	0	113	5.35
4	*Brahmina coriacea*	0	18	26	3	0	0	0	47	2.23
5	*Anomala bengalensis*	5	36	71	53	34	19	0	218	10.33
6	*Anomala rugosa*	9	37	83	48	10	0	0	187	8.86
7	*Anomala* sp.1	0	11	35	50	61	7	0	164	7.77
8	*Adoretus simplex*	0	25	58	57	119	76	22	357	16.91
9	*Adoretus* sp.1	7	38	78	44	10	2	0	179	8.48
10	*Holotrichia serrata*	12	42	126	184	170	50	0	584	27.66
11	*Phyllognathus dionysius*	0	5	0	8	0	0	0	13	0.61
12	*Maladera* sp.	0	2	0	0	0	0	0	2	0.09
13	*Apogonia setosa*	0	0	28	26	0	0	0	54	2.56
14	*Phyllognathus* sp.	0	0	22	65	1	0	0	88	4.17
15	*Hemiserica nasuta*	0	0	4	6	0	0	0	10	0.47
16	*Sophrops* sp.	0	0	0	17	0	0	0	17	0.80
17	*Anomala dimidiata*	0	0	0	6	1	0	0	7	0.33
18	*Mimela* sp.	0	0	2	0	0	0	0	2	0.09
	Total	60	286	599	584	406	154	22	2111	

Peak Emergence Period (PEP): 24th April– 12th May 2020. Total rainfall on 18th April 2020: 25.7 mm

Emergence of beetles of *Holotrichia serrata* started: 28th March, 2020

FARMER - GHAZIABAD

Methodology:

Pilot survey for species profiling was conducted in western UP covering 14 locations at ten villages in four districts; Dabana (2) Jalalabad (2) Noorpur (1), Mohammadpur kaddim (1) in Ghaziabad, Bisrakh (1), Santhali (2) in Gautambudhh Nagar; Athain (1), Bahadasadat (2), Meghakhari (1) in Muzaffarnagar and Jallopur (1) in Amroha. Locations were selected for conducting survey on the basis of cropping pattern and presence of host trees. The collections of beetles were carried out after onset of first showers of pre monsoon and monsoon rains in the months of April - September, 2020. However, it was observed that the emergence of beetles was mainly recorded in the months of June - July, 2020.

The survey was conducted by using Light traps fitted with fitted with 6-8 watts mercury tube Light; ACTINIC BL, PHILIPS and Pheromone traps fitted with vials and foam containing Anisole; Methoxy Benzene. The Light traps and Pheromone traps were placed in the field at a height of three feet to ten feet above the ground and operated between 7:30 PM to 9:30 PM to attract the beetles in maximum numbers. The average temperature and relative humidity during the period of emergence (April-September) of adult beetles were ranging between 24.1^0C-42.3^0C and 19-66 % RH, respectively. The collected beetles were processed in the laboratory for preliminary morphological identification and were preserved in 70% alcohol. After preliminary screening, the specimens of species which were not confirmed in our laboratory were forwarded for identification up to the genus level to Dr. (Mrs.) Kolla Sreedevi, Principal Scientist (Agricultural Entomology), Division of Insect Systematic, ICAR- National Bureau of Agricultural Insect Resources, Bengaluru, Karnataka, for confirmation of identification and report of which is enclosed at **Annexure - I**.

Result: A total of number of 2142 white grub beetles belonging to 14 species of Scarabaeidae family were collected during 2020. The 14 species of white grubs collected during the period are; *Holotrichia serrata*, *H. nagpurensis, H consanguinea*, *Melladera insanabilis, Schizonycha ruficollis* from the sub family Melolonthinae, *Anomala polita, A. dimidiate*, *A. dorsalis* belong to sub family Rutelinae, *Phyllognathus dionysius, Alissonotum* sp., *Pentodon sp., Dynastine* sp. of sub family Dynastinae; *Onthophagus* sp. and Onitis sp. of sub family Scarabaeinae. Out of total 14 species of white grub, the species *Holotrichia serrata* was recorded as predominant species (74.09%). A new white grub species *Alissonotum* sp. (F.), subfamily Dynastinae, family Scarabaeidae collected from village Behada sadat in Muzaffarnagar district of western UP was also recorded.

Table 16. Month wise details of Temperature, Humidity, Rainfall Rain Days and Number of Beetles collected during 2020-21

S. No.	Months	Temperature (°C)	Humidity (%)	Rainfall (mm)	Rain days (no.)	No. of beetles collection (no)
1.	April	24.1-38.2	22	13	4.6	0
2.	May	29.1-42.3	19	6	3.5	3
3.	June	31.3-42.4	29	22	7.2	378
4.	July	28.9-37.3	57	118	21.2	1761
5.	August	27.3-35.2	66	119	21.5	0
Total						2142

Table 17. White grub beetles trapped during April to September 2020

S. No.	**Family**	**Sub family**	**Scientific name**	**No.**	**Rel. abun**	**Location (districts)**
1	Scarabaeidae	Melolonthinae	*Holotrichia serrata*	1587	74.09	Muzaffarnagar, Ghaziabad, GB Nagar, Amroha
2		Rutelinae	*Anomala polita*	90	4.20	Ghaziabad
3		Melolonthinae	*H. consanguinea*	84	3.92	Ghaziabad, Muzaffarnagar
4		Scarabaeinae	**Onthophagus* sp.	69	3.22	GB Nagar, Ghaziabad
5		Dynastinae	*Phyllognathus dionysius*	54	2.52	GB Nagar, Ghaziabad
6		Rutelinae	*A. dimidiate*	48	2.24	Ghaziabad
7		Melolonthinae	*H. nagpurensis*	48	2.42	GB Nagar, Ghaziabad
8		Melolonthinae	*Schizonycha ruficollis*	48	2.42	Muzaffarnagar, Ghaziabad
9		Rutelinae	*A. dorsalis*	42	1.96	Ghaziabad
10		Melolonthinae	*Maladera insanabilis*	39	1.82	Muzaffarnagar
11		Scarabaeinae	**Onitis* sp.	23	1.07	Ghaziabad, GB Nagar, Amroha
12		Dynastinae	*Alissonotum* sp.	6	0.28	Muzaffarnagar
13		Dynastinae	*Pentodon sp.*	3	0.14	Ghaziabad
14		Dynastinae	Dynastine sp.	1	0.05	Ghaziabad
Total	1	4	14	2142		4

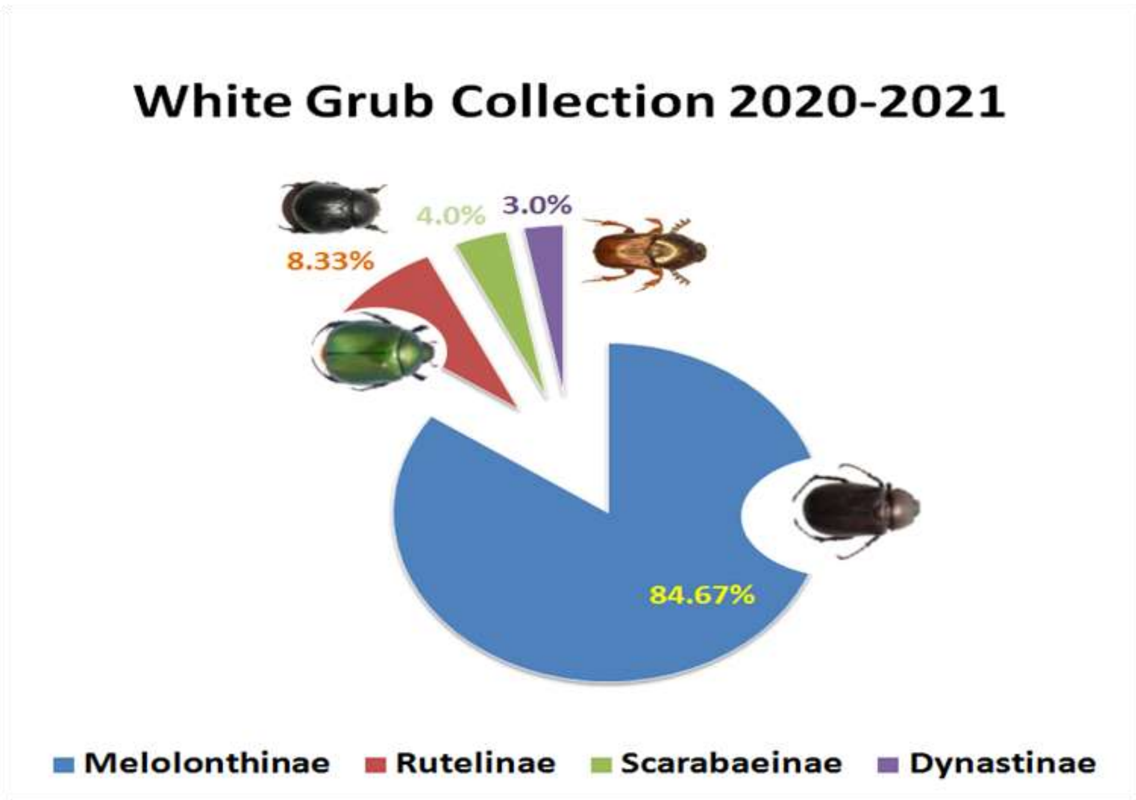


Fig. 5. White grub beetles prevailing in western Uttar Pradesh during 2020-2021

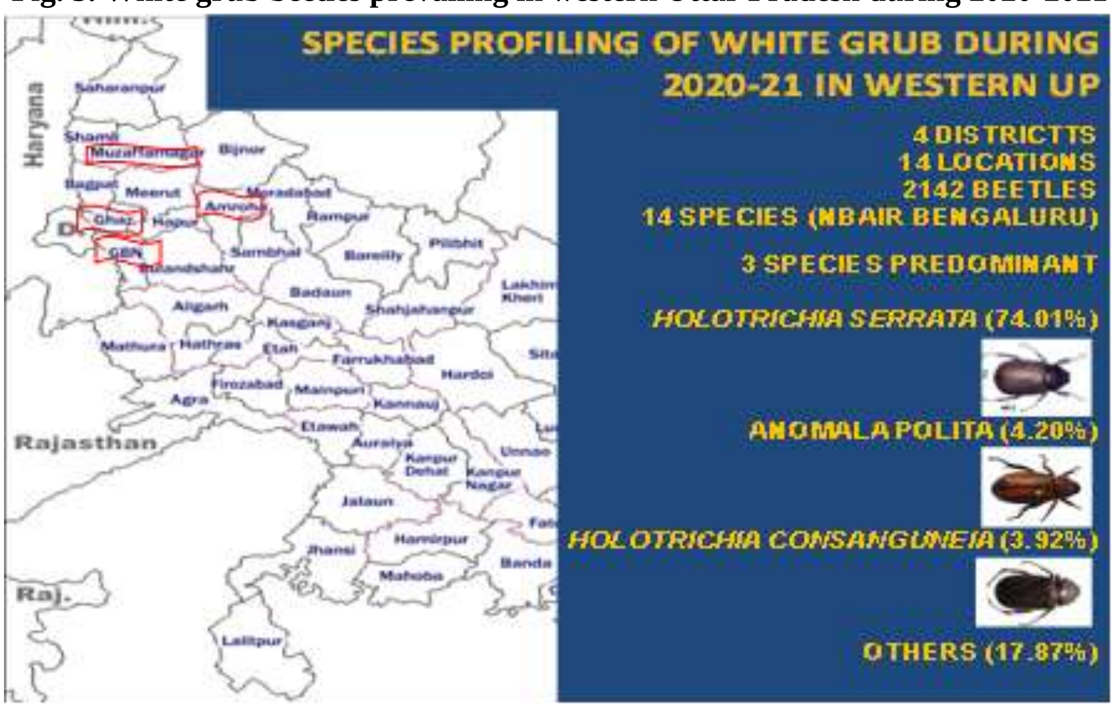


Fig. 6. Species profiling of white grub in western UP during 2020-21

Table 18 Beetles collection during April to September 2020 from western UP

SN	Species	Location (districts)	Number of beetles collected								Relative abundance (%)
			March	April	May	June	July	Aug.	Sept.	Total	
					A. Melolonthinae						
1	Holotrichia consanguinea	Dabana, Noorpur, Jalalabad, Ghaziabad; Behrah Sadat, Muzaffarnagar	-	-	-	15	69	-	-	84	3.92
2	Holotrichia nagpurensis	Dabana, Jalalabad, Ghaziabad; Santhali, GB Nagar	-	-	-	24	15	9	-	48	2.42
3	Holotrichia serrata	Athain, Bahara sadat, Muzaffarnagar; Dabana, Jalalabad, Noorpur, Ghaziabad; Santhali, GB Nagar; Jallopur, Amroha	-	-	3	180	1344	60	-	1587	74.09
4	Maladera insanbilis	Bahara sadat, Muzaffarnagar	-	-	-	-	39	-	-	39	1.82
5	Schizonycha ruficollis	Dabana, Ghaziabad; Behrah sadat, Muzaffarnagar;	-	-	-	12	36	-	-	48	2.42
					B. Rutelinae						
1	Anomala polita	Dabana, Ghaziabad	-	-	-	30	60	-	-	90	4.20
2	Anomala dimidiata	Dabana, Noorpur, Ghaziabad	-	-	-	-	48	-	-	48	2.24
3	A. dorsalis	Noorpur, Ghaziabad	-	-	-	-	42	-	-	42	1.96
					C. Dynastinae						
1	Phyllognathus dionysius (F.)	Dabana, Ghaziabad; Santhali, GB Nagar	-	-	-	18	36	-	-	54	2.52
2	Pentodon sp.	Dabana, Ghaziabad	-	-	-	-	3	-	-	3	0.14
3	Alissonotum sp. (F.)	Behrah sadat, Muzaffarnagar	-	-	-	-	6	-	-	6	0.28
4	Dynastine sp.	Mohammadpur kiddim, Ghaziabad	-	-	-	-	1	-	-	1	0.05
					D. Scarabaeinae						
1	*Onthophagus sp.	Bisrakh, GB Nagar; Dabana, Noorpur, Ghaziabad	-	-	-	24	45	-	-	69	3.22
2	*Onitis sp.	Dabana, Mh. Kiddim, Ghaziabad; Santhali, GB Nagar; Jallopur, Amroha	-	-	-	6	17	-	-	23	1.07
	Total	14	-	-	3	309	1761	69	-	2142	-

Fig. 7 Beetles collection by using Pheromone Trap

Fig. 8 Beetles collection by using Pheromone Trap

Fig. 9 Beetles collection by using Light Trap

Fig. 10 Beetles collection by using Light Trap

Summary/Conclusion:

The total number of white grub beetles collected during the season belongs to four sub family viz., Melolonthinae (84.67%), Rutelinae (8.34%), Scarabaeinae (4.29%) and Dynastinae (2.99%). Out of 14 white grub species collected, the species namely *Holotrichia serrata* (Melolonthinae) was found in abundance during the period (74.09%). The prevalence of one new species *Alissonotum* sp. (F.), subfamily Dynastinae, family Scarabaeidae has been recorded in western UP. The total number of prevailing species of white grub in western UP has been increased to 31, as 30 species had already been recorded prevailing in the area during the survey conducted by FARMER in previous years.

VPKAS- Almora

A survey was conducted in 3 districts of Uttarakhand (Almora, Nainital and Bageshwar) and a total of 2362 scarab beetles of 24 species belonging to 5 subfamilies *viz*., Rutelinae, Melolonthinae, Scarabaeinae, Dynastinae and Geotrupidae were trapped in light trap in 2020. Members of the subfamily Rutelinae predominated with 52.7% of the species, followed by Melolonthinae (41.5%), Scarabaeinae (4.11%), Dynastinae (1.52%) and Geotrupidae (0.17%). The predominant species were *Anomala* sp. (51.5%) and *Hemiserica nausta* (35.7%).

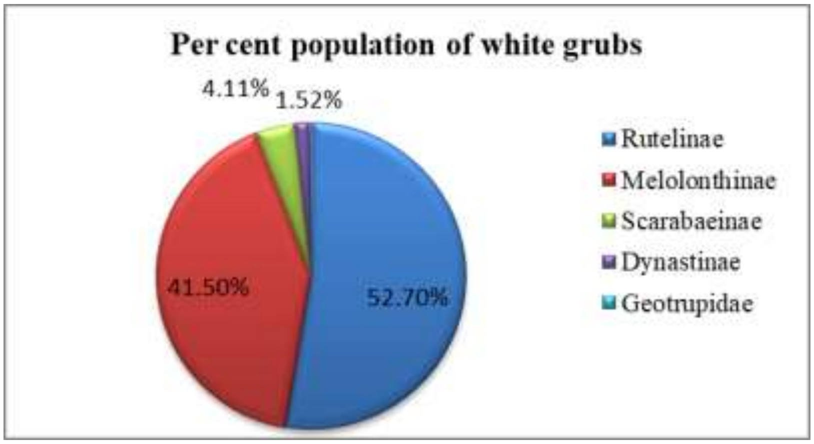


Fig.11. Species diversity and population dynamics of scarab beetles in Uttarakhand

Studies to compare species diversity in light trap catches v/s *in situ* counts (sub family wise)

A total of 843 Scarab beetles belonging to 18 genera under 4 subfamilies viz., Rutelinae, Melolonthinae, Dynastinae and Cetoniinae were collected by in situ sampling. While, 8062 scarab beetles of 18 genera and 32 species belonging to 5 subfamilies viz., Rutelinae, Melolonthinae, Dynastinae, Aphodiinae and Scarabaeinae were trapped in light trap during Kharif- 2020. Sub-family Rutelinae dominated the in-situ counts as well as light trap catches with 60.26% and 46.07% populations (Table 19).

Table 19. Comparison of species diversity in light trap catches v/s *in situ* counts

In situ counts			Light trap catches		
Subfamily	**Total no. of scarab beetles collected by insitu sampling**	**% Dominance**	**Subfamily**	**Total no. of scarab beetles collected by insitu sampling**	**% Dominance**
Rutelinae	508	**60.26**	Rutelinae	3,714	**46.07**
Melolonthinae	328	38.91	Melolonthinae	3,170	39.32
Dynastinae	3	0.35	**Aphodiinae**	650	8.063
Cetoniinae	2	**0.24**	Dynastinae	472	5.855
Unidentified	2	**0.24**	**Scarabinae**	56	**0.695**
Total	**843**	**100**	**Total**	**8,062**	**100**

COA-Kolhapur

At Trap (T_1) three species were identified. On pre-monsoon shower, 2020 in April emergence of *H. serrata* started and reached to maximum in May, 2020. However, *Holotrichia rufloflava* (12 beetles), *Holotrichia consanguinea* (17 beetles) and *Adoretus versutus* (42 beetles) were observed as there were when 325 mm rainfall was received. At trap (T_2) *Phyllognathus dionysius* found dominent species with 40.46 per cent abundance. At Trap (T_3) emergence of *Leucopholis lepidophora* started in July with its peak in August with 16.43 per cent abundance. The emergence of all species depends on the rainfall; however, the emergence of *L. lepidophora* depends on flood water in rivers (Table 20).

Table 20. Number of beetles of different species of white grub trapped in the light trap at Kolhapur 2020-21 (Melolonthinae / Rutelinae)

Sr. No	Name of species	Number of beetles collected									abun (%)
		Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Total	
1	T_1 *Holotrichia serrata*	70	110	362	42	27	12			623	37.51
2	*Holotrichia rufloflava*				1 2					12	0.72
3	*Holotrichia consanguinea*				17					17	1.02
4	*Adoretus versutus*			42						42	2.53
5	T_2 *Apogonia* sp.			22						22	1.32
6	*Phyllognathus dionysius*		35	310	265	62				672	40.46
7	T_3 *Leucopholis lepidophora*					27	162	65	19	273	16.43
	Total	70	145	736	336	116	174	65	19	1661	
Total Rainfall (mm)		85	45	325	89	32	25	10	25		

B. POPULATION MONITORING OF SOIL ARTHROPOD ON HOST TREES

RARI, Durgapura

To identify the host rang of different whitegrub species population monitoring was done on host trees at six locations i.e., Balolaye, jaisinghpura, Bobas, Bagru, Piprali, Ramgardh, and Kaladera villages near Jaipur and Sikar district during June to August. At all the locations maximum number of beetles was collected during July followed by August and then June. The most preferred host was apple ber, but it was at par with Neem. Next in sequence was khejari, ber and sanjana. The catches were low in the month of June because of the emergence started with the onset of rains in the first week of July. The catches were reduced at all these locations after August. In the month of July highest number of beetles was found on appleber at Ramgadh village. Search was also done to identify new host preferred by the beetles. (Table 21).

Table 21. Population monitoring of major scarab beetles on host trees from June to August 2020 in different villages near Jaipur/Sikar

Month	Location	Host Trees	No. of beetles collected	Species
June	Balolaye	**Neem**	**205**	*H. consanguinea* *M. insanabilis* *H. serrata*
		Khejari	155	
		Ber	131	
		Melbery	190	
	Bobas	**Neem**	**241**	*H. consanguinea* *M. insanabilis* *H. serrata*
		Khejari	217	
		Ber	99	
		Sanjana	101	
	Bagru	**Neem**	**211**	*H. consanguinea* *M. insanabilis* *H. serrata*
		Khejari	187	
		Ber	121	
		Sanjana	143	
	Piprali	**Neem**	**322**	*H. consanguinea*
		Khejari	213	
		Ber	107	
		Sanjana	129	
	Ramgardh	**Neem**	**289**	*H. consanguinea* *M. insanabilis* *H. serrata*
		Khejari	203	
		Ber	119	
		Sanjana	98	
	Kaladera	Apple ber	**398**	*H. consanguinea*
		Neem	304	
		Khejari	187	
		Sanjana	154	
July	Balolaye	**Neem**	**1301**	*H. consanguinea*

		Khejari	967	*M. insanabilis*
		Ber	981	
		Sanjana	603	
	Bobas	**Neem**	**1276**	*H. consanguinea* *M. insanabilis*
		Khejari	923	
		Ber	689	
		Sanjana	556	
	Bagru	**Neem**	**1137**	*H. consanguinea* *M. insanabilis*
		Khejari	1032	
		Ber	794	
		Sanjana	710	
	Piprali	**Neem**	1198	*H. consanguinea*
		Khejari	910	
		Ber	683	
		Sanjana	643	
	Ramgadh	Apple ber	**1467**	*H. consanguinea*
		Neem	1107	
		Khejari	773	
		Sanjana	591	
	Kaladera	**Neem**	**1245**	*H. consanguinea* *M. insanabilis*
		Khejari	1036	
		Ber	779	
		Sanjana	632	
August	Balolaye	**Neem**	**676**	*H. consanguinea* *M. insanabilis*
		Khejari	445	
		Ber	475	
		Sanjana	423	
	Bobas	**Neem**	**645**	*H. consanguinea* *M. insanabilis*
		Khejari	366	
		Ber	345	
		Sanjana	300	
	Bagru	**Neem**	**789**	*H. consanguinea* *M. insanabilis*
		Khejari	587	
		Ber	399	
		Sanjana	378	
	Piprali	**Neem**	734	*H. consanguinea* *M. insanabilis*
		Khejari	523	
		Ber	456	
		Sanjana	400	
	Ramgardh	Apple ber	645	*H. consanguinea* *M. insanabilis*
		Neem	556	
		Khejari	456	
		Sanjana	320	
	Kaladera	**Neem**	**823**	*H. consanguinea* *M. insanabilis*
		Khejari	501	
		Ber	345	
		Sanjana	308	

Khejri

Neem

Ber

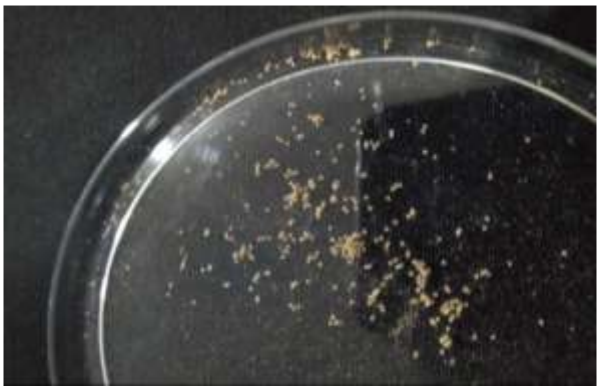
Mehndi

Defoliated Sahnjana

Different host trees of white grub in Rajasthan

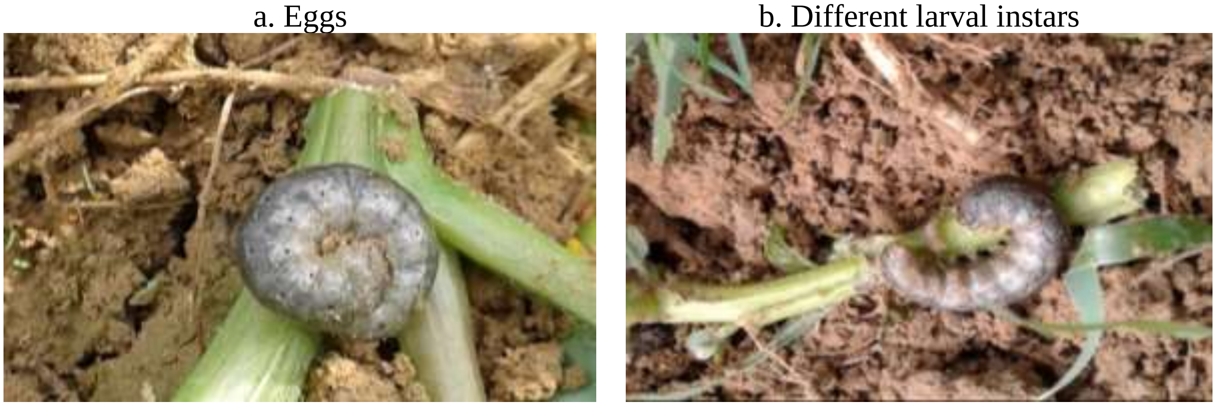
AAU, JORHAT

Surveys were conducted to monitor the incidence of cutworm, *Agrotis ipsilon* in potato and king chilli cultivated areas of Jorhat district of Assam (26.7509° N, 94.2037° E) during the *rabi* season of 2020-21 (Fig. 13 A-B). Pest incidence was recorded higher during the survey period as compared to the earlier seasons. Few lucanid and Passalid beetles were also collected during the survey programmes conducted at the Changlang district of Arunachal Pradesh (27.7422º N, 96.6424º E) (Fig. 14 C).



a. Eggs

b. Different larval instars



c. Larvae infesting potato seedlings

d. Pupal stage

e. Cutworm moth

Fig. 4. A (a-e). Different life stages of cutworm observed during the survey period in

potato

a. Larval stage

b. Pupal stage

Fig. 4. B (a-b). Different life stages of cutworm observed in king chilli plots

Fig. 4. C. Lucanid and Passalid beetles observed during the survey programmes conducted at Arunachal Pradesh, India

CSK HPKV - PALAMPUR

During 2020, adult sampling of scarab beetles was done at four different locations of Himachal Pradesh **(Table 22).** At Palampur, sampling was done on pear, rose, nectrine, apple, toon, mulberry and pecannut. *H. longipennis* was collected in great numbers on toon. At Barot, beetles of *P. fullo* were collected in low numbers on walnut, apple, passion fruits and *Bathua* plants. On *Bathua* plants, *P. fullo* was also recorded during day time. In Kullu, *M. cuprescens*, was collected in higher numbers on apple trees. In Mandi district, *H. longipennis* and *B. coricea* were found to be predominant species and were recorded on rose, *toon* and apple.

Table 22. Beetles collected on different host trees in Himachal Pradesh during 2019

Species	Palampur	Kullu	Badagaon	Chailchowk
A.lineatopennis	+	+	-	-
A. varicolor	+	-	-	-
A. rufiventris	+	+	+	-
A. dimidiata	+	-	+	-
B. coriacea	+	+	+	-
H. longipennis	+	+	-	+
H. sikkimensis	+	-	+	+
M. insanabilis	+	+	+	+
M. thomsoni	+	+	-	+
M. cuprescens	-	+	+	+
M. furcicauda	+	+	+	-
M. indica	+	+	-	-
P. fullo	-	-	+	-

(+): Present; (-): Absent

GKVK, BENGALURU

The host plants were surveyed and searched for adult scarab beetles which have the behavior of emerging *én massé* and aggregating on tree canopies during night hours. Effort was made to collect all the beetles from the host plants using insect nets with long handles. Wherever this was not possible (as in *Leucopholis lepidophora*, *L. burmeisteri* and *L. coneophora*), their numbers were recorded using flashlights. Number of beetles per plant was calculated. Similarly, the abundance of anthophilous scarabs was also recorded in the same manner.

Two persons walked along the road looking for host trees on either side for a stretch of 3 km. Each of the potential host plants encountered was searched for scarab beetles and collections were made. The geographical details of the study areas have been recorded using GPS and furnished in Appendix-II.

Results: Estimated adult beetles density of scarab beetles on tree canopies during night hours in different agro-climatic zones in Karnataka. Adult beetle activity of scarabs was monitored and population of beetles on different host plants estimated in GKVK campus and other areas during 2020-21. The details on abundance of beetles on tree canopies recorded during 2020 are furnished in table 23.

Table 23: Abundance of major scarab beetles on tree canopies in 2020

Date	Location	Coordinates	Tree canopy	Scarab species	Number of beetles
3-3-2020	Mahadeshwarapura (Mandya)	N: 12.57'; E: 76.67'	Neem (10 plants)	*Holotrichia serrata*	1490
4-3-2020	Mahadeshwarapura (Mandya)	N: 12.57'; E: 76.67'	Neem (11 plants)	*H. serrata*	1406
21-3-2020	GKVK, Bengaluru	N: 13.077; E: 77.57'	Neem (2 plants)	*H. serrata*	44
7-4-2020			Neem (4 plants)	*H. serrata*	158
				H. rufoflava	48
			Mulberry (128 plants)	*H. serrata*	102
10-4-2020			Neem (plants)	*H. serrata*	1844
				H. rufoflava	225
				H. reynaudi	65
			Mulberry (201 plants)	*H. serrata*	113
			Subabul (1 plant)	*H. serrata*	5
24-4-2020			Neem (10 plants)	*H. serrata*	1209
				H. rufoflava	212
				H. reynaudi	128
			Mulberry (52 plants)	*H. serrata*	52
6-5-2020	Sira	N: 13.77; E: 76.82'	Neem (2 plants)	*H. serrata*	1834
7-5-2020	Devanahalli (Bengaluru)	N: 13.30; E: 77.72'	Neem (3 plants)	*H. serrata*	324
				H. rufoflava	58
27-5-2020	Sira	N: 13.77; E: 76.82'	Neem (2 plants)	*H. serrata*	2574
				H. rufoflava	9
				Adoretus sp.	7
			Jamun (1plant)	*Anomala* sp.	10
				H. reynaudi	230

In March & April, 2021 adult aggregation of different species of scarab beetles was estimated in endemic regions. During the sampling conducted, 12,556 beetles of *H. serrata from* canopies of neem (*Azadirachta indica, Ricinus communis* and *Morus* sp.), 869 beetles of *H. rufoflava* from canopies of neem and *Anomala* sp. (123 numbers from *Cassia fistula* tree) were collected. The detail of abundance of adult beetles on tree canopies is given in table 24.

Table 24 Abundance of major scarab beetles on tree canopies in March & April, 2021

Date	Location	Coordinates	Tree canopy	Scarab species collected	No. of beetles collected
30.03.2021	Medhani (Mysuru)	12.20523°N; 77.118344°E	*A. indica*	*H. serrata*	663
31.03.2021	Medhani (Mysuru)	12.20523°N; 77.118344°E	*A. indica*	*H. serrata*	1456
15.04.2021	Gunnanayakanahalli, (Mandya)	12.618973°N; 76.836894°E	*A. indica, Ricinus communis, Acacia auriculiformis*	*H. serrata*	2678
19.04.2021	Katrighatta, (Hassan)	12.9354°N; 76.32555°E	*A. indica, Morus* sp.	*H. serrata*	2354
22.04.2021	GKVK, Farm (Agronomy)	13.083204°N; 77.5691°E	*A. indica*	*H. serrata*	532
				H. rufoflava	23
26.04.2021	GKVK, Medicinal plots.	13.081203°N; 77.5676°E	*A. indica*	*H. serrata*	1632
				H. rufoflava	241
27.04.2021	GKVK, Medicinal plots.	13.081203°N; 77.5676°E	*A. indica*	*H. serrata*	1853
				H. rufoflava	152
			Cassia fistula	*Anomala* sp.	123
28.04.2021	GKVK, Farm (Crop Physiology)	13.081216°N; 77.5681°E	*A. indica*	*H. serrata*	638
			A. indica	*H. rufoflava*	453
28.04.2021	Sorekunte (Tumkur)	13.7465°N; 76.8363°E	*A. indica*	*H. serrata*	2614

A total of 12, 811 adult beetles of sugarcane white grub, *Holotrichia serrata* and 440 beetles of *H. rufoflava* were collected from different tree canopies *viz.*, Neem (*Azadirachta indica*), mahogany (*Swietenia macrophylla*), mango (*Mangifera indica*), tamarind

(*Tamarindus indica*) and Hebbevu (*Melia dubia*) from Chikkaballapur, Chamarajnagar and Bengaluru rural. During the field visits several hands on *training-cum-demonstration on adult beetle collection* were conducted in white grub endemic areas. The detail of abundance of scarab beetles on tree canopies is given in table 25.

Table 25: Abundance of major scarab beetles on tree canopies in May, 2021

Date	Location	Coordinates	Tree canopy	Scarab species collected	No. of beetles collected
03.05.2021	Muddalapalli (Chikkaballapur)	13.80037°N; 77.87799°E	Neem	*H. serrata*	814
05.05.2021	Palya, Kollegal Tq, Chamarajanagar Dist	12.184816 °N; 77.184485°E	Neem	*H. serrata*	3542
07.05.2021	Agara, Yelandur Tq. Chamarajanagar Dist	12.116843 °N; 77.076167°E	Mahogany	*H. serrata*	5024
13.05.2021	Gunnahalli, Chintamani Taluk, Chikkaballapur dist	13.320788°N; 78.010241°E	Neem	*H. serrata*	856
			Tamarind	*H. serrata*	254
				H. rufoflava	65
			Hebbevu	*H. serrata*	648
			Mango	*H. serrata*	257
19.05.2021	Dodda Muddenahalli, Chikkabalapur Tq and Dist	13.329941°N; 77.763361°E	Neem	*H. serrata*	864
				H. rufoflava	251
25.05.2021	Muduguriki, Devanahalli Tq, Bengaluru Rural Dist.	13.343221°N; 77.722589°E	Neem	*H. serrata*	552
				H.rufoflava	124

Studies on the influence of weather parameters on emergence pattern of adult beetles of *Holotrichia serrata* revealed that rainfall has negatively correlated with soil temperature and in turn triggering the adult emergence. Further, the study also confirmed the event is greatly location specific.

Summary/Conclusion: *H. serrata* found to be the predominant species among scarab beetles collected during the operation followed by *H. rufoflava* and *Anomala* sp. Aggregation of *H. serrata* was noticed on tree canopies other than its usual host *i.e.*, neem such as castor, mulberry and acasia. This information was shared with the farmers and line department official for efficient collection of adult beetles during night hours of the day.

GBPUA&T, Pantnagar

Host preference of *Holotrichia serrata* beetle among the various available host plants in Crop Research Centre, was studied during the year 2020-21. Total six plants were observed during the 8.0 pm and number of beetles was counted on selected branches. The average number of beetle beetles on selected branch indicated that *H. serrata* preferred neem as host with 28.52 % of beetles population. This was followed by Jackfruit where 28.52% of beetles were recorded. Mango was least preferred host plant followed by Jamun as host plant of *H. serrata*. During the study, highest population of beetle was recorded in month of April followed by May during the study year 2020-21.

Study indicated that neem is most preferred host plant for the predominating major species of white grub (*Holotrichia serrata*) occurring in Udham Singh Nagar district. Thus, the study can be utilized by adopting the practice i.e., at the time of peak emergence, the neem and other major host must be sprayed with economically safe insecticide to reduce the beetle population (Table 26).

Table 26. Host preference of *Holotrichia serrata* beetle among the various available host plants in Crop Research Centre, Pantnagar during year 2020-21.

Sl. no.	Name of host Plant	Number of beetles collected in months								
		March	April	May	June	July	Aug.	Sept.	Total	% Catch
1.	Jackfruit (*Atrocarpus heterophyllus*)	22	86	32	8	1	0	0	149	27.59
2.	Guava (*Psidium guajava*)	3	36	18	2	0	0	0	59	10.93
3.	Neem (*Azadirachta indica*)	9	98	42	5	0	0	0	154	28.52
4.	Mango (*Mangifera indica*)	6	17	7	0	0	0	0	30	5.56
5.	Jamun (*Syzygium cumini*)	8	27	14	2	0	0	0	51	9.44
6.	*Ficus* sp.	12	45	26	12	1	1	0	97	17.96
Total		**60**	**309**	**139**	**29**	**2**	**1**	**0**	**540**	**-**

Jamun

***Ficus* sp.**

Jack fruit

Neem

Guava

Mango

Fig 15. White grub on various hosts

FARMER, Ghaziabad

Methodology:

The periodical visual survey of different host trees of white grub beetles were conducted at different locations during day and night time in the months of April-September 2020. The survey was conducted at 14 locations in four districts; Muzaffarnagar, Ghaziabad, Gautambuddh Nagar, Bulandshahar on common host trees; Neem (*Azadirachta indica*) and Sheesham (*Dalbergia sissoo*), Poplar (Populus sp.) Guvava (*Psidium guajava*) and Jamun (*Syzgiumcum cumini*), Bakayan (*Melia azedarach*), Tun (*Meliaceae* family) during day and night time.

Fig. 16. White grub Beetles feeding on host trees
1. Sheesham (*Dalbergia sissoo*)
2. Neem (*Azadirachta indica*)

Result: The white grub beetles were found feeding on host trees namely Neem (*Azadirachta indica*) and Sheesham (*Dalbergia sissoo*), Poplar (Populus sp.) Guvava (*Psidium guajava*) and Jamun (*Syzgiumcum cumini*), Bakayan (*Melia azedarach*), Tun (Meliaceae family) at 14 different locations during night time in the month of June - July 2020 and the leaves of these host trees were also found damaged during day time (Table 27).

Summary/Conclusion: The emergence of beetles and feeding on host trees mainly noticed in the months of June and July in western UP and feeding on Neem (*Azadirachta indica*) and Sheesham (*Dalbergia sissoo*), Poplar (Populus sp.) Guvava (*Psidium guajava*) and Jamun (*Syzgiumcum cumini*), Bakayan (*Melia azedarach*), Tun (Meliaceae family).

Table 27 A summary of population monitoring of phytophagous scarab beetles on host trees

S. No.	Location	Species	Host trees
1	Athain, Muzaffarnagar	*H. serrata*	Neem (*Azadirachta indica*)
			Jamun (*Syzgiumcum cumini*)
2	Bisrakh, GB Nagar	-	Neem (*Azadirachta indica*)
3	Dabana, Ghaziabad	*H. serrata*, *H. nagpurensis*,	Neem (*Azadirachta indica*)
			Sheesham (*Dalbergia sissoo*)

		A. polita, *Phylloganthus sp.,* *Schizonycha ruficollis,* *Pentodon,* *H. consanguinea*	Guava (*Psidium guajava*)
4	Dabana, Ghaziabad	*H. serrata,* *A. polita,* *Pentodon*	Neem (*Azadirachta indica*) Sheesham (*Dalbergia sissoo*) Guava (*Psidium guajava*)
5	Santhali, Gautam Budh Nagar	*H. serrata,* *H. nagpurensis*	Neem (*Azadirachta indica*)
6	Behrah Sadat, Muzaffarnagar	*Maladera insanabilis,* *Schizonycha ruficollis,* *H. consangunia,* *Alissonotum sp.*	Neem (*Azadirachta indica*) Sheesham *Dalbergia sissoo*) Jamun (*Syzgiumcum cumini*)
7	Jalalabad, Ghaziabad	*H. serrata,* *H. consangunia,* *H. nagpurensis,* *A. dimidiate*	Neem (*Azadirachta indica*) Poplar (Populus sp.) Sheesham (*Dalbergia sissoo*)
8	Santhali, Gautambudh Nagar	*H. serrata,* *Polyganthus sp.*	Neem (*Azadirachta indica*) Guava (*Psidium guajava*) Bakayan (*Melia azedarach*)
9	Noorpur, Ghaziabad	*A. dimidiate,* *H. serrata,* *H. consangunia,* *A. dorsalis,* *H. consanguinea*	Neem (*Azadirachta indica)* Guava (*Psidium guajava*)
10	Jallopur, Amroha	*H. serrata*	Jamun (*Syzgiumcum cumini*) Tunn (*Toona ciliate*) Neem (*Azadirachta indica*) Poplar (Populus sp.) Sheesham (*Dalbergia sissoo*)
11	Behada Sadat, Muzaffarnagar	*Meladera insanabilis,* *H. serrata*	Neem (*Azadirachta indica*) Sheesham (*Dalbergia sissoo*) Jamun (*Syzgiumcum cumini*)
12	Meghakhari, Muzaffarnagar		Neem (*Azadirachta indica*) Poplar (Populus sp.)
13	Mohammadpur kiddim, Ghaziabad	*Dynastinae* sp.	Neem (*Azadirachta indica*) Poplar (Populus sp.) Guava (*Psidium guajava*)
14	Jalalabad, Ghaziabad	*H. serrata*	Neem (*Azadirachta indica*) Sheesham (*Dalbergia sissoo*)

VPKAS, Almora

A total of nine carab beetle species were tracked to identify their preferred host plants and finally recommend a suitable pest management strategy against the adults of scarab beetles.

Table 28. Preferred host plants of nine white grub beetles in Indian Himalayas

S.no	**Scarab beetle species**	**Host plants**	**Scarab beetle on host plant**
1.	*Adoretus simplex* 	*Rosa indica*, *Helianthus annuus*, *Zinnia elegans*, *Sapium* sp., *Largestroemia indica*, *Carya illinoinesis*, *Ligustrum nepalensis*, *Hibiscus rosa-sinensis*, *Juglans regia*	
2.	*Adoretus versutus* 	*Rosa indica*, *Helianthus annuus*, *Zinnia elegans*, *Sapium* sp., *Largestroemia indica*, *Carya illinoinesis*, *Ligustrum nepalensis*, *Hibiscus rosa-sinensis*, *Juglans regia*	
3.	*Anomala benglensis* 	*Ligustrum nepalensis*, *Largestroemia indica*, *Carya illinoinesis*	
4.	*Anomala dimidiate* 	*Largestroemia indica*, *Rosa indica*, *Ligustrum nepalensis*	

5.	*Holotrichia longipennis* 	*Sapium* sp., *Carya illinoinesis, Rosa indica, Largestroemia indica, Helianthus annuus, Juglans regia*	
6.	*Holotrichia rosettae* 	*Sapium* sp., *Juglans regia, Largestroemia indica, Carya illinoinesis, Ligustrum nepalensis, Rosa indica, Helianthus annuus*	
7.	*Holotrichia seticollis* 	*Rosa indica, Helianthus annuus, Dalbergia sisso, Cedrus deodara, Thuja occidentalis, Sapium* sp., *Largestroemia indica*	
8.	*Maladera similana* 	*Rosa indica, Helianthus annuus, Tagetes erecta, Solanum tuberosum, Zinnia elegans, Hibiscus rosa-sinensis, Sapium* sp., *Largestroemia indica, Carya illinoinesis, Ligustrum nepalensis, Juglans regia*	
9.	*Sophrops* sp. 	*Carya illinoinesis, Rosa indica, Sapium* sp., *Largestroemia indica, Ligustrum nepalensis, Helianthus annuus, Hibiscus rosa-sinensis, Juglans regia*	

COA-Kolhapur

The survey of major groundnut and sugarcane growing areas of Hatkanangle, Shirol, and Karveer Tashils of Kolhapur district during pre-monsoon and monsoon season from March to August, 2020 reveled two species of Melolonthinae from two genera (Table 2). The

896 beetles were observed and collected from various tree species indicated that distinct host preferences occur among the species encountered. *Holotrachia serrata* and *Leucopholis lepidophora* were dominant in the Kolhapur districts which were collected from various host plants.

Table 29. White grub species collected as adults on host trees

Sr. No.	Species	Location	Host trees	No of adult collected
1.	*Holotrachia serrata*	Hatkanangle	Neem, Babul, Ber,	349
		Shirol	Neem, Moringa	217
		Karveer	Neem, Moringa, Almond	157
			A-total	623
2.	*Leucopholis lepidophora*	Shirol	Sugarcane	91
		Karveer	Sugarcane	182
			B-total	273
		Total	A + B	896

C. POPULATION MONITORING OF SOIL ARTHROPOD PESTS AND THEIR EXTENT OF DAMAGE IN DIFFERENT CROPS

RARI, DURGAPURA

The population monitoring of grub stage of whitegrub was done at eight locations near Jaipur *i.e.*, Bobas, Kalkh, Ajitgardh, Sargot, Rainwa, Kalwad, Bagru, RARI Research Farm.

At these villages mainly groundnut and pearl millet field were observed. Pits sampling was done as per the standard procedure. The pit sampling was also done at Research farm RARI, Durgapura. The maximum number of grubs was recorded at Sargot (12 grubs/m^2), followed by Bobas (11 grubs/m^2), Ajitgadh (9 grubs/m^2) & Bagru (7 grubs/m^2), at RARI Research Farm 6 grubs per m^2 pit was recorded. The extent of damage at these locations was high where the population was above 5 whereas low level of damage was observed at population of grubs were below 5 grubs/pit (Table 30).

Table 30 Population monitoring of grubs in soil at different villages near Jaipur

S N	Location	Average grubs collected/pit	Host plant	Extent of damage
1	Bobas	11	Groundnut, Pearl millet	High
2	Kalkh	4	Groundnut	Low
3	Ajitgadh	9	Pearl millet, Groundnut	High

4	Sargot	12	Groundnut	High
5	Rainwal	3	Groundnut, Pearl millet	Low
6	Kalwad	2	Groundnut, Pearl millet	Low
7	Bagru	7	Pearl millet	High
8	RARI Research Farm	6	Groundnut	High


Larval population of white grub **Infestation in Prealmillet field**
At farmers field

AAU, JORHAT

Extensive surveys were conducted to monitor the different soil insects as well as molluscan pests and their extent of damage to different crops and the details are presented in Table 31.

Table 31. Extent of damage caused by major soil insect and molluscan pests in Assam

Species	Peak activity	Crop infested	Stage of the crop	Infestation (%)
I. White grubs				
Lepidiota mansueta Study area: Majuli river island	Whole year (grubs)	Potato	Seedling & tuber	25-30
		Sugarcane	Standing crop	15-20
		Colocasia	Corm formation	25-35
		Green gram	Seedling	25-30
Lepidiota albistigma Study area: Sorbhog, Barpeta	Whole year (grubs) April-May (Adults)	Mango	Standing crop	10-20
		Ramie		15-20
		Arecanut		10-15
		Black pepper		5-7

***Pentodon* sp.** Study area: Majuli river island & Dhemaji	May-July (Grubs and Adults)	Kharif Rice	Standing crop	10-15
		Sugarcane		30-40
Heteronychus lioderus Study area: Lakhimpur, Dhemaji, Jorhat, Golaghat, Nagaon, Baksa, Karbi Anglong & Dima Hasao districts of Assam Lohit & Namsai districts of Arunachal Pradesh	Sept.-Oct. (Grubs)	Transplanted summer rice (Early *ahu*)	Panicle initiation stage	15-20
II. Cutworm				
Agrotis ipsilon Study area: Jorhat & Majuli river island	Nov.- Feb.	Potato	Seedling	20-25
			Tuber	5-10
		Toria	Seedling	10-15
		King chilli	Seedling	10-15
III. Termite				
Odontotermes obesus Study area: Jorhat	Feb-March	Sugarcane	Setts (preserved)	35-50
	Aug.- Dec.		Standing crop	12-15
	Round the year	Tea	Shed and standing crop	15-20
		Citrus	Standing crop	5-10
IV. Red ants				
Dorylus orientalis Study area: Jorhat	Nov.- Jan.	Potato	Tuber	20-25
	Oct.-Dec.	French bean	Root	15-20
	Dec.-Jan.	Cabbage	Standing crop	10-15
V. Snails				
Achatina fulica Study area: Jorhat	June-Aug.	Papaya	Fruit	20-30
		Banana	Fruit/ Leaf	25-30
		Spine gourd	Leaf	20-25
		Ridge gourd	Leaf	10-20
		Brinjal	Leaf & fruit	5-10
		Arecanut seedlings	Leaf	5-10
		Cole crops	Leaf and fruit	10-15
VI. Slugs				

Yellow slug, ***Deroceras* sp.** Study area: Jorhat	May-Aug.	Summer vegetables	Leaf and fruit	5-10
Common garden slug, ***Laevicaulis alte*** Study area: Jorhat	Oct.-Feb.	Winter vegetables	Leaf and fruit	5-10

A. Collection of soil insects as well as snails

B. *Pentodon* sp.

C. *Dorylus orientalis*

Fig. 17 (A-C). Survey and collection of soil insect and molluscan pests from diverse habitats of Assam and Arunachal Pradesh

CSK HPKV PALAMPUR:

Abundance and incidence of white grubs in potato during 2020: The problem of white grubs in potato was quite serious in high hills where the potatoes are grown during summer season as rain fed crop under long day conditions. In Badagaon, Kothikohar and Nalhota area of Kangra district and Barot area of Mandi district, *P. fullo* was the predominant species in potato fields. The grubs of *P. fullo* inflicted large circular holes in potato tubers and in certain cases entire tuber was eaten by the grubs **(Plate 2).** Maximum tuber damage was recorded at Badagaon (35.0 %) followed by Kothi Kohar (31.25 %) due to attack of *P. fullo*. The grub population was also high at these locations which was ranged from 10.2 ± 1.62 to 15.5 ± 1.07 grub population /ft^3. Least number of grubs were recorded from Barot (5.8 ± 1.03 grubs/ft^3) with tuber damage of 21.25 per cent (**Table 13**).

Table 13. Incidence of white grubs in potato during 2020

Location	District	Sampling size (n)	Grub population /ft^3	Tuber damage (%)
Baragaon	Kangra	10	15.5 ± 1.07	35.0
Kothi Kohar	Kangra	10	10.2 ± 1.62	31.25
Nalhota	Kangra	10	9.7 ± 1.23	30.0
Barot	Mandi	10	5.8 ± 1.03	21.25

Plate 2. Tuber damage by *P. fullo*

GKVK - Bengaluru:

a. Incidence of *Holotrichia serrata* in groundnut

In August, 2020, seven groundnut fields were sampled in and around Chintamani and recorded incidence of *Holotrichia serrata.* The extent of damage ranged from 5 to 15 per cent.

b. Incidence of white grubs in Sugarcane and estimation of larval population

A total of 21 sugarcane fields were surveyed. The incidence of *H. serrata* was recorded from 60 per cent of fields sampled.

In August, 2020, six sugarcane fields were sampled in Mandya and recorded incidence of *H. serrata*. The extent of damage ranged 5 to 25 per cent. Four sugarcane fields were sampled and recorded incidence of *H. serrata* in Mysuru district in September, 2020. The extent of damage ranged 5 to 25 per cent. In October, 2020, five sugarcane fields and two onions were sampled and recorded incidence of *H. serrata* in Mandya and Chamarajnagar districts. The extent of damage ranged from 10 to 40 per cent. During the survey sporadic incidence of *H. serrata* was also noticed on banana, teak seedlings, onion and maize. However, the incidence was patchy and not severe. Physical collection of grubs from the affected patch was suggested by digging the infested plants (Table 32).

In November, 2020, five sugarcane fields were sampled and recorded incidence of *Holotrichia serrata* in Krinshnarajpet (Mysuru) and two fields in Mandya districts. The severity ranged from 10 to 40 per cent. The age structure included majority of late third-instar grubs, pre –pupa, pupa and a few adults.

Farmers were suggested not to apply any insecticide during this period as insecticides would not be effective, therefore uneconomical. However, advised to plough the severely affected fields, collect and destroy the larvae to minimize the buildup of population in the coming season.

c. Incidence of white grubs in arecanut and estimation of larval population

In August, 2020, surveyed 15 arecanut gardens in Western Ghats and coastal areas of Karnataka and recorded incidence of *Leucopholis* spp. The extent of damage ranged from 25 to 50 per cent.

In October, nine arecanut gardens were sampled and recorded abundance and age structure of arecanut white grubs, *Leucopholis burmeisteri* and *L. lepidophora* in Western Ghats of Karnataka (13°.41’-13°.48’N; 75°.01’-75°.24’E). The extent of damage ranged from 30 to 50 per cent in the affected fields. The age structure of the pest population comprised of first instar grubs of *L. burmeisteri* in Araga, Hulagar and Shuntikatte fields. In Kannagi, Biluve, Hodala, Bejjavalli, Madlu and Kanukoppa third instar grubs of *L. lepidophora* were observed.

Table 32 Incidence of *H. serrata* in sugarcane and onion fields during October, 2020.

Sl. No	Name & address of the farmer	Acreage and Crop stage	Pest incidence level
1	Venktesh, Mahadeshwarapura, Mandya	3.5 acre; First ratoon.	The grub population varied from 3 to 11 grubs per clump. About 40 per cent of the area was damaged by white grub infestation.
2	Rangashetty, Gowdalli village, Agara hobli, Yalandur taluk.	2 acre; First ratoon.	The grub population varied from 0 to 3 grubs per clump. About 10 per cent of the area was damaged by white grub infestation.
3	Mahadevaswamy, Gowdalli village, Agara hobli, Yalandur taluk.	1.5 acre; First ratoon.	The grub population varied from 1 to 3 grubs per clump. About 40 per cent of the area was damaged by white grub infestation.
4	Jayanna, Demally, Santemaralli hobli, Chamarajanagara taluk	2 acre; First ratoon.	The grub population varied from 3 to 17 grubs per clump. About 30 per cent of the area was damaged by white grub infestation. Apart from grubs a few pupae were also observed.

5	Rajashekarappa, Bachally, Angala hobli, Gundlupet taluk	3 acre; First ratoon.	The grub population varied from 2 to 9 grubs per clump. About 40 per cent of the area was damaged by white grub infestation.
6	Y. M. Nagaraja, Eriyur, Terakanambi hobli, Gundlupet taluk	Onion-3 acre; 4 month old	Affected plants showed stunted and wilting symptoms; about 30 per cent of the area was damaged by white grub infestation. Single third instar grub was observed in each affected plant.
7	Raveesh, Eriyur, Terakanambi hobli, Gundlupet taluk	Onion-2 acre; 4 month old	Affected plants showed stunted and wilting symptoms; about 70 per cent of the area was damaged by white grub infestation. Single third instar grub was observed in each affected plant.

In November, 2020, surveyed six arecanut gardens in Western Ghats and three gardens in coastal Karnataka and recorded incidence of arecanut white grubs, *Leucopholis burmeisteri, L. lepidophora* and *L. coneophora*. The extent of damage ranged from 10 to 50 per cent. Highest white grub damage was noticed in marginal to small land holdings of one to five acres.

In December, 2020, Surveyed twelve arecanut gardens in Western Ghats of Karnataka and recorded incidence of arecanut white grubs, *Leucopholis burmeisteri* and *L. lepidophora*. The extent of damage ranged from 30 to 50 per cent. The damage was observed both in young (~one year old) and old palms (above 10 years). The abundance of third instar grubs per affected palm varied from 2 to 18.

Summary/Conclusion: The results of the study revealed that the white grub infestation is steadily increasing in different cropping systems across different agro-climatic regions. High labour cost, lack of knowledge of the pest and labour scarcity were posed as the main constraints for adoption of the entire management strategies in its entirety. The study provides a comprehensive information base for strengthening the extension programmes on management of white grubs in the state**.**

C. Incidence of Giant African Snail

In August, 2020, a wide spread incidence of the giant African snail was recorded in Mulabagilu, Kolar district. The snails were found to feed on foliage of almost all the vegetables. Suitable control measures were suggested to the affected farmers.

FARMER- Ghaziabad

Methodology: Visual monitoring of soil arthropod pest species and their extent of damage in different crops was conducted during the year 2020-2021 at different locations in western UP. The survey of sugarcane, sorghum, cucurbits, maize, papaya crops growing fields was undertaken to monitor damaging stage of white grub in the villages Dabana, Jalalabad, Ujjeda and Mohamadpur Kadeem of Ghaziabad district, Santhali village in Gautambudh Nagar, Behada Sadat, Meghakhari, Datyana, Chario, Trivani Sugarcane Mill in Muzaffarnagar and Jallopur village in Amroha, Chario in Deoband in Saharanpur, Village Etmadpur village in Bulandshahr district of western UP. Infestation of white grub was recorded from each point.

		
Fig 18. Population monitoring of damaging stages of soil arthropod pests and their extent of damage in Papaya crop field	**Fig 19. 2^{nd} stage white grub in papaya crop field**	**Fig 20. 3^{rd} stage grub in cucumber crop field**
		
Fig. 21. 3^{rd} stage grub in each cucumber plant	**Fig. 22. White grub infestation in pumpkin crop**	**Fig 23. White grub infestation in sugarcane crop**
		
Fig 24. 3^{rd} stage grub in sugarcane crop	**Fig 25. White grub infestation in sugarcane crop**	**Fig 26. White grub in harvested sugarcane field**

The population of white grub larvae of 2nd and 3rd instars 0 - 10 white grubs per sq. m was recorded in sugarcane, papaya, sorghum and cucurbits crop in the months of June to September 2020. The 3rd instars white grub population was also recorded in harvested sugarcane crop field in the month of January 2021. The per square meter minimum and maximum grub population was recorded as 0-3 and 7-10 respectively.

Summary/Conclusion: The white grub infestation ranging from 0-3 and 7-10 per clump of was recorded in different crop; sugarcane crop at Dabana village, papaya crop in Sadarpur village and cucurbits crops in Surena village, Ghaziabad district, Sugarcane crop in Jallopur villages in Amroha district, Sugarcane and Sorghum crops in Bahada sadat, Meghakhari and Datyana villages in Muzaffarnagar district and chirao village in Deoband, Saharanpur district.

COA-Kolhapur

The survey of major groundnut and sugarcane growing areas of Kolhapur district during *Kharif* season of 2020 revealed that 24 numbers of grubs were observed at only one survey in August. Among these, 16 and 8 grubs were collected from sugarcane and ground nut field respectively. On an average 3.2 grubs were observed per 5 clumps of sugarcane; while it was 1.6/m^2 in groundnut field (Table 33).

Table 33. Monitoring of damaging stage of white grub and their extent of damage in different crops

Sr. No.	Species	Location	Crop	No of grubs/5 clump [5m^2]	Crop	No of grubs/m^2
1	*Holotrachia serrata*	Gadmudshingi, Karveer	Sugarcane	4	Ground nut	5
2		Kanheri math, Karveer	Sugarcane	9	Ground nut	10
3		Banage, Kagal	Sugarcane	1	Ground nut	2
4		Saverde Bk, Kagal	Sugarcane	5	Ground nut	7
5		Lingnur, Kagal	Sugarcane	7	Ground nut	9
6		Vathar, Hatkanagale	Sugarcane	2	Ground nut	3
7		Ghunaki, Hatkanagale	Sugarcane	3	Ground nut	4
8		Mandukali, Gaganbawada	Sugarcane	3	Ground nut	4

9		Ambewadi, Chandgad	Sugarcane	1	Ground nut	2
10		Gadhingalaj	Sugarcane	8	Ground nut	9
11		Yerdul, Ajara	Sugarcane	6	Ground nut	8
	Total			49		63
	Average	--		4.45		5.73

Table 34. Extent of damage by white grub, *Holotrachia serrata* in sugarcane.

Sr. No.	**Location**	**No of grubs/5 clump [5m²]**	**Yield t/ha**		% Damage
			Treated	**Untreated**	
1	Gadmudshingi, Karveer	4	90	73	19
2	Kanheri math, Karveer	9	85	60	29
3	Banage, Kagal	1	96	84	13
4	Saverde Bk, Kagal	5	89	70	21
5	Lingnur, Kagal	7	87	65	25
6	Vathar, Hatkanagale	2	93	79	15
7	Ghunaki, Hatkanagale	3	92	75	18
8	Mandukali, Gaganbawada	3	91	76	16
9	Ambewadi, Chandgad	1	94	81	14
10	Gadhingalaj	8	85	62	27
11	Yerdul, Ajara	6	88	68	23
	--	4.45	90.00	72.17	20.00

Table 35. Extent of damage by white grub, *Holotrachia serrata* in groundnut.

Sr. No.	**Location**	**No of grubs/5 clump [5m²]**	**Yield q/ha**		**% Damage**
			Treated	**Untreated**	
1	Gadmudshingi, Karveer	5	15	11	28
2	Kanheri math, Karveer	10	11	7	38
3	Banage, Kagal	2	19	16	15
4	Saverde Bk, Kagal	7	14	10	31
5	Lingnur, Kagal	9	13	9	34
6	Vathar, Hatkanagale	3	17	13	21
7	Ghunaki, Hatkanagale	4	17	13	23
8	Mandukali, Gaganbawada	4	16	12	25

9	Ambewadi, Chandgad	2	18	15	18
10	Gadhingalaj	9	12	8	36
11	Yerdul, Ajara	8	14	9	33
	--	5.73	15.09	11.12	27.45

D. Pheromonal Studies

AAU-Jorhat

Pheromonal and Kairomonal studies of *Lepidiota mansueta*

Five pheromonal compounds (Cis-9 Hexadecenoic acid, Octadec- 9 enoic acid, 1-Tetradecene, 1-Hexadecene and 1-Octadecenol) in pure form and their five different blends were tested along with male and female body wash in a heavy *L. mansueta* endemic field at Maharichuk village, Majuli during April, 2021. Two pheromonal compounds *viz*., Cis-9 Hexadecenoic acid and Octadec-9 enoic acid were synthesized at ATGC Biotech Pvt. Ltd., Hyderabad through outsourcing and the rest of the compounds *i.e.* 1-Tetradecene, 1-Hexadecene and 1-Octadecenol were procured from Sigma Aldrich and Avra synthesis Pvt. Ltd. Water traps were selected for conducting the experiments where the pure pheromonal compounds along with its blends were loaded (Fig. 28. A-B) and the treatments were evaluated on the basis of the average number of beetles trapped to each treatment.

A. Preparation of blends

B. Loading of pheromonal and kairomonal lures

C. Water traps with loaded lures

Fig. 28. A. Setting up of water traps and loading of pheromonal and kairomonal lures

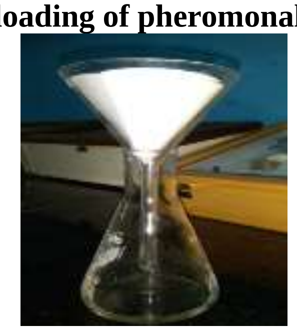


Fig. 29. B. Preparation of male and female body wash for kairomonal studies

Among the 13 different pheromonal and kairomonal blends tested, the mean maximum numbers of beetles (6.64) were recorded in the treatment T_4 (Octadec-9-enoic acid @ 100%) followed by T_{12}: Female body wash @ 100 per cent (6.08) and T_{11}: Male body wash @ 100 per cent (5.89) (Fig. 29 & Table 36). However, the nos. of beetles trapped in the aforementioned compounds were found to be statistically *at par* with the untreated control (7.50 nos.).

Fig. 30. *Lepidiota* beetles trapped in different treatments

Table 36. Efficacy of five pure pheromonal compounds, their different blends and male & female body wash used in trapping *L. mansueta* adults during 2021

Treatments	Total beetles trapped (Nos.) Mean±SD
T_1 (Hexadecene @100%)	1.91±0.51 (7.90)
T_2 (Tetradecene @100%)	3.46±2.75 (10.08)
T_3 (Hexadecenoic acid @100%)	3.96±1.71 (11.29)
T_4 (Octadec-9-enoic acid @ 100%)	**6.64±4.04 (14.42)**
T_5 (1-Octadecenol @100%)	5.14±1.66 (12.97)
T_6 (Hexadecene @ 20% + Tetradecene @ 20% + Hexadecenoic acid @ 20% + Octadec-9-enoic acid @ 20% +1-Octadecenol @ 20%)	3.79±2.43 (10.84)
T_7 (Hexadecene @ 30% + Tetradecene @ 20% + Hexadecenoic acid @ 20% +Octadec-9-enoic acid @ 20% + 1-Octadecenol @ 10%)	3.23±2.54 (9.87)
T_8 (Hexadecene @ 20% + Tetradecene @ 30% + Hexadecenoic acid @ 20% + Octadec-9-enoic acid @ 20% + 1-Octadecenol @ 10%)	3.16±0.83 (10.19)
T_9 (Hexadecene @ 20% + Tetradecene @ 20% + Hexadecenoic acid @ 30% + Octadec-9-enoic acid @ 20% + 1-Octadecenol @ 10%)	2.75±1.39 (9.29)
T_{10} (Hexadecene @ 20% + Tetradecene @ 20% + Hexadecenoic acid @ 20%+ Octadec-9-enoic acid @ 30%+ 1-Octadecenol @10%)	4.52±1.20 (12.19)
T_{11} (Male body wash @ 100%)	**5.89±5.72 (13.03)**
T_{12} (Female body wash @ 100%)	**6.08±2.96 (13.99)**
T_{13} (Male body wash @ 50% + Female body wash @ 50%)	5.08±2.45 (12.72)
Control (Water)	**7.50±2.52 (15.72)**
S. Ed (±)	0.93
CD (P=0.05)	1.88

* Data are mean of 12 days & data in parenthesis are angular transformed values

By observing the results obtained from the previous experiment, an additional experiment was also conducted by selecting the 3 probables superior pheromonal compounds in trapping *L. mansueta* adults along with an untreated control. Experimental results revealed a relatively lower attraction of beetles in all the treatments as compared to the previous experiments. The mean beetles trapped during the experiment was ranged between 0.66-1.40 nos. in all the treatments where maximum was recorded from Octadec-9-enoic acid @100 per cent (Table 37).

Table 37. Efficacy of probable superior pheromonal compounds in trapping *L. mansueta* adults during 2021

Treatments	Total beetles trapped (Nos.)
	Mean±SD
T_1 (Octadec-9-enoic acid @ 100%)	**1.40±0.64 (6.64)**
T_2 (Male body wash @ 100%)	0.66±0.41 (4.51)
T_3 (Female body wash @ 100%)	0.86±0.96 (4.40)
Control (Water)	**1.00±0.85 (4.99)**
S. Ed (±)	0.69
CD (P=0.05)	1.50

Data in parenthesis are angular transformed values

The efficacy of Octadec-9 enoic acid @ 100 per cent was also statistically compared with the untreated control in an additional experiment laid out and designed with "paired t" test. Data presented in Table 5 revealed that the T (cal) value is 0.473 which is less than the T (p=0.05) *i.e.*, 2.776 and hence, there was no statistical difference observed between the aforementioned 2 treatments (Table 38).

Table 38. Efficacy of Octadec-9-enoic acid @ 100 per cent in comparison with control

Replications	Octadec-9-enoic acid @100 %	Control
	Nos. of beetle trapped	
R_1	3.00	1.28
R_2	5.42	1.28
R_3	2.14	2.28
R_4	2.57	4.28
R_5	3.42	4.85
Mean	**3.31**	**2.79**
T (cal)	**0.473**	
T (p=0.05)	**2.776**	

A separate experiment was also conducted with 9 numbers of pheromonal lures received from NBAIR, Bengaluru for field evaluation (Fig. 31). However, all the lures were found to be ineffective as the mean numbers of beetles trapped in the treatments were ranged between 0.60 to 2.38 and all the treatments showed statistical parity with each other except for the T_9 (Table 39).

Fig. 31. Field testing of pheromonal lures received from NBAIR, Bengaluru

Table 39. Efficacy of 9 different pheromonal lures received from NBAIR, Bangalore in trapping *L. mansueta* adults during 2021

Treatments	Total beetles trapped (Nos.)
	Mean±SD
T_1	1.42±1.02 (6.57)
T_2	2.38±0.70 (8.78)
T_3	1.70±1.21 (7.19)
T_4	1.25±0.58 (6.29)
T_5	1.46±1.09 (6.56)
T_6	2.00±1.16 (7.89)
T_7	1.32±0.82 (6.35)
T_8	1.64±0.52 (7.28)
T_9	0.60±0.54 (4.14)
Control (Water)	1.70±1.01 (7.22)
S. Ed (±)	**0.58**
CD (P=0.05)	**1.18**

Data in parenthesis are angular transformed values

A large number of pupae were also collected from different locations of Majuli and were reared in AINP on Soil Arthropod Pests Laboratory (Fig. 32). Sex based separation was done at the pupal stages so as to get sufficient numbers of virgin male and female beetles. A total of 140 nos. of pupae (70 male & 70 female) along with laboratory reared adults of 1032 numbers (566 male and 470 female) were also sent in six different batches to the Semiochemicals Laboratory for conducting electrophysiological studies in collaboration with Dr. P D Kamala Jayanthi, Principal Scientist, Department of Entomology, Indian Institute of Horticultural Research, Bengaluru (Fig. 33. A-B).

Furthermore, efforts were also made to identify the probable kairomonal compounds present in both the male and female body wash. Male and female body wash were prepared using standard protocols and extracts were sent to Guwahati Biotech Park, Indian Institute of Technology, Guwahati for GC-MS analysis. Due to the Covid pandemic situation in the state, the results are yet to be received from the aforementioned institute.

Fig. 32. Collection and rearing of pupae collected from farmer's field of Majuli

A. Separation of male and females beetles of *L. mansueta*

B. Shipment of samples

Fig. 33 (A-B). Separation and shipment of pupae and adults to IIHR, Bengaluru for electrophysiological studies

GKVK-Bengaluru

Pheromonal studies on predominant white grub species:

In 2020 amid the COVID-19 pandemic visited the white grub affected gardens and collected 1631 male and 118 female beetles of *Leucopholis burmeisteri.* Unfortunately, with no means of transport due to the lockdown, soon after the collection the samples could not be taken to the laboratory for isolation of pheromone. In 2021 the adult beetles did not emerge as the said species completes its life cycle in two years.

E. Monitoring of natural enemies of soil arthropods

FARMER-Ghaziabad

Methodology: To monitor the occurrence of natural enemies (parasitoids, predators & pathogens) of major soil arthropods, seasonal soil sampling was done in the endemic pockets of white grub infestation. Entomopathogenic Nematodes (EPNs) and Entomopathogenic Fungus (EPFs) were isolated by baiting and serial dilution method respectively and will be forwarded to Indian Agriculture Research Institute, New Delhi for identification. Soil samples (141) were collected to isolate EPNs and EPFs from village Meghakhari, Datyana, Behada Sadat in Muzaffarnagar district and Chirao, Deoband in Saharanpur district; Mohammadpur Kaddim, Sadarpur, Surana, Sobhapur, in Ghaziabad district, Salempur in Bulandshahar district, covering 14 locations in four districts in western UP.

Fig. 34 Collection of soil samples for isolation of EPNs and EPFs

Fig. 35 Isolation of Entomopathogenic nematodes by bating methodology

Fig. 36 *Galleria mellonella* cadavers infected by different EPN species (under Leica S9i stereozoom microscope)

Fig. 37 *Galleria mellonella* cadavers on White Trap for IJs isolation

Fig. 38 Emergence of IJs from H. *indica* infected *Galleria* cadaver (under Leica S9i stereozoom microscope)

Fig. 39 Free moving stage of *H. indica* IJs in water (under Leica S9i stereozoom microscope)

Results: The two strains of entomopathogenic nematodes (EPNs), initially infected *Galleria mellon*ella larva colors indicate that both are belong to *Heterorhabditis* sp. had been isolated by bating method from the soil samples collected during the current season (Figure 39 and 40). Further multiplication of EPNs on host insect (*Galleria mellonella*, wax moth larvae) is going on in FARMER laboratory to maintain strain wise culture and for forwarding to Division of Nematology, Indian Agriculture Research Institute, New Delhi for identification.

Fig. 40 ***Galleria mellonella*** **cadavers effected by a new strain of EPN; isolated from sugarcane crop field in Muzaffarnagar (under Leica S9i stereozoom microscope)**

Fig. 41 ***Galleria mellonella*** **cadavers effected by a new strain of EPN; isolated from sugarcane crop field in Muzaffarnagar (under Leica S9i stereozoom microscope)**

Eight strains of Entomopathogenic fungus (EPFs) also isolated during current session by FARMER VC Ghaziabad. Further multiplication of EPFs is going on in laboratory to maintain strain wise culture and for forwarding to IARI, New Delhi for identification.

Summary/Conclusion: Two types of EPNs and Eight types of EPFs were isolated from 141 soil samples during the year. EPNs and EPFs were present in 1.42% and 5.67% respectively of total soil samples. Now, a total of 9 EPNs strains are available in FARMER VC Ghaziabad. Culture of isolated strains is being maintained throughout the year.

Table 40 Isolated and identified strains of EPN by FARMER VC Ghaziabad

Year	Infected *Galleria* cadaver	Molecular identification by ITS marker	Crop	Location	Gene Bank Accession No.
2014		*Heterorhabditis indica*	Mango	Noorpur Ghaziabad, UP	*MK078600*
2014		*Steinernema thermophilum/ abbasi*	Sugarcane	Chilla, Amroha, UP	*MK078603*
2016		*Heterorabditis indica*	Mango	Sabitgarh, Bulandshahr, UP	*MK078602*
2016		*Steinernema thermophilum/ abbasi*	Sugarcane	Jallopur, Amroha, UP	*MK078606*
2017		*Heterorhabditis indica*	Sugarcane	Noorpur Ghaziabad, UP	*MK078601*
2017		*Steinernema siamkayai*	Pigeon pea	Kushaliya, Ghaziabad, UP	*MK078604*
2017		*Steinernema siamkayai*	Star fruit	Moh. kidim, Ghaziabad, UP	*MK078605*

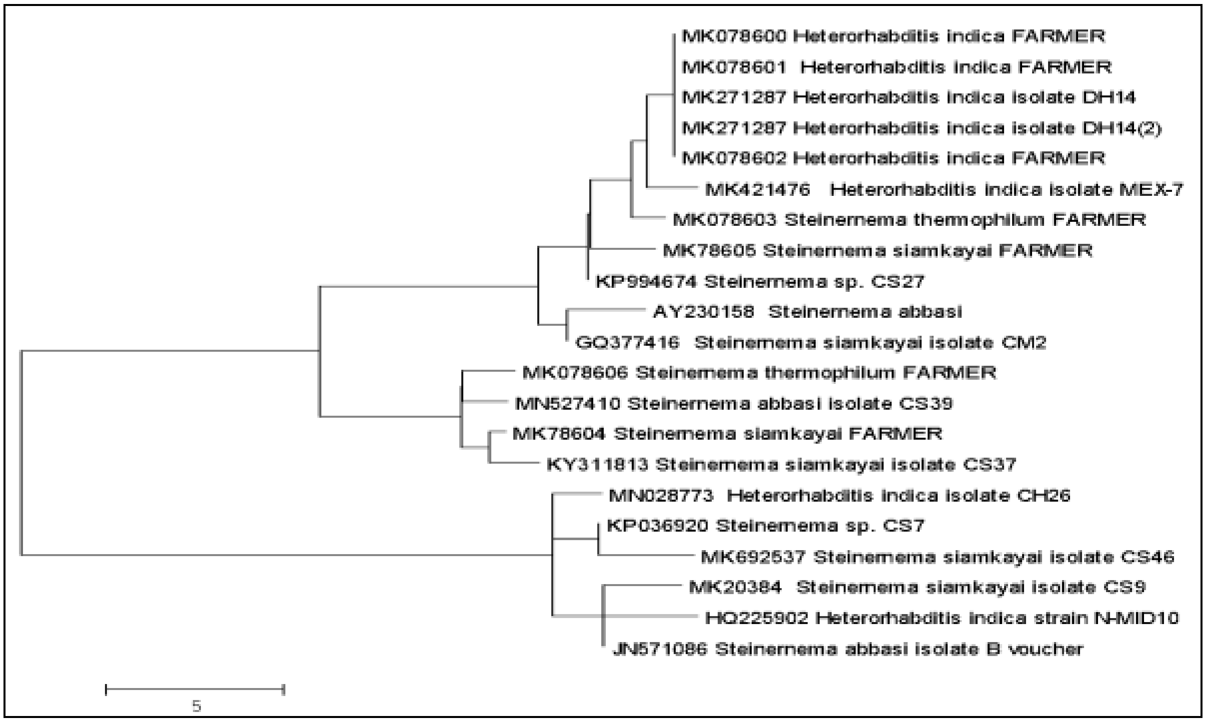


Fig. 42 Copy of identification report indicating Phylogenetic relationship of Entomopathogenic nematodes species/ Strains based on ITS region by Neighbour-joining method

COA-Kolhapur

Based on information collected from the students and their host as well as contact farmers the bird crow is major predator followed by bandicoot, however, statistical data is not available.

Table 41 Natural enemies of white grub, *Holotrachia serrata* in sugarcane and groundnt.

Sr. No.	Location	Natural enemies	Observations
1	Gadmudshingi, Karveer	Crow, Crane	
2	Kanheri math, Karveer	Crow, Crane, Bandicoot	Sugarcane trash mulching
3	Banage, Kagal	Crow, Crane	
4	Saverde Bk, Kagal	Crow, Crane	
5	Lingnur, Kagal	Crow, Crane	
6	Vathar, Hatkanagale	Crow, Crane	
7	Ghunaki, Hatkanagale	Crow, Crane, Rats	Sugarcane trash mulching

II. MANAGEMENT OF WHITE GRUBS THROUGH CHEMICALS

RARI, DURGAPURA

A. Evaluation of granular insecticides against white grub, *Holotrichia consanguinea* in groundnut crop during *kharif* (2020-21)

For control of white grub through granular insecticides an experiment was conducted. The data present in table 4 indicated that minimum plant mortality and maximum pod yield was recorded in chlorantraniliprole 0.4 % GR with 10.47 % plant mortality and 20.01 q/ha yield followed by imidacloprid 70WG. In untreated check 100 per cent plant mortality was recorded (Table 42).

Table 42 Evaluation of granular insecticides against white grub, *Holotrichia consanguinea* in groundnut crop during *kharif* (2020-21)

S. No.	Treatments	Dose	Plant mortality (%)	Larval population /m^2	Pod yield (q/ha)
1	Carbofuran 3G	750 g a.i./ha	80.04 (63.44)*	5.33	5.05
2	Clothianidin 50 WDG	120 g a.i./ha	56.13 (48.51)	3.33	10.51
3	Fipronil 0.3G	50 g a.i./ha	66.87 (54.89)	4.00	8.06
4	Thiamethoxam 25WG	80 g a.i./ha	82.06 (65.24)	5.00	5.40
5	**Imidacloprid 70 WG**	**300g a.i./ha**	**15.41 (22.37)**	**0.33**	**19.68**
6	**chlorantraniliprole 0.4% GR***	**100 g a.i./ha**	**11.47 (19.67)**	**0.33**	**20.01**
7	Fifronil40%+Imidacloprid 40%WG*	300 g/ha	82.84 (65.51)	4.67	4.16
8	Untreated check	750 g a.i./ha	100.00 (90.00)	6.33	0.00
	SE(m)	-	2.454	0.406	0.761
	C.D. at 5%	-	7.51	1.24	2.33
	C.V. %	-	7.91	9.17	14.48

*Data in parentheses are angular transformed values

AAU, JORHAT

A. Evaluation of granular insecticides against white grubs in potato during 2020-21

Field efficacy of six insecticides were evaluated against *L. mansueta* in potato at farmers' field of Maharichuk, Majuli, Assam. The experimental design was laid out in 3RBD with individual plot size of 4 × 3 sq. m (Fig. 43). The variety "*Kufri Khyati*" was grown by following all the recommended package and practices of Assam. The required amount of insecticides were incorporated with pulverized soil and applied in seed furrows before sowing of the tubers. The crop was sown on 9th November, 2020 and harvested on 25th February, 2021. The effectiveness of different treatments were recorded on the basis of per cent tuber damage caused by the grubs both in weight and number basis, number of grubs per sq. m at the time of harvest, tuber yield and cost benefit ratio.

Experimental results revealed that all the insecticidal treatments were significantly superior over the untreated control in reducing per cent tuber damage (weight and number basis) as well as number of grubs per sq. m and increasing the tuber yield (Table 43). On weight basis, clothianidin 50 WDG @ 120 g *a.i.*/ha treated plots recorded the lowest per cent of tuber damage (3.73%) and this treatment was found to be significantly superior over rest of the insecticidal treatments. The plots treated with chlorantraniliprole 0.4 GR @ 100 g *a.i.*/ha recorded 4.48 per cent of tuber damage on weight basis which was followed by imidacloprid 70 WG @ 300 g *a.i.*/ha (5.30%) and fipronil 40% + imidacloprid 40% WG @ 300 g *a.i.*/ha (6.81%). Rest of the two treatments *viz*., thiamethoxam 25 WG @ 80 g *a.i*/ha and fipronil 0.3 G @ 50 g *a.i.*/ha registered 8.51 and 8.61 per cent of tuber damage, respectively and showed statistical parity with each other. The untreated control plot registered 22.20 per cent of tuber damage (Table 8).

Similar trend was observed while assessing the tuber damage on number basis. The plots treated with clothianidin 50 WDG @ 120 g *a.i.*/ha recorded statistically lowest percentage of tuber damage (3.04) as compared to other treatments. The plots treated with chlorantraniliprole 0.4 GR @ 100 g *a.i.*/ha, imidacloprid 70 WG @ 300 g *a.i.*/ha and fipronil 40% + imidacloprid 40% WG @ 300 g *a.i.*/ha registered 4.05, 5.12 and 6.24 per cent of tuber damage, respectively. Thiamethoxam 25 WG @ 80 g *a.i.*/ha and fipronil 0.3 G @ 50 g *a.i.*/ha recorded 7.93 and 8.37 per cent of tuber damage which were statistically *at par* with each other. The untreated control plots recorded 21.04 per cent of tuber damage (Table 8).

At the time of harvesting, the grub population ranged between 2.00-4.00 nos./sq. m. in the insecticidal treated plots in which clothianidin 50 WDG @ 120 g *a.i.*/ha recorded the least number of grubs. The number of grubs recorded in untreated control plot was 4.67 nos./ sq.m. Among all the treatments, highest tuber yield (262.31 q/ha) was recorded in clothianidin 50 WDG @ 120 g *a.i.*/ha treated plots which was significantly higher as compared to rest of the treatments. The plots treated with chlorantraniliprole 0.4 GR @ 100 g *a.i.*/ha and imidacloprid 70 WG @ 300 g *a.i.*/ha recorded tuber yield of 253.95 and 243.87 q/ha. The untreated control plot registered the yield of 202.68 q/ha.

Benefit cost ratio was highest in case of clothianidin 50 WDG @ 120 g *a.i.*/ha treated plots (2.47) followed by chlorantraniliprole 0.4 GR @ 100 g *a.i.*/ha (2.36) and imidacloprid 70 WG @ 300 g *a.i.*/ha (2.18) (Table 8).

Table 43 Evaluation of granular insecticides against *L. mansueta* in potato at Majuli during 2020-21

Treatments	Doses (g *a.i.*/ha)	Per cent tuber damage		No. of grubs/ sq.m.	Yield (q/ha)	B:C ratio
		Weight basis	Number basis			
Clothianidin 50 WDG	120	3.73 (11.15)	3.04 (10.05)	2.00	262.31	2.47
Fipronil 0.3 G	50	8.61 (17.07)	8.37 (16.81)	4.00	215.17	1.92
Thiamethoxam 25 WG	80	8.51 (16.96)	7.93 (16.37)	3.67	216.67	1.97
Imidacloprid 70 WG	300	5.30 (13.32)	5.12 (13.07)	3.00	243.87	2.18
Chlorantraniliprole 0.4 GR	100	4.48 (12.23)	4.05 (11.62)	2.67	253.95	2.36
Fipronil 40% + Imidacloprid 40% WG	300	6.81 (15.13)	6.24 (14.47)	3.33	233.43	2.08
Untreated control	-	22.20 (28.12)	21.04 (27.29)	4.67	202.68	
S.Ed (±)		**0.11**	**0.34**	**0.11**	**1.00**	
CD (p=0.05)		**0.24**	**0.73**	**0.24**	**2.17**	

Data in parenthesis are angular transformed values

A. General view of the experimental plots


B. Layout of the experiment | **C. Application of insecticides in seed furrows**


D. Infested tubers | **E. Healthy tubers**

Fig. 43 (A-E). Evaluation of granular insecticides against *L. mansueta* in potato at Majuli during 2020-21

CSKHPKV- Palampur

Evaluation of granular insecticides against white grubs in potato

Location	Sazar, District Shimla
Crop	Potato cv Kufru Jyoti
Sowing time	17 April, 2020
Design	RBD
Treatments	6
Replications	4
Date of harvesting	14 October, 2020

The experiment was conducted in potato fields in Shimla hills. Potato cv Kufri Jyoti was sown in plots of 12 m^2 in the month of April. The crop was raised as per recommended package of practices. All the treatments were applied in the first week of July during the time of earthing up. Data on tuber damage on number and weight basis were recorded at the time of harvesting in October 2020 to calculate the per cent tuber damage. Grub population was also recorded and expressed as number of grubs/m^2. Among all the tested insecticides, clothianidin was found most effective with least tuber damage on weight basis (3.3%) and number basis (3.91%). Fipronil 40%+ imidacloprid 40% was least effective among all the tested insecticides and per cent tuber infestation of 9.76% and 10.32% was recorded on weight and number basis, respectively. On weight basis, thiamethoxam, imidacloprid and chlorantraniliprole yielded 4.8, 4.2 and 3.79% tuber damage. In untreated check, 21.12% tubers were found damaged. While, on number basis, 3.91-4.99% tuber damage was recorded in thiamethoxam, imidacloprid and chlorantraniliprole, respectively. 22.63% infested tubers were recorded in untreated check. Maximum number of grubs (grubs/plant) were recorded in Fipronil 40%+ imidacloprid 40% treatment while least number of grubs (1.11 grubs ft^2) were recorded in clothianidin treatment. The population of grubs varied 1.82-2.73 grubs/feet^2 in imidacloprid, thiamethoxam and fipronil 40%+ imidacloprid 40% treated plots, as compared to 5.87 grubs/feet^2 in untreated plots (**Table 44**).

Table 44. Evaluation of granular insecticides against white grubs in potato during 2020

Treatments	**Dose**	**Per cent tuber infestation**		**No. of grubs/plant**
		Weight basis	**Number basis**	
Clothianidin 50 WDG	120 g ai/ha	3.30	3.43	0.84
Thiamethoxam 25 WG	80 g a.i/ha	4.80	4.99	1.08
Imidacloprid 70 WG	300 g ai/ha	4.20	4.32	0.96
Chlorantraniliprole 0.4% G	100 g ai/ha	3.79	3.91	0.75
Fipronil 40%+ Imidacloprid 40% WG	300 g/ha	9.76	10.32	2.40
Control		21.12	21.00	5.52
CD (=0.05%)		2.77	2.32	1.64

COA- Kolhapur

Evaluation of granular insecticides against white grubs in Groundnut during 2018-19

The incidence of the white grub started 40 DAT. The treatment with Fifronil 40%+Imidacloprid 40%WG @300 g a.i./ha recorded 1.57 per cent mortality of the clumps as compared to 11.33 per cent in untreated control. However, Fifronil 40%+Imidacloprid 40%WG @300 g a.i./ha was found on par with chlorantraniliprole 0.4% GR @ 100g a.i./ha and chlothianidin 50 WDG @ 120 g a.i./ha.when observations were recorded 40 DAT

The mortality of the clump ranged from 2.43 to 15.20 per cent, when observations were recorded 60 DAT. The treatment with Fifronil 40%+Imidacloprid 40%WG @300 g a.i./ha 2.43 per cent clump mortality was recorded which was significantly superior over all other insecticide treatment. The treatment with chlorantraniliprole 0.4% GR @ 100g a.i./ha (4.33 per cent) and chlothianidin 50 WDG @ 120 g a.i./ha (6.67 per cent) were next in order of efficacy. Siginificant differences did not existed among rest of the treatment. Similar results were recorded 80DAT.

Among the treatments Fifronil 40%+Imidacloprid 40%WG @300 g a.i./ha recorded highest yield (50.68 t/ ha) followed by 47.59 t/ha in the treatment with chlorantraniliprole 0.4% GR @ 100g a.i./ha, chlothianidin 50 WDG @ 120 g a.i./ha (42.08 t/ha), thiamethoxam 75 SG @ 75g ai / ha (41.98) and fipronil 0.3 G (41.45 t/ha) were next in order of efficacy as compared to 20.13 t / ha in untreated control (Table 45).

Conclusion: The treatment with Fifronil 40%+Imidacloprid 40%WG @300 g a.i./ha, chlorantraniliprole 0.4% GR @ 100g a.i./ha and chlothianidin 50 WDG @ 120 g a.i./ha found effective in reducing clump mortality and suggested in management of white grub in sugarcane.

Table 45 Management of white grub in Sugarcane, *Leucopholis lepidophora* through soil treatment with granular insecticide.

SN	Treatment and dose	Initial plant popl^{n}	Per cent clump mortality (DAT)				% Protection over UTC	Yield (t/ha)	No. of grubs/m^{2}
			40	60	80	Mean			
1	Carbofuran 3G	668	9.07 (17.50)	10.67 (19.05)	14.00 (21.95)	11.24 (19.50)	29.44	88.85	1.04
2	Clothianidin 50 WDG	687	5.57 (13.75)	6.67 (14.95)	7.63 (16.02)	6.62 (14.90)	58.44	92.08	0.41
3	Fipronil 0.3G	681	5.43 (13.47)	7.23 (15.59)	8.57 (17.00)	7.07 (15.35)	55.61	91.45	1.17
4	Thiamethoxam 25WG	679	8.33 (16.77)	8.43 (16.87)	8.53 (16.97)	8.43 (16.87)	47.08	91.98	1.17
5	Imidacloprid 70 WG	665	7.97 (16.38)	10.00 (18.42)	10.67 (19.05)	9.54 (17.95)	40.11	90.60	0.97
6	Chlorantraniliprole 0.4 GR	698	3.37 (10.56)	4.33 (12.00)	6.67 (14.95)	4.79 (12.50)	69.93	97.59	0.35
7	Fifronil40%+ Imidacloprid 40%WG	672	1.57 (7.11)	2.43 (8.96)	3.43 (10.65)	2.47 (8.90)	84.49	90.68	0.31
8	Untreated check	679	11.33 (19.65)	15.20 (22.93)	21.27 (27.43)	15.93 (23.33)	--	70.13	4.32
	S.Em ±	38	0.41	0.25	0.32	0.33	--	2.53	0.08
	CD at 5%	NS	1.25	0.77	0.99	1.03	--	6.30	0.23

*figures in parenthesis are arcsine transformed value

GPUA&T- Pantnagar

Field evaluation of pre sown application of different granular insecticides against white grub infesting soybean during *kharif*, 2020

Field evaluation of pre sown application of different granular insecticides was carried out against white grub infesting soybean during *kharif*, 2020. There was no significant different in initial plant population. During the study, the plant mortality was ranged from 3.65 to 23.48 percent. After application of 40 days of insecticidal treatment, the plant mortality was ranged from 3.65 to 9.17 percent while in control it was 14.21 percent. Lowest plant mortality was recorded in Fipronil 40%+ Imidacloprid 40% WG applied @ 300 ml *a.i.* ha^{-1} were the plant mortality was 3.65 percent followed by non-significantly Clothianidin 50 WDG applied @ 120 g a.i. ha^{-1}. After 60 days of application of insecticide, the cumulative plant mortality was ranged from 4.82 to 16.79 percent. The lowest and highest plant mortality was observed in Fipronil 40%+ Imidacloprid 40% WG (applied @ 300 ml a.i. ha^{-1}) and Chlorantraniliprole 0.4% GR (applied @ 100 ml a.i. ha^{-1}) i.e. 4.82 % and 16.79 %, respectively. Similarly, after 60 days of application of insecticide, lowest cumulative infestation was recorded in Fipronil 40%+ Imidacloprid 40% WG (applied @ 300 ml a.i. ha^{-1}) followed by Clothianidin 50 WDG where the cumulative plant mortality was 9.41 and 10.33 percent, respectively.

Highest yield i.e., 24.83 qha^{-1} was recorded Fipronil 40%+ Imidacloprid 40% WG (applied @ 300 ml a.i. ha^{-1}) followed by Clothianidin 50 WDG where the yield was 22.41 q ha^{-1}. Highest net return was also observed in Fipronil 40%+ Imidacloprid 40% WG (applied @ 300 g a.i. ha^{-1}) i.e., rupee 50.6 thousand. Thus, study revealed that Fipronil 40%+ Imidacloprid 40% WG (applied @ 300 g a.i. ha^{-1}) was found to be best insecticide followed by Clothianidin 50 WDG (applied @ 120 g a.i. ha^{-1}) with lowest infestation of white grub and highest yield (Table 46).

Table 46 Field evaluation of pre sown application of different granular insecticides against white grub infesting soybean during *kharif*, 2020.

Tr. No.	Treatment	Dose (g a.i/ha)	Mean initial plant population (2 x 2 m^2)	Mean % plant mortality (DAS)			Grain yield (q/ ha $^{-1}$)	Cost of treatment (Rs ha $^{-1}$)	Net return over control (Rs ha $^{-1}$)	Mean no. of grubs/pit (15.10.2020)
				40	60	80				
T_1	Carbofuran 3G	750	132.00	7.62 (15.99)	10.36 (18.76)	14.54 (22.41)	18.59	3000	31000	1.40
T_2	Clothianidin 50 WDG	120	134.67	4.55 (12.20)	7.49 (15.87)	10.33 (18.74)	22.41	3200	43788	0.60
T_3	Fipronil 0.3 G	50	130.33	8.13 (16.56)	13.56 (21.60)	16.38 (23.87)	15.64	1900	22070	1.80
T_4	Thiamethoxam 25 WG	80	134.00	9.17 (17.61)	14.41 (22.30)	21.16 (27.39)	14.27	1500	17812	2.60
T_5	Imidacloprid 70WG	300	132.00	5.72 (13.09)	9.81 (18.24)	12.32 (20.54)	20.42	4150	36072	1.20
T_6	Chlorantraniliprole 0.4% GR	100	134.00	9.84 (18.28)	16.79 (24.18)	23.48 (28.98)	13.81	4650	13098	2.20
T_7	Fipronil 40%+ Imidacloprid 40% WG	300	136.00	3.65 (10.96)	4.82 (12.68)	9.41 (17.86)	24.83	4550	50666	1.00
T_8	Untreated control	-	134.33	14.21 (22.14)	22.16 (28.08)	40.37 (39.44)	8.59	-	-	3.40
SEm (±)			**NS**	**0.58**	**0.34**	**0.36**				
C.D. (5%)			**-**	**1.75**	**1.03**	**1.09**				
CV (%)			**-**	**6.25**	**2.92**	**2.51**				

Figures in parentheses are angular transformation

Rate of soybean grain: Rs. 3400.0 per quintal

*Labour Charge: Rs. 300

Field evaluation of post sown application of different granular insecticides in soybean against the white grub during *kharif*, 2020.

Field evaluation of post-sown application of different granular insecticides against the white grub infesting soybean was carried out during *kharif*, 2020. There was no significant different in initial plant population. During the study, the infestation was ranged from 5.74 to 29.15 percent while in control, it was 19.63 to 34.41 percent. After 40 days application of insecticidal treatment, the infestation was ranged from 5.74 to 14.43 percent while in control it was 19.63 percent. Lowest infestation was recorded in Fipronil 40%+ Imidacloprid 40% WG applied @ 300 ml a.i. ha^{-1} were the infestation was 5.74 percent followed by non-significantly Clothianidin 50 WDG applied @ 125 ml a.i. ha^{-1} where plant mortality was 7.46 percent. After 60 days of application of insecticide, the cumulative plant mortality was ranged from 8.23 to 23.62 percent. The lowest and highest plant mortality was observed in Fipronil 40%+ Imidacloprid 40% WG (applied @ 300 ml a.i. ha^{-1}) and Chlorantraniliprole 18.5 % SC (applied @ 500 ml a.i. ha^{-1}). Similarly, after 80 days of application of insecticide, lowest cumulative plant mortality was recorded in Fipronil 40%+ Imidacloprid 40% WG (applied @ 300 ml a.i. ha^{-1}) followed by Clothianidin 50 WDG where the cumulative plant mortality was 10.14 and 11.91 percent, respectively (Table 47).

Highest yield i.e. 25.80 qha^{-1} was recorded Fipronil 40%+ Imidacloprid 40% WG (applied @ 300 ml a.i. ha^{-1}) followed by Clothianidin 50 WDG where the yield was 22.65 qha^{-1}. Highest net return was also observed in Fipronil 40%+ Imidacloprid 40% WG (applied @ 300 ml a.i. ha^{-1}). Thus, study revealed that Fipronil 40%+ Imidacloprid 40% WG (applied @ 300 ml a.i. ha^{-1}) was found to be best insecticide for post sown application followed by Clothianidin 50 WDG (applied @ 300 ml a.i. ha^{-1}) with lowest infestation of white grub and highest yield.

Table 47 Field evaluation of post-sown application of different granular insecticides against the white grub infesting soybean during *kharif*, 2020.

Tr. No.	Treatment	Dose (g a.i/ha)	Mean initial plant population (2 x 2 m^2)	Mean % plant mortality (DAS)			Grain yield (q/ ha $^{-1}$)	Cost of treatment (Rs ha $^{-1}$)	Net return over control (Rs ha $^{-1}$)	Mean no. of grubs/pit (15.10.20)
				40	60	80				
T_1	Imidacloprid 17.8% SL	60	129.00	10.52 (18.92)	13.24 (21.34)	16.58 (24.02)	17.92	3300	32944	1.40
T_2	Thiamethoxam 30FS	150	130.33	12.63 (20.81)	17.45 (24.68)	24.22 (29.48)	16.93	3400	29478	2.00
T_3	Fipronil 5 SC	100	132.00	13.78 (21.78)	20.53 (26.94)	26.64 (31.07)	15.95	2100	27446	1.00
T_4	Clothianidin 50 WDG	125	131.00	7.46 (15.83)	9.56 (18.00)	11.91 (20.18)	22.65	1600	50726	0.40
T_5	Imidacloprid 600 FS	1000	130.67	8.57 (17.01)	11.07 (19.42)	12.59 (20.78)	20.73	4300	41498	0.60
T_6	Chlorantraniliprole 18.5% SC	500	132.00	14.43 (22.31)	23.62 (29.07)	29.15 (32.67)	14.36	4850	19315	1.20
T_7	Fipronil 40%+ Imidacloprid 40% WG	300	131.00	5.74 (13.85)	8.23 (16.66)	10.14 (18.56)	25.80	4750	59413	0.20
T_8	Untreated control		130.67	19.63 (26.30)	26.29 (30.85)	34.41 (35.91)	7.26	-	-	2.40
SEm (±)			**NS**	**0.42**	**0.36**	**0.34**				
C.D. (5%)			**-**	**1.27**	**1.09**	**1.03**				
CV (%)			**-**	**3.69**	**2.52**	**2.23**				

Figures in parentheses are angular transformation

Rate of soybean grain: Rs. 3400.0/q.

*Labour Charge: Rs. 300

Field evaluation of pre-sown soil application of different granular insecticides against the white grub in Sugarcane during *kharif*, 2020-21.

Various insecticide in as mentioned in table was mixed up in the soil at the time of sowing of sugarcane crop. The data was recorded after 40, 60 and 80 days of application of insecticide. It was observed that the plant mortality was ranged from 3.64 to 17.28 percent while in control it ranged from 15.48 to 28.31 percent. After 40 days of application of insecticide, highest (9.27%) plant infestation was recorded in Chlorantraniliprole 0.4% GR applied @ 100 g a.i. ha^{-1} while lowest infestation (3.64%) was in Fipronil 40%+ Imidacloprid 40% WG GR applied @ 300 g a.i. ha^{-1}. Similarly, after 80 days of application of insecticide, lowest cumulative plant mortality i.e. 8.58 % was still in Fipronil 40%+ Imidacloprid 40% WG GR applied @ 300 g a.i. ha^{-1} followed by Clothianidin 50 WDG applied @ 120 g a.i. ha^{-1} where the percent plant mortality was 9.32 which was non significantly higher than Imidacloprid 70WG applied @ 300 g a.i. ha^{-1}.

Among the various treatment, highest cane yield i.e. 78.05 t ha^{-1} was recorded in Fipronil 40%+ Imidacloprid 40% WG applied @ 300 g a.i. ha^{-1} followed by Clothianidin 50 WDG applied @ 120 g a.i. ha^{-1} where the yield was 76.33 t ha^{-1}. Lowest yield and net return was observed in Chlorantraniliprole 0.4% GR i.e. 67.04 t ha^{-1} while in control it was 52.43 t ha^{-1} (Table 48).

Table 48 Field evaluation of pre-sown soil application of different granular insecticides against the white grub in Sugarcane during *kharif*, 2020-21.

Tr. No.	Treatment	Dose (g a.i/ha)	Mean % plant mortality (DAS)			Cane yield (t/ ha $^{-1}$)	Cost of treatment (Rs ha $^{-1}$)	Net return over control (Rs ha $^{-1}$)	Mean no. of grubs/pit at harvest
			40	**60**	**80**				
T_1	Carbofuran 3G	750	5.89 (14.02)	8.02 (16.44)	12.37 (20.58)	72.58	3000	62487.50	4.00
T_2	Clothianidin 50 WDG	120	3.91 (11.39)	6.23 (14.45)	9.32 (17.76)	76.33	3200	74475.00	1.80
T_3	Fipronil 0.3 G	50	6.30 (14.53)	8.58 (17.03)	14.39 (22.29)	71.35	1900	59590.00	3.00
T_4	Thiamethoxam 25 WG	80	7.93 (16.34)	9.72 (18.15)	15.57 (23.23)	69.27	1500	53230.00	4.00
T_5	Imidacloprid 70WG	300	4.56 (12.31)	6.65 (14.94)	9.91 (18.34)	74.75	4150	68390.00	2.60
T_6	Chlorantraniliprole 0.4% GR	100	9.27 (17.72)	12.44 (20.65)	17.28 (24.56)	67.04	4650	42832.50	4.20
T_7	Fipronil 40%+ Imidacloprid 40% WG	300	3.64 (10.97)	5.82 (13.95)	8.58 (17.02)	78.05	4550	78715.00	1.40
T8	Untreated control		15.48 (22.16)	20.57 (26.97)	28.31 (32.14)	52.43	-	-	8.20
SEm (±)			**0.42**	**0.40**	**0.40**	**0.43**			
C.D. (5%)			**1.28**	**1.21**	**1.21**	**1.39**			
CV (%)			**4.87**	**3.88**	**3.15**	**5.12**			

Figures in parentheses are angular transformation

Rate of Sugarcane: Rs. 3250.0/tone.

Labour Charge: Rs. 300/-

4. Field evaluation of pre-sown soil application of different granular insecticides in potato for the management of white grub, (Var. Kufri Jyoti) 2020-21

Field evaluation of pre-sown soil application of different granular insecticides in potato, (Var. Kufri Jyoti) was made for the management of white grub during the year 2020-21. Treatments wise insecticide was mixed 06.10.2020 and the data was recorded at the time of harvesting of crop. Among the various insecticides, highest tuber infestation was recorded Imidacloprid 17.8 SL applied @ 60 g a.i. ha^{-1} where the tuber damage was 17.62 percent. This was followed by non significantly Thiamethoxam 25 WG applied @ 80 g a.i. ha^{-1}. Similarly, lowest tuber infestation was recorded in Clothianidin 50 WDG applied @ 120 g a.i. ha^{-1} followed by Fipronil 0.3G applied @ 50 g a.i. ha^{-1} where the percent infestation was 6.81 and 7.48 percent, respectively.

Among the treatment highest yield i.e. 141.94 q ha^{-1} was recorded in Clothianidin 50 WDG applied @ 120 g a.i. ha^{-1} followed by followed by Fipronil 0.3G applied @ 50 g a.i. ha^{-1} where the yield was 133.73 q ha^{-1}. Similarly, lowest yield i.e. 108.35 q ha^{-1} was recorded in Imidacloprid 17.8 SL applied @ 60 g a.i. ha^{-1} followed by Thiamethoxam 25 WG applied @ 80 g a.i. ha^{-1} where the yield was 116.27 q ha^{-1}. In control, the yield was 48.15 qha^{-1} (Table 49).

Table 49 Field evaluation of pre-sown soil application of different granular insecticides in potato for the management of white grub, (Var. Kufri Jyoti) 2020-21

Tr. No.	Treatment	Dose (g a.i/ha)	Mean % tuber damage	Marketable tuber yield (q ha^{-1})
T_1	Carbofuran 3G	750	9.16 (17.60)	124.45
T_2	Fipronil 0.3G	50	7.48 (15.86)	133.73
T_3	Thiamethoxam 25 WG	80	15.39 (23.10)	116.27
T_4	Imidacloprid 17.8 SL	60	17.62 (24.82)	108.35
T_5	Clothianidin 50 WDG	120	6.81 (15.09)	141.94
T_6	Untreated Check	-	32.19 (34.56)	48.15
SEm (±)			**0.48**	**0.39**
C.D. (5%)			**1.52**	**1.24**
CV (%)			**3.82**	**2.31**

Figures in parentheses are angular transformation

RARI, DURGAPURA

B. Evaluation of some insecticides used as seed dresser against whitegrub, *Holotrichia consanguinea* in groundnut crop during *kharif* (2020-21)

To protect the groundnut crop against whitegrub different insecticides were evaluated by using them as seed dresser. Perusal of the data in table 5 indicated that imidacloprid 600 FS at 6.5 ml/kg seed and clothianidin 50 WDG at 2 g/kg seed were found superior to all the other tested insecticides, with minimum 10.16 and 11.70 per cent plant mortality and maximum 27.37 and 25.83 q/ha pod yield, respectively. Larval population was found 0.33 larvae/m^2 in both the treatment. In untreated check 100 per cent plant damage was recorded **(Table 50).**

Table 50 Evaluation of some insecticides used as seed dresser against white grub, *Holotrichia consanguinea* in groundnut crop during *kharif* (2020-21)

Sr. No.	Treatments	Dose per kg seed	Plant mortality (%)	Larval population /m^2	Pod yield (q/ha)
1	Imidacloprid 17.8 SL	3.0 ml	22.99 (28.61)*	0.67	22.45
2	Thiamethoxam 30 FS	4.0 ml	74.89 (59.97)	3.33	6.94
3	Fipronil 5 SC	8.0 ml	80.80 (64.04)	4.00	5.06
4	**Clothianidin 50 WDG**	**2.0 g**	**11.70 (19.93)**	**0.33**	**25.83**
5	**Imidacloprid 600 FS**	**6.5 ml**	**10.16 (18.51)**	**0.33**	**27.37**
6	Chlorantraniliprole 18.5 SC	2.0 ml	63.62 (52.93)	3.00	9.95
7	Fipronil 40% + Imidacloprid 40%	3.0 g	56.71 (48.89)	2.67	9.73
8	Untreated check	-	100.00 (90.00)	6.00	0.00
	SE(m)	-	1.627	0.401	1.163
	C.D. at 5%	-	4.98	1.22	3.56
	C.V. %	-	8.89	10.79	13.01

*Data in parentheses are angular transformed values

Growth of groundnut crop seed treatment by imidacloprid 600FS

CSK-HPKV, Palampur

B. Management of white grub in rajmash in Barot valley through seed treatment

Different insecticides were evaluated through seed treatment against white grubs in rajamsh in Barot valley of district Mandi. Observations on per cent plant damage were recorded after three weeks of treatment. The per cent plant damage was minimum (5.9%) in Fifronil 40% + Imidacloprid 40%WG with 2.1 grubs/m^2 followed by Clothianidin 50 WDG with 7.9% plant damage and 4.0 grubs/m^2. Whereas, in control 20.4 % plant damage was recorded with with 9.1grubs/m^2 (**Table 51**).

Table 51. Management of white grub in rajmash in Barot valley through seed treatment after three weeks of treatment

Treatments	Dose (g/ml per kg seed)	Plant damage (%)	Mean no. of grubs/ m^2
Thiamethoxam 25 WG	3.2 g	11.5	6.6
Imidacloprid 17.8 SL	3.0 ml	10.6	6.2
Acephate 50% + imidacloprid1.8%	4.0 g	9.8	5.2
Fifronil 5 SC	6.0 ml	8.2	4.2
Clothianidin 50 WDG	1.5 g	7.9	4.0
Fifronil 40% + Imidacloprid 40%WG	3 g	5.9	2.1
Chlorpyriphos 20 EC	4.0 ml	13.5	8.1
Untreated check	-	20.4	9.1
CD (0.05)		1.8	1.4

RARI Durgapura:

C. Evaluation of some insecticides used against whitegrub, *Holotrichia consanguinea* in standing crop of groundnut during *kharif* (2020-21)

For the management of white grubs, if farmer escapes the seed treatment at the time of sowing done after the monsoon rain or in early sowing of the groundnut crop than standing crop treatment is required within 21 days of mass emergence of beetles. For this purpose an experiment was conducted to evaluate different insecticides applied as standing crop of groundnut. It was found that application of imidacloprid 17.8 SL @ 360 ml/ha and chlorantraniliprole 18.5 SC @ 500 ml/ha was found significant to all the other tested insecticides in respect to protection as well as production. However, in these treatments 14.29 & 17.58 per cent plant mortality were observed. The maximum yield were recorded in similar manner with 25.02 and 23.29 q/ha, respectively. In untreated check 100 per cent plant mortality was observed (Table 52).

Table 52 Evaluation of some insecticides used against whitegrub, *Holotrichia consanguinea* in standing crop of groundnut crop during *kharif* (2020-21)

Sr.No.	Treatments	Dose per ha	Plant mortality (%)	Larval population /m^2	Pod yield (q/ha)
1	Imidacloprid 17.8 SL	360 ml	14.29 (22.18)*	0.33	25.02
2	Thiamethoxam 30 FS	600 ml	79.14 (62.87)	3.67	5.18
3	Fipronil 5 SC	3.0 lit.	50.83 (45.46)	2.67	12.36
4	Clothianidin 50 WDG	300 g	52.24 (46.27)	3.33	12.63
5	Imidacloprid 600 FS	1042 ml	58.16 (49.69)	2.67	11.47
6	Chlorantraniliprole 18.5 SC	500 ml	17.58 (24.73)	0.67	23.29
7	Fipronil 40% + Imidacloprid 40%	500 g	42.59 (40.68)	3.00	14.86
8	Untreated check	–	100 (90.00)	6.33	0.00
	SE(m)	-	1.363	0.365	0.712
	C.D. at 5%	-	4.17	1.11	2.18
	C.V. %	-	7.94	9.28	9.42

*Data in parentheses are angular transformed values

Field evaluation of different liquid insecticides as drenching in standing crop in post-sown sugarcane against the white grub at Bareilly during *kharif*, 2020-21

Various insecticide in as mentioned in table was used as drenching of crop to evaluate the effect on white grub infestation. The drenching of crop was done on 24.04.2021. The data of cane mortality was recorded after 70, 90, and 110 days of crops. It was observed that the plant mortality was ranged from 5.97 to 21.18 percent while in control it ranged from 16.29 to 35.70 percent. After 70 days of application of insecticide, highest (13.32 %) plant infestation was recorded in Chlorantraniliprole 18.5% SC followed by Thiamethoxam 30FS applied @ 150 g a.i. ha^{-1} while lowest infestation (5.97%) was in Fipronil 40%+ Imidacloprid 40% WG GR applied @ 300 g a.i. ha^{-1}. Similarly, after 110 days of application of insecticide, lowest cumulative plant mortality i.e. 10.36 % was still in Fipronil 40%+ Imidacloprid 40% WG GR applied @ 300 g a.i. ha^{-1} followed by Clothianidin 50 WDG applied @ 125 g a.i. ha^{-1} where the percent plant mortality was 10.97 which was non significantly higher than Imidacloprid 70WG applied @ 1000 g a.i. ha^{-1}.

Among the various treatment, highest cane yield i.e. 76.37 t ha^{-1} was recorded in Fipronil 40%+ Imidacloprid 40% WG applied @ 300 g a.i. ha^{-1} followed by Clothianidin 50 WDG applied @ 125 g a.i. ha^{-1} where the yield was 74.93 t ha^{-1}. Lowest yield and net return was observed in Chlorantraniliprole 0.4% GR i.e. 67.21 t ha^{-1} while in control it was 51.48 t ha^{-1} (Table 53).

Table 53 Field evaluation of different liquid insecticides as drenching in standing crop in post-sown sugarcane against the white grub at Dharmpur (Bareilly) during *kharif*, 2020-21

Tr. No.	Treatment	Dose (kg a.i/ha)	Mean % plant mortality (DAS)			Cane yield (q/ ha $^{-1}$)	Cost of treatment (Rs ha $^{-1}$)	Net return over control (thousand Rs ha $^{-1}$)	Mean no. of grubs/pit at harvest 29.03.2021
			70	90	110				
T_1	Imidacloprid 17.8% SL	60	8.21 (16.61)	11.44 (19.75)	13.56 (21.60)	71.53	3300	61.86	4.20
T_2	Thiamethoxam 30FS	150	11.54 (19.84)	13.23 (21.32)	16.39 (23.88)	68.82	3400	52.95	5.40
T_3	Fipronil 5 SC	100	9.42 (17.87)	12.18 (20.42)	14.51 (22.39)	68.70	2100	53.86	4.40
T_4	Clothianidin 50 WDG	125	6.25 (14.46)	9.24 (17.68)	10.97 (19.33)	74.93	1600	74.61	2.60
T_5	Imidacloprid 600 FS	1000	6.74 (15.01)	10.59 (18.98)	11.62 (19.93)	72.29	4300	63.33	3.20
T_6	Chlorantraniliprole 18.5% SC	500	13.32 (21.39)	15.76 (23.39)	21.18 (27.40)	67.21	4850	46.27	5.60
T_7	Fipronil 40%+ Imidacloprid 40% WG	300	5.97 (14.15)	8.48 (16.92)	10.36 (18.76)	76.37	4750	76.14	2.20
T8	Untreated control	-	16.29 (23.80)	27.41 (31.57)	35.70 (36.69)	51.48	-	-	9.60
SEm (±)			**0.53**	**0.42**	**0.40**	**0.41**			
C.D. (5%)			**1.62**	**1.28**	**1.22**	**1.25**			
CV (%)			**5.27**	**3.44**	**2.94**	**3.28**			

Figures in parentheses are angular transformation

Rate of Sugarcane: Rs. 3250.0/tone.

Labour Charge: Rs. 300/-

COA-Kolhapur

Management of white grub, *Leucopholis lepidophora* in Sugarcane through soil treatment /soil furrow application of some insecticides

The clump mortality ranged from 1.50 to 8.69 per cent in various treatments as compared to 11.17 in untreated control when observations were recorded 40 DAT. All the insecticidal treatments found significantly superior over untreated control. The treatment with Imidacloprid 40% + Fipronil 40%-80 WG 3 g/kg was found to be superior where 1.50 per cent clump mortality was recorded. However, it was on par with the treatment with Chlorantraniliprole 18.5 SC @ 500ml/ha (3.30 per cent).

The mortality of the sugarcane clump ranged from 2.40 to 12.80 per cent in various treatments as compared to 15.00 per cent in untreated control when observations were recorded 60 DAT. The treatment with Imidacloprid 40% + Fipronil 40%-80WG 3g/ha was found to be consistently superior over all other insecticidal treatments and recorded 2.40 per cent clump mortality and was on par with Chlorantraniliprole 18.5 SC @ 500ml/ha and Clothianidin 50 WDG @ 80 g a.i./ha with 4.27 per cent and 6.47 per cent clump mortality respectively. The incidence of white grub was observed after 30DAP. Treatment with Thiamethoxam 70WS @ 80 g. a.i./ha, Fipronil 5% SC@ 100 g.a.i./ha and Imidacloprid 600 FS @500 g a.i./ha were next in order of efficacy.

Treatment with Imidacloprid 40% + Fipronil 40%- 80WG @ 3g/kg and Chlorantraniliprole 18.5 SC @ 500ml/ha were found to be equally effective at 80 DAT where 3.10 and 6.33 per cent clump mortality was recorder, respectively. Treatment with Clothianidin 50 WDG @ 80 g a.i./ha. and Thiamethoxam 70WS @ 80 g. a.i./ha were next in order of efficacy.

Among the treatments Imidacloprid 40% + Fipronil 40%-80WG 3g/ha recorded highest yield (45.23 t/ acre) followed by 41.97 t /acre in the treatment with Chlorantraniliprole 18.5 SC @ 500ml/ha, 38.48 t / acre in Clothianidin 50 WDG @ 80 g a.i./ acre and Imidacloprid 600 FS @500 g a.i./ha (35.71 t / acre) as compared to 22.74 t / acre in untreated control (Table 54).

Table 54 Management of white grub, *Leucopholis lepidophora* in Sugarcane through soil treatment /soil furrow application of some insecticides

SN	Treatment and dose	Initial plant popln	Per cent Clump mortality (DAS)				% Protection over control	Yield t/ha	No. of grubs/m^2
			40	60	80	Mean			
1	Imidacloprid 17.8 SL	634	8.20 (16.63)	8.30 (16.73)	8.30 (16.73)	8.26 (16.69)	64.11	87.63	1.40
2	Thiamethoxam 30 FS	653	7.54 (15.95)	10.77 (19.17)	12.46 (20.67)	10.26 (18.60)	55.43	82.60	0.55
3	Fipronil 5SC	645	5.37 (13.38)	7.07 (15.40)	8.40 (16.84)	6.94 (15.20)	69.85	85.17	1.58
4	Clothianidin 50WDG	642	5.57 (13.63)	6.47 (14.72)	7.50 (15.88)	6.51 (14.74)	71.72	88.48	1.31
5	Imidacloprid 600 FS	598	7.83 (16.24)	9.83 (18.26)	10.53 (18.92)	9.39 (17.80)	59.20	85.71	0.47
6	Chlorantraniliprole 18.5 SC	647	3.30 (10.45))	4.27 (11.91)	6.33 (14.56)	4.63 (12.30)	79.88	91.97	1.05
7	Fifronil 40% + Imidacloprid 40WG	658	1.50 (6.97)	2.40 (8.89)	3.10 (10.13)	2.33 (8.66	89.87	95.23	1.40
8	Untreated check	644	11.17 (19.50)	15.00 (22.77) (31.76)	20.60 (26.97)	15.59 (23.08)	--	72.74	5.83
	S.Em ±		0.54	0.72	0.64	0.63	--	1.80	0.49
	CD at 5%	NS	1.15	1.56	1.39	1.37	--	3.96	1.37

*Figures in parentheses are arcsine transformed values

III. MICROBIAL CONTROL OF WHITEGRUB

RARI, Durgapura:

Management of whitegrub in groundnut crop through bio-control agents

To investigate the field efficacy of different microbial agents against *H.consanguinea*, on groundnut a field trial was conducted at RARI Durgapura during *kharif* 2020-21. The result indicated that the combined formulation of *S.abbassi* + *B. bassiana* treated plots were found to be most effective in reducing the plant mortality (40.67 %) followed by the treatment *B. bassiana* (49.33%). These two treatments were superior over rest of the microbial treatments. In untreated check 92.67 per cent plant mortality and 3.06 q/ha yield was observed (Table 55).

Table 55 Management of White grubs, *Holotrichia consanguinea* through Bio-control Agents in groundnut crop during *kharif* (2020-21)

SN	Treatments	Dose per kg seed	Plant mortality (%)	Protection over control	Pod yield (q/ha)

				(%)	
1	*Heterorhabditis indica*	0.5g/m^2	81.67 (64.67)*	11.87	5.96
2	*Steinernema abbassi*	0.5g/m^2	72.33 (58.25)	21.94	6.33
3	*Metarhizium anisopliae*	0.5g/m^2	65.67 (54.24)	29.13	6.06
4	*Beauveria bassiana*	0.5g/m^2	49.33 (44.59)	46.76	12.56
5	*H. indica + M. anisopliae*	0.5g/m^2	40.67 (39.57)	56.11	13.73
6	*H. indica + B. bassiana*	0.5g/m^2	60.67 (51.19)	34.53	11.46
7	*S. abbassi + M. anisopliae*	0.5g/m^2	68.67 (56.05)	25.89	6.56
8	*S. abbassi + B. bassiana*	0.5g/m^2	66.67 (54.76)	28.05	6.66
9	EPN *(H. indica)* infected galleria larvae supplied by FARMER	3 galleria/m^2	55.00 (47.86)	40.64	11.90
10	EPN*(S.abbassi)*infected galleria larvae supplied by FARMER	3 galleria/m^2	61.67 (51.81)	33.45	9.26
11	Local isolates	3 LIJ/m^2	69.67 (56.61)	24.81	5.93
12	Untreated control		92.67 (74.41)	-	3.06
	SE(m)	-	2.358	-	0.557
	C.D. at 5%	-	6.96	-	1.64
	C.V. %	-	7.51	-	11.62

*Data in parentheses are angular transformed values

AAU, JORHAT

A. 1. Evaluation of different entomopathogenic fungi against *Lepidiota mansueta* in pea at Majuli

To investigate the field efficacy of different Entomopathogenic Fungi (EPF) against *L. mansueta*, a field trial was conducted at Maharichuk village, Majuli during 2020-21. The experiment was conducted in 3 RBD and the individual plot size measured 2×3 sq. m. (Fig. 44). Three different EPF *viz.*, *Beauveria brongniartii*, *Metarhizium anisopliae* and *B. bassiana* in unadulterated form along with their combination with farm yard manure (FYM) and an additional insecticidal check were evaluated against *L. mansueta* in pea. The crop (Variety: Aman) was raised by following all the recommended package and practices of

Assam. The seeds were sown on 11th November, 2020 and harvested on 18th February, 2021. The efficiency of different treatments was assessed on the basis of plant mortality at 30 and 60 days after sowing (DAS), number of grubs per sq.m. at harvesting and seed yield.

Data presented in Table 56 and Fig. 45 revealed that among all the EPF tested, the combined application of *B. brongniartii* with FYM registered lowest plant mortality (7.98 and 9.34 per cent at 30 and 60 DAS, respectively) and found significantly superior over rest of the EPF treatments. The plots treated with *B. brongniartii* exhibited 8.55 and 10.25 per cent of plant mortality at 30 and 60 DAS, respectively and this treatment was followed by *M. anisopliae* + FYM (8.94 and 11.19%) and *M. anisopliae* (10.00 and 12.05%) treated plots. Comparatively higher plant mortality was observed in the plots treated with *B. bassiana* in combination with FYM and sole application of *B. bassiana* which recorded 11.08 & 13.42 and 12.05 & 14.41 per cent at 30 and 60 DAS, respectively. The insecticidal check *i.e.* clothianidin 50 WDG @ 120 g *a.i.*/ha registered lowest plant mortality (3.99 and 4.06% at 30 and 60 DAS respectively) over all the EPF treatments. The control plots recorded 20.06 and 22.09 per cent of plant mortality caused by *L. mansueta* grubs at 30 and 60 DAS, respectively.

While assessing the mean grub population in different EPF treatments, it was found that the population was ranged between 2.33-4.67 nos./sq. m. The mean grub population recorded in *B. brongniartii* + FYM, *B. brongniartii*, *M. anisopliae* + FYM, *M. anisopliae*, *B. bassiana* + FYM and *B. bassiana* was 3.00, 3.33, 3.67, 4.00, 4.33 and 4.67/sq. m. The lowest grub population (2.33/ sq.m.) was recorded in the plots treated with clothianidin 50 WDG @ 120 g *a.i.*/ha.

Considering the yield recorded in different treatments, highest yield was recorded in clothianidin 50 WDG @ 120 g *a.i.*/ha (10.39 q/ha) followed by *B. brongniartii* + FYM (9.40 q/ha) and sole application of *B. brongniartii* (8.85 q/ha) treated plots. The control plots registered yield of 6.86 q/ha.

A. Layout of the experiment

B. Application of Entomopathogenic Fungi

C. View of the experimental plots

Fig. 44 (A-C). Effect of different entomopathogenic fungi against *L. mansueta* in pea during 2020-21

Table 56. Efficacy of different Entomopathogenic fungi against *L. mansueta* in Pea at Majuli during 2020-21

Treatments	Doses	Initial plant population (Numbers)	Plant mortality (%)		Grub popl^{n}. (No/sqm.)	Yield (q/ha)
			30DAS	60 DAS		
Metarhizium anisopliae	1×10^{9} CFU per gm/m^{2}	650	10.00 (18.44)	12.05 (20.31)	4.00	7.87
Metarhizium anisopliae + FYM		671	8.94 (17.41)	11.19 (19.55)	3.67	8.10
Beauveria bassiana		639	12.05 (20.32)	14.41 (22.32)	4.67	7.06
Beauveria bassiana + FYM		641	11.08 (19.45)	13.42 (21.50)	4.33	7.26
Beauveria		655	8.55	10.25	3.33	8.85

brongniartii			(17.01)	(18.68)		
Beauveria brongniartii + FYM		664	7.98 (16.42)	9.34 (17.80)	3.00	9.40
Clothianidin 50 WDG	120 g *a.i.*/ ha	672	3.99 (15.34)	4.06 (16.49)	2.33	10.39
Control	-	648	20.06 (26.62)	22.09 (28.04)	5.00	6.86
S.Ed (±)	-	-	**0.07**	**0.35**	**0.23**	**0.09**
CD (p=0.05)	-	-	**0.15**	**0.75**	**0.49**	**0.19**

Figures in parentheses are angular transformed values

DAS: Days after sowing

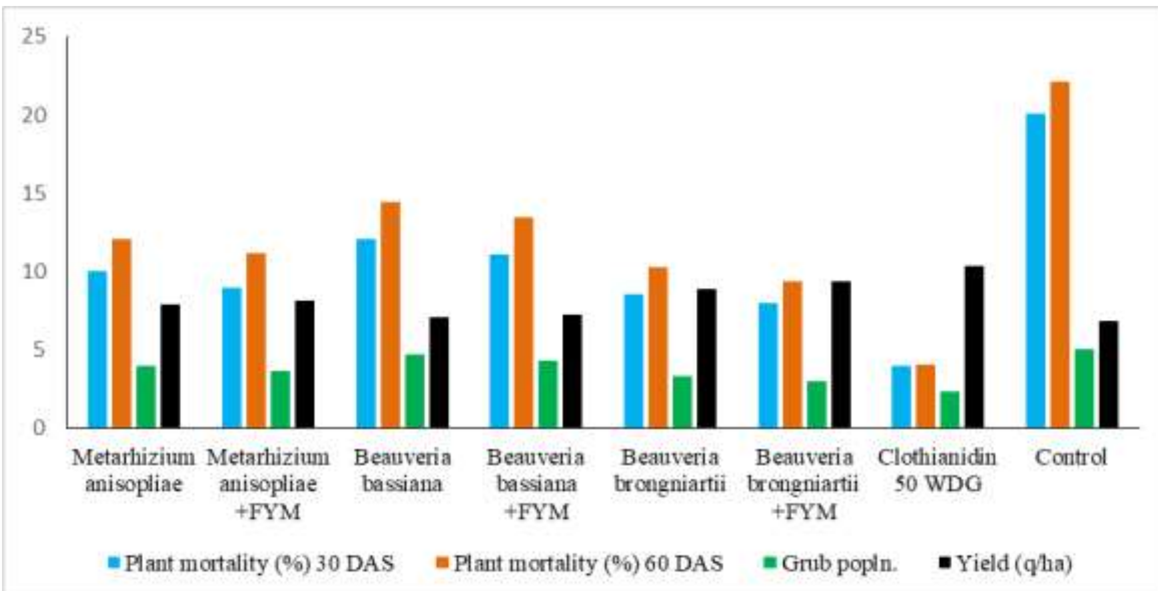


Fig. 45. Evaluation of different Entomopathogenic fungi against *L. mansueta* in Pea during 2020-21

A. 2. Scaling up of effective dose of EPN, *Heterorhabditis indica* against *Lepidiota mansueta* in green gram

Altogether six different doses of the Entomopathogenic Nematode (EPN), *Heterorhabditis indica* were tested against the 3rd instar grubs of *Lepidiota mansueta* in green gram crop at farmer's field of Maharichuk village of Majuli during 2020. The experiment was conducted in 3 RBD and the individual plot size was 3×2 sq. m (Fig. 46). Green gram (variety: SGC-16) was raised by following all the recommended package and practices of Assam. The crop was sown on 25th Sept., 2020 and harvesting was done on 11th Dec., 2020. The standardization of different doses was determined on the basis of per cent plant mortality, number of grubs/ sq.m and yield.

Experimental results indicated that among all the doses of *H. indica* tested, the lowest plant mortality (16.00 and 16.32 % at 40 and 60 days after sowing, respectively) was recorded when applied at the rate of 2.5 lakhs IJS/5g/ sq. m. and this treatment was found to be significantly superior over rest of the treatments (Table 57 and Fig. 47). The per cent plant mortality recorded in case of *H. indica* applied at the rate of 1.87 lakhs IJS/3.75g/ sq. m and 1 galleria cadaver/ sq. m were 16.88 & 17.21 and 19.48 & 19.83 after 40 and 60 days after sowing, respectively. The plots applied with *H. indica* @ 1 lakhs IJS/ 2g/ sq. m. and 1 galleria cadaver/ 1.5 sq. m recorded 20.78 & 21.14 and 21.14 & 21.50 per cent at 40 and 60 days after sowing, respectively. Among all the doses, the highest plant mortality (23.35 and 23.71 % at 40 and 60 DAS, respectively) was recorded in the plots treated with *H. indica* @ 1 galleria cadaver/ 2.0 sq. m. The per cent plant mortality registered in case of untreated control was 27.16 and 27.53 per cent at 40 and 60 days after sowing (Table 57 and Fig. 47).

The grub population was ranged between 3.67 to 4.67/sq. m. in all the EPN treated plots at the time of harvesting. However, among all the doses tested, the lowest number of grubs/ sq. m. (3.67 nos.) was recorded when *H. indica* was applied at the rate of 2.5 lakhs IJS/5 g/ sq. m (Table 57 and Fig. 47). The grub population in control was 5.33 nos./sq.m.

As regards to grain yield, highest yield (8.85 q/ha) was recorded in *H. indica* treated plots when applied @ 2.5 lakhs IJS/5 g/ sq. m. and this treatment was found to be significantly superior over rest of the doses. The grain yield recorded in case of *H. indica* @ 1.87 lakhs IJS/3.75 g/ sq. m. and *H. Indica* infected galleria larvae @ 1 galleria/1 sq.m. registered 8.32 and 8.04 q/ha, respectively. Rest of the doses of *H. indica viz*., 1 lakh IJS/ 2g/ sq. m., 1 galleria/1.5 sq. m. and 1 galleria/ 2 sq. m. registered 7.78, 7.69 and 7.12 q/ ha, respectively. The untreated control plots recorded the lowest yield of 5.25 q/ha (Table 57 and Fig. 47).

A. Sowing of green gram　　B. Application of EPNs　　C. Experimental plots

Fig. 46 (A-C). Standardization of the dose of *H. indica* against *L. mansueta* in green gram during 2020

Table 57. Scaling up of effective dose of EPN, *H. indica* against 3rd instar grubs of *L. mansueta* in green gram during 2020

Treatments	Initial plant population (Nos.)	Plant mortality (%)		Grub popn (Nos/ m^2)	Yield (q/ha)
		40 DAS	60 DAS		
Heterorhabditis indica @ 1 lakhs IJS/2g/m^2	189.33	20.78 (27.13)	21.14 (27.38)	4.67	7.78
H. indica @ 1.87 lakhs IJS/3.75 g/m^2	205.33	16.88 (24.27)	17.21 (24.52)	4.33	8.32
H. indica @ 2.5 lakhs IJS/5 g/m^2	208.33	16.00 (23.59)	16.32 (23.84)	3.67	8.85
H. Indica infected galleria larvae @ 1 galleria/2 m^2	181.33	23.35 (28.91)	23.71 (29.16)	5.33	7.12
H. Indica infected galleria larvae @ 1 galleria/1.5 m^2	187.67	21.14	21.50	4.67	7.69

		(27.39)	(27.64)		
H. Indica infected galleria larvae @ 1 galleria/1 m^2	191.67	19.48 (26.20)	19.83 (26.46)	4.67	8.04
Control	178.00	27.16 (31.42)	27.53 (31.66)	5.33	5.25
S. Ed (±)		**0.12**	**0.14**	**0.28**	**0.10**
CD (P=0.05)		**0.26**	**0.31**	**0.61**	**0.23**

Data in parenthesis are angular transformed values
DAS: Days after sowing

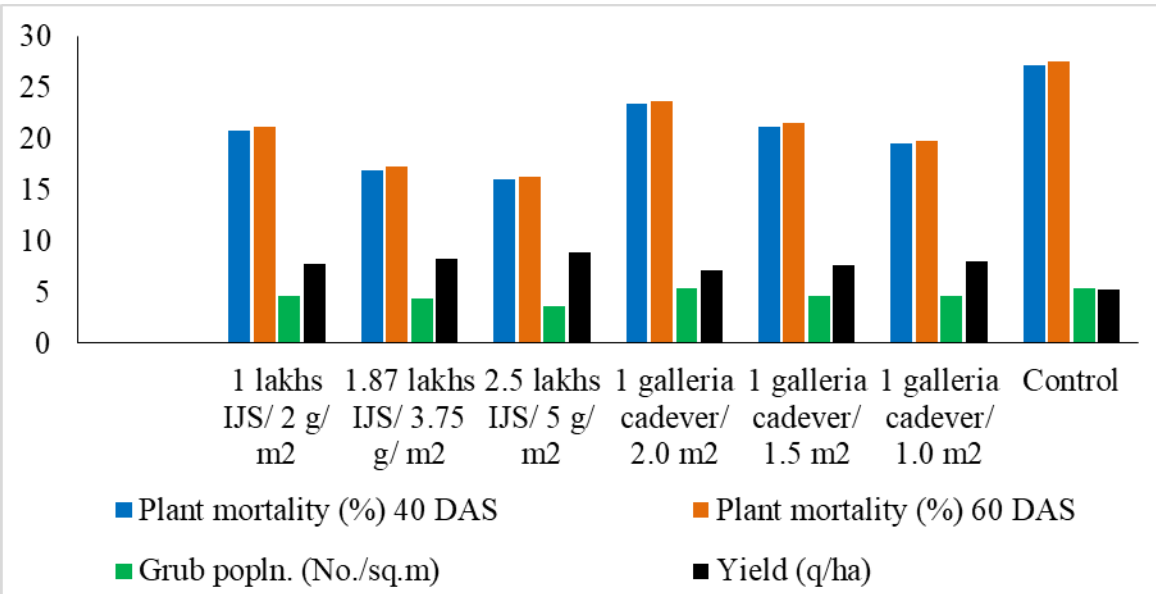


Fig. 47. Standardization of the dose of *H. indica* against *L. mansueta* in green gram during 2020

A. 3. Evaluation of entomopathogenic bacterial strains against *Lepidiota mansueta* in potato at Majuli during 2020-2021

Field efficiency of three entomopathogenic bacterial strains against *L. mansueta* was studied at the farmers' field of Maharichuk village, Majuli, Assam during 2020-21. The experiment was conducted 4 RBD and the individual plot size was 8×5 sq. m. (Fig. 48). Variety "*Kufri Jyoti*" was grown by following all recommended package and practices under rainfed conditions. The crop was sown on 9th November, 2020 and harvested on 25th February, 2021. Finally, the efficiency of different treatments were assessed on the basis of per cent tuber damage caused by the grubs, number of grubs per sq. m at the time of harvest and tuber yield.

Experimental results indicated that all the treatments were significantly superior over untreated control in reducing the per cent tuber damage both in weight and number basis, number of grubs/ sq. m at the time of harvest and tuber yield (Table 58 & Fig. 49).

Among the entomopathogenic bacterial strains, the plot treated with NBAIR-BtAN4 strain of *Bacillus thuringiensis* applied @ 3 lit/acre registered lowest tuber damage (7.26%) on weight basis followed by NBAIR-Bt25 strain of *B. thuringiensis* @ 3 lit/acre (8.30%) and NBAIR-BATP strain of *B. albus* @ 2.5 kg of talc + 100 kg of FYM (9.56%). The plots treated with clothianidin 50 WDG @ 120 g *a.i.*/ha and untreated control plots recorded 4.12 and 15.14 per cent of tuber damage, respectively.

A similar trend was observed while assessing the tuber damage on number basis. The tuber damage recorded in case of NBAIR-BtAN4, NBAIR-Bt25 @ 3 lit/acre and NBAIR-BATP @ 2.5 kg of talc + 100 kg of FYM were 6.98, 8.13 and 8.78 per cent, respectively. The lowest per cent of tuber damage was recorded in clothianidin 50 WDG @ 120 g *a.i.*/ha treated plots (3.82%) which was significantly superior over rest of the treatments. The untreated control plot recorded 13.41 per cent of tuber damage (Table 58 & Fig. 49).

At the time of harvest, clothianidin 50 WDG @ 120 g *a.i.*/ha treated plots effectively reduced the grub population (2.25 nos./sq. m). The number of grubs recorded in NBAIR-BtAN4, NBAIR-Bt25 @ 3 lit/acre and NBAIR-BATP @ 2.5 kg of talc + 100 kg of FYM were 3.00, 3.50 and 4.50 nos./sq. m, respectively. The untreated control plot recorded highest (6.00) number of grubs per sq. m. (Table 58 & Fig. 49).

Among the entomopathogenic bacterial strains tested, NBAIR-BtAN4 strain of *B. thuringiensis* @ 3 lit/acre recorded considerably higher tuber yield (114.56 q/ha) as compared to NBAIR-Bt25 strain of *B. thuringiensis* @ 3 lit/acre (110.32 q/ha) and NBAIR-BATP strain of *B. albus* @ 2.5 kg of talc + 100 kg of FYM (104.57 q/ha). However, significantly highest tuber yield was recorded in clothianidin 50 WDG @ 120 g *a.i*/ha treated plots (118.03 q/ha) whereas the untreated control plot registered lowest tuber yield of 94.57 q/ha (Table Table 58 & Fig. 49).

A. Lay out of the experimental plot

B. Sowing of potato tubers

C. Infested tubers

D. Healthy tubers

E. General view of the experimental plots

Fig. 48 (A-E). Evaluation of entomopathogenic bacterial strains against white grub in potato at Majuli during 2020-2021

Table 58. Field evaluation of entomopathogenic bacterial strains against white grub in potato at Majuli during 2020-2021

Treatments	Doses	Per cent tuber damage		No. of grubs/ sq. m	Yield (q/ha)
		Weight basis	Number basis		
NBAIR-BtAN4 strain of *Bacillus thuringiensis*	3 lit./acre	7.26 (15.63)	6.98 (15.33)	3.00	114.56
NBAIR-Bt25 strain of *Bacillus thuringiensis*	3 lit./acre	8.30 (16.75)	8.13 (16.57)	3.50	110.32
NBAIR-BATP strain of *Bacillus albus*	2.5 kg of talc + 100 kg of FYM	9.56 (18.02)	8.78 (17.25)	4.50	104.57
Clothianidin 50 WDG	120 g *a.i.*/ha	4.12	3.82	2.25	118.03

		(11.72)	(11.27)		
Untreated control	-	15.14 (22.91)	13.41 (21.48)	6.00	94.57
S.Ed (±)		**0.12**	**0.18**	**0.21**	**1.51**
CD (p=0.05)		**0.25**	**0.37**	**0.44**	**3.15**

Figures in parentheses are angular transformed values

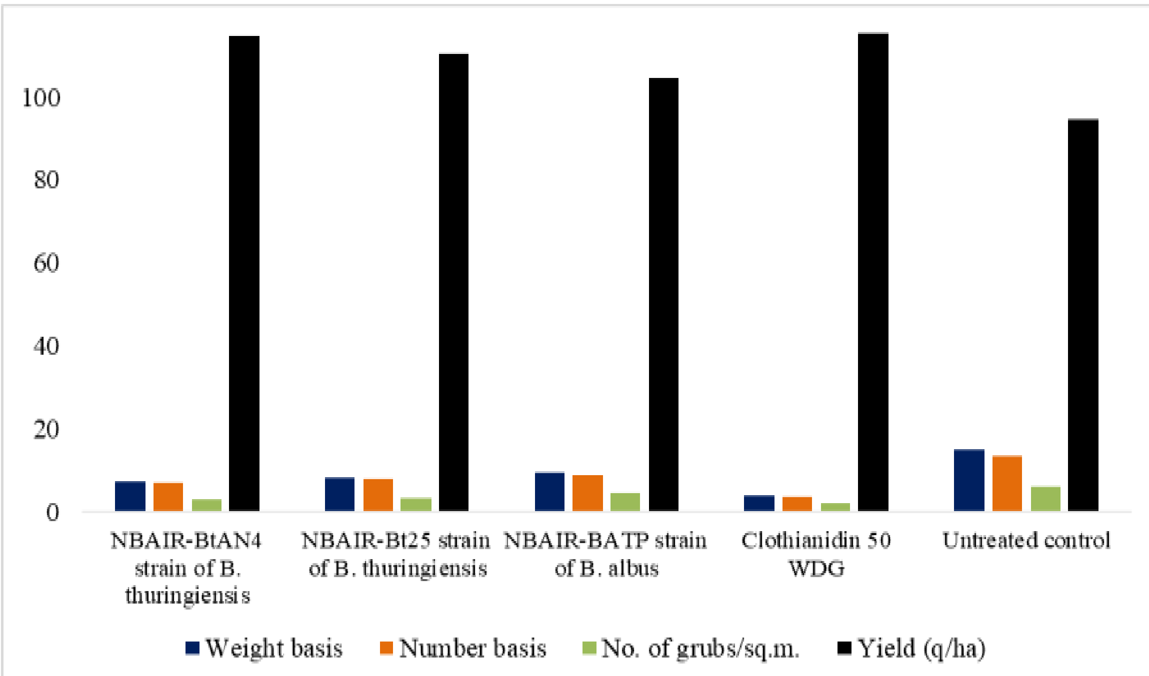


Fig. 49. Evaluation of entomopathogenic bacterial strains against white grub in potato at Majuli during 2020-2021

B. Study of local isolates of Entomopathogenic fungi and EPNs for their infectivity against soil arthropod pests

Laboratory experiments were carried out to evaluate the infectivity of two native Entomopathogenic Nematodes (EPNs), *Heterorhabditis bacteriophora* and *Steinernema aciari* against termite, *Odontotermes obesus* and potato cutworm, *Agrotis ipsilon*. Different concentrations of Infective Juveniles (IJs) of both the EPN species were tested along with untreated control (Fig. 50). Both *O. obesus* workers and *A. ipsilon* larvae were found susceptible to the two native EPN species at different concentrations and time intervals.

Experimental results indicated that both *H. bacteriophora* and *S. aciari* were able to cause mortality at 24 hours in case of the workers of *O. obesus* (Table 59-60). At 24 hours, *H. bacteriophora* induced 10, 30 and 40 per cent mortality at inoculation rates of 200, 250 and 300 IJs/termite, respectively whereas *S. aciari* caused 10 and 30 per cent mortality at inoculation rates of 250 and 300 IJs/ termite, respectively. However, both the EPN species were able to register at least 50 per cent mortality at 48 hours at an inoculation rate of 150 and 200 IJs/termite in case of *H. bacteriophora* whereas *S. aciari* exhibited 60 per cent mortality at 250 IJs/termite. Complete mortality of the workers was achieved by *H. bacteriophora* and *S. aciari* at an inoculation rate of 300 IJs/termite at 72 and 96 hours, respectively (Table 59). The mortality of the workers seems to be increasing with an increase in concentration and time of exposure and the LD_{50} and LT_{50} values of both the EPN species showed variable differences. In case of *H. bacteriophora*, the highest and lowest LD_{50} values were 693.194 and 13.054 IJs/termite at 24 and 96 hours respectively. With respect to *S. aciari,* the highest LD_{50} obtained was 2997.000 IJs/termite at 24 hours and the lowest value was 42.040 IJs/termite at 96 hours (Table 60). Based on the mortality rates observed as well as considering the lower values of LD_{50}, *H. bacteriophora* was found to be more virulent against the workers of *O. obesus* than *S. aciari.*

While studying the infectivity of both the EPN species against *A. ipsilon*, it was recorded that none of them showed any mortality of larvae up to 48 hours and the mortality was observed at 72 hours after exposure only (Table 61). After 72 hours, *H. bacteriophora* recorded 10, 10, 20 and 30 per cent mortality at an inoculation rate of 150, 200, 250 and 300 IJs/ cutworm, respectively. In case of *S. aciari*, mortality rates of 10, 20 and 20 per cent were observed at inoculation rates of 200, 250 and 300 IJs/ cutworm, respectively at 72 hours. However, after 96 hours, both the EPN species were able to surpass the 50 per cent mortality level. *H. bacteriophora* caused 60 per cent mortality at 250 IJs/cutworm whereas *S. aciari* showed 50 per cent mortality at an inoculation rate of 250 and 300 IJs/cutworm. Complete mortality of the larvae was achieved by *H. bacteriophora* and *S. aciari* at an inoculation rate of 300 IJs/ cutworm at 144 and 168 hours respectively. Comparatively lower LD_{50} values were registered in case of *H. bacteriophora* than *S. aciari* (Table 62). The highest and lowest LD_{50} values of *H. bacteriophora* were 1314.790 and 35.711 IJs/cutworm at 72 and 168 hours, respectively. As regards to *S. aciari*, the highest and lowest LD_{50} values were 156.655 and 104.691 IJs/cutworm at 72 and 168 hours respectively. Considering mortality rates as well LD_{50} and LT_{50} estimated, it can be inferred that *A. ipsilon* larvae were more vulnerable to *H. bacteriophora* than *S. aciari.*

Table 59. Per cent mortality of *O. obesus* workers due to *H. bacteriophora* and *S. aciari* infection at different time intervals under laboratory conditions

Nematode	Inoculation rate per termite	Mortality (%) after			
		24 hr	48 hr	72 hr	96 hr
Heterorhabditis bacteriophora	10	0	20	50	70
	50	0	30	60	70
	100	0	40	70	80
	150	0	50	70	90
	200	10	50	80	100
	250	30	70	90	100

	300	40	90	100	100
Steinernema aciari	10	0	10	30	50
	50	0	10	40	60
	100	0	20	50	70
	150	0	30	50	80
	200	0	40	70	90
	250	10	60	80	100
	300	30	80	90	100
Control	0	0	0	10	30

Table 60. Dose response mortality of *O. obesus* workers due to *H. bacteriophora* and *S. aciari* at different time intervals

Exposure Time	***H. bacteriophora***			***S. aciari***		
	LD_{50} (No. of IJs/termite)	**Lower Fiducial Limit**	**Upper Fiducial Limit**	**LD_{50} (No. of IJs/termite)**	**Lower Fiducial Limit**	**Upper Fiducial Limit**
24 hours 1 DAT	693.194	241.596	1988.930	2997.000	458.643	19565.030
48 hours 2 DAT	105.691	30.808	362.589	215.737	80.617	577.333
72 hours 3 DAT	23.237	4.951	109.054	84.431	25.548	279.033
96 hours 4 DAT	13.054	2.902	58.729	42.040	14.840	119.093

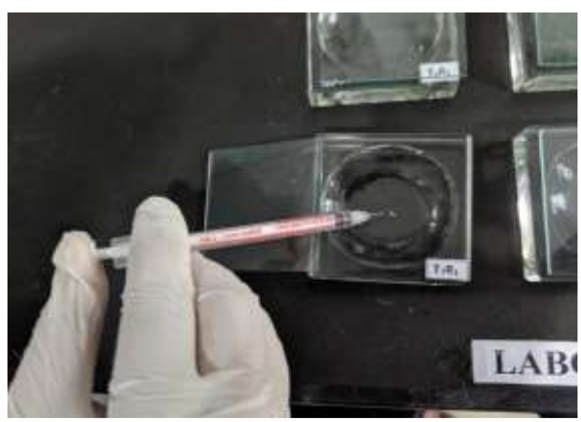
Table 61. Per cent larval mortality of *A. ipsilon* due to *H. bacteriophora* and *S. aciari* infection at different time intervals under laboratory conditions

Nematode	Inoculation rate per cutworm	Mean Mortality (%) after				
		72 hr	**96 hr**	**120 hr**	**144 hr**	**168 hr**
Heterorhabditis bacteriophora	10	0	0	20	40	60
	50	0	10	30	40	60
	100	0	30	40	60	80
	150	10	40	50	80	90
	200	10	40	60	90	100
	250	20	60	70	90	100

	300	30	70	90	100	100
Steinernema aciari	10	0	0	10	30	50
	50	0	0	20	30	60
	100	0	10	20	40	70
	150	0	20	30	50	80
	200	10	40	50	70	80
	250	20	50	60	70	90
	300	20	50	70	80	100
Control	0	0	0	10	20	40

Table 62. Dose response mortality of *A. ipsilon* larvae due to *H. bacteriophora* and *S. aciari* at different time intervals

Exposure Time	***H. bacteriophora***			***S. aciari***		
	LD_{50} (No. of IJs/cutworm)	**Lower Fiducial Limit**	**Upper Fiducial Limit**	**LD_{50} (No. of IJs/cutworm)**	**Lower Fiducial Limit**	**Upper Fiducial Limit**
72 hours 3 DAT	1314.790	307.990	5612.720	156.655	125.307	195.846
96 hours 4 DAT	200.752	90.050	447.541	153.592	118.875	198.447
120 hours 5 DAT	131.532	49.986	346.111	127.233	101.361	159.708
144 hours 6 DAT	56.107	21.742	144.784	110.660	88.680	138.089
168 hours 7 DAT	35.711	12.976	98.281	104.691	86.462	126.763



A. Experimental Setup

B. Application of IJs

C. Inoculation of IJs

D. Emergence of EPNs from cadaver of worker termite

E. Emergence of EPNs from cutworm cadaver

Fig. 50 (A-E). Laboratory evaluation native EPNs against termite and cutworm

GKVK, BENGALURU

A. Effect of EPN on third instar grubs of *Holotrichia serrata* under sugarcane ecosystem

Table 63. Effect of EPN on third instar grubs of *Holotrichia serrata* under sugarcane ecosystem

Sr. No.	Treatment	Dose	3rd instar White grub population/m row		
			PTC	15 DAA	30 DAA
T_1	*Heterorhabditis indica* (WP)	1 lakhs IJS per $2g/m^2$	10.11	10.52	9.98
T_2	*Heterorhabditis indica* (WP)	1.87 lakh IJS per 3.75 g/m^2	10.28	11.01	9.02

T_3	*Heterorhabditis indica* (WP)	2.5 lakhs IJS per 5g/m^2	10.24	10.54	10.11
T_4	*H. indica* infected galleria larvae	1 galleria per 2.0 m^2	9.94	11.51	10.22
T_5	*H. indica* infected galleria larvae	1 galleria per 1.5 m^2	10.04	11.00	9.54
T_6	*H. indica* infected galleria larvae	1 galleria per 1.0 m^2	11.08	10.87	10.18
T_7	Untreated Control	-	10.34	10.52	10.30
		S.Em±	**0.68**	**0.72**	**0.70**
		CD (P=0.05)	**NS**	**NS**	**NS**

Conclusion: The results revealed that none the EPN formulations and doses were effective against third instar grubs of *Holotrichia serrata* under sugarcane ecosystem.

B. Study of local isolates of Entomopathogenic microbes for their Infectivity against soil arthropod pests

Table 64 Effect of different bioagents on third instar grubs of *Holotrichia serrata* under sugarcane ecosystem.

Tr. No.	Treatment	Dose	Application Rate	3rd instar White grub population/m row			% Decrease Over untreated control at 30 DAA
				PTC	15 DAA	30 DAA	
T_1	*Metarhizium anisopliae* (WP)	1x10^9 CFU per gm/m^2	10 g/kg soil/m^2	10.85	9.10	7.11	32.98
T_2	*Metarhizium anisopliae* (WP) mixed with FYM	1x10^9 CFU per gm/m^2	10 g/kg FYM/m^2	11.20	9.10	6.89	35.06
T_3	*Beauveria bassiana* (WP)	1x10^9 CFU per gm/m^2	10 g/kg soil/m^2	10.62	9.12	6.82	35.72
T_4	*Beauveria bassiana* (WP) mixed with FYM	1x10^9 CFU per gm/m^2	10 g/kg FYM/m^2	10.11	9.05	6.12	42.31
T_5	*Beauveria brongniartii* (Soil Formulation)	1x10^9 CFU per gm/m^2	10 g/kg soil/m^2	10.24	7.58	4.22	60.22
T_6	*Beauveria brongniartii* (Soil Formulation) mixed with FYM	1x10^9 CFU per gm/m^2	10 g/kg FYM/m^2	10.30	7.11	4.13	61.07
T_7	Recommended insecticide (Imidacloprid 17.8 SL)	1 ml per litre		9.88	4.58	3.11	70.68
T_8	Untreated Control	-		10.58	10.83	10.61	-
			S.Em±	**0.71**	**0.16**	**0.14**	-
			CD (P=0.05)	**NS**	**0.44**	**0.38**	-

Conclusion: The results revealed that Bengaluru centre EPF isolate *Beauveria brongniartii* recorded 60 per cent mortality of III instar grubs of *Holotrichia serrata* under sugarcane ecosystem.

CSK HPKV Palampur

a) Evaluation of entomopathogenic fungi *B. brongniartii* (BbUASB16 isolate) against second and third instar grubs of *H. longipennis* and *B. coriacea*

To prepare suspension of *B. brongniartii*, 500g of contaminated soil was dissolved in 1 lt of water. 100g of sterilized soil was put in each cup along with maize seedlings and one grub each of *B. coriacea* and *H. longipennis* were released in the respective cups. After that 10 ml suspension was put in each cup with the help of a dropper. The mortality data were recorded at weekly interval and mortality data got stabilized after five weeks of treatment.

In second instar of *B. coriacea*, observed mortality ranged from 29.67-70.67 in subsequent weeks. The mortality decreased gradually from second to third instar and ranged between 24.0-61.33% during1-5 weeks (Table 65).

Table 65. Laboratory mortality of second and third instar grubs of *B. coriacea* due to *B. brongniartii* (BbUASB16 isolate)

Instar	No. of grubs treated	Observed mortality (%) after indicated weeks			Mean (%)
		1	3	5	
Second	45	29.667	47.667	70.667	49.333
Third	45	24.000	34.000	61.333	39.778
CD Factor (A): 1.54 Factor (B): 1.89 Factor (A X B): 2.68					

In case of *H. longipennis*, second instar grubs exhibited mortality of 32.33, 44.67 and 72.33 in first, second and third week, respectively. Gradually the mortality decreased in third instar and showed mortality in the range of 26.00-63.33% in subsequent weeks (**Table 66**).

Table 66. Laboratory mortality of second and third instar grubs of *H. longipennis* due to *B. brongniartii* (BbUASB16 isolate)

Instar	No. of grubs treated	Observed mortality (%) after indicated weeks			Mean mortality (%)
		1	3	5	
Second	45	32.333	44.667	72.333	49.778
Third	45	26.000	35.333	63.333	41.556
CD Factor (A): 2.76 Factor (B): 3.79 Factor (A X B): 2.1					

b) Interaction effects of entomopathogens with insecticides against third instar grubs of *H. longipennis*

For evaluating the interaction effects among entomopathogenic fungi and nematodes with insecticides, each fungi was tested in combination with commonly used insecticides viz. imidacloprid, chlorpyriphos, clothianidin, flubendiamide, spinosad and chlorantraniliprole against third instar grubs of *B.coriacea*. Entomopathogenic fungi i.e. *B. bassiana* and *M. anisopliae* were applied @ $5x10^7$ and $6x10^7$ conidia/ml, respectively. Entomopathogenic nematode, *H.indica* was applied @ 400 IJs/ml. The insecticides were used at lower concentrations viz. 150, 100, 75, 50, 50 and 45 ppm for chlorpyriphos, imidacloprid, clothianidin,flubendiamide, spinosad and chlorantraniliprole, respectively. The entomopthogenic fungi were applied as dip treatment while insecticides were applied as soil application and entomopathogenic nematode was applied in the soil. The insecticides were applied after four days of fungal application and for entomopathogenic nematode, the insecticides were applied simultaneously. Synergistic, additive and antagonistic interactions between different treatments were determined using a χ^2 test (Rodriguez and Peck (2009). Before subjecting the data to χ^2 test, the mortality was corrected by using Abbott's (1925) formula.Treatment of third instar grubs of *B. coriacea* with clothianidin, imidacloprid, chlorpyriphos,flubendiamide, spinosad and chlorantraniliprole produced 17.6-25.8 per cent mortality as indicated in **table 67**.

In case of *H.indica* combinations, the mortality increased when *H.indica* was appllied with different insecticides and observed mortality ranged between 50.5-57.8 for clothianidin, imidacloprid,chlorpyriphos,flubendiamide, spinosad and chlorantraniliprole. The χ^2 values varied between 6.42-10.55 and signified synergistic interactions. In case of *B. bassiana* combinations with clothianidin, imidacloprid, chlorpyriphos, flubendiamide, spinosad and chlorantraniliprole, mortality data ranged between 40-44.4 per cent. The expected mortality for different treatments of *B. bassiana* was calculated to be in the range of 27.5-39.47 per cent. The χ^2 values varied between 5.5-8.49 and the interactions between *B. bassiana* with different tested insecticides were synergistic in nature. Similar trend was obtained for *M. anisopliae* +clothianidin or imidacloprid or chlorpyriphos and the interaction was also found to be synergistic.

Table 67. Interaction of *B. bassiana* and *M. anisopliae* and *H. indica,* with different insecticides against third instar of *H. longipennis*

Treatment	Observed mortality	Expected mortality	χ2	Interaction type
Clothianidin	22.2	-	-	-
Imidacloprid	17.8	-	-	-
Chlorpyriphos	20	-	-	-
Chlorantraniliprole	24.6	-	-	-

Flubendiamide	25.8	-	-	-
Spinosad	25.6	-	-	-
H. indica	22.2	-	-	-
H. indica+Clothianidin	57.8	39.47	8.49	Synergistic
H. indica+Imidacloprid	55.6	36.05	10.55	Synergistic
H. indica+Chlorpyriphos	53.3	37.76	6.42	Synergistic
H. indica+ Chlorantraniliprole	54.2	39.47	8.49	Synergistic
H. indica+Flubendiamide	54.1	36.05	10.55	Synergistic
H. indica+ Spinosad	50.5	37.76	6.42	Synergistic
B. bassiana	11.1	-	-	-
B. bassiana +Clothianidin	44.4	31.28	5.5	Synergistic
B. bassiana +Imidacloprid	40.0	27.5	5.68	Synergistic
B. bassiana +Chlorpyriphos	42.2	29.39	5.58	Synergistic
B. bassiana+ Chlorantraniliprole	40.8	39.47	8.49	Synergistic
B. bassiana +Flubendiamide	42.6	36.05	8.45	Synergistic
B. bassiana + Spinosad	43.3	37.76	6.42	Synergistic
M. anisopliae	10.8	-	-	-
M. anisopliae +Clothianidin	42.4	32.72	4.17	Synergistic
M. anisopliae +Imidacloprid	39.0	29.02	4.15	Synergistic
M. anisopliae +Chlorpyriphos	38.2	30.87	4.16	Synergistic
M. anisopliae+Chlorantraniliprole	41.8	39.47	8.49	Synergistic
M. anisopliae +Flubendiamide	42.6	36.05	10.55	Synergistic
M. anisopliae + Spinosad	42.3	37.76	6.42	Synergistic

c) Field evaluation of *H. indica* cadavers and WP supplied by FARMER, Ghaziabad in potato in Nawar valley in Shimla hills

Field efficacy of *H. indica* against potato white grubs during 2020-21 was done in Shimla district of H.P. The potato crop was sown in first week of April. The treatments were applied during earthing up in first week of August. Two types of formulations were applied: wettabale powder and infected cadaversof *G. mellonella*. The WP formulation was applied by mixing with FYM and then applied in the channels. The cadavers were placed near the base of potato plant. A small hole which was 3-4 cm deep was dug near the base of the plant with the help of a stick and in each hole one cadaver was gently placed, and it was covered with soil. Each plot was of 3 x 4 m^2 size, and different treatments were applied accordingly. In total, there were seven treatments which were replicated three times. Minimum number of damage was recorded in the treatment 6 i.e.1 cadaver/1m^2 with 10.4% grub damage and recorded 51.6% decrease over control. Minimum number of grubs were also recorded in Treatment six with 3.8/m^2 which was 36.19% less over control (**Table 68**).

Table 68. Field evaluation of *H. indica* against potato white grubs in HP during 2020-21

Treatment	Dose	Applied at the time of earthing up			
		Damage (%) number basis	Per cent decrease over control	No. of grubs/m^2	Per cent decrease over control
H. indica (WP)	T_1: 2g/ m^2	13.6	36.74	6.2	59.05
	T_2: 3.75 g/ m^2	13.1	39.07	6	57.14
	T_3: 5 g/m^2	12.8	40.47	5.8	55.24
H. indica infected *Galleria* cadaver	T_4: 1 cadver/2m^2	11.8	45.12	4.2	40.00
	T_5: 1 cadver/1.5m^2	11.6	46.05	4	38.10
	T_6: 1 cadver/1m^2	10.4	51.63	3.8	36.19
CD		1.01		1.2	

COA-Kolhapur

Biological control of white grub, *Leucopholis lepidophora* in sugarcane

Experimental results indicated that the treatment with *Heterorhabditis indica* 10 kg/ha was found to be significantly superior over all other microbial treatments where 5.61 per cent clump mortality was recorded at 40 DAT. However, the treatment with *Heterorhabditis indica* + *M. Anisopliae* @50%+50% found to be equally effective where 6.57 per cent clump mortality was recorded. The significant difference did not exist among the rest of the treatments.

At 60 DAT, the treatment with *Heterorhabditis indica* 10 kg/ha, *Heterorhabditis indica* + *M. anisopliae* @50%+50%, *Metarhizium anisopliae* alone found significantly superior over other treatments where 6.79, 7.73 and 8.93 per cent clump mortality was recorded. The treatment with EPN infected galleria larvae supplied by FARMER and *H. indica* + *B. Bassiana* @ 50%+50% combination was on par with each other where 11.62 and 11.55 per cent clump mortality was recorded (Table 69).

The clump mortality was found to be increased at 80 DAT. The treatment with *Heterorhabditis indica* found significantly superior and recorded 8.89 per cent clump mortality and was on par with *Heterorhabditis indica* + *M. anisopliae* @50%+50%, *Metarhizium anisopliae* alone where 9.11 and 11.55 per cent clump mortality was reported, respectively. The significant difference did not exist among rest of the treatment.

The treatment with *Heterorhabditis indica* + *M. anisopliae* @50%+50% recorded 40.53 t/ha yield followed by 40.57 t/ha in *Heterorhabditis indica* 10 kg/ha and 36.61 t/ha in EPN infected galleria larvae supplied by FARMER.

Due to the cold temperature at harvesting the grubs goes 2 feet deep in the soil and rarely only few grubs were in the upper strata. The treatment with *Beauveria bassiana* @ 10 kg/ha recorded 3 grubs/m^2 followed by *H.indica* @ 10 kg/ha.

Conclusion: The treatment with *H.indica* 10 kg/ha alone and with combination with *M.anisopliae* @10 kg/ha found effective in the management of white grub on the banks of river which will minimize risk of water pollution in river.

Table 69. Biological control of white grub, *Leucopholis lepidophora* in sugarcane

S	Treatment	Initia	Per cent Clump mortality	%	Yiel	No.

N	and dose	l plant popl n	(DAS)				Protection over control	d (t/ha)	of grubs /m^2
			40	60	80	Mean			
1	*Heterorhabditis indica*	668	5.61 (13.56)	6.79 (15.09)	8.00 (16.42)	6.8 (15.02)	51.04	40.57	0.71
2	*Metarhizium anisopliae*	672	6.59 (14.86)	8.93 (17.36)	9.70 (18.13)	8.40 (16.78)	39.52	38.72	0.71
3	*Beauveria bassiana*	598	7.68 (16.09)	10.29 (18.75)	12.35 (20.85)	10.10 (18.56)	27.28	29.47	3.00
4	*H. indica + M. anisopliae*	664	6.57 (14.83)	7.73 (16.13)	9.11 (17.59)	7.80 (16.18)	43.84	40.53	0.00
5	*H. indica + B. bassiana*	612	8.43 (16.87)	11.55 (9.85)	15.94 (23.54)	11.97 (16.75)	13.82	34.32	1.72
6	EPN infected galleria larvae supplied by FARMER	647	8.18 (16.64)	11.62 (19.94)	15.53 (22.95)	11.77 (19.84)	15.26	36.61	2.00
7	Check	652	8.93 (17.36)	15.85 (23.38)	16.90 (24.24)	13.89 (21.66)		23.45	4.65
	S.Em ±		0.71	1.07	0.81	0.86		0.87	0.64
	CD at 5%	NS	1.52	2.32	1.75	1.86		1.89	1.33

IV. WHITE GRUB TAXONOMY

A. Taxonomic Studies on Scarabaeidae of India

GKVK- Bangaluru

a. Compilation of literature on Scarabs of India- Continued

About 2000 bibliographies published on scarabs have been complied. Accessing literature is one of the impediments in the taxonomic studies of scarabs. Hence, in order to enable the timely availability of the publications to scientists/research scholars, the Bengaluru centre is planning to digitize these literatures with the help of ICAR.

b. Development of Taxonomic keys for Scarabs of India

Development of pictorial taxonomic keys for species of the genus *Holotrichia* and *Anomala* is in progress.

c. Description of White grubs of Karnataka, Tamil Nadu, Telangana, Kerala, Himachal Pradesh, Eastern states, Uttarakhand, Utter Pradesh and Rajasthan in phased manner.

Re-description of species of the genus *Apogonia* Kirby is in progress. Prepared the checklists for 83 species of the genus *Holotrichia* Hope (Scarabaeidae: Melolonthinae) from India and SriLanka; 36 species of the tribe Hopliini Latreille, 1829 (Scarabaeidae: Melolonthinae) from India. The checklists have been sent to experts for the comments.

Creating digital repository of Indian Scarabaeidae using specimens available at Bengaluru centre.

The scarab specimens maintained in Bengaluru centre were sorted and catalouged. In the first phase-initiated digitization of species of the genus *Holotrichia* Hope available in the repository. The work is in progress.

V. DEVELOPMENT OF DISTRIBUTION MAPS OF WHITE GRUB PESTS

GKVK- Bngaluru

The distribution map of *H. serrata* and *Leucopholis* spp. with respect to ecological factors such as elevation, soil type and annual rainfall in Karnataka has been generated (Fig.51-53) Development of spatial maps for other species is in progress.

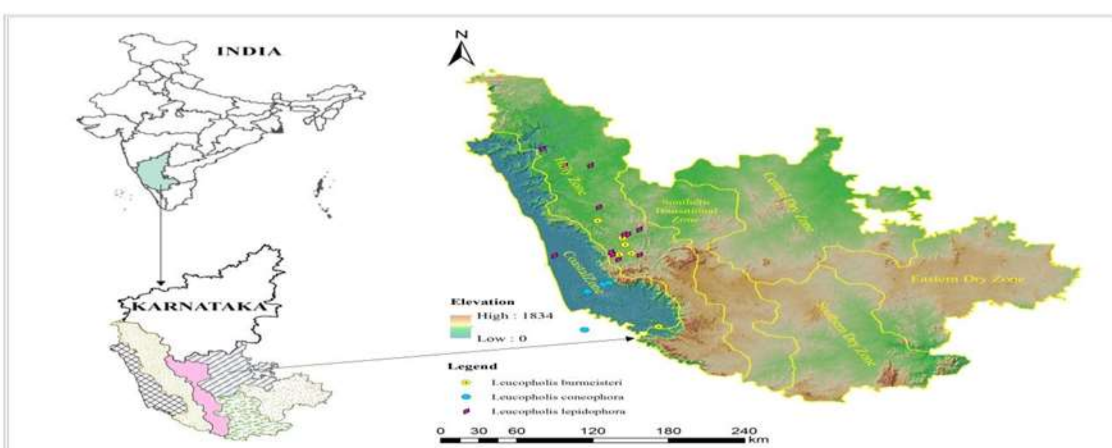


Fig. 51: Distribution of *Leucopholis* spp. in different agro-climatic zones of Karnataka

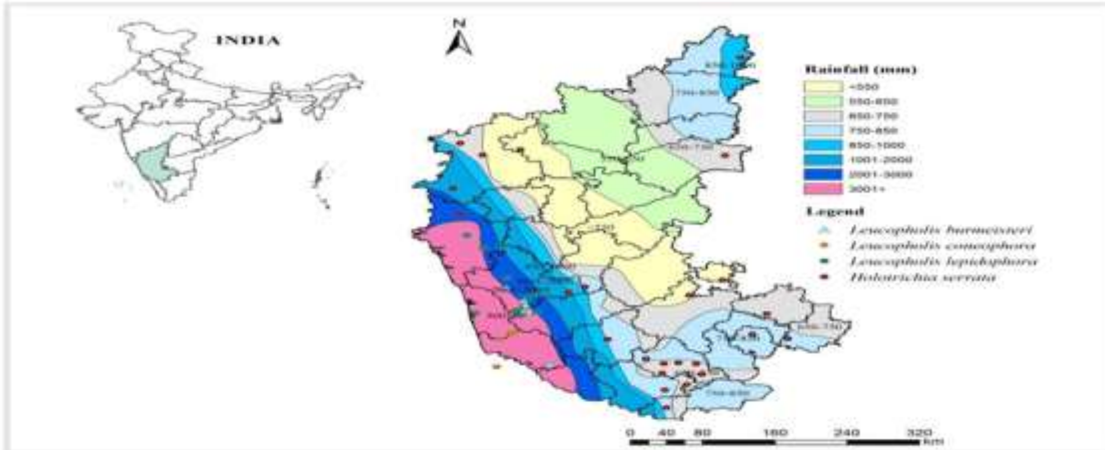


Fig. 52: Distribution of major white grubs in different rainfall regime of Karnataka

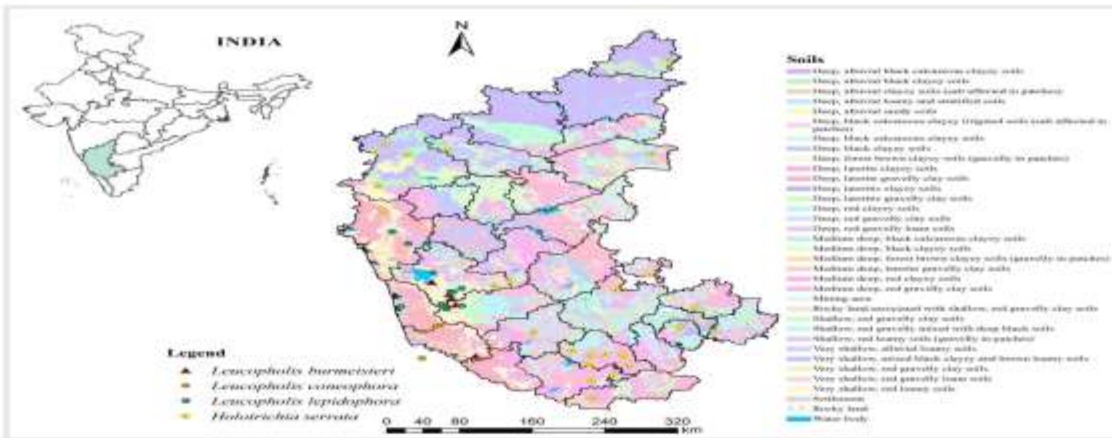


Fig. 53: Distribution of major white grubs in different soil types of Karnataka

AAU-Jorhat

Extensive surveys were carried out to monitor the abundant phytophagous scarab species in the Changlang district of Arunachal Pradesh, India (27.7422º N, 96.6424º E) and efforts were also made to develop distribution map of the most dominant species. During the survey period, two phytophagous species of white grubs *i.e.*, *Holotrichia* sp. and *Anomala* sp. were recorded which were predominantly distributed across the district. Further survey programmes during the active season could not be done due to ban on the inter-district as well as interstate movement due to COVID-19 pandemic.

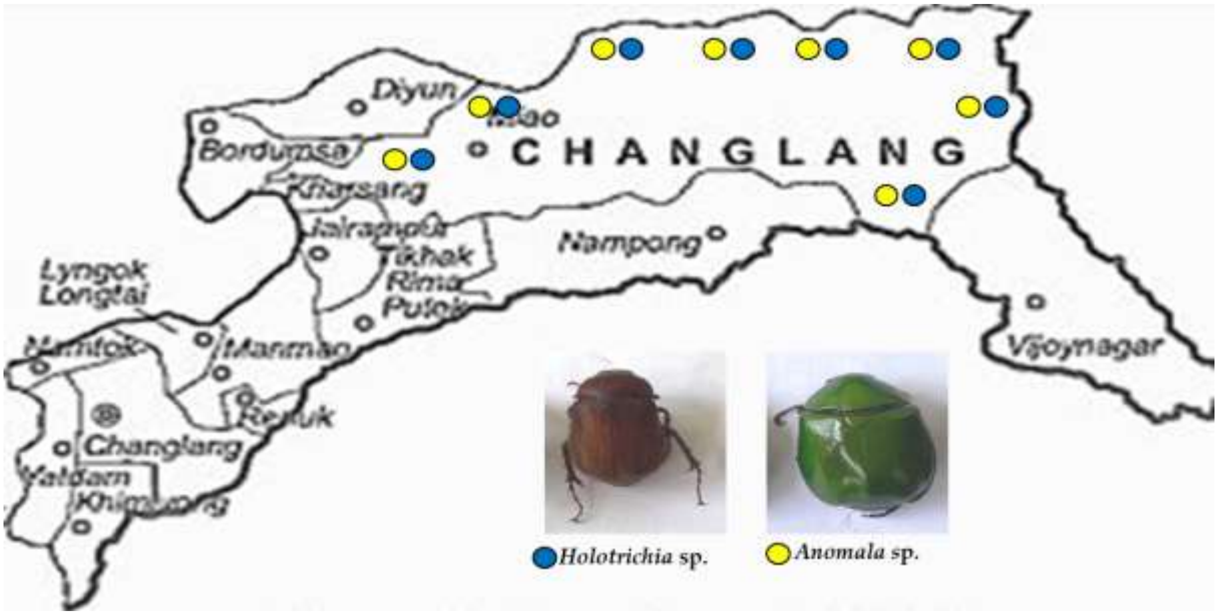


Fig. 54. Distribution map of *Holotrichia* sp. and *Anomala* sp. in Changlang district, Arunachal Pradesh

VI. SOCIAL ENGINEERING

RARI, Durgapura

Surveys carried out in white grub endemic areas and created awareness among the farmers. As many as 18 training programmes and 15 farmers' meets through virtual mode were conducted in groundnut fields. The scientists of AINP-SAP also participated as resource persons in training programmes organized by various departments/ NGOs/ farmers. During field demonstrations, farmers were educated about adult emergence, host range, feeding and breeding behaviour in groundnut fields.


Awareness programme at farmers field **Demonstration of seed treatment**





Farmers training

Demonstration of Pheromone anisol and nanogel pheromone trap at farmer's fields

AAU, JORHAT

Large community mobilization approach for the adult management of *L. mansueta* through light trap and scouting was continued in Majuli river island of Assam during 2021. This mass campaigning programme was conducted by involving 36 numbers of Lepidiota Management Group (LMG) in collaboration with district administration, State Department of Agriculture, NGOs etc. This mass campaigning programme received overwhelming response and was exceedingly successful leading to massive collection and killing of about 75000 beetles with a total of 12.43 lakhs of beetles during 2010-21 (Fig. 55 & Table 70). The mass collection of beetles was carried out in both cultivated and noncultivated areas of endemic villages, however approximately 90 per cent of the beetles were collected from the noncultivated areas such as the breeding ground located in bare land and sandbar areas having enough wild host plants (Fig. 22 A-B). By observing the acceptance of *L. mansueta* beetles as culinary delight by the populace of Majuli, extensive efforts were also made to demonstrate the exploration of these beetles for entomophagy purposes at different strategic locations.

A simple mathematical model was calculated out to know the possible impact of mass destruction of beetles over the years (2010-21) in terms of possible reduction of grub load and thereby savings on insecticide application. The model is presented below:

Total number of beetles collected and destroyed during 2010-2021 = 12.43 lakhs

Sex ratio of L. mansueta = (1:3) (Female: Male)

So the estimated female beetle population = 4.14 lakhs

Say there will be 20% of natural mortality of gravid females

Now, the total gravid female after considering 20% mortality = 3.31 lakhs

Expected fecundity @ 27 eggs/female = 3.31 lakh x 27 nos. = 89.37 lakhs

Say out of 89.37 lakhs egg load, 20% of eggs did not hatch due to natural mortality, desiccation, predation, disease etc.

Then expected 1st instar grubs would be = 71.50 lakhs

Let there will be 50% of mortality of 1st instar grubs due to various factors like natural mortality, predation, parasitization, overcrowding etc.

Then the total reduction of grub load during 2010-2021 would be = 37.75 lakhs

It has also been estimated that this non chemical approach of managing the huge population of *L. mansueta* beetles otherwise could have required to spend about Rs. 2.0 crores for the purchase of insecticide, insecticide application equipment, manpower to be deployed for spraying operations and other costs. The negative impact of synthetic chemical insecticide application was also avoided in respect of insecticide residue, ground water contamination, contamination of mighty Brahmaputra.

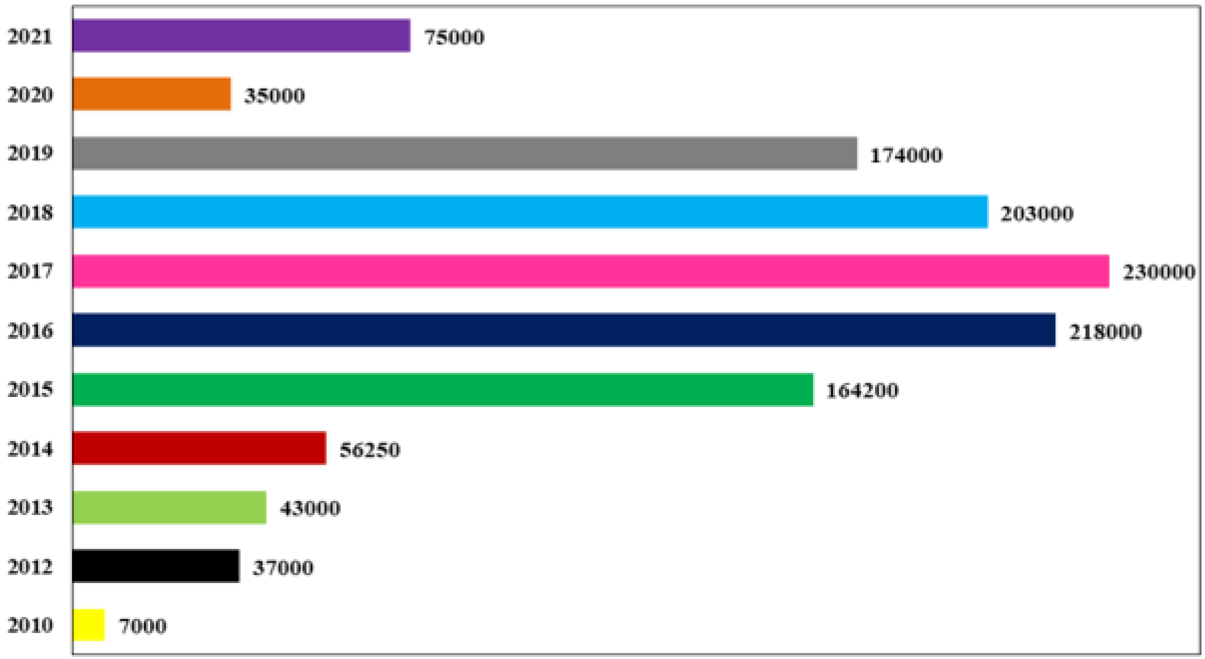


Fig. 55. Lepidiota beetles collected and destroyed during 2010-21
(Unsuccessful collection in 2011 due to heavy rain and low emergence of beetles)

Table. 70. Day wise collection of *Lepidiota* beetles during mass campaigning programme conducted at Majuli

Date	Weather				Beetles Collected	Remarks
	Morning	Noon	Evening	Night		
29-03-2021	Clear sky	Clear sky	Clear sky	Clear sky	500	Emergence started
30-03-2021	Clear sky	Clear sky	Clear sky	Clear sky	1600	Heavy emergence
31-03-2021	Clear sky	Clear sky	Clear sky	Clear sky	2100	-do-
01-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	3000	-do-
02-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	4500	-do-
03-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	11500	-do-
04-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	8000	-do-
05-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	7000	-do-
06-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	6500	-do-
07-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	4600	Moderate emergence
08-04-2021	Clear sky	Windy	Partly Cloudy	Rainfall	-	No emergence
09-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	6000	Moderate emergence
10-04-2021	Rainfall	Cloudy	Clear sky	Clear sky	4800	-do-
11-04-2021	Hazzy	Clear sky	Clear sky	Clear sky	3700	-do-
12-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	2800	-do-
13-04-2021	Hailstorm	Clear sky	Clear sky	Rainfall	-	No emergence

14-04-2021	Clear sky	Clear sky	Clear sky	Rainfall	-	No emergence
15-04-2021	Storm	Clear sky	Clear sky	Clear sky	4400	Moderate emergence
16-04-2021	Cloudy	Clear sky	Clear sky+ windy	Rainfall	-	No emergence
17-04-2021	Drizzle	Clear sky	Clear sky	Clear sky	1500	Moderate emergence
18-04-2021	Clear sky	Rainfall	Clear sky	Rainfall	-	No emergence
19-04-2021	Rainfall	Cloudy	Clear sky	Rainfall	-	-do-
20-04-2021	Gloomy	Clear sky	Clear sky	Rainfall	-	-do-
21-04-2021	Clear sky	Clear sky	Clear sky	Hazzy	1100	Moderate emergence
22-04-2021	Cloudy	Clear sky	Cloudy	Clear sky	700	Low emergence
23-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	400	-do-
24-04-2021	Cloudy	Clear sky	Clear sky+ windy	Rainfall	-	No emergence
25-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	130	Low emergence
26-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	100	-do-
27-04-2021	Clear sky	Clear sky	Clear sky	Clear sky	70	-do-
				Total:	**75000 (Approx.)**	

Fig. 56. A. Glimpses of mass campaigning programme against *L. mansueta* at various endemic villages in Majuli during 2021

Fig. 57. B. Glimpses of mass campaigning programme against *L. mansueta* at various endemic villages in Majuli during 2021

GKVK, Bengaluru

The scientists of AINP-SAP participated as resource persons in the following training programmes (Table 71).

Table 71: Number of farmers training programmes organized/attended during 2020-21

Sl. No.	Date	Place	Topic	Organised by
1	12-6-2020	Hulagaru	IPM of arecanut white grubs	Jointly organized by AINP-SAP & local farmers
2	17-6-2020	Araga	IPM of arecanut white grubs	Jointly organized by AINP-SAP & local farmers
3	18-6-2020	Shuntikatte	IPM of arecanut white grubs	Jointly organized by AINP-SAP & local farmers
4	27-8-2020	Mysuru	IPM of white grubs in different crops	District Agriculture Training Centre, Mysuru
5	12-1-2021	Online	IPM of white grubs in different crops	District Agriculture Training Centre, Mysuru
6	30-4-2021	Online	IPM of white grubs in different crops	District Agriculture Training Centre, Mysuru
7	17-12-2020	Nandila Moodabidre	IPM of white grubs in different crops	Jointly organized by AINP-SAP & local farmers
8	5-5-2021	Online	IPM of white grubs in different crops	AINP-SAP
9	7-5-2021	Online	IPM of white grubs in different crops	AINP-SAP
10	13-5-2021	Online	IPM of white grubs in different crops	AINP-SAP
11	18-5-2021	Online	IPM of white grubs in different crops	AINP-SAP

FARMER-Ghaziabad

During the months of April and May 2020; Sugar Mills, District Cane Officers, farmers, Krishi Vigyan Kendra in western UP have been sensitized by issuing advisory through webinar, emails and WhatsApp to keep watch on emergence of beetles and inform FARMER organization for future studies and its management. In the months of June and July, 2020; Booklets / pamphlet published by FARMER were distributed among farmers belongs to Ghaziabad, Muzaffarnagar, Gautambudhh Nagar and Amroha districts and encouraged them to adopt practices for Integrated Management of national pest; white grub as explained in the literature. A five days training to one scientist entrepreneur, Dr. Shashi Rao, Convergence Bio Science, Hyderabad, was imparted in "Rearing of Host Insect *Galleria Mellonella* (Wax Moth) and *in vivo* multiplication of entomopathogenic nematodes (EPN).

Four training programmes and exposure visits of farmers (188) from different CD Blocks of Ghaziabad District to interact with and learn from each other by adopting integrated approach for management of white grub and termites was organized. Allowing them to view practical examples of successful integration of sustainable practices in farming communities like their own. Four groups of around 40 participants in each were given training and facilitated visit of the FARMER laboratory to acquire technical information about different unit viz., soil testing unit, bio-inputs production unit, EPN production unit, EPF production unit, collection of white grub specimens, demo of white grub collection through Light trap and pheromone trap, *Galleria* cadavers application for soil arthropod pests management in different crops. Dr. Jagpal Singh presented brief overview and benefits of use of these all technologies in soil arthropod pest management to the participants. The other researchers Dr. Seema Rani, Mr. Riazuddin, Mrs. Rinni Sahrawat, Mr. Manish K Sharma, delivered lecture on different aspects of production of EPN and other bioagents as well as management of white grub and termites through bio-control agents. This visit has inspired the participants to adopt IPM for soil arthropod pest management.

The objectives of the training and visit were to build up capacity of farmers and inspire them to adopt IPM in pest management. Through the trained farmers, it was further envisaged that they will work as catalyst at local level in order to impart their knowledge gained from orientation and exposure. The events helped bringing farmers and FARMER VC Ghaziabad on a common platform for better coordination in future, which will ultimately help in acquire good results in soil arthropod pest management. Healthy debate and discussion over myths about IPM and financial benefits were held during the discussions.

Twelve women farmers also participated in this programme and they showed keen interest in the events. This programme proved to be extremely successful in terms of geographical coverage of participation, gender involvement and media coverage. Moreover, majority of participating farmers expressed their willingness to switch over to IPM from their current mode of chemical control. At many places, even those farmers, who were already adopting IPM, came to know about many new and traditional ways of soil arthropod pests management strategies. They accepted that such trainings are the first of their kind. The farmers were inspired by the events and showed immense interest to adopt IPM for soil arthropod pest management especially in sugarcane crop.

The published material on management of white grub and production and use of bioagents in Hindi and English language has been distributed to farmers during these events. WhatsApp groups also formed of each farmers visit for future conservation on soil arthropod pest management and sharing of advance advisory on soil arthropod pest management.

Table 72 Details of four training programmes and exposure visits of farmers (188) from different CD Blocks of Ghaziabad

CD Block	Event	Women	Man	Total
Bhojpur	11.01.2021	1	44	45
Loni	12.01.2021	0	45	45
Muragnagar	18.01.2021	0	45	45
Razapur	23.01.2021	11	42	53
Total		12	176	188



Farmer trainings by FARMER organization Ghaziabad

TERMITES

I. MANAGEMENT OF TERMITES THROUGH CHEMICALS

A. Through seed treatment

RARI, Durgapura

Evaluation of some insecticides used as seed dresser against termites, in groundnut crop during *kharif* (2020-21)

For the management of termite in groundnut two formulations of imidacloprid (17.8 SL & 600 FS), thiamethoxam (30 FS & 25 WG) each and one formulation, fipronil 5 SC, clothianidin 50 WDG, mixture of acephate 50%+imidacloprid 1.8% and bifenthrin 10 EC, mixture of fipronil 40% +Imidacloprid, clothianidin 50 WDG and chlorantraniliprole 18.5 SC were used as seed dresser. Maximum protection with 9.51 per cent plant damage was recorded in imidacloprid 600FS. This was followed by imidacloprid 17.8 SL with 11.62 per cent plant damage. However, these treatments were at par with each other. Production wise also similar trend was observed. Maximum yield was recorded in imidacloprid 600 FS (18.64q/ha) followed by fipronil 5 SC (16.75 q/ha) which were at par with each other (Table 73). In untreated check 64.72 per cent plant damage and 4.90q/ha pod yield was recorded (Table 74).

Table 73: Plant mortality of groundnut by termite

Sr.No.	Treatments	Dose/ kg seed	Plant mortality (%)			
			2018	2019	2020	Mean
1	Thiamethoxam 25 WDG	3.2 g	13.67 (21.28)	16.11 (23.60)	14.85 (22.61)	14.87 (22.67)
2	Imidacloprid 17.8 SL	4.0 ml	9.00 (17.29)	12.13 (20.27)	11.62 (19.92)	10.91 (19.24)
3	Acephate 50% +Imidacloprid 1.8%	4.0 g	23.00 (28.36)	24.73 (29.76)	20.62 (26.74)	22.78 (28.48)
4	Fipronil 5 SC	10.00 ml	7.33 (15.59)	11.51 (19.48)	12.74 (20.89)	10.52 (18.81)
5	Thiamethoxam 30 FS	3.0 ml	15.33 (22.69)	17.03 (24.34)	19.67 (26.04)	17.34 (24.57)
6	**Imidacloprid 600 FS**	**6.5 ml**	**6.67 (14.88)**	**8.67 (17.07)**	**9.51 (17.95)**	**8.28 (16.67)**
7	**Clothianidin 50 WDG**	**2.0g**	**12.33 (20.32)**	**13.55 (21.58)**	**15.40 (23.08)**	**13.76 (21.74)**
8	Fipronil 40% + Imidacloprid 40%	3.0 g	20.33 (26.75)	22.63 (28.39)	22.89 (28.53)	21.95 (27.91)
9	Chlorantraniliprole 18.5 SC	2.0 ml	21.67 (27.53)	22.94 (28.57)	23.23 (28.78)	22.61 (28.38)
10	Untreated check	-	89.33 (71.11)	63.49 (53.03)	64.72 (53.54)	72.51 (59.08)
	SE(m)	-	1.721	1.768	1.599	2.159
	C.D. at 5%	-	5.15	5.29	4.78	6.46
	C.V. %	-	11.21	11.50	10.32	13.97

Table 74: Pod yield of groundnut

Sr. No.	Treatments	Dose/ kg seed	Pod yield (q/ha)				ICBR ratio
			2018	2019	2020	Mean	
1	Thiamethoxam 25 WDG	3.2 g	13.93	14.05	11.55	13.17	1:19.22
2	Imidacloprid 17.8 SL	4.0 ml	16.03	15.80	16.19	16.00	1:20.24
3	Acephate 50% +Imidacloprid 1.8%	4.0 g	9.30	12.55	12.49	11.44	1:21.12
4	Fipronil 5 SC	10.00 ml	17.30	16.15	15.60	16.35	1:24.73
5	Thiamethoxam 30 FS	3.0 ml	13.06	13.65	13.60	13.43	1:20.98
6	**Imidacloprid 600 FS**	**6.5 ml**	**18.46**	**18.20**	**19.77**	**18.81**	**1:21.80**
7	Clothianidin 50 WDG	2.0g	14.26	15.20	15.81	15.09	1:10.08
8	Fipronil 40% + Imidacloprid 40%	3.0 g	11.33	13.00	12.87	12.40	1:4.50
9	Chlorantraniliprole 18.5 SC	2.0 ml	10.23	12.85	12.52	11.86	1:5.62
10	Untreated check	-	3.47	5.35	5.88	4.90	1:19.22
	SE(m)	-	0.938	0.933	1.136	0.555	
	C.D. at 5%	-	2.80	2.79	3.40	1.66	
	C.V. %	-	12.75	11.81	14.30	9.18	

Evaluation of insecticides as seed dresser against termites

AAU, JORHAT

A. Management of termite through sett treatment in sugarcane crop

The technology on "Management of termites through clothianidin 50 WDG @ 1g/ lit. in preserved setts of sugarcane" has been approved as OFT at 3 *KVK*s of AAU (*KVK*: Golaghat, Dhemaji & Nagaon). This OFT is under progress (Fig. 58) and the experimental results are yet to be received from the *KVK*s.

Fig. 58. OFT on "Management of termites through clothianidin 50 WDG @ 1g/ lit. in preserved setts of sugarcane" at different *KVK*s of AAU

CSK HPKV Palampur

Management of termites in wheat through chemicals treatment of seed during 2020

The field trials was conducted in randomized block design comprising 6 treatments and 4 replications with a plot size of 4 x 3 m^2 having row spacing of 22 cm at Village Sujjal in Kangra district, which is an endemic area for termites. The treated seed were sown on 20-11-2020. Wheat seeds were treated with different chemical insecticide treatments at recommended dose before sowing. The data were recorded on per cent tiller damage. The infested tillers start drying up and become light straw coloured. Such infested tillers if pulled come out very easily from the ground. Their underground parts are completely eaten up by the termites resulting in very thin or no Grains in the ears which hampers the overall yield of the crop. Perusal of data presented in table 20 showed significant differences in the tiller damage in different treatments.

Minimum tiller damage (3.4%) was recorded in in clothianidin 50 WDG treatment applied @ 1.5 g/ kg seed as compared to 12.3 per cent in untreated check (**Table 75**).

Table 75. Management of termite in wheat at village Sujjal through seed treatment during 2020

Treatment	Dose (per kg seed)	Tiller Damage (%)
T_1: Thiamethoxam 25WG	3.2 g	7.2
T_2: Imidacloprid 17.8 SL	3.0 ml	5.8
T_3: Acephate 50%+ Imidacloprid 1.8% SP	4.0 g	5.2
T_4: Fipronil 5SC	10 ml	5.6
T_5: Clothianidin 50 WDG	1.5 g	3.4
T_6: Untreated check	-	12.3
CD (P=0.05)		**1.5**

Wheat trial for termite management at Sujjal

Incidence of termite causing white tillers in wheat

GKVK – Bengaluru

Management of termites through seed treatment:

Experimental Details:

Location : Mullahalli, Chintamani Tq, Chikkaballapur Dist
Farmer Name : Venkatesh, M.
Design : RBD
Replication :3
Date of Sowing : 16.07.2020

Table 76: Effect of different seed treatment insecticides on the incidence of termites in groundnut.

S.N.	Treatments	Dose (Per kg seed)	% Germination at 15 DAS
1.	Thiamethoxam 25 WG	3.2 g	91.00
2.	Imidacloprid 17.8 SL	3.0 ml	92.00
3.	Acephate 50% + imidacloprid 1.8%	4.0 g	90.00
4.	Fipronil 5 SC	10.00 ml	93.00
5.	Thiamethoxam 30 FS	3.0 ml	92.00
6.	Imidacloprid 600 FS	6.5 ml	95.00
7.	Clothianidin 50 WDG	1.5	90.66
8.	Fipronil 40%+Imidacloprid 40%WG*	3.0 g	91.00
9.	Chlorantraniliprole 18.5 SC*	2.0 ml	90.00
10.	Untreated check	-	70.88
		S.Em±	**1.52**
		CD at 5%	**4.56**

Conclusion: All the seed treatment insecticides were effective in enhancing seed germination by reducing the white grubs damage compared to untreated check under groundnut ecosystem.

B. Through drenching

RARI Durgapura:

Evaluation of some insecticides used against termite in standing crop of groundnut during *kharif* (2020-21)

In groundnut crop most of the time termite damage appears in later stage of the crop. To protect the standing crop of groundnut some insecticides were applied by broadcasting after mixing them with soil. It was observed that fipronil 5 SC (3 l/ha) and imidacloprid 17.8 SL provided maximum protection 11.61 and 13.01 percent and maximum yield 15.76 and 15.01 q/ha pod yield, respectively. However, it was at par with imidacloprid 600 FS and clothianidin 50WDG where 13.86 and 14.65 percent plant damage, respectively. In untreated check 62.59 per cent plant damage and 4.81q/ha pod yield was recorded (Table 74).

Table 74: Evaluation of some insecticides used against termite in standing crop of groundnut crop during *kharif* (2018-19)

Sr.No.	Treatments	Dose per ha	Plant mortality (%)	Pod yield (q/ha)
1	Thiamethoxam 25 WDG	600 g	18.97 (25.74)	14.52
2	**Imidacloprid 17.8 SL**	**360 ml**	**13.01 (21.12)**	**15.01**
3	Acephate 50% + Imidacloprid 1.8%	1250g	26.30 (30.79)	11.74
4	**Fipronil 5 SC**	**3.0 lit.**	**11.61 (19.91)**	**15.76**
5	Thiamethoxam 30 FS	600ml	18.42 (25.31)	13.68
6	Imidacloprid 600 FS	1042ml	13.86 (21.83)	14.11
7	Clothianidin 50 WDG	300g	14.65 (22.40)	14.40
8	Fipronil 40% + Imidacloprid 40%	500 g	18.52 (25.35)	11.95
9	Chlorantraniliprole 18.5 SC	500 ml	23.55 (29.00)	11.73
10	Untreated check	-	62.59 (52.28)	4.81
	SE(m)	-	1.441	1.045
	C.D. at 5%	-	4.31	3.13
	C.V. %		9.11	14.17

GKVK-Bengaluru

Management of termite through sett treatment in sugarcane crop

Experimental Details

Location : Mahadeswarapura, Pandavapura Tq
Farmer Name : Sri Venkateshappa
Design : RBD
Replication :3
Date of planting : 08.07.2020

Table 75: Effect of different sett treatment insecticides on the incidence of *Holotrichia serrata* in sugarcane.

S.N.	Treatments	Dose (per litre water)	% setts germination at 45 DAP
1.	Thiamethoxam 25 WG	1 g	82.66
2.	Imidacloprid 17.8 SL	1ml	89.12
3.	Acephate 50% + imidacloprid 1%	1 g	82.11
5.	Fipronil 5 SC	1 ml	86.00
6.	Thiamethoxam 35 FS	1 ml	84.00
7.	Imidacloprid 600 FS	1 ml	88.33
8.	Clothianidin 50 WDG	1 g	86.50
9.	Fifronil 40%+Imidacloprid 40%WG	1 g	85.11
10.	Chlorantraniliprole 18.5 SC	0.5ml	80.10
12.	Untreated check	-	68.58
		S.Em±	**0.71**
		CD at 5%	**2.10**

Conclusion: All the seed treatment insecticides were effective in enhancing sett germination sugarcane by reducing the white grubs damage compared to untreated check.

AAU- Jorhat

B. Drenching in standing tea crop through water

An experiment was conducted to evaluate six insecticides against termites (*Odontotermes obesus*) in tea crop at Charaibahi village of Jorhat during January-April, 2021. The experiment was conducted as 3 RBD by following all the recommended package and practices. The required amount of insecticides were drenched in standing tea crop through water. The treatments were applied on 30th January, 2021 and the observations were taken at 30 and 60 days after treatment (DAT). The efficacy of different treatments were recorded on the basis of per cent infestation on number and portion basis.

Experimental results indicated that all the insecticidal treatments were found to be significantly superior over the untreated control in reducing both number and portion of infestation (Table 76 and Fig. 59). Significantly lowest number of infestation was recorded in clothianidin 50 WDG @ 250 g/ha (8.70 and 9.76% at 30 and 60 DAT, respectively) followed by chlorantraniliprole 18.5 SC @ 500 ml (10.68 and 11.93% at 30 and 60 DAT, respectively) and imidacloprid 600 FS @ 800 ml (12.63 and 14.71% at 30 and 60 DAT, respectively). The plots treated with imidacloprid 17.8 SL @ 350 ml, imidacloprid 70 WS @ 160 ml and fipronil 5 SC @ 2/lit. registered 15.89 & 16.81, 18.28 & 19.19 and 20.22 & 22.68 per cent at 30 and 60 DAT, respectively. The untreated control plots registered 32.05 and 37.93 per cent of infestation on number basis by the termites at 30 and 60 DAT, respectively.

While considering the portion of infestation, it was revealed that clothianidin 50 WDG @ 250 g/ha treated plots recorded lowest infestation (7.79 and 9.41% at 30 and 60 DAT, respectively) which was statistically superior over rest of the treatments. This treatment was followed by chlorantraniliprole 18.5 SC @ 500 ml (9.68 and 10.94% at 30 and 60 DAT, respectively) and imidacloprid 600 FS @ 800 ml (11.90 and 13.87% at 30 and 60 DAT, respectively) treated plots. The per cent infestation on portion basis in imidacloprid 17.8 SL @ 350 ml, imidacloprid 70 WS @ 160 ml and fipronil 5 SC @ 2/lit. registered 14.66 & 15.64; 17.27 & 19.40 and 19.87 and 21.95 per cent at 30 and 60 DAT, respectively. The untreated check plots registered 31.25 and 34.98 per cent portion of infestation by termites at 30 and 60 DAT, respectively (Table 76).

Table 76. Evaluation of some insecticides against termite in tea during 2021

Treatment	Doses/ha	30 DAT*		60 DAT*	
		No. of infestation (%)	Portion of infestation (%)	No. of infestation (%)	Portion of infestation (%)
Imidacloprid 600 FS	800 ml	12.63 (20.85)	11.90 (20.19)	14.71 (22.58)	13.87 (21.89)
Imidacloprid 17.8 SL	350 ml	15.89 (23.55)	14.66 (22.53)	16.81 (24.27)	15.64 (23.31)
Fipronil 5 SC	2 lit	20.22 (26.76)	19.87 (26.49)	22.68 (28.44)	21.95 (27.97)
Imidacloprid 70 WS	160 ml	18.28 (25.33)	17.27 (24.58)	19.19 (26.00)	19.40 (26.15)
Clothianidin 50 WDG	250 g	8.70 (17.13)	7.79 (16.20)	9.76 (18.22)	9.41 (17.87)
Chlorantraniliprole 18.5 SC	500 ml	10.68 (19.08)	9.68 (18.12)	11.93 (20.18)	10.94 (19.32)
Untreated control	-	32.05 (34.56)	31.25 (34.01)	37.93 (38.02)	34.98 (36.28)
SEd (±)		**0.80**	**0.34**	**0.66**	**0.35**
CD (P=0.05)		**1.75**	**0.73**	**1.45**	**0.76**

(Figures in parentheses are angular transformed values)

*DAT: Days after treatment

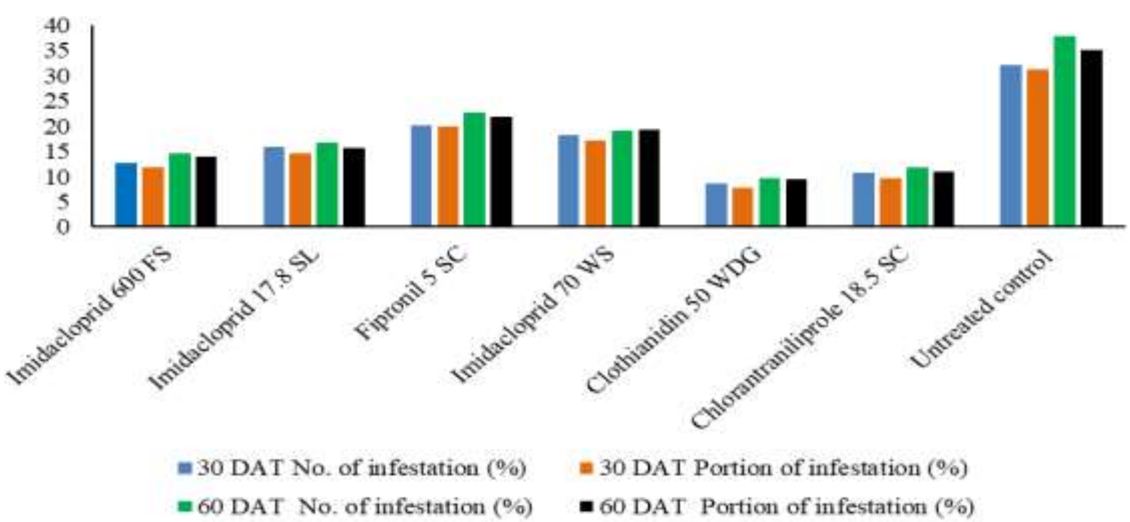
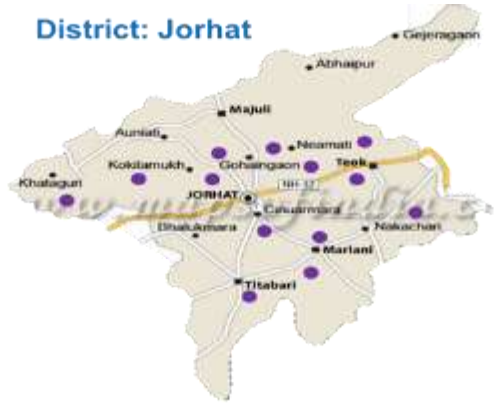


Fig. 59. Evaluation of some insecticides against termite in tea during 2021

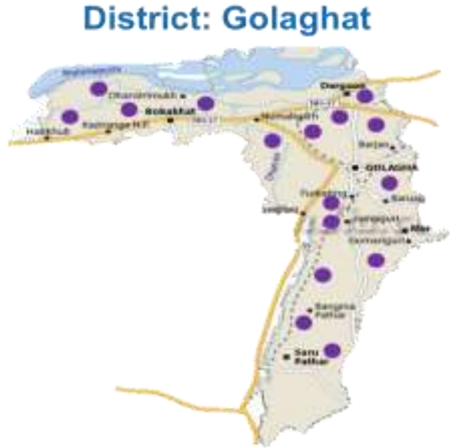
Biodiversity studies and development of distribution maps of termites of Assam

AAU, Jorhat

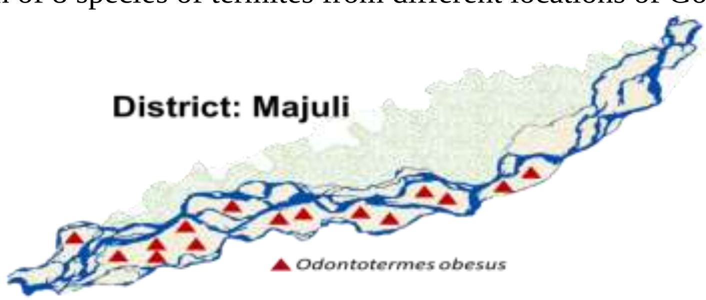
GPS based surveys were initiated during 2017 onwards to study the diversity of termites as well as to prepare the distribution maps of termite pests of Assam. Termite samples were collected from four different habitats *viz*., forest, agriculture, rural and urban areas of Jorhat (26.7509° N, 94.2037° E), Golaghat (26.5239° N, 93.9623° E) and Majuli (32.2432° N, 77.1892° E) districts of Assam. Sampling in different habitats revealed the presence of 8 species of termites in both the Jorhat and Golaghat districts whereas only the species *Odontotermes obesus* was recorded from Majuli (Fig. 60. The species were identified in collaboration with Dr. Kalleshwara Swamy, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka. Further the species were confirmed with the help of both Stereo-zoom and Scanning Electron Microscopy. Among the 8 different species of termites recorded, 5 species were belonged to Macrotermitinae subfamily, whereas the other 3 species belonged to the subfamily Nasutitermitinae, Kalotermitinae and Amitermitinae. In the study, the genus *Odontotermes* was found dominant which consisted of 4 species *viz., Odontotermes obesus* (Rambur), *O. feae* (Wasmann), *O. parvidens* (Holmg. and Holmg.) and *O. kapuri* (Roonwal and Chhotani) while the remaining 4 species were belonged to different genera *viz*., *Microtermes mycophagous* (Desneux), *Trinervitermes biformis* (Wasmann), *Neotermes buxensis* (Roonwal and Sen-sarma) and Speculitermes chadaensis (Chatterjee and Thapa) (Fig. 61 & 62). Among the 8 species recorded during the study period, 2 species *viz*., *O. obesus* and *O. feae* were dominantly distributed in all the habitats. Collection of termites from different habitats also revealed the higher population of the termite species in forest habitats as compared to the rural, agricultural and urban habitats in all the studied districts.



A. Collection of 8 species of termites from different locations of Jorhat district

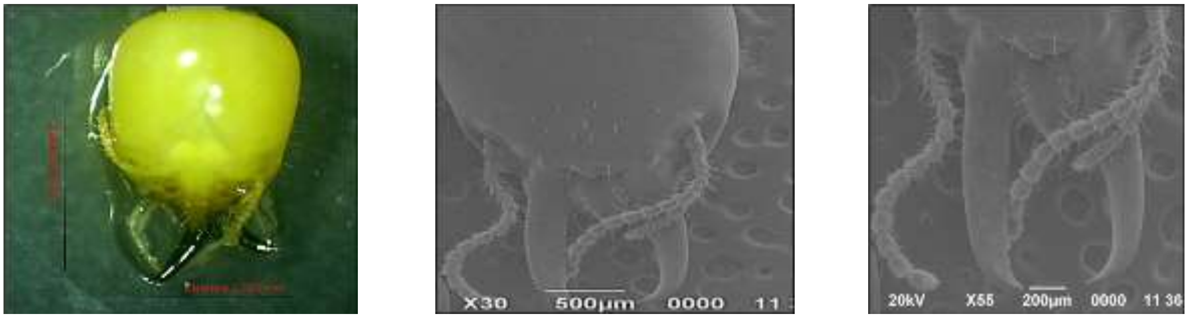


B. Collection of 8 species of termites from different locations of Golaghat district

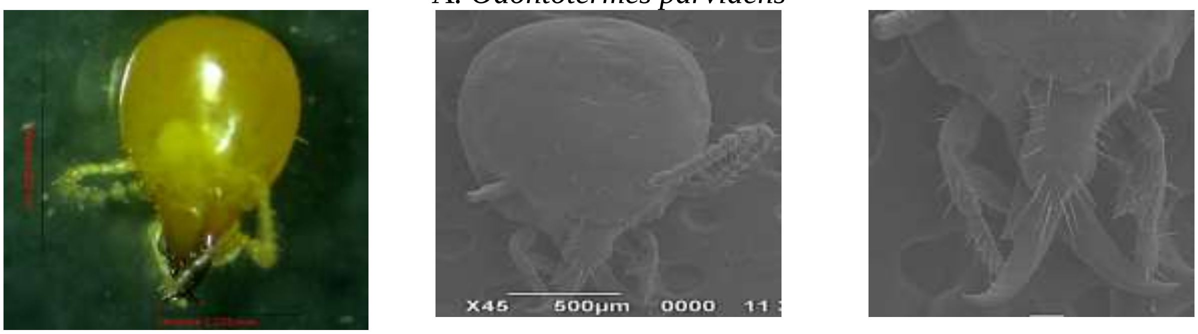


C. Collection of *Odontotermes obesus* from Majuli district

Fig. 60 (A-C). Distribution map of different species of termites collected from 3 districts of Assam

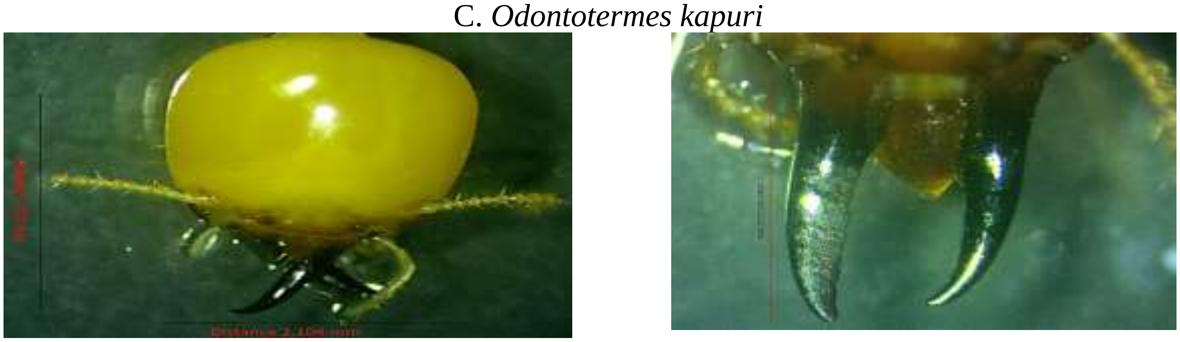


A. *Odontotermes parvidens*



B. *Odontotermes obesus*

C. *Odontotermes kapuri*

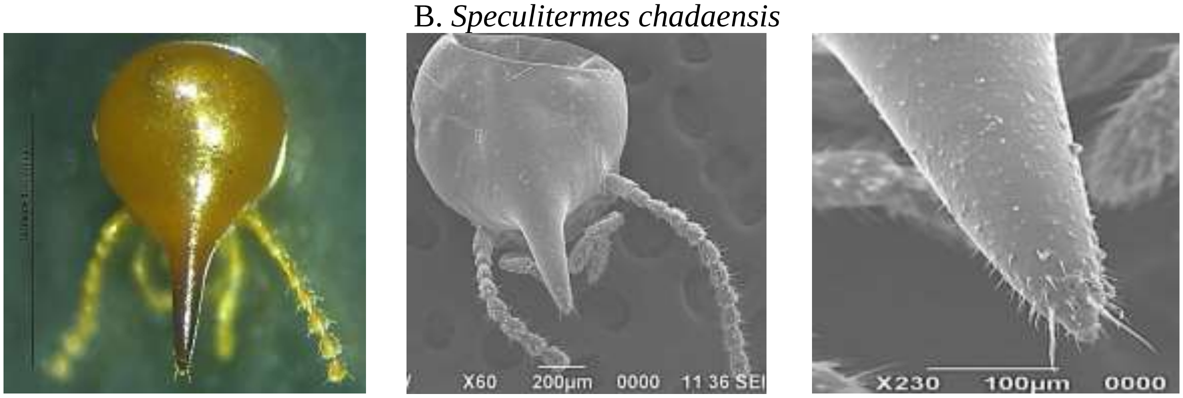


D. *Odontotermes feae*

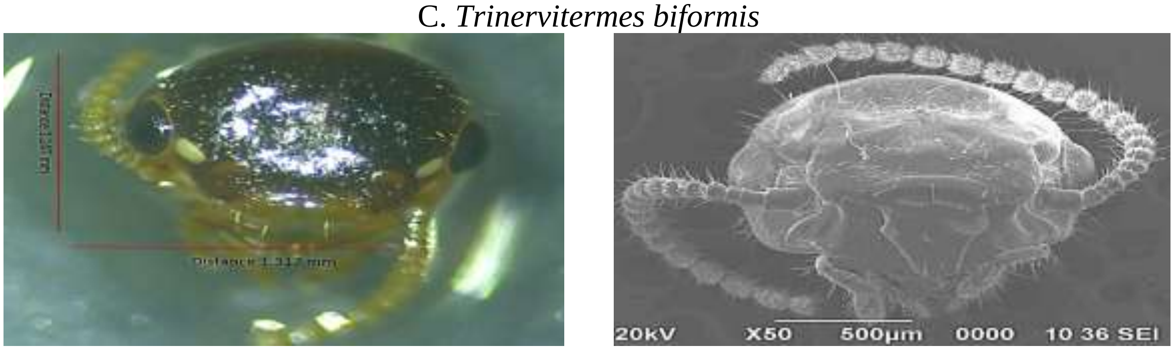
Fig. 61. (A-D). Identification of the four *Odontotermes* species through Stereo zoom and Scanning Electron Microscopy of the mandibles

A. *Microtermes mycophagous*

B. *Speculitermes chadaensis*



C. *Trinervitermes biformis*



D. *Neotermes buxensis*

Fig. 62 (A-D). Stereozoom and Scanning Electron Microscopy of the mandible of 3 other termite species recorded from Assam

POPULATION MONITORING AND MANAGEMENT OF CUTWORMS

CSK HPKV- PALAMPUR

a) Monitoring of cutworms on light trap during 2020 at Palampur: Light trap was installed at Palampur for monitoring the adult activity of *A. ipsilon* and *A. segetum* during 2020. The emergence of *A. ipsilon* was started in first week of April with a peak catch (12 moths/ week) in the second week of May, 2020. *A. segetum* was also caught in the light trap with maximum catch (9 moths/ week) observed in first week of May **(Table 77)**.

Table 77 Monitoring of cutworms on light trap during 2020 at Palampur

Month	Week	*A. ipsilon*	*A. segetum*
April	13	2	0
	14	4	2
	15	4	4
	16	7	5
May	17	8	9
	18	12	6
	19	9	4
	20	6	4
	21	3	3
June	22	6	4
	23	8	6
	24	2	1
	25	1	1
July	26	0	0
	27	0	0
	28	0	0

b) Incidence of cutworms in different crops at Palampur, 2020: Data on incidence of cutworm were recorded on six crops i.e pea, cabbage, cauliflower, tomato, potato and maize during January to June 2019. Maximum plant infestation was recorded in cabbage (10.2 %) followed by cauliflower (8.4 %) and potato (7.3 %). **(Table 78).**

Table 78 Incidence of cut worms in vegetable crops in Palampur during 2020

Crop	Time of sampling	Per cent plant infestation
Pea	Jan	5.1
Cabbage	Jan	10.2
Cauliflower	Jan	8.4
Tomato	March-April	5.2
Potato	April	7.3
Maize	June	6.0

c. Chemical control of cutworms in cabbage during 2020

Location : Research Farm, Department of Entomology, Palampur
Crop : Cabbage
Plot size : 4x3 m^2
Date of sowing : 9.11.2020
Treatments : 6
Replications : 4

All the treatments were applied at the time of transplanting of the cabbage crop. Observations on plant mortality were recorded after one and two weeks after treatment. The per cent plant infestation was minimum (1.5%) in clothianidin 50WDG in the 2nd week of observation after treatment, whereas, in control 13.25% plant infestation was recorded (**Table 79**).

Table 79. Field evaluation of pre sown application of different insecticides against cutworms at Palampur 2020

Treatments	Dose (g a.i./ ha)	Per cent plant infestation after week of treatment	
		1st week	2nd week
T1: Imidacloprid 17.8 SL	60	3.25	6.0
T2: Carbofuran 3G	750	5.75	11.25
T3: Clothianidin 50WDG	120	0.5	1.5
T4: Fipronil 0.3G	50	4.5	7.25
T5: Thiamethoxam 25WG	80	1.5	5.25
T6: Untreated check	-	10.5	13.25

GBPUA&T- Pantnagar

Species profiling of cutworm moths through light trap at R.S. Majhera, Kumaun region of district Udham Singh Nagar of Uttarakhand during, 2020-21

From the results presented in Table 7, it is evident that total four species of cutworm moths were trapped on the light trap during the active season. The emergence of cutworm moths started from 15th March, 2020 and only three adults of *Agrotis ipsilon* was trapped on the light trap. In the month of March, total 56 cutworm moths were trapped on the light trap and *Agrotis ipsilon* occupied major species (10.38% catch) followed by *A. flammatra* (17.78% catch). Highest number i.e., 167 moth were trapped in the month of April, 2020 and major proportion i.e., 76 moths (45.50% catch) were trapped during the second and third week of April, 20 (10th April – 20th April, 20). Thus, the Peak Emergence Period (PEP) was observed to be 2nd - 3rd week of April, 20 at Majhera. A decreasing trend in the light trap catch was observed from May to September, 2020. As regard the population of moths trapped during the month of May, 2020, total 142 moths were caught on the light trap which declined to the extent of 76, 25 and 03 in the months of June, July and August, respectively. No moths were trapped during the month of September 2012 on light trap. The cutworm species namely *Agrotis ipsilon* exhibited highest relative abundance (61.62%) followed by *Agrotis flammatra* (19.19%). *Agrotis segetum* occupied third rank (14.07%) while *Agrotis c. nigrum* occupied lowest proportion (5.18% relative abundance) during the active season (Table 80).

Table 80. Light trap studies on cutworm moths at Majhera 2020-21

Month & Year	Light trap catches				Total No. of moths trapped	Relative abundance among the cutworm species (%)			
	Agrotis ipsilon	*Agrotis flammatra*	*Agrotis segetum*	*Agrotis c. nigrum*		*Agrotis ipsilon*	*Agrotis flammatra*	*Agrotis segetum*	*Agrotis c. nigrum*
March	30	16	8	2	56	10.38	17.78	12.12	8.33
April	109	21	27	10	167	37.72	23.33	40.91	41.67
May	91	29	19	3	142	31.49	32.22	28.79	12.50
June	46	18	7	5	76	15.92	20.00	10.61	20.83
July	10	6	5	4	25	3.46	6.67	7.57	16.67
August	3	-	-	-	3	1.04	-	-	-
	289	90	66	24	469	61.62	19.19	14.07	5.18

LOCATION SPECIFIC TRIALS

RARI-Durgapura

A. Management of soil arthropods in groundnut crop through IPM

Soil arthropods management in groundnut crop through integrated pest management practices were carried out with four IPM modules including one control module. The data present in table 11, 12 and 13 indicated that minimum plant mortality and maximum pod yield was recorded in IPM module Ist with 4.43 % plant mortality and 29.41 q/ha pod yield followed by IPM module II and IPM module III. In untreated check 100 per cent plant mortality was recorded (Table 81).

Table 81: Plant mortality in different IPM modules (treatments) on groundnut

Sr. No.	Treatments	Per cent plant mortality of groundnut		
		Kharif-2019	*Kharif*-2020	Mean
IPM-I	**Soil application of Neem cake 250kg/ha** **Seed treatment with imidacloprid 600 FS-@ 6.5 ml/kg seed** ***Application of Beauveria bassiana* –0.5g/m^2** **Application of imidacloprid 17.8 SL@ 300 ml/ha**	**3.37 (10.32)**	**4.43 (12.13)**	**3.90 (11.23)**
IPM-II	Soil application of Neem cake 250kg/ha Seed treatment with imidacloprid 600 FS-@ 6.5ml/kg seed*Application of Metarhizium anisopliae-0.5*g/m^2 Application of Fifronil 5 SC-3.0 lit./ha	6.68 (14.78)	7.33 (15.63)	7.00 (15.20)
IPM-III	Soil application of Neem cake 250kg/ha Seed treatment with imidacloprid 600 FS-@6.5ml/kg seed *Application of H.indica-0.5*g/m^2 *Application of* Fifronil40%+Imidacloprid 40%WG@ 300g/ha	14.91 (22.55)	16.21 (23.72)	15.56 (23.13)
IPM-IV	Untreated check	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
	SE(m)	1.095	0.545	
	C.D. at 5%	3.32	1.699	
	C.V. %	7.79	8.02	

Table 82: Effect of IPM modules (treatments) on population of white grub on groundnut

Sr. No.	Treatments	Larval population of white grub per square meter		
		Kharif-2019	*Kharif*-2020	Mean
IPM-I	**Soil application of Neem cake 250kg/ha** **Seed treatment with imidacloprid 600 FS-@ 6.5 ml/kg seed** **Application of Beauveria bassiana –0.5g/m^2** **Application of imidacloprid 17.8 SL@ 300 ml/ha**	**0.00**	**0.00**	**0.00**
IPM-II	Soil application of Neem cake 250kg/ha Seed treatment with imidacloprid 600 FS-@ 6.5ml/kg seed *Application of Metarhizium anisopliae-0.5*g/m^2 Application of Fifronil 5 SC-3.0 lit./ha	0.17	0.20	0.18
IPM-III	Soil application of Neem cake 250kg/ha Seed treatment with imidacloprid 600 FS-@6.5ml/kg seed *Application of H.indica-0.5*g/m^2 *Application of* Fifronil40%+Imidacloprid 40%WG@ 300g/ha	0.50	0.55	0.52
IPM-IV	Untreated check	7.00	7.15	7.07
	SE(m)	0.149	0.272	
	C.D. at 5%	0.45	0.84	
	C.V. %	12.05	14.18	

Table 83: Effect of IPM modules (treatments) on yield of groundnut

Sr. No.	Treatments	Yield of groundnut			ICBR ratio
		Kharif-2019	*Kharif*-2020	Mean	
IPM-I	**Soil application of Neem cake 250kg/ha** **Seed treatment with imidacloprid 600 FS-@ 6.5 ml/kg seed** ***Application of Beauveria bassiana* –0.5g/m^2** **Application of imidacloprid 17.8 SL@ 300 ml/ha**	**32.50**	**33.20**	**32.85**	**1:23.16**
IPM-II	Soil application of Neem cake 250kg/ha Seed treatment with imidacloprid 600 FS-@ 6.5ml/kg seed *Application of Metarhizium anisopliae-0.5*g/m^2 Application of Fifronil 5 SC-3.0 lit./ha	29.05	27.45	28.25	1:14.27

IPM-III	Soil application of Neem cake 250kg/ha Seed treatment with imidacloprid 600 FS-@6.5ml/kg seed *Application of H.indica-0.5*g/m^2 *Application of* Fifronil40%+Imidacloprid 40%WG@ 300g/ha	26.33	25.00	25.66	1:12.83
IPM-IV	Untreated check	0.00	0.00	0.00	-
	SE(m)	1.128	0.779		
	C.D. at 5%	3.43	2.42		
	C.V. %	12.78	11.05		

Management of soil arthropods in groundnut crop through IPM

B. Management of soil arthropods in groundnut crop through chemicals

To protect the groundnut crop against soil arthropod pests with different insecticides were evaluated by using them as seed dresser and standing crop treatments. Perusal of the data in table 16 indicated that Imidaclprid 600 FS at 6.5 ml/kg seed followed by standing treatment at 21 days after sowing with imidacloprid 17.8 SL @ 500 ml/ha was found superior to all the other tested insecticides, with minimum 3.53 per cent plant mortality and maximum 31.94 q/ha pod yield, respectively. Larval population was found 0.0 larvae/m^2 in the treatment. In untreated check 100 per cent plant damage was recorded (Table 84).

Table 84: Management of whitegrub, *Holotrichia consanguinea* in groundnut crop during *kharif* (2020-21)

Sr. No.	Treatments	Dose per kg seed	Treatments	Dose/ha	Plant mortality (%)	Larval population /m^2	Pod yield (q/ha)
1	Clothianidin 50 WDG	2.0 g	Imidacloprid 17.8 SL	300 ml	6.31 (14.43)*	0.00	25.64
2	Clothianidin 50 WDG	2.0 g	Imidacloprid 17.8 SL	500 ml	5.01 (12.93)	0.00	28.86
3	Clothianidin 50 WDG	2.0 g	Fipronil 40% + Imidacloprid 40%	500 g	10.49 (18.87)	0.13	23.09
4	Imidacloprid 600 FS	6.5 ml	Imidacloprid 17.8 SL	300 ml	4.84 (12.66)	0.00	29.23
5	Imidacloprid 600 FS	6.5 ml	Imidacloprid 17.8 SL	500 ml	3.53 (10.73)	0.00	31.94
6	Imidacloprid 600 FS	6.5 ml	Fipronil 40% + Imidacloprid 40%	500 g	9.55 (17.91)	0.13	23.90
7	Imidacloprid 600 FS	6.5 ml	Fipronil 5 SC	3.0 lit.	12.44 (20.56)	0.20	20.16
8	Clothianidin 50 WDG	2.0 g	Fipronil 5 SC	3.0 lit.	16.07 (23.50)	0.27	18.74
9	Untreated check	-	-	-	100.00 (90.00)	6.00	0..00
	SE(m)	-			1.170	0.199	0.493
	C.D. at 5%	-			3.53	0.60	1.49
	C.V. %	-			8.23	8.05	7.81

*Figures in parenthesis are angular transformed value

Evaluation of insecticdes as seed treatment followed by standing crop treatment

C. Comparative evaluation of pheromone, methoxy benzene (Anisole) and Nanogel of methoxy benzene at RARI, Durgapura, Jaipur on 15 meter distance during kharif, 2020

The already isolated and characterized pheromone methoxy benzene of predominant species of groundnut ecosystem *Holotrichia consenguniea* at RARI Durgapura is aggregating pheromone but it is highly volatile in nature so, daily putting of new septa on host tree does require. To overcome this problem for farmers, slow release "Nano gel formulation of Methoxy benzene" was prepared by Nano gel technology for beetle (*Holotrichia consenguniea)* management and the technology has been tested in white grub endemic areas of Rajasthan and perfected.

This slow release "Nano gel formulation is effective in aggregation of beetles up to one month and now daily loading of new septa wouldn't be required upto one month (Table 85).

The beetle catcheswere started in nanogel formulation first week of July and as continue till last week of July in comparision to anisole the catches were only on day of installation (Table 15). **Recommendations**

✓ For the management of white grub beetles slow release nanogel of pheromone methoxy benzene (anisole) is effective up to 25 days of installation.

Table: 85 Comparative evaluation of pheromone, methoxy benzene (Anisole) and Nanogel of methoxy benzene at RARI, Durgapura, Jaipur on 15 meter distance during kharif, 2020

Treat	Date of traps																				Mean adult catch/ trap
	3/7	4/7	5/7	6/7	7/7	8/7	9/7	10/7	11/7	12/7	13/7	14/7	15/7	16/7	17/7	18/7	19/7	20/7	21/7	22/7	
N	71	56	42	21	10	7	3	36	21	12	10	8	6	5	4	5	4	3	2	2	16.40
N	98	55	35	18	11	7	4	37	23	15	10	7	8	6	4	3	1	2	1	1	17.30
N	64	46	30	17	7	55	3	33	21	14	11	8	7	9	5	3	2	2	3	1	14.55
N	79	41	31	19	9	7	4	31	19	11	7	8	5	7	4	4	3	2	2	1	14.70
N	77	56	38	16	7	6	2	36	16	10	9	5	6	5	4	4	3	2	2	1	15.25
A	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.40
A	109	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.45
A	98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.90
A	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.70
A	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.45

Management of *H. consenguniea* by developed technology "slow release nanogel of pheromone methoxy benzene" has been published in ICAR news letter

D. Management of termite through some chemicals in chick pea crop.

a. Management of termite damage through seed treatment of insecticides in chickpea crop during (2020-21) at Durgapura Jaipur.

The experiment for the control of termite through seed treatment was carried out at the Rajasthan Agriculture Research Institute, Durgapura under irrigated conditions and the results are summarized in Table 86. The data further revealed that termite damage was maximum in untreated check (27.00%), whereas it was minimum in the treatment of Imidacloprid 600 FS @ 6 ml/kg seed (4.83%). The grain yield data computed on the basis of q / ha from different treatments indicated that maximum yield was observed in Imidacloprid 600 FS (27.50 / ha) and lowest yield was observed in untreated check (11.16 q / ha).

Table 86: Management of termite damage through seed treatment in chickpea crop during 2020-21 at Durgapura Jaipur.

Sr. No.	Treatment	Dose/kg seed	Per cent Plant Damage	Yield (q/ha)
			2020-21	2020-21
1	Fipronil 40%+Imidacloprid 40%	3.0g	6.70 (15.02)*	21.36
2	Fipronil 40%+Imidacloprid 40%	5.0g	5.67 (13.75)	22.97
3	Imidacloprid 17.8 SL	4.0ml	7.60 (16.06)	17.45
4	Fipronil 5SC	10.0 ml	6.43 (14.75)	20.08
5	Clothianidin 50 WDG	2.0g	7.83 (16.23)	18.75
6	Imidacloprid 600FS	4.0ml	6.50 (14.75)	23.70
7	Imidacloprid 600FS	5.0ml	5.33 (13.33)	25.50
8	Imidacloprid 600FS	6.0 ml	4.83 (12.66)	27.50
9	Chlorantraniliprole 18.5 SC	2.0ml	11.00 (19.35)	17.18
10	Control	---	27.00 (31.29)	11.16
SEm+			0.394	1.066
CD @ 5%			1.17	3.19
CV%			5.07	8.97

*Figures in parenthesis are angular transformed value

b. Management of termite damage through broadcasting of insecticides in standing chickpea crop during (2020-21) at Durgapura Jaipur.

The experiment for the control of termite through seed treatment was carried out at the Rajasthan Agriculture Research Institute, Durgapura under irrigated conditions and the results are summarized in Table 87. The data further revealed that termite damage was maximum in untreated check (29.33%), whereas it was minimum in the treatment of Imidacloprid 17.8 SL (5.33%). The grain yield data computed on the basis of q / ha from different treatments indicated that maximum yield was observed in Imidacloprid 17.8 SL (27.19 / ha) and lowest yield was observed in untreated check (10.85 q / ha).

Table 87: Management of termite damage through broadcasting of insecticides in standing chickpea crop during 2020-21 at Durgapura, Jaipur

Sr. No.	Treatment	Dose/kg seed	Per cent Plant Damage	Yield (q/ha)
			2020-21	2020-21
1	Fipronil 40% +Imidacloprid 40%	400g	7.00 (15.31)*	21.36
2	Fipronil 40% +Imidacloprid 40%	500g	6.33 (14.50)	23.83
3	Imidacloprid 17.8 SL	360ml	5.33 (13.33)	27.19
4	Fipronil 5SC	3.0 lit	6.67 (14.94)	22.51
5	Clothianidin 50 WDG	300g	9.33 (17.43)	19.06
6	Imidacloprid 600FS	700ml	10.00 (18.41)	18.80
7	Imidacloprid 600FS	900ml	9.33 (17.43)	22.50
8	Imidacloprid 600FS	1042ml	8.33 (16.88)	22.88
9	Chlorantraniliprole 18.5 SC	100ml	11.00 (19.35)	15.03
10	Control	-	29.33 (32.77)	10.85
SEm+			0.591	0.874
CD @ 5%			1.76	2.61
CV%			5.66	7.46

*Figures in parenthesis are angular transformed value

Recommendation:

✓ For the management of termite in groundnut, seed treatment with Imidacloprid 600 FS @ 6.5 ml per kg seed is most effective.

AAU JORHAT

A. Evaluation of some bait materials against red ant, *Dorylus orientalis* in Potato during 2020-21

Field trial was conducted to determine the efficacy of 8 promising bait materials at a highly endemic red ant field of Charaibahi village, Jorhat, Assam in potato during 2020-21. Based on two years of experimentation, this technology has been recommended as OFT to be conducted at different *KVK*s of AAU (*KVK*: Bongaigoan, Karimganj, Nagaon and Golaghat) during the coming *rabi* season.

A. View of the experimental plots

B. Attraction of red ants to rice bran oil+boric acid

Fig. 63 (A-B). Evaluation of some bait materials against red ant, *Dorylus orientalis* in Potato

B. 1. Nutritional profiling of desert locust, *Schistocerca gregaria*

Nutritional composition of desert locust powder was assessed on the basis of proximate and elemental composition during 2020-21. The locust powders were received from Rajasthan Agricultural Research Institute, Durgapura, Jaipur, Rajasthan.

Under proximate analysis the per cent of moisture, carbohydrate, crude fat, crude fibre and ash content of the sample was analysed by following standard protocols and the results are presented in Table 88. Experimental results revealed that the moisture, carbohydrate, crude fat, crude fibre and ash content of the sample was found to be 12.33, 17.05, 44.08, 12.01 and 3.36 per cent, respectively. The other proximate parameters *viz*., crude protein and energy content is in progress.

Altogether, 7 elements were estimated by using Atomic Absorption Spectroscopy (AAS) and the results are presented in Table 89. The concentration of macro elements *viz*., Na, K, Ca and Mg were recorded to be 34.77, 49.93, 26.15 and 20.15 mg/100g, respectively whereas the micro elements *viz*., Fe, Zn and Cu were recorded to be 12.76, 12.18 and 4.85 mg/100g, respectively.

Table 88. Proximate composition of Desert locust

Insect species	Moisture	Carbohydrate	Crude fat	Crude fibre	Ash content
	(%) (Mean±SD)				
S. gregaria	12.33±0.21	17.05±0.11	44.08±2.13	12.01±0.15	3.36±0.30

Data are mean of three replications

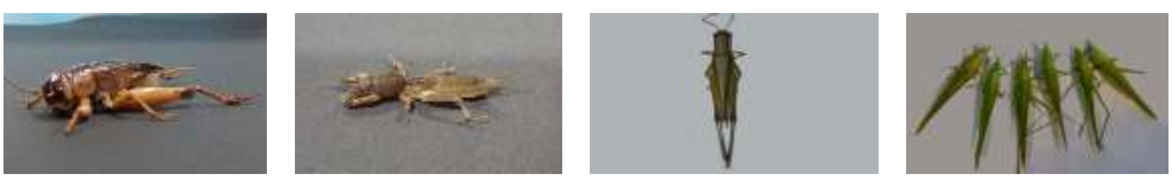
Table 89. Elemental composition of Desert Locust

Insect species	Na	Zn	K	Ca	Mg	Fe	Cu
	(mg/100g) (Mean±SD)						
S. gregaria	34.77±0.90	12.18±1.58	49.93±1.17	26.15±5.86	20.15±0.47	12.76±2.16	4.85±0.89

Data are mean of three replications

B. 2. Nutritional profiling of some edible orthopteran insects of Assam

The nutritive value of four edible orthopteran insect species *viz*., field cricket (*Brachytrupes portentosus*), mole cricket (*Gryllotalpa africana*), rice grasshopper (*Oxya* sp.) and cone headed grasshopper (*Ruspolia nitidula*) was assessed based on their proximate & elemental content, amino & fatty acid profiles and antioxidant & anti-nutritional properties (Fig. 64).



A. *Brachytrupes portentosus* B. *Gryllotalpa africana* C. *Oxya* sp. D. *Ruspolia nitidula*

Fig. 64 (A-D). Some orthopteran edible species of Assam

The data pertaining to the proximate analysis of all the four edible insect powders are presented in Table 20. Experimental results revealed that the moisture content ranged from 2.55-7.53 per cent. Perusal of data showed that the highest mean percentage of moisture content was recorded in *B. portentosus* (7.53%) whereas *R. nitidula* registered the least moisture content (2.55%). The carbohydrate content of the studied species varied widely and ranged from 5.13-24.21 per cent where the maximum (24.21%) was registered in *Oxya* sp. and the lowest (5.13%) was recorded in *B. portentosus*. Appreciable amount of crude protein content was estimated in all the studied species which ranged from 45.89-69.59 per cent. The highest (69.59%) crude protein was registered in *Oxya* sp. and it was found to be significantly superior over rest of the species. The protein content recorded in *G. africana*, *B. portentosus* and *R. nitidula* were 67.88, 53.09 and 45.89 per cent, respectively. Crude fat content registered in the studied species varied significantly and was ranged from 8.47-37.61 per cent. The highest (37.61%) crude fat content was recorded in *R. nitidula* followed by *B. portentosus* (25.34%) and *Oxya* sp. (10.77%) whereas *G. africana* recorded the lowest (8.47%) amount of crude fat content. The crude fibre content varied from 2.89-9.13 per cent and *Oxya* sp. registered significantly high amount of crude fibre (9.13%) content followed by *B. portentosus* (8.40%) and *G. africana* (7.55%). The highest (5.95%) ash content was recorded in *B. portentosus* which showed statistical parity with *G. africana* (5.68%) whereas the lowest (1.64%) was recorded in case of *R. nitidula.* While analyzing the energy content (kcal/100g) of all the four species, the maximum energy content (573.37) was estimated in *R. nitidula* followed by *Oxya* sp. (472.19) and *B. portentosus* (461.05) whereas, *G. africana* recorded the lowest energy content of 374.33 kcal/100g.

Table 90. Proximate composition of four edible orthopteran insect species

Insect species	Moisture (%)	Carbohydrate (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Ash content (%)	Energy content (kcal/100g)
B. portentosus	7.537±0.34	5.138±0.27	53.096±0.052	25.347±0.524	8.409±0.19	5.958±0.31	461.059±4.89
G. africana	5.583±0.32	6.623±0.19	67.884±0.552	8.478±0.133	7.553±0.14	5.686±0.30	374.330±2.21
Oxya sp.	4.509±0.29	24.219±0.24	69.591±0.134	10.773±0.130	9.138±0.18	1.836±0.05	472.197±0.99
R. nitidula	2.559±0.34	12.808±0.16	45.892±0.276	37.619±0.145	2.899±0.14	1.642±0.04	573.371±2.32
SEd(±)	**0.23**	**0.15**	**0.22**	**0.20**	**0.12**	**0.15**	**2.10**
CD (p=0.05)	**0.49**	**0.33**	**0.48**	**0.43**	**0.25**	**0.32**	**4.47**

Data are mean of four replications

All values are mean ± SE

Table 90. Elemental composition of four edible orthopteran insect species

Insect species	Na	K	Ca	Mg	Fe	Zn	Mn	Cu
	(mg/100g)							
B. portentosus	35.694±0.58	58.868±1.32	29.765±0.65	20.319±0.49	17.685 ± 0.19	15.295 ± 0.67	0.866 ± 0.05	3.348 ± 0.27
G. africana	36.648±0.46	52.330±1.32	26.393±0.63	20.626±0.34	53.280 ±0.61	15.423 ± 0.77	4.325 ± 0.08	3.220 ± 0.21
Oxya sp.	32.864±0.30	53.983±2.20	14.528±0.55	20.095±0.16	12.231 ± 0.64	12.950 ± 0.61	1.474 ± 0.09	3.160 ± 0.26
R. nitidula	29.549±0.13	49.573±1.44	8.188±0.32	17.105±0.04	21.075 ± 0.38	7.848 ± 0.11	6.579 ± 0.07	0.566 ± 0.05
SEd(±)	**0.29**	**1.14**	**0.39**	**0.22**	**0.35**	**0.42**	**0.05**	**0.15**
CD (p=0.05)	**0.61**	**2.43**	**0.83**	**0.47**	**0.74**	**0.90**	**0.11**	**0.33**

Data are mean of four replications

All values are mean ± SE

Altogether 8 minerals as elemental composition were estimated in all the studied species. The mineral analysis indicated that the concentration of macro elements *viz*., potassium and calcium were significantly higher (58.868 & 29.765, mg/100g, respectively) in *B. portentosus* except for sodium and magnesium (35.694 & 20.319 mg/100g) whereas the lowest amount (49.573, 8.188, 17.105 and 29.549 mg/100g, respectively) was recorded in *R. nitidula* (Table 89). Considerable amount of four micro elements were also recorded in all the studied species. The iron content estimated in the studied species ranged from 12.231-53.280 mg/100g where *G. africana* registered the highest iron content (53.280 mg/100g) which was significantly superior over rest of the species. Zinc content (mg/100g) was estimated to be the highest (15.423) in *G. africana* which showed statistical parity with *B. portentosus* (15.295) whereas significantly superior over *Oxya* sp. (12.950) and *R. nitidula* (7.848). Manganese and copper content of all the species were found comparatively in trace amounts which ranged from 0.866-6.579 mg/100g and 0.566-3.348 mg/100g, respectively (Table 90).

Perusal of data as regards to the amino acid composition of all the four edible species indicated the availability of 18 common amino acids, out of which 8 were essential (Table 91). Among all the amino acids quantified, glutamic acid was found to be the most abundant (7.87-5.14%) in all the four species. Alanine, leucine, aspartic acid and valine were the other amino acids available in appreciable amount with values ranging from 7.21-4.86, 5.11-3.89, 4.78-3.47 and 4.18-2.83 per cent, respectively. The percentage of savory amino acids (*i.e.* glutamate & aspartic acid) was estimated to be highest in *B. portentosus* (7.87 & 4.78%) followed by *Oxya* sp. (7.69 & 4.62%) and *G. africana* (7.28 & 3.85%), respectively. In case of sweet amino acids (*i.e.* alanine & glycine), the highest amount was recorded in *Oxya* sp. (7.70 & 3.93%) followed by *B. portentosus* (7.21 & 3.42%) and *G. africana* (5.90 & 3.26%), respectively. Relatively trace amount (0.69-1.14 and 0.10-0.25%) of total sulphur containing amino acids (methionine and cysteine) were quantified in all studied edible insects, respectively (Table 91).

The total fatty acid analysis of all the four species revealed that the highest (13.22, 25.31 and 2.47%) amount of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) were recorded in *R. nitidula* followed by *B. portentosus* (9.61% SFA, 10.56 % MUFA and 8.13 % PUFA) and *G. africana* (5.45 % SFA, 7.18 % MUFA and 4.82 % PUFA) (Table 92). Quantification of the fatty acid profile revealed that palmitic acid was the most predominant fatty acid in all the studied species and was recorded to be highest in *R. nitidula* (11.35%) followed by *B. portentosus* (7.14%) and *G. africana* (3.60%) whereas the least (1.55%) amount was recorded in *Oxya* sp. The findings also revealed the presence of one essential omega 6 fatty acid *i.e.* linoleic acid (1.65%) in *Oxya* sp. The rest of the fatty acids were recorded in relatively trace amounts in all the studied insect species (Table 92).

Table 91. Amino acid profiling of four edible orthopteran insect species

Amino acids	*B. portentosus*	*G. africana*	*Oxya* sp.	*R. nitidula*
	Per cent content			
Leucine (Leu)	5.11	4.77	5.54	3.89
Valine (Val)	4.18	3.80	4.50	2.83
Isoleucine (Ile)	2.62	2.77	2.99	2.16
Lysine (Lys)	3.35	2.97	3.53	2.41
Threonine (Thr)	1.94	2.16	2.42	1.65
Phenylalanine (Phe)	2.21	2.08	2.07	1.36
Methionine (Met)	0.69	1.14	0.95	0.80
Histidine (His)	1.15	1.12	1.29	0.91
Glutamic acid* (Glu)	7.87	7.28	7.69	5.14
Glycine (Gly)	3.42	3.26	3.93	2.48
Alanine (Ala)	7.21	5.90	7.70	4.86
Serine (Ser)	4.08	3.17	3.76	2.48
Aspartic acid** (Asp)	4.78	3.85	4.62	3.47
Proline (Pro)	3.97	3.45	4.24	2.56
Tyrosine (Tyr)	3.21	2.93	3.27	1.94
Arginine (Arg)	3.35	3.10	3.56	2.36
Cysteine (Cys)	0.25	0.15	0.13	0.10

Average of 2 samples
*Includes both glutamic acid and glutamine
**Includes both aspartic acid and asparagine

Table 92. Fatty acid profiling of four edible orthopteran insect species

Fatty acid profile	***B. portentosus***	***G. africana***	***Oxya* sp.**	***R. nitidula***
	Per cent content			
Saturated Fatty Acid (SFA)	9.61	5.45	2.48	13.22
Monounsaturated Fatty Acid (MUFA)	10.56	7.18	1.56	25.31
Polyunsaturated Fatty Acid (PUFA)	8.13	4.82	3.05	2.47
Lauric acid	-	0.17	-	-
Myristic acid	0.32	0.54	-	-
Myristoleic acid	0.10	0.10	-	-
Tridecanoic acid	-	0.10	-	-
Pentadecanoic acid	0.15	0.11	-	-
Palmitic acid	7.14	3.60	1.55	11.35
Palmitoleic acid	0.38	0.98	-	1.67
Heptadecanoic acid	0.15	0.12	-	-
Cis 10 Hepta decanoic acid	0.17	0.17	-	-
Stearic acid	2.07	1.03	0.93	1.88
Linoleic acid	-	-	1.65	-
Oleic acid	-	-	1.56	23.64
11,14 Eicosadienoic acid	-	-	1.40	2.98
Unidentified			2.1	3.24

Average of 2 samples

As antioxidants, phenol and flavonoid contents of all the studied edible insect species was estimated and the data found to be varied from 1.062-4.467 mg catechol equivalent/g and 2.412-4.470 mg quercetin equivalent/g, respectively (Table 93). *Oxya* sp. registered the highest (4.467 mg catechol equivalent/g) phenol content and was found to be significantly superior over rest of the species. The highest flavonoid content (4.470 mg quercetin equivalent/g) was also registered in *Oxya* sp. followed by *B. portentosus* (3.071 mg quercetin equivalent/g) and *G. africana* (2.799 mg quercetin equivalent/g). Tannin, phytic acid and oxalic acid contents were also estimated as antinutritional factors and were recorded within the permissible limit (250-500 mg/100g). The concentration of phytic acid and tannin were ranged from 26.620-122.427 mg/100g and 97.823-210.500 mg tannic acid equivalent/100g, respectively. The oxalic acid recorded in case of *B. portentosus*, *G. africana*, *Oxya* sp. and *R. nitidula* were 3.542, 2.910, 3.530 and 3.795 mg/100g, respectively (Table 94).

Table 93. Anti-oxidant properties of four edible orthopteran insect species

Insect species	**Phenol** (mg catechol equivalent/g)	**Flavonoid** (mg quercetin equivalent/g)
B. portentosus	1.062± 0.031	3.071± 0.121
G. africana	1.332± 0.085	2.799± 0.094
Oxya sp.	4.467± 0.089	4.470± 0.102
R. nitidula	1.561± 0.078	2.412± 0.016
SEd (±)	**0.05**	**0.07**
CD (p=0.05)	**0.11**	**0.14**

Data are mean of four replications

All values are mean ± SE

Table 94. Tannin, phytic acid and oxalic acid contents as antinutritional compounds recorded in four edible orthopteran insect species

Insect species	**Tannin (mg tannic acid equivalent/100g)**	**Phytic acid (mg/100g)**	**Oxalic acid (mg/100g)**
B. portentosus	109.560±0.36	108.169±0.34	3.542±0.29
G. africana	210.500±0.28	122.427±0.36	2.910±0.31
Oxya sp.	97.823±0.43	26.620±0.46	3.530±0.37
R. nitidula	102.523±0.38	113.394±0.40	3.795±0.31
SEd (±)	**0.26**	**0.28**	**0.23**
CD (p=0.05)	**0.55**	**0.59**	**0.49**

Data are mean of four replications

All values are Mean ± SE

C. Evaluation of insecticidal materials against some major soil insect pests of potato

An effort has been made to develop few insecticidal mixtures consist of different organic materials having pesticidal properties and tested their effectiveness against few major soil insect pests *viz*., cutworm (*Agrotis ipsilon*), white grub (*Lepidiota mansueta*) and red ant (*Dorylus orientalis*). Initially, 14 numbers of locally and naturally available eco-friendly insecticidal materials were collected and grouped into four different groups based on their different properties *viz*., Group I-Physical poisons (Fine sand, ash and saw dust), Group II-Biopesticides and bio-enhancer (cow dung, cow urine and mustard oil cake), Group III-Botanicals (leaf powders of neem, jatropha and tobacco, pongamia seed powder and king chilli powder) and Group IV-Minerals (lime, charcoal powder and rock phosphate). Individual screening of the 14 insecticidal materials were done against the aforementioned pests in laboratory conditions and among all, only 11 individual insecticidal materials were selected based on their efficacy for further study. Altogether, 15 numbers of insecticidal mixtures were prepared from the selected 11 insecticidal materials through trial and error method, out of which 5 numbers of mixtures (Mixture II: mustard oil cake + cow urine + wood ash + neem leaf powder + saw dust; Mixture IV: mustard oil cake + cow urine + wood ash + tobacco leaf powder + fine sand; Mixture VIII: mustard oil cake + cow urine + wood ash + jatropha leaf powder + saw dust; Mixture XI: mustard oil cake + cow urine + wood ash + pongamia seed powder + saw dust and Mixture XIII: mustard oil cake + cow urine + wood ash + king chili powder + fine sand) were recorded to be superior over the other mixtures in causing mortality of *A. ipsilon* larvae, *L. mansueta* grubs and *D. orientalis* in laboratory conditions.

Based on superiority, the aforementioned 5 mixtures along with two insecticidal checks (chlorpyriphos 20 EC and malathion 5% dust) were considered to investigate their possible effects on soil physico-chemical properties under laboratory conditions and the results are presented in Table 95 and Fig. 65. Highest available N (260.9 kg ha^{-1}) was recorded in soil treated with mixture XI (T_4) which was significantly superior over other mixtures. Maximum available P (33.16 kg ha^{-1}) was estimated in soil treated with mixture II (T_1) and found *at par* with all other mixtures except for mixture IV (T_2). Soil amended with mixtures IV and XI registered significantly highest available K (214.39 kg ha^{-1}) and CEC [5.58 cmol (p+) kg^{-1}], respectively as compared to the other mixtures tested. However, the pH content was varied from 5.10 to 5.12 in the soil treated with the 5 individual mixtures and found nonsignificant. Mixture XI registered the highest organic carbon content (0.69%) followed by mixture II (0.67%) and mixture VIII (0.67%) at 90 DAT, respectively. Minimum bulk density (1.32 Mg cm^{-3}) was recorded in soil treated with mixture XI which showed statistical parity with other mixtures. The Soil Microbial Biomass Carbon content was found maximum (124.9 µg g^{-1}) in soil treated with mixture XI and was found statistically *at par* with mixtures II, IV and VIII, but significantly higher than mixture XIII. No change in the soil textural class was registered during the course of study.

Activity of five key soil enzymes *viz.*, Phosphomonoesterase (PMEase), Fluorescein di-acetate hydrolysis (FDA), Dehydrogenase, Urease and β-glucosidase of the treated soils with the individual mixtures as well as insecticidal checks were assessed by raising French bean as the test crop. Perusal of data presented in Table 96 revealed that the highest PMEase activity (196.39 µg *p*-nitrophenol g^{-1} soil h^{-1}) was observed in the soil treated with mixture II (T_1) which showed statistical parity with mixture XI (T_4) (189.54 µg *p*-nitrophenol g^{-1} soil h^{-1}) but significantly superior over rest of the mixtures. FDA activity was significantly recorded to be the highest (6.51 µg fluorescein g^{-1} soil h^{-1}) in the soil treated with mixture XI (T_4) over other mixtures except mixture II (T_1) which was found nonsignificant. Enzyme activities in respect of dehydrogenase (94.20 µg TTF g^{-1} soil 24 h^{-1}), urease (119.17 µg NH_4^+N g^{-1} soil 2 h^{-1}) and β-glucosidase (125.50 µg p-nitrophenol g^{-1} dry soil 2 h^{-1}) were also recorded as the highest in the soil mixed with mixture XI (mustard oil cake + cow urine + wood ash + pongamia seed powder + saw dust) and was significantly superior over rest of the mixtures. As regards to per cent increase in enzymatic activities, the insecticidal mixture XI recorded 124.98, 125.43, 169.55, 200.02 and 155.49 per cent of PMEase, FDA, dehydrogenase, urease and β-glucosidase activities, respectively as compared to their initial enzymatic activity status. A declining trend of enzyme activities was observed in the soils treated with chlorpyriphos 20 EC and malathion 5 per cent dust as compared to the untreated control.

Based on the results obtained by studying the effect of insecticidal mixtures on soil physico-chemical properties and key soil enzyme activities, mixture XI @ 250 kg/ha was considered for field evaluation along with two insecticidal checks against the targeted 3 major soil insect pests of potato. Experimental results indicated that all the treatments were significantly superior in suppressing infestaion inflicted by various soil insect pests as compared to the untreated control (Table 97 and Fig. 65). Mixture XI recorded tuber damage

(9.86 and 10.43% on weight and number basis, respectively) which was statistically *at par* with malathion 5 per cent dust @ 40 kg/ha (9.11 and 9.27% tuber damage on weight and number basis, respectively) but significantly higher than chlorpyriphos 20 EC @ 300 g *a.i.*/ha (6.06 and 6.40% tuber damage, respectively). As regards to tuber yield, mixture XI resistered 168.29 q/ha which was found to be *at par* with malathion 5 per cent dust (169.77 q/ ha) and chlorpyriphos 20 EC (178.63 q/ ha) treated plots. The untreated control plot registered 21.52 and 22.10 per cent of tuber damage both in weight and number basis, respectively and recorded tuber yield of 129.16 q/ha (Table 97).

The Scanning Electron Microscopy of the Mixture-XI was also carried out which showed clear heterogeneous nature of the particles present in the mixture under different magnifications (Fig. 66). Energy Dispersive X-ray (EDX) analysis also revealed the presence of 2 numbers of macro elements and 7 numbers of microelements in the mixture sample (Fig. 67). Twelve numbers of volatile compounds were also detected through GC-MS analysis which reveals the possible role in insect pests (Table 98). Furthermore, few detected volatile compounds *viz*., Oleic acid, Succinic acid, 3,7-dimethyloct-6-en-1-yl hexadecyl ester and 1-fluoro-dodecane were already reported in different plant disease management strategies as well as in host plants resistance. The proposed name for the aforementioned product is "*Joiba Shakti*" and this product will be tested under 4 *KVK*s of AAU as On Farm Testing.

A. Raw materials of the best insecticidal mixture (Mixture XI)

B. Physical appearance of Mixture XI after mixing

C. Experiment on the impact of different insecticidal mixtures on the physico-chemical properties of soil

D. Impact of different insecticidal mixtures on the key soil enzyme activities

E. Application of "Mixture XI" in seed furrows

F. Experimental plot

Fig. 65 (A-F). Glimpses of developing and testing of the best insecticidal mixture

Table 95. Evaluation of insecticidal mixtures and two insecticides based on their effects on soil physico-chemical properties at 90 days after treatment

Treatments	Soil physico-chemical properties								
	Soil texture	**BD (Mg cm^{-3})**	**OC (%)**	**pH**	**Av. N (kg ha^{-1})**	**Av. P_2O_5 (kg ha^{-1})**	**Av. K_2O (kg ha^{-1})**	**CEC [cmol (p+) kg^{-1}]**	**SMBC (µg g^{-1})**
T_1: Mixture II	Clay loam	1.33	0.67	5.12	248.4	33.16	196.55	5.50	118.6
T_2: Mixture IV		1.34	0.65	5.12	244.6	28.29	214.39	5.36	114.6
T_3: Mixture VIII		1.35	0.67	5.11	232.1	30.32	180.77	5.33	111.6
T_4: Mixture XI		1.32	0.69	5.12	260.9	31.65	200.02	5.58	124.9
T_5: Mixture XIII		1.36	0.65	5.10	219.5	29.57	172.44	5.26	106.2
T_6: Chlorpyriphos 20 EC		1.40	0.53	5.08	170.6	25.93	152.12	5.17	64.5
T_7: Malathion dust 5%		1.41	0.53	5.07	169.3	25.75	151.91	5.15	62.9
T_8: Soil (Untreated Control)		1.40	0.54	5.08	171.7	26.19	152.80	5.18	66.4
T_9: Soil (Before application of any materials)		1.39	0.58	5.11	213.2	26.67	149.34	5.21	95.7
S.Ed±		**0.03**	**0.03**	**0.01**	**4.8**	**1.81**	**3.42**	**0.03**	**6.6**
CD (5%)		**0.06**	**0.05**	**0.02**	**10.2**	**3.87**	**7.32**	**0.07**	**14.1**

Mixture II: mustard oil cake + cow urine + wood ash + neem leaf powder + saw dust
Mixture IV: mustard oil cake + cow urine + wood ash + tobacco leaf powder + fine sand
Mixture VIII: mustard oil cake + cow urine + wood ash + jatropha leaf powder + saw dust
Mixture XI: mustard oil cake + cow urine + wood ash + pongamia seed powder + saw dust
Mixture XIII: mustard oil cake + cow urine + wood ash + king Chili powder + fine sand

Table 96. Effect of five insecticidal mixtures and two insecticides on soil enzyme activities after 30 days of seed sowing (Test crop: French bean) under laboratory conditions

Treatments	**Soil enzyme activity**				
	PMEase (µg *p*-nitrophenol g^{-1} soil h^{-1})	**FDA (µg fluorescein g^{-1} soil h^{-1})**	**Dehydrogenase (µg TTF g^{-1} soil 24 h^{-1})**	**Urease (µg NH^{+}_4 g soil^{-1} 2h^{-1})**	**β-glucosidase (µg p-nitrophenol g^{-1} dry soil 2h^{-1})**
T_1: Mixture II	196.39 (129.49)	6.13 (118.11)	82.58 (148.63)	107.71 (180.78)	119.12 (147.59)
T_2: Mixture IV	175.11 (115.46)	5.96 (114.84)	79.91 (143.83)	91.67 (153.86)	115.42 (143.01)
T_3: Mixture VIII	183.87 (121.24)	5.89 (113.49)	73.83 (132.88)	80.21 (134.63)	108.32 (134.21)
T_4: Mixture XI	189.54 (124.98)	6.51 (125.43)	94.20 (169.55)	119.17 (200.02)	125.50 (155.49)
T_5: Mixture XIII	171.43 (113.04)	5.83 (112.33)	72.23 (130.00)	73.33 (123.08)	104.78 (129.82)
T_6: Chlorpyriphos 20 EC	146.82 (96.81)	5.14 (99.03)	51.14 (92.04)	55.00 (92.31)	76.20 (94.41)
T_7: Malathion 5% dust	143.22 (94.43)	5.10 (98.27)	47.89 (86.20)	50.42 (84.63)	73.60 (91.19)
T_8: Soil (Untreated Control)	161.03 (106.18)	5.25 (101.16)	58.92 (106.05)	64.18 (107.72)	84.16 (104.27)
T_9: Soil (Initial)	151.66	5.19	55.56	59.58	80.71
S.Ed±	**4.73**	**0.20**	**4.76**	**4.44**	**2.29**
CD (5%)	**10.12**	**0.42**	**10.18**	**9.49**	**4.89**

Figures in the parentheses are per cent increase over initial enzyme activity

Mixture II: mustard oil cake + cow urine + wood ash + neem leaf powder + saw dust

Mixture IV: mustard oil cake + cow urine + wood ash + tobacco leaf powder + fine sand

Mixture VIII: mustard oil cake + cow urine + wood ash + jatropha leaf powder + saw dust

Mixture XI: mustard oil cake + cow urine + wood ash + pongamia seed powder + saw dust

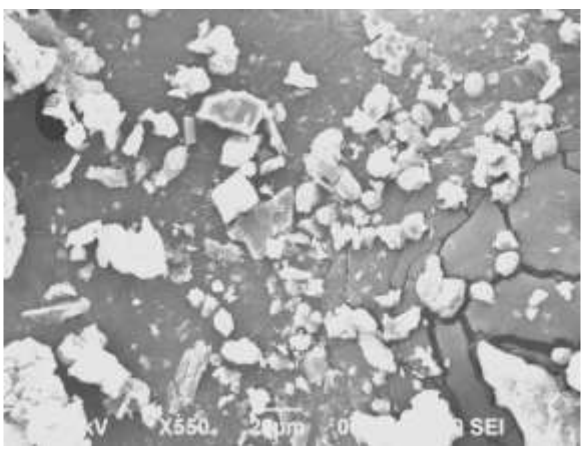
Mixture XIII: mustard oil cake + cow urine + wood ash + king Chili powder + fine sand

Table 97. Effect of different treatments in suppressing various soil insect pests in potato

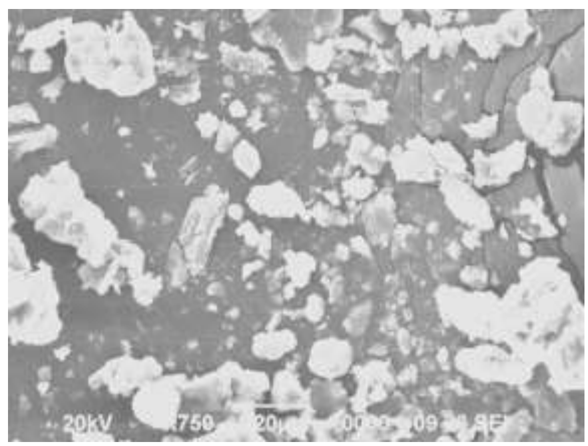
Treatments	Tuber damage (%)		Tuber Yield (q/ha)	BCR
	Weight basis	Number basis		
T_1: Mixture XI (@ 250 kg/ha)	9.86 (18.13)	10.43 (18.75)	168.29	3.26
T_2: Malathion 5% dust (@ 40 kg/ha)	9.11 (17.11)	9.27 (17.42)	169.77	3.05
T_3: Chlorpyriphos 20EC (@ 300 g *a.i*/ha)	6.06 (14.25)	6.40 (14.56)	178.63	3.49
T_4: Untreated control	21.52 (27.32)	22.10 (27.99)	129.16	
S.Ed±	**1.36**	**0.96**	**5.87**	
CD (5%)	**2.96**	**2.09**	**12.78**	

Figures in parentheses are angular transformed values

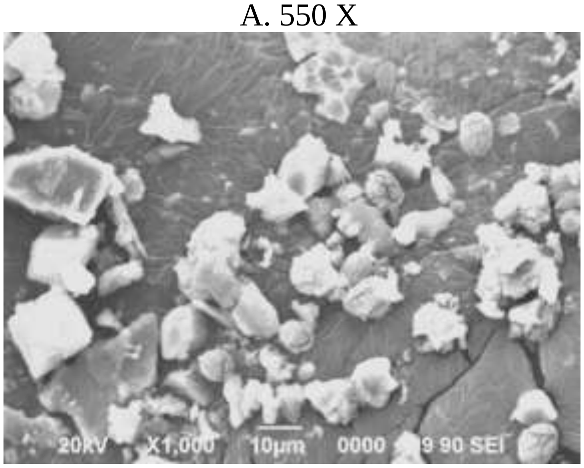
Mixture XI (mustard oil cake + cow urine + wood ash + pongamia seed powder + saw dust)



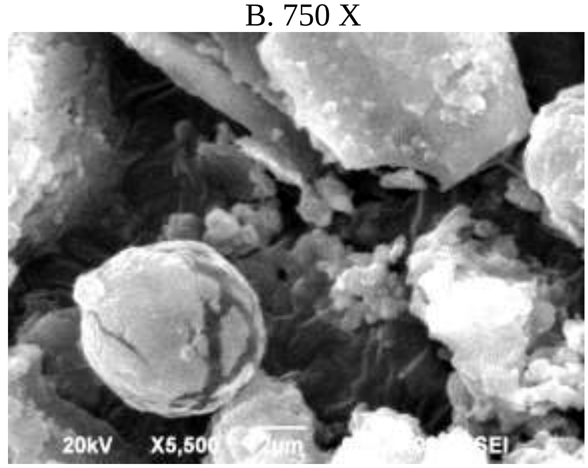
A. 550 X



B. 750 X

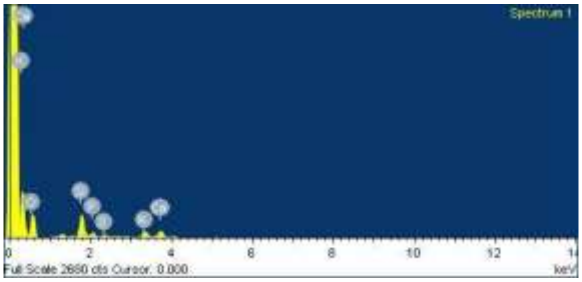


C. 1000 X

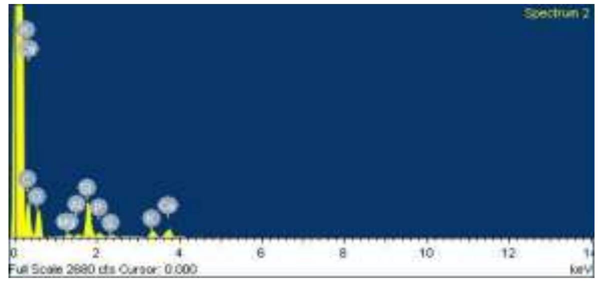


D. 5500 X

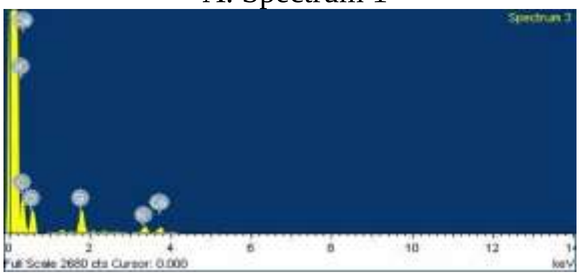
Fig. 66 (A-D). SEM micrographs of the best insecticidal mixture at different magnifications



A. Spectrum 1



B. Spectrum 2



C. Spectrum 3

Spectrum 1	C, Ca, K, O, Si, P, S, K, Ca
Spectrum 2	K, Ca, C, O, Mg, Al, Si, P, S, K, Ca
Spectrum 3	K, Ca, C, O, Si, K, Ca

D. Detected elements

Fig. 67 (A-D). Some macro and micro elements present in mixture XI as detected through Scanning Electron Microscopy and Energy Dispersive X-Ray Analysis

Table 98. GC-MS analysis of major volatile compounds present in the extract of mixture XI

Peak	RT* (min)	Compound identified	Molecular formula	MW** (g mol^{-1})	Source
1	15.061	Dodecamethyl-cyclohexasiloxane	$C_{12}H_{36}O_6Si_6$	444	Wood ash
2	16.762	Oleic acid	$C_{18}H_{34}O_2$	282	Pongamia seed/ mustard oil cake
3	18.127	Tetradecamethyl-cycloheptasiloxane	$C_{14}H_{42}O_7Si_7$	518	Wood ash
4	21.089	1-chloro-dodecane	$C_{12}H_{25}Cl$	204	Pongamia seed/ cow urine/ saw dust
5	22.494	Chloro-acetic acid hexadecyl ester	$C_{18}H_{35}ClO_2$	318	Cow urine/ mustard oil cake/ saw dust/ wood ash
6	22.689	1-hexadecanol	$C_{16}H_{34}O$	242	Cow urine
7	23.840	Octadecamethyl cyclononasiloxane	$C_{18}H_{54}O_9Si_9$	666	Wood ash
8	24.580	N-decanoic acid	$C_{10}H_{20}O_2$	172	Mustard oil cake
9	24.885	1-chloro-octadecane	$C_{18}H_{37}Cl$	288	Mustard oil cake
10	28.472	Salicylic acid	$C_7H_6O_3$	222	Saw dust
11	30.182	Succinic acid, 3,7-dimethyloct-6-en-1-yl hexadecyl ester	$C_{30}H_{56}O_4$	480	Mustard oil cake/ cow urine
12	31.598	1-fluoro-dodecane	$C_{12}H_{25}F$	188	Pongamia seed/ cow urine

GKVK Bangaluru

A. Studies on biogeography of major white grubs in Karnataka

The studies on the biogeography of *H. serrata* and *Leucopholis* spp. in Karnataka have been completed. A study on the biogeography of Sophrops sp. and Anomala sp. of southern India has been initiated.

B. Evaluation of bio-agents against white grubs

1. Evaluation of *Beauveria brongniartii* Isolate maintained at Bengaluru centre against sugarcane and arecanut white grubs.

Mass production of the fungus is in progress on both both adult and grubs of *H. serrata* in the laboratory. Samples of the fungus have been sent to other centres for testing against local white grub species.

2. Evaluation of NBAIR, Bengaluru isolates of *Beauveria bassiana* and *Metarhizium anisopliae* against sugarcane and arecanut white grubs and termites in sugarcane.

3. Evaluation of EPNs developed by the FARMER, Ghaziabad.

This study will be implemented during July-August, 2021 against sugarcane and arecanut white grubs.

C. Demonstration and popularization of insecticide free management practices for arecanut white grubs such as digging and removal of grown-up larvae.

Approximately 2400 larvae and 17 yet-to-emerge adult beetles were removed from a field infested by *Leucopholis lepidophora* in Araga village, Thirthahally taluk. In a field from Mantrady (Dakshina Kannada district) affected by *L. coneophora* ~3000 larvae were collected from 8 ac of garden. As many as 107 larvae were removed from Shuntikatte, Thirthahally taluk infested by *L. burmeisteri* from an area of 2 ac.

A total of 63 third instar grubs of *L. Lepidophora* were collected in Madalu villagae, Thirthahalli. Mr. Prasad Shetti of Iruvail village, Dakshina Kannada removed ~400 grown up larvae of *L. coneophora* from 2 ac during November, 2020. Mr. Clement DSouza of Naravi village collected 1200 larvae. Similar kind operation has been continued in four gardens in malnad (data not available).

The above gardens were relied on insecticides for controlling white grubs. After understanding the advantages of chemical free approach and disadvantages of chemical method of controlling white grubs in ecologically fragile environments the farmers have wisely selected this economical and eco-friendly method.

D. Creating digital repository of Indian Scarabaeidae using specimens available at Bengaluru centre.

The scarab specimens maintained in Bengaluru centre were sorted and catalouged. In the first phase-initiated digitization of species of the genus *Holotrichia* Hope available in the repository. The work is in progress.

CSKHPKV-PALAMPUR

A. Evaluation of natural products against beetles of *Maladera insanabilis*

Three natural products viz; Agniastra, Brahmastra and Neemastra were tested under laboratory conditions against field collected adults of *M. insanabilis* by leaf dip method at concentration ranging from 1.25-20 percent. No mortality was recorded with either of the products at tested concentrations. However, all these products reduced feeding in a dose dependent manner, therefore the FD_{50} (Feeding deterrence) values for these products were determined by calculating the reduction in feeding at different concentrations in comparison to control. Perusal of the data presented in the **table 99** revealed that after 48 hours of treatment, 20 per cent concentration induced 82.6 per cent reduction in food consumption over control compared to 62.4, 40.9, 29.8 and 20.6 per cent in reduction in feeding at 10, 5, 2.5 and 1.25 per cent, respectively. The FD50 value was calculated to be 5.62 per cent with 95 per cent fiducial limits ranging from 3.94 -8.32 per cent, and the FD90 value was computed to be 43.71 per cent with fiducial limits ranging from 24.28-63.14 per cent. Regression line gave best fit with slope (b) of 1.41 as shown in fig4.30. The calculated value of $\chi 2$ was 1.14 indicating homogeneity of data.

Brahmastra: Brahmastra at 20 per cent reduced food consumption by 72.7 per cent over control after 48hours of treatment. At concentrations of 10.0, 5.0, 2.5 and 1.25, the reduction in food consumption over control was 57.3, 29.2, 24.9 and 12.7 per cent, respectively. The FD50 value was computed to be 7.71 per cent and its fiducial limits were calculated to be 5.58 and 11.77 per cent, whereas the FD90 values were determined to be 51.12 per cent with 95 per cent fiducial limits lying in the range of 33.04-79.11 per cent. The regression line gave best fit and the value of the slope (b) was determined to be 1.63. The calculated value of $\chi 2$= 1.56 clearly indicates homogenous nature of data.

Neemastra: Results showed that after 48 hours of treatment 20 per cent concentration of Neemastra induced 68.1 reductions in feeding over control. The reduction in feeding at concentration ranging from 1.25-10 per cent was recorded to be 1.9-51.8 per cent as shown in table4.32. The FD50and FD90 values were calculated to be 11.01-46.02 per cent, with 95 per cent fiducial limits of FD50 ranging from 8.36-16.03 per cent. The 95 per cent fiducial limits of ID90values were recorded in the range of 32.81 and 64.56 per cent. The slope (b) of regression line was determined to be 2.06 and it demonstrated a best fit. The $\chi 2$ value was calculated to be 0.85 indicating homogeneity of the data at $p = 0.05$. On the basis of FD50 values, Agniastra was highly effective, being statistically at par with Brahmastra, but differed significantly from Neemastra on the basis of 95 per cent fiducial limits. The 95 per cent fiducial limits of Agniastra and Brahmastra showed an overlap, but 95 per cent fiducial limits of Agniastra and Neemastra did not show any overlap, therefore clearly indicating higher efficacy of Agniastra over Neemastra. The 95 per cent fiducial limits of Brahmastra and Neemastra are overlapping with each other suggesting statistically non-significant differences in their efficacy against beetles of *M. insanabilis*.

Table 99. Concentration-feeding deterrence response of *M. insanabilis* beetles to different organic products

Organic products	No. of insects treated	Observed feeding deterrence over control after 48 hours (%)	FD_{50}	Fiducial limits (%)	$\chi 2$cal
Agniastra	30	20.6-82.6	5.62	3.94 and 8.32	1.14
Brahmastra	30	12.7-72.7	7.71	5.58 and 11.77	1.63
Neemastra	30	1.9-68.1	11.01	8.36 and 16.03	0.85

B. Biology and morphometrics of *M. virescens* [*Polyphylla fullo* (Linnaeus)]

Eggs: The emergence of *M. virescens* (= *P. fullo*) from soil started in second week of July, peak activity occurred during August, and then perished in first week of September. Mating was observed at dusk under laboratory conditions and it lasted for 16-20 minutes. The beetles were also observed on host plants during day time both under field and laboratory conditions. The eggs were deposited at a depth of 10-12 cm. The eggs were pearly white and when freshly laid were elongated in shape (Plate 3). The field-collected beetles observed a pre-oviposition period of 7-9 days under laboratory conditions in captivity. Oviposition occurred in soil during third to fourth week of July. The period of oviposition was brief varying from 2-3 days. A single female laid 13-21 eggs during her life time under laboratory conditions. Newly laid eggs measured from 3.62-4.21 mm in length, and 2.57-3.09 mm in width. As the development progressed, they enlarged and assumed nearly spherical shape, as do the eggs of other scarab species. Prior to hatching, the length of eggs was recorded to be 4.73-4.98 mm with an average of 4.86 ± 0.03 mm (**Table 15**). Duration of egg stage ranged from 16-18 days with an average of 17.2 ± 0.35 days **(Table 14**). Under laboratory conditions, the eggs hatched during second week of August.

Larva:

First instar: The newly hatched grubs were creamy-white in colour (Plate 3). The width of head capsule ranged from 2.60-2.84 mm. The fully fed first instar grubs of *M. virescens* (= *P. fullo*) measured 10.16-13.97 mm in body length (**Table 15**). The duration of first instar averaged 47.9 ± 0.57 days with a range of 46-51 days. The young grubs after 1-2 days, started gnawing roots of rajmash/oats, and became more active within 4-5 days. The fully fed first instar larvae stopped feeding and started downward movement before 10-15 days of moulting. Under field conditions, the larvae were found only in sandy soil with permeable subsoil. The upper 6-8 inches generally hosts only mature larvae with younger stages occurring at greater depths feeding on the finer roots. The duration of first instar larvae averaged 47.9 ± 0.57 days with a range of 46-51 days **(Table 14).** In laboratory, the first instar moulted into second instar during the month of October.

Second instar: The first instar grubs moulted to second instar in the month of October. On moulting, the head was whitish, and it soon turned brown (Plate 3). The average width of head capsule was recorded to be 4.68 ± 0.17 mm (range: 4.33-5.13 mm). The body length of fully grown second instar grubs ranged from 23.65-27.70 mm with an average of 25.89 ± 0.71 mm. The growth ratio (GR) for head capsule width was calculated to be 1.72 for second instar as compared with first instar. The second instar grubs inflicted large holes in potato tubers rendring them unfit for marketing. Second instar grubs constructed earthen cells during second week of May, and moulted inside these cells. After the hibernation, they return to the root zone and feed throughout the following summer. These behavioural differences are attributed to the fact that *P. fullo* has triennial life cycle in Turkey. However, in *P. decemlineata*, the grubs complete their second instar in the following growing season as observed in the present study. The duration of the second instar varied from 214-229 days (mean: 221.7 ± 1.71 days) as shown in.

Third instar: The grubs in third instar were robust and slightly yellowish to creamish-white in colour (Plate 3). The length of third instar grubs of *M. virescens (= P. fullo)* ranged from 48.33-54.17 mm with an average of 50.17 ± 1.03 mm. The width of head capsule in third instar varied from 7.92-8.48 mm with an average of 8.19 ± 0.11 mm. The ratio (GR) for head capsule width of *P. fullo* was calculated to be 1.75 for third instar as compared with the second instar. The overall growth ratio (GR) has been worked out to be 1.74 for *P. fullo.* The majority of the damage is done by second and third instar during second year of their development. Third instar grubs produced large irregular cavities into the potato tubers and the infested tubers were rendered totally useless. Duration of third instar averaged 314.1 ± 1.19 days, ranging from 309-320 days. Fully fed third instar grubs stopped feeding, constructed hard earthen cells and remained inactive inside these cells till adult emergence in next summer. In the present study, the first earthen cell was formed as early as second week of December during 2018. Grubs moved deeper into the soil in December and have been found as deep as 30 inches under field conditions. A few mature grubs may be found at such depths at any time of the year. The third instar grubs were found near the surface from February until pupation in May. In the present study, the larval stage was recorded to occur from August, 2017 to March, 2019. The total larval period ranged from 574-594 days with an average of 583.7 ± 2.10 days **(Table 100 & 101).** In Raster, the palidia is short and each palidium consisted of 15 pali. The pali pointing inward with septula indistinct. The V shaped anal slit, more or less flat in the centre, tapers gradually on both sides and becomes almost flat for a considerable length on both sides. Anal cleft is absent. The lower anal lobe is broadly oval in shape (**Plate 3**).

Pre-pupa: The fully fed third instar grubs stopped feeding, formed earthen cells and contracted in size (Plate 3). It was termed as pre-pupa. The body length of pre-pupa ranged from 33.33-38.32 mm (mean = 35.99 ± 0.59 mm). Duration of this stage was short, and this stage lasted for 15-23 days with an average of 19.3 ± 0.83 days.

Pupa: Pupa was without any cocoon inside the earthen cells formed by third instar grubs. The last larval skin was shed off before the formation of pupae which was found at its posterior end. Sexual diamorphism was evident in pupal stage and newly formed pupae of both sexes were light yellow and gradually became yellowish brown (Plate 3). The average body length x width of male pupae has been recorded to be 30.92-34.10 mm x 14.20-14.27 mm with an average of 32.72 ± 0.41 mm x 14.23 ± 0.01 mm. The female pupa was larger than male pupa. The length x width of female pupa ranged from 33.67-34.10 mm x 14.21-14.27. In the present study, the earliest record of pupation under laboratory conditions was on 22.04.2019. Pupal duration was estimated as 14-22 days (mean = 18.6 ± 0.82 days). Most pupal cells formed were about four inches deep, and oblong in shape.

Total life cycle: The total life cycle from egg to adult stage was determined to be of 619-652 days with an average of 638.8 ± 3.48 days.

Adult: The adult emergence usually began during second week of May, 2019. The new adult does not necessarily fly at once, but often remained in the soil until a favourable evening, with flight probably dependant on temperature. The adults are elongate, dark brown beetles, clothed very densely and evenly with pale scales (Plate 3). The female beetles measured 22.80-26.15 mm (mean = 24.69 ± 0.38 mm) in length and 11.92-13.24 mm (mean = 12.77 ± 0.16 mm) in width (Table 4.27). However, in males, the body length averaged 23.35 ± 0.46 mm (range = 21.59-25.75 mm), and the mean body width was recorded to be 10.89 ± 0.18 mm (range = 10.22-11.89 mm**)**. In male genitaila, phallobase is shorter than parameres. The attachment of phalloabse to parameres showed concavity towards the base of phallobase Parameres asymmetrical, and the left paramere appears boarder than right paramere.

Adult longevity: The pre-oviposition period of *P. fullo* females ranged from 7-9 days with an average of 8.1 ± 0.28 days. The oviposition period was very short and it was observed to range from 2-3 days (mean: 2.3±0.15 days). The mean fecundity was recorded to be 21 eggs per female. The post-oviposition period was comparatively longer and it averaged 11.1 ± 0.41 days with a range of 10-14 days. The female beetles survived for a longer period than male beetles. The overall longevity of females of *P. fullo* has been recorded to vary from 18-16 days (mean: 21.5 ± 1.0 days), and there was reduction in longevity of male beetles, the maximum and minimum being 11 and 19 days (mean: 15.1 ± 0.90) as shown in **table 100**.

Table 100 Duration of different stages of *M. virescens* (= *P. fullo*)

Stage	**Duration in days**	
	Range	**Mean ± SE**
Egg	16-18	17.2±0.35
Larvae I	46-51	47.9±0.57
II	214-229	221.7±1.71
III	309-320	314.1±1.19
Total larval period	574-594	583.7±2.10
Pre-pupal period	15-23	19.3±0.83
Pupa	14-22	18.6±0.82
Total duration	619-652	638.8±3.48
Adult longevity		
Male	11-19	15.1±0.90
Female	18-26	21.5±1.0
Pre-oviposition period	7-9	8.1±0.28
Oviposition period	2-3	2.3±0.15
Post-oviposition period	10-14	11.1±0.41

Table 101 Morphometrics of different stages of *M. virescens* (= *P. fullo*)

Stage	**Length (mm)**		**Width (mm)**	
	Range	**Mean ± SE**	**Range**	**Mean ± SE**
Egg Freshly laid	3.62-4.21	3.88±0.07	2.57-3.09	2.81±0.06
Prior to hatch	4.73-4.98	4.86±0.03	3.10-3.38	3.23±0.03
Larvae I	10.16-13.97	12.08±0.78	2.60-2.84	2.72±0.05
II	23.65-27.70	25.89±0.71	4.33-5.13	4.68±0.17
III	48.33-54.17	50.17±1.03	7.92-8.48	8.19±0.11
Pre-pupa	33.33-38.32	35.99±0.59	-	-
Pupa	30.92-34.10	32.72±0.41	14.20-14.27	14.23±0.01
Adult	21.59-25.75	23.35±0.46	10.22-11.89	10.89±0.18
Female	22.80-26.15	24.69±0.38	11.92-13.24	12.77±0.16

a

b

c

d

e

Plate 3. Different stages of *M. virescens* (= *P. fullo*), a) Eggs, b) Grub, c) Prepupa, d) Pupa e) Adults

Plate 3. a) Raster pattern, b) Male genitalia

C. Sequencing and phylogenetic analysis of *Melolontha* species

The length of amplified *Cox1* gene sequences (**Table 102**) of *M. cuprescens*, *M. furcicauda*, *M. indica* and *M. virescens* (= *P. fullo*) were recorded to be 873 bp, 874 bp, 678 bp and 873 bp, respectively. The amplified *28S rRNA* gene sequences (**Table 103**) in *M. cuprescens*, *M. furcicauda*, *M. indica* were 686 bp, 684 bp and 686 bp, respectively.

Table 102 Sequences of amplified products of *Cox1* gene of *M. cuprescens*, *M. furcicauda*, *M. indica* and *M. virescens (= P. fullo)*

Insect	Sequence
M. cuprescens	TTAGAAATTAGTTAATATGGGGAGTTCAGAGTAGCTATGTTCAGCAGGGGGTATTAGTTGGAATCATTC AATTGAAGTAGTTATACTTAGGGGCACTAAGCTTTTTCGGTGTGAAATAAATCTGTCTCAAATAACAAA TAAAAACATAATAATTCTAATAAGGGAAATTAGGGATCCGATTGAGGAGATCACATTTCAAGAAGTATA GGCATCTGGGTAATCAGAGTATCGTCGGGGTATTCCACTAAGTCCCAGAAAATGTTGGGGAAAGAAGGT TATATTAACTCCAATAAATATGGTTATAAATTGGATTTTTAAAAATTTTCCATTAAGGGTTAAGCCAGAG AATAGGGGGAATCAGTGAGTGAATCCTGCTATAATTCTAAAAACGGCTCCTATAGAAAGGACATAATG GAAGTGTGCTACGACATAGTAGGTGTCGTGTAGAATAATGTCGATTGAAGAGTTAGCTAAGATTACTCC AGTCAATCCTCCCACTGTAAATAAAAATACGAATCCTAGGGCTCACAGAAGTGATGGGGAGTAGTTTAA TTGGGTCCCATGAAGTGTAGCAATTCATCTGAAAATTTTAATACCGGTGGGTACAGCAATGATTATGGT GGCTGAAGTAAAATAAGCCCGAGTATCGACATCTATGCCCACTGTGAATATGTGATGGGCTCAGACAAT AAATCCTAATAAGCCAATCGCTATTATAGCATAGATTATTCCTAGTGTTCCGAATGTTTCTTTTTTGTTCC TTTCTTGGCTAATAATGTGGGAGATTATTCCAAATCCGGGGAGAATTAGAATATAAACTTCAGGGTGTC CAAAAAATCAAAATAA
M. furcicauda	TTAGAAATTAGTTAATATGGGTAGTTCGGAGTACCTATGTTCAGCTGGGGGTATTATTTGGAATCATTCG ATAGAAGTTGTTATGTTTAGGGGGGATAGGCTTTTTCGTATAGAGATAAATCTATCTCAAATAATAAAT AAAAATAGAATAATACTAATTAAGGAAATTAATGAACCAATAGATGAGATAATATTTCATACAGTATAG GCGTCGGGGTAATCTGAGTATCGTCGGGGTATGCCTCTTAATCCTAGAAAATGTTGAGGAAAAAAGGTT ATGTTTACTCCAATGAATATTGTAAAAAATTGAATTTTTAAAAGTTTTCTATTAAGTATTAAACCTGTAA ATAGGGGGAATCAGTGTACAAATCCTGCTATAATAGCAAATACGGCTCCTATTGATAGAACGTAATGAA

	AGTGGGCTACTACGTAATAAGTATCATGAAGGATAATATCAATTGAAGAATTTGCCAGGATAACTCCCGTTAAACCCCCCACTGTAAATAAGAATACAAATCCTAGGGCTCATAGCAATGATGGGGAATAATTTAATTGAGTTCCATGGAGAGTGGCCAATCATCTGAAAATTTTGATACCAGTAGGTACAGCAATAATTATTGTTGCAGAGGTAAAATAAGCTCGGGTATCTACATCTATTCCTACTGTAAATATATGATGGGCCCATACGATAAAGCCTAATAGGCCAATAGCTATTATGGCATAAATTATTCCTAAAGTGCCGAATGTTTCCTTTTTGTTGCTTTCTTGTCTAATAATGTGGGAAATTATTCCAAATCCCGGGAGAAATAAAATATAAACTTCTGGGTGTCCAAAAAATCAAAATAAGTGTTG
M. indica	GAATAGTTTTCTATTTAATGTTAGTCCTGTAAATAACGGAAACCAATGGACAAATCTAGCTATGATAGCAAATACTGCTCCTATTGAAAGTACGTAATGAAAATGGGTTGCAACATAGTAAGTATCATGAAGGTTGATATTAATTGAAGAGTTTGCAAGAATAACTCCTGTTAATCCTCCCACAGTAAATAAGACTACAAAACCTAGGGCGCATAGTAAGGATGGGGAATAGTTTAGTTGAGTTCCGCGTAGAGTAGCCAGTCATCTGAAAATTTTAATACCCGTAGGTACTGCAATAATTATGGTTGCTGAGGTAAAGTAGGCTCGTGTATCAACATCTATTCCTACAGTAAATATGTGATGAGCTCATACAATGAAGCCTAACAATCCAAGAGCTATTATTGCATAGATTATCCCTAAAGTACCGAATGTTTCTTTTCTGTTTCTTTCTTGTCTAATAATATGAGAAATTATTCCAAATCTTGGGAGGATTAAAATATAAACTTTTGGATGTCCAAAAAATCAAAATAA
P. fullo	TTAGAAATTAGTTAATATGGGGAGTTCAGAGTAGCTATGTTCAGCAGGGGGTATTAGTTGGAGTCATTCAATTGAAGTAGTTATACTTAGGGGCACTAAGCTTTTTCGGTGTGAAATAAATCTGTCTCAAATAACAAATAAAAACATAATAATTCTAATAAGGGAAATTAGGGATCCGATTGAGGAGATCACATTTCAAGAAGTATAGGCATCTGGGTAATCAGAGTATCGTCGGGGTATTCCACTAAGTCCCAGAAAATGTTGGGGAAAGAAGGTTATATTAACTCCAATAAATATGGTTATAAATTGGATTTTTAAAAATTTTCCATTAAGGGTTAAGCCAGAGAATAGGGGGAATCAGTGAGTGAATCCTGCTATAATTCTAAAAACGGCTCCTATAGAAAGGACATAATGGAAGTGTGCTACGACATAGTAGGTGTCGTGTAGAATAATGTCGATTGAAGAGTTAGCTAAGATTACTCCAGTCAATCCTCCCACTGTAAATAAAAATACGAATCCTAGGGCTCACAGAAGTGATGGGGAGTAGTTTAATTGGGTCCCATGAAGTGTAGCAATTCATCTGAAAATTTTAATACCGGTGGGTACAGCAATGATTATGGTGGCTGAAGTAAAATAAGCCCGAGTATCGACATCTATGCCCACTGTGAATATGTGATGGGCTCAGACAATAAATCCTAATAAGCCAATCGCTATTATAGCATAGATTATTCCTAGTGTTCCGAATGTTTCTTTTTTGTTCCTTTCTTGGCTAATAATGTGGGAGATTATTCCAAATCCGGGGAGAATTAGAATATAAACTTCAGGGTGTCCAAAAAATCAAAATAA

Table 103 Sequences of amplified products of *28S rRNA* gene of *M. cuprescens*, *M. furcicauda* and *M. indica*

Insect	Sequence
M. cuprescens	GGGACCCGTCCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGGACTCTGACGAAACCTAAAGGCGTAATGAAAGTGAAGGTCCGCCTGGCGCGGACCGAGGGAGGATGGGCGGACCCGAGGGGCCGCCTCGCACTCCCGGGGCGTCTCGTTCTCATCGCGAGAAGAGGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGACGAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCGGAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGTTTCCCTCAGGATAGCTGGCGCTCGCTTCTTGCGAGTCTCATTCGGTAAAGCGAATGATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGATCTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCACTTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCCGAGTTAAAGCGCCTAAATCGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCATGGAAGTCGGAATCCGCTAAGGAGTGTGTAA
M. furcicauda	GGGACCCGTCCTTGAAACACGGACCAAGGTGTTGGGCCCCCTTTCCGAAACACACGGACCAGGGGTTTTGTTAAATGCGTAAGTAAACCGTTCTTGATTAGGCTGTGGAGGGAAAGAGAATGCATTGGTTCGATTCTTCGGTCCGGACGCTGTTGAAAGAGCGCAGCAACGAGGTCTTAACAGGCACTCATAGCGCATTTACCGGTACCCGAAAAAATGGTGATCTATGCCTGACCAAGACGAAGCCAGAGGAAACTCTGGTGGAGGTCTGTAACGGTTCTGACGTGCAAATCGATCGTCATACTTGGGTATAGGGGCGAAAGACTAATCGAACCATCTTGTAGCTGGTTCCTTCCGAAGTTTCCCTCAGGATAGCAGGGGTGGCCAACCGAAGTTTCTCTTTGTTCCGGTGAAGCGAAAGGATTGAGGGCTTGGGGTCCAAAAGAACTTCATCCAATCCCCAACTTTTAATGGGTCCCAAGACCTATTTTCCTCCTTGGATGGGTGATCATCACAATAACCCTCCCTTGTGGGCCCTTTTGGTAAACAAAACTGGCGCCGGGGTATGAACCAAACGTTGAATTAAATCGTCCAAAATTACGCTAACAAACCCATTGAAAGTGGTTAATTCTTCACTCAGCAGGACGTTGACCTGGGATGTTGAATCCCCCTACGAGTGGGGTAAAACATGAGTCGGATCCGCTAAGGAGTGTGTAA

M. indica	GGGACCCGTCCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGGACTCTGTTGAAG CCTAAAGGCGTAATGAAAGTGAAGGTCCGCCCTGCGCGGACCGAGGGAGGATGGGTGGACCCGAGGGG CCGCCCCGCACTCCCGGGGCGTCTCGTTCTCATCGCGAGAAGAGGCGCACCCAGAGCGTACACGCTGGG ACCCGAAAGATGGTGAACTATGCCTGGTCAGGACGAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGC GATTCTGACGTGCAAATCGATCGTCGGAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAG CTGGTTCCCTCCGAAGTTTCCCTCAGGATAGCTGGCGCTCGCTTCTTGCGAGTCTCATTCGGTAAAGCGA ATGATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGATCTCCGG CTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCACTTTTGGTAAGCAGAA CTGGCGCTGTGGGATGAACCAAACGCCGAGTTAAAGCGCCTAAATCGACGCTTATGGGATACCATGAA AGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCATGGAAGTCGGAATCCGCTAAGGAGTGTGTAA

The sequences of *Cox1* gene from *Melolontha* species and *Polyphylla* species

The sequences of *Cox1* gene from *Melolontha* species and *Polyphylla* species were retrieved from National Centre for Biotechnology Information (NCBI), database (https://www.ncbi.nlm.nih.gov/). The sequences were subsequently used for phylogenetic analysis along with sequences obtained in the present study. The sequences of *Cox1* gene retrieved from NCBI are as follows:

***Melolontha hippocastani* (HM120757)**

GAAGTTTATATTTTAATTCTCCCAGGATTTGGAATAATTTCCCACATCATTAGACAAGAAAGTAACAAAAAGGAAACATTTGG
CACTTTAGGAATAATTTATGCCATAATAGCCATTGGTTTATTAGGCTTTATTGTATGGGCCCACCATATATTCACTGTAGGTAT
AGATGTTGATACTCGAGCCTACTTTACCTCAGCAACCATAATTATCGCAGTACCTACTGGTATTAAAATTTTTAGATGATTAGC
TACTCTCCATGGAACTCAACTAAATTATTCCCCATCCCTATTATGAGCCCTCGGCTTTGTATTTTTATTCACAGTAGGAGGACT
AACAGGAGTTATTCTCGCAAATTCTTCAATTGACATTATTCTTCATGATACTTATTATGTCGTAGCTCATTTTCATTATGTACTT
TCAATGGGTGCAGTATTTGCAATTATAGCGGGATTTGTCCATTGATTCCCTTTATTCACAGGACTAGTATTAAACAGAAAATT
ATTAAAAATCCAATTTTTTGCAATATTTATTGGCGTAAATATAACCTTCTTTCCCCAACACTTTTTAGGATTAAGGGGTATACC
ACGCCGATACTCAGATTACCCTGATGCCTATACAACTTGAAATGTTGTTTCATCTATCGGATCACTAATTTCCCTAATCAGTAT
TATTTTATTCTTATTTATTATTTGAGACAGATTTAT

***Melolontha hippocastani* (KX087316)**

CAACATTTATTTTGATTTTTTGGTCACCCAGAAGTTTATATTTTAATTCTCCCAGGATTTGGAATAATTTCCCACATCATTAGAC
AAGAAAGTAACAAAAAGGAAACATTTGGCACTTTAGGAATAATTTATGCCATAATAGCCATTGGTTTATTAGGCTTTATTGTA
TGGGCCCACCATATATTTACTGTAGGTATAGATGTCGATACTCGAGCCTACTTTACCTCAGCAACCATAATTATCGCAGTACCT
ACTGGTATTAAAATTTTTAGATGATTAGCTACTCTCCACGGAACTCAACTAAATTATTCCCCATCCCTATTATGAGCCCTCGGC
TTTGTATTTTTATTCACAGTAGGAGGACTAACAGGAGTTATTCTCGCAAATTCTTCAATTGACATTATTCTTCATGATACTTATT
ATGTCGTAGCTCATTTTCATTATGTACTTTCAATGGGTGCAGTATTTGCAATTATAGCGGGATTTGTCCATTGATTCCCTTTATT
CACAGGACTAGTATTAAACAGAAAATTATTAAAAATCCAATTTTTTGCAATATTTATTGGCGTAAATATAACCTTCTTTCCCCA
ACACTTTTTAGGATTAAGGGGTATACCACGCCGATACTCAGATTACCCTGATGCCTATACAACTTGAAATGTTGTTTCATCTAT
CGGATCACTAATTTCCCTAATCAGTATTATTTTATTCTTATTTATTATTTGAGACAGATTTATTTCTATACGAAAAAGACTATCC
CCCCTAAATATGACAACCTCCATTGAATGATTTCAATCTATACCACCAGCTGAACATAGATACTCTGAACTACCAATATTAAC
TAATTTCTAATATGGCAGACTAGTGCAATGGA

***Polyphylla gracilicornis* (MW143080)**

CAACATTTATTTTGATTTTTTGGACACCCTGAAGTTTACATCCTAATTCTCCCTGGATTTGGAATAATCTCCCACATCATTAGCC
AAGAGAGAAACAAAAAGGAAACCTTTGGAACACTAGGCATAATCTATGCTATAATAGCAATTGGTTTATTAGGATTCATTGT
CTGAGCTCACCACATATTTACAGTGGGAATAGATGTTGATACCCGAGCTTATTTTACCTCAGCCACCATAATCATTGCTGTGCC
CACTGGTATTAAAATTTTTAGATGACTAGCCACACTCCATGGAACCCAATTAAACTACTCCCCATCACTCTTATGAGCACTAG
GATTTGTCTTTTTATTTACAGTAGGTGGCTTAACTGGAGTAGTCCTAGCTAACTCTTCCATTGATATTATTTTACACGATACTTA
TTATGTAGTAGCACATTTCCATTATGTCCTTTCCATAGGAGCCGTTTTTAGAATTATAGCAGGATTCACACATTGATTCCCCCT
ATTCTCTGGCTTAACCCTTAATGGAAAATTTTTAAAAATTCAATTTATAACCATATTTATTGGAGTTAATATAACCTTTTTCCCC
CAACATTTCCTGGGACTTAACGGAATACCCCGCCGATACTCGGATTACCCTGATGCTTATACATCTTGAAATGTGATCTCCTCA
GTCGGATCCCTAATCTCCCTAATTAGAATTATTATATTTTTATTTATTATTTGAGAAAGACTTATTTCACACCGAAAAAGATTA

GTATCATTAAATATAAATACTTCAATTGAATGATTTCAGCTAATACCCCCCGCTGAACATAGCTACTCTGAGCTTCCCATATTA
ACTAATTTCTAATATGGCAGATTAGTGC

***Polyphylla laticollis* (KF544959)**

CAACATCTATTCTGATTTTTCGGCCATCCTGAAGTTTATATTTTAATTTTACCTGGATTTGGAATAATCTCTCACATCATTAGTC
AAGAAAGTAACAAAAAAGAAACCTTTGGAACTCTGGGTATAATTTATGCTATAATGGCAATCGGTTTACTAGGATTTATTGTA
TGGGCTCATCATATATTCACAGTGGGTATAGATGTTGATACTCGTGCTTATTTTACTTCAGCCACTATAATTATTGCAGTGCCA
ACAGGAATTAAAATCTTTAGATGATTGGCCACTCTACATGGGGCCCAACTAAATTACTCACCTTCATTACTATGGGCTTTAGG
TTTTGTTTTTTTATTTACAGTAGGCGGATTAACAGGAGTAATTCTGGCTAATTCATCAATTGATATTATTTTACATGACACTTAC
TATGTTGTCGCACATTTTCATTATGTCCTCTCCATAGGCGCAGTATTTAGTATCATAGCAGGATTTACACATTGATTCCCCCTA
TTCACTGGTTTAATACTCAACGAAAAATTCTTAAAAATTCAATTTATCACTATATTTATTGGTGTAAATATGACATTTTTTCCTC
AACATTTTCTAGGATTAAGGGGAATGCCTCGCCGATACTCCGACTACCCAGATGCCTATACTTCTTGAAATATCGTCTCATCTA
TTGGATCTCTAATCTCTTTAATTAGAATTATCATATTCCTATTTATTATCTGAGATAGATTTACTTCAAAACGAAAAAGATTGA
TATCATTAAATATAACTACCTCAATTGAGTGATTCCAATTAATGCCCCCAGCTGAACATAGTTACTCTGAACTACCTATGCTAA
CTAATTTCTAATATGGCAGATTAGTGCAATGGA

The sequences of *28s rRNA* gene from different scarab species

The sequences of *28s rRNA* gene from *Melolontha* species were retrieved from National Centre for Biotechnology Information (NCBI), database (https://www.ncbi.nlm.nih.gov/). The sequences were subsequently used for phylogenetic analysis along with sequences contained in the present study. The sequences of *28s rRNA* gene retrieved from NCBI are as follows:

***Melolontha melolontha* (EU084231)**

GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGACTCTGATGAAACCTAAAGGCGTAATG
AAAGTGAAGGTCCGCCCTGCGCGGACCGAGGGAGGATGGGTGGACCCGAGGGGCCGCCCCGCACTCCCGGGGCGTCTCGTTC
TCATCGCGAGAAGAGGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGACGAAGTCA
GGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCGGAACTGGGTATAGGGGCGAAAGACTAATC
GAACCATCTAGTAGCTGGTTCCCTCCGAAGTTTCCCTCAGGATAGCTGGCGCTCGCTTCTTGCGAGTCTCATTCGGTAAAGCG
AATGATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGATCTCCGGCTTGCTTGAACTG
TGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCACTTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGC
CGAGTTAAAGCGCCTAAATCGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCATGGA
AGTCGGAATCCGCTAAGGAGTGTGTAA

***Lepidiota albistigma* (DQ524590)**

GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGACTCTGACTAAACCTAAAGGCGTAATG
AAAGTGAAGGTCCGCCCTGCGCGGACCGAGGGAGGATGGGCGGACCCAAGGGGCCGCCTCGCACTCCCGGGGCGTCTCGTTC
TCATCGCGAGAAGAGGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGACGAAGTCA
GGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCGGAACTGGGTATAGGGGCGAAAGACTAATC
GAACCATCTAGTAGCTGGTTCCCTCCGAAGTTTCCCTCAGGATAGCTGGCGCTCGCTTCTTGCGAGTCTCATTCGGTAAAGCG
AATGATTAGAGGCATTGGGGTCGAAACGACCTCAACCTATTCTCAAACTTTAAATGGGTGAGATCTCCGGCTTGCTTGAACTG
TGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCACTTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGC
CGAGTTAAAGCGCCTAAATCGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCATGGA
AGTCGGAATCCGCTAAGGAGTGTGTAA

***Lepidiota stradbrokensis* (EU084209)**

GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGACTCAGACTAAACCTAAAGGCGTAATG
AAAGTGAAGGTCCGCCCTGCGCGGACCGAGGGAGGATGGGCGGACCCGAGGGGCCGCCTCGCACTCCCGGGGCGTCTCGTTC
TCATCGCGAGAAGAGGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGACGAAGTCA
GGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCGGAACTGGGTATAGGGGCGAAAGACTAATC

GAACCATCTAGTAGCTGGTTCCCTCCGAAGTTTCCCTCAGGATAGCTGGCGCTCGCTTCTTGCGAGTCTCATTCGGTAAAGCG
AATGATTAGAGGCATTGGGGTCGAAACGACCTCAACCTATTCTCAAACTTTAAATGGGTGAGATCTCCGGCTTGCTTGAACTG
TGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCACTTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGC
CGAGTTAAAGCGCCTAAATCGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTATGACAGCAGGACGGTGGCCATGGA
AGTCGGAATCCGCTAAGGAGTGTGTAA

***Maladera holosericea* (EU084216)**

GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGATTTTTACTAAACCTAAAGGCGCAATG
AAAGTGAAGGTCCGCCTTGCGCGGACCGAGGGAGGATGGACCGTCCCGAGGGACGGCCTCGCACTCCCGGGGCGTCTCGTTC
TCATCGCGAGAAGAGGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGACGAAGTCA
GGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCGGAACTGGGTATAGGGGCGAAAGACTAATC
GAACCATCTAGTAGCTGGTTCCCTCCGAAGTTTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCATTCGGTAAAGCG
AATGATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGATCTCCGGCTTGCTTGAACTG
TGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCACTTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGC
CGAGTTAAAGCGCCTAAATCGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCATGGA
AGTCGGAATCCGCTAAGGAGTGTGTAA

***Maladera significans* (EU084221)**

GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGATTTTTACTAAACCTAAAGGCGCAATG
AAAGTGAAGGTCCGCCTTGCGCGGACCGAGGGAGGATAGACCGTACCGAGGTACGGCCTCGCACTCCCGGGGCGTCTCGTTC
TCATCGCGAGAAGAGGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGACGAAGTCA
GGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCGGAACTGGGTATAGGGGCGAAAGACTAATC
GAACCATCTAGTAGCTGGTTCCCTCCGAAGTTTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCATTCGGTAAAGCG
AATGATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGATCTCCGGCTTGCTTGAACTG
TGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCACTTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGC
AGAGTTAAAGCGCCTAAATCGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCATGGA
AGTCGGAATCCGCTAAGGAGTGTGTAA

***Adoretus lasiopygus* (DQ524609)**

GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGACTCTAACGAAACCTAAAGGCGTAATG
AAAGTGAAGGTCCGCCTTGCGCGGACCGAGGGAGGATGGGCGATCTTTAGGGATCGTCCCGCACTCCCTGGGCGTCTCGTTCT
CATCGCGAGAAGAGGCGCACCAAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGACGAAGTCAG
GGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCGGAACTGGGTATAGGGGCGAAAGACTAATCG
AACCATCTAGTAGCTGGTTCCCTCCGAAGTTTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCATTCGGTAAAGCGA
ATGATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGATCTCCGGCTTGCTTGAACTGT
GAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCACTTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCT
GAGTTAAAGCGCCTAAATCGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCATGGAA
GTCGGAATCCGCTAAGGAGTGTGTAA

***Holotrichia seticollis* (DQ524596)**

GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGACTCTGACGAAACCTAAAGGCGCAATG
AAAGTGAAGGTTCGCCTAGCGCGGACCGAGGGAGGATGGGTGGTCTCGCGGGACCACCTCGCACTTCCGGGGCGTCTCGTTC
TCACTGCGAGAAGAGGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGACGAAGTCA
GGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCGGAACTGGGTATAGGGGCGAAAGACTAATC
GAACCATCTAGTAGCTGGTTCCCTCCGAAGTTTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCATTCGGTAAAGCG
AATGATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGATCTCCGGCTTGCTTGAACTG
TGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCACTTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGC
AGAGTTAAAGCGCCTAAATCGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCATGGA
AGTCGGAATCCGCTAAGGAGTGTGTAA

***Chiloloba acuta* (DQ524581)**

GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGACTCTAACGAAACCTAAAGGCGTAATG
AAAGTGAAGGTCCGCCTAGCGCGGGCCGAGGGAGGATGGGTGACCCCGAGGGGCGCCCCGCACTCCCAGGGCGTCTCGTTCT
CATTGCGAGAAGAGGCGCACCAAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGACGAAGTCAG
GGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCGGAACTGGGTATAGGGGCGAAAGACTAATCG
AACCATCTAGTAGCTGGTTCCCTCCGAAGTTTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCATTCGGTAAAGCGA
ATGATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGATCTCCGGCTTGCTTGAACTGT
GAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCACTTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCT
GAGTTAAAGCGCCTAAATCGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCATGGAA
GTCGGAATCCGCTAAGGAGTGTGTAA

Cetonia aurata aurata **(EU084146)**

GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGACTCTAACGAAACCTAAAGGCGTAATG
AAAGTGAAGGCTCGCCTAGCGCGGGCCGAGGGAGGATGGGTGTCCCCGAGGGGACGCCTCGCACTCCCAGGGCGTCTCGTTC
TCATTGCGAGAAGAGGCGCACCATGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGACGAAGTCA
GGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCGGAACTGGGTATAGGGGCGAAAGACTAATC
GAACCATCTAGTAGCTGGTTCCCTCCGAAGTTTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCATTCGGTAAAGCG
AATGATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGATCTCCGGCTTGCTTGAACTG
TGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCACTTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGC
TGAGTTAAAGCGCCTAAATCGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCATGGA
AGTCGGAATCCGCTAAGGAGTGTGTAA

Anomala **sp. (DQ524588)**

GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGACTCTAACGAAACCTAAAGGCGTAATG
AAAGTGAAGGTTCGCCACGCGCGAACCGAGGGAGGATGGACGGTCGATAGTGGCCGTCCCGCACTCCCTGGGCGTCTCGTTC
TCATCGCGAGAAGAGGCGCACCAAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGACGAAGTCA
GGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCGGAACTGGGTATAGGGGCGAAAGACTAATC
GAACCATCTAGTAGCTGGTTCCCTCCGAAGTTTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCATTCGGTAAAGCG
AATGATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGATCTCCGGCTTGCTTGAACTG
TGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCACTTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGC
CGAGTTAAAGCGCCTAAATCGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCATGGA
AGTCGGAATCCGCTAAGGAGTGTGTAA

Multiple sequence alignment of *Cox1* gene sequences

The *Cox1* sequences of *M. cuprescence*, *M. furcicauda*, *M. indica* and *M. virescens* (= *P. fullo*) were aligned with *Cox1* sequences of *Melolontha hippocastani* (HM120757), *Melolontha hippocastani* (KX087316), *Polyphylla gracilicornis* (MW143080) and *Polyphylla laticollis* (KF544959). The multiple sequence alignment of *Cox1* gene from all these species is given as follows:

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M.indica                    ------------------------------------------------------------  0
M.furcicauda                TCCAATGCACTAATCTGCCATATTAGAAATTAGTTAATATGGGTAGTTCGGAGTACCTAT  60
M.cuprescens                TCCAATGCACTAATCTGCCATATTAGAAATTAGTTAATATGGGGAGTTCAGAGTAGCTAT  60
P.fullo                     TCCAATGCACTAATCTGCCATATTAGAAATTAGTTAATATGGGGAGTTCAGAGTAGCTAT  60
HM120757-M.hippocastani     ------------------------------------------------------------  0
KX087316-M.hippocastani     ---------------------------CAACATTTATTTTG-------------------  14
MW143080-P.gracilicornis    ---------------------------CAACATTTATTTTG-------------------  14
KF544959-P.laticollis       ---------------------------CAACATCTATTCTG-------------------  14

M.indica                    ------------------------------------------------------------  0
M.furcicauda                GTTCAGCTGGGGGTATTATTTGGAATCATTC-GATAGAAGTTGTTATGTTTAGGGGGGAT  119
M.cuprescens                GTTCAGCAGGGGGTATTAGTTGGAATCATTC-AATTGAAGTAGTTATACTTAGGGGCACT  119
P.fullo                     GTTCAGCAGGGGGTATTAGTTGGAGTCATTC-AATTGAAGTAGTTATACTTAGGGGCACT  119
HM120757-M.hippocastani     ------------------------------GAAGTTTATATTTTAATTCTCCCAGG-ATT  29
KX087316-M.hippocastani     --------------ATTTTTTGGTCACCCAGAAGTTTATATTTTAATTCTCCCAGG-ATT  59
MW143080-P.gracilicornis    --------------ATTTTTTGGACACCCTGAAGTTTACATCCTAATTCTCCCTGG-ATT  59
KF544959-P.laticollis       --------------ATTTTTCGGCCATCCTGAAGTTTATATTTTAATTTTACCTGG-ATT  59
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M.indica                        ------------------------------------------------------------    0
M.furcicauda                    AGGCTTTTTCGTATAGAGATAAATCTATCTC-AAATAATAAATAAAAATAGAATAATACT    178
M.cuprescens                    AAGCTTTTTCGGTGTGAAATAAATCTGTCTC-AAATAACAAATAAAAACATAATAATTCT    178
P.fullo                         AAGCTTTTTCGGTGTGAAATAAATCTGTCTC-AAATAACAAATAAAAACATAATAATTCT    178
HM120757-M.hippocastani         TGG------AATAATTTCCCACATCATTAGACAAGAAAGTAACAAAAAGGAAACATTTGG    83
KX087316-M.hippocastani         TGG------AATAATTTCCCACATCATTAGACAAGAAAGTAACAAAAAGGAAACATTTGG    113
MW143080-P.gracilicornis        TGG------AATAATCTCCCACATCATTAGCCAAGAGAGAAACAAAAAGGAAACCTTTGG    113
KF544959-P.laticollis           TGG------AATAATCTCTCACATCATTAGTCAAGAAAGTAACAAAAAAGAAACCTTTGG    113

M.indica                        ----------TCCAATGCACTAATCTGCCATATTA-GAAATTAGTTAATATGGGTAGTTC    49
M.furcicauda                    AATTAAGGAAATTAATGAACCAATAGATGAGATAA-TATTTCATACAGTATAGGCG--TC    235
M.cuprescens                    AATAAGGGAAATTAGGGATCCGATTGAGGAGATCA-CATTTCAAGAAGTATAGGCA--TC    235
P.fullo                         AATAAGGGAAATTAGGGATCCGATTGAGGAGATCA-CATTTCAAGAAGTATAGGCA--TC    235
HM120757-M.hippocastani         CACTTTAGGAATAATTTATGCCATAATAGCCATTGGTTTATTAGGCTTTATTGTA---TG    140
KX087316-M.hippocastani         CACTTTAGGAATAATTTATGCCATAATAGCCATTGGTTTATTAGGCTTTATTGTA---TG    170
MW143080-P.gracilicornis        AACACTAGGCATAATCTATGCTATAATAGCAATTGGTTTATTAGGATTCATTGTC---TG    170
KF544959-P.laticollis           AACTCTGGGTATAATTTATGCTATAATGGCAATCGGTTTACTAGGATTTATTGTA---TG    170
                                             *         **      **         *      ** *     *

M.indica                        AGAATATCTATGTTCAGCTGGTGGTATTATTTGAAATCATTCAATAGATGTTGTTATTCT    109
M.furcicauda                    GGGGTAATCTGAGTATCGTCGGGGTATGCCTCTTAATCCTAGAAAATGTTGAGGAAAAAA    295
M.cuprescens                    TGGGTAATCAGAGTATCGTCGGGGTATTCCACTAAGTCCCAGAAAATGTTGGGGAAAGAA    295
P.fullo                         TGGGTAATCAGAGTATCGTCGGGGTATTCCACTAAGTCCCAGAAAATGTTGGGGAAAGAA    295
HM120757-M.hippocastani         GGCCCACCATATATTCACTGTAGGTATAGATGTTGATACTCGAGCCTACTTTA-------    193
KX087316-M.hippocastani         GGCCCACCATATATTTACTGTAGGTATAGATGTCGATACTCGAGCCTACTTTA-------    223
MW143080-P.gracilicornis        AGCTCACCACATATTTACAGTGGGAATAGATGTTGATACCCGAGCTTATTTTA-------    223
KF544959-P.laticollis           GGCTCATCATATATTCACAGTGGGTATAGATGTTGATACTCGTGCTTATTTTA-------    223
                                 *   *       *        ** **         *

M.indica                        TACTGGAGAAAGTCTTTTTCGTATTGAAATTTGAAATATTTTGAATAGTTTTCT------    163
M.furcicauda                    GGTTATGTTTACTCCAATGAATATTGTAAAAAATTGAATTTTTAAAAGTTTTCT------    349
M.cuprescens                    GGTTATATTAACTCCAATAAATATGGTTATAAATTGGATTTTTAAAAATTTTCC------    349
P.fullo                         GGTTATATTAACTCCAATAAATATGGTTATAAATTGGATTTTTAAAAATTTTCC------    349
HM120757-M.hippocastani         -----CCTCAGCAACCATAATTATCGCAGTACCTACTGGTATTAAAATTTTTAGATGATT    248
KX087316-M.hippocastani         -----CCTCAGCAACCATAATTATCGCAGTACCTACTGGTATTAAAATTTTTAGATGATT    278
MW143080-P.gracilicornis        -----CCTCAGCCACCATAATCATTGCTGTGCCCACTGGTATTAAAATTTTTAGATGACT    278
KF544959-P.laticollis           -----CTTCAGCCACTATAATTATTGCAGTGCCAACAGGAATTAAAATCTTTAGATGATT    278
                                                 *    ** *               * ** *  ***

M.indica                        --------------------------------------------------------ATTT    167
M.furcicauda                    --------------------------------------------------------ATTA    353
M.cuprescens                    --------------------------------------------------------ATTA    353
P.fullo                         --------------------------------------------------------ATTA    353
HM120757-M.hippocastani         AGCTACTCTCCATGGAACTCAACTAAATTATTCCCCATCCCTATTATGAGCCCTCGGCTT    308
KX087316-M.hippocastani         AGCTACTCTCCACGGAACTCAACTAAATTATTCCCCATCCCTATTATGAGCCCTCGGCTT    338
MW143080-P.gracilicornis        AGCCACACTCCATGGAACCCAATTAAACTACTCCCCATCACTCTTATGAGCACTAGGATT    338
KF544959-P.laticollis           GGCCACTCTACATGGGGCCCAACTAAATTACTCACCTTCATTACTATGGGCTTTAGGTTT    338
                                                                                          *

M.indica                        AATGTTAGTCCTGTAAATAACGGAAACCAATGGACAAATCTAGCTATGATAGCAAA-TAC    226
M.furcicauda                    AGTATTAAACCTGTAAATAGGGGGAATCAGTGTACAAATCCTGCTATAATAGCAAA-TAC    412
M.cuprescens                    AGGGTTAAGCCAGAGAATAGGGGGAATCAGTGAGTGAATCCTGCTATAATTCTAAA-AAC    412
P.fullo                         AGGGTTAAGCCAGAGAATAGGGGGAATCAGTGAGTGAATCCTGCTATAATTCTAAA-AAC    412
HM120757-M.hippocastani         TGTATTTTTATTCACAGTAGGAGGACTAACAGGAGTTATTCTCGCAAATTCTTCAATTGA    368
KX087316-M.hippocastani         TGTATTTTTATTCACAGTAGGAGGACTAACAGGAGTTATTCTCGCAAATTCTTCAATTGA    398
MW143080-P.gracilicornis        TGTCTTTTTATTTACAGTAGGTGGCTTAACTGGAGTAGTCCTAGCTAACTCTTCCATTGA    398
KF544959-P.laticollis           TGTTTTTTTATTTACAGTAGGCGGATTAACAGGAGTAATTCTGGCTAATTCATCAATTGA    398
                                    **         * **   *     *  *      *          *     *

M.indica                        TGCTCCTATTGAAAGTACGTAATGAAAATGGGTTGCAACATAGTAAGTATCATGAAGGTT    286
M.furcicauda                    GGCTCCTATTGATAGAACGTAATGAAAGTGGGCTACTACGTAATAAGTATCATGAAGGAT    472
M.cuprescens                    GGCTCCTATAGAAAGGACATAATGGAAGTGTGCTACGACATAGTAGGTGTCGTGTAGAAT    472
P.fullo                         GGCTCCTATAGAAAGGACATAATGGAAGTGTGCTACGACATAGTAGGTGTCGTGTAGAAT    472
HM120757-M.hippocastani         CATTATTCTTCATGATACTTATTATGTCGTAGCTCATTTTCATTATGTACTTTCAATGGG    428
KX087316-M.hippocastani         CATTATTCTTCATGATACTTATTATGTCGTAGCTCATTTTCATTATGTACTTTCAATGGG    458
MW143080-P.gracilicornis        TATTATTTTACACGATACTTATTATGTAGTAGCACATTTCCATTATGTCCTTTCCATAGG    458
KF544959-P.laticollis           TATTATTTTACATGACACTTACTATGTTGTCGCACATTTTCATTATGTCCTCTCCATAGG    458
                                   *  * *  *    ** ** *        *         * ** **    *  *

M.indica                        GATATTAATTGAAGAGTTTGCAAGAATAACTCCTGTTAATCCTCCCACAGTAAATAAGAC    346
M.furcicauda                    AATATCAATTGAAGAATTTGCCAGGATAACTCCCGTTAAACCCCCCACTGTAAATAAGAA    532
M.cuprescens                    AATGTCGATTGAAGAGTTAGCTAAGATTACTCCAGTCAATCCTCCCACTGTAAATAAAAA    532
P.fullo                         AATGTCGATTGAAGAGTTAGCTAAGATTACTCCAGTCAATCCTCCCACTGTAAATAAAAA    532
HM120757-M.hippocastani         TGCAGT-ATTTGCAATTATAGCGGGATTTGTCCATTGATTCCCTTTATTCACAGGACTAG    487
KX087316-M.hippocastani         TGCAGT-ATTTGCAATTATAGCGGGATTTGTCCATTGATTCCCTTTATTCACAGGACTAG    517
MW143080-P.gracilicornis        AGCCGT-TTTTAGAATTATAGCAGGATTCACACATTGATTCCCCCTATTCTCTGGCTTAA    517
KF544959-P.laticollis           CGCAGT-ATTTAGTATCATAGCAGGATTTACACATTGATTCCCCCTATTCACTGGTTTAA    517
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M.indica                   TACAAAACCTAGGGCGCATAGTAAGGATGGGGAATAGTTTAGTTGAGTTCCGCGTAGAGT   406
M.furcicauda               TACAAATCCTAGGGCTCATAGCAATGATGGGGAATAATTTAATTGAGTTCCATGGAGAGT   592
M.cuprescens               TACGAATCCTAGGGCTCACAGAAGTGATGGGGAGTAGTTTAATTGGGTCCCATGAAGTGT   592
P.fullo                    TACGAATCCTAGGGCTCACAGAAGTGATGGGGAGTAGTTTAATTGGGTCCCATGAAGTGT   592
HM120757-M.hippocastani    TA----------------------------------------------------------   489
KX087316-M.hippocastani    TA----------------------------------------------------------   519
MW143080-P.gracilicornis   CC----------------------------------------------------------   519
KF544959-P.laticollis      TA----------------------------------------------------------   519

M.indica                   AGCCAGTCATCTGAAAATTTTAATACCCGTAGGTACTGCAATAATTATGGTTGCTGAGGT   466
M.furcicauda               GGCCAATCATCTGAAAATTTTGATACCAGTAGGTACAGCAATAATTATTGTTGCAGAGGT   652
M.cuprescens               AGCAATTCATCTGAAAATTTTAATACCGGTGGGTACAGCAATGATTATGGTGGCTGAAGT   652
P.fullo                    AGCAATTCATCTGAAAATTTTAATACCGGTGGGTACAGCAATGATTATGGTGGCTGAAGT   652
HM120757-M.hippocastani    ----TTAAACAGAAAATTATTAAAAATCCAATTTTTTGCAATATTTATTGGCGTAAATAT   545
KX087316-M.hippocastani    ----TTAAACAGAAAATTATTAAAAATCCAATTTTTTGCAATATTTATTGGCGTAAATAT   575
MW143080-P.gracilicornis   ----CTTAATGGAAAATTTTTAAAAATTCAATTTATAACCATATTTATTGGAGTTAATAT   575
KF544959-P.laticollis      ----CTCAACGAAAAATTCTTAAAAATTCAATTTATCACTATATTTATTGGTGTAAATAT   575
                                   *    *** * ** * *        *    * **  **** *  *   * *

M.indica                   AAAGTAGG---------CTACATCTATTCCTACAGTAAA--TATGTGATGAGCTCATACA   515
M.furcicauda               AAAATAAGCTCGGGTATCTACATCTATTCCTACTGTAAA--TATATGATGGGCCCATACG   710
M.cuprescens               AAAATAAGCCCGAGTATCGACATCTATGCCCACTGTGAA--TATGTGATGGGCTCAGACA   710
P.fullo                    AAAATAAGCCCGAGTATCGACATCTATGCCCACTGTGAA--TATGTGATGGGCTCAGACA   710
HM120757-M.hippocastani    AACCTTCT-------TTCCCCAACACTTTTTAGGATTAAGGGGTATACCACGCCGATACT   598
KX087316-M.hippocastani    AACCTTCT-------TTCCCCAACACTTTTTAGGATTAAGGGGTATACCACGCCGATACT   628
MW143080-P.gracilicornis   AACCTTTT-------TCCCCCAACATTTCCTGGGACTTAACGGAATACCCCGCCGATACT   628
KF544959-P.laticollis      GACATTTT-------TTCCTCAACATTTTCTAGGATTAAGGGGAATGCCTCGCCGATACT   628
                            *  *            *  ** *  *           *      *     **  * **
M.indica                   ATGAAGCCTAACAATCCAA-----------------GAGCTATTATTGCATAGATTATCC   558
M.furcicauda               ATAAAGCCTAATAGGCCAA-----------------TAGCTATTATGGCATAAATTATTC   753
M.cuprescens               ATAAATCCTAATAAGCCAA-----------------TCGCTATTATAGCATAGATTATTC   753
P.fullo                    ATAAATCCTAATAAGCCAA-----------------TCGCTATTATAGCATAGATTATTC   753
HM120757-M.hippocastani    CAGATTACCCTGATGCCTATACAACTTGAAATGTTGTTTCATCTATCGGATCACTAATTT   658
KX087316-M.hippocastani    CAGATTACCCTGATGCCTATACAACTTGAAATGTTGTTTCATCTATCGGATCACTAATTT   688
MW143080-P.gracilicornis   CGGATTACCCTGATGCTTATACATCTTGAAATGTGATCTCCTCAGTCGGATCCCTAATCT   688
KF544959-P.laticollis      CCGACTACCCAGATGCCTATACTTCTTGAAATATCGTCTCATCTATTGGATCTCTAATCT   688
                              *   *    *  *  *                    *     * * **   * **

M.indica                   CTAAAGTACCGAATGTTTCTTTTCTGTTTCTTTCTTGT-----------CTAATAATATG   607
M.furcicauda               CTAAAGTGCCGAATGTTTCCTTTTTGTTGCTTTCTTGT-----------CTAATAATGTG   802
M.cuprescens               CTAGTGTTCCGAATGTTTCTTTTTTGTTCCTTTCTTGG-----------CTAATAATGTG   802
P.fullo                    CTAGTGTTCCGAATGTTTCTTTTTTGTTCCTTTCTTGG-----------CTAATAATGTG   802
HM120757-M.hippocastani    CCCTAATCAGTATTATTTTATTCTTATTTATTATTTGAGACAGATTTAT-----------   707
KX087316-M.hippocastani    CCCTAATCAGTATTATTTTATTCTTATTTATTATTTGAGACAGATTTATTTCTATACGAA   748
MW143080-P.gracilicornis   CCCTAATTAGAATTATTATATTTTTATTTATTATTTGAGAAAGACTTATTTCACACCGAA   748
KF544959-P.laticollis      CTTTAATTAGAATTATCATATTCCTATTTATTATCTGAGATAGATTTACTTCAAAACGAA   748
                           *     *    * * *    **  * **  **   **
M.indica                   AGAAATTATTCCAAATCT--------------TGGG-AGGATTAAAATATAAACTTTTGG   652
M.furcicauda               GGAAATTATTCCAAATCC--------------CGGGAAGAAATAAAATATAAACTTCTGG   848
M.cuprescens               GGAGATTATTCCAAATCC--------------GGGG-AGAATTAGAATATAAACTTCAGG   847
P.fullo                    GGAGATTATTCCAAATCC--------------GGGG-AGAATTAGAATATAAACTTCAGG   847
HM120757-M.hippocastani    ------------------------------------------------------------   707
KX087316-M.hippocastani    AAAGACTATCCCCCCTAAATATGACAACCTCCATTGAATGATTTCAATCTATACCACCAG   808
MW143080-P.gracilicornis   AAAGATTAGTATCATTAAATATAAATACTTCAATTGAATGATTTCAGCTAATACCCCCCG   808
KF544959-P.laticollis      AAAGATTGATATCATTAAATATAACTACCTCAATTGAGTGATTCCAATTAATGCCCCCAG   808

M.indica                   A--------------------TGTCCAAAAAA----------------TCAAAATAATGT   676
M.furcicauda               G--------------------TGTCCAAAAAA----------------TCAAAATAATGT   872
M.cuprescens               G--------------------TGTCCAAAAAA----------------TCAAAATAATGT   871
P.fullo                    G--------------------TGTCCAAAAAA----------------TCAAAATAATGT   871
HM120757-M.hippocastani    ------------------------------------------------------------   707
KX087316-M.hippocastani    CTGAACATAGATACTCTGAACTACCAATATTAACTAATTTCTAATATGGCAGACTAGTGC   868
MW143080-P.gracilicornis   CTGAACATAGCTACTCTGAGCTTCCCATATTAACTAATTTCTAATATGGCAGATTAGTGC   868
KF544959-P.laticollis      CTGAACATAGTTACTCTGAACTACCTATGCTAACTAATTTCTAATATGGCAGATTAGTGC   868

M.indica                   TG----   678
M.furcicauda               TG----   874
M.cuprescens               TG----   873
P.fullo                    TG----   873
HM120757-M.hippocastani    ------   707
KX087316-M.hippocastani    AATGGA   874
MW143080-P.gracilicornis   ------   868
KF544959-P.laticollis      AATGGA   874
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Multiple alignment of *28s rRNA* gene sequences

The *28s rRNA* sequences of *M. cuprescence*, *M. furcicauda* and *M. indica* were aligned with *28s rRNA* sequences of *Melolontha melolontha* (EU084221), *Lepidiota albistigma* (DQ524590), *Lepidiota stradbrokensis* (EU084209), *Holotrichia seticollis* (DQ524596), *Maladera holosericea* (EU084216), *Maladera significans* (EU084221), *Adoretus lasiopygus* (DQ524609), *Anomala* sp. (DQ524588), *Chiloloba acuta* (DQ524581) and *Cetonia aurata aurata* (EU084146). The multiple sequence alignment of *28s rRNA* gene from all these species is given as follows:

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M.furcicauda                GGGACCCGTCCTTGAAACACGGACCAAGGTGTTGGGCCCCCTTTCCGAAACACACGGACC    60
DQ524581-C.acuta            -GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGG-GACT    58
EU084146-C.aurata           -GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGG-GACT    58
DQ524609-A.lasiopygus       -GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGG-GACT    58
DQ524588-Anomala            -GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGG-GACT    58
EU084216-M.holosericea      -GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGG-GATT    58
EU084221-M.significans      -GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGG-GATT    58
DQ524596-H.seticollis       -GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTG-GGACT    58
EU084231-M.melolontha       -GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTG-GGACT    58
DQ524590-L.albistigma       -GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTG-GGACT    58
EU084209-L.stradbrokensis   -GGGACCCGTCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTG-GGACT    58
M.cuprescens                GGGACCCGTCCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGGACT    60
M.indica                    GGGACCCGTCCTTGAAACACGGACCAAGGAGTCTAGCATGTGCGCGAGTCATTGGGGACT    60
                             **  **   ******************* **   **       *           **

M.furcicauda                AGGGGTTTTGTTAAATGCGTAAGTAAACCGTTCTTGATTAGGCTGTGGAGGGAAAGAGAA    120
DQ524581-C.acuta            CTAACGAAACCTAAAGGCGTAATGAAAGTGAAGGTCCGCCTAGCGCGGGCCGAGGGAGGA    118
EU084146-C.aurata           CTAACGAAACCTAAAGGCGTAATGAAAGTGAAGGCTCGCCTAGCGCGGGCCGAGGGAGGA    118
DQ524609-A.lasiopygus       CTAACGAAACCTAAAGGCGTAATGAAAGTGAAGGTCCGCCTTGCGCGGACCGAGGGAGGA    118
DQ524588-Anomala            CTAACGAAACCTAAAGGCGTAATGAAAGTGAAGGTTCGCCACGCGCGAACCGAGGGAGGA    118
EU084216-M.holosericea      TTTACTAAACCTAAAGGCGCAATGAAAGTGAAGGTCCGCCTTGCGCGGACCGAGGGAGGA    118
EU084221-M.significans      TTTACTAAACCTAAAGGCGCAATGAAAGTGAAGGTCCGCCTTGCGCGGACCGAGGGAGGA    118
DQ524596-H.seticollis       CTGACGAAACCTAAAGGCGCAATGAAAGTGAAGGTTCGCCTAGCGCGGACCGAGGGAGGA    118
EU084231-M.melolontha       CTGATGAAACCTAAAGGCGTAATGAAAGTGAAGGTCCGCCCTGCGCGGACCGAGGGAGGA    118
DQ524590-L.albistigma       CTGACTAAACCTAAAGGCGTAATGAAAGTGAAGGTCCGCCCTGCGCGGACCGAGGGAGGA    118
EU084209-L.stradbrokensis   CAGACTAAACCTAAAGGCGTAATGAAAGTGAAGGTCCGCCCTGCGCGGACCGAGGGAGGA    118
M.cuprescens                CTGACGAAACCTAAAGGCGTAATGAAAGTGAAGGTCCGCCTGGCGCGGACCGAGGGAGGA    120
M.indica                    CTGTTGAAGCCTAAAGGCGTAATGAAAGTGAAGGTCCGCCCTGCGCGGACCGAGGGAGGA    120
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M.furcicauda               TGCATTGGTTCGATTCTTCGGTCCGGACGCTGTTGAAAGAGCGCAGCAACGAGGTCTTAA   180
DQ524581-C.acuta           TGGGTGACCCCGAGG-GGCGCCCCGCACTCCCAGGGCGTCTCGTTCTCATTGCGAGAAGA   177
EU084146-C.aurata          TGGGTGTCCCCGAGGGGACGCCTCGCACTCCCAGGGCGTCTCGTTCTCATTGCGAGAAGA   178
DQ524609-A.lasiopygus      TGGGCGATCTTTAGGGATCGTCCCGCACTCCCTGGGCGTCTCGTTCTCATCGCGAGAAGA   178
DQ524588-Anomala           TGGACGGTCGATAGTGGCCGTCCCGCACTCCCTGGGCGTCTCGTTCTCATCGCGAGAAGA   178
EU084216-M.holosericea     TGGACCGTCCCGAGGGACGGCCTCGCACTCCCGGGGCGTCTCGTTCTCATCGCGAGAAGA   178
EU084221-M.significans     TAGACCGTACCGAGGTACGGCCTCGCACTCCCGGGGCGTCTCGTTCTCATCGCGAGAAGA   178
DQ524596-H.seticollis      TGGGTGGTCTCGCGGGACCACCTCGCACTTCCGGGGCGTCTCGTTCTCACTGCGAGAAGA   178
EU084231-M.melolontha      TGGGTGGACCCGAGGGGCCGCCCCGCACTCCCGGGGCGTCTCGTTCTCATCGCGAGAAGA   178
DQ524590-L.albistigma      TGGGCGGACCCAAGGGGCCGCCTCGCACTCCCGGGGCGTCTCGTTCTCATCGCGAGAAGA   178
EU084209-L.stradbrokensis  TGGGCGGACCCGAGGGGCCGCCTCGCACTCCCGGGGCGTCTCGTTCTCATCGCGAGAAGA   178
M.cuprescens               TGGGCGGACCCGAGGGGCCGCCTCGCACTCCCGGGGCGTCTCGTTCTCATCGCGAGAAGA   180
M.indica                   TGGGTGGACCCGAGGGGCCGCCCCGCACTCCCGGGGCGTCTCGTTCTCATCGCGAGAAGA   180
                           *                      ** **      *      **     *    *     *

M.furcicauda               CAGGCACTCATAGCGCATTTACCGGTACCCGAAAAATGGTGATCTATGCCTGACCAAGAC   240
DQ524581-C.acuta           GGCGCACCAAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGAC   237
EU084146-C.aurata          GGCGCACCATGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGAC   238
DQ524609-A.lasiopygus      GGCGCACCAAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGAC   238
DQ524588-Anomala           GGCGCACCAAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGAC   238
EU084216-M.holosericea     GGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGAC   238
EU084221-M.significans     GGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGAC   238
DQ524596-H.seticollis      GGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGAC   238
EU084231-M.melolontha      GGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGAC   238
DQ524590-L.albistigma      GGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGAC   238
EU084209-L.stradbrokensis  GGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGAC   238
M.cuprescens               GGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGAC   240
M.indica                   GGCGCACCCAGAGCGTACACGCTGGGACCCGAAAGATGGTGAACTATGCCTGGTCAGGAC   240
                              ****    **** *    * ** ******** ******* *********  ** ***

M.furcicauda               GAAGCCAGAGGAAACTCTGGTGGAGGTCTGTAACGGTTCTGACGTGCAAATCGATCGTCA   300
DQ524581-C.acuta           GAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCG   297
EU084146-C.aurata          GAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCG   298
DQ524609-A.lasiopygus      GAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCG   298
DQ524588-Anomala           GAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCG   298
EU084216-M.holosericea     GAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCG   298
EU084221-M.significans     GAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCG   298
DQ524596-H.seticollis      GAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCG   298
EU084231-M.melolontha      GAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCG   298
DQ524590-L.albistigma      GAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCG   298
EU084209-L.stradbrokensis  GAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCG   298
M.cuprescens               GAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCG   300
M.indica                   GAAGTCAGGGGAAACCCTGATGGAGGTCCGTAGCGATTCTGACGTGCAAATCGATCGTCG   300
                           **** *** ****** *** ******** *** ** ***********************

M.furcicauda               TACTTGGGTATAGGGGCGAAAGACTAATCGAACCATCTTGTAGCTGGTTCCTTCCGAAGT   360
DQ524581-C.acuta           GAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGT   357
EU084146-C.aurata          GAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGT   358
DQ524609-A.lasiopygus      GAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGT   358
DQ524588-Anomala           GAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGT   358
EU084216-M.holosericea     GAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGT   358
EU084221-M.significans     GAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGT   358
DQ524596-H.seticollis      GAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGT   358
EU084231-M.melolontha      GAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGT   358
DQ524590-L.albistigma      GAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGT   358
EU084209-L.stradbrokensis  GAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGT   358

M.cuprescens               GAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGT   360
M.indica                   GAACTGGGTATAGGGGCGAAAGACTAATCGAACCATCTAGTAGCTGGTTCCCTCCGAAGT   360
                            *  ********************************** ************ ********

M.furcicauda               TTCCCTCAGGATAGCAGGGGTGGCCAACCGAAGTTTCTCTTTGTTCCGGTGAAGCGAAAG   420
DQ524581-C.acuta           TTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCA----TTCGGTAAAGCGAATG   413
EU084146-C.aurata          TTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCA----TTCGGTAAAGCGAATG   414
DQ524609-A.lasiopygus      TTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCA----TTCGGTAAAGCGAATG   414
DQ524588-Anomala           TTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCA----TTCGGTAAAGCGAATG   414
EU084216-M.holosericea     TTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCA----TTCGGTAAAGCGAATG   414
EU084221-M.significans     TTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCA----TTCGGTAAAGCGAATG   414
DQ524596-H.seticollis      TTCCCTCAGGATAGCTGGCGCTCGCTTCTCGCGAGTCTCA----TTCGGTAAAGCGAATG   414
EU084231-M.melolontha      TTCCCTCAGGATAGCTGGCGCTCGCTTCTTGCGAGTCTCA----TTCGGTAAAGCGAATG   414
DQ524590-L.albistigma      TTCCCTCAGGATAGCTGGCGCTCGCTTCTTGCGAGTCTCA----TTCGGTAAAGCGAATG   414
EU084209-L.stradbrokensis  TTCCCTCAGGATAGCTGGCGCTCGCTTCTTGCGAGTCTCA----TTCGGTAAAGCGAATG   414
M.cuprescens               TTCCCTCAGGATAGCTGGCGCTCGCTTCTTGCGAGTCTCA----TTCGGTAAAGCGAATG   416
M.indica                   TTCCCTCAGGATAGCTGGCGCTCGCTTCTTGCGAGTCTCA----TTCGGTAAAGCGAATG   416
                           *************** ** *    *  *    *  ****     * **** ******* *
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M.furcicauda                  GATTGAGGGCTTGGGGTCCAAAAGAACTTCATCCAATCCCCAACTTTTAATGGGTCCCAA    480
DQ524581-C.acuta              ATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGAT    473
EU084146-C.aurata             ATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGAT    474
DQ524609-A.lasiopygus         ATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGAT    474
DQ524588-Anomala              ATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGAT    474
EU084216-M.holosericea        ATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGAT    474
EU084221-M.significans        ATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGAT    474
DQ524596-H.seticollis         ATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGAT    474
EU084231-M.melolontha         ATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGAT    474
DQ524590-L.albistigma         ATTAGAGGCATTGGGGTCGAAACGACCTCAACCTATTCTCAAACTTTAAATGGGTGAGAT    474
EU084209-L.stradbrokensis     ATTAGAGGCATTGGGGTCGAAACGACCTCAACCTATTCTCAAACTTTAAATGGGTGAGAT    474
M.cuprescens                  ATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGAT    476
M.indica                      ATTAGAGGCATTGGGGTCGAAACGGCCTCAACCTATTCTCAAACTTTAAATGGGTGAGAT    476
                                * ****  ******** *** *  **  * * * ** * ****** *******    *

M.furcicauda                  GACCTATTTTCCTCCTTGG----ATGGGTGATCATCACAATAACCCTCCCTTGTGGGCCC    536
DQ524581-C.acuta              CTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCAC    533
EU084146-C.aurata             CTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCAC    534
DQ524609-A.lasiopygus         CTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCAC    534
DQ524588-Anomala              CTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCAC    534
EU084216-M.holosericea        CTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCAC    534
EU084221-M.significans        CTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCAC    534
DQ524596-H.seticollis         CTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCAC    534
EU084231-M.melolontha         CTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCAC    534
DQ524590-L.albistigma         CTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCAC    534
EU084209-L.stradbrokensis     CTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCAC    534
M.cuprescens                  CTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCAC    536
M.indica                      CTCCGGCTTGCTTGAACTGTGAAGCCGCGAGATATCGGATCAGAGTGCCAAGTGGGCCAC    536
                                **   ** * *     *       *      ***  *  *     **     ** * *

M.furcicauda                  TTTTGGTAAACAAAACTGGCGCCGGGGTATGAACCAAACGTTGAATTAAATCGTCCAAAA    596
DQ524581-C.acuta              TTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCTGAGTTAAAGCGCCTAAAT    593
EU084146-C.aurata             TTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCTGAGTTAAAGCGCCTAAAT    594
DQ524609-A.lasiopygus         TTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCTGAGTTAAAGCGCCTAAAT    594
DQ524588-Anomala              TTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCCGAGTTAAAGCGCCTAAAT    594
EU084216-M.holosericea        TTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCCGAGTTAAAGCGCCTAAAT    594
EU084221-M.significans        TTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCAGAGTTAAAGCGCCTAAAT    594
DQ524596-H.seticollis         TTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCAGAGTTAAAGCGCCTAAAT    594
EU084231-M.melolontha         TTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCCGAGTTAAAGCGCCTAAAT    594
DQ524590-L.albistigma         TTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCCGAGTTAAAGCGCCTAAAT    594
EU084209-L.stradbrokensis     TTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCCGAGTTAAAGCGCCTAAAT    594
M.cuprescens                  TTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCCGAGTTAAAGCGCCTAAAT    596
M.indica                      TTTTGGTAAGCAGAACTGGCGCTGTGGGATGAACCAAACGCCGAGTTAAAGCGCCTAAAT    596
                              ********* ** ********* * ** ************  ** ***** ** * ***

M.furcicauda                  TTACGCTAACAAACCC--ATTGAAAGTGGTTAATTCTTCACTCAGCAGGACGTTGACCTG    654
DQ524581-C.acuta              CGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCAT    653
EU084146-C.aurata             CGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCAT    654
DQ524609-A.lasiopygus         CGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCAT    654
DQ524588-Anomala              CGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCAT    654
EU084216-M.holosericea        CGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCAT    654
EU084221-M.significans        CGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCAT    654
DQ524596-H.seticollis         CGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCAT    654
EU084231-M.melolontha         CGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCAT    654
DQ524590-L.albistigma         CGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCAT    654
EU084209-L.stradbrokensis     CGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTATGACAGCAGGACGGTGGCCAT    654
M.cuprescens                  CGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCAT    656
M.indica                      CGACGCTTATGGGATACCATGAAAGGCGTTGGTAACTTAAGACAGCAGGACGGTGGCCAT    656
                                ***** *          **  ** * * *     ***    ********** ** **

M.furcicauda                  GGATGTTGAATCCCCCTACGAGTGGGGTAA    684
DQ524581-C.acuta              GGAAGTCGGAATCCGCTAAGGAGTGTGTAA    683
EU084146-C.aurata             GGAAGTCGGAATCCGCTAAGGAGTGTGTAA    684
DQ524609-A.lasiopygus         GGAAGTCGGAATCCGCTAAGGAGTGTGTAA    684
DQ524588-Anomala              GGAAGTCGGAATCCGCTAAGGAGTGTGTAA    684
EU084216-M.holosericea        GGAAGTCGGAATCCGCTAAGGAGTGTGTAA    684
EU084221-M.significans        GGAAGTCGGAATCCGCTAAGGAGTGTGTAA    684
DQ524596-H.seticollis         GGAAGTCGGAATCCGCTAAGGAGTGTGTAA    684
EU084231-M.melolontha         GGAAGTCGGAATCCGCTAAGGAGTGTGTAA    684
DQ524590-L.albistigma         GGAAGTCGGAATCCGCTAAGGAGTGTGTAA    684
EU084209-L.stradbrokensis     GGAAGTCGGAATCCGCTAAGGAGTGTGTAA    684
M.cuprescens                  GGAAGTCGGAATCCGCTAAGGAGTGTGTAA    686
M.indica                      GGAAGTCGGAATCCGCTAAGGAGTGTGTAA    686
                              *** ** * *  ** *** *    * ****
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Phylogenetic analysis

***Cox1* gene**

The *M. cuprescens* sequence showed 99.89 per cent similarity to *M. virescens* (= *P. fullo*), whereas *M. furcicauda* sequence showed 89.47 per cent similarity to *M. indica* (Fig. 1). This is the first report of *Cox1* sequences from *M. cuprescens, M. furcicauda, M. indica* and *M. virescens* (= *P. fullo*). The sequences of gene from these four species were also compared with closely related species *Melolontha* i.e. *M. hippocastani* (HM120757) and *M.*

hippocastani (KX087316) and two species of *Polyphylla* i.e. *Polyphylla gracilicornis* (MW143080) and *Polyphylla laticollis* (KF544959). The *Melolontha* species and *Polyphylla* species used in the present study did not show high similarity to *M. hippocastani* (HM120757), *M. hippocastani* (KX087316), *P. gracilicornis* (MW143080) and *P. laticollis* (KF544959) whose sequences were retrieved from the database. The *Cox1* sequences of *M. furcicauda* showed 86.02 and 86.51 per cent similarity to *M. hippocastani* (HM120757) and *M. hippocastani* (KX087316), and 82.34 and 81.64 per cent similarity to *P. gracilicornis* (MW143080) and *P. laticollis* (KF544959), respectively. The *M. indica* had 84.15 and 84.69 per cent similarity to *M. hippocastani* (HM120757) and *M. hippocastani* (KX087316), whereas it showed 82.84 and 83.33 per cent similarity to *P. gracilicornis* (MW143080) and *P. laticollis* (KF544959), respectively. The *M. cuprescens* showed 81.47 per cent similarity to *M. hippocastani* (HM120757), 81.69 per cent to *M. hippocastani* (KX087316), 80.32 per cent to *P. gracilicornis* (MW143080) and 82.49 per cent to *P. laticollis* (KF544959). *P. gracilicornis* (MW143080) and *P. laticollis* (KF544959) were distantly related to our species in the present study. The *M. hippocastani* strains were from France, *P. gracilicornis* from China and *P. laticollis* from Korea. The beetles of *Melolontha* and *Polyphylla* used in the present study were from north western Himalayan state of Himachal Pradesh, India, and represented geographically distinct regions. In confirmation to identification based on morphology, the *Melolontha* species were close to each other with the exception of *P. fullo*, which showed high similarity to *M. cuprescens*. The study further suggested that *Cox1* sequences could be used as barcode for identification purposes in insects.

The nucleotide frequencies in amplified *Cox1* sequences of three *Melolontha* species and one *Polyphylla* species were Adenine 34.4 per cent (A), Thymine 30.6 per cent (T), Cytosine 14.4 per cent (C), and Guanine 20.6 per cent (G). From these results it is inferred that across all sequences there existed an excess of Adenine and Thymine over Cytosine and Guanine. The transition/transversion rate ratios are k1 = 3.152 (purines) and k2 = 2.043 (pyrimidines). The overall transition/transversion bias is R = 1.264.

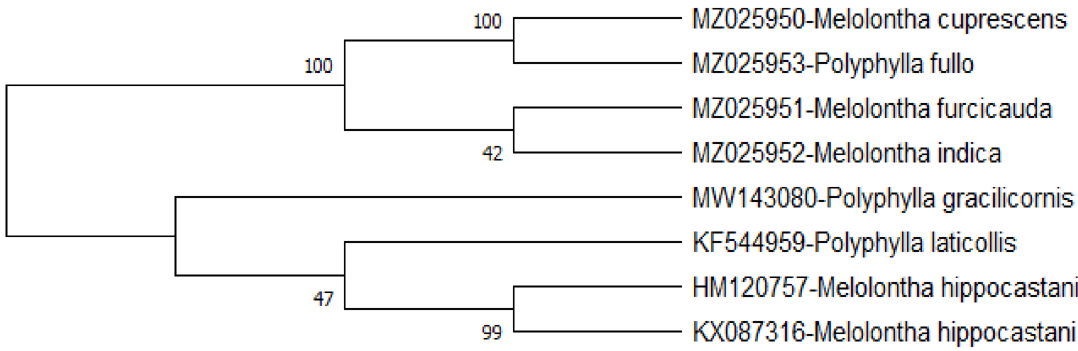


Fig 68. Phylogenetic relationships between five *Melolontha* and three *Polyphylla* species based on *Cox1* gene sequences. The tree was constructed using maximum likelihood method. The Boot Strap values are given on the branches

***28s rRNA* gene**

Based on the *28s rRNA* gene sequence, *M. indica* showed maximum identity of 99.42 per cent to *M. melolontha* (EU084231) as compared to *M. cuprescens* and *M. furcicauda* which were distantly related (Fig. 2). The *M. cuprescens* and *M. furcicauda* showed 98.88 and 89.02 per cent similarity to *M. melolontha*, respectively. *M. indica* is closer *L. albistigma* (DQ524590) and *L. stradbrokensis* (EU084209) as compared to *M. cuprescens* and *M. furcicauda* suggesting limited utility of *28s rRNA* gene in barcoding and identification of whitegrubs.

The nucleotide frequencies for *28s rRNA* gene sequences were Adenine 25.4 per cent (A), Thymine 21.4 per cent (T), Cytosine 23.4 per cent (C), and Guanine 29.8 per cent (G). Acursery look on the data clearly reflected an excess of Guanine and Adenine over Thymine and Cytosine across all sequences. The transition/transversion rate ratios were k1 = 1.086 (purines) and k2 = 16.956 (pyrimidines). The overall transition/transversion bias was R = 3.786.

The result obtained in the present study implies limited utility of *28s rRNA* gene sequences in taxonomical identification of white grubs especially *Melolontha* and *Polyphylla* species. It is pertinent to mention that the genera and species included for phylogenetic analysis were from India, Germany and Great Britain.

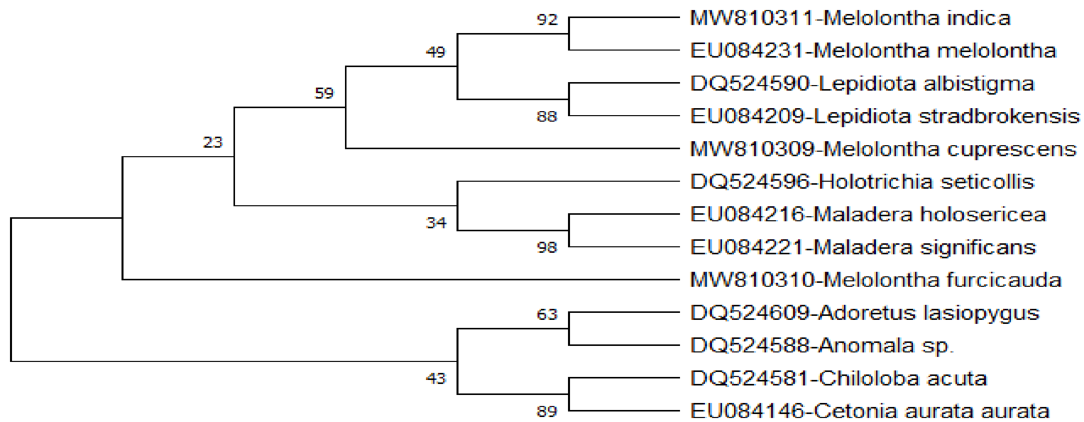


Fig. 69 Phylogenetic relationships between four *Melolontha* and nine different white grub species based on *28s rRNA* gene sequences. The tree was constructed using maximum likelihood method. The Boot Strap values are given on the branches

GBPUA&T, Pantnagar

1. Evaluation of IPM Strategy for the management of white grub damaging soybean (2020-21).

As the table 104 revealed that the plant mortality ranged from 3.26 to 24.20 percent during the study. Among the treatments, lowest plant mortality (3.26 %) was observed in treatment III after 40 days of application of treatment followed by treatment II having plant mortality of 6.33 percent. Similarly, after 80 days, lowest plant mortality was recorded in treatment III i.e. 13.67 % followed by treatment II. Highest plant mortality was observed in treatment I i.e. 24.20.

Highest and lowest yield was observed in treatment III and treatment II i.e. 20.15 and 12.12 q ha^{-1}, respectively. Thus, treatment III was found to be better than the all of the treatments including control where maximum reduction of yield was recorded.

Table 104 Evaluation of IPM Strategy for the management of white grub damaging soybean (2020-21).

Sl. No.	Treatment	Mean % plant mortality (DAS)			Grain yield (q ha^{-1})
		40	60	80	

T_1	IPM-I (*B. bassiana* 5g/m^2+seed treatment+ drenching of Imidacloprid 17.8 SL at 50 days after sowing)	6.65 (14.93)	16.38 (23.87)	24.20 (29.47)	12.12
T_2	IPM-I I (*M. anisopliae 5g*/m^2+seed treatment+ drenching of Fipronil 5 SC 3 l/ha at 50 days after sowing)	6.33 (14.55)	14.46 (22.34)	20.24 (26.73)	14.36
T_3	IPM-III (*M. anisopliae* 5g/m^2 +seed treatment+ drenching of Fipronil 40%+ Imidacloprid40% @ 500ml/ha at 50 days after sowing)	3.26 (10.31)	6.16 (14.36)	13.67 (21.69)	20.15
T_4	IPM-IV	9.43 (17.86)	27.64 (31.72)	46.93 (43.24)	7.67
SEm (±) **C.D. (5%)** **CV (%)**		0.53 1.83 6.37	0.24 0.84 1.83	0.45 1.56 2.58	0.45 1.56 2.58

2 Evaluation of IPM Strategy for the management of white grub damaging sugarcane (during 2020-21)

As the table 105 revealed that the sugarcane plant mortality ranged from 6.39 to 13.45 percent during the study while in control it ranged 13.63 to 13.45 percent. Among the treatments, lowest plant mortality (6.39 %) was observed in treatment III after 40 days of application of treatment followed by treatment, I having plant mortality of 7.37 percent. Similarly, after 80 days, lowest plant mortality was recorded in treatment III i.e. 9.63 % followed by treatment I. Highest plant mortality was observed in treatment T_2 i.e. 13.45.

Highest and lowest yield was observed in treatment T_3 and treatment T_1 i.e. 47.23 t /ha and 68.03 t / ha, respectively. Thus, treatment T_1 was found to be better than the all of the treatments including control where maximum reduction of yield was recorded.

Table 105. Evaluation of IPM Strategy for the management of white grub damaging sugarcane (during 2020-21).

Tr. No.	**Treatment**	**Mean % plant mortality (DAS)**			**Cane yield (t/ ha $^{-1}$)**
		40	**60**	**80**	
T_1	IPM-I (*B. bassiana 5g*/m^2+seed treatment+ drenching of Imidacloprid 17.8 SL at 50 days after sowing)	7.37 (15.72)	9.15 (17.59)	11.59 (19.89)	68.03

T_2	IPM-I I (*M. anisopliae* 5g/m^2+seed treatment+ drenching of Fipronil 5 SC 3 l/ha at 50 days after sowing)	8.50 (16.93)	11.66 (19.96)	13.45 (21.51)	65.73
T_3	IPM-III (*M. anisopliae* 5g/m^2 +seed treatment+ drenching of Fipronil 40%+ Imidacloprid40% @ 500ml/ha at 50 days after sowing)	6.39 (14.62)	8.50 (16.93)	9.63 (18.07)	68.32
T_4	IPM-IV	13.63 (21.66)	17.39 (24.64)	20.49 (26.91)	47.23
SEm (±) **C.D. (5%)** **CV (%)**		0.71 2.45 7.12	0.57 1.96 4.96	0.49 1.71 3.97	**0.82** **2.50** **8.46**

3. Management of soil arthropods i.e., cutworm through IPM in potato.

As the table 106 revealed that the mean percent tuber damage ranged from 7.80 to 17.56 percent during the study while in control it was 25.64 percent. Among the treatments, lowest tuber damage was observed in treatment 2 where the percent damage was 7.80 followed by Treatment III. Highest yield was also recorded in T2 i.e., 142.0.0 q/ha followed by Treatment III having 137.0 q/ha yield.

Table: 106. Management of soil arthropods i.e., cutworm through IPM in potato.

Sl. No.	Treatment	Mean % tuber damage (By number)	Marketable tuber yield (qha^{-1})
1	IPM-I (*B. bassiana 5g*/m^2+seed treatment+ drenching of Imidacloprid 17.8 SL at 50 days after sowing)	17.56 (24.77)	116.0
2	IPM-I I (*M. anisopliae* 5g/m^2+seed treatment+ drenching of	7.80 (16.20)	142.0

	Fipronil 5 SC 3 l/ha at 50 days after sowing)		
3	IPM-III (*M. anisopliae* 5g/m^2 +seed treatment+ drenching of Fipronil 40%+ Imidacloprid40% @ 500ml/ha at 50 days after sowing)	10.26 (18.68)	137.5
4	IPM-IV	25.64 (30.42)	48.03
SEm (±)		0.45	**1.082**
C.D. (5%)		1.56	**3.157**
CV (%)		3.47	**8.350**

VPKAS-Almora

1. Laboratory bioassay of 20 locally available insecticides against nine species of Scarabaeid beetles, native to Uttarakhand, Himalayas

Investigations under laboratory conditions were carried out to test the contact toxicity of twenty commonly used chemical insecticides, *viz*., acephate, acetamiprid, buprofezin, cartap hydrochloride, chlorantraniliprole, chlorfenapyr, chlorpyriphos, cyantraniliprole, cypermethrin, deltamethrin, dichlorvos, emamectin benzoate, fipronil, flubendiamide, imidacloprid, indoxacarb, lambdacyhalothrin, malathion, metasystox and spinosad against scarab beetle, *Popillia cupricollis*. Among the twenty insecticides, the treatment with chlorpyriphos 20% EC @ 2 mL/L and dicholorvos 76% EC @ 1 mL/L caused 100% mortality after 24 h of treatment, while malathion 50% EC @ 2 mL/L caused 93.33% mortality after 48 hours of treatment. These three insecticides were found to be the most efficient over all other insecticides tested.

2. Studies on gut microflora of major white grub species of Uttarakhand Himalayas

Endosymbiotic cellulolytic and chitinolytic bacteria were isolated from different regions *i.e*. midgut, anterior hindgut, fermentation chamber and posterior hindgut of the gastrointestinal tract of four white grub species (*Anomala bengalensis, Holotrichia seticollis, Anomala dimidiata* and *Holotrichia longipennis*) by cultural method (Plate 6). Cellulolytic activity of isolated cellulolytic bacteria was confirmed by the congo red clearing zone assay. Twenty six isolates that showed the highest cellulolytic activity *i.e*. cellulolytic index greater than 5 were chosen for further study. Eleven bacterial isolates were identified by phylogenetic analysis of 16S ribosomal RNA (rRNA) gene fragments. The result of BLAST-N (Basic Local Alignment Search Tool for Nucleotides) showed that cellulolytic bacteria isolated from white grub gut were *Bacillus subtilis, Bacillus velezensis, Nonumuraea* sp., *Paenibacillus* sp., *Streptomyces* sp. and rest six isolates belong to *Bacillus* sp. The phylogenetic tree of major cellulolytic bacteria isolated from guts of white grubs is given below.

Plate 6. Gut regions of white grub species (midgut, anterior hindgut, fermentation chamber and posterior hindgut of the gastrointestinal)

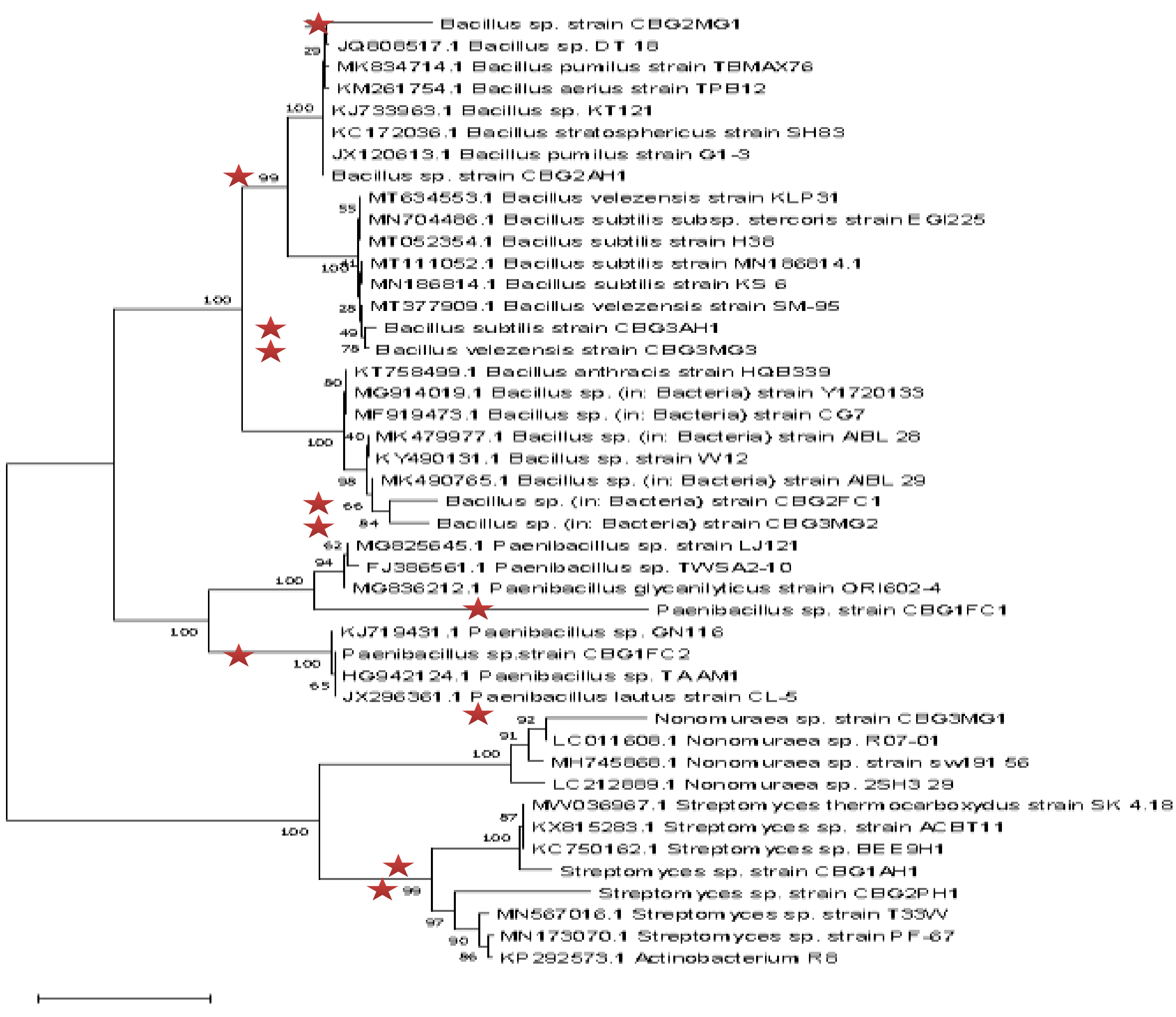


Fig. 70. Phylogenetic tree of major cellulolytic bacteria isolated from guts of four white grub species

- Twenty one chitinolytic bacteria were also isolated from the gut of white grub. Based on the 16S rDNA sequence, 07 isolates were identified as *Bacillus* sp., 02 as *Bacillus subtilis*, 02 as *Bacillus licheniformis*, 01 as *Actinobacterium* sp. and 01 as *Micromonospora* sp. (Fig 71)

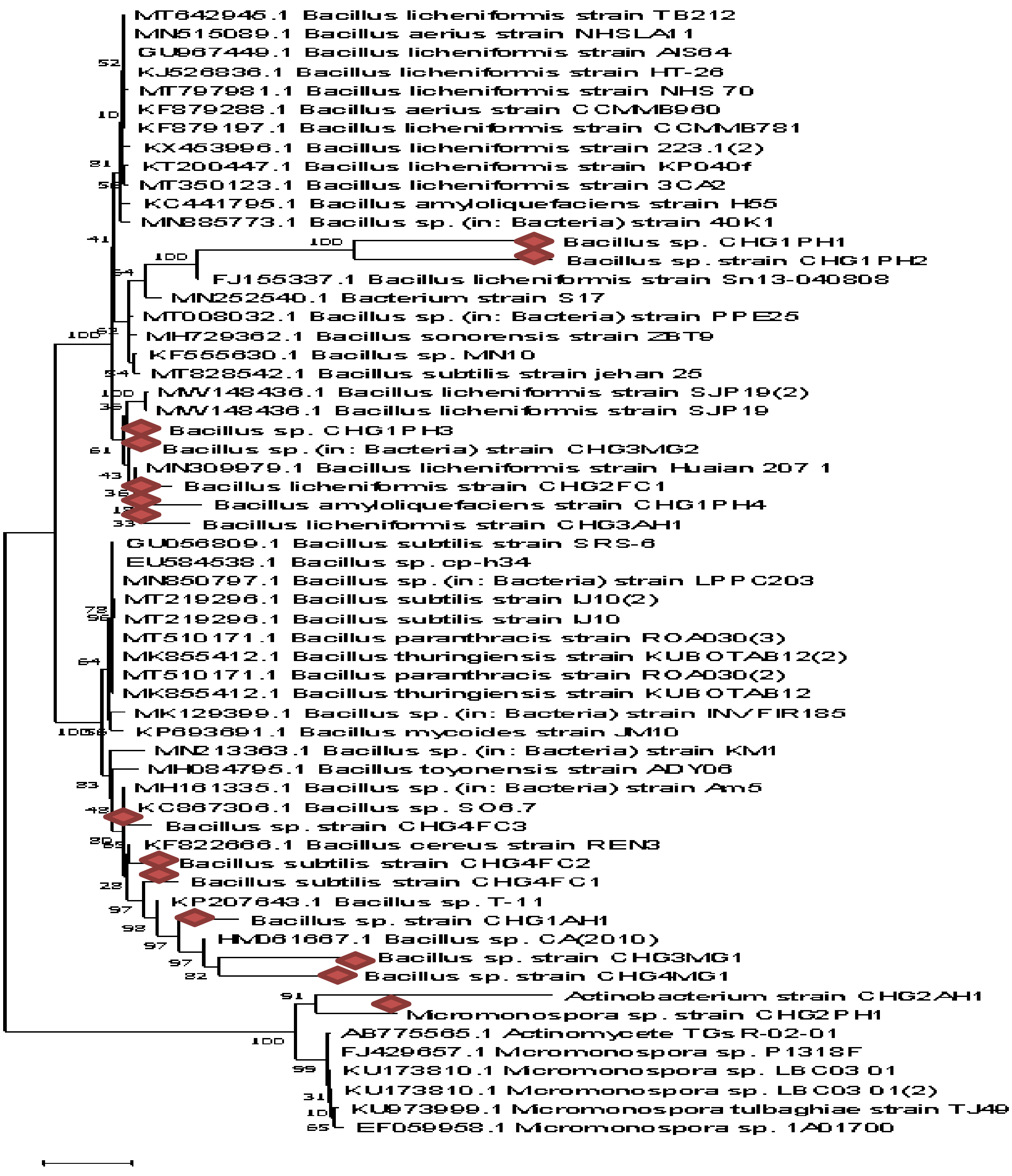


Fig. 71. Phylogenetic tree of major chitinolytic bacteria isolated from guts of four white grub species

3. DGGE analysis of unculturable gut bacterial diversity associated with white grubs

In order to analyse the gut bacterial diversity associated with white grubs an uncultured methodology, denaturing gradient gel electrophoresis (DGGE) was adopted to compare the diversity in prokaryotic community (alpha, beta, gamma proteobacteria and firmicutes) from gut compartments (midgut and hindgut) of five important species of white grubs *viz*., *A. dimidiata*, *A. bengalensis, A. lineatopennis, H. seticollis* and *H. Longipennis* (Figure 72a and b). The DGGE phylograms revealed high diversity of gamma-proteobacteria in midguts and alpha-proteobacteria in hindguts (Figure 5). Irrespective to the species, bacterial diversity is high in hindgut (39 phylotypes) rather than midgut (22 phylotypes). The phylotype patterns of all the tested prokaryotic groups in midguts are more or less similar in all the beetle species whereas, in hindgut are largely different. In hindgut phylotypes distinct differences particular to beetle species are observed, except for gamma proteobacteria where one prominent phylotype was present in all the tested species. A preliminary identification of the phylotypes using band sequencing also showed predominance of *Bacillus* species in firmicutes and *Enterobacter* and *Entomomonas* in gamma proteobacteria. The study reveals a preliminary comparison on gut prokaryotic community between white grub species which is first of its kind and also provides evidence of occurrence of some species/genus specific as well as coevolved community associated with this ecologically and agriculturally important taxa.

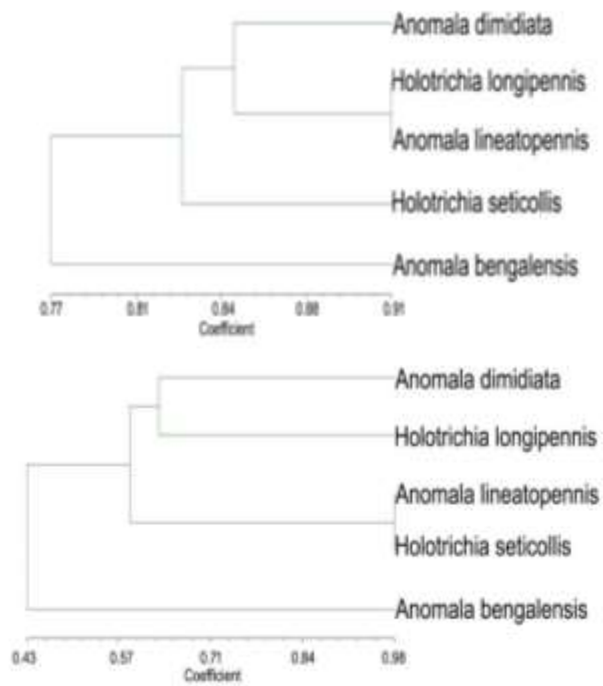


Fig. 72 a & b. Dendrogram of DGGE derived band diversity of white grub microbiota of midgut and hind gut

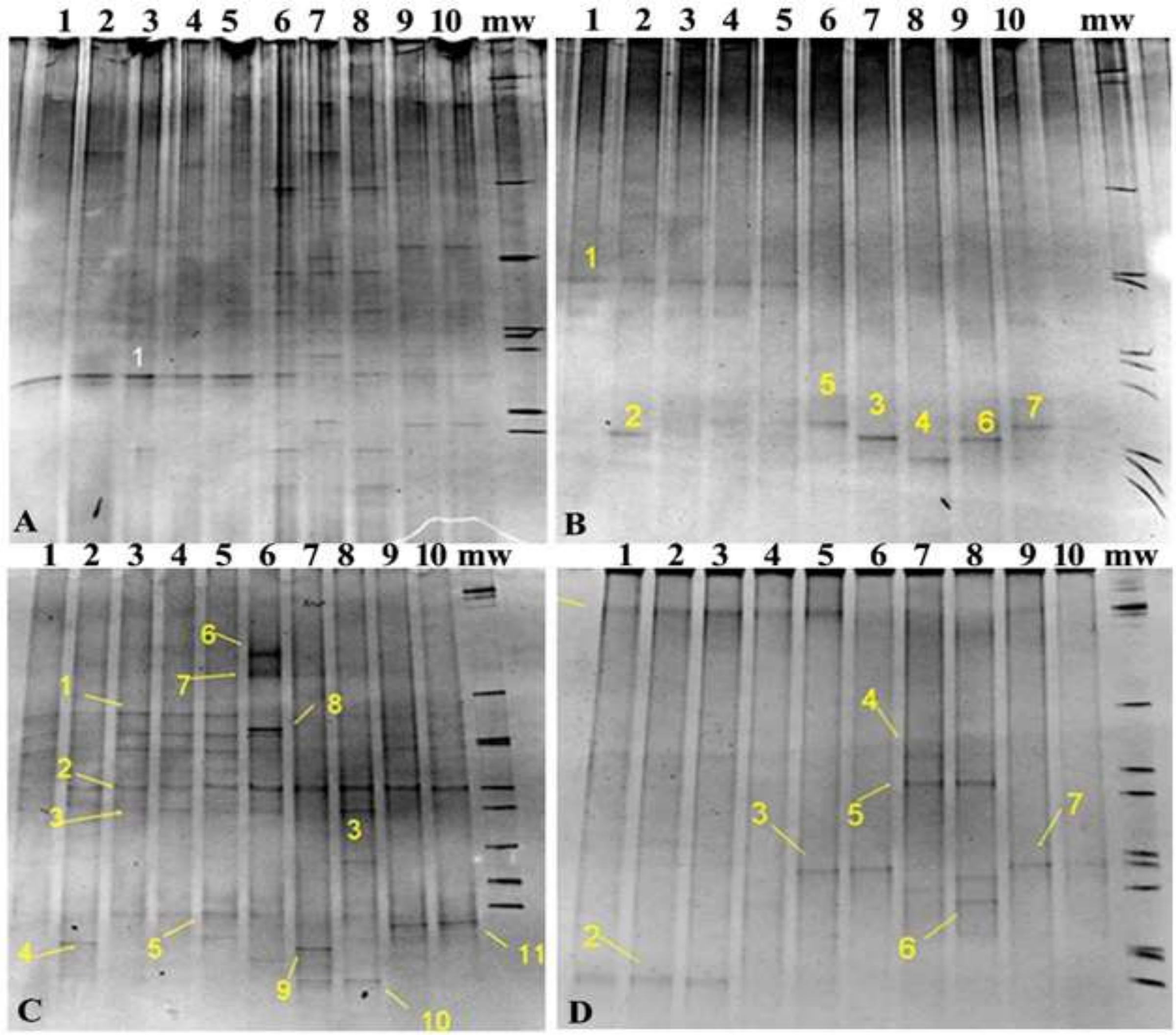


Fig. 73. Denaturing Gradient gel electrophoresis (DGGE) of 16SrRNA gene fragments of respective bacteria (A) α-Proteobacteria (B) β-Proteobacteria (C) γ-Proteobacteria and (D) Firmicutes. Line 1-5: Midguts of *A. dimidiata*, *A. bengalensis*, *A. lineatopennis*, *H. seticollis* and*H. longipennis* Line 6-10: Hindguts of *A. dimidiata*, *A. bengalensis*, *A. lineatopennis*, *H. seticollis* and *H. longipennis* respectively.

4. Phylogenetic studies on the major white grubs of the region

Out of the total 83 species of Scarabaeids available in the Uttarakhand, Himalayas, 60 species have been morphologically characterized and 45 species have been molecularly characterized using two universal primers specific to insects (COI and Cyt B). The complete lists of white grubs, whose COI and CytB genes are sequenced are furnished in table below (Table 107).

Table 107. List of white grub species molecularly characterized

Rutelinae	Species	COI	Cytb
1R	*Anomala dimidiata*	702	693
2R	*A. lineatopennis**	765	Seq
3R	*A. bengalensis* *	Seq	Seq
4R	*Adoretus sp1 #*	785	Seq
5R	*Mimela fulgidivittata*	797	722
6R	*A. rugosa*	791	746
7R	*Anomala sp1*	726	760
8R	*Adoretus versutus#*	754	Seq
9R	*A. rufiventris*	768	Seq
10R	*Anomala sp2*	777	760
11R	*Popillia cupricollis* *	Seq	Seq
12R	*P. cyanea* *	Seq	Seq
13R	*Adoretus simplex* *	Seq	Seq
14R	*Adoretus sp.nr. nasalis*	NP	NP
15R	*A. polita* *	Seq	Seq
16R	*A. biocolar* *	Seq	Seq
17R	*A. tristis* *	Seq	Seq
18R	*A. varicolor*	NP	NP
19R	*A. xanthoptera*	NP	NP
20R	*Mimela sps*	NP	NP
21R	*P. nasuta*	NP	NP

Melolonthinae	Species	COI	Cytb
1M	*Apogoniasetosa* *	753	Seq
2M	*Holotrichia longipennis*	691	745
3M	*Maladera similana*	619	715
4M	*Asactopholis microsquamosus* *	Seq	Seq
5M	*Sophrops sp1* *	Seq	Seq
6M	*Maladera iridescens*	780	701
7M	*Holotrichia sp1 #*	799	Seq
8M	*H. seticollis* *	733	Seq
9M	*Lepidiota stigma #*	649	697
10M	*Melolonthaindica*	772	762
11M	*M. nepalensis*	762	737
12M	*M. furcicauda* *	Seq	Seq
13M	*Maladera sp1*	815	Seq
14M	*L. sticticoptera #*	725	715
15M	*Brahmina coriaceae* *	Seq	Seq
16M	*Chrysoserica stebnickae*	796	682
17M	*Anticephalabatillina* *	Seq	Seq
18M	*Brahmina Sp1*	NP	NP
19M	*Brahmina Sp2*	NP	NP
20M	*Cephaloserica thomsoni* *	Seq	Seq
21M	*Hemiserica nasuta* *	Seq	Seq
22M	*Hilyotrogusholo sericeus*	NP	NP
23M	*H. rosettae* *	Seq	Seq
24M	*Holotrichia sp2*	NP	NP
25M	*Holotrichia sp3*	NP	NP
26M	*Holotrichia sp4*	NP	NP
27M	*Idionycha excise* *	Seq	Seq
28M	*Maladera marginella* *	Seq	Seq

Cetoninae	Species	COI	Cytb		Dynastinae	Species	COI	Cytb
1C	*Chiloba acuta*	771	698		1D	Xylotrupus gideon	762	718
2C	*Clinteria klugi*	NP	NP		2D	*Phyllognathus dionysius*	NP	NP
3C	*Clinteria spilota*	NP	NP		3D	*Eupatorius hardwickei*	NP	NP
4C	*Heterorrhina porpyretica*	NP	NP					
5C	*Oxycetonia jucunda*	NP	NP		Scarabinae	Species	COI	Cytb
6C	*Oxycetonia versicolor*	Seq	Seq		1S	*Helicopris* sp	793	666
7C	*Rhomborrhina opalina*	NP	NP					

FARMER- Ghaziabad

a. Scaling up of effective dose of EPN infected *Galleria* Cadaver for the control of White Grub on Sugarcane and other crops

The national pest white grub is a root feeder pest of major crops viz., sugarcane, groundnut, potato, sorghum, maize, turmeric and cucurbits vegetables. Sugarcane is one of the main commercial crop in the states of Uttar Pradesh, Uttrakhand, Maharashtra, Karnataka, Haryana and Punjab states of India covering an area of 5 million hectares out of which about 50% area is in UP alone. The 20-30% crop losses had generally been found in sugarcane, however, sometimes crop losses more than 80 percent has been recorded. Though, the infestation of white grub in western UP has mainly been recorded on sugarcane, sorghum, corn, etc. crops, however, the infestation on sugarcane, groundnut, soybean, turmeric, arecanut, coconut etc. crops in the states of Rajasthan, Haryana, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Gujarat, Assam and West Bengal has also been recorded.

With the ineffectiveness of chemical control of white grub, the application of bio-agents; Entomopathogenic Fungi (EPF) and Entomopathogenic Nematodes (EPNs) is showing promising results for management of white grub. Amongst EPF and EPN, the Entomopathogenic Nematode (EPN) - *Heterorhabditis indica* has emerged as one of the most potential bio-agent for the management of white grub attacking various crops, especially sugarcane.

Heterorhabditis indica (Nematoda: Rhabditida) is a heat tolerant species of entomopathogenic nematodes (EPNs) and is found parasitic to many soil dwelling insect pests at >25 degree centigrade. This beneficial nematode parasite of insects also uses a cruiser- type of foraging strategy to find their insect hosts. Infective juveniles of *H. indica* carry hundreds of cells of symbiotic bacteria (*Photorhabdus luminescens*) in their gut and this microflora becomes the weapon to kill their insect hosts. Evidently the native strain of EPN is more suitable for managing soil insect pests because of higher adaptation to local climate and other population regulating microbial flora. In a study conducted by FARMER, the native strain of EPN *Heterorhabditis indica* (MK078602) was isolated from village Sabitgarh, Bulandshahar district in Uttar Pradesh. The efficacy of the native strain of *H. indica* against *H. serrata* was evaluated by using surface soil incorporation method; under laboratory conditions and the results revealed maximum mortality with LD_{50} 89.601 and 115.050 against 1^{st} and 2^{nd} instar larvae after 168 hr of inoculation at ambient temperature. The efficacy of the native strain of *H. indica* in *Galleria* cadavers form was further studied against white grub in sugarcane crop field at Jallopur village in Amroha district of Uttar Pradesh during 2019-2020. The implantation of *H. indica* infected *Galleria* cadavers was done in sub soil at 8-10 cm depth near root zone @ 2,000 *Galleria* Cadavers (GC) per acre during June showed promising results with 69.23% white grub pest population reduction within 30-40 days after treatment. The eco-friendly alternative -EPNs showed good compatibility with most available pesticides also, hence, these can be incorporated as a potential bio-control agent in IPM strategies of root grubs and other soil arthropod pests.

b. Isolation and identification of Entomopathogenic Nematodes and Entomopathogenic Fungus from local soils.

Two types of EPN and Eight types of EPFs isolated from 141 soil samples during the current year 2020-21 from different crops viz., sugarcane, papaya, banana, and several vegetables fields. EPN and EPF are present in local soil at 1.42% and 5.67% respectively.

The two strains of entomopathogenic nematodes (EPNs) and eight strains of Entomopathogenic fungus (EPFs) isolated during current season by FARMER VC Ghaziabad.

Further multiplication of isolated strains of EPNs and EPFs is going on in laboratory to maintain strain wise culture and forwarded to IARI, New Delhi for identification.

Fig. 74 *Galleria mellonella* cadavers effected by new strain of EPNs; isolated from sugarcane crop field in Muzaffarnagar district

Now, a total of 9 EPNs strains are available in FARMER VC Ghaziabad. Culture maintained throughout the year of isolated and identified and unidentified strains of EPNs from different locations by FARMER VC Ghaziabad.

c. Study of Biology of major species of White Grub prevailing in Western U.P

The adult beetles of *H. Serrata*, *H. nagpurensis*, *H. Consanguinea* and *A. Dimidiate* were collected from field and placed in desiccators containing moist soil for oviposition and monitored eggs population laid by beetles on alternate days. The eggs were collected by sieving with 5 meshes on trays and then transferred to petri-plates containing moist soil. After hatching the neonates were transferred in to individual Plant pots on live roots of maize up to pupation and data of biological studies was recorded.

The growth and development of predominant species of white grub; *Holotrichia serrata* in western UP was studied on live roots of five different host plants, viz., maize (*Zea mays*), Sorghum (Sorghum bicolor), millet (*Pennisetum glaucum*), wheat (*Triticum aestivum*), and Barley (*Hordeum vulgare*) under controlled conditions at 30±5^{o}C temperature, 65±5% RH and 16:8 scoto photo period. The results are given bellow in table 108.

Table 108 Growth and development of *Holotrichia serrata* Fabricius on different host plants

Biological parameters	Host plants				
	Barley	Wheat	Millet	Sorghum	Maize
**Fecundity /Female (No.)	38±6.5	38±6.5	38±6.5	38±6.5	38±6.5
**Fertility /female (%)	94.2±11.3	94.2±11.	94.2±11.3	94.2±11.3	94.2±11.3
**Eggs period (days)	11.2±0.6	11.2±0.6	11.2±0.6	11.2±0.6	11.2±0.6
1st instar period (days)	15.0±1.0	16.3±1.0	15.7±1.5	25.0±1.0	21.3±1.2
2nd instar period (days)	36.3±2.0	39.0±2.5	30.0±2.0	48.7±1.5	37.7±2.0
3rd instar period (days)	36.7±3.5	64.3±1.5	77.0±3.5	99.0±3.5	96.0±3.5
Total grub period (days)	116.0±3	119.7±4.0	122.7±1.0	172.7±5	155.0±7.0
Pupation percentage	43.3±3.3	54.4±8.3	60.0±3.3	61.1±1.7	67.8±5.0
Pupal period (days)	35.3±1.5	34.7±3.5	30.3±3.0	26.7±2.5	22.7±2.5
Developmental period (days)	151.3±4.0	154.3±6.5	153.0±2.5	199.3±7.0	177.7±9.5
Emergence percentage	38.4±6.4	67.1±2.2	66.7±12.8	61.8±1.0	75.2±6.7
Adult period (days)	46.3±3	49.7±4	58.3±8	116.7±5.5	113.7±6.5
Survival percentage	16.7±3.3	35.5±6.7	40.0±8.3	37.8±1.7	75.2±6.7
Total period(days)	205.0±13.5	215.0±10.5	222.3±8.5	327.2±7.5	302.3±5.5
Grub growth index	0.37±0.03	0.45±0.07	0.49±0.03	0.35±0.02	0.44±0.02
Pupal growth index	1.09±0.36	1.95±0.27	2.22±1.14	2.33±0.22	3.37±0.67
Developmental index	0.20±0.05	0.23±0.08	0.26±0.06	0.19±0.01	0.28±0.04

*Mean of three replications, 30 neonates in each replicate

** Average of five field collected females

Further, the growth and development of predominant species of white grub; *Holotrichia serrata*, *H. consanguinea*, *H. Nagpurensis* in western UP was studied on live roots of maize (*Zea mays*) under controlled conditions at 30±5^{o}C temperature, 65±5% RH and 16:8 scoto photo period. The results are given in Table 109. The data will be analyzed for publication in esteemed journal.

Table 109. Biological attributes of three species of white grub reared on live maize roots in laboratory

Biological attributes	White grub species		
	H. serrata	***H. consanguinea***	***H. nagpurensis***
Fecundity (no)	38±6.5	45.8±4.5	29.8±8.0
Eggs period (days)	11.2±0.6	11.16±1.0	13.0±1.4
Fertility (%)	94.2±11.3	82.1 ±13.0	92.6±2.7
Pupation percentage (%)	68.16±11.14	50.00±18.3	71.2±16.8
Emergence percentage (%)	77.86±16.74	87.23±13.2	91.7±7.2
Survival percentage (%)	50.00±13.88	28.82±9.8	59.8±13.1
1st stage Grub period (days)	22±2.0	20.4±1.5	17.7±1.3
2nd stage Grub period (days)	38.6±3.5	34.86±2.9	35.1±1.4
3rd stage Grub period (days)	95.8±3.5	55.06±6.2	86.1±1.9
Total grub period(days)	156.4±7.0	110.32±6.1	137.3±3.9
Pupal period (days)	22.8±2.5	21.42±5.2	25.9±1.5
Beetle period (days)	115.2±6.5	54.3±3.2	101.9±10.4
Developmental period (days)	179.2±9.5	131.7±6.8	163.1±4.4
Total life cycle (days)	305.56±6.9	197.2±6.6	278.0±9.23
Grub growth index	179.2±9.5	0.47±0.19	0.52±0.11
Pupal growth index	3.25±0.70	4.18±0.74	3.54±0.24
Developmental index	0.26±0.07	0.27±0.08	0.37±0.07

d. Isolation of Phenomenal Compounds based on Air Entrainment Technology

The experiment could not be conducted due to the reason that the beetles collected from field were not virgin as they did not released gland when put in apparatus.

Fig. 75 *H. serrata* beetle with eggs

Fig. 76 3 Enlarged view of eggs of *H. consanguinea*

Fig. 78 Enlarged view of *H. nagpurensis* eggs

Fig. 79 Eggs and neonates oh *H .serrata*

Fig. 80 Eggs and neonates of *H consanguinea*

Fig. 81 Clearly visible embryo in side eggs and neonates of *H serrata*

Fig. 82 Neonate of *H. serrata*

Fig. 83 Second stage grubs of *H serrata*

Fig. 84 1st, 2nd and 3rd stage grub of *H. serrata*

Fig. 85 Pupa of *H. serrata*

Figure 86 Adult of *H. serrata*

Study on Biology of major species of White Grub prevailing in Western U.P

TSP programme

AAU JORHAT

The AINP on Soil Arthropod Pests, Assam Agricultural University, Jorhat centre has received an amount of Rs. 40.00 lakhs (Rupees forty lakhs only) during the financial year 2019-20 under the TSP grant from ICAR, New Delhi. The fund was utilized for giving material incentives like wheel hoe (40 nos.), water traps (400 nos.), solar dryers (10 nos.) etc. as well as publication and distribution of extension bulletin on red ants (1000 nos.) and book on "Arthropod and Molluscan Pests of North East India and Their Management" (250 nos.) to 400 farmers of Majuli. The materials were distributed in the "Awareness meeting on white grub" which was organized on 23rd Dec., 2020 to commemorate National Farmers' Day. An "Exposure visit programme" (3 days) of 40 organic progressive farmers of Majuli river island to Pabhoi Greens, a leading organic farm located at Biswanath, Assam was also organized to impart capacity building on organic exotic seed production, Hi-tech horticulture, Green house technology, apiculture, fisheries etc (Fig. 87).

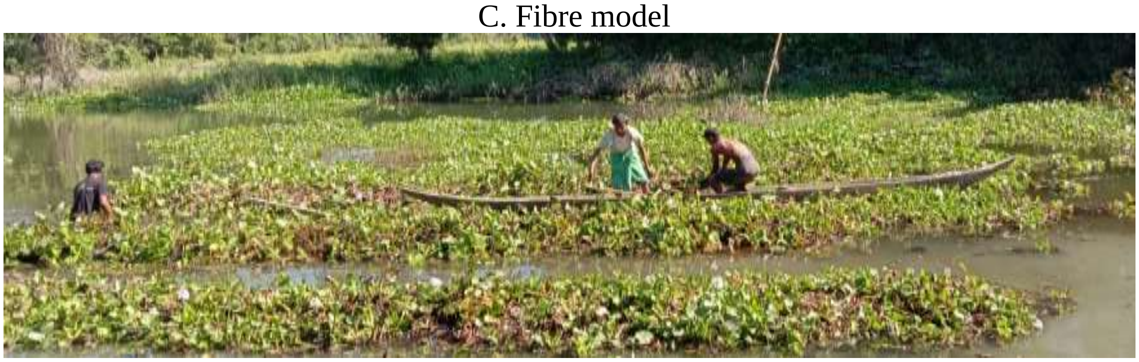
First ever attempt was made to prepare a fibre model depicting the technology on "Mechanical elimination of termite queen" for showcasing in the exhibitions/ farmers fair etc. Under capacity building programme, efforts have been made to introduce "Floating Agriculture" in the large water bodies of Majuli river island. Entrepreneurship development for making value added products by using insect powders through tribal women SHGs has also been initiated by utilizing the TSP fund. By following Farmers' Participatory Approach, efforts have already been made to construct "Village Training Centres" by depicting tribal culture and traditions at 4 different white grub endemic villages of Majuli, Assam. It would be explored as a common facility to impart training programmes as well as to explore the centre as a meeting place to interact with the farmers by the AAU Scientists/State Departments/NGOs etc. Those centres could also be used as relief camp during flood.

Efforts are also in progress to prepare a Documentary to showcase "Exploration of large community mobilization in white grub management at Majuli river island" as a success story of non-chemical management of white grubs (Fig. 88).


A. Distribution of materials to the beneficiary tribal farmers of Majuli

B. Exposure Visit of tribal farmers


C. Fibre model



D. Floating agriculture

Fig. 87 (A-D). Glimpses of activities undertaken by utilizing the TSP fund 2019-20

Fig. 88. Glimpses of shooting of documentary on "Exploration of large community

mobilization in white grub management at Majuli river island"

Transfer of Technology:

RARI Durgapura:

Under transfer of technology programme of the project, training programmes were organized in collaboration with govt. officials of Department of Agriculture, Govt. of Rajasthan for the farmers to educate them about whitegrub and its management. The trainings were organized about white grub control at different villages of Jaipur and Sikar districts. During training the farmers were apprised with the damage in various crops mainly groundnut and bajra, life cycle of the whitegrub, beetle and grub management through IPM technology including pheromone technology of beetle management, chemical and cultural control of grubs in the soil. At all locations farmers showed their keen interest and promised to adopt the technology in coming *kharif* season.

The beetle management was done on pre and post monsoon rain for three consecutive days. This operation was followed by sowing of groundnut after seed treatment with imidacloprid 600FS 6.5ml/kg seed. Standing crop treatment was also done on fields where sowing was done earlier without seed treatment with imidacloprid 17.8 SL at 300 ml/ha dose. Regarding impact of the technology, the compilation of the data is in progress.

TV talk: The scientists of AINP-SAP delivered TV talk on "Eco-friendly Management of white grub".

STAFF POSITION

RARI Durgapura

Post Sanctioned	In-position	Date of joining in the present post	Educational qualifications
Professor & Network Coordinator	Dr. Arjun Singh Baloda		Ph.D.(Agri.)
Assoc Professor	Dr. B.L. Jakhar	21.06.2018	Ph.D.(Agri.)
Agril. Supervisor	Sh. Ashok Kumar Verma		Secondary
Agril. Supervisor	Sh. Amar Chand Verma		Secondary
Senior Research Fellow	Dr. Kamal Kishor Saini	03.01.2018	Ph.D. Plant Pathology

AAU-Jorhat

Post Sanctioned	In-position	Date of joining in the present position	Educational qualifications
Principal Scientist & PI	Dr. Badal Bhattacharyya	01.07.2014	Ph.D (Agri.)
Junior Scientist	Dr. Sudhansu Bhagawati	01.03.2016	-do-
	Dr. Kritideepan Sarmah	24.06.2019	-do-
Senior Research Fellow	Dr. E. Bidyarani Devi	25.09.2018	-do-
	Ms. Nang Sena Manpoong	07.02.2019	M.Sc. (Agri.)

CSKHPKV- Palmpur

Name of the post	Name of the person	Working since
Principal Scientist	Dr. R. S. Chandel (PI)	01.04.2006
Professor (Entomology)	Dr. K. S. Verma (CoPI)	Since Feb, 2018
Junior Research Fellows	i) Dr. (Mrs) Suman Sanjta ii) Dr. Abhishek Rana	Since 12.03.2019 Since 06.03.2019

GKVK-Bengaluru

Name	Designation	Date of joining	Date of leaving
D. Rajanna	Associate Professor	3-2-2018	-
K V Prakash	Associate Professor	16-07-2009	-
U. Sahana	Senior Research Fellows	18-06-2018	on contract basis
P. Nirmala	Senior Research Fellows	8-6-2020	

GBPUA&T – Pantnagar

Name of the Post Sanctioned	No.	Name of the Incumbent	Date of joining	Date of leaving
Entomologist	One	Vacant	-	Continuing
Senior Entomologist	One	Vacant	-	-

LIST OF PUBLICATION

RARI, Durgapura

Research papers published

1. Nagal, G., Agarwal, V.K. and Baloda, A.S. (2021). Intrinsic toxicity evaluation of some newer insecticides against beetles of *Holotrichia consanguinea* Blanch. through adult vial test. *Journal of entomology and zoology studies* 9(1):1481-1484.
2. Jakhar, B.L., Baloda, A.S., Saini, K.K. and Yadav, T. (2020). Evaluation of some insecticides as seed dresser against white grubs in groundnut crop. Journal of Entomology and Zoology Studies, 8(3): 1468-1469.
3. Baloda, A.S., Jakhar, B.L., Saini, K.K. and Yadav, T. (2020). Efficacy of insecticides as standing crop treatment against white grubs in groundnut crop. Journal of Entomology and Zoology Studies, 9(2): 973-975.
4. Jakhar, B.L, Baloda, A.S., Saini, K.K. and Jakhar, M.L. (2020). Development and validation of IPM modules against major soil insect pests of groundnut. Journal of Entomology and Zoology Studies, 8(6): 1565-1567.
5. Chandel RS, Verma KS, Rana A, Sanjta S, Badiyala A, Vashisth S, Kumar R and Baloda A.S. (2021). The ecology and management cutworms in India. Oriental Insects, https//doi.org/10.1080/00305316.1936256.

AAU-Jorhat

BOOK		
1.	**"Arthropod and Molluscan Pests of North East India and Their Management"** by Badal Bhattacharyya, Sudhansu Bhagawati, Arjun Singh Baloda, Kritideepan Sarmah, Elangbam Bidyarani Devi, Nang Sena Manpoong, Partha Pratim Gyanudoy Das and Peter Shyam	
BOOK CHAPTER		
1.	**"Indigenous Pesticidal Plants of North-East India"** by Badal Bhattacharyya, Sudhansu Bhagawati, Snigdha Bhattacharjee, Partha Pratim G. Das and E. Bidyarani Devi	
2.	**"Biopesticides for pest management"** by Badal Bhattacharyya, Sudhansu Bhagawati and Snigdha Bhattacharjee	
3.	**"Insect Choreography"** by Dhanalakhi Gogoi, A.A.L.H. Baruah and Badal Bhattacharyya	
4.	**"Insect Memory"** by Dipendu Debbarma, Elangbam Bidyarani Devi and Badal Bhattacharyya	
5.	**"Insect Genomic Resources"** by Foridur Rahman Bora, A.A.L.H. Baruah and Badal Bhattacharyya	
6.	**"Insect robotics"** by Himangshu Mishra and Badal Bhattacharyya	
NAAS RATED NATIONAL JOURNAL		
1.	Gayan, A., Nath, D.J., Bhattacharyya, B. and Dutta, N. 2020. Assessment of soil quality indicators under rice ecosystem of Assam, India.	*Journal of Environmental Biology*, **41**: 1655-1664. (NAAS pt.: 6.56)

2.	S. Bhagawati, B. Bhattacharyya, B. K. Medhi, S. Bhattacharjee and H. Mishra. 2020. Diversity and density of Collembola as influenced by soil physicochemical properties in fallow land ecosystem of Assam, India.	*Journal of Environmental Biology*, **41**: 1626-1631. (NAAS pt.: 6.56)
3.	Devi, G., Amuri, B., Bhattacharyya, B., Pathak, K., and Bhagawati, S. 2020. Report of entomopathogenic nematode, *Heterorhabditis bacteriophora* from parasitised white grubs in lower Brahmaputra valley.	*Journal of Entomology and Zoology Studies*, **8** (5): 1198-1202. (NAAS pt.: 5.53)
4.	Das, M., Bhattacharyya, B., Bhagawati, S. and Mishra, H. 2020. Effect of different tillage practices on the existence of beetle holes of white grub, *Lepidiota mansueta* B. (Coleoptera: Scarabaeidae) in Majuli river island, Assam.	*Journal of Entomological Research*, **44** (2): 253-255. (NAAS pt.: 5.89)
5.	Das, P.P.G., Bhattacharyya, B., Bhagawati, S., Devi, E.B., Manpoong, N.S. and Bhairavi, K. S. 2020. Slug: An emerging menace in agriculture: A review.	*Journal of Entomology and Zoology Studies*, **8** (4): 01-06. (NAAS pt.: 5.53)
6.	Bhairavi, K.S. Bhattacharyya, B., Manpoong, N.S., Das, P.P.G, Devi, E.B and Bhagawati, S. 2020. Recent advances in exploration of acoustic pest management: A review.	*Journal of Entomology and Zoology Studies*, **8** (3): 2056-2061. (NAAS pt.: 5.53)
7.	Bhagawati, S., Bhattacharyya, B., Bhattacharjee, S., Devi, E. B., Manpoong, N.S., and Das, P.P.G. 2020. Microbial Bioremediation of Pesticide Residues: A Review.	*International Journal of Current Microbiology and Applied Sciences*, **9** (4): 1551-1561. (NAAS pt.: 5.38)
8.	Sailo, S., Bhagawati, S., Baishya, S., Sarmah, K. and Pathak, K. 2020. Nutritional and antinutritional properties of few common edible insect species of Assam.	*Journal of Entomology and Zoology Studies*, **8** (2): 1785-1791. (NAAS pt.: 5.53)
9.	Das,M.; Bhattacharyya, B.; Bhagawati, S. Devi, E.B. 2021. Efficiency of light sources in trapping *Lepidiota mansueta* adults in Assam.	*Indian Journal of Entomology*, **83**. doi No.: 10.5958/0974-8172.2020.00259.X (NAAS pt.: 5.08)
10.	Borkataki, S., Bhattacharyya, B., Sen, S., Taye, R.R., Reddy, M.D. and Nanda, S.P. 2021. Torpor in Insects.	*Current Science* (NAAS pt.: 6.73)
11.	Dutta, N., Mahanta, K., Gayan, A., Nath, D.J. and Bhattacharyya, B. 2020. Harnessing the potential of native cyanobacteria for plant growth promoting substances and lipid content.	*Journal of Environmental Biology*, **42**, 420-427. (NAAS pt.: 6.56)
12.	Borkataki, S., Bhattacharyya, B., Medhi, B.K. and Bhagawati, S. 2020. Impact of water quality parameters on aquatic insect fauna of Majuli river island, Assam, India.	*Journal of Environmental Biology*, **41**. doi: http://doi.org/10.22438/jeb (NAAS pt.: 6.56)

13.	Devi, E.B., Bhattacharyya, B. and Bhagawati, S. 2020. Evaluation of some IPM modules against red ant, *Dorylus orientalis* Westwood in potato.	*Indian Journal of Entomology* (Accepted) (NAAS pt.: 5.89)
14.	Das. P.P.G., Bhattacharyya, B., Bhagawati, S., Nath, D.J. and Sarmah, K. 2020. Methods of extraction of mucin from Giant African Snail *Achatina fulica* Bowdich. 2020.	*Indian Journal of Entomology* (Accepted) (NAAS pt.: 5.89)
15.	Devi, E.B., Bhattacharyya, B. and Bhagawati, S. 2021. Population Dynmamics of Red Ant *Dorylus orientalis* in potato grown under flood free/prone conditions.	*Indian Journal of Entomology*, 83. doi No.: 10.5958/0974-8172.2021.00086.9 (NAAS pt.: 5.89)
NON-NAAS RATED NATIONAL JOURNAL		
1.	Bhattacharyya, B., Bhagawati, S., Manpoong. N.S., Das, P.P.G. and Devi, E.B. 2021.	*Insect Environment*, **24** (1): 46-49.
LEAD PAPER PRESENTATION		
1.	Badal Bhattacharyya. Entomophagy for rural livelihood and nutritional security in India. /In: National Web Symposium on Recent Advances in Beneficial Insects and Natural Resins & Gums, organized by Society for Advancement of Natural Resins and Gums and ICAR-Indian Institute of Natural Resins and Gums, Namkum, Ranchi during February 25-26, 2021.	
2.	Badal Bhattacharyya, Nang Sena Manpoong, Partha Pratim Gyanudoy Das, Elangbam Bidyarani Devi and Sudhansu Bhagawati. 2021. Priorities of plant protection services of KVKs and social networking in ensuring food and nutritional security. Souvenir-cum-Abstract Book of National Conference on Priorities Crop Protection for Sustainable Agriculture.	
LECTURES DELIVERED IN CAFT & SHORT COURSES		
1.	Badal Bhattacharyya, P.P. Gyanudoy Das, E. Bidyarani Devi and Nang Sena Manpoong. 2020. Bioecology and Management of Giant African Snail in Organic Farming, CAFT lecture, Department of Soil Science, AAU, Jorhat.	
2.	**प्रमाणित किया जाता है कि डॉ बादल भट्टाचार्य, असम कृषि विश्वविद्यालय, जोरहट, असम ने दिनांक 08 अक्टूबर 2020 को ज़ूम पर आयोजित प्रशिक्षण वेबिनार शीर्षक 'अधिक आय एवं सुरक्षित पर्यावरण हेतु समेकित कीट प्रबंधन एवं उपयोगी कीट पालन' में व्याख्यान देकर सहभागिता की । भा.कृ.अनु.प.- भारतीय कृषि अनुसंधान संस्थान (MODEL TRAINING COURSE)**	
RESEARCH BULLETINS/ EXTENSION BULLETIN		
1.	*"Ronga Poruar huhangato niyantran Pranali"* by Badal Bhattacharyya, Sudhansu Bhagawati, Kritideepan Sarmah, Partha Pratim Gyanudoy Das, E. Bidyarani Devi, Nang Sena Manpoong and Peter Shyam.	
POPULAR ARTICLE		
1.	Badal Bhattacharyya, Sudhansu Bhagawati and Partha Pratim Gyanudoy Das. 2021. Entomophagy for Rural Livelihood and Nutritional Security in North East India. Rupantor (Souvenir), National Agri-Horticultural Show, Government of Assam (Date: 21-23 January, 2021), pp. 41-44.	

CSKHPKV- Palmpur

Research papers published

1. Chandel RS, Verma KS, Rana A, Sanjta S, Badiyala A, Vashisth S, Kumar R and Baloda A. 2021. Biology and management of cutworms in India. Oriental Insects (published online) DOI: 10.1080/00305316.2021.1936256 (NAAS: 6.33)
2. Chandel RS, Vshisth S, Soni S, Kumar and Kumar V. 2020. The Potato tuber moth, *Phthorimaea operculella* Zeller in India: Biology, ecology and control. Potato Research 63: 15-39.(NAAS: 6.93)
3. Chandel Y, Chandel RS, Verma KS and Rana A. 2021. New records of Scarabaeid beetles from Himachal Pradesh. National Academy Science Letters-India (Accepted) (NAAS: 6.42)
4. Joshi MJ, Rana Abhishek, Prithiv Raj V, Kaushal Shruti, Inamdar AG, Verma KS and Chandel RS. 2020. The potency of chemical insecticides in management of cutworm, *Agrotis ipsilon* Hufnagel (Noctuidae: Lepidoptera): A review. *Journal of Entomology and Zoology Studies* 2020 8(3): 307-311 (NAAS: 5.53
5. Rana Abhishek, R.S. Chandel, Verma K.S. and Joshi MJ. 2020. Termites in agriculturally important crops and their management- A review. Indian Journal of Entomology (published online) (NAAS: 5.89)
6. Rimpy and Verma K S. 2020. Toxicity of some insecticides against *Agrotis* spp. infesting cabbage. *Indian Journal of Entomology* 82(1): 139-142 (NAAS: 5.89)
7. Sanjta Suman, Mehta P.K. and Chandel R.S. 2020. Interaction effects of entomopathogenic nematodes and insecticides for the management of grubs of *Holotrichialongipennis* and *Brahminacoriacea*. *Journal of Environmental Biology* 41(3):637-643 (NAAS: 6.56)
8. Verma KS, Joshi M and Chandel RS, 2021. Threshold temperature and cumulative energy requirement for the development of cutworm, *A. ipsilon* Hufnagel. 2021. *Journal of Agrometereology* 23 (2) : 260-263 (NAAS: 6.47)

VPKAS, Almora

Research papers published

1. Subbanna, A. R. N. S., Stanley, J., Deol, A., Gupta, J. P., Mishra, P. K., Sushil, S. N., ... & and Amit Paschapur, J. B. (2020). Field evaluation of native white grub bio-agent, *Bacillus cereus* strain WGPSB-2 in Uttarakhand Himalayas and its impact on soil microbiota. Journal of Entomology and Zoology studies. 8(5): 2334-2340. (NAAS:5.53)
2. Nutan, A.R.N.S. Subbanna, **Amit Paschapur**, Ila Bisht, J. Stanley, K K Mishra. (2021). Efficacy of insecticides against common pleurostict scarab beetle species (coleoptera: scarabaeidae) of NW Himalayas, Uttarakhand, India. *Indian Journal of agricultural Sciences*. (Under review) (NAAS:6.25)
3. ARNS Subbanna, Nutan, **Amit Paschapur**, PK Mishra, J. Stanley, K K Mishra and L Kant. (2021). Gut microbial diversity across five important species of white grubs: An unculturable analysis on beetles of rutelinae and melolonthinae (Scarabaeidae: Coleoptera). *Biotech-3*. (Under review) (NAAS:7.80)

Book chapter

4. Paschapur, A., Subbanna, A. R. N. S., Singh, A. K., Jeevan, B., Stanley, J., Rajashekhar,

H., & Mishra, K. K. 2021. Unraveling the Importance of Metabolites from Entomopathogenic Fungi in Insect Pest Management. Microbes for Sustainable lnsect Pest Management: Hydrolytic Enzyme & Secondary Metabolite–Volume 2, 89.

FARMER-Ghaziabad

Research papers published

1. Swati, Jagpal Singh, Riazuddin, Rinni Sahrwat, Seema Rani **(2020)** In vivo evaluation of indigenous strain of *Heterorhabditis indica* against *Holotrichia serrata* F. Indian Journal of Entomology. 82(4): 858-860. (NAAS rating 5.89)
2. Riazuddin, Rinni Saharwat, Swati, Seema Rani, Jagpal Singh **(2020)** Efficacy of entomopathogenic nematodes against *Galleria mellonella* L. Indian Journal of Entomology. 82(3): 476-478. (NAAS rating 5.89).
3. Rinni Saharwat, Riazuddin, Seema Rani, Jagpal Singh **(2021)** Pathogenicity of entomopathogenic fungi *Metarhizium anisopliae* to white grub *Holotrichia serrata*. Journal of Entomology and Zoology Studies. 9 (1): 1207-1209. (NAAS rating 5.53)

Technology manual:

1. Jagpal Singh, Riazuddin, Rinni Sharawat, Seema Rani, Manish Kumar Sharma. **(2020)** Technology Manual-Automation Process for in vivo Mass Multiplication of Entomopathogenic Nematodes (EPN). Foundation for Agricultural Resources Management and Environmental Remediation (FARMER) (Accepted for publication in Indian Journal of Entomology)

Abstracts: (Total 4)

1. Jagpal Singh, Rajendran TP and Seema Rani **(2021)** Opportunities of Entrepreneurship Development in Indian Agriculture Sector, 6th National Youth Convention jointly organized by AIASA, ICAR and PJTSAU, Hyderabad from 20-21st February, 2021

2. Jagpal Singh, Seema Rani and Riazuddin **(2021)** Management of National Pest White Grub in Sugarcane Crop through *Heterorhabditis indica* infected *Galleria* Cadavers. Virtual Conference on "Biocontrol of Plant Diseases under Current Scenario of Restricted Pesticide Use" and the Annual Meeting of MEZ during January 27-28, 2021 at Aligarh Muslim University, Aligarh (UP), India. Abstract 18, page no. 14.

3. Jagpal Singh, Seema Rani, Riazuddin and Rinni Sehrawat **(2021)** Entomopathogenic Nematodes and Entomopathogenic Fungi suppress white grub pest in Sugarcane farms. Foundation for Agricultural Resources Management and Environmental Remediation (FARMER), Ghaziabad, UP, India, 2ND January 2021.

4. Seema Rani and Jagpal Singh **(2021)** Isolation and Identification of Entomopathogenic Nematodes and its Efficacy against Lepidopteran and Coleopterans Larvae, National Conference Organizing by Central Agricultural University, Imphal, on "Priorities in Crop Protection for Sustainable Agriculture" SUB THEM IPM Technologies: Bio-pesticides/ Biological control/Natural enemies, sponsored by ICAR- National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru at College of Agriculture, Iroisemba (CAU, Imphal) Manipur during March 16-18, 2021, IV-3: 181, https://www.researchgate.net/publication/350439616

LIST OF ESTEEMED VISITORS TO AINP ON SAP LABORATORY DURING 2020-21

Sl. No.	Name of the visitor	Date of visit	Designation
1.	Dr. Punabati Heisnam	26/02/2020	Assistant Professor, College of Horticulture and Forestry, CAU, Pasighat
2.	Dr. Sidhu Murmu	26/02/2020	Assistant Professor, BCKV, Mohanpur, Nadia, West Bengal
3.	Dr. Kaushik Batabyal	26/02/2020	Assistant Professor, Soil Science, Directorate of Research, BCKV, West Bengal
4.	Dr. Prerna B. Chikte	26/02/2020	Assistant Professor, Entomology, AICRP (Chickpea), PDKV, Akola
5.	Dr. Vijaymahantesh	26/02/2020	Assistant Professor, Agronomy, UHS, Karnataka
6.	Dr. Madan K. Bhattacharyya	28/02/2020	Professor, Department of Agronomy, Iowa State University, Ames, US
7.	Ms. Babita Begum Choudhury	18/03/2020	SAMETI, Guwahati
8.	Ms. Purnima Das	18/03/2020	SAMETI, Guwahati
9.	Mr. Vinod Seshan	31/10/2020	IAS, State Project Director, ARIAS Society, Govt. of Assam
10.	Dr. Sreemant Phukan	05/01/2021	Monitoring and Evaluation Specialist, ARIAS Society, Govt. of Assam
11.	Mr. Puspadhar Das	28/01/2021	MD, Sitajakhala Milk Cooperative Society, Jagiroad, Assam

Annexure I

Division of Germplasm Collection and Characterization
ICAR- National Bureau of Agricultural Insect Resources, H. A. Farm Post,
Hebbal, Bellary Road, Bengaluru - 560 024, Karnataka, India

10-08-2020

Dr. Kolla Sreedevi
Senior Scientist

To,
Sri Jagpal Singh,
FARMER,
Ghaziabad- 201 002, U.P.

Sir,

Sub: Identification of the specimens received on 20-07-2020 – reg

Kindly find below the identification report of the specimens sent to us from your organization.

Code No.	No of specimens	Scientific name	Sub family	Family
1	01	*Alissonotum* sp. (F.)	Dynastinae	Scarabaeidae
2	01	*Alissonotum* sp. (F.)		
3	01	*Alissonotum* sp. (F.)		
4	01	*Onthophagus* sp.	Scarabaeinae	
5	01	*Phyllognathus dionysius* (F.)	Dynastinae	
6	01	*Phyllognathus dionysius* (F.)		
7	01	*Phyllognathus dionysius* (F.)		
8	01	*Onthophagus* sp.	Scarabaeinae	
9	01	*Phyllognathus dionysius* (F.)	Dynastinae	
10	01	*Onthophagus* sp.	Scarabaeinae	
11	01	*Holotrichia serrata* (F.)	Melolonthinae	
12	01	*Onitis* sp.	Scarabaeinae	

13	01	Dynastine sp.	Dynastinae	
14	01	Dynastine sp.		
15	01	*Phyllognathus dionysius* (F.)		
16	01	*Holotrichia serrata* (F.)	Melolonthinae	
17	01	*Holotrichia serrata* (F.)		
18	01	*Holotrichia serrata* (F.)		
19	01	*Holotrichia serrata* (F.)		
20	01	*Holotrichia serrata* (F.)		
21	01	*Holotrichia serrata* (F.)		
22	01	*Phyllognathus dionysius* (F.)	Dynastinae	
23	01	*Holotrichia serrata* (F.)	Melolonthinae	
24	01	*Holotrichia serrata* (F.)		
25	01	*Holotrichia serrata* (F.)		
26	01	*Holotrichia serrata* (F.)		
27	01	*Holotrichia serrata* (F.)		
28	01	*Holotrichia nagpurensis* Khan and Ghai		
29	01	*Holotrichia serrata* (F.)		
30	01	*Holotrichia serrata* (F.)		
31	01	*Holotrichia serrata* (F.)		
32	01	*Holotrichia serrata* (F.)		
33	01	*Holotrichia serrata* (F.)		
34	01	*Holotrichia serrata* (F.)		
35	01	*Holotrichia serrata* (F.)		
36	01	*Holotrichia consanguinea* (Blanchard)		
37	01	*Holotrichia serrata*		
38	01	*Holotrichia serrata* (F.)		

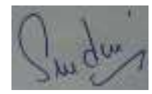
39	01	*Holotrichia serrata* (F.)		
40	01	*Holotrichia serrata* (F.)		
41	01	*Holotrichia serrata* (F.)		
42	01	*Holotrichia serrata* (F.)		
43	01	*Holotrichia serrata* (F.)		
44	01	*Holotrichia serrata* (F.)		
45	01	*Holotrichia serrata* (F.)		
46	01	*Holotrichia serrata* (F.)		
47	01	*Holotrichia serrata* (F.)		
48	01	*Holotrichia nagpurensis* Khan and Ghai		
49	01	*Holotrichia serrata* (F.)		
50	01	*Holotrichia serrata* (F.)		
51	01	*Holotrichia serrata* (F.)		
52	01	*Holotrichia serrata* (F.)		
53	01	*Holotrichia serrata* (F.)		
54	01	*Holotrichia serrata* (F.)		
55	01	*Holotrichia serrata* (F.)		
56	01	*Holotrichia serrata* (F.)		
57	01	*Holotrichia serrata* (F.)		
58	01	*Holotrichia serrata* (F.)		
59	01	*Holotrichia serrata* (F.)		
60	01	*Holotrichia serrata* (F.)		
61	01	*Holotrichia nagpurensis* Khan and Ghai		
62	01	*Holotrichia serrata* (F.)		
63	01	*Holotrichia serrata* (F.)		
64	01	*Holotrichia serrata* (F.)		

65	01	*Holotrichia serrata* (F.)		
66	01	*Holotrichia serrata* (F.)		
67	01	*Holotrichia serrata* (F.)		
68	01	*Holotrichia serrata* (F.)		
69	01	*Holotrichia serrata* (F.)		
70	01	*Holotrichia serrata* (F.)		
71	01	*Holotrichia serrata* (F.)		
72	01	*Holotrichia serrata* (F.)		
73	01	*Holotrichia serrata* (F.)		
74	01	*Holotrichia serrata* (F.)		
75	01	*Holotrichia consanguinea* (Blanchard)		
76	01	*Anomala dorsalis* (F.)	Rutelinae	
77	01	*Holotrichia serrata* (F.)	Melolonthinae	
78	01	*Holotrichia serrata* (F.)		
79	01	*Holotrichia serrata* (F.)		
80	01	*Holotrichia serrata* (F.)		
81	01	*Holotrichia serrata* (F.)		
82	01	*Holotrichia serrata* (F.)		
83	01	*Holotrichia serrata* (F.)		
84	01	*Holotrichia serrata* (F.)		
85	01	*Holotrichia serrata* (F.)		
86	01	*Holotrichia serrata* (F.)		
87	01	*Holotrichia serrata* (F.)		
88	01	*Holotrichia serrata* (F.)		
89	01	*Holotrichia serrata* (F.)		
90	01	*Holotrichia serrata* (F.)		

91	01	*Holotrichia serrata* (F.)		
92	01	*Holotrichia serrata* (F.)		
93	01	*Holotrichia serrata* (F.)		
94	01	*Holotrichia serrata* (F.)		
95	01	*Holotrichia consanguinea* (Blanchard)		
96	01	*Holotrichia serrata* (F.)		
97	01	*Holotrichia nagpurensis* Khan and Ghai		
98	01	*Schizonycha ruficollis*		
99	01	*Holotrichia serrata*		
100	01	*Holotrichia serrata* (F.)		
101	01	*Holotrichia serrata* (F.)		
102	01	*Holotrichia serrata* (F.)		
103	01	*Holotrichia serrata* (F.)		
104	01	*Holotrichia serrata* (F.)		
105	01	*Holotrichia serrata* (F.)		
106	01	*Holotrichia serrata* (F.)		
107	01	*Holotrichia serrata* (F.)		
108	01	*Holotrichia serrata* (F.)		
109	01	*Holotrichia serrata* (F.)		
110	01	*Holotrichia serrata* (F.)		
111	01	*Holotrichia serrata* (F.)		
112	01	*Holotrichia serrata* (F.)		
113	01	*Holotrichia serrata* (F.)		
114	01	*Holotrichia serrata* (F.)		
115	01	*Holotrichia serrata* (F.)		
116	01	*Holotrichia serrata* (F.)		

117	01	*Holotrichia serrata* (F.)		
118	01	*Holotrichia serrata* (F.)		
119	01	*Holotrichia serrata* (F.)		
120	01	*Holotrichia serrata* (F.)		
121	01	*Holotrichia serrata* (F.)		

Yours sincerely



(K. SREEDEVI)

Annexure 1I

Geographical details of the study areas Karnataka

Location	Longitude	Latitude	Altitude (m)
Shivally	12.587043	76.82164	771
Mahadeshwarapura	12.57539	76.673053	678
Gejjalagere	12.569458	76.999234	653
Gundlupet	11.808346	76.692726	816
Medini	12.211023	76.903801	653
KR Pet	12.659594	76.489716	813
Malavalli	12.385343	77.05358	632
Nanjanagudu	12.11597	76.678249	670
Palalli	12.409603	76.653544	718
Chikkaballapur	13.435498	77.731534	919
GKVK	13.080072	77.578515	945
Malur	13.003723	77.938303	910
Sira	13.765437	76.940077	651
Rajavanthi	14.029001	77.283439	678
Hassan	13.003323	76.100389	943
Bhadravathi	13.827272	75.706378	601
Kukwada	13.922944	75.871189	776
Hulagar	13.480995	75.224178	668
Shuntikatte	13.607234	75.265771	650
Araga	13.689496	75.244989	631
Naravi	13.12347	75.147355	113
Iruvail	13.011537°	74.991310°	71
Mantrady	13.105601°	75.105403°	85
Kannangi	13.796748°	75.369600°	655
Laxmipura	13.607234°	75.265771°	665