STUDIES ON PRESENT STATUS OF WHITE GRUB, *Holotrichia serrata* (Fabricius) (Coleoptera : Scarabaeidae) IN BELAGAVI DISTRICT AND ITS MANAGEMENT

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CONTENTS

Sl. No.	Chapter Particulars
	CERTIFICATE
	ACKNOWLEDGEMENT
	LIST OF TABLES
	LIST OF FIGURES
	LIST OF PLATES
	LIST OF APPENDIX
1.	INTRODUCTION
2.	REVIEW OF LITERATURE
	2.1 Species composition of white grubs
	2.2 Population dynamics of white grubs
	2.3 Behavioural pattern of white grubs
	2.4 Loss estimation due to white grubs
	2.5 Efficacy of Entomopathogens and newer molecules of insecticides against white grubs
3.	MATERIAL AND METHODS
	3.1 Species composition of white grubs
	3.2 Population dynamics of sugarcane white grub*, Holotrichia serrata*
	3.3 Behavioural pattern of *Holotrichia serrata* adult in sugarcane
	3.4 Loss estimation in sugarcane due to *Holotrichia serrata* and per cent infestation in other crops
	3.5 Efficacy of Entomopathogens and newer molecules of insecticides against white grub, *Holotrichia serrata*
4.	EXPERIMENTAL RESULTS
	4.1 Species composition of white grubs
	4.2 Population dynamics of sugarcane white grub, *Holotrichia serrata*
	4.3 Behavioural pattern of *Holotrichia serrata* adults in sugarcane
	4.4 Loss estimation in sugarcane due to *Holotrichia serrata* and per cent infestation in other crops
	4.5 Efficacy of entomopathogens and newer molecules of insecticides against *Holotrichia serrata*
5.	DISCUSSION
	5.1 Species composition and abundance of *Holotrichia serrata*
	5.2 Population dynamics of sugarcane white grub, *Holotrichia serrata*
	5.3 Behavioural pattern of *Holotrichia serrata* adults in sugarcane
	5.4 Loss estimation in sugarcane due to *Holotrichia serrata* and per cent infestation in

	other crops
	5.5 Efficacy of entomopathogens and newer molecules of insecticides against *Holotrichia serrata*
6.	SUMMARY AND CONCLUSIONS
	REFERENCES
	APPENDIX

LIST OF TABLES

Table No.	Title
1.	Materials/sources used for trapping *Holotrichia serrata*. adults
2.	Chemicals used for trapping adults of *Holotrichia serrata*
3.	Entomopathogens evaluated in the laboratory/field against *Holotrichia serrata* grub
4.	Evaluation of newer molecules of insecticides used in the laboratory/field against grubs of *Holotrichia serrata*
5.	Species composition and abundance of white grubs in sugarcane ecosystem - Kadapur
6.	Species composition and abundance of white grubs in sugarcane ecosystem – Soundalga
7.	Species composition and abundance of white grubs in sugarcane ecosystem – Bellad Bagewadi
8.	Species composition and abundance of white grubs in sugarcane ecosystem – Sankeshwar
9.	Species composition and abundance of white grubs in rainfed ecosystem – Hattarwat
10.	Correlation studies for adult emergence of white grub over different locations during 2011-13
11.	Population dynamics of different stages of sugarcane white grub, *Holotrichia serrata* in Ankali location of Belagavi district during 2011- 2012
12.	Pooled population dynamics (2011 and 2012) of different stages of sugarcane white grub, *Holotrichia serrata* in Ankali location of Belagavi district
13.	Population dynamics of different stages of sugarcane white grub, *Holotrichia serrata* in Bellad Bagewadi location of Belagavi district during 2011-2012
14.	Pooled population dynamics (2011-2012) of different stages of sugarcane white grub, *Holotrichia serrata.* in Bellad Bagewadi location of Belagavi district
15.	Population dynamics of different stages of sugarcane white grub, *Holotrichia serrata* in Kadapur location of Belagavi district during 2011-2012
16.	Pooled population dynamics (2011-2012) of different stages of sugarcane white grub, *Holotrichia serrata* in Kadapur location of Belagavi district
17.	Population dynamics of different stages of sugarcane white grub, *Holotrichia serrata* in Kochari location of Belagavi district during 2011-2012
18.	Pooled population dynamics (2011-2012) of different stages of sugarcane white grub, *Holotrichia serrata* in Kochari location of Belagavi district
19.	Population dynamics of different stages of sugarcane white grub, *Holotrichia serrata* in Sankeshwar location of Belagavi district during 2011-2012
20.	Pooled population dynamics (2011-2012) of different stages of sugarcane white grub,

	Holotrichia serrata in Sankeshwar location of Belagavi district
21.	Population dynamics of different stages of sugarcane white grub, *Holotrichia serrata* in Soundalga location of Belagavi district during 2011-2012
22.	Pooled population dynamics (2011-2012) of different stages of sugarcane white grub, *Holotrichia serrata* in Soundalga location of Belagavi district
23.	Evaluation of different trapping sources on mean number of *Holotrichia serrata* beetles caught under natural conditions (2011)
24.	Evaluation of different trapping sources on mean number of *Holotrichia serrata* beetles caught under natural conditions (2012)
25.	Pooled data on evaluation of different trapping sources on mean number of *Holotrichia serrata* beetles caught under natural conditions
26.	Field evaluation of chemicals with pheromone/kairomone activity on mean number of *Holotrichia serrata* adults caught (2011)
27.	Field evaluation of chemicals with pheromone/kairomone activity on mean number of *Holotrichia serrata* adults caught (2012)
28.	Pooled data (2011 and 2012) on field evaluation of chemicals with pheromone/kairomone activity on mean number of *Holotrichia serrata* adults caught
29.	Mean grub load of *Holotrichia serrata* in different *Kharif* crops -2011
30.	Mean grub load of *Holotrichia serrata* in different *Kharif* crops -2012
31.	Pooled mean grub load of *Holotrichia serrata* in different *Kharif* crops
32.	Mean grub load of *Holotrichia serrata* in different *Rabi* crops
33.	Varietal reaction and loss estimation of yield and yield related parameters due to *Holotrichia serrata* infestation (2011)
34.	Varietal reaction and loss estimation of yield and yield related parameters due to *Holotrichia serrata* infestation (2012)
35.	Varietal reaction and loss estimation of yield and yield related parameters due to *Holotrichia serrata* infestation (pooled)
36.	Per cent infestation of *Holotrichia serrata* in different crops
37.	Laboratory evaluation of entomopathogens against second instar sugarcane white grub, *Holotrichia serrata*
38.	Field evaluation of entomopathogens against white grub, *Holotrichia serrata*
39.	Pooled data on field evaluation of entomopathogens against white grub, *Holotrichia serrata*
40.	Laboratory evaluation of newer molecules of insecticides against second instar *Holotrichia serrata* grub
41.	Field evaluation of newer molecules of insecticides against *Holotrichia serrata*
42.	Pooled data on field evaluation of newer molecules of insecticides against *Holotrichia serrata*
43.	Cost economics of different entomopathogens
44.	Cost economics of different insecticidal treatments

LIST OF FIGURES

Figure No.	Title
1.	Species composition and abundance of white grubs in sugarcane ecosystem – Kadapur
2.	Species composition and abundance of white grubs in sugarcane ecosystem – Soundalga
3.	Species composition and abundance of white grubs in sugarcane ecosystem – Bellad Bagewadi
4.	Species composition and abundance of white grubs in sugarcane ecosystem – Sankeshwar
5.	Species composition and abundance of white grubs in rainfed ecosystem – Hattarwat
6.	Pooled data on evaluation of different trapping sources on mean number of *Holotrichia serrata* beetles caught under natural conditions
7.	Pooled data on varietal reaction and loss estimation of yield and yield related parameters due to *Holotrichia serrata* in different sugarcane genotypes
8.	Pooled data on NMC and cane yield as influenced by entomopathogens against white grub, *Holotrichia serrata*
9.	Pooled data on NMC and cane yield as influenced by newer molecules of insecticides against white grub, *Holotrichia serrata*

LIST OF PLATES

Plate No.	Title
1.	Cotton swab with attractant material for trapping adults
2.	Soil thermometer installed for recording soil temperature
3.	Field nurseries for rearing *Holotrichia serrata* grubs
4.	Plastic boxes/trays used for laboratory evaluation of entomopathogens and newer insecticides
5.	Species composition of white grubs
6.	Third instar grub, pupa and quiescent adult of *Holotrichia serrata* (Bellad Bagewadi)
7.	Third instar grub and Pupa of *Holotrichia serrata* (Kadapur)
8.	Third instar grub of *Holotrichia serrata* (Kochari)
9.	Third instar grub and pupa of *Holotrichia serrata* (Bellad Bagewadi)

10.	Quiscent adult of *Holotrichia serrata*
11.	Neem leaves as a trapping source for *Holotrichia serrata* adults
12.	Infestation of *Holotrichia serrata* in brinjal, soybean, groundnut and turmeric crops
13.	Infestation of *Holotrichia serrata* in paddy, sorghum, sugarcane and chilli
14.	Reaction of different varieties (120 days old) to *Holotrichia serrata* infestation
15.	Cane girth in unprotected and protected plots of CoC671
16.	*M. anisopliae* infected *H. serrata* grub (early symptom)
17.	*M. anisopliae* infected *H. serrata* grub (late symptom)
18.	B. Bassiana infected *H. serrata* grub
19.	Comparative field view of treated (imidacloprid + fipronil - 80 WG) and untreated plots of Co 86032

LIST OF APPENDICES

Appendix No.	Title
Ia.	Weather data for the year 2011
Ib.	Weather data for the year 2012

INTRODUCTION

White grubs (Coleoptera: Scarabaeidae) are soil inhabiting and root feeding immature stages of scarab beetles. The white grub family, Scarabaeidae is the second largest family within the order Coleoptera. The world fauna of white grub exceeds 30,000 species (Mittal, 2000) and there are about 1300 North American species (Borror *et al.,* 1975). The maximum number occurs in the tropical areas of the world, particularly in African and Oriental regions. The fauna of the Indian sub-region is very rich and diverse but it is yet to be fully explored (Mishra and Singh, 1999). White grubs have become serious pests of most agricultural crops, fruits, vegetables, ornamental plants, plantation crops, pastures, turf and meadow grasses, lawns, golf courses and forest trees in different parts of the world (Guppy and Harcourt, 1970; Potter *et al.,* 1992). White grubs are polyphagous pests having a wide range of hosts which are damaged by both adult and larval stages and of these the larvae are of a greater nuisance. Beetles are defoliating pests and damage a large number of horticultural and forest species by feeding on apical buds and tender leaves, whereas, the grubs feed on plant roots causing yellowing. They cause wilting which is characterized by initial yellowing of the leaves, followed by drying resulting in the death of affected plants and reduced vigour or lodging of canes in sugarcane crop. Larvae feed by making circular holes into lower internodes rendering them unfit for marketing. Some plants wilt and ultimately die; such plants can be easily pulled out. The extent of damage caused by white grubs solely depends upon the species involved, the numbers present and the host crop.

Stebbing (1902) for the first time reported the occurrence of white grub in India. Gupta and Avasthy (1957) reported white grub as a pest of sugarcane in India. Further, there are about 1500 species recorded from India, out of which 40 species are reported to be serious pests. In India, white grub is one of the five pests of national importance (Yadava and Vijayavergia, 1994). In many crops, white grubs cause losses to the extent of 40-80 per cent (Prasad and Thakur, 1959).

Crop protection has been practised since quite a long time and it passed through different phases as per the prevailing situations and the available options (Van Emden and Peakall, 1996). In the present scenario, crop protection has undergone dramatic change in most parts of developed and developing countries. The emphasis has shifted from the hitherto dominant chemical pesticides to integrated pest management (IPM), where the focus is on biological control and other natural resources with reduced reliance on chemicals. Such a change became imminent mainly due to the increasing failures of chemical pesticides in controlling most of the major pests and also due to the ever-increasing global awareness about the undesirable side-effects such as environmental pollution, health hazards, destruction of beneficial organisms, pest resurgence, pest outbreaks, loss of biodiversity, deterioration of plant and soil health, *etc.* (Baker and Gyawali, 1994). Pesticides, once thought to be a panacea for all our pest problems, are today viewed with suspicion and great concern.

Several predators and parasitoids have been identified on white grubs but their unsuitability to manipulation has led to the exploitation of insect pathogens such as *Metarhizium anisopliae* (Metsch.) and *Beauveria bassiana* (Balsm.) which are considered to have great potential. Several isolates of *M. anisopliae* have been identified to be highly virulent against the insects living in soil and cryptic habitats and have been subsequently used in research against a range of insect pests. Unlike agrochemicals which are tested in the field very early in their development, microbial control agents (MCAs) are developed in the laboratory and/or glasshouse environment over a long period of time.

Metarhizium, which is commonly known as "green muscardine" fungus, is capable of infecting insects living in diverse habitats including fresh water, soil and aerial locations (Hajek and Leger, 1994). It is infective to more than 200 insect species of various orders. *Metarhizium's* potentiality against few insect species belonging to Orthroptera, Isoptera, Homoptera and Coleoptera has been experimentally proved and is being exploited in isolated parts of the world. This fungus has been successfully utilized in the management of white grubs in Brazil (Tang and Hou, 1998) ; rhinoceros beetle in Western Somoa (Tey and Ho, 1995) ; locust and grasshoppers in Africa and Australia (Langewald *et al.*, 1999).

Green muscardine fungus has also been reported to have considerable potential to control scarab beetles infecting sugarcane and pasture; brown plant hopper in rice; sugarcane pyrilla; diamond back moth in crucifers; rice leaf folder; cotton whitefly and American boll worm. In the present scenario, strategies for the management of white grubs rely upon chemicals. Chemicals though effective have been proved to be uneconomical and unsafe, mainly because of their indiscriminate use and lowering of natural biotic pressure due to destruction of natural enemies.

Therefore, the entomopathogens *Metarhizium anisopliae* (Met.) Sorokin and *Beauveria bassiana* can be effectively utilized as an important tool in the management of white grubs under integrated approach.

Belagavi district is considered the sugar bowl of Karnataka with 1.24 lakh ha under sugarcane cultivation. Traditionally, sugarcane was cultivated in this area under transitional belt, recieving well distributed rainfall. But in subsequent decades sugarcane cultivation has come up even in non-traditional belts owing to availability of various sources of irrigation such as river, borewells and open wells. Shift from traditional belt to non-traditional belt has resulted in increased white grub menace year after year paving way for the establishment of the pest throughout the sugarcane growing areas. This has also enabled the white grub spread on to non-traditional areas affecting both agricultural and horticultural crops increasing its host diversity.

Among the various species of white grubs, *Holotrichia serrata* (Fabricius) has become a key species by causing 30 to 40 per cent loss in sugarcane alone under irrigated ecosystem of Belagavi district. Apart from sugarcane, *H. serrata* infestation has spread to both *kharif* and *rabi* crops in these areas and *H. serrata* has become a devastating pest causing economic concerns for Belagavi and adjoining districts.

Since the white grub menace has spread across to different crops, over the years it has changed its behaviour attaining perennial status. In view of the changed pest behaviour, crop diversity and loss estimation in sugarcane and other crops, a separate strategy is required for the management of white grub by utilizing newer molecules of insecticides and entomopathogens. Entomopathogens are ecofriendly, self perpetuating, highly persistent, cost effective and especially the irrigated sugarcane ecosystem provides the ideal microclimate for multiplication of the entomopathogens.

Keeping this in view, investigations were undertaken in Belagavi district with the following objectives.

1. Determination of species composition of white grubs.
2. Population dynamics of the sugarcane white grub*, H. serrata*.
3. Behavioral pattern of *H.serrata* adults in sugarcane.
4. Loss estimation in sugarcane due to *H.serrata* and per cent infestation in other crops.
5. Efficacy of entomopathogens and newer molecules of insecticides against the white grub, *H.serrata*.

REVIEW OF LITERATURE

The literature pertaining to species composition, population dynamics, behavioural pattern of adult white grub, loss estimation and evaluation of entomopathogens and newer molecules of insecticides has been reviewed and presented hereunder.

2.1 Species composition of white grubs

There are nearly 200 species of white grubs in the sub-families, Melolonthinae, Rutelinae, Dynastinae and Cetoniinae, which are economically injurious to crops in India. The genus *Holotrichia* Hope alone has more than 100 economically important species. The most widely distributed and destructive species in India are *Holotrichia serrata* and *H. consanguinea*. *Holotrichia serrata* is found throughout India, whereas *H. consanguinea* is restricted to northern part of India. These two species of white grubs have assumed the status of national pest in India (Frey, 1971).

The abundance and distribution of the beetles depends upon the species involved, the preferred host and its location in relation to the site of emergence. Adults of *H. serrata* fly towards the source of light but concentrate around 5 to 10 meters away from the source of light (Veeresh, 1977).

Lolage and Patil (1984) studied the diversity of white grub species in Konkan region indicating *H. fissa* being the predominant species causing economic loss in groundnut. Emergence of the beetles started soon after the onset of monsoon. Incubation period ranged 7-8 days. Three larval instars lasted for an average of 19.7, 26.0 and 30.1 days respectively. Total larval period ranged from 73 to 88 days. Pupal period lasted for 14-18 days.

Adsule *et al.* (1990) studied the relative abundance of scarabaeid beetles using light trap in western Maharashtra. Three years data indicated that adult emergence coincided with the onset of rainfall with maximum insect catches in May, June, September and October.

Dashad *et al.* (2008) reported from Bawal, Hariyana that the emergence of white grubs started from 18^{th} standard week after first pre-monsoon rainfall of the season. Totally 13 species (1998 beetles) of white grubs were reported with maximum number of *Holotrichia consanguinea* (1214) followed by *H. serrata* (382 beetles). Peak emergence was observed from the month of July.

Scarab adults were collected from neem trees on which they were feeding and/or mating and larvae (white grubs) from groundnut fields. *Holotrichia* species, especially *H. reynaudi* and *H. serrata,* were the major species associated with groundnut. *Holotrichia reynaudi* predominated in the central Deccan area, while *H. serrata* was most abundant in the south and west. A new undescribed *Holotrichia* species near *H. consanguinea* was collected in south and southwest of Hyderabad in mixed populations with *H. reynaudi*. However, the full extent of this new species' distribution remains uncertain. *Holotrichia rufoflava* was rarely associated with groundnut but was common as an adult at some locations. Other genera encountered during surveys were *Anomala*, *Adoretus*, *Schizonycha* and *Autoserica* (Anitha *et al*., 2006).

Theurkar *et al.* (2012) reported five major species of white grubs especially in Maharashtra namely *H. consanguinea, H. serrata, H. fissa, Leucopholis lepidophora* (Melolonthidae), *Anomala* sp. (Rutelidae). Scarabaeid adults were collected from leaves of host plants like neem, babul, ber and khair. *Holotrichia serrata* was the most abundant species found in Khed Taluka which is part of Northern Western Ghats (Maharashtra), India. Major crops grown were groundnut, maize, pea, potato and sugarcane

2.2 Population dynamics of white grubs

David and Kalra (1966) from Hospet taluk of Bellary district reported that *H. serrata* beetles remain in a quiescent state at some depth in the soil, become active during March-May when they emerge from the soil. They feed on the leaves of some trees and shrubs, *viz*., *Pithecellobium dulce, Melia azadirachta, Zizyphus jujube* and *Ficus glomerata* during night time when mating and egg-laying also take place. After an incubation period of 7 to 10 days the grubs hatch out and begin to damage roots of grasses *etc.* growing on the bunds and near the water channels. Damage to sugarcane roots occurs during July-September. Later they migrate deeper into the soil and after a larval period of 142-178 days, pupation takes place inside earthen cells constructed by the grubs for the purpose. The pupal period lasts 14-24 days. There is only one generation of the pest in a year.

Kalra *et al.* (1984) studied the population dynamics of *H. consanguinea.* The data were recorded from the beginning of June to end of November. The fortnightly observations revealed that during June - July, due to paucity of rains, very less number of adults were encountered within the pits. Maximum number of adults (7 and 6 adults/pit) was recorded during August-September. The adult population had a significant correlation with rainfall.

Studies on population build up of *H. consanguinea* revealed that less number of adult beetles were encountered in June and October, whereas it was more during July-September. Grub population was also more during July-September. Groundnut followed by moong bean, pearl millet, cowpea and fallow land had more number of grubs as compared to cotton, sorghum and guar. Scanning of soil around trees suggested that the grub and adult population was more underneath *jujube* followed by *Acacia* sp., neem, karonda and falsa (Kalra *et al.,* 1991).

Patil and Adsule (1991) counted stages in the life cycle of the scarabaeid *L. lepidophora* in soil samples taken twice a month in cultivated land in Maharashtra during 1985-87. All stages except 2nd instar larvae were present in August. Eggs were found in August-October, 1st instar larvae during August-January, 2nd instar larvae in November-March, 3rd instar larvae in February-October and pupae and adults during June-October. Population occurred in April at a depth of 20-30 cm. Since 2nd and 3rd instar larvae were the only damaging stages and these were observed during February-November, this period appeared to be the most suitable for control measures,as this coincides with cultural operations.

Mishra and Singh (1993) studied the biology of *H. serrata* on potatoes in Uttar Pradesh, India, during May-September 1991. Adult emergence began at the end of May and peaked in the 2nd week of June. Eggs and 1st instar larvae were found during June-July with 2nd and 3rd instar larvae damaging tubers at the end of July and during mid-August, respectively. Larvae migrated downwards in the soil at the end of October and over-wintered in a quiescent state.

Chandla *et al.* (2001) from Shimla (Himachal Pradesh) reported that tuber damage due to *H. consanguinea* decreased as the elevation increased. A significant correlation between elevation, soil type and tuber damage was also observed. Less damage was observed in crops grown in clay soil. Plants near the bund side and corners were attacked more by white grubs compared to those in the middle of the plot. Well distributed rainfall favoured pest buildup resulting in increased tuber damage.

Chandel *et al.* (2003) conducted soil sampling study at Shimla which revealed a high number of *Brahmina coriacea* at all stages. Pupae were found in the soil during April followed by adults in May and eggs in June-July. Larvae were in the soil from July to April. The third instar grubs infested the crops during September-October and over-wintered in the soil up to April. Adult emergence started in May and was maximum in mid-June.

2.3 Behavioural pattern of white grubs

2.3.1 Adult emergence and adult trapping

Veeresh (1977) reported emergence of *H. serrata* during April in South India while in North India, it was either in May-June or July. Adult food is the chief environmental factor affecting the beetle behaviour and is one of the most important considerations in the distribution of both adults and larvae. There is direct relationship between adult host plants present in a certain locality and the amount of injury caused by white grubs (Veeresh, 1978).

The emergence of *H. serrata* beetles started after receipt of 33 mm rainfall. The average pre-oviposition period was 4.50 days. The beetles were polygamous and the same pair of male and female did not necessarily mate with each other. Similarly beetles did not exercise any special preference for the same tree. The beetles were seen feeding on the leaves of 'neem' and 'babul' trees as reported earlier by several workers. However, they were found to be feeding on the leaves of 'gulmohar' (May flower) trees for the first time in Maharashtra State. The emergence of beetles starts in the evening and completes within about 10 to 15 minutes during 7.20 PM to 7.50 PM. Immediately after emergence, the mating starts and lasts for 5 to 11 minutes. The beetles migrate to the soil usually between 5.40 to 6.00 AM (Patil and Hasabe, 1979). Brar and Sandhu (1982) studied the field biology of *H. consanguinea* in Punjab, India during 1978 and 1979. Adults emerged in the 2nd fortnight of June when it rained (26.2 – 34.0 mm) and the temperature was 29-30^{0}C and the relative humidity was 70-72 per cent. Adults emerged between 19.45 and 20.00 h and entered the soil the next morning at about 05.30 h, this was continued for 27-35 days

The light trap collection of white grub beetles at 950 meters above mean sea level revealed the presence of 24 species of white grub occurring in Meghalaya, among which *Anomala* spp., predominated the population. The beetles started emerging from April and were observed up to October with a peak emergence in May. The maximum attraction of beetles towards light source was between 19.00 and 20.00 h. Light trap can be successfully used at medium altitude hills for survey and control of white grub beetles (Gangawar, 1988).

Nath and Singh (1988a) studied the aggregation nature of different stages of white grubs, attributed aggregation to different factors but mainly habitat heterogeneity and behaviour of the insect.

Light trap study by Nath and Singh (1988 b) showed irregular emergence pattern of beetles. The combined and individual effects of rainfall, temperature, relative humidity and sunshine hours on the beetle emergence were of significant importance. The rainfall and relative humidity play major role on the emergence pattern of these insects.

Adsule *et al.* (1990) studied the relative abundance of scarabaeid beetles using light trap in western Maharashtra. Three years data indicated that adult emergence coincided with the onset of rainfall with maximum insect catch during May, June, September and October. Eleven scarbaeid species from four subfamilies of Coleoptera were recorded of which *H. fissa* was economically important.

2.3.2 Trapping and phermones of white grubs

Neem leaves were utilized in capturing 70,000 and 85,000 adults of *H. serrata* at Rampur during 1968 and 1969, respectively and over 1,00,000 at Palhera Farm (Daurala) in Meerut district in 1971. The technique consists in planting fresh branches of neem about 1.25 to 2 metre long before sunset in the infested area @ 2 per hectare daily during the peak period, *i.e.*, June-July. The adults are attracted probably by its smell but the exact chemical nature of the attractant is yet to be determined. The adults which congregate on the branches for copulation and feeding can easily be captured and destroyed. High wind velocity in the evening, however, reduces its efficiency to some extent. Adults of *H. consanguinea* and *H. insularis* are also attracted to neem leaves (Gupta, 1973).

Chandramohan and Nanjan (1991) conducted light trap experiments to monitor the emergence of coleopteran pests during 1991 in Tamil Nadu, India. More than 70 per cent of *Anomala nathani* and *A. communis* emerged within a week of the first summer rain. Within a fortnight, 53 per cent of *Holotrichia excisa*, 82 per cent of *H. repetita* and most of *Autoserica* sp. near *A. calicutensis* had emerged. It is concluded that application of insecticides a fortnight after the first summer rain should coincide with the occurrence of the vulnerable eggs and 1st instar larvae of the pests.

Scarab species associated with groundnut ecosystem surveyed in Andhra Pradesh, Karnataka and Tamil Nadu (India) by using sex pheromone of *Phyllophaga crinita* revealed that a total of 8,664 males were captured with no female catches (Robbins *et al*., 2003).

The antennal response of adults of *H. serrata* to host volatiles and pheromone gland extracts was assessed by electroantennography. The volatiles from neem *Azadirachta indica* leaf extract elicited higher antennal response than gulmohur *Delonix regia* flowers and *Ailanthus excelsa* leaf extracts (Kesavan *et al*., 2012).

2.4 Loss estimation due to white grubs

Avasthy (1965) reported that *Alissonotum, Anomala, Heteronychus* and *Holotrichia* species damaging sugarcane are univoltine and complete only one generation in a year. Extent of damage has been observed to vary considerably with soil, nature of planting, characteristics of sugarcane hybrids and species. In years of heavy population, almost 80 per cent of the crop was observed to be completely destroyed. Mechanical control has been found to be tedious, erratic and costly. Changes in crop rotation, planting resistant varieties and maintenance of food plants for the parasites around the cane fields are expected to minimize grub damage. Biological control with exotic parasites of white grubs (like *Tiphia parallela*) of proved economic value, soil application of the green muscardine fungus *Metarhizium anisopliae* (Metch.) are reported to be effective in Formosa and the bacterial spore powder (*Bacillus popilliae*) is known to cause milky-white disease in June beetles in U. S. A. and Japan.

All white grubs are polyphagous, they can feed on any root or underground stem. No plant is completely resistant to white grub attack. However, certain crops can tolerate more than 50 per cent root damage (Veeresh, 1977).

Sithanantham (1978) reported that the genus *Holotrichia* is predominantly associated with cane. *Holotrichia consanguinea* is common in U. P., Rajasthan, Gujarat and Andhra Pradesh, whereas *H. serrata* causes considerable damage in Tamil Nadu, Maharashtra, Karnataka and U. P. Greater damage occurs in February plantings than in October plantings, so also ratoons are more vulnerable than plant crops. Varieties like Co 453 and Co 6304 tolerate the damage considerably.

Losses in yield of groundnut caused by *H. consanguinea* and collar rot (caused by *Aspergillus niger*) were investigated in the field in Punjab, India, in 1978 and 1979. Granular formulations of phorate, carbofuran, isofenphos and fensulfothion at 1 kg a.i. per ha were highly effective against *H. consanguinea*, plant mortality being reduced from 10.7 per cent in untreated plots to 0.7-2. 8 per cent in treated ones. Collar rot was controlled with thiram. The losses avoided when *H. consanguinea*, collar rot and the two together were controlled with pesticides were estimated to be 28.74 - 40.34, 16.48 - 32.80 and 32.30 - 66.17 per cent, respectively (Bakhetia, 1982).

One or two grubs per clump of sugarcane is known to have incremental effect on the cane due to compensatory effort put up by the cane but more than this number will cause damage (David and Anantha Narayana, 1982).

David *et al.* (1984) reported that 17 varieties, *viz.*, Co 285, Co 421, Co 453, Co 775, Co 976, Co 6304, Co 6311, Co 6501, Co 6512, Co 6914, Co 7313, Co 7626, CoS 510, CoL 29, CoJ 65, CoJ 75 and Bo 92 were resistant/tolerant to *H. serrata* under artificial infestation in pot experiments. Evaluation of the efficacy of some of the insecticides was tested through foliar feeding of the adults with the insecticide treated leaves. The insecticides tested were fenthion 0.05 per cent, lindane 0.1 per cent, monocrotophos 0.05 per cent and carbaryl 0.1 per cent. The mortality of the adult beetles was high ranging from 84.0 to 92.3 per cent. The egg mortality was 100 per cent in treatments with phorate and chlorpyriphos at 3.8 g in 1 kg of soil. Phorate, sevidol, quinalphos and endosulfan were effective in killing the different instars.

Forty-three accessions of *Saccharum barberi*, 134 of *S. robustum*, 29 of *S. sinense*, 19 of *S. spontaneum* and 60 of *Erianthus [Saccharum]* spp. were screened for tolerance to white grub, *H. serrata*, during 1991-96 under artificial infestation of pot cultured plants in Coimbatore, Tamil Nadu, India. Tolerance was assessed based on the ability of a single clump (120-130 days old) of a single-budded set to withstand the attack of three grubs for the lowest mean grub period of 120 days. Of the 61 tolerant accessions, seven had tolerance for more than three grubs. *Erianthus* spp. had the highest percentage of tolerant genotypes and showed a very high degree of tolerance up to the 6-grub level. Among *S. barbei, S. robustum, S. spontaneum* and *S. sinense* accessions, 1, 9, 13 and 0 were tolerant, respectively (Mukunthan and Nirmala, 2002).

Chirame *et al.* (2003) studied the field efficacy of *Beauveria brongniartii* against *Holotrichia serrata* infesting sugarcane cv. Co 419. The spores of *B. brongniartii* were applied at 10^9 spores/ml. The treated plots showed 2.5 per cent crop damage, 1.5 white grub larvae per meter of row length and a yield of 119 t per ha. The untreated plots showed 74 per cent crop damage, 36 white grub larvae per meter row length and a yield of 23 t per ha.

Misra (2003a) estimated the avoidable losses in potato yield through the management of white grubs, *Holotrichia* spp. The study revealed that an additional yield of healthy potatoes (free from white grub damage) obtained by applying phorate 10 G and chlorpyrifos was determined as 57.95 and 37.54 q per ha, respectively. Further, the cost benefit ratio for ware and seed potatoes was calculated as 1: 18.98 and 1: 27.31, respectively, when phorate 10 G was applied in the first experiment during 1995 and 1996. However, during 1997 and 1998 potato crop season, the cost:benefit ratio was 1:20.87 and 1 : 29.98, respectively, on ware and seed potatoes from crop sprayed with chlorpyrifos 20 EC. The reason for somewhat higher cost: benefit ratio in the later case could be attributed mainly to the lower cost of critical inputs incurred on plant-protection measures.

The avoidable yield losses in potato yield through the management of white grubs, *Holotrichia* spp. were determined in field experiments conducted in Himachal Pradesh, India, during 1995-96. The damage on potatoes by the white grubs was higher in 1995 and 1996 compared to 1997 and 1998. Additional yield of healthy potatoes (free from white grubs damage) was obtained by applying phorate 10G (57.95 q/ha) and chlorpyrifos 20 EC (37.54 q/ha) (Misra, 2003b).

The damage potential of two phytophagous scarab larvae on groundnut (peanut) yield was determined. *Holotrichia serrata*, a root and pod feeding species from southern India, was studied in microplots while the damage potential of *Heteronyx piceus*, a pod feeder from Queensland, Australia, was determined by analysis of on-farm chemical-rate trials. *Holotrichia serrata* larva reduced groundnut yield by an average of 7.52 g per larva. In crops yielding less and more than 1900 kg per ha, *H. piceus* reduced yield by 4.20 and 1.43 g per larva, respectively. These damage potential estimates were used to determine provisional economic injury levels (EIL). For *H. piceus*, the provisional EIL is 1.67 and 4.91 larvae/row-metre in crops yielding less and more than 1900 kg per ha, respectively. For *H. serrata*, the provisional EIL is one *H. serrata* larva in 7.1 m^2. As more than 70 per cent of southern India groundnut fields have *Holotrichia* populations greater than one larva in 1.35 m^2, more widespread use of chlorpyriphos seed dressing of groundnut is likely to produce regional economic benefits (John Rogers *et al.*, 2005).

2.5 Efficacy of entomopathogens and newer molecules of insecticides against white grubs

2.5.1 Efficacy of entomopathogens on white grubs

Biological control with exotic parasites of white grubs (like *Tiphia parallela*) proved to be of economic value, soil application of the green muscardine fungus *Metarhizium anisopliae* (Metch.) Sor. reported to be effective in Formosa and the bacterial spore powder (*Bacillus popilliae*) was known to cause milky-white disease in June beetles in U. S. A. and Japan (Avasthy, 1965).

Field study was conducted by Bhagat *et al.* (2003) in Himachal Pradesh to determine the field efficacy of talc-based conidial formulations of *Metarhizium anisopliae* and *Beauveria bassiana* from 1999 to 2001 against whitegrubs (*Brahmina*) in potato cv. Kufri Jyoti. Treatments comprised of *M. anisopliae* (1×10^{14} or 5×10^{13}/ha), *B. bassiana* (1×10^{14} or 5×10^{13}/ha) or chlorpyrifos (200 or 400 g/ha) alone or in combination. *Metarhizium. anisopliae* formulation applied at 5×10^{13} conidia per ha along with chlorpyrifos 20 EC at 200 g a.i. per ha was effective in controlling the grub population (56.5%), exhibiting the maximum reduction in plant mortality (75-80%) and tuber damage (63.7%), which resulted in the highest tuber yield (155 q/ha).

The pathogenicity of *M.anisopliae* and *B.bassiana* were tested under laboratory conditions against third instar grubs and adults of *H. consanguinea* by crawling the grubs on cultures and confining the grubs to soil inoculated with spores. Positive pathogenicity was noted in case of both the pathogens. Mortality was highest when the treated insects were kept at 28ºC (Singh *et al.*, 1979).

Gupta *et al.* (2003) studied the effect of different moisture levels on the infectivity of *M. anisopliae* isolate Ma-4 against the larval stage of whitegrub (*H. consanguinea*). Mortality period decreased with the increase in soil moisture. Complete mortality in the first- and second-instar larvae occurred within 11 and 31 days, respectively, when they were exposed to 16 or 18 per cent soil moisture compared to 16 and 39 days period for mortality at lower soil moisture (8 per cent). In another pot experiment, initial soil moisture (13 per cent) recouped after every 72 or 96 h resulted in high grub mortality than the moisture resumption done every 24 h. However, resumption of moisture done at 120 h did not cause any mortality. Similarly, a high percentage of grub mortality (77%) was achieved when 50 ml water/pot every 24 h was applied than that of only 11 to 33 per cent mortality when 25 ml and/or 100 ml water was applied daily in each pot.

Sharma and Gupta (2003) studied the pathogenicity of three entomopathogenic fungi *viz., B. bassiana, B. brongniartti* and *M. anisopliae* on adults of *H. consanguinea* and *Maladera insanabilis.* Complete mortality of *H. consanguinea* and *M. insanabilis* was observed 10 and 9 days after *M. anisopliae* treatment, respectively. On the other hand, *B. brongniartii* recorded a median lethal time of 5.55 and 9.42 (by insect inoculation) and 17.47 and 10.56 days (by soil inoculation) against *H. consanguinea* and *M. insanabilis*, respectively. *Beauveria bassiana* was comparatively weak in controlling the pests.

Yadav *et al.* (2004) studied the efficacy of *M. anisopliae* and *B. bassiana*, alone or in combination with 5, 10 or 15 g nicast/compost, in controlling *H. consanguinea* in pot experiments. The efficiency of both increased when applied with increasing rates of nicast/compost.

Easwaramoorthy *et al.* (2005) conducted laboratory and field experiments with three entomopathogenic fungi *viz.*, *B. brongniartii, B. bassiana* and *M. anisopliae* against *H. serrata*. In laboratory bioassays on eggs at an overall concentration range of 10^4-10^9 spores/ml, *M. anisopliae* caused higher rates of infection than *B. brongniartii* and *B. bassiana*; the differences amongst concentrations were significant for *M. anisopliae* but not for *Beauveria* spp. Against second and third instar grubs at a similar concentration range, both *Beauveria* spp. were more infective than *M. anisopliae*. In pot culture experiments with *B. brongniartii* at a dosage equivalent of 10^{12}-10^{18} spores per ha, third instar grubs showed higher levels of mortality than first instar. In a field experiment (Tamil Nadu, India), *B. brongniartii* applied to the root zone of sugarcane crop at 1.6 × 10^{14} spores per ha produced significantly higher infection rates in third instar grubs in treated plots than in control

Three biocontrol agents, *viz.*, *B. bassiana*, *B. brongniartii* and *M. anisopliae* proved pathogenic at each level of concentration 1 x 10^8, 1 x 10^6, 1 x 10^4 and 1 x 10^2 spore mL^{-1} studied, but mortality in a shorter duration was observed at a spore concentration of 1x10^8, spore mL^{-1}. Enhanced mortality was observed with increase in inoculum dose (Sajad Mohi-Uddin *et al*., 2006).

Prabhu *et al.* (2011) studied the bioefficacy of bioagents and plant products against arecanut white grub, *Leucopholis lepidophora*. The results revealed that chlorpyriphos 20 EC @ 6 ml per palm was found effective by recording 77.36 per cent grub mortality. The entomopathogens studied at two different dosages *viz.*, *M. anisopliae* and *B bassiana,* with 2 × 10^8 conidia per g @ 10 and 20 g per palm,wherein *M. anisopliae* with 2 x 10^8 conidia per g @ 20 g per palm recorded 31.38 per cent grub mortality as against aqueous mixture of soapnut and neem oil @ 5 per cent performing superior by recording 53.55 per cent grub mortality.

Application of *M. anisopliae* against sugarcane *H. serrata* at 4 × 10^9 conidia/ha-1 was found effective next to chlorpyriphos and registered 92 per cent reduction in grub population on 60th DAT. The highest cane yield was recorded when chlorpyriphos was applied @ 3 lit per ha (110.5t/ha), followed by *M. anisopliae* @ 4 × 10^9 conidia/ha (100.6 t/ha). However, incremental benefit cost ratio (IBCR) was high with higher doses of *M. anisopliae* (7.58) followed by drenching of chlorpyriphos (6.09) (Manisegaran *et al.,* 2011).

Rakesha *et al.* (2012) evaluated two fungal pathogens against arecanut white grub, *L. lepidophora, Metarhizium anisopliae* @ 4 x 10^8 conidia per g has recorded 33.33 per cent grub mortality and was superior over lower dosage of 2 x 10^8 conidia per g that recorded 14.81 per cent mortality. *Beauveria brongniartti* recorded 22.22 and 14.81 per cent grub mortality at two dosages tried @ 4 × 10^8 and 2 × 10^8 conidia per g, respectively.

Results on quality parameters in sugarcane recorded in different formulations of *M. anisopliae* indicated that liquid formulation was significantly superior with respect to pol per cent (19.30), purity per cent (90.28), CCS (%) of 12.40 and 17.28 per cent of glucose over talc and lignite formulations. Talc, lignite and liquid formulations were mixed well with decomposed farmyard manure and applied near the cane root zone at 5 – 10 cm depth and irrigated immediately after application. Two applications were made at 15 days interval. The liquid formulation was efficient for the control of sugarcane white grub *H. serrata* (Thamarai *et al.,* 2011).

2.5.2 Efficacy of insecticide molecules

Among the organo-phosphate insecticides, phorate 10 G, turbufos 5 G (counter), quinalphos 5 G and carbofuran 3 G all @ 1.0 kg a.i. per acre and chlorpyriphos (Dursban 20 EC) @ 0.5 kg a.i. per acre gave good control of grubs provided the time of application was synchronized with the emergence and egg laying of *H. serrata* (Veeresh, 1977).

Veeresh *et al.* (1978) evaluated certain insecticides against *H. serrata* for their efficacy under different conditions of cultivation and observed that the effect of insecticides was more pronounced under irrigated condition compared to no irrigation after treatment. The per cent control in unirrigated condition was 31.0, 24.1, 27.5, 37.9 and 31.0 in chlordane, chlorpyriphos, aldicarb, torbophos and phorate respectively compared to 53.1, 93.7, 0.0, 90.6 and 84.3 per cent control, respectively under irrigated condition.

Granular insecticides like phorate 10G @ 25 kg per ha and 20 kg/ha; mophospholan 3G @ 25 kg per ha and quinalphos 5G @ 25 kg per ha were found effective. Dusting with BHC 10 per cent @ 125 kg per ha was also found effective in protecting the crops (Patil and Hasabe, 1979).

Gajare *et al.* (1981) evaluated granular insecticides against *H. serrata* at different doses and three dusts were applied at the time of planting. The germination count after planting was found to be maximum (62. 62 per cent) in fensulfothion G at 3 kg a.i. per ha at 6 weeks and 64. 92 per cent in carbofuran G. at 3 kg a.i. per ha at 8 weeks. All the treated plots showed higher germination than untreated (control) plot. The treatment with disulfoton G and carbofuran G at 3 kg a.i. per ha and quinalphos at 2 kg a.i. per ha had no dead canes due to white grub attack at 8 and 12 weeks after planting.

Granular formulations of phorate, carbofuran, isofenphos and fensulfothion at 1 kg a.i. per ha were highly effective against *H. consanguinea*, plant mortality being reduced from 10.7 per cent in untreated plots to 0.7 to 2.8 per cent in treated ones (Bakhetia, 1982.)

David *et al.* (1986) evaluated four insecticides against *H. serrata* in sugarcane. The results revealed cent per cent mortality of eggs with phorate @ 38 mg per kg of soil was significantly superior over other treatments. However, phorate, sevidol, quinolphos and endosulfan were effective in killing the different instars.

Bhagat *et al.* (2001) evaluated five insecticides *viz*., acephate (0.48 kg a.i./ha), chlorpyriphos (0.400 kg a.i./ha), diazinon (0.400 kg a.i./ha), endosulfan (0.400 kg a.i./ha) and phorate (2.50 kg a.i./ha) against *Brahmina coriacea* in potato. Results revealed that per cent tuber damage was lowest in phorate treated plots (37.50%) and all other insecticides gave significantly higher yield than the control.

Patil and Bhagat (2005) conducted field evaluation studies of insecticides against *Holotrichia* in maize. The results revealed that seed treatment with imidacloprid 70 WS @ 3.5 g a.i./kg seed, chlorpyriphos 20 EC @ 5 g a.i./kg seed, soil application of chlorpyriphos 10 G (@ 2 kg a.i per ha + NICAST (@ 500 kg per ha, respectively) and chlorpyriphos 10 G @ 2 kg a.i. per ha resulted in decreased plant mortality in maize due to white grub over control (75.85, 71.38, 66.67 and 56.59 per cent, respectively). These treatments also exhibited corresponding increase in yield over control (46.15, 45.27, 44.39 and 37.52 per cent, respectively) and reduction in grub population. Neem cake and castor cake (each @ 500 kg/ha) treated plots recorded 24.10 and 13.50 per cent decrease in plant mortality over control. Grub population in these treatments varied from 0.50-0.83/0.25 m^2 as compared to 1.00/0.25 m^2 in control. Application of *B. bassiana* and *M. anisopliae* (@ 5×10^{13} conidia per ha each) resulted in 43.02 and 47.16 per cent decrease in plant mortality over control.

Swaroop Singh *et al.* (2012) evaluated four insecticides along with standard checks namely imidacloprid 17.8 SL, chlorpyriphos 25 EC and quinalphos 25 EC against *H. consanguinea.* All the insecticides were used as seed dresser on groundnut seeds. Pooled analysis of data pertaining to damage and dry pod yield revealed that the neonicotinoid, clothianidin 50 WDG at 2.0 g per kg seed, provided maximum protection (82.64%) with minimum plant damage (5.47%) followed by its higher dose of 3.0 g per kg seed (82.39 per cent and 5.55 per cent, respectively) and imidacloprid 17.8 SL at 3 ml (80.36 per cent and 6.19 per cent, respectively). Maximum yield of 23.30 quintals per ha in 3.0 g per kg seed dose of clothianidin 50 WDG followed by its lower dose 2.0 g per kg seed (22.24 q/ha) and imidacloprid 17.8 SL (20.93 q/ha).

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MATERIAL AND METHODS

Investigations on species composition, population density, behavioural pattern of adult white grub, loss estimation, evaluation of entomopathogens and newer molecules of insecticides were carried out during 2010-2012. Field studies on evaluation of chemicals with pheromone activity and adult trapping sources were taken up at Agricultural Research Station (ARS) Farm. Loss estimation studies, evaluation of entomopathogens and newer molecules of insecticides were taken up in farmer fields in white grub endemic areas at Hukkeri and Chikkodi taluks of Belgaum district during 2010-11 and 2011-12.

The Agricultural Research Station, Sankeshwar is located in the transitional tract, region IV of Karnataka (Zone-8) at 10.15N Latitude and 74.29E Longitude with an Altitude of 623.3 m above mean sea level. The mean annual rainfall of Sankeshwar is about 744.3 mm distributed all over a period of seven to eight months with two prominent peaks occurring in July and October. The meteorological observations during the experimentation period are presented in Appendix I.

The details of the materials used and the methodology adopted during the course of investigation are described hereunder.

3.1 Species composition of white grubs

3.1.1 Monitoring of adults

Monitoring of adult beetles was carried out for two years (2011 and 2012) in five locations *viz.*, Kadapur, Soundalga, Bellad Bagewadi, Sankeshwar and Hattarwat from 5th Meteorological Standard Week (MSW) (February) to 24th MSW (June). For this study, host trees *viz.*, neem (*Azadirichta. indica*), ber (*Zizyphus* sp.) and *Acacia* sp. located along bunds and nearby cultivated fields were selected and wherever possible 125 watt fluorescent bulbs were installed and in other places a powerful torch was used for locating the beetles on host trees. This was carried out everyday from 7.00 pm to 10.30 pm in all the locations.

Adults of the different species so collected were brought to the laboratory and preserved in 70 per cent ethyl alcohol for further identification. Beetles collected everyday were counted and average was worked out for respective MSW in all the study locations. Per cent soil moisture and soil temperature were also recorded as explained under the sections 3.3.3.1 and 3.3.3.2

3.2 Population dynamics of sugarcane white grub, *Holotrichia serrata*

Different stages *viz.*, egg, 1st instar, 2nd instar, 3rd instar, pupa and quiescent adults of *H. serrata* were collected from sugarcane fields of Ankali, Kadapur and Soundalga locations of Chikkodi taluk and Bellad Bagewadi, Kochari and Sankeshwar of Hukkeri taluk during 2011-12 by following destructive sampling method. During sampling, all the stages of white grubs collected were recorded separately and mean numbers of various stages were worked out. Soil moisture and soil temperature were recorded.

3.3 Behavioural pattern of *Holotrichia serrata* adults in sugarcane

3.3.1 Adult emergence and adult trapping

The field experiment was carried out in the sugarcane fields at ARS, Sankeshwar during 2011-12. Regular monitoring for adult emergence was done from March (10th MSW) to May (16th MSW) using 125 watt fluorescent bulb as light source.

To evaluate different adult trapping sources, an experiment was laid out during 2011-12 at ARS, Sankeshwar. Four different materials / sources *viz.*, FYM, pressmud, sugarcane setts and neem leaves in various combinations were selected for the study (Table 1). The experiment comprised 12 treatments, which were replicated thrice in randomized block design. Experiment was laid out in an area of 20 m $\times$ 20 m with 1 m buffer zone in-between each treatment and replication. Adult beetles attracted to different sources were physically hand picked and recorded at weekly interval.

3.3.2 Evaluation of chemicals with pheromone/kairomone activity

Different chemicals with pheromone activity *viz.*, methoxy benzene derivates, ethyl acetate and aqueous neem leaf extract in various combinations (Table 2) were evaluated during 2011-12 at ARS, Sankeshwar under field conditions.

Table 1: Materials/sources used for trapping adults of *Holotrichia serrata*

Treatment No.	Treatment details	Quantity
T_1	Farmyard manure (FYM)	5.0 kg/treatment
T_2	Pressmud	5.0 kg/treatment
T_3	Sugarcane setts/slits	5.0 kg/treatment
T_4	Neem leaves/twigs	5.0 kg/treatment
T_5	FYM + Pressmud	2.5 kg + 2.5 kg/treatment
T_6	FYM + Sugarcane setts/silts	2.5 kg + 2.5 kg/treatment
T_7	FYM + Neem leaves/twigs	2.5 kg + 2.5 kg/treatment
T_8	Pressmud + Sugarcane setts	2.5 kg + 2.5 kg/treatment
T_9	Pressmud + Neem leaves/twigs	2.5 kg + 2.5 kg/treatment
T_{10}	Sugarcane setts + Neem leaves/twigs	2.5 kg + 2.5 kg/treatment
T_{11}	Light source (125 watt fluorescent bulb)	1 No.
T_{12}	Light source + Neem	1 No. + 5 kg/treatment

Table 2: Chemicals used for trapping adults of *Holotrichia serrata*

Treatment No.	Treatment details
T_1	Methoxy benzene (Anisole) @ 10 ml/treatment
T_2	Methoxy 2 benzene @ 10 ml/treatment
T_3	Methoxy 5 benzene @ 10 ml/treatment
T_4	Ethyl acetate @ 10 ml/treatment
T_5	Methoxy benzene @ 5 ml + Methoxy 2 benzene @ 5 mltreatment
T_6	Methoxy benzene @ 5 ml + Methoxy 5 benzene @ 5 ml/treatment
T_7	Methoxy benzene @ 5 ml + Ethyl acetate @ 5 ml/treatment
T_8	Methoxy 2 benzene @ 5 ml + Methoxy 5 benzene @ 5 ml/treatment
T_9	Methoxy 2 benzene @ 5 ml + Ethyl acetate @ 5 ml/treatment
T_{10}	Methoxy 5 benzene @ 5 ml + Ethyl acetate @ 5 ml/treatment
T_{11}	Neem leaf extract 10% @ 10 ml/treatment

They were loaded in cotton swab (Plate 1) with 10 ml of the blend solution by placing them in perforated plastic containers. Trial was laid out in randomized block design with 11 treatments, replicated three times. Eleven traps were placed on wooden poles of 2 m height, all along the sugarcane fields. Traps were placed 10 m apart. The traps were installed in the field from 10^{th} MSW to 16^{th} MSW during both the years (2011 and 2012).

3.3.3 Grub load in different crops

Larval population in different crops of both *kharif* (groundnut, soybean, paddy, maize, chilly, capsicum, brinjal, sugarcane and turmeric) and *rabi* (wheat, sorghum and bengal gram) seasons were recorded by following fixed plot survey in different locations of Hukkeri and Chikkodi taluks. For each crop five fields were selected and from each field five randomly selected spots were collected following destructive sampling method. Regular observations were made at fortnightly intervals in 1 m × 1 m area and finally average was worked out for all five spots, fields and locations.

3.3.3.1 Soil moisture per cent

The amount of soil moisture from the experimental fields was determined by taking the soil weights before and after drying. Soil moisture was driven out by exposing it to higher temperature (100 – 105^0C) in hot air oven. Moisture content was expressed on dry soil w/w and w/v basis.

Per cent soil moisture was calculated by using the formula,

$$\text{Per cent soil moisture} = \frac{\text{Fresh weight of soil (g)}}{\text{Oven dry weight of soil (g)}} \times 100$$

3.3.3.2 Soil temperature

Soil temperature levels in experimental sites were recorded by using soil thermometer installed at 30 cm depth in sugarcane cropping systems (Plate 2). Soil temperature was recorded at fortnightly interval.

3.3.3.3 Depth of larval availability

Soil sampling was carried out at monthly interval from June to September in different crops *viz.*, sugarcane, soybean, groundnut, maize, vegetables, sorghum, wheat and bengal gram *etc.* for two successive years (2011 and 2012) both at Hukkeri and Chikkodi talukas and depth at which larvae were available was recorded with the help of measuring scale.

3.4 Loss estimation in sugarcane due to *Holotrichia serrata* and per cent infestation in other crops

A separate study was conducted for the estimation of yield loss in sugarcane due to *H. serrata* infestation during 2011-12 in seed production plots of Organic Jaggery Park Technology (OJPT) of Sadalga of Chikkodi taluka, comprising five different varieties of sugarcane *viz.*, CoC 671, Co 86032, CoSnk 03632, CoM 265 and Co 8011 in a single block of 5 acres. All the varieties were planted during October in 2010 and November during 2011.

Half an acre in each variety was maintained under complete randomized block with four replications by applying *M. anisopliae* @ 10 kg per acre (obtained from Bio-Pesticide Laboratory, IOF, UAS, Dharwad) during February and remaining half an acre with four replications was left without taking any protection and maintained as control plot to assess the reaction of varieties both under protected and unprotected conditions.

Grub population per m^2 area was taken during June month which coincided with peak grub incidence in June month in protected as well as unprotected plots following destructive sampling . Various growth and yield related parameters were recorded as described hereunder.

3.4.1 Average cane girth

The diameter of five millable canes in each clump was recorded on the middle internode of the cane by using Vernier Calipers at the time of harvest and average girth was expressed in centimeters.

Plate 1: Cotton swab with attractant material for trapping adults

Plate 2: Soil thermometer installed for recording soil temperature

3.4.2 Average millable cane height (cm)

The height of five millable canes was recorded from ground level to the last internode of millable canes in each clump with the help of measuring scale and the average height was expressed in centimeters.

3.4.3 Number of millable canes (NMC) per clump

All the canes from each clump were cut, dressed, counted and recorded as number of millable canes per clump.

3.4.4 Average single cane weight (SCW)

The weight of millable canes in each clump was recorded at harvest and the average weight was worked out and expressed as average single cane weight in kilograms.

3.4.5 Cane yield per clump (kg)

All the canes in each clump were cut close to ground level, the tops and trash were removed and cane weight per clump was recorded and expressed as cane yield per clump in kilograms.

3.4.6 Brix per cent

Five randomly selected canes were harvested and brix reading was recorded using the brix hydrometer. The corrected brix reading was worked out using Bur standards. It was used to calibrate / workout per cent juice in cane.

3.4.7 Purity per cent

The ratio of sucrose per cent to the corrected brix was expressed as purity of the juice, which indicates the proportion of the sucrose in the total solids present in juice. It was calculated at the time of harvesting by selecting five canes from each treatment.

3.4.8 Number of roots per clump

From each plot, two randomly selected clumps were uprooted by digging the soil without affecting the roots, washed gently and the number of roots was counted, averaged and expressed as number of roots per clump to know the grub reaction in different varieties.

3.4.9 Root dry weight per clump at harvest

Two clumps per treatment were selected, the roots were cut at the base and were separated and kept for drying at 80^0C till a constant weight was attained and expressed as grams per clump.

3.4.10 Average root length at harvest

The length of all the roots in a clump upto the tip was measured with the help of measuring scale and expressed as average root length in centimeters.

In other crops grown during *kharif* (groundnut, soybean, chilly, maize, paddy and vegetables) and *rabi* (sorghum, wheat and bengalgram) seasons, per cent infestation was worked out with respect to plant population, per m^2 where in total plant population in different crops was recorded per unit area. Similarly, based on visual symptoms, infested plants per m^2 were recorded by following destructive sampling and later per cent infestation was worked out.

Per cent infestation was calculated by using the formula,

$$\text{Per cent infestation} = \frac{\text{Total No. of white grub infested plants}}{\text{Total No. of plants}} \times 100$$

3.5 Efficacy of entomopathogens and newer molecules of insecticides against white grub, *Holotrichia serrata*

Evaluation of entomopathogens and newer molecules of insecticides was carried out separately against second instar sugarcane white grub under laboratory condition during 2011-12 at ARS, Sankeshwar.

3.5.1 Laboratory evaluation of entomopathogens and newer molecules of insecticides

The experiment consisted of nine treatments which were replicated thrice in completely randomized design. To maintain uniformity, mated females were collected from field during February - April 2011 and were reared under field cages (Plate 3). White grubs were reared in nurseries by providing optimum moisture and potato slices as food. The subsequent population (2^{nd} instar larvae) from this lot was used for studies. Fungal formulations of *Metarhizium anisopliae* (Accession No. KF408075) and *Beauveria bassiana* were obtained from Bio-pesticide Laboratory, Institute of Organic Farming, UAS, Dharwad (Karnataka). Further laboratory dosages of different treatment under study were calculated based on the surface area of trays.

Grubs collected from field nurseries were released into autoclaved soil medium in rectangular plastic trays of 45 cm × 30 cm × 4 cm (Plate 4). Refined (20%) moisture level was maintained by watering at regular intervals. Sprouted maize seeds and potato slices were provided as food. For each treatment, 15 second instar grubs were released which were replicated thrice. The treatments were imposed with dosages as mentioned in Table 3. A separate untreated control was maintained. Application of the powder formulation of two entomopathogens was done by mixing *M. anisopliae* @ 4 $\times 10^8$ conidia per g + *B. bassiana* @ 4 $\times 10^8$ conidia per g and *M. anisopliae* @ 2 $\times 10^8$ conidia per g + *B. bassiana* @ 2 $\times 10^8$ conidia per gram in the soil before release of grubs. Chlorpyriphos was drenched into soil and mixed thoroughly. Observations on larval mortality were recorded at 7, 14, 28, 45 and 60 days after treatment (DAT) and per cent mortality was worked out.

Similarly, laboratory evaluation of newer molecules of insecticides (Table 4) consisted of eight treatments, which were replicated thrice in completely randomized design and the test was carried out by following the methodology described earlier for entomopathogens. Observations on larval mortality were recorded at 7, 14, 28 and 45 DAT and per cent mortality was worked out.

3.5.2 Field evaluation of entomopathogens

Field trials on evaluation of entomopathogens were carried out for two consecutive years during 2010-12 in white grub endemic area *i.e.*, at Bellad Bagewadi of Hukkeri taluka. The trials were laid out in randomized block design with nine treatments and three replications.

The cane variety Co 86032 was planted during the month of October in both 2010 and 2011, with inter-row spacing of 90 cm over a plot size of 10 m × 10 m for each treatment. All the recommended package of practices were followed except for the management of white grub *viz.*, *M. anisopliae* and *B. bassiana* and their combinations. Various treatments as detailed (Table 3) were imposed.

Chlorpyriphos 20 EC @ 10 ml per lit of water was prepared and the actual quantity required for the treatment was calculated for drenching the soil around the clump by making holes of 15 cm depth and 3 cm diameter with the help of crow bar. Neem cake was applied to soil near root zone.

Observations were made a day before and 15, 30, 45 and 60 days after imposition of treatments on larval count in 1 m^2 area. In each treatment five randomly selected spots were observed for larval population at different intervals. Finally, at harvest, number of millable canes (NMCs) and cane yield (t/ha) were recorded in all the treatments.

3.5.3 Field evaluation of newer molecules of insecticides

Field evaluation of newer molecules of insecticides (Table 4) was carried out during 2011-12 at Kadapur village of Chikkodi taluka.

The cane variety CoC 671 was planted during the month of November in 2010 and October in 2011 with inter-row spacing of 90 cm over a plot size of 10 m × 10 m for each treatment by following all the recommended package of practices except for management of white grub. The trial was laid out in randomized block design with eight treatments (Table 4) replicated thrice.

Plate 3: Field nurseries for rearing *Holotrichia serrata* grubs

Plate 4: Plastic boxes/trays used for laboratory evaluation ofentomopathogens and newer insecticides

Table 3: Entomopathogens evaluated in the laboratory and field against *Holotrichia serrata* grub

Treatment No.	Treatments details	Dosage	
		Laboratory (g)	Field (ha)
T_1	*Metarhizium anisopliae* @ 4 × 10^8 conidia/g	1.37	25 kg + 125 kg FYM
T_2	*Metarhizium anisopliae* @ 2 × 10^8 conidia/g	0.68	12.5 kg + 62.5 kg FYM
T_3	*Beauveria bassiana* @ 4 × 10^8 conidia/g	1.37	25 kg + 125 kg FYM
T_4	*Beauveria bassiana* @ 2 × 10^8 conidia/g	0.68	12.5 kg + 62.5 kg FYM
T_5	*Metarhizium anisopliae* @ 4 × 10^8 conidia/g + *B. bassiana* @ 4 × 10^8 conidia/g	2.74	25 kg + 25 kg with 250 kg FYM
T_6	*Metarhizium anisopliae* @ 2 × 10^8 conidia/g + *B. bassiana* @ 2 × 10^8 conidia/g	1.37	12.5 kg + 12.5 kg with 125 kg FYM
T_7	Neem cake	27.54	500 kg alone
T_8	Chlorpyriphos 20 EC	0.55 ml	10000 mlha
T_9	Untreated check	-	-

Table 4: Evaluation of newer molecules of insecticides used in the laboratory and field against grubs of *Holotrichia serrata*

Treatments	Treatment details	Dosage	
		a.i./ha	Formulation (ha)
T_1	Imidacloprid 17.8 SL	178 g	@ 1000 ml
T_2	Fipronil 5 EC	75 g	@ 1500 ml
T_3	Lamdacyholothrin 5 EC	75 g	@ 1500 ml
T_4	Imidacloprid + fipronil - 80 WG	200 g	@ 500 g
T_5	Chlorpyriphos 20 EC	2000 g	@ 10000 ml
T_6	Rynaxypyr 4 G	320 g	@ 20 kg
T_7	Phorate 10 G	2500 g	@ 25 kg
T_8	Untreated check	-	-

Insecticide treatments were applied to the root zone of sugarcane clump according to the respective dosages. The treatments were imposed in the second week of June 2011 and 2012 by soil drenching method *i.e.*, spot filling for insecticide solution by making holes of 15 cm depth and 10 cm diameter with the help of a crow bar. Similarly, granular formulations *viz*., phorate and rhynaxypyr were applied near root zone.

Observations were made separately on the number of grubs per m^2 area in the root zone a day before and 7, 14, 28 and 45 days after imposition of treatment. Number of millable canes and cane yield (t/ha) were recorded at harvest.

3.5.4 Statistical analysis

The number of adults trapped in each treatment in the evaluation of different trapping sources and chemicals with pheromone /kairmone activity, experiments was transformed to $\sqrt{x+1}$ and subjected to statistical analysis and data on per cent mortality of grubs in both laboratory and field experiments was transformed to arcsine transformation and then subjected to one way ANOVA using MSTAT-C® Software package. The treatment effect was compared by following Duncan's Multiple Range Test (DMRT).

EXPERIMENTAL RESULTS

The studies conducted on species composition, population dynamics, behavioural pattern of adult white grub, loss estimation and evaluation of entomopathogens and newer chemical insecticides during 2011-12 are presented below.

4.1 Species composition of white grubs

Monitoring studies conducted over two years (2011 and 2012) in irrigated ecosystem of Kadapur, Soundalga, Bellad Bagewadi and Sankeshwar and rainfed ecosystem of Hattarwat village to know the species composition (Plate 5) on naturally available host plants are presented below.

Kadapur

Monitoring studies conducted during 2011 indicated the abundance of three species of white grubs *viz., H. serrata*, *Anomala bengalensis* and *Anomala ruficapilla* which are presented in Table 5.

The emergence of *H. serrata* adults commenced from March 8^{th} MSW (March) with weekly mean catches of 2.40, which gradually increased from 10^{th} MSW and reached peak during 12^{th} MSW with adult catches of 14.40 at 23.80 per cent soil moisture. However, the other two species *viz., A. bengalensis* and *A. ruficapilla* started emerging from 11^{th} MSW (April) continued up to 13^{th} MSW with meager catches of 0.10-0.21 and 0.10 - 0.00 for *A. bengalensis* and *A. ruficapilla*, respectively at soil moisture per cent ranging from 22.50 - 23.80. Irrespective of species, totally 64.43 adults were caught of which *H. serrata* accounted for 98.12 per cent.

During 2012 similar trend was noticed with respect to *H. serrata* which peaked during 12^{th} week. However, *A. bengalensis*, *A. ruficapilla, P. dionysius* accounted for only 0.11 to 0.33, 0.21 to 0.16 and 0.12 to 0.22 during 11^{th} and 12^{th} MSW (March). *H. serrata* accounted for more than 98.22 per cent catch.

Pooled data analysis revealed the dominance of *H. serrata,* accounting for 98.17per cent catch recording peak between 11^{th} to 13^{th} MSW.

Soundalga

Results pertaining to adult emergence indicated the presence of three species *viz., H. serrata*, *A. bengalensis* and *A. ruficapilla* on neem tree. Emergence of *H. serrata* commenced from 9^{th} MSW (March), increased gradually from 10^{th} MSW and reached peak (12.10) during 13^{th} MSW. Soil moisture of 25.20 per cent and soil temperature of 29.50°C were recorded during peak emergence. *A. bengalensis* and *A. ruficapilla* were recorded from 12^{th} MSW but *A. bengalensis* reached peak during 13^{th} MSW at soil moisture level of 25.20 per cent and temperature of 29.50 °C (Table 6). Totally 35.65 adults were trapped of which 34.97 (98.09%) were *H. serrata* and remaining 0.68 (1.91%) comprised of both *A. bengalensis* and *A. ruficapilla*.

During 2012, similar to 2011, peak emergence of *H. serrata* was observed at 13^{th} MSW and was the dominant species accounting for 95.96 per cent catches at soil moisture of 23.00 percent.

Pooled data analysis indicated trend similar to 2011 and 2012 with respect to species composition, abundance and peak emergence time.

Bellad Bagewadi

Monitoring studies conducted during 2011 indicated the presence of three species of white grubs as noticed in Soundalga location. However, the emergence of *H. serrata* in this location commenced from 7^{th} MSW (February) and continued upto 16^{th} MSW (April) and peak was recorded during 9^{th} - 10^{th} MSW. Irrespective of species, *H. serrata* was the major one with total catches of 35.93 accounting for 96.17 per cent. *A. bengalensis* and *A. ruficapilla* were the other two species recorded whose emergence was observed during 9^{th} to 11^{th} MSW (March) accounting for only 3.83 per cent catch. Soil moisture per cent ranged from 22.20 to 24.60 and soil temperature ranged from 25.60 to 31.60 °C (Table 7).

During 2012 also a similar trend was observed. However, adult emergence commenced from 7^{th} MSW continued upto 16^{th} MSW and peaked during 10^{th} MSW. Again *H. serrata* with total catches of 33.92 accounted for 97.50 per cent and was the dominant species.

Pooled data analysis indicated confirmed the pattern observed during 2011 and 2012 with respect to species composition, abundance and peak emergence time.

Anomala bengalensis Blanchard

Anomala ruficapilla Burmeister

Holotrichia serrata Fab.

Phyllognathus dionysius (Fabricus)

Holotrichia fissa Br

Plate 5: Species composition of white grubs

Table 5: Species composition and abundance of white grubs in sugarcane ecosystem - Kadapur

Sl. No.	Species	Mean adult numbers in MSW – 2011										
		8 (Feb)	9 (March)	10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	2.40	7.10	8.70	12.80	14.40	11.40	4.30	1.70	0.42	63.22	98.12
2	*Holotrichia fissa*										0.00	0.00
3	*Anomola bengalensis*				0.10	0.14	0.21				0.45	0.70
4	*Anomola ruficapilla*				0.66	0.10					0.76	1.18
5	*Phyllognathus Dionysius*										0.00	0.00
											64.43	
	Soil temperature (^{0}C)	25.80	26.90	27.30	28.40	29.10	29.40	30.10	30.70	31.30		
	Soil moisture (%)	18.20	19.70	21.20	22.50	23.80	23.00	22.50	21.10	20.50		
Sl. No.	Species	Mean adult numbers in MSW – 2012										
		8 (Feb)	9 (March)	10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	1.42	4.51	8.10	15.10	15.90	10.60	5.30	2.10	0.30	63.33	98.22
2	*Holotrichia fissa*										0.00	0.00
3	*Anomola bengalensis*				0.11	0.33					0.44	0.68
4	*Anomola ruficapilla*				0.21	0.16					0.37	0.57
5	*Phyllognathus Dionysius*				0.22	0.12					0.34	0.53
											64.48	
	Soil temperature (^{0}C)	26.20	27.90	28.10	28.60	29.30	29.80	30.40	30.90	31.60		
	Soil moisture (%)	19.30	20.10	21.70	23.80	24.00	22.50	21.70	20.60	19.10		
Sl. No.	Species	Mean adult numbers in MSW –Pooled										
		8 (Feb)	9 (March)	10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	1.91	5.81	8.40	13.95	15.15	11.00	4.80	1.90	0.36	63.28	98.17
2	*Holotrichia fissa*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	*Anomola bengalensis*	0.00	0.00	0.00	0.11	0.24	0.11	0.00	0.00	0.00	0.45	0.69
4	*Anomola ruficapilla*	0.00	0.00	0.00	0.44	0.13	0.00	0.00	0.00	0.00	0.57	0.88
5	*Phyllognathus Dionysius*	0.00	0.00	0.00	0.11	0.06	0.00	0.00	0.00	0.00	0.17	0.26
											64.46	
	Soil temperature (^{0}C)	26.00	27.40	27.70	28.50	29.20	29.60	30.25	30.80	31.45		
	Soil moisture (%)	18.75	19.90	21.45	23.15	23.90	22.75	22.10	20.85	19.80		

Table 6: Species composition and abundance of white grubs in sugarcane ecosystem – Soundalga

Sl. No.	Species	Mean adult numbers in MSW -2011										
		9 (March)	10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)	17 (April)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	1.14	2.42	5.10	8.85	12.10	3.20	1.45	0.57	0.14	34.97	98.09
2	*Holotrichia fissa*										0.00	0.00
3	*Anomola bengalensis*				0.14	0.33					0.47	1.32
4	*Anomola ruficapilla*				0.21						0.21	0.59
5	*Phyllognathus dionysius*										0.00	0.00
											35.65	
	Soil temperature (^{0}C)	26.70	27.70	28.30	29.10	29.50	30.10	30.90	31.00	31.20		
	Soil moisture (%)	23.10	23.40	23.70	24.30	25.20	23.90	22.60	21.80	20.10		
Sl. No.	Species	Mean adult numbers in MSW – 2012										
		9 (March)	10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)	17 (April)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	1.42	2.71	4.44	10.11	11.68	2.44	1.10	0.21	0.12	34.23	95.96
2	*Holotrichia fissa*										0.00	0.00
3	*Anomola bengalensis*			0.21	0.67	0.14					1.02	2.86
4	*Anomola ruficapilla*				0.31	0.11					0.42	1.18
5	*Phyllognathus dionysius*										0.00	0.00
											35.67	
	Soil temperature (^{0}C)	26.90	27.60	28.50	29.30	29.70	30.30	30.80	31.20	31.60		
	Soil moisture (%)	23.10	23.40	23.30	23.90	24.80	23.60	22.80	21.30	20.20		
Sl. No.	Species	Mean adult numbers in MSW – Pooled										
		9 (March)	10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)	17 (April)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	1.28	2.57	4.77	9.48	11.89	2.82	1.28	0.39	0.13	34.60	97.03
2	*Holotrichia fissa*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	*Anomola bengalensis*	0.00	0.00	0.11	0.41	0.24	0.00	0.00	0.00	0.00	0.75	2.09
4	*Anomola ruficapilla*	0.00	0.00	0.00	0.26	0.06	0.00	0.00	0.00	0.00	0.32	0.88
5	*Phyllognathus dionysius*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
											35.66	
	Soil temperature (^{0}C)	26.80	27.65	28.40	29.20	29.60	30.20	30.85	31.10	31.40		
	Soil moisture (%)	23.10	23.40	23.50	24.10	25.00	23.75	22.70	21.55	20.15		

Table 7: Species composition and abundance of white grubs in sugarcane ecosystem – Bellad Bagewadi

Sl. No.	Species	Mean adult numbers in MSW – 2011											
		7 (Feb)	8 (Feb)	9 (March)	10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	1.28	3.27	8.71	12.45	4.71	3.10	1.42	0.57	0.28	0.14	35.93	96.17
2	*Holotrichia fissa*											0.00	0.00
3	*Anomola bengalensis*			0.67	0.38	0.15						1.20	3.21
4	*Anomola ruficapilla*				0.23							0.23	0.62
5	*Phyllognathus dionysius*											0.00	0.00
												37.36	
	Soil temperature (^{0}C)	25.60	26.10	26.70	27.70	28.20	29.10	29.40	30.40	31.10	31.60		
	Soil moisture (%)	23.20	23.90	24.10	24.60	23.70	23.30	23.10	22.80	22.50	22.20		
Sl. No.	Species	Mean adult numbers in MSW – 2012											
		7 (Feb)	8 (Feb)	9 (March)	10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	1.57	3.85	8.28	10.57	5.28	2.56	1.28	0.28	0.14	0.11	33.92	97.50
2	*Holotrichia fissa*											0.00	0.00
3	*Anomola bengalensis*			0.14	0.33	0.26						0.73	2.10
4	*Anomola ruficapilla*				0.14							0.14	0.40
5	*Phyllognathus dionysius*											0.00	0.00
												34.79	
	Soil temperature (^{0}C)	25.30	26.20	26.90	27.60	28.50	29.10	29.70	30.60	31.30	31.70		
	Soil moisture (%)	22.60	22.90	23.10	24.80	24.20	23.50	23.10	22.70	22.40	22.20		
Sl. No.	Species	Mean adult numbers in MSW - Pooled											
		7 (Feb)	8 (Feb)	9 (March)	10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	1.43	3.56	8.50	11.51	5.00	2.83	1.35	0.43	0.21	0.13	34.93	96.81
2	*Holotrichia fissa*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	*Anomola bengalensis*	0.00	0.00	0.41	0.36	0.21	0.00	0.00	0.00	0.00	0.00	0.97	2.67
4	*Anomola ruficapilla*	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.51
5	*Phyllognathus dionysius*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.08	
	Soil temperature (^{0}C)	25.45	26.15	26.80	27.65	28.35	29.10	29.55	30.50	31.20	31.65		
	Soil moisture (%)	22.90	23.40	23.60	24.70	23.95	23.40	23.10	22.75	22.45	22.20		

Sankeshwar

During 2011, adult emergence of *H. serrata* commenced from 10th MSW (March) and gradual increase was noticed from 11th MSW onwards and the peak was observed between 13th MSW to 15th MSW (5.14 – 6.85) while gradual decline was noticed from 17th MSW (May) onwards. Irrespective of species totally 29.14 adults were trapped of which 28.14 accounted for *H. serrata* (97.43%) while the two species of *Anomala* spp. contributed only 3.44 per cent (Table 8).

During 2012, emergence of *H serrata* commenced from 10th MSW (0.42) reaching peak between 13th to 15th MSW (5.57 – 7.60). Decline was noticed from 17th MSW. Totally, 28.45 adults were collected of which 27.74 accounted for *H. serrata* (97.50%) while the remaining 2.50 per cent were occupied by *Anomola* spp.

Pooled data analysis indicated similarity to 2011and 2012 with respect to species composition abundance and period of emergence.

Hattarwat

Results of monitoring study conducted during 2011 in rainfed ecosystem of Hattarwat location revealed the presence of four species of white grubs *viz., H. serrata*, *H. fissa, A. bengalensis* and *A. ruficapilla* (Table 9). The emergence of *H. serrata* adults commenced from 14th MSW (April), but maximum beetles (16.94) were caught upto 18th MSW (May) which gradually declined from 19th MSW onwards reaching nil at 21st MSW, whereas emergence of *H. fissa* though commenced from 14th MSW (April) gradually increased from 17th MSW onwards reaching peak during 20th MSW (May) with 24.99 catches. From 21st MSW onwards decline was noticed. However, the adult emergence of *Anomala* spp. commenced from 14th MSW, *A. bengalensis* gradually increased and peaked on 19th MSW (7.00) reaching nil from 22nd MSW, while *A. ruficapilla* peaked during 18th MSW reaching nil on 19th MSW.

Irrespective of species, totally 157.84 adults were trapped during 2011 of which *H. fissa* was the major one accounting for 96.18 (60.94%) catches, followed by *H. serrata* and *Anomola* spp. *H. fissa* is being recorded for the first time from northern Karnataka (Table 9).

During 2012, totally 102.96 adults comprising four species *viz., H. serrata*, *H. fissa, A. bengalensis* and *A. ruficapilla* were trapped, of which *H. fissa* was the most dominant species accounting for 82.59 numbers and 80.22 per cent catch, followed by other species *viz., H. serrata*, *A. bengalensis* and *A. ruficapilla* all together accounting for 16.57 per cent.

Pooled data analysis indicated that irrespective of species, emergence commenced from 14th MSW. *H. serrata* and *A. ruficapilla* peaked during 18th MSW, while *H. fissa* peaked on 20th MSW and *A. bengalensis* peaked during 17th MSW.

Comparison among locations

Irrespective of locations, *H. serrata* adults were caught between 8th to 15th MSW that ranged from 94.15 to 98.12 per cent and soil moisture ranging from 22.50 to 25.20. However, other species of white grubs encountered in irrigated ecosystem were *A. bengalensis*, *A. ruficapilla* and *P. dionysius* respectively accounting for 1.88 to 4.85 per cent indicating the dominance of *H. serrata.* Peak emergence was noticed between 9th to 10th MSW (March) in Bellad Bagewadi whereas in Kadapur and Soundalga locations, peak was observed during 12th and 13th MSW (March and April). However in Sankeshwar adult emergence commenced from 10th MSW (March) and peak emergence period was from 13th to 15th MSW (March to April).

Adult emergence of *H. serrata* at Kadapur commenced from 8th MSW (February) and continued upto 16th MSW (April). However, peak period was observed during 12th MSW (March). In sugarcane ecosystem, *H. serrata* was the only species occurring with more than 98 per cent adult catch indicating its dominance. Per cent soil moisture during the period of adult emergence ranged between 18.75 to 23.90 while during peak period it was 23.90 per cent.

Similar pattern of adult emergence with respect to *H. serrata* was observed even at Bellad Bagewadi and Soundalga locations. However, at Bellad Bagewadi commencement of emergence was recorded from 7th MSW (February) and continued upto 16th MSW (April) with peak period observed during 13th MSW (March), where as at Soundalga emergence started from 9th MSW (March) and continued upto 17th MSW (April) and 13th MSW recorded the peak noticed. Per cent soil moisture recorded ranged from 20.15 to 25.00 and 22.20 to 24.70 per cent Bellad Bagewadi and Soundalga locations respectively.

Table 8: Species composition and abundance of white grubs in sugarcane ecosystem – Sankeshwar

Sl. No.	Species	Mean adult numbers in MSW – 2011										
		10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)	17 (April)	18 (May)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	0.57	1.28	3.14	5.14	5.71	6.85	3.85	1.57	0.28	28.39	97.43
2	*Holotrichia fissa*										0.00	0.00
3	*Anomola bengalensis*				0.11	0.33	0.20				0.64	2.20
4	*Anomola ruficapilla*					0.11					0.11	0.38
5	*Phyllognathus dionysius*										0.00	0.00
											29.14	
	Soil temperature (^{0}C)	27.70	28.60	29.10	29.50	30.20	31.10	31.50	31.60	31.80		
	Soil moisture (%)	21.80	22.70	23.10	22.90	23.00	24.60	25.40	24.50	22.20		
Sl. No.	Species	Mean adult numbers in MSW – 2012										
		10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)	17 (April)	18 (May)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	0.42	1.10	2.57	5.57	6.10	7.60	3.14	1.10	0.14	27.74	97.50
2	*Holotrichia fissa*										0.00	0.00
3	*Anomola bengalensis*				0.16	0.18	0.23				0.57	2.00
4	*Anomola ruficapilla*					0.14					0.14	0.49
5	*Phyllognathus dionysius*										0.00	0.00
											28.45	
	Soil temperature (^{0}C)	27.70	28.60	29.30	29.70	30.20	30.90	31.50	31.80	32.00		
	Soil moisture (%)	18.80	20.30	22.70	23.50	22.80	24.10	23.70	23.20	22.90		
Sl. No.	Species	Mean adult numbers in MSW - Pooled										
		10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)	17 (April)	18 (May)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	0.50	1.19	2.86	5.36	5.91	7.23	3.50	1.34	0.21	28.07	97.46
2	*Holotrichia fissa*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	*Anomola bengalensis*	0.00	0.00	0.00	0.14	0.26	0.22	0.00	0.00	0.00	0.61	2.10
4	*Anomola ruficapilla*	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.13	0.43
5	*Phyllognathus dionysius*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
											28.84	
	Soil temperature (^{0}C)	27.70	28.60	29.20	29.60	30.20	31.00	31.50	31.70	31.90		
	Soil moisture (%)	20.30	21.50	22.90	23.20	22.90	24.35	24.55	23.85	22.55		

Table 9: Species composition and abundance of white grubs in rainfed ecosystem – Hattarwat

Sl. No.	Species	Mean adult numbers in MSW – 2011										
		14 (April)	15 (April)	16 (April)	17 (April)	18 (May)	19 (May)	20 (May)	21 (May)	22 (May)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	1.96	0.98	3.57	2.94	16.94	0.98	0.00	0.00	0.00	27.37	17.34
2	*Holotrichia fissa*	0.98	4.97	7.98	8.47	14.98	19.95	24.99	10.92	2.94	96.18	60.94
3	*Anomola bengalensis*	0.77	3.08	4.27	5.95	0.70	7.00	5.17	1.40	0.00	28.34	17.95
4	*Anomola ruficapilla*	1.54	0.98	1.47	0.98	0.98	0.00	0.00	0.00	0.00	5.95	3.77
											157.84	
	Soil temperature (^{0}C)	31.20	31.40	30.80	31.60	32.20	32.40	33.10	32.60	31.90		
	Soil moisture (%)	16.50	16.85	17.25	18.00	19.85	22.15	23.00	21.20	20.45		
Sl. No.	Species	Mean adult numbers in MSW – 2012										
		14 (April)	15 (April)	16 (April)	17 (April)	18 (May)	19 (May)	20 (May)	21 (May)	22 (May)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	0.98	1.54	2.87	4.20	0.70	0.70	0.70	0.00	0.00	11.69	11.35
2	*Holotrichia fissa*	1.40	4.62	7.70	9.31	15.54	18.75	23.17	1.40	0.70	82.59	80.22
3	*Anomola bengalensis*	0.00	0.00	1.47	2.31	0.98	0.70	0.00	0.00	0.00	5.46	5.30
4	*Anomola ruficapilla*	0.00	0.00	0.00	0.98	1.47	0.77	0.00	0.00	0.00	3.22	3.13
											102.96	
	Soil temperature (^{0}C)	30.80	31.60	31.10	30.90	32.00	32.70	31.90	33.20	33.10		
	Soil moisture (%)	22.25	23.10	24.30	23.70	24.70	24.40	23.90	23.70	22.60		
Sl. No.	Species	Mean adult numbers in MSW - Pooled										
		14 (April)	15 (April)	16 (April)	17 (April)	18 (May)	19 (May)	20 (May)	21 (May)	22 (May)	Total No. of catches	Per cent catch
1	*Holotrichia serrata*	1.47	1.26	3.22	3.57	8.82	0.84	0.35	0.00	0.00	19.53	14.98
2	*Holotrichia fissa*	1.19	4.80	7.84	8.89	15.26	19.35	24.08	6.16	1.82	89.39	68.55
3	*Anomola bengalensis*	0.39	1.54	2.87	4.13	0.84	3.85	2.59	0.70	0.00	16.90	12.96
4	*Anomola ruficapilla*	0.77	0.49	0.74	0.98	1.23	0.39	0.00	0.00	0.00	4.59	3.52
											130.40	
	Soil temperature (^{0}C)	31.00	31.50	30.95	31.25	32.10	32.55	32.50	32.90	32.50		
	Soil moisture (%)	19.38	19.98	20.78	20.85	22.28	23.28	23.45	22.45	21.53		

At Sankeshwar, *H. serrata* adult emergence commenced from 10th MSW (March) and continued upto 18th MSW (May) and the peak was during 15th MSW (April). Per cent soil moisture recorded during this period ranged from 20.30 to 24.55.

Under rainfed ecosystem the adult emergence of *H. serrata* commenced from 14th MSW (April) only after receipt of pre-monsoon showers and continued upto 22nd MSW (May). Per cent soil moisture recorded during emergence period ranged from 19.38 to 23.45. However, under rainfed situations, *Holotrichia fissa* dominated accounting for more than 68.00 per cent catch followed by *H. serrata* (14.98%).

Studies conducted over two years indicated that irresepective of the locations, *H. serrata* was the only commonly occurring species in sugarcane ecosystem, whereas in rainfed ecosystem *H. fissa* was the major species. However, under irrigated conditions emergence started from 7th MSW (February) and continued upto 18th MSW (April) but in rainfed ecosystem, emergence commenced from 14th MSW (April) only after the receipt of pre-monsoon showers and continued upto 22nd MSW (May).

4.1.1 Corelation and regression studies

Bellad Bagewadi

Correlation matrix for adult emergence of *H. serrata* revealed highly significant association with soil moisture (r= 0.706**), while soil temperature (r= -0.284) had negative and non-significant relationship (Table 10). Results of the multiple linear regression analysis between independent (soil moisture and soil temperature) weather parameters for the dependent factor (adult catch) showed R^2 value of 0.65 indicating 65 per cent influence of soil physical properties (soil moisture and soil temperature) on adults emerged.

The results indicated that while increase in soil temperature would lead to decrease of 0.476 adults, increase in 1 per cent soil moisture would lead to increase of 2.194 adults.

In case of *Anomola bengalensis,* correlation matrix for adult emergence indicated highly significant association with soil moisture (r = 0.556**), while soil temperature (r = -0.198) had negative non-significant relationship. Results pertaining to multiple linear regression analysis between independent parameters and the dependent factor (adult catches) showed a R^2 value of 0.388 indicating 38.8 per cent influence of abiotic factor, on adult emergence.

The results indicated that, while 1^{o}C increase in soil temperature lead to decrease of 0.15 adults, 1 per cent increase in soil moisture lead to increase of 0.76 adults.

For *Anomola ruficapilla* correlation matrix for adult emergence indicated significant association with soil moisture (r = 0.437*), while soil temperature (r = -0.099) had negative non-significant relationship. Results of the multiple linear regression analysis between independent variables and dependent factor *i.e.,* adult catch showed a R^2 value of 0.218 indicating 21.8 per cent influence of weather parameters on adult emergence.

The results indicated that increase in 1^{o}C soil temperature lead to decrease of 0.003 adults, while increase in 1 per cent soil moisture lead to increase of 0.019 adults.

Soundalga

Correlation matrix for adult emergence of *H. serrata* indicated highly significant association with soil moisture (r = 0.759**), while soil temperature (r = 0.182) had non-significant relationship. Results of the multiple linear regression analysis between independent weather parameters and the dependent adult population indicated R^2 value of 0.619 indicating 61.9 per cent influence of weather factors on adult emergence.

The results indicated that, increase in 1^{o}C soil temperature lead to decrease of 0.280 adults and increase in 1 per cent soil moisture lead to increase of 1.761 adults.

For *A. bengalensis*, correlation matrix revealed significant relation with soil moisture (r = 0.448*), while soil temperature (r =0.109) had non-significant association. Results of multiple linear regression analysis between independent and dependent factor (adults catches) indicated R^2 value of 0.216 indicating 21 per cent influence of soil physical factors on the emergence of *A. bengalensis.*

The results indicated that while increase in 1^{o}C soil temperature lead to decrease of 0.006 adults, increase in 1 per cent soil moisture lead to increase of 0.040 adults.

Table 10: Correlation studies for adult emergence of white grub over different locations during 2011-13

Location	White grub species	Soil temperature (X_1) (^0C)	Soil Moisture (X_2) (%)	Multiple linear regression equation developed	R^2 value
Bellad Bagewadi	*H. serrata*	-0.284	0.706**	$Y= 33.743-0.476 X_1+2.194 X_2$	0.65
	A. bengalensis	-0.198	0.556**	$Y=1.227-0.15 X_1+0.76 X_2$	0.388
	A. ruficapilla	-0.099	0.437*	$Y=0.327-0.003 X_1+0.019 X_2$	0.218
Soundlaga	*H. serrata*	0.182	0.759**	$Y=28.530-0.280 X_1+1.76 X_2$	0.619
	A. bengalensis	0.109	0.448*	$Y=0.650-0.006 X_1+0.040 X_2$	0.216
	A. ruficapilla	0.098	0.377*	$Y=0.272-0.002 X_1+0.016 X_2$	0.151
Sankeshwar	*H. serrata*	0.462*	0.621**	$Y=16.200-0.194 X_1+1.073 X_2$	0.402
	A. bengalensis	0.284	0.376*	$Y=0.350+00.010 X_1+0.023 X_2$	0.146
	A. ruficapilla	0.148	0.126	$Y=0.036+0.002 X_1+3.325 X_2$	0.022
Kadapur	*H. serrata*	0.083	0.693**	$Y=41.633+0.845 X_1+3.317 X_2$	0.647
	A. bengalensis	0.081	0.618**	$Y=0.552+0.010 X_1+0.42 X_2$	0.509
	A. ruficapilla	0.016	0.379*	$Y=0.553+0.013 X_1+0.045 X_2$	0.211
	P. Dionysius	0.038	0.690**	$Y=0.461+0.007 X_1$	0.580
Hattarwat	*H. serrata*	0.185	-0.071	$Y=1.321+0.080 X_1+0.047 X_2$	0.079
	H. fissa	0.581**	0.504**	$Y=9.488-0.258 X_1+0.115 X_2$	0.384
	A. ruficapilla	0.333	-0.057	$Y=0.337+0.023 X_1-0.016 X_2$	0.198

In the case of *A. ruficapilla* correlation matrix for adult emergence indicated significant relation with soil moisture (r = 0.377*), while soil temperature (r = 0.098) had non-significant relationship. Results of the multiple linear regression analysis between independent factors and the dependent factor (adult population) showed R^2 value of 0.151 indicating 15.1 per cent influence of soil physical factors on adult emergence.

The results indicated that while increase in 1°C soil temperature lead to decrease of 0.002 adults increase in 1 per cent soil moisture lead to increase of 0.016 adults.

Sankeshwar

Correlation matrix for adult emergence of *H. serrata* indicated highly significant relation with soil moisture (r = 0.621**) while, soil temperature (r = 0.462*). Results pertaining to multiple linear regression analysis showed R^2 value of 0.402 indicating 40.2 per cent influence of soil physical factors.

The results indicated that increase in 1°C soil temperature lead to decrease of 0.194 adults while increase in 1 per cent soil moisture lead to increase of 0.1073 adults.

For *A. bengalensis* correlation matrix for adult emergence indicated significant relation with soil moisture (r = 0.376 *) while soil temperature (r = 0.284) had non-significant relationship. Results of multiple linear regression analysis between independent and dependent factors showed R^2 value of 0.146 indicating 14.6 per cent influence of soil physical factors on adult emergence of *A. bengalensis.*

The results indicated that increase in 1°C soil temperature lead to increase of 0.010 adults whereas increase in 1 per cent soil moisture lead to increase of 0.023 adults.

Correlation matrix for adult emergence in *A ruficapilla* indicated positive relation with soil moisture (r = 0.126), while soil temperature (r = 0.148) had non-significant relationship. Result of multiple linear regression analysis between independent factors and dependent factor (adult number) showed a R^2 value of 0.002, indicating influence of weather factors to the tune of 0.20 per cent on emergence of *A. ruficapilla* adults

The results indicated that while increase in 1°C soil temperature lead to increase of 0.002 adults, increase in 1 per cent soil moisture lead to increase of 3.325 adults.

Kadapur

For, *H. Serrata* adults, the correlation matrix produced highly significant relation with soil moisture (r = 0.693**) while soil temperature (r = 0.083) had non-significant relationship. Result of multiple linear regression analysis between independent factors and *H. serrata* adult (dependent) number showed a R^2 value of 0.647 indicating the influence of soil physical factors to the tune of 64.7 per cent on adult emergence.

The results indicated that increase in 1°C soil temperature lead to increase of 0.845 adults, while increase in 1 per cent soil moisture lead to increase of 3.317 adults.

Correlation matrix for emergence of *A. bengalensis* adults revealed highly significant association with soil moisture (r = 0.618**), while soil temperature (r = 0.081) had non-significant association. Multiple linear regression analysis between independent for the dependent factor showed a R^2 value of 0.509 indicating 50.9 per cent influence of soil physical factors.

The results indicated that 1°C increase in soil temperature lead to increase of 0.010 adults and with increase in 1 per cent soil moisture lead to increase of 0.042 adults.

Correlation matrix for *A. ruficapilla* adult emergence indicated significant relation with soil moisture (r = 0.379*), while soil temperature (r = 0.016) had non-significant association with adult emergence. Multiple linear regression analysis between independent factors and dependent variable showed a R^2 value of 0.211 indicating 21.1 per cent influence of soil physical factors.

The results indicated that while increase in 1°C soil temperature would lead to increase of 0.013 adults increase in 1 per cent soil moisture would lead to increase of 0.045 adults.

For, *Phyllognatuhs dionysius,* correlation matrix for emergence indicated highly significant association with soil moisture (r = 0.690 **) while soil temperature (r = 0.038) had non-significant association. Multiple linear regression analysis between independent factors to the dependent factor showed a R^2 value of 0.580 indicating 58.0 per cent influence of independent variables.

The results indicated that while increase in 1°C soil temperature lead to increase of 0.007 adults increase in 1 per cent soil moisture lead to increase of 0.033 adults.

Hattarwat (Rainfed ecosystem)

Correlation matrix for adult emergence of *H. serrata* indicated non siginificant negative association with soil moisture (r = -0.071), while soil temperature (r = 0.185) had non-significant positive relationship. Multiple linear regression analysis between independent factors and dependent variable should a R^2 value of 0.079, indicated 0.79 per cent influence of soil physical factors on emergence of *H. serrata* adults.

The results indicated that increase in 1°C soil temperature lead to decrease of 0.080 adults and increase in 1 per cent soil moisture lead to decrease of 0.047 adults.

Correlation matrix for *H. fissa* adult emergence revealed highly significant relation with both soil moisture (r = 0.504 **) and soil temperature (r = 0.581**). Multiple linear regression analysis between independent factors and adult emergence (dependent) factor showed a R^2 value of 0.384, indicating 38.4 per cent influence of soil physical factors on *H. fissa* adult emergence.

The results indicated that increase in 1°C soil temperature lead to decrease of 0.258 adults and increase in 1 per cent soil moisture lead to increase of 0.115 adults.

For, *A. ruficapilla,* correlation matrix indicated negative association with soil moisture (r = -0.057), while soil temperature (r = 0.333) had non-significant association, multiple linear regression analysis between independent factor and dependent factor (adult population) showed an R^2 value of 0.198 indicating 19.8 per cent influence of soil physical factors.

The results indicated that increase in 1°C soil temperature lead to increase of 0.82 adults increase in 1 per cent soil moisture lead to decrease of 0.041 adults.

4.2 Population dynamics of sugarcane white grub *Holotrichia serrata*

Studies conducted on occurrence of different stages *viz.,* egg, first, second, third instar grubs, pupa and quiescent adults of white grub in sugarcane eco-system in different locations during 2011-12 are summarized below.

Ankali

January -April 2011

Mean number of adult count ranged from 0.10 to 1.50 while the mean egg and first instar count was 0.30 and 0.36 respectively (Table 11).

January - April 2012

The number of pupae recorded ranged from 0.26 to 0.60, whereas adult count ranged from 0.20 to 1.20, egg and first instar grub count ranged from 0.10 to 0.60 and 0.10 to 0.90 respectively (Table 11). Pooled data analysis revealed 0.26 to 0.60 pupae and 0.20 to 1.33 adults, whereas egg and first instar grub number ranged from 0.10 to 0.35 and 0.10 to 0.58 respectively (Table 12).

May - August 2011

During May to August 2011, 0.30 to 0.40, 0.20 to 0.70 and 0.40 to 1.05 first, second and third instar grubs were recorded while pupae accounted for 0.20 per m^2.

May – August 2012

The mean number of different stages *viz,* egg, first, second and third instars recorded were 0.60, 0.20-0.90, 0.10-0.70 and 0.60-2.00 respectively. Pooled data analysis indicated the pattern similar to 2011 and 2012 on occurrence of different stages *viz.,* egg (0.60), first (0.25 – 0.65), second (0.10 – 0.90) and third instar (0.50 – 1.48) grubs, respectively. However, 0.20 pupae were also recorded during this period.

September - December 2011

During 2011, 0.60 third instar grubs, 0.30 – 0.62 pupae and 0.20 – 0.60 adults were recorded.

Table 11: Population dynamics of different stages of sugarcane white grub, *Holotrichia serrata* in Ankali location of Belagavi district during 2011- 2012

Sl. No.	Period	2011								2012							
		No. per m²								No. per m²							
		Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (⁰C)	Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (⁰C)
1	January 1st Fortnight	-	-	-	-	-	1.6			-	-	-	-	0.21	1.00	20.40	24.60
2	January 2nd Fortnight	-	-	-	-	-	1.3	20	25.1	-	-	-	-	0.30	1.40	21.20	24.60
	Mean- I	-	-	-	-	-	1.45	19.8	25	-	-	-	-	0.26	1.20	20.80	24.60
3	February 1st Fortnight	-	-	-	-	-	1.4	19.2	24	-	-	-	-	0.80	0.60	18.40	25.10
4	February 2nd Fortnight	-	-	-	-	-	1.6	19	26.3	-	-	-	-	0.40	0.80	19.90	26.10
	Mean- II	-	-	-	-	-	1.5	19.1	25.15	-	-	-	-	0.60	0.70	19.15	25.60
5	March 1st Fortnight	-	-	-	-	-	0.1	23.4	26.9	0.10	-	-	-	-	0.20	24.90	27.00
6	March 2nd Fortnight	-	-	-	-	-	0.1	24.9	29.1	0.10	0.10	-	-	-	0.41	26.50	29.10
	Mean-III	-	-	-	-	-	0.1	24.15	28	0.10	0.10	-	-	-	0.31	25.25	28.05
7	April 1st Fortnight	0.2	0.41	-	-	-	-	24.1	29.9	0.60	0.60	-	-	-	0.20	25.80	30.10
8	April 2nd Fortnight	0.4	0.3	-	-	-	-	23.8	31.4	0.20	1.00	-	-	-	-	-	-
	Mean-IV	0.3	0.36	-	-	-	-	23.95	30.65	0.40	0.80	-	-	-	0.20	25.80	30.10
9	May 1st Fortnight	-	0.4	0.4	-	-	-	22.4	31.9	0.80	1.20	0.40	-	-	-	22.60	31.30
10	May 2nd Fortnight	-	0.4	0.4	-	-	-	22.4	31.9	0.40	0.60	1.00	-	-	-	22.10	32.10
	Mean-I	-	0.4	0.4	-	-	-	22.4	31.9	0.60	0.90	0.70	-	-	-	22.35	31.70
11	June 1st Fortnight	-	0.4	0.6	-	-	-	24.7	31.8	-	0.20	1.20	0.40	-	-	23.80	30.90
12	June 2nd Fortnight	-	0.2	0.8	0.4	-	-	22.3	29.9	-		1.00	0.80	-	-	2110	30.30
	Mean-II	-	0.3	0.7	0.4	-	-	23.5	30.85	-	0.20	0.10	0.60	-	-	22.45	30.60
13	July 1st Fortnight	-	-	0.2	1.1	-	-	24.1	27.3	-		0.60	1.60	-	-	25.30	27.80
14	July 2nd Fortnight	-	-		1	-	-	24.1	27.3	-	-	0.40	2.20	-	-	21.20	25.90
	Mean-III	-	-	0.2	1.05	-	-	24.1	27.3	-	-	0.50	1.90	-	-	23.25	26.85
15	August 1st Fortnight	-	-	-	0.6	0.2	-	23.9	25.3	-	-	0.10	1.40	-	-	25.30	23.60
16	August 2nd Fortnight	-	-	-	1.2		-	25.3	26.1	-	-	-	2.60	-	-	25.00	
	Mean-IV	-	-	-	0.9	0.2	-	24.6	25.7	-	-	0.10	2.00	-	-	25.15	23.60
17	September 1st Fortnight	-	-	-	0.6	0.2	-	23.6	26.5	-	-	-	0.82	0.30	-	23.80	26.20
18	September 2nd Fortnight	-	-	-	0.6	0.4	-	22.9	27	-	-	-	0.45	0.41	-	24.80	26.70
	Mean-I	-	-	-	0.6	0.3	-	23.25	26.75	-	-	-	0.64	0.36	-	24.30	26.45
19	October 1st Fortnight	-	-	-	0.6	0.4	-	24	27.5	-	-	-	0.50	0.46	-	22.10	27.60
20	October 2nd Fortnight	-	-	-	-	0.4	-	22.8	27.7	-	-	-		0.35	-	27.50	24.60
	Mean-II	-	-	-	0.6	0.4	-	23.4	27.6	-	-	-	0.50	0.41	-	24.80	26.10
21	November 1st Fortnight	-	-	-	-	0.6	0.2	21.8	27.3	-	-	-	-	0.50	0.10	27.40	22.60
22	November 2nd Fortnight	-	-	-	-	0.6	0.2	24.2	26.3	-	-	-	-	0.71	0.16	26.40	21.60
	Mean-III	-	-	-	-	0.6	0.2	23	26.8	-	-	-	-	0.61	0.13	26.90	22.10
23	December 1st Fortnight	-	-	-	-	0.62	0.4	19.3	25.4	-	-	-	-	-	0.12	27.20	24.80
24	December 2nd Fortnight	-	-	-	-		0.8	22.4	24.9	-	-	-	-	-	0.72	25.80	21.30
	Mean-IV	-	-	-	-	0.62	0.6	20.85	25.15	-	-	-	-	-	0.42	26.50	23.05

Table 12: Pooled population dynamics (2011 and 2012) of different stages of sugarcane white grub, *Holotrichia serrata* in Ankali location of Belagavi district

Sl. No.	Period	No. per m^2							
		Egg	1^{st} instar	2^{nd} instar	3^{rd} instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^{0}C)
1	January 1^{st} Fortnight	-	-	-	-	0.21	1.30	20.00	24.75
2	January 2^{nd} Fortnight	-	-	-	-	0.30	1.35	20.60	24.85
	Mean-I	-	-	-	-	0.26	1.33	20.30	24.80
3	February 1^{st} Fortnight	-	-	-	-	0.80	1.00	18.80	24.55
4	February 2^{nd} Fortnight	-	-	-	-	0.40	1.20	19.45	26.20
	Mean-II	-	-	-	-	0.60	1.10	19.13	25.38
5	March 1^{st} Fortnight	0.10	-	-	-	-	0.15	24.15	26.95
6	March 2^{nd} Fortnight	0.10	0.10	-	-	-	0.26	25.25	29.10
	Mean-III	0.10	0.10	-	-	-	0.21	24.70	28.03
7	April 1^{st} Fortnight	0.40	0.51	-	-	-	0.20	24.95	30.00
8	April 2^{nd} Fortnight	0.30	0.65	-	-	-	-	23.80	31.40
	Mean-IV	0.35	0.58	-	-	-	0.20	24.38	30.70
9	May 1^{st} Fortnight	0.80	0.80	0.40	-	-	-	22.50	31.60
10	May 2^{nd} Fortnight	0.40	0.50	0.70	-	-	-	22.25	32.00
	Mean-I	0.60	0.65	0.55	-	-	-	22.38	31.80
11	June 1^{st} Fortnight	-	0.30	0.90	0.40	-	-	24.25	31.35
12	June 2^{nd} Fortnight	-	0.20	0.90	0.60	-	-	21.70	30.10
	Mean-II	-	0.25	0.90	0.50	-	-	22.98	30.73
13	July 1^{st} Fortnight	-	-	0.40	1.35	-	-	24.70	27.55
14	July 2^{nd} Fortnight	-	-	0.40	1.60	-	-	22.65	26.60
	Mean-III	-	-	0.40	1.48	-	-	23.68	27.08
15	August 1^{st} Fortnight	-	-	0.10	1.00	0.20	-	24.60	24.45
16	August 2^{nd} Fortnight	-	-	-	1.90	-	-	25.15	26.10
	Mean-IV	-	-	0.10	1.45	0.20	-	24.88	25.28
17	September 1^{st} Fortnight	-	-	-	0.71	0.25	-	23.70	26.35
18	September 2^{nd} Fortnight	-	-	-	0.53	0.41	-	23.85	26.85
	Mean-I	-	-	-	0.62	0.33	-	23.78	26.60
19	October 1^{st} Fortnight	-	-	-	0.55	0.43	-	23.05	27.55
20	October 2^{nd} Fortnight	-	-	-	-	0.38	-	25.15	26.15
	Mean-II	-	-	-	0.55	0.41	-	24.10	26.85
21	November 1^{st} Fortnight	-	-	-	-	0.55	0.15	24.60	24.95
22	November 2^{nd} Fortnight	-	-	-	-	0.66	0.18	25.30	23.95
	Mean-III	-	-	-	-	0.61	0.17	24.95	24.45
23	December 1^{st} Fortnight	-	-	-	-	0.62	0.26	23.25	25.10
24	December 2^{nd} Fortnight	-	-	-	-	-	0.76	24.10	23.10
	Mean-IV	-	-	-	-	0.62	0.51	23.68	24.10

September - December 2012

Similar to 2011, only third instar pupae and adults were recorded during 2012. Pooled data analysis revealed the occurrence of third instar, pupae and adults as observed during 2011 and 2012.

Bellad Bagewadi

January - April 2011

During this period, quiescent adults (Plate 6) were more abundant and ranged from 0.18 to 1.80, while mean egg and first instar count varied from 0.15 to 0.30 and 0.70, respectively (Table 13).

January - April 2012

During 2012, the various stages recorded were pupae (0.10 – 0.20), quiescent adults (0.10 – 1.70), first instar (0.20 to 1.00) and second instar (0.80 to 1.70) (Table 13). Pooled data analysis indicated the occurrence of egg, first instar, pupae and adults. The mean number of egg and first instar larvae varied from 0.10 to 0.65 and 0.20 to 0.85, respectively. However, mean number of pupae and adults recorded during this period ranged from 0.10 to 0.20 and 0.10 to 1.65 per m^2 area, respectively (Table 14).

May - August 2011

Mean number of first, second and third instar grubs recorded ranged from 0.20 to 0.40, 0.60 to 0.95 and 0.60 to 0.80 respectively.

May - August 2012

During 2012, mean number of different stages *viz.,* eggs was 0.20, first instar was 0.20 – 1.60, second instar was 0.20 – 1.40, third instar was1.50 – 2.85 and 0.6 pupae, respectively. Pooled data analysis indicated the occurrence of 0.20 eggs, 0.20 to 0.65 first, 0.20 to 1.18 second and 1.25 to 1.78 third instar grubs while mean number of pupae recorded was 0.55.

September - December 2011

During this period, mean number of third instar grubs recorded ranged between 0.20 to 0.30 and other stages *viz.,* pupae and quiscent adults varied between 0.20 to 0.70 and 0.60 to 0.70 respectively.

September - December 2012

During 2012, the mean number of third instars ranged between 0.10 to 0.41, whereas pupal count accounted from 0.58 to 0.93 and adult count ranged between 0.35 to 1.02, respectively. Pooled data analysis indicated the occurrence of third instar, pupa and quiscent adults during this period (Plate 6).

Kadapur

January - April 2011

Data presented in Table 15 revealed that the mean number of adults occurred ranged from 0.10 to 1.90 during March 2011 while mean egg and first instar count recorded was 0.20 and 0.40 respectively.

January - April 2012

Mean number of pupae recorded was 0.26 that ranged from 0.21 to 0.30 during January 2012. Adults were also recorded from January to April with mean number ranging from 0.31 to 1.90 while eggs and first instar recorded ranged from 0.15 to 0.31 and 0.10 to 0.60, respectively. Pooled data analysis revealed a trend similar to 2011and 2012 with respect to density of different stages (Table 16).

May - August 2011

Table 15 gives comparative account of different stages *viz.,* eggs (0.21) first instar (0.40 – 0.50), second instar (0.20 – 0.60) and third instar (0.20 – 0.80) per m^2 area, respectively.

May - August 2012

The different stages like egg, first, second and third instars recorded ranged from 0.70, 0.30 - 0.90, 0.20 - 1.40 and 0.40 - 2.00, respectively. Pooled data indicated similar pattern as observed during 2012 with 0.50 eggs, 0.35 – 0.70 first instar, 0.20 – 1.00 second instar and 0.30 – 1.40 third instar and 0.20 pupa, respectively.

September to December 2011

Mean number of third instar grubs, pupae and adults recorded during this period ranged from 0.40 to 0.60, 0.40 to 0.80 and 0.20 to 0.76 respectively (Plate 7).

September to December 2012

During 2012, mean number of third instar larvae recorded ranged from 0.30 to 0.60 whereas pupal count ranged from 0.32 to 0.75 and adults ranged from 0.17 to 0.55 respectively. Pooled data revealed the occurrence of third instar (0.35 – 0.60), pupae (0.36 – 0.78) and adults (0.19 – 0.66).

Kochari

January- April 2011

Results pertaining to the occurrence of different stages indicated that the mean number of pupae, adults, eggs and first instar varied from 0.46 to 0.60, 0.30 to 1.10, 0.41 and 0.20 respectively.

January- April 2012

During 2012, 0.20 – 0.50 pupae, 0.80 – 1.00 adults and 0.40 egg count were recorded respectively (Table 17). Pooled data analysis indicated a trend similar to 2011 and 2012 with the occurrence of pupae, adults, eggs and first instar (Table 18).

May to August 2011

It was intersting to note that during this period egg count recorded was 0.60 and all the larval stages *i.e.,* first instar, second instar and third instar were noticed to the tune of 0.20 to 0.70, 0.20 to 0.80 and 0.50 to 0.80 respectively.

May to August 2012

Trend similar to 2011 was noticed during 2012, with 0.90 eggs, 0.50 – 1.20 first instar, 0.20 – 1.00 second instar and 0.90 – 1.90 third instar respectively. Pooled data analysis also depicted the occurrence of eggs, first instar, second instar and third instar.

September to December 2011

This period was dominated by third instar larvae with a range of 0.70 to 1.05, but pupae ranged from 0.20 to 0.70 while adults ranged from 0.20 to 0.40 (Plate 8).

September to December 2012

Similarly, during 2012 the different stages *viz.,* third instar, pupae and adults ranged from 0.45 to 1.08, 0.58 to 0.78 and 0.11 to 0.31, respectively. Pooled data analysis indicated mean count of 0.58 – 1.07 third instar, 0.20 – 0.74 pupae and 0.16 to 0.38 adults.

Sankeshwar

January - April 2011

Pupae and adults recorded during January - February months ranged from 0.76 to 1.00 and 0.60 to 0.70. However, during March and April only adults were recorded with a mean number of 0.30. Further, adults with 0.33 and eggs with 0.20 numbers were recorded (Table 19).

January - April 2012

During 2012, trend similar to 2011 was seen with mean count of 0.60 – 1.30 pupae, 0.40 – 1.50 adults and 0.20 eggs (Table 19). Pooled data analysis revealed similar pattern in 2011 and 2012 (Table 20).

May - August 2011

Mean egg count recorded during this period was 0.35 while first instar larvae accounted for 0.20. However, second and third instar ranged from 0.40 to 0.60 and 0.05 to 0.90 respectively.

Plate 6: Third instar grub, pupa and quiescent adult of *Holotrichia serrata* (Bellad Bagewadi)

Table 13: Population dynamics of different stages of sugarcane white grub, *Holotrichia serrata* in Bellad Bagewadi location of Belagavi district during 2011-2012

Sl. No.	Period	2011								2012							
		No. per m^2								No. per m^2							
		Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^{0}C)	Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^{0}C)
1	January 1st Fortnight	-	-	-	-	-	1.60	21.45	24.80	-	-	-	-	0.10	1.60	20.80	24.20
2	January 2nd Fortnight	-	-	-	-	-	1.60	20.25	25.40	-	-	-	-		1.80	20.00	25.10
	Mean-I	-	-	-	-	-	1.60	20.85	25.10	-	-	-	-	0.10	1.70	20.40	24.65
3	February 1st Fortnight	-	-	-	-	-	1.60	16.90	26.10	-	-	-	-	0.20	1.20	19.20	25.40
4	February 2nd Fortnight	-	-	-	-	-	2.00	23.60	28.40	0.10	-	-	-	0.20	0.40	23.60	25.90
	Mean-II	-	-	-	-	-	1.80	20.25	27.25	0.10	-	-	-	0.20	0.80	21.40	25.65
5	March 1st Fortnight	0.10	-	-	-	-	0.30	24.10	28.60	0.60	-	-	-	-	0.20	25.30	26.70
6	March 2nd Fortnight	0.20	-	-	-	-	0.05	23.30	28.20	0.40	0.20	-	-	-	0.20	23.10	28.60
	Mean-III	0.15	-	-	-	-	0.18	23.70	28.40	0.50	0.20	-	-	-	0.20	24.20	27.65
7	April 1st Fortnight	0.40	0.80	-	-	-	-	24.60	30.60	1.20	1.40	-	-	-	0.10	24.10	30.50
8	April 2nd Fortnight	0.20	0.60	-	-	-	-	24.20	31.00	0.80	0.60	0.80	-	-	-	-	-
	Mean-IV	0.30	0.70	-	-	-	-	24.40	30.80	1.00	1.00	0.80	-	-	0.10	24.10	30.50
9	May 1st Fortnight	-	0.60	0.60	-	-	-	25.10	32.40	0.20	1.60	1.20	-	-	-	24.10	31.20
10	May 2nd Fortnight	-	0.20	0.60	-	-	-	23.80	33.40			1.60	-	-	-	22.10	32.10
	Mean-I	-	0.40	0.60	-	-	-	24.45	32.90	0.20	1.60	1.40	-	-	-	23.10	31.65
11	June 1st Fortnight	-	0.20	0.80	-	-	-	24.10	31.90	-		1.40	1.20	-	-	22.10	32.10
12	June 2nd Fortnight	-		1.10	0.80	-	-	23.00	31.40	-	0.20	1.40	1.80	-	-	23.00	29.40
	Mean-II	-	0.20	0.95	0.80	-	-	23.55	31.65	-	0.20	1.40	1.50	-	-	22.55	30.75
13	July 1st Fortnight	-	-	-	0.80	-	-	21.00	27.60	-	-	0.40	2.20	-	-	24.90	27.30
14	July 2nd Fortnight	-	-	-	0.40	-	-	21.00	27.60	-	-	0.20	2.80	-	-	23.10	26.70
	Mean-III	-	-	-	0.60	-	-	21.00	27.60	-	-	0.30	2.50	-	-	24.00	27.00
15	August 1st Fortnight	-	-	-	0.80	0.60	-	25.80	26.00	-	-	0.20	2.90	0.40	-	24.90	23.80
16	August 2nd Fortnight	-	-	-	0.60	0.40	-	21.80	26.60	-	-		2.80	0.80	-	22.30	
	Mean-IV	-	-	-	0.70	0.50	-	23.80	26.30	-	-	0.20	2.85	0.60	-	23.60	23.80
17	September 1st Fortnight	-	-	-	0.40	0.60	-	22.80	27.10	-	-	-	0.51	0.90	-	21.20	26.30
18	September 2nd Fortnight	-	-	-	0.20	0.80	-	23.50	27.30	-	-	-	0.30	0.95	-	25.20	27.50
	Mean-I	-	-	-	0.30	0.70	-	23.15	27.20	-	-	-	0.41	0.93	-	23.20	26.90
19	October 1st Fortnight	-	-	-	0.20	0.60	0.60	22.60	27.60	-	-	-	0.10	0.82	0.30	24.10	27.90
20	October 2nd Fortnight	-	-	-	-	0.40	0.60	21.00	27.90	-	-	-		0.51	0.40	27.60	22.60
	Mean-II	-	-	-	0.20	0.50	0.60	21.80	27.75	-	-	-	0.10	0.67	0.35	25.85	25.25
21	November 1st Fortnight	-	-	-	-	0.40	0.80	22.40	27.20	-	-	-	-	0.35	0.71	27.20	22.10
22	November 2nd Fortnight	-	-	-	-	0.40	0.60	25.10	27.00	-	-	-	-	0.81		26.90	21.30
	Mean-III	-	-	-	-	0.40	0.70	23.75	27.10	-	-	-	-	0.58	0.71	27.05	21.70
23	December 1st Fortnight	-	-	-	-	0.20	0.60	21.20	26.10	-	-	-	-	-	0.82	27.80	21.90
24	December 2nd Fortnight	-	-	-	-		0.60	19.40	25.00	-	-	-	-	-	1.22	25.30	21.40
	Mean-IV	-	-	-	-	0.20	0.60	20.30	25.55	-	-	-	-	-	1.02	26.55	21.65

Table 14: Pooled population dynamics (2011-2012) of different stages of sugarcane white grub, *Holotrichia serrata.* in Bellad Bagewadi location of Belagavi district

Sl. No.	Period	No. per m^2							
		Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^{0}C)
1	January 1st Fortnight	-	-	-	-	0.10	1.60	21.13	24.50
2	January 2nd Fortnight	-	-	-	-		1.70	20.13	25.25
	Mean-I	-	-	-	-	0.10	1.65	20.63	24.88
3	February 1st Fortnight	-	-	-	-	0.20	1.40	18.05	25.75
4	February 2nd Fortnight	0.10	-	-	-	0.20	1.20	23.60	27.15
	Mean-II	0.10	-	-	-	0.20	1.30	20.83	26.45
5	March 1st Fortnight	0.35	-	-	-		0.25	24.70	27.65
6	March 2nd Fortnight	0.30	0.20	-	-	-	0.13	23.20	28.40
	Mean-III	0.33	0.20	-	-	-	0.19	23.95	28.03
7	April 1st Fortnight	0.80	0.10	-	-	-	0.10	24.35	30.55
8	April 2nd Fortnight	0.50	0.60	0.80	-	-	-	24.20	31.00
	Mean-IV	0.65	0.85	0.80	-	-	0.10	24.28	30.78
9	May 1st Fortnight	0.20	1.10	0.90	-	-	-	24.60	31.80
10	May 2nd Fortnight	-	0.20	1.10	-	-	-	22.95	32.75
	Mean-I	0.20	0.65	1.00	-	-	-	23.78	32.28
11	June 1st Fortnight	-	0.20	1.10	1.20	-	-	23.10	32.00
12	June 2nd Fortnight	-	0.20	1.25	1.30	-	-	23.00	30.40
	Mean-II	-	0.20	1.18	1.25	-	-	23.05	31.20
13	July 1st Fortnight	-	-	0.40	1.50	-	-	22.95	27.45
14	July 2nd Fortnight	-	-	0.20	1.60	-	-	22.05	27.15
	Mean-III	-	-	0.30	1.55	-	-	22.50	27.30
15	August 1st Fortnight	-	-	0.20	1.85	0.50	-	25.35	24.90
16	August 2nd Fortnight	-	-	-	1.70	0.60	-	22.05	26.60
	Mean-IV	-	-	0.20	1.78	0.55	-	23.70	25.75
17	September 1st Fortnight	-	-	-	0.46	0.75	-	22.0	26.70
18	September 2nd Fortnight	-	-	-	0.25	0.88	-	24.35	27.40
	Mean-I	-	-	-	0.36	0.82	-	23.18	27.05
19	October 1st Fortnight	-	-	-	0.15	0.71	0.45	23.35	27.75
20	October 2nd Fortnight	-	-	-	-	0.46	0.50	24.30	25.25
	Mean-II	-	-	-	0.15	0.59	0.48	23.83	26.50
21	November 1st Fortnight	-	-	-	-	0.38	0.76	24.80	24.65
22	November 2nd Fortnight	-	-	-	-	0.61	0.60	26.00	24.15
	Mean-III	-	-	-	-	0.50	0.68	25.40	24.40
23	December 1st Fortnight	-	-	-	-	0.20	0.71	24.50	24.00
24	December 2nd Fortnight	-	-	-	-		0.91	22.35	23.20
	Mean-IV	-	-	-	-	0.20	0.81	23.43	23.60

Table 15: Population dynamics of different stages of sugarcane white grub, *Holotrichia serrata* in Kadapur location of Belagavi district during 2011-2012

Sl. No.	Period	2011								2012							
		No. per m^2								No. per m^2							
		Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^{0}C)	Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^{0}C)
1	January 1st Fortnight	-	-	-	-	-	1.50	18.75	24.60	-	-	-	-	0.21	0.80	21.10	24.30
2	January 2nd Fortnight	-	-	-	-	-	1.30	19.60	25.30	-	-	-	-	0.30	1.00	19.00	23.80
	Mean-I	-	-	-	-	-	1.40	19.18	24.95	-	-	-	-	0.26	0.90	20.05	24.05
3	February 1st Fortnight	-	-	-	-	-	1.70	18.60	25.10	-	-	-	-	-	1.70	18.60	25.10
4	February 2nd Fortnight	-	-	-	-	-	2.10	18.10	26.80	-	-	-	-	-	2.10	18.10	26.80
	Mean-II	-	-	-	-	-	1.90	18.35	25.95	-	-	-	-	-	1.90	18.35	25.95
5	March 1st Fortnight	-	-	-	-	-	0.10	23.30	26.60	0.10		-	-	-	0.20	23.30	26.60
6	March 2nd Fortnight	-	-	-	-	-	0.10	25.10	29.50	0.20	0.10	-	-	-	0.42	25.10	29.50
	Mean-III	-	-	-	-	-	0.10	24.20	28.05	0.15	0.10	-	-	-	0.31	24.20	28.05
7	April 1st Fortnight	0.20	-	-	-	-	-	23.80	30.20	0.41	0.80	-	-	-	0.20	23.80	30.20
8	April 2nd Fortnight	0.20	0.40	-	-	-	-	24.10	31.10	0.20	0.40	-	-	-	0.80	24.10	31.10
	Mean-IV	0.20	0.40	-	-	-	-	23.95	30.65	0.31	0.60	-	-	-	0.50	23.95	30.65
9	May 1st Fortnight	0.21	0.60	0.20	-	-	-	24.20	31.90	1.00	1.40	0.20	-	-	-	22.00	30.90
10	May 2nd Fortnight		0.40	0.40	-	-	-	21.85	32.00	0.40	0.40	0.80	-	-	-	21.60	31.90
	Mean-I	0.21	0.50	0.30	-	-	-	22.85	31.95	0.70	0.90	0.50	-	-	-	21.80	31.40
11	June 1st Fortnight	-	0.60	0.60	-	-	-	25.20	32.00		0.40	1.40	0.20	-	-	24.60	31.70
12	June 2nd Fortnight	-	0.20	0.60	0.20	-	-	21.70	30.10		0.20	1.40	0.60	-	-	20.90	31.20
	Mean-II	-	0.40	0.60	0.20	-	-	23.45	31.05		0.30	1.40	0.40	-	-	22.75	31.45
13	July 1st Fortnight	-	-	0.20	0.80	-	-	22.50	27.80	-	-	0.40	1.40	-	-	24.60	28.10
14	July 2nd Fortnight	-	-		0.80	-	-	22.50	27.80	-	-	0.20	1.80	-	-	22.70	26.10
	Mean-III	-	-	0.20	0.80	-	-	22.50	27.80	-	-	0.30	1.60	-	-	23.65	27.10
15	August 1st Fortnight	-	-	-	0.60	-	-	25.40	25.80	-	-	0.20	1.80	-	-	25.80	24.00
16	August 2nd Fortnight	-	-	-	1.00	-	-	24.10	26.40	-	-		2.20	-	-	23.80	
	Mean-IV	-	-	-	0.80	-	-	24.75	26.10	-	-	0.20	2.00	-	-	24.80	24.00
17	September 1st Fortnight	-	-	-	0.60	0.40	-	23.90	26.30	-	-	-	0.70	0.30	-	24.60	26.70
18	September 2nd Fortnight	-	-	-	0.60	0.40	-	24.10	27.30	-	-	-	0.50	0.33	-	25.00	25.80
	Mean-I	-	-	-	0.60	0.40	-	24.00	26.80	-	-	-	0.60	0.32	-	24.80	26.25
19	October 1st Fortnight	-	-	-	0.40	0.40	-	23.10	27.70	-	-	-	0.30	0.35	-	22.30	26.90
20	October 2nd Fortnight	-	-	-		0.41	-	22.40	27.80	-	-	-	0.30	0.40	-	27.30	21.10
	Mean-II	-	-	-	0.40	0.41	-	22.75	27.75	-	-	-	0.30	0.38	-	24.80	24.00
21	November 1st Fortnight	-	-	-	-	0.80	0.20	22.90	27.90	-	-	-	-	0.70	0.10	27.10	23.00
22	November 2nd Fortnight	-	-	-	-	0.80	0.20	21.10	26.60	-	-	-	-	0.80	0.24	26.80	23.40
	Mean-III	-	-	-	-	0.80	0.20	22.00	27.25	-	-	-	-	0.75	0.17	26.95	23.20
23	December 1st Fortnight	-	-	-	-	0.60	0.42	18.72	25.70	-	-	-	-	-	0.20	27.60	25.10
24	December 2nd Fortnight	-	-	-	-		1.10	19.10	25.20	-	-	-	-	-	0.90	26.10	20.20
	Mean-IV	-	-	-	-	0.60	0.76	18.90	25.45	-	-	-	-	-	0.55	26.85	22.65

Table 16: Pooled population dynamics (2011-2012) of different stages of sugarcane white grub, *Holotrichia serrata* in Kadapur location of Belagavi district

Sl. No.	Period	No. per m² area							
		Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (⁰C)
1	January 1st Fortnight	-	-	-	-	0.21	1.15	19.93	24.45
2	January 2nd Fortnight	-	-	-	-	0.30	1.15	19.30	24.55
	Mean –I	-	-	-	-	0.26	1.15	19.61	24.50
3	February 1st Fortnight	-	-	-	-	-	1.70	18.60	25.00
4	February 2nd Fortnight	-	-	-	-	-	2.10	18.10	26.30
	Mean –II	-	-	-	-	-	1.90	18.35	25.65
5	March 1st Fortnight	0.10	-	-	-	-	0.15	23.30	26.85
6	March 2nd Fortnight	0.20	0.10	-	-	-	0.26	25.10	29.45
	Mean-III	0.15	0.10	-	-	-	0.21	24.20	28.15
7	April 1st Fortnight	0.31	0.80	-	-	-	0.20	23.80	30.40
8	April 2nd Fortnight	0.20	0.40	-	-	-	0.80	24.10	
	Mean –IV	0.26	0.60	-	-	-	0.50	23.95	30.40
9	May 1st Fortnight	0.61	1.00	0.20	-	-	-	23.10	31.40
10	May 2nd Fortnight	0.40	0.40	0.60	-	-	-	21.55	31.95
	Mean-I	0.50	0.70	0.40	-	-	-	22.33	31.68
11	June 1st Fortnight	-	0.50	1.00	0.20	-	-	24.90	31.85
12	June 2nd Fortnight	-	0.20	1.00	0.40	-	-	21.30	30.65
	Mean-II	-	0.35	1.00	0.30	-	-	23.10	31.25
13	July 1st Fortnight	-	-	0.30	1.10	-	-	23.55	27.95
14	July 2nd Fortnight	-	-	0.20	1.30	-	-	22.60	26.95
	Mean-III	-	-	0.25	1.20	-	-	23.08	27.40
15	August 1st Fortnight	-	-	0.20	1.20	0.20	-	25.60	24.90
16	August 2nd Fortnight	-	-	-	1.60	-	-	23.95	26.40
	Mean-IV	-	-	0.20	1.40	0.20	-	24.78	25.65
17	September 1st Fortnight	-	-	-	0.65	0.35	-	24.25	26.50
18	September 2nd Fortnight	-	-	-	0.55	0.37	-	24.55	26.55
	Mean-I	-	-	-	0.60	0.36	-	24.40	26.53
19	October 1st Fortnight	-	-	-	0.35	0.37	-	22.70	27.30
20	October 2nd Fortnight	-	-	-	-	0.41	-	24.85	24.45
	Mean-II	-	-	-	0.35	0.39	-	23.78	25.88
21	November 1st Fortnight	-	-	-	-	0.75	0.15	25.00	25.45
22	November 2nd Fortnight	-	-	-	-	0.80	0.22	23.95	25.00
	Mean-III	-	-	-	-	0.78	0.19	24.48	25.23
23	December 1st Fortnight	-	-	-	-	0.60	0.31	23.15	25.40
24	December 2nd Fortnight	-	-	-	-		1.00	22.60	22.70
	Mean-IV	-	-	-	-	0.60	0.66	22.88	24.05

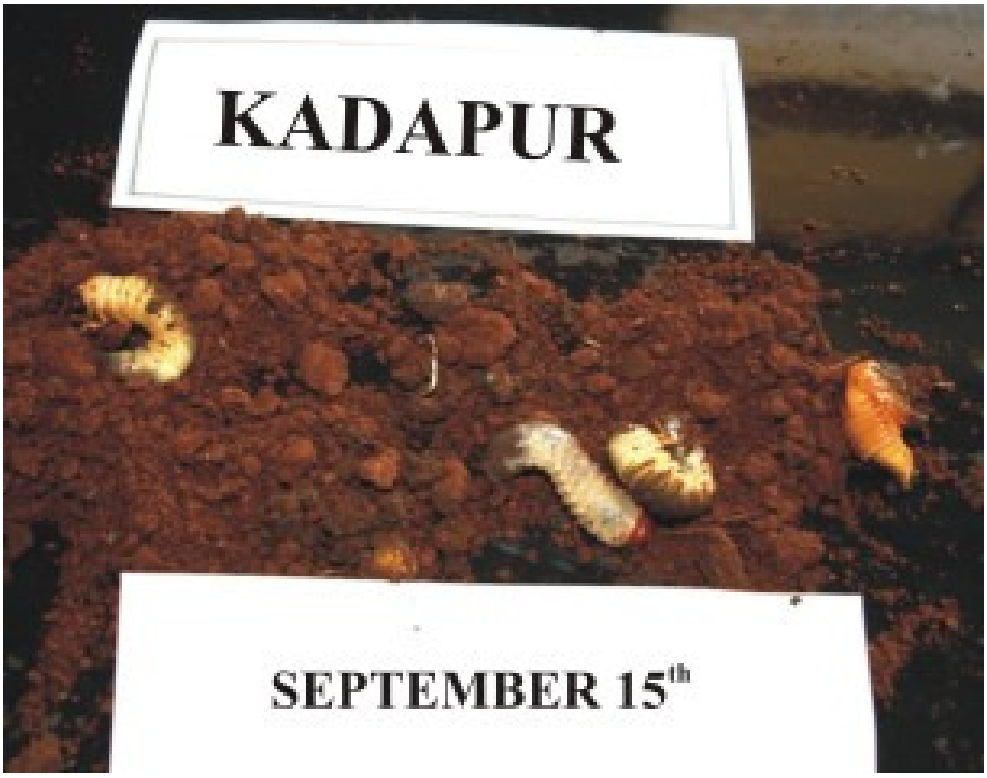


Plate 7: Third instar grub and Pupa of *Holotrichia serrata* (Kadapur)

May - August 2012

During the month of May, egg count recorded varied from 1.20 to 1.80 and first instar larvae accounted for 1.40 to 1.60. However, in subsequent months (June to August) all the larval instars were present and mean number ranged from 0.10 to 1.50 (I instar), 0.60 to 1.80 (II instar) and 0.50 to 1.40 (III instar), respectively. Pooled data analysis revealed occurrence of eggs and all instars. Mean number of eggs was 0.93 while first, second and third instar ranged from 1.13 – 1.15, 0.55 to 1.60 and 0.50 to 1.15, respectively.

September -December 2011

During the month of September, occurrence of third instar grub ranged from 0.90 to 1.20 while pupal count varied from 0.30 to 0.61. Whereas, adults accounted only 0.20.

September -December 2012

Occurrence of third instar larvae accounted for 0.90 to 1.20 while for pupae 0.30 to 0.61. However, mean number of 0.20 adults were also recorded. Pooled data analysis indicated the similar trend as was observed during both 2011 and 2012 with respect to occurrence of different stages.

Soundalga

January - April 2011

Abundance of adult, pupae, eggs and first instar larvae during this period varied from 0.10 to 1.40, 0.33, 0.21 and 0.31, respectively (Table 21).

January - April 2012

During 2012, different stages *viz.,* pupae, adults, eggs and first instar larvae ranged from 0.15 to 0.50, 0.40 to 1.20, 0.18 to 0.50 and 0.10 to 0.60, respectively (Table 21). Pooled data revealed occurrence of first instar, pupae, adults and eggs (Table 22).

May - August 2011

All the larvae stages *viz,.* first instar (0.40 – 0.50), second instar (0.40 – 2.50) and third instar (0.40 – 0.95) were recorded during this period.

May - August 2012

However, during 2012, mean number of eggs noticed was 0.60, first instar was 0.70, second instar was 0.30 – 0.90 and third instar was 0.70 – 2.05. Pooled data revealed occurrence of different stages *viz.,* eggs (0.60), first instar (0.40 – 0.60), second instar (0.20 – 1.70), third instar (0.55 – 1.40) and pupae (0.40) respectively.

September - December 2011

During 2011 mean number of pupal count varied from 0.20 to 0.50, adult population ranged from 0.40 to 0.85 while third instar larvae ranged from 0.60 to 0.70 (Plate 9).

September - December 2012

During 2012, 0.44 – 0.50 pupae, 0.27 – 0.58 adults and 0.40 – 0.62 third instar occurred respectively. Pooled data supported the trend observed during both 2011 and 2012.

Population density of different stages at Ankali location during 2011-12 indicated the presence of quiescent adult during November - April months, pupa during August - February, egg during March - May and first instar grubs during March to June, second instar during May - August and third instar from June to October months.

At Bellad Bagewadi quiescent adults were observed from October - April months, pupae during August - February, egg from February - May whereas first instar grubs during March - June and second instar during June - October months.

Results of Kadapur location indicated the occurrence of quiescent adults from November - April months, pupae during August - January months, eggs from March - May months, first and second instar grubs during March - June and May - August respectively, whereas third instar grubs were noticed from June to October months.

Quiescent adults were noticed at Kochari from November - April, pupae during October - March months. Eggs noticed from April - May, first instar grubs during April - July, second instar from May – August, while third instar grub noticed from July - October.

At Soundalga location quiescent adults were reccorded from November - April, pupae during August - February, while eggs were noticed from March - May, first instar grubs during April - June and second instar during May - August, while third instar appeared during June - October.

Occurrence of different stages of white grub at Sankeshwar location revealed the presence of quiescent adults (Plate 10) from December to April, pupa during November - March, eggs during April - May months, whereas first and second instar grubs from May - June and June - August months and third instar grubs during July - December months, respectively.

4.3 Behavioural pattern of *Holotrichia serrata* adult in sugarcane

4.3.1 Evaluation of different trapping sources against beetles of *Holotrichia serrata*

Mean number of weekly trapped beetles as influenced by different treatments is presented in Table 23-25.

2011

Among the different treatments, light+ neem leaves was significantly superior over all other treatments at 10th, 11th, 12th, 13th and 14th MSW with mean adult catches of 22.80, 24.20, 25.60, 27.10 and 22.00, respectively. This was followed by neem leaves alone with 19.80, 21.10, 24.00, 27.00 and 20.00 adult catch. The next best treatment was light source which recorded a mean catch ranging from 1.10 to 20.00 at different MSW. However, the neem combination treatments T_9 (pressmud + neem leaves), T_{10} (sugarcane setts + neem leaves) and T_7 (FYM + neem leaves) recorded modest number of adults. All other treatments were ineffective in trapping the adults at all the intervals of observation. Irrespective of treatments, 13th MSW recorded peak number of adults in T_7, T_9, T_{10}, T_{11} and T_{12}.

2012

Similar trend was noticed during 2012 wherein light+ neem (T_{12}) was significantly superior by trapping higher number of adults ranging from 3.30 to 28.70 from 10th to 16th MSW followed by light source (T_{11}) that attracted 1.80 to 21.60 adults. Pooled data analysis revealed the superiority of T_{12} with adult catches of 22.50, 24.90, 25.85, 27.90, 22.60, 14.60 and 2.77 during 10th, 11th, 12th, 13th, 14th, 15th and 16th MSW respectively.

Two years data indicated that, among the different trapping sources, light +neem was found superior by trapping highest number of adults, followed by neem leaves alone. However, light source was the next best source for trapping adults with modest catches. Combination of neem leaves with other sources had modest adult catches strongly indicating the attractant property of neem to the adults (Plate 11).

4.3.2 Field evaluation of chemicals with pheromone/kairomone activity against *Holotrichia serrata*

Mean number of weekly adult catches as influenced by various treatments is given in Tables 26-28.

Neem leaf extract 10 per cent @ 10 ml per trap was significantly superior over remaining treatments by attracting maximum number of adults with 8.42, 11.86, 14.61, 14.86, 15.10, 5.33, 5.56 and 9.10, 12.20, 13.88, 16.21, 14.33, 8.92 and 2.26 both during 2011 and 2012. However, all other treatments failed to attract any adults at all the intervals *i.e.,* from 10th MSW to 16th MSW tested. Pooled data analysis revealed a similar pattern with adult catches of 8.76, 12.03, 14.14, 15.33, 14.71, 7.12 and 4.83 at 10th, 11th, 12th, 13th, 14th, 15th and 16th MSW, respectively. Results revealed that the neem leaf extract 10% was promising with highest adult catches while all other treatments were ineffective in attracting the adults.

Table 17: Population dynamics of different stages of sugarcane white grub, *Holotrichia serrata* in Kochari location of Belagavi district during 2011-2012

Sl. No.	Period	2011								2012							
		No. per m^2								No. per m^2							
		Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^{0}C)	Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^{0}C)
1	January 1st Fortnight	-	-	-	-	0.30	1.30	19.60	23.90	-	-	-	-	0.20	0.40	21.20	24.90
2	January 2nd Fortnight	-	-	-	-	0.62	0.70	18.80	5.30	-	-	-	-	0.80	1.40	18.50	25.00
	Mean –I	-	-	-	-	0.46	1.00	19.20	24.60	-	-	-	-	0.50	0.90	19.85	24.95
3	February 1st Fortnight	-	-	-	-	0.60	1.10	17.40	25.20	-	-	-	-	0.40	0.60	19.60	25.20
4	February 2nd Fortnight	-	-	-	-	0.60	1.10	21.00	26.10	-	-	-	-	0.40	1.40	21.80	25.70
	Mean –II	-	-	-	-	0.60	1.10	19.20	25.65	-	-	-	-	0.40	1.00	20.70	25.45
5	March 1st Fortnight	-	-	-	-	-	0.30	21.60	27.20	-	-	-	-	0.20	0.80	23.00	26.60
6	March 2nd Fortnight	-	-	-	-	-		22.80	29.10	-	-	-	-	0.20	0.80	25.20	29.30
	Mean-III	-	-	-	-	-	0.30	22.20	28.15	-	-	-	-	0.20	0.80	24.10	27.95
7	April 1st Fortnight	0.41	0.20	-	-	-	0.30	23.90	31.00	0.40	-	-	-	-	0.80	23.90	30.30
8	April 2nd Fortnight	0.40		-	-	-		23.70	31.30	0.40	-	-	-	-	-	-	-
	Mean -IV	0.41	0.20	-	-	-	0.30	23.80	31.15	0.40	-	-	-	-	0.80	23.90	30.30
9	May 1st Fortnight	0.80	0.20	-	-	-	-	24.60	31.70	1.20	1.00	-	-	-	-	25.20	31.60
10	May 2nd Fortnight	0.40	0.20	-	-	-	-	21.10	31.80	0.60	1.40	0.20	-	-	-	24.00	32.40
	Mean-I	0.60	0.20	-	-	-	-	22.85	31.75	0.90	1.20	0.20	-	-	-	24.60	32.00
11	June 1st Fortnight	-	0.60	0.20	-	-	-	25.00	30.80	-	0.80	0.40	-	-	-	21.80	32.40
12	June 2nd Fortnight	-	0.80	0.20	-	-	-	22.60	30.20	-	1.40	1.20	-	-	-	23.40	29.90
	Mean-II	-	0.70	0.20	-	-	-	23.80	30.50	-	1.10	0.80	-	-	-	22.60	31.15
13	July 1st Fortnight	-	-	0.80	0.40	-	-	22.70	27.30	-	0.80	0.40	0.40	-	-	26.00	27.30
14	July 2nd Fortnight	-	-	-	0.60	-	-	22.70	27.30	-	0.20	1.60	1.40	-	-	24.30	26.50
	Mean-III	-	-	0.80	0.50	-	-	22.70	27.30	-	0.50	1.00	0.90	-	-	25.15	26.90
15	August 1st Fortnight	-	-	-	0.60	-	-	24.60	25.90	-	-	0.40	1.70	-	-	25.20	22.60
16	August 2nd Fortnight	-	-	-	1.00	-	-	22.10	25.80	-	-	0.60	2.10	-	-	21.70	
	Mean-IV	-	-	-	0.80	-	-	23.35	25.85	-	-	0.50	1.90	-	-	23.45	22.60
17	September 1st Fortnight	-	-	-	1.00	-	-	24.60	25.90	-	-	-	1.05	-	-	22.80	25.90
18	September 2nd Fortnight	-	-	-	1.10	-	-	24.20	26.90	-	-	-	1.10	-	-	25.80	27.70
	Mean-I	-	-	-	1.05	-	-	24.40	26.40	-	-	-	1.08	-	-	24.30	26.80
19	October 1st Fortnight	-	-	-	0.80	-	-	23.60	26.90	-	-	-	0.80	-	-	22.40	26.80
20	October 2nd Fortnight	-	-	-	0.60	0.20	-	22.40	26.90	-	-	-	0.10	-	-	26.90	20.80
	Mean-II	-	-	-	0.70	0.20	-	23.00	26.90	-	-	-	0.45	-	-	24.65	23.80
21	November 1st Fortnight	-	-	-	-	0.80	0.20	22.70	27.30	-	-	-	-	0.70	0.11	27.80	23.20
22	November 2nd Fortnight	-	-	-	-	0.60		23.30	25.90	-	-	-	-	0.85		25.80	22.10
	Mean-III	-	-	-	-	0.70	0.20	23.00	26.60	-	-	-	-	0.78	0.11	26.80	22.65
23	December 1st Fortnight	-	-	-	-	0.40	0.40	18.90	25.20	-	-	-	-	0.80		27.20	22.10
24	December 2nd Fortnight	-	-	-	-	0.42	0.40	22.30	24.60	-	-	-	-	0.35	0.31	25.40	22.20
	Mean-IV	-	-	-	-	0.41	0.40	20.60	24.90	-	-	-	-	0.58	0.31	26.30	22.15

Table 18: Pooled population dynamics (2011-2012) of different stages of sugarcane white grub, *Holotrichia serrata* in Kochari location of Belagavi district

Sl. No.	Period	No. per m^2							
		Egg	1^{st} instar	2^{nd} instar	3^{rd} instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^{0}C)
1	January 1st Fortnight	-	-	-	-	0.25	0.85	20.40	24.40
2	January 2nd Fortnight	-	-	-	-	0.71	1.05	18.65	25.15
	Mean –I	-	-	-	-	**0.48**	**0.95**	**19.53**	**24.78**
3	February 1st Fortnight	-	-	-	-	0.50	0.85	18.50	25.20
4	February 2nd Fortnight	-	-	-	-	0.50	1.25	21.40	25.90
	Mean –II	-	-	-	-	**0.50**	**1.05**	**19.95**	**25.55**
5	March 1st Fortnight	-	-	-	-	0.20	0.55	22.30	26.90
6	March 2nd Fortnight	-	-	-	-	0.20	0.80	24.00	29.20
	Mean –III	-	-	-	-	**0.20**	**0.68**	**23.15**	**28.05**
7	April 1st Fortnight	0.40	0.20	-	-	-	0.55	23.90	30.65
8	April 2nd Fortnight	0.40		-	-	-		23.70	31.30
	Mean –IV	**0.41**	**0.20**	-	-	-	**0.55**	**23.80**	**30.98**
9	May 1st Fortnight	1.00	0.60	-	-	-		24.90	31.65
10	May 2nd Fortnight	0.50	0.80	0.20	-	-	-	22.55	32.10
	Mean-I	**0.75**	**0.70**	**0.20**	-	-	-	**23.73**	**31.88**
11	June 1st Fortnight	-	0.70	0.30	-	-	-	23.40	31.60
12	June 2nd Fortnight	-	1.10	0.20	-	-	-	23.00	30.05
	Mean-II	-	**0.90**	**0.25**	-	-	-	**23.20**	**30.83**
13	July 1st Fortnight	-	0.80	0.60	0.40	-	-	24.35	27.30
14	July 2nd Fortnight	-	0.20	1.60	1.00	-	-	23.50	26.90
	Mean-III	-	**0.50**	**1.10**	**0.70**	-	-	**23.93**	**27.10**
15	August 1st Fortnight	-	-	0.40	1.15	-	-	24.90	24.25
16	August 2nd Fortnight	-	-	0.60	1.55	-	-	21.90	25.80
	Mean-IV	-	-	**0.50**	**1.35**	-	-	**23.40**	**25.03**
17	September 1st Fortnight	-	-	-	1.03	-	-	23.70	25.90
18	September 2nd Fortnight	-	-	-	1.10	-	-	25.00	27.30
	Mean-I	-	-	-	**1.07**	-	-	**24.35**	**26.60**
19	October 1st Fortnight	-	-	-	0.80	-	-	23.00	26.85
20	October 2nd Fortnight	-	-	-	0.35	0.20	-	24.65	23.85
	Mean-II	-	-	-	**0.58**	**0.20**	-	**23.83**	**25.35**
21	November 1st Fortnight	-	-	-	-	0.75	0.16	25.25	25.25
22	November 2nd Fortnight	-	-	-	-	0.73		24.55	24.00
	Mean-III	-	-	-	-	**0.74**	**0.16**	**24.90**	**24.63**
23	December 1st Fortnight	-	-	-	-	0.60	0.40	23.05	23.65
24	December 2nd Fortnight	-	-	-	-	0.39	0.36	23.85	23.40
	Mean-IV	-	-	-	-	**0.50**	**0.38**	**23.45**	**23.53**

Plate 8: Third instar grub of *Holotrichia serrata* (Kochari)

Table 19: Population dynamics of different stages of sugarcane white grub, *Holotrichia serrata* in Sankeshwar location of Belagavi district during 2011-2012

Sl. No.	Period	2011								2012							
		No. per m^2								No. per m^2							
		Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^0C)	Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^0C)
1	January 1st Fortnight	-	-	-	-	0.60	1.10	20.20	24.10	-	-	-	-	0.60	0.60	19.80	25.10
2	January 2nd Fortnight	-	-	-	-	0.91	0.30	19.10	25.30	-	-	-	-	1.40	0.20	19.10	24.90
	Mean –I	-	-	-	-	0.76	0.70	19.65	24.70	-	-	-	-	1.00	0.40	19.45	25.00
3	February 1st Fortnight	-	-	-	-	0.80	0.60	17.90	25.60	-	-	-	-	1.20	0.2	20.10	25.60
4	February 2nd Fortnight	-	-	-	-	1.20	0.6	22.05	26.30	-	-	-	-	1.40	0.80	22.00	26.10
	Mean –II	-	-	-	-	1.00	0.60	19.98	25.95	-	-	-	-	1.30	0.50	21.05	25.85
5	March 1st Fortnight	-	-	-	-		0.30	20.70	27.10	-	-	-	-	1.00	1.80	22.80	27.00
6	March 2nd Fortnight	-	-	-	-		0.30	21.60	29.00	-	-	-	-	0.20	1.20	20.10	29.00
	Mean -III	-	-	-	-		0.30	21.15	28.05	-	-	-	-	0.60	1.50	21.45	28.00
7	April 1st Fortnight	0.20	-	-	-		0.60	23.70	31.50	0.20	-	-	-	-	1.00	23.20	30.40
8	April 2nd Fortnight	0.20	-	-	-		0.05	23.20	31.50	0.20	-	-	-	-			
	Mean - IV	0.20	-	-	-		0.33	23.45	31.50	0.20	-	-	-	-	1.00	23.20	30.40
9	May 1st Fortnight	0.10	-	-	-	-	-	24.20	31.60	1.80	1.40	-	-	-	-	23.60	31.90
10	May 2nd Fortnight	0.60	0.20	-	-	-	-	20.40	31.60	1.20	1.60	-	-	-	-	23.50	32.00
	Mean-I	0.35	0.20	-	-	-	-	22.30	31.60	1.50	1.50	-	-	-	-	23.55	31.95
11	June 1st Fortnight	-	0.40	-	-	-	-	24.60	31.00	-	1.40	0.20	-	-	-	21.40	31.30
12	June 2nd Fortnight	-	1.10	0.40	-	-	-	21.80	30.40	-	1.60	1.40	-	-	-	22.80	30.60
	Mean-II	-	0.75	0.40	-	-	-	23.20	30.70	-	1.50	0.80	-	-	-	22.10	30.95
13	July 1st Fortnight	-	0.10	0.60	0.40	-	-	23.30	27.50	-	1.20	1.60	0.20	-	-	25.80	27.40
14	July 2nd Fortnight	-			0.60	-	-	23.30	27.50	-	0.40	2.10	0.80	-	-	24.00	26.60
	Mean-III	-	0.10	0.60	0.50	-	-	23.30	27.50	-	0.80	1.85	0.50	-	-	24.90	27.00
15	August 1st Fortnight	-	-	-	0.40	-	-	23.70	26.20	-	0.10	0.40	1.60	-	-	25.50	23.00
16	August 2nd Fortnight	-	-	-	1.40	-	-	23.70	25.30	-		0.80	1.20	-	-	21.40	
	Mean-IV	-	-	-	0.90	-	-	23.70	25.75	-	0.10	0.60	1.40	-	-	23.45	23.00
17	September 1st Fortnight	-	-	-	1.20	-	-	23.30	26.20	-	-	-	1.10	-	-	24.00	25.10
18	September 2nd Fortnight	-	-	-	1.20	-	-	24.60	26.70	-	-	-	1.20	-	-	4.60	26.80
	Mean-I	-	-	-	1.20	-	-	23.95	26.45	-	-	-	1.15	-	-	24.30	25.95
19	October 1st Fortnight	-	-	-	0.80	-	-	24.20	27.10	-	-	-	0.10	-	-	21.90	27.50
20	October 2nd Fortnight	-	-	-	1.00	-	-	22.20	27.10	-	-	-	0.60	-	-	27.10	21.00
	Mean-II	-	-	-	0.90	-	-	23.20	27.15	-	-	-	0.35	-	-	24.50	24.25
21	November 1st Fortnight	-	-	-	1.00	0.20	-	23.40	27.30	-	-	-	0.10	0.10	-	27.60	24.60
22	November 2nd Fortnight	-	-	-	-	0.40	-	22.80	25.70	-	-	-	0.10	0.11	-	25.10	23.50
	Mean-III	-	-	-	1.00	0.30	-	23.10	26.50	-	-	-	0.10	0.11	-	26.35	24.05
23	December 1st Fortnight	-	-	-	-	0.60	0.20	18.40	25.20	-	-	-	0.40	0.40	-	27.00	21.80
24	December 2nd Fortnight	-	-	-	-	0.61	0.20	20.80	24.50	-	-	-		0.60	0.12	25.70	23.10
	Mean-IV	-	-	-	-	0.61	0.20	19.60	24.85	-	-	-	0.40	0.50	0.12	26.35	22.45

Table 20: Pooled population dynamics (2011-2012) of different stages of sugarcane white grub, *Holotrichia serrata* in Sankeshwar location of Belagavi district

Sl. No.	Period	No. per m^2							
		Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^{0}C)
1	January 1st Fortnight	-	-	-	-	0.60	0.85	20.00	24.60
2	January 2nd Fortnight	-	-	-	-	1.16	0.25	19.10	25.10
	Mean –I	-	-	-	-	0.88	0.55	19.55	24.85
3	February 1st Fortnight	-	-	-	-	1.00	0.40	19.00	25.60
4	February 2nd Fortnight	-	-	-	-	1.30	0.70	22.03	26.20
	Mean –II	-	-	-	-	1.15	0.55	20.51	25.90
5	March 1st Fortnight	-	-	-	-	1.00	1.05	21.75	27.05
6	March 2nd Fortnight	-	-	-	-	1.20	0.75	20.85	29.00
	Mean –III	-	-	-	-	0.60	0.90	21.30	28.03
7	April 1st Fortnight	0.20	-	-	-	-	0.80	23.45	30.95
8	April 2nd Fortnight	0.20	-	-	-	-	0.05	23.20	31.50
	Mean- IV	0.20	-	-	-	-	0.43	23.33	31.23
9	May 1st Fortnight	0.95	1.40	-	-	-	-	23.90	31.75
10	May 2nd Fortnight	0.90	0.90	-	-	-	-	21.95	31.80
	Mean-I	0.93	1.15	-	-	-	-	22.93	31.78
11	June 1st Fortnight	-	0.90	0.20	-	-	-	23.00	31.15
12	June 2nd Fortnight	-	1.35	0.09	-	-	-	22.30	30.50
	Mean-II	-	1.13	0.55	-	-	-	22.65	30.83
13	July 1st Fortnight	-	-	1.10	0.30	-	-	24.55	27.45
14	July 2nd Fortnight	-	-	2.10	0.70	-	-	23.65	27.05
	Mean-III	-	-	1.60	0.50	-	-	24.10	27.25
15	August 1st Fortnight	-	-	0.40	1.00	-	-	24.60	24.60
16	August 2nd Fortnight	-	-	0.80	1.30	-	-	22.55	25.30
	Mean-IV	-	-	0.60	1.15	-	-	23.58	24.95
17	September 1st Fortnight	-	-	-	1.15	-	-	23.65	25.65
18	September 2nd Fortnight	-	-	-	1.20	-	-	24.60	26.75
	Mean-I	-	-	-	1.18	-	-	24.13	26.20
19	October 1st Fortnight	-	-	-	0.45	-	-	23.05	27.30
20	October 2nd Fortnight	-	-	-	0.80	-	-	24.65	24.10
	Mean-II	-	-	-	0.63	-	-	23.85	25.70
21	November 1st Fortnight	-	-	-	0.55	0.15	-	25.50	25.95
22	November 2nd Fortnight	-	-	-	0.10	0.26	-	23.95	24.60
	Mean-III	-	-	-	0.33	0.21	-	24.73	25.28
23	December 1st Fortnight	-	-	-	0.40	0.50	0.20	22.70	23.50
24	December 2nd Fortnight	-	-	-	-	0.61	0.16	23.25	23.80
	Mean-IV	-	-	-	0.40	0.56	0.18	22.98	23.65

Table 21: Population dynamics of different stages of sugarcane white grub, *Holotrichia serrata* in Soundalga location of Belagavi district during 2011-2012

Sl. No.	Period	2011								2012							
		No. per m^2								No. per m^2							
		Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^0C)	Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (^0C)
1	January 1st Fortnight	-	-	-	-		1.70	20.20	24.30	-	-	-	-	0.20	1.20	22.20	24.80
2	January 2nd Fortnight	-	-	-	-	0.33	1.10	19.50	24.90	-	-	-	-	0.10	1.20	23.00	24.70
	Mean –I	-	-	-	-	0.33	1.40	19.85	4.60	-	-	-	-	0.15	1.20	22.60	24.75
3	February 1st Fortnight	-	-	-	-	-	1.40	18.80	24.60	-	-	-	-	0.20	0.40	20.00	25.30
4	February 2nd Fortnight	-	-	-	-	-	1.30	19.00	6.20	-	-	-	-	0.80	0.60	20.10	26.00
	Mean –II	-	-	-	-	-	1.35	18.90	25.40	-	-	-	-	0.50	0.50	20.05	25.65
5	March 1st Fortnight	-	-	-	-	-	0.30	23.80	27.10	0.15	-	-	-	-	0.4	25.00	26.90
6	March 2nd Fortnight	-	-	-	-	-	0.20	24.60	28.90	0.20	0.10	-	-	-	0.40	23.80	28.80
	Mean –III	-	-	-	-	-	0.25	24.20	28.00	0.18	0.10	-	-	-	0.40	24.40	27.85
7	April 1st Fortnight	0.20	0.21	-	-	-	0.10	23.80	30.40	0.40	0.40	-	-	-	0.40	25.30	29.80
8	April 2nd Fortnight	0.21	0.40	-	-	-	-	23.60	30.90	0.60	0.80	-	-	-	-	-	-
	Mean- IV	0.21	0.31	-	-	-	0.10	23.70	30.65	0.50	0.60	-	-	-	0.40	25.30	29.80
9	May 1st Fortnight	-	0.40	0.40	-	-	-	23.40	31.90	1.00	1.00	0.60	-	-	-	23.80	31.00
10	May 2nd Fortnight	-	0.60	0.40	-	-	-	22.10	32.20	0.20	0.40	1.00	-	-	-	23.40	31.80
	Mean-I	-	0.50	0.40	-	-	-	22.75	32.05	0.60	0.70	0.80	-	-	-	23.60	31.40
11	June 1st Fortnight	-	0.40	0.40	-	-	-	23.20	31.70	-	-	1.00	0.40	-	-	22.10	31.40
12	June 2nd Fortnight	-	-	4.60	0.40	-	-	21.80	28.90	-	-	0.80	1.00	-	-	22.80	29.70
	Mean-II	-	0.40	2.50	0.40	-	-	22.50	30.30	-	-	0.90	0.70	-	-	22.45	30.55
13	July 1st Fortnight	-	-	0.40	0.80	-	-	23.80	27.10	-	-	0.40	1.20	-	-	25.80	27.50
14	July 2nd Fortnight	-	-	-	1.10	-	-	23.80	27.10	-	-	0.20	2.00	-	-	22.00	26.20
	Mean-III	-	-	0.40	0.95	-	-	23.80	27.10	-	-	0.30	1.60	-	-	23.90	26.85
15	August 1st Fortnight	-	-	-	0.70	0.40	-	24.60	25.10	-	-	0.20	1.80	-	-	25.60	25.10
16	August 2nd Fortnight	-	-	-	0.80	-	-	22.60	26.30	-	-	-	2.30	-	-	23.10	
	Mean-IV	-	-	-	0.75	0.40	-	23.60	25.70	-	-	0.20	2.05	-	-	24.35	25.10
17	September 1st Fortnight	-	-	-	0.80	0.30	-	24.80	26.70	-	-	-	0.68	0.50	-	22.90	26.00
18	September 2nd Fortnight	-	-	-	0.60	0.20	-	23.30	27.10	-	-	-	0.55	0.50	-	24.60	26.90
	Mean-I	-	-	-	0.70	0.25	-	4.05	6.90	-	-	-	0.62	0.50	-	23.75	26.45
19	October 1st Fortnight	-	-	-	0.60	0.40	-	21.80	27.30	-	-	-	0.40	0.41	-	21.80	27.30
20	October 2nd Fortnight	-	-	-	-	0.60	-	21.10	27.60	-	-	-		0.46	-	27.50	23.10
	Mean-II	-	-	-	0.60	0.50	-	21.45	27.45	-	-	-	0.40	0.44	-	24.65	25.20
21	November 1st Fortnight	-	-	-	-	0.60	0.40	22.10	27.60	-	-	-	-	0.45	0.20	27.30	22.80
22	November 2nd Fortnight	-	-	-	-	0.40	0.40	24.70	26.10	-	-	-	-	0.55	0.34	27.00	24.10
	Mean-III	-	-	-	-	0.50	0.40	23.40	26.85	-	-	-	-	0.50	0.27	27.15	23.45
23	December 1st Fortnight	-	-	-	-	0.20	0.60	20.40	25.30	-	-	-	-	-	0.35	27.10	23.60
24	December 2nd Fortnight	-	-	-	-	-	1.10	18.50	24.80	-	-	-	-	-	0.80	24.60	21.60
	Mean-IV	-	-	-	-	0.20	0.85	19.45	25.05	-	-	-	-	-	0.58	25.85	22.60

Table 22: Pooled population dynamics (2011-2012) of different stages of sugarcane white grub, *Holotrichia serrata* in Soundalga location of Belagavi district

Sl. No.	Period	No. per m^2							
		Egg	1st instar	2nd instar	3rd instar	Pupa	Adult (Quiescent)	Soil moisture (%)	Soil temp (⁰C)
1	January 1st Fortnight	-	-	-	-	0.20	1.45	21.20	24.55
2	January 2nd Fortnight	-	-	-	-	0.22	1.15	21.25	24.80
	Mean-I	-	-	-	-	0.21	1.30	21.23	24.68
3	February 1st Fortnight	-	-	-	-	0.20	0.90	19.40	24.95
4	February 2nd Fortnight	-	-	-	-	0.80	0.95	19.55	26.10
	Mean-II	-	-	-	-	0.50	0.93	19.48	25.53
5	March 1st Fortnight	0.15	-	-	-	-	0.35	24.40	27.00
6	March 2nd Fortnight	0.20	0.10	-	-	-	0.30	24.20	28.85
	Mean-III	0.18	0.10	-	-	-	0.33	24.30	27.93
7	April 1st Fortnight	0.30	0.31	-	-	-	0.25	24.55	30.10
8	April 2nd Fortnight	0.41	0.60	-	-	-	0.00	23.60	30.90
	Mean-IV	0.36	0.46	-	-	-	0.25	24.08	30.50
9	May 1st Fortnight	1.00	0.70	0.50	-	-	-	23.60	31.45
10	May 2nd Fortnight	0.20	0.50	0.70	-	-	-	22.75	32.00
	Mean-I	0.60	0.60	0.60	-	-	-	23.18	31.73
11	June 1st Fortnight	-	0.40	0.70	0.40	-	-	22.65	31.55
12	June 2nd Fortnight	-	-	2.70	0.70	-	-	22.30	29.30
	Mean-II	-	0.40	1.70	0.55	-	-	22.48	30.43
13	July 1st Fortnight	-	-	0.40	1.00	-	-	24.80	27.30
14	July 2nd Fortnight	-	-	0.20	1.55	-	-	22.90	26.65
	Mean-III	-	-	0.30	1.28	-	-	23.85	26.98
15	August 1st Fortnight	-	-	0.20	1.25	0.40	-	25.10	25.10
16	August 2nd Fortnight	-	-	0.00	1.55	-	-	22.85	26.30
	Mean-IV	-	-	0.20	1.40	0.40	-	23.98	25.70
17	September 1st Fortnight	-	-	-	0.74	0.40	-	23.85	26.35
18	September 2nd Fortnight	-	-	-	0.58	0.35	-	23.95	27.00
	Mean-I	-	-	-	0.66	0.38	-	23.90	26.68
19	October 1st Fortnight	-	-	-	0.50	0.41	-	21.80	27.30
20	October 2nd Fortnight	-	-	-	-	0.53	-	24.30	25.35
	Mean-II	-	-	-	0.50	0.47	-	23.05	26.33
21	November 1st Fortnight	-	-	-	-	0.53	0.30	24.70	25.20
22	November 2nd Fortnight	-	-	-	-	0.48	0.37	25.85	25.10
	Mean-III	-	-	-	-	0.51	0.34	25.28	25.15
23	December 1st Fortnight	-	-	-	-	0.20	0.48	23.75	24.45
24	December 2nd Fortnight	-	-	-	-	-	0.95	21.55	23.20
	Mean-IV	-	-	-	-	0.20	0.72	22.65	23.83

Plat 9: Third instar grub and pupa of *Holotrichia serrata* (Bellad Bagewadi)

Plate 10: Quiscent adult of *Holotrichia serrata*

Table 23: Evaluation of different trapping sources on mean number of *Holotrichia serrata* beetles caught under natural conditions (2011)

Sl. No.	Treatments	Meteorological Standard Week (MSW)						
		10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)
1	FYM	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)
2	Press mud	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)
3	Sugarcane setts	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)
4	Neem leaves	19.80 ab (4.56)	21.10 ab (4.70)	24.00 a (5.00)	27.00 a (5.29)	20.00 a (4.58)	19.60 a (4.54)	3.33 a (2.08)
5	T1 + T2	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)
6	T1 + T3	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)
7	T1 + T4	10.10 c (3.33)	8.66 d (3.11)	12.10 c (3.62)	13.00 cd (3.74)	8.80 cd (3.13)	4.10 d (2.26)	0.56 d (1.25)
8	T2 + T3	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)
9	T2 + T4	10.66 c (3.41)	12.60 c (3.69)	13.00 c (3.74)	15.10 c (4.01)	11.60 bc (3.55)	6.66 c (2.77)	1.30 c (1.52)
10	T3 + T4	8.20 c (3.03)	9.10 d (3.18)	10.00 c (3.32)	11.00 d (3.46)	7.40 d (2.90)	3.10 d (2.02)	0.80 cd (1.34)
11	Light source	16.00 b (4.12)	17.10 b (4.25)	18.30 b (4.39)	20.00 (4.58) b	13.00 b (3.74)	11.10 b (3.48)	1.10 cd (1.45)
12	Light + Neem	22.80 a (4.80)	24.20 a (5.02)	25.60 a (5.16)	27.10 a (5.30)	22.00 a (4.80)	14.00 b (3.87)	2.24 b (1.80)
	SEm. ±	0.17	0.18	0.17	0.18	0.17	0.16	0.08
	C.D. @ 5%	0.49	0.49	0.49	0.48	0.49	0.48	0.23
	CV (%)	11.84	11.57	11.09	10.70	12.07	13.89	10.62

Figures in the parentheses are $\sqrt{x+1}$ transformed values, means showing similar alphabets do not differ significantly by DMRT

Table 24: Evaluation of different trapping sources on mean number of *Holotrichia serrata* beetles caught under natural conditions (2012)

Sl. No.	Treatments	Meteorological Standard Week (MSW)						
		10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)
1	FYM	0.00 (1.00)d	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)
2	Press mud	0.00 d (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)
3	Sugarcane setts	0.00 d (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)
4	Neem leaves	20.60 ab (4.65)	22.70 a (4.87)	25.30 a (5.13)	28.20 a (5.40)	21.60 a (4.75)	21.00 a (4.69)	4.14 a (2.27)
5	T1 + T2	0.00 d (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)
6	T1 + T3	0.00 d (1.00)	0.00 e (1.00)	0.00 cd (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)
7	T1 + T4	12.00 c (3.61)	7.80 d (2.97)	11.60 e (3.55)	12.72 d (3.70)	8.20 c (3.03)	3.30 d (2.07)	0.33 cd (1.15)
8	T2 + T3	0.00 d (1.00)	0.00 e (1.00)	0.00 bc (1.00)	0.00 e (1.00)	0.00 b (1.00)	0.00 e (1.00)	0.00 d (1.00)
9	T2 + T4	11.80 c (3.58)	13.10 c (3.75)	15.00 d (4.00)	16.90 c (4.23)	12.20 c (3.63)	7.10 c (2.85)	1.80 b (1.67)
10	T3 + T4	9.60 c (3.26)	10.20 cd (3.35)	11.10 b (3.48)	11.80 d (3.58)	8.10 b (3.02)	4.33 d (2.31)	0.90 bc (1.38)
11	Light source	16.90 b (4.23)	18.10 b (4.37)	19.00 a (4.47)	21.60 b (4.75)	14.20 a (3.90)	12.30 b (3.65)	1.80 b (1.67)
12	Light + Neem	23.10 a (4.91)	25.60 a (5.16)	26.10 (5.21)	28.70 a (5.45)	23.20 a (4.92)	15.20 b (4.02)	3.30 a (2.07)
	SEm. ±	0.17	0.18	0.17	0.16	0.17	0.16	0.10
	C.D. @ 5%	0.49	0.53	0.49	0.48	0.49	0.48	0.31
	CV (%)	11.46	11.37	10.88	10.46	11.84	13.54	13.48

Figures in the parentheses are $\sqrt{x+1}$ transformed values, means showing similar alphabets do not differ significantly by DMRT

Table 25: Pooled data (2011-12) on evaluation of different trapping sources on mean number of *Holotrichia serrata* beetles caught under natural conditions

Sl. No.	Treatments details	Meteorological Standard Week (MSW)						
		10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)
1	FYM	0.00 e (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 c (1.00)
2	Press mud	0.00 e (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 c (1.00)
3	Sugarcane setts	0.00 e (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 c (1.00)
4	Neem leaves	20.20 ab (4.60)	22.40 a (4.84)	24.65 a (5.06)	27.60 a (5.35)	20.80 a (4.67)	20.30 a (4.62)	3.73 a (2.17)
5	FYM + FYM	0.00 e (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 c (1.00)
6	FYM + Sugarcane setts	0.00 e (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 c (1.00)
7	FYM + Neem leaves	12.55 c (3.68)	8.23 d (3.04)	11.85 c (3.58)	13.36 cd (3.79)	8.50 c (3.08)	3.70 d (2.17)	0.44 d (1.20)
8	Press mud + Sugarcane setts	0.00 e (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 d (1.00)	0.00 e (1.00)	0.00 c (1.00)
9	Press mud + Neem leaves	11.23 cd (3.50)	12.85 bc (3.72)	14.00 c (3.87)	16.00 c (4.12)	11.90 b (3.59)	7.85 c (2.97)	1.55 b (1.60)
10	Sugarcane setts + Neem leaves	8.90 d (3.15)	9.65 cd (3.26)	10.55 c (3.40)	11.40 d (3.52)	7.75 c (2.96)	3.71 d (2.17)	0.85 b (1.36)
11	Light source	16.45 b (4.18)	14.10 b (3.89)	18.65 b (4.43)	20.80 b (4.67)	13.60 b (3.82)	11.70 b (3.56)	1.45 b (1.57)
12	Light + Neem	22.50 a (4.85)	24.90 a (5.09)	25.85 a (5.18)	27.90 a (5.38)	22.60 a (4.86)	14.60 b (3.95)	2.77 a (1.94)
	SEm. ±	0.49	0.49	0.49	0.49	0.49	0.49	0.24
	C.D. @ 5%	0.17	0.17	0.17	0.17	0.17	0.17	0.08
	CV (%)	11.56	11.61	10.99	10.55	12.13	13.62	10.93

Figures in the parentheses are $\sqrt{x+1}$ transformed values, means showing similar alphabets do not differ significantly by DMRT

Plate 11: Neem leaves as a trapping source for *Holotrichia serrata* adults

Table 26: Field evaluation of chemicals with pheromone/kairomone activity on mean number of *Holotrichia serrata* adults caught (2011)

Sl. No.	Treatments	Meteorological Standard Week (MSW)						
		10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)
1	Anisole @ 10 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
2	Methoxy 2 benzene @ 10 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
3	Methoxy 5 benzene @ 10 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
4	Ethyl acetate @ 10 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
5	T1 + T2 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
6	T1 + T3 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
7	T1 + T4 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
8	T2 + T3 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
9	T2 + T4 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
10	T3 + T4 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
11	Neem leaf extract 10% @ 10 ml	8.42 a (3.07)	11.86 a (3.59)	14.61 a (3.95)	14.86 a (3.98)	15.10 a (4.01)	5.33 a (2.52)	5.56 a (2.56)
	SEm. ±	0.03	0.07	0.08	0.09	0.09	0.09	0.08
	C.D. @ 5%	0.19	0.21	0.23	0.26	0.26	0.26	0.23
	CV (%)	10.06	10.15	10.29	11.89	11.86	11.84	11.88

Figures in the parentheses are √x+1 transformed values, means showing similar alphabets do not differ significantly by DMRT

Table 27: Field evaluation of chemicals with pheromone/kairomone activity on mean number of *Holotrichia serrata* adults caught (2012)

Sl. No.	Treatments	Meteorological Standard Week (MSW)						
		10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)
1	Anisole @ 10 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
2	Methoxy 2 benzene @ 10 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
3	Methoxy 5 benzene @ 10 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
4	Ethyl acetate @ 10 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
5	T1 + T2 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
6	T1 + T3 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
7	T1 + T4 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
8	T2 + T3 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
9	T2 + T4 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
10	T3 + T4 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
11	Neem leaf extract 10% @ 10 ml	9.10 a (3.18)	12.20 a (3.63)	13.88 a (3.86)	16.21 a (4.15)	14.33 a (3.92)	8.92 s (3.15)	2.26 a (4.10)
	SEm. ±	0.09	0.08	0.09	0.09	0.10	0.07	0.09
	C.D. @ 5%	0.26	0.23	0.26	0.26	0.28	0.21	0.26
	CV (%)	12.68	11.00	12.17	11.62	13.09	10.09	13.53

Figures in the parentheses are $\sqrt{x+1}$ transformed values, means showing similar alphabets do not differ significantly by DMRT

Table 28: Pooled data (2011 and 2012) on field evaluation of chemicals with pheromone/kairomone activity on mean number of *Holotrichia serrata* adults caught

Sl. No.	Treatments	Meteorological Standard Week (MSW)						
		10 (March)	11 (March)	12 (March)	13 (March)	14 (April)	15 (April)	16 (April)
1	Anisole @ 10 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
2	Methoxy 2 benzene @ 10 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
3	Methoxy 5 benzene @ 10 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
4	Ethyl acetate @ 10 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 (1.00)b
5	T1 + T2 @ 5 ml + 5 ml	0.00 (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
6	T1 + T3 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00b (1.00)
7	T1 + T4 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
8	T2 + T3 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
9	T2 + T4 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
10	T3 + T4 @ 5 ml + 5 ml	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)	0.00 b (1.00)
11	Neem leaf extract 10% @ 10 ml	8.76 a (3.12)	12.03a (3.61)	14.14 a (3.89)	15.33a (4.07)	14.71a (3.96)	7.12a (2.85)	4.83a (2.41)
	SEm. ±	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	C.D. @ 5%	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	CV (%)	7.52	7.31	7.16	7.07	7.13	7.74	8.02

Figures in the parentheses are $\sqrt{x+1}$ transformed values, means showing similar alphabets do not differ significantly by DMRT

4.3.3 Grub load of *Holotrichia serrata* in different crops

4.3.3.1 Mean grub load of *Holotrichia serrata* in different crops

Mean number of grubs per m^2 during June - November 2011 in different crops as influenced by soil depth and soil moisture pertaining to different crops are presented in Tables 29-32 (Plate 12-13).

June 2011

The grub load recorded in different crops ranged from 0.78 to 11.33 per m^2. Among the *kharif* crops, paddy (rainfed) grown in medium black soil with a soil depth of 10.5 cm recorded 3.66 grubs followed by turmeric in red soil at 8.5 cm depth recording 3.60. In medium black soil, chilli and groundnut recorded 2.80 and 2.33 grubs at soil depth of 14.20 and 11.50 cm respectively. However, sugarcane recorded highest number (11.33) at soil depth of 27.60 cm, whereas lowest number (0.78) was recorded in soybean at 11.10 cm soil depth. Per cent soil moisture recorded in different crops during this period ranged from 19.50 to 23.00.

July 2011

Irrespective of the crop there was slight increase in larval count during July 2011 as compared to June 2011 (Table 29). The grub load ranged from 0.66 to 15.30 per m^2. However, higher number of grubs was recorded in sugarcane (15.30) and least number was in soybean (0.66). The grub load was higher in rainfed paddy (6.33) as compared to all other irrigated crops but for sugarcane. Availability of grubs at varied soil depth ranged from 9.80 to 29.10 cm, soil moisture per cent varied from 20.40 to 26.64 in both red and medium black soils.

August 2011

During this period, grub load in different crops ranged between 0.33 and 12.32 in different crops *viz.,* sugarcane (12.32), paddy (6.12), soybean (0.33), ground nut (12.50), maize (12.50), chilly (11.20), capsicum (11.60), brinjal (12.00) and turmeric (1.30). Availability of grubs during this period, at varied depth of 10.60 to 30.10 cm and soil moisture, ranged between 19.80 and 22.80.

September 2011

Irrespective of crops grub load declined from September onwards and varied between 0.20 (soybean) and 8.55 (sugarcane). The soil moisture per cent ranged between 18.90 and 24.15 in both red and medium black soils. The depth of larval availability ranged between 11.22 and 27.20 cm.

October 2011

Grub load recorded during this period on three main *rabi* crops *viz.,* wheat, sorghum and bengalgram ranged between 2.60 (sorghum) to 3.33 (wheat). However, bengalgram recorded 3.30 larvae per m^2 and the per cent soil moisture varied between 17.80 to 19.00 and depth of larval availability ranged from 9.00 to 10.10 cm.

November 2011

Grub load increased in all crops as compared to October month and ranged from 1.14 to 2.62. Higher number was recorded in wheat (2.62), bengalgram (1.37) followed by sorghum (1.14) with per cent soil moisture ranging between 17.40 to 18.50.

June 2012

During June 2012, the trend was similar to June 2011 where the grub load ranged from 0.33 to 11.60. However, sugarcane recorded maximum number (11.60) followed by turmeric (5.12), paddy (5.10) and maize (4.33). Soil moisture during this period varied from 20.60 to 23.10 per cent while soil depth ranged from 10.25 to 26.30 cm, respectively (Table 30).

July 2012

Grub load recorded during July 2012 varied from 0.33 to 9.50. Highest number was recorded in sugarcane (9.50) followed by paddy (6.00) and least was recorded in soybean (0.33). Irrespective of the soil type the per cent soil moisture and depth of larval availability in red and medium black soils ranged 21.40 - 24.00 and 10.00 - 26.30 cm respectively (Table 30).

Table 29: Mean grub load of *Holotrichia serrata* in different *Kharif* crops -2011

Sl. No.	Crops	Soil type	June			July			August		September			
			No./m^2	Soil moisture (%)	Soil depth (cm)	No./m^2	Soil moisture (%)	Soil depth (cm)	No./m^2	Soil moisture (%)	Soil depth (cm)	No./m^2	Soil moisture (%)	Soil depth (cm)
1	Ground nut	Medium Black	2.33	20.02	11.50	3.76	21.20	12.50	3.12	19.80	12.60	2.01	21.00	13.00
2	Soybean	Medium Black	0.78	19.80	11.10	0.66	21.30	10.10	0.33	20.00	11.82	0.20	19.60	12.50
3	Maize	Medium Black	2.66	19.50	12.20	3.66	21.00	12.50	2.50	22.50	13.33	1.33	20.80	15.10
4	Paddy	Medium Black	6.33	22.10	6.33	6.33	23.10	10.60	6.12	22.80	11.75	2.10	20.10	12.65
5	Chilly	Medium Black	2.80	19.70	14.20	3.33	22.69	11.20	3.02	21.30	12.61	2.00	20.00	13.00
6	Brinjal	Medium Black	2.10	20.00	13.50	2.65	21.70	12.00	2.33	20.69	13.38	0.66	18.90	14.10
7	Sugarcane	Medium Black	11.33	23.00	27.60	15.30	21.50	29.10	12.32	21.10	30.10	8.66	24.15	27.20
8	Capsicum	Red	2.33	19.60	13.30	3.66	22.50	11.60	4.10	21.20	12.72	1.00	19.90	13.30
9	Cabbage	Red	1.30	20.00	10.10	2.66	21.80	9.80	1.02	22.30	10.60	-	20.50	11.20
10	Turmeric	Red	3.60	20.10	8.50	2.66	20.40	10.10	1.30	21.20	11.50	-	19.80	12.80

Table 30: Mean grub load of *Holotrichia serrata* in different *Kharif* crops -2012

Sl. No.	Crops	Soil type	June			July			August			September		
			No./m^2	Soil moisture (%)	Soil depth (cm)	No./m^2	Soil moisture (%)	Soil depth (cm)	No./m^2	Soil moisture (%)	Soil depth (cm)	No./m^2	Soil moisture (%)	Soil depth (cm)
1	Ground nut	Medium Black	3.33	23.10	10.50	3.66	22.80	11.30	3.00	23.90	12.40	0.66	20.70	12.30
2	Soybean	Medium Black	0.33	22.70	10.25	0.33	23.60	10.80	0.10	23.80	12.00	0.00	18.90	12.70
3	Maize	Medium Black	4.33	21.90	11.50	3.33	22.60	12.10	2.40	24.00	12.80	1.66	21.10	13.30
4	Paddy	Medium Black	5.10	23.00	10.50	6.00	24.00	10.85	6.00	24.60	11.60	2.10	18.80	13.00
5	Chilly	Medium Black	3.15	22.40	13.00	3.00	23.80	11.40	3.00	22.60	12.70	2.33	19.60	13.20
6	Brinjal	Medium Black	2.00	21.80	13.50	2.00	22.60	11.90	2.33	21.40	13.50	0.33	19.20	13.00
7	Sugarcane	Medium Black	11.60	21.08	26.30	9.50	22.50	26.30	8.60	23.20	29.50	5.45	21.60	29.80
8	Capsicum	Red	3.30	22.20	12.50	4.12	23.10	11.65	4.10	22.40	12.90	1.66	20.30	13.10
9	Cabbage	Red	1.00	22.30	11.00	2.00	22.80	10.00	1.00	20.70	10.80	0.00	19.60	11.10
10	Turmeric	Red	5.12	20.60	8.50	4.33	21.40	10.30	1.30	20.00	11.50	0.00	21.20	12.70

Table 31: Pooled (2011-12) mean grub load of *Holotrichia serrata* in different *Kharif* crops

Sl. No.	Crops	Soil types	June			July			August			September		
			No./m^2	Soil moisture (%)	Soil depth (cm)	No./m^2	Soil moisture (%)	Soil depth (cm)	No./m^2	Soil moisture (%)	Soil depth (cm)	No./m^2	Soil moisture (%)	Soil depth (cm)
1	Ground nut	Medium Black	2.83	21.65	11.00	3.71	22.00	11.90	3.06	21.85	12.50	1.34	20.85	12.65
2	Soybean	Medium Black	0.56	21.25	10.68	0.50	22.45	10.45	0.22	21.90	11.91	0.10	19.25	12.60
3	Maize	Medium Black	3.50	20.70	11.85	3.50	21.80	12.30	2.45	23.25	13.07	1.50	20.95	14.20
4	Paddy	Medium Black	5.72	22.55	8.42	6.17	23.55	10.73	6.06	23.70	11.68	2.10	19.45	12.83
5	Chilly	Medium Black	2.98	21.05	13.60	3.17	23.25	11.30	3.01	21.95	12.66	2.17	19.80	13.10
6	Brinjal	Medium Black	2.05	20.90	13.50	2.33	22.15	11.95	2.33	21.05	13.44	0.50	19.05	13.55
7	Sugarcane	Medium Black	11.47	22.04	26.95	12.40	22.00	27.70	10.46	22.15	29.80	7.06	22.88	28.50
8	Capsicum	Red	2.82	20.90	12.90	3.89	22.80	11.63	4.10	21.80	12.81	1.33	20.10	13.20
9	Cabbage	Red	1.15	21.15	10.55	2.33	22.30	9.90	1.01	21.50	10.70	0.00	20.05	11.15
10	Turmeric	Red	4.36	20.35	8.50	3.50	20.90	10.20	1.30	20.60	11.50	0.00	20.50	12.75

August 2012

Larval number declined as compared to July 2012 and ranged from 0.10 to 8.60 per m^2 on different crops. Soybean recorded least number of 0.10. Sugarcane registered maximum number (8.60). Irrespective of soil type the soil moisture ranged between 20.00 - 24.60 per cent while soil depth ranged from 10.80 - 29.50 cm.

September 2012

During this period grub number declined in different crops. Higher number was recorded in sugarcane (5.45), while soybean and cabbage recorded no population. Per cent soil moisture and soil depth ranged from 11.10 to 21.60 and 11.10 to 19.80 cm respectively.

Pooled`

June 2011-12

There was increase in grub number during this period which ranged from 0.56 (soybean) to 11.47 (sugarcane). However, paddy recorded 5.72 grubs followed by capsicum (2.82), groundnut (2.83), maize (3.50), turmeric (4.36), chilli (2.98) and brinjal (2.05). Per cent soil moisture and larval depth ranged from 20.35 to22.55 and 8.42 to 26.95 cm, respectively (Table 31).

July 2011-12

Irrespective of soil type, there was increase in grub number during this period that ranged from 0.50 (soybean) to 12.40 (sugarcane). However, paddy recorded 6.16 grubs followed by capsicum (3.89), groundnut (3.71), maize and turmeric (3.50), chilli (3.17) and brinjal (2.33). Per cent soil moisture and larval depth ranged from 20.90 to 23.55 and 9.90 to 27.70 cm, respectively.

August 2011-12

As compared to July there was decline in larval count in different crops. Soybean recording least of 0.22 while sugarcane had highest of 10.46. Soil moisture per cent varied from 20.60 to 23.70 and the soil depth ranged between 10.70 to 29.80 cm, respectively.

September 2011-12

Irrespective of the crop there was decline in larval population during September. Neverthless soybean recorded lowest of 0.10 and sugarcane recorded maximum of 7.06. Soil moisture ranged from 19.05 to 22.88 and larval depth availability ranged from 11.15 to 28.50 cm.

Grub load of *Holotrichia serrata* in *rabi* crops

October 2011

Among the *rabi* crops, wheat recorded higher number of grub load (3.33) followed by bengalgram (3.30) and sorghum (2.60). Soil moisture per cent varied from 17.80 to 19.00 and soil depth ranged from 9.60 to 10.10 cm, respectively (Table 32).

November 2011

In November, wheat recorded higher number of grub load (2.62) followed by bengalgram (1.37) and sorghum (1.14). Soil moisture per cent varied from 17.40 to 18.50 and soil depth ranged from 10.20 to 10.90 cm, respectively.

October 2012

Among the *rabi* crops, wheat recorded higher number of grub load (4.66) followed by bengalgram (3.37) and sorghum (3.12). Soil moisture per cent varied from 18.20 to 18.80 and soil depth ranged from 9.70 to 10.60 cm, respectively.

November 2012

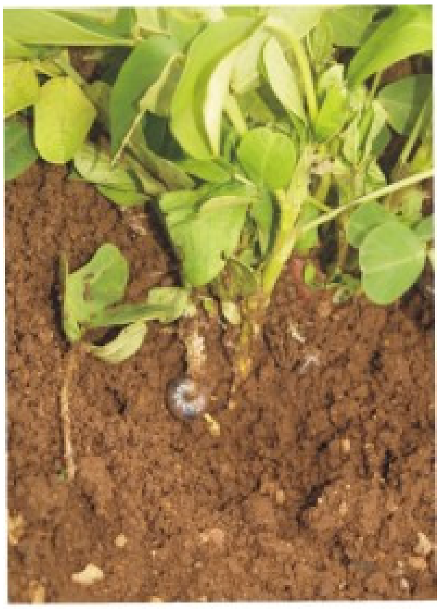
Among the *rabi* crops, wheat recorded higher number of grub load (3.60) followed by bengalgram (1.20) and sorghum (1.10). Soil moisture per cent varied from 16.40 to 16.90 and soil depth ranged from 10.00 to 11.10 cm, respectively.

Table 32: Mean grub load of *Holotrichia serrata* in different *Rabi* crops

Sl. No.	Crops	Soil type	October			November		
	2011		No./m^2	Soil moisture (%)	Soil depth (cm)	No./m^2	Soil moisture (%)	Soil depth (cm)
1	Wheat	Black	3.33	19.00	9.80	2.62	18.50	10.70
2	Jowar	Black	2.60	18.00	10.10	1.14	17.40	10.90
3	Bengal gram	Black	3.30	17.80	9.60	1.37	17.40	10.20
	2012							
1	Wheat	Black	4.66	18.80	9.60	3.60	16.90	10.90
2	Jowar	Black	3.12	18.40	10.60	1.10	16.70	11.10
3	Bengal gram	Black	3.37	18.20	9.70	1.20	16.40	10.00
	Pooled							
1	Wheat	Black	3.99	18.90	9.70	3.11	17.70	10.80
2	Jowar	Black	2.86	18.20	10.35	1.12	17.05	11.00
3	Bengal gram	Black	3.33	18.00	9.65	1.28	16.9	10.10

Brinjal

Soybean



Groundnut

Turmeric

Plate 12: Infestation of *Holotrichia serrata* in brinjal, soybean, groundnut and turmeric crops

Paddy

Sorghum

Sugarcane

Chilli

Plate 13: Infestation of *Holotrichia serrata* in paddy, sorghum, sugarcane and chilli

Pooled

October

Among the *rabi* crops, wheat recorded higher number of 3.99 followed by bengalgram (3.33) and sorghum (2.86). Soil moisture per cent varied from 18.00 to 18.90 and soil depth ranged from 9.65 to 10.35 cm respectively (Table 32).

November

Inspite of decline in per cent soil moisture there was increase in larval number in all the three crops as compared to October Wheat recorded 3.11, Bengal gram recorded 1.28 while sorghum recorded 1.12. Soil depth varied between 10.12 to 11.00 cm.

4.3.3.2 Larval availability at different depths in soils of different crops

During June 2011, the depth of the larval availability near root zones of different crops varied between 8.50 to 27.60 cm, whereasin subsequent months, *i.e.,* July to September depth ranged from 9.80 to 29.10 cm (July), 10.60 to 30.10 cm (August) and 11.20 to 27.20 (September). During *rabi* season (October and November) the larval available depth ranged from 9.60 to 10.10 cm and 11.30 to 12.00 cm, respectively.

Irrespective of the soil type grub load recorded in different *kharif* crops indicated higher number of grubs in sugarcane followed by paddy, turmeric and maize. Soil moisture per cent during June to September varied from 19.50 to 23.70 and soil depth ranged from 8.42 to 29.80 cm in different crops.

However, in *rabi* crops wheat recorded highest number of grubs followed by Bengal gram and Sorghum. Per cent soil moisture during this period ranged from 16.40 to 19.00 and depth of larval availability ranged from 9.60 to 11.10 cm. With the depletion of soil moisture the root penetration of various crops increased and depth of larval availability also increased.

4.4 Loss estimation in sugarcane due to *Holotrichia serrata* and per cent infestation in other crops

Five different cane varieties were evaluated for their reaction to *H. serrata* both under protected (application of *M. anisopliae*) and unprotected conditions for various parameters. The results are presented in Table 33-35.

4.4.1 Grub load

2011

Under unprotected and protected plots grub load recorded in different varieties was CoM 265 (11.89 and 0.67), CoC-671 (11.81 and 0.57), Co 8011 (11.76 and 0.65), CoSnk 632 (10.79 and 0.63) and Co 86032 (10.74 and 0.62), indicated significant differences.

2012

Under unprotected and protected plots grub load recorded in different varieties was CoM 265 (9.97 and 0.50), CoC 671 (11.59 and 0.35), Co 8011 (14.40 and 0.64), CoSnk 632 (10.54 and 0.78) and Co 86032 (13.50 and 0.64) respectively. Pooled under natural and protected plots grub load recorded in different varieties was CoM 265 (10.93 and 0.50), CoC 671 (11.70 and 0.46), Co 8011 (13.08 and 0.65), CoSnk 632 (10.67 and 0.71) and Co 86032 (12.12 and 0.63), indicated considerable differences.

4.4.2 Number of roots per clump at 240 days after planting

2011

The number of roots recorded at 240 DAP in unprotected plots ranged from 63.48 to 147.28. CoM 265 recorded significantly higher number of roots compared to other varieties. However, in protected plots, the root number ranged from 97.50 to 177.25, varieties *viz.,* CoC 671 (96.43), Co 8011 (103.99), Co 86032 (167.79) recorded significantly lower number of roots as compared to CoM 265 and CoSnk 632 which recorded significantly higher number of roots of 174.79 and 167.79, respectively.

Table 33: Varietal reaction and loss estimation of yield and yield related parameters due to *Holotrichia serrata* infestation (2011)

Sl. No	Varieties	Grub load per m^2		No. of roots		Av. Root length (cm)		Av. Root biomass per clump		Av. Single cane weight (kg)		Av. Cane height (m)		Av. Cane girth (cm)		% Pol		% Brix		NMC (000/ha)		Yield (t/ha)	
		UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P
1	CoC 671	11.81	0.57	63.48	97.50	14.89	19.45	0.78	1.50	0.78	1.84	1.82	1.84	2.40	2.89	16.83	18.80	19.15	22.68	41.00	77.60	35.65	124.89
2	Co 86032	10.74	0.62	88.98	112.25	13.77	19.65	0.85	1.64	0.75	1.06	2.32	1.06	1.84	2.51	16.67	17.70	19.05	21.12	42.89	86.51	28.39	88.83
3	Co Snk 03 632	10.79	0.63	138.38	175.75	17.62	21.53	1.85	3.05	1.83	2.56	2.66	2.56	2.47	2.70	17.37	17.62	18.47	21.23	51.86	71.54	88.31	184.36
4	CoM 265	11.89	0.67	147.28	177.25	19.20	24.45	2.61	3.37	2.48	2.83	2.71	2.83	2.59	2.79	15.79	18.65	18.12	20.76	48.95	73.83	117.65	242.50
5	Co 8011	11.76	0.65	69.63	105.25	18.52	20.15	2.39	1.72	0.79	1.60	1.96	1.60	2.18	2.74	15.52	17.70	17.97	21.73	42.14	74.78	33.94	93.18
	SEm. ±	0.14	0.04	0.73	1.19	0.48	0.61	0.07	0.07	0.10	0.07	0.08	0.07	0.13	0.10	0.30	0.47	0.45	0.72	1.78	0.31	0.63	11.26
	C.D. at (5%)	0.42	0.14	2.25	3.67	1.49	1.89	0.23	0.22	0.29	0.22	0.25	0.22	0.40	0.29	0.92	1.03	1.40	2.20	5.48	0.95	1.93	34.68
	CV (%)	2.40	13.97	1.44	1.78	5.78	5.82	10.54	6.41	14.37	7.31	6.96	7.31	11.25	7.02	3.59	3.74	4.90	6.58	7.84	6.81	2.06	15.34

P = Protected with *Metarhizium anisopliae*, UP = Un protected NMC = Number of Millable canes

Table 34: Varietal reaction and loss estimation of yield and yield related parameters due to *Holotrichia serrata* infestation (2012)

Sl. No.	Varieties	Grub load per m^2		No. of roots		Root length (cm)		Root biomass per clump		Single cane weight (kg)		Cane height (m)		Cane girth (cm)		% Pol		% Brix		NMC (000/ha)		Yield (t/ha)	
		UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P
1	CoC 671	11.59	0.35	61.00	95.36	13.18	19.62	0.74	1.29	0.84	1.61	1.62	1.55	2.05	2.81	16.12	18.67	19.84	21.62	39.93	74.21	35.64	122.04
2	Co 86032	13.50	0.64	87.88	104.97	13.40	17.79	0.72	1.44	0.75	1.16	2.12	2.22	1.77	2.48	16.14	17.58	18.44	20.45	42.21	86.16	32.68	88.69
3	Co Snk 03 632	10.54	0.78	136.01	159.82	16.20	20.87	1.80	2.95	1.60	2.45	2.24	2.52	2.26	2.88	16.34	17.34	18.41	20.50	36.68	73.76	78.57	173.10
4	CoM 265	9.97	0.50	142.18	172.32	19.30	21.76	2.15	3.17	2.26	2.72	2.25	2.49	2.18	2.67	15.34	16.44	17.69	18.98	35.36	72.62	107.73	198.74
5	Co 8011	14.40	0.64	68.79	102.72	14.63	18.71	0.72	1.39	0.82	1.29	1.94	2.22	1.91	2.33	15.00	16.53	16.96	18.80	34.57	70.03	42.98	92.29
	SEm. ±	0.14	0.03	1.01	1.29	0.31	0.26	0.04	0.07	0.07	0.07	0.05	0.14	0.06	0.07	0.16	0.21	0.19	0.15	0.82	1.14	3.44	2.82
	C.D. at 5%	0.42	0.09	3.10	3.96	0.96	0.81	0.13	0.22	0.23	0.21	0.17	0.42	0.19	0.20	0.50	0.65	0.57	0.46	2.54	3.52	10.60	8.68
	CV (%)	2.26	10.14	2.03	2.03	4.06	2.67	6.74	6.86	11.69	7.57	5.39	12.38	6.04	4.97	2.07	2.43	2.04	1.48	4.36	3.03	11.56	4.17

P = Protected with *Metarhizium anisopliae*, UP = Unprotected NMC = Number of Millable canes

Table 35: Pooled data (2011-12) on varietal reaction and loss estimation of yield and yield related parameters due to *Holotrichia serrata* infestation

Sl. No.	Varieties	Grub load per m^2		No. of roots		Root length (cm)		Root biomass per clump		Single cane weight (kg)		Cane height (m)		Cane girth (cm)		% Pol		% Brix		NMC (000/ha)		Yield (t/ha)	
		UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P	UP	P
1	CoC 671	11.70	0.46	62.24	96.43	14.04	19.54	0.76	1.40	0.81	1.73	1.72	1.70	2.23	2.85	16.48	18.74	19.50	22.15	40.47	75.91	32.78	130.94
2	Co 86032	12.12	0.63	88.43	108.61	13.59	18.72	0.79	1.54	0.75	1.11	2.22	1.64	1.81	2.50	16.41	17.64	18.75	20.79	42.55	86.34	31.91	95.83
3	Co Snk 03 632	10.67	0.71	137.20	167.79	16.91	21.20	1.83	3.00	1.72	2.51	2.45	2.54	2.37	2.79	16.86	17.48	18.44	20.87	44.27	72.65	75.92	181.99
4	CoM 265	10.93	0.59	144.73	174.79	19.25	23.11	2.38	3.27	2.37	2.78	2.48	2.66	2.39	2.73	15.57	17.55	17.91	19.87	42.16	73.23	99.91	203.20
5	Co 8011	13.08	0.65	69.21	103.99	16.58	19.43	1.56	1.56	0.81	1.45	1.95	1.91	2.05	2.54	15.26	17.12	17.47	20.27	38.36	72.41	30.88	104.63
	SEm. ±	0.07	0.03	1.01	1.29	0.31	0.26	0.04	0.07	0.07	0.07	0.05	0.14	0.06	0.07	0.16	0.21	0.19	0.15	0.82	1.14	3.44	2.82
	C.D. at 5%	0.23	0.09	3.10	3.96	0.96	0.81	0.13	0.22	0.23	0.21	0.17	0.42	0.19	0.20	0.50	0.65	0.57	0.46	2.54	3.52	10.60	8.68
	CV (%)	11.69	10.14	2.03	2.03	4.06	2.67	6.74	6.86	11.69	7.57	5.39	12.38	6.04	4.97	2.07	2.43	2.04	1.48	4.36	3.03	11.56	4.17

P = Protected with *Metarhizium anisopliae*, UP = Unprotected NMC = Number of Millable canes

Plate 14: Reaction of different varieties (120 days old) to *Holotrichia serrata* infestation

2012

The number of roots at 240 DAP in unprotected plots ranged from 61.00 to 142.18. However, CoM 265 was significantly superior to other varieties by recording highest number of roots, followed by CoSnk 632 with 136.01 roots. The number of roots in protected plots ranged from 95.36 to 172.32. Pooled data indicated that two varieties viz.,CoM 265 and CoSnk 632 were significantly superior over remaining varieties by recording 144.73 and137.20 roots per clump in unprotected plots, respectively. In protected plots number of roots recorded were 144.73 to 174.79 and 137.20 to 167.39 incase of CoM 265 and CoSnk 632, respectively.

4.4.3 Average root length

2011

Root length in unprotected plots ranged from 13.77 to 19.20 cm. In protected plots CoM 265 was significantly superior over rest of the varieties with root length of 24.45 cm (Plate 14).

2012

Root length recorded in unprotected plots ranged from 13.18 to 19.30 cm as against 17.79 to 21.76 cm in protected plots. Irrespective of varieties, protected plots registered increased root length. However, CoM 265 could record maximum root length of 21.76 cm. Pooled root length recorded in unprotected plots ranged from 13.59 to 19.25 cm. The two varieties *viz.,* CoM 265 and CoSnk 03632 were significantly superior to the remaining varieties. In protected plots, CoM 265 and CoSnk 03632 recorded significantly superior root length of 23.11 and 21.20 cm, respectively over rest of the varieties.

CoM 265 and CoSnk 03632 were found significantly superior over remaining varieties in both unprotected and protected plots. However,protected plots produced minimum damage in all the varieties and less damage was recorded even in unprotected plots in case of CoM 265 and CoSnk 03632.

4.4.4 Average root biomss (dry matter)

2011

The direct effect of root biomass (dry matter) revealed a positive effect on grub attack and cane yield. Results indicated that in unprotected plots, root biomass ranged from 0.78 to 2.61 kg. Both CoM 265 and CoSnk 03632 were significantly superior over remaining varieties but were at par with each other. Similar trend was observed in protected plots and root biomass ranged from 1.50 to 3.37 kg. CoM 265 with 3.37 kg was significantly superior to remaining varieties with respect to biomass.

2012

Results pertaining to dry matter weight ranged from 0.72 to 2.15 kg in unprotected plots. CoM 265 recorded 2.15 kg and significantly superior over rest of the varieties. However, CoSnk 03632 was the next best with 1.80 kg, but in protected plots both CoM 265 and CoSnk 03632 recorded significantly higher root dry matter of 3.17 and 2.95, respectively. Other varieties *viz.,* CoC 671, Co 86032 and Co 8011 recorded 1.29, 1.44 and 1.39 kg of dry matter, respectively. Pooled higher root biomass / dry matter was recorded in both CoM 265 and CoSnk 03632 varieties and were significantly superior over remaining varieties by recording 2.38, 1.83 and 3.27, 3.00 g in both unprotected and protected plots, respectively.

4.4.5 Single cane weight (SCW)

2011

This parameter exhibited a wide range in unprotected plots ranging from 0.78 to 2.48 kg. CoM 265 recorded higher cane weight (2.48 kg) and significantly superior over remaining varieties. The trend observed in protected plots indicated similar pattern as that of unprotected and ranged from 1.06 (Co 86032) to 2.83 kg (CoM 265).

2012

CoM 265 was significantly superior over remaining varieties by recording 2.26 and 2.72 kg cane weight in unprotected and protected plots, respectively. The next best was CoSnk 03632 with 1.60 and 2.45 kg in unprotected and protected plots, respectively. Pooled results pertaining to single cane weight in unprotected plots ranged from 0.75 to 2.37 kg and higher cane weight was recorded in

CoM 265 (2.37 kg) and CoSnk 03632 (1.72 kg) and were significantly superior over rest of the varieties. Similar trend was observed in protected plots and the weight ranged from 1.11 to 2.78 kg. CoM 265 and CoSnk 03632 were significantly superior by recording 2.78 and 2.51 kg, respectively.

4.4.6 Average cane height (m)

2011

The millable cane height of different varieties under study in unprotected plots ranged between 1.82 to 2.71 m. CoM 265 (2.71 m) and CoSnk 03632 (2.66 m) were significantly superior over remaining genotypes. However, in protected plots this parameter ranged from 1.06 to 2.83 m and CoM 265 (2.83 m) was significantly superior over rest of the varieties.

2012

The cane height of five varieties in unprotected plots ranged from 1.62 to 2.25 m. CoM 265 was significantly superior over remaining varieties. However, in protected plots all the varieties except CoC 671 were significantly superior with respect to cane height. Results of pooled data revealed that average cane height ranged from 1.72 to 2.48 in unprotected plots. Three varieties *viz.,* Co 86032, CoSnk 03632 and CoM 265 were significantly superior over remaining varieties. However, in protected plots CoM 265 (2.66 m) and CoSnk 03632 (2.54 m) were significantly superior over rest of the varieties.

4.4.7 Average cane girth (cm)

2011

Cane girth recorded ranged from 1.84 to 2.59 cm in unprotected plots and three varieties *viz.,* CoC 671 (2.40 cm) (Plate 15), CoSnk 03632 (2.47 cm) and CoM 265 (2.59) were significantly superior as compared to Co 86032 (1.84 cm) and Co 8011 (2.18 cm), whereas in protected plots except Co 86032, other four varieties were significantly superior and were on par with one another.

2012

Results pertaining to this trait in unprotected plots ranged from 1.77 to 2.26 cm and the varieties *viz.,* CoM 265 (2.18 cm) and CoSnk 03632 (2.26 cm) recorded significantly superior cane girth over rest of the treatments. However, in protected plots, it ranged from 2.33 to 2.88 cm. CoSnk 03632, CoC 671 and CoM 265 were significantly superior recording 2.88, 2.81 and 2.65 cm, respectively over rest of the varieties. Pooled CoC 671 was significantly superior by recording 2.39 cm girth in unprotected plots followed by CoSnk 03632 (2.37 cm). However, CoC 671, CoSnk 632 and CoM 265 with cane girth of 2.85, 2.79 and 2.73 cm, respectively were significantly superior over other treatments in protected plots.

4.4.8 Per cent purity

2011

In unprotected plots purity ranged from 15.52 to 17.37 per cent. Three varieties *viz.,* CoC 671 (16.83%), Co 86032 (16.67%) and CoSnk 03632 (17.32%) recorded significantly more purity but were on par with one another. In protected plots, similar trend of treatment significance was observed with all the varieties.

2012

Per cent purity in unprotected plots ranged from 15.00 to 16.34 CoC 671, Co 86032 and CoSnk 632 were significantly superior over Co 265 and CO 8011. However, in *M. anisopliae* applied plots CoC 671 with 18.67 per cent purity was significantly superior over rest of the varieties. Pooled CoC 671 was significantly superior over remaining varieties in protected plots by recording 18.74 per cent, followed by Co 86032 (17.64 per cent).

4.4.9 Per cent brix

2011

Per cent brix ranged from 17.97 to 19.15 per cent in unprotected plots. The variety CoC 671 recorded highest per cent brix (19.15) followed by Co 86032 (19.05), CoSnk 03632 (18.47), CoM 265 (18.12%) and lower per cent brix was recorded in the variety Co 8011 (17.97).

Plate 15: Cane girth in unprotected and protected plots of CoC671

However, in protected plots per cent, brix ranged from 20.76 to 22.68 per cent. CoC 671 recorded highest per cent brix (22.68) followed by Co 8011 (21.73), CoSnk 632 (21.23), Co 86032 (21.12) and CoM 265 (20.76)

2012

This parameter ranged from 16.96 to 19.84 per cent, the highest being in CoC 671 with 19.84% in unprotected plots. Co 86032, CoSnk 03632 and CoM 265 were significantly superior over Co 8011. In protected plots, CoC 671 was significantly superior over rest of the varieties by recording 21.62 per cent brix. Co 86032 and CoSnk 03632 were the next best varieties with 20.45 and 20.50 per cent brix and significantly superior over CoM 265 and Co 8011. Pooled results pertaining to this trait ranged from 17.47 to 19.50 in unprotected plots as against 19.87 to 22.15 in protected plots. Among the five varieties tested, CoC 671 was significantly superior over remaining four varieties in both unprotected and protected plots by recording 19.50 and 22.15 per cent brix values. However, other two varieties *viz.,* Co 86032 and CoSnk 03632 were the next best treatments with respect to brix per cent. CoM 265 and Co 8011 were significantly inferior as compared to CoC 671, Co 86032 and CoSnk 03632.

4.4.10 Number of millable canes (000/ha)

2011

Results indicated that the varieties CoM 265 and CoSnk 03632 were significantly superior over remaining varieties in unprotected plots and ranged from 41.00 to 51.86. In protected plots, highest number of millable canes (86.51) was observed in Co 86032 and this was significantly superior over remaining varieties.

2012

Similar to 2011, Co 86032 was significantly superior recording 87.00 NMC's followed by CoC 671 (74.21), CoSnk 632 (73.76) and CoM 265 (72.62). Pooled data revealed that variety CoSnk 632 was superior over remaining varieties in unprotected plots by recording 44.27 NMC's, whereas in protected plots Co 86032 was significantly superior over rest of the treatments with NMC's of 86.34 per ha.

4.4.11 Yield (t/ha)

2011

Cane yield in unprotected plots ranged from 28.39 (CoC 671) to 117.65 t/ha (CoM 265). Similar trend was observed in protected plots. CoM 265 recorded significantly higher cane yield of 242.50 t/ha. CoSnk 03632 was the next best with cane yield of 184.36 t/ha.

2012

Similar to 2011, CoM 265 recorded higher cane yield of 107.73 and 198.74 t/ha in unprotected and protected plots and was significantly superior over rest of the varieties. CoSnk 03632 was the next best variety with 78.57 and 173.10 t/ha cane yield and significantly superior over CoC 671 (35.64 and 122.04 t/ha), Co 8011 (42.98 and 92.29 t/ha) and Co 86032 (32.68 and 88.69 t/ha). Pooled data indicated that irrespective of protection CoM 265 could tolerate white grub damage and was significantly superior over all other varieties. The next best was CoSnk 03632 with 75.92 t/ha cane yield even without protection. However, in protected plots the yield recorded ranged from 99.91 to 203.20 and from 75.92 to 181.99 t/ha in case of CoM 265 and CoSnk 632 respectively. Investigation carried out over two years (2011 & 2012) on varietal reaction to white grub attack and loss estimation in sugarcane revealed that CoM 265 and CoSnk 632 were tolerant to white grub attack. Irrespective of the varieties grub population drastically reduced in protected plots leading to higher yield as compared to unprotected plots.

4.4.12 Per cent infestation of *Holotrichia serrata* in different crops

Kharif 2011

Second instar grub population recorded during *kharif* season varied from lowest of 0.66 in soybean to highest of 22.40 in sugarcane followed by paddy (6.33), maize and turmeric (3.66), respectively (Table 36). Per cent infestation in different crops ranged from a minimum of 4.30 in soybean to highest of 38.00 in sugarcane, which was followed by paddy (21.00%), capsicum (20.00%), chilli and turmeric (18.50%) and maize (16.5%).

Table 36: Per cent infestation of *Holotrichia serrata* in different crops

Sl. No.	Crops	Grub load m^2			Percent infestation (%)		
		2011	2012	Pooled	2011	2012	Pooled
Kharif							
1	Ground nut	2.33	2.60	2.47	6.00	7.50	6.75
2	Soybean	0.66	0.33	0.50	4.30	1.50	2.90
3	Chilly	3.33	3.00	3.17	18.50	20.00	19.25
4	Capsicum	4.00	3.66	3.83	20.00	27.50	23.75
5	Paddy	6.33	6.00	6.17	21.00	30.50	25.75
6	Maize	3.66	4.00	3.83	16.50	15.00	15.75
7	Brinjal	2.66	2.00	2.33	5.00	7.00	6.00
8	Cabbage	2.33	1.33	1.83	8.50	9.10	8.80
9	Turmeric	3.66	2.66	3.16	18.50	15.00	16.75
10	Sugarcane	22.40	20.50	21.45	38.00	43.00	40.50
Rabi							
11	Jowar	6.66	12.60	9.63	16.30	19.00	17.65
12	Wheat	7.00	16.60	11.80	19.00	31.00	25.00
13	Bengal Gram	6.30	11.60	8.95	28.50	30.50	29.50

Table 37: Laboratory evaluation of entomopathogens against second instar sugarcane white grub*, Holotrichia serrata*

Sl. No.	Treatments	Per cent mortality				
		7DAT	14 DAT	28 DAT	45 DAT	60 DAT
		2010-11	2010-11	2010-11	2010-11	2010-11
1	*Metarhizium anisopliae* with $4x10^8$ conidia/g	0 b (0)	0 c (0)	19.66 bc (26.31)	38.73 bc (38.47)	46.65 bc (43.06)
2	*M. anisopliae* with $2x10^8$ conidia/g	0 b (0)	0 c (0)	16.81 c (23.51)	28.74 de (32.41)	38.66 cd (39.42)
3	*B. bassiana* with $4x10^8$ conidia/g	0 b (0)	0 c (0)	17.61 c (24.26)	34.73 cd (35.79)	41.64 c (39.80)
4	*B. bassiana* with $2x10^8$ conidia/g	0 b (0)	0 c (0)	15.70 c (23.12)	24.63 e (28.67)	33.33 d (35.24)
5	*M. anisopliae* $2x\ 10^8$ + *B. bassiana* with $2x10^8$ conidia/g	0 b (0)	0 c (0)	17.27 c (24.86)	30.33 d (34.26)	39.88 cd (39.16)
6	*M. anisopliae* $4\ x\ 10^8$ + *B. bassiana* with $4x10^8$ conidia/g	0 b (0)	0 c (0)	23.20 b (28.78)	41.81 b (40.27)	51.40 b (45.78)
7	Neem cake @ 500 k g/ha	0 (0)	7.86 b (16.06)	10.66 d (19.05)	11.22 f (19.56)	14.22 e (22.14)
8	Chlorpyriphos 20 EC @ 10 ml/l	61.90 a (51.86)	76.10 a (60.71)	83.71 a (79.36)	83.71 a (79.36)	83.71 a (79.36)
9	UTC	0 b (0)	0 c (0)	0 e (0)	0 f (0)	0 f (0)
	SEm. ±	0.19	0.28	0.79	0.98	1.06
	C.D. at 1%	0.62	1.01	3.25	4.03	4.37
	C.V. (%)	5.21	5.07	5.25	5.29	5.33

*Figures in parentheses are arc sine values; means showing similar alphabets do not differ significantly by DMRT
*DAT-Days After Treatment
*15 second instar grubs/treatment (pre count)

Plate 16: ***M. anisopliae*** **infected** ***H. serrata*** **grub (early symptom)**

Plate 17: ***M. anisopliae*** **infected** ***H. serrata*** **grub (late symptom)**

Plate 18: B. Bassiana infected ***H. serrata*** **grub**

Table 38: Field evaluation of entomopathogens against white grub *Holotrichia serrata*

Sl. No.	Treatments	Mean grub load per m^2															
		Pre count		Post count													
				7DAT		14 DAT		28 DAT		45 DAT		60 DAT		NMC (000/ha)		Cane yield/(mt/ha)	
		2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
1	*Metarhizium anisopliae* @ 25 k g/ha along with 125 kg FYM	12.64a (3.69)	13.32a (3.78)	11.86a (3.59)	12.97a (3.74)	9.24 a (3.20)	9.40 bc (3.37)	5.50 bc (2.66)	5.54 bc (2.67)	3.06 cd (2.01)	3.10 cd (2.02)	2.21 cd (1.79)	2.26 de (1.81)	70.15abc	69.86abc	89.73ab	85.62abc
2	*Beauveria bassiana* @ 25 k g/ha along with 125 kg FYM	12.89a (3.73)	13.61a (3.82)	12.06a (3.61)	13.13a (3.76)	9.32 a (3.30)	9.50 bc (3.33)	5.58 bc (2.94)	5.61 abc (3.01)	3.41 bc (2.26)	3.28 cd (2.29)	3.16 bc (2.04)	2.56 cd (2.06)	68.81abc	67.23abcd	86.91bc	82.74bc
3	*Metarhizium anisopliae* @ 12.5 k g/ha along with 62.5 kg FYM	12.12a (3.62)	13.83a (3.85)	12.14a (3.62)	13.66a (3.83)	10.89a (3.45)	11.26bc (3.50)	8.13 abc (3.02)	8.96 abc (3.16)	5.12 bc (2.47)	5.23 bcd (2.50)	4.17 bc (2.27)	4.21 cd (2.28)	67.20bc	65.86bcd	80.32d	79.16c
4	*Beauveria bassiana* @ 12.5 k g/ha along with 62.5 kg FYM	12.19a (3.63)	14.05a (3.88)	11.96a (3.60)	13.12a (3.76)	10.92a (3.45)	12.14 a (6.62)	8.85abc (3.14)	8.92 abc (3.15)	5.96 bc (2.64)	5.98 bc (2.64)	5.23 b (2.50)	5.27 bc (2.50)	64.72c	62.85d	78.66d	79.64c
5	*Metarhizium anisopliae* @ 12.5 k g/ha along with 62.5 kg FYM + *Beauveria bassiana* @ 12.5 k g/ha along with 62.5 kg FYM	12.11a (3.62)	13.54a (3.81)	11.87a (3.59)	13.23a (3.77)	10.55a (3.40)	12.05bc (3.61)	7.87 bc (2.98)	7.85 abc (2.97)	5.10 bc (2.47)	5.07 bcd (2.46)	4.00 bc (2.24)	4.09 cd (2.26)	66.16bc	64.12cd	83.12cd	82.87bc
6	*Metarhizium anisopliae* @ 25 k g/ha along with 125 kg FYM + *Beauveria bassiana* @ 25 k g/ha along with 125 kg FYM	13.12a (3.76)	13.17a (3.76)	12.42a (3.66)	12.67a (3.70)	8.74 a (3.12)	8.93 c (3.15)	4.83 cd (2.41)	4.87 cd (2.42)	2.67 cd (1.92)	2.72 de (1.93)	1.96 cd (1.72)	1.99 de (1.73)	72.42ab	71.81ab	91.30ab	87.94ab
7	Neem cake 500 k g/ha	12.33a (3.65)	13.10a (3.75)	11.88a (3.59)	12.66a (3.70)	11.00a (3.46)	12.10 b (3.82)	9.55 ab (3.25)	10.05 ab (3.32)	7.99 ab (3.00)	8.21 b (3.03)	6.10 b (2.66)	7.33 b (2.89)	53.60d	52.90e	64.50e	63.80d
8	Chloropyriphos 10000 mlha	12.24a (3.64)	13.11a (3.76)	6.13 b (2.67)	6.32 b (2.71)	3.12 b (2.03)	3.14 d (2.03)	2.16 d (1.78)	2.11 d (1.76)	0.91 d (1.38)	0.87 e (1.37)	0.57 d (1.25)	0.62 e (1.27)	75.72a	73.33a	95.66a	91.24a
9	UTC	12.66a (3.70)	13.45a (3.80)	12.58a (3.69)	13.22a (3.77)	12.12a (3.62)	12.41bc (3.66)	13.12 a (3.76)	13.23 a (3.77)	12.05 a (3.61)	12.46 a (3.67)	12.32 a (3.65)	12.38 a (3.66)	37.81e	32.46f	39.62f	36.46e
	SEm.±	0.25	0.25	0.25	0.25	0.19	0.19	0.25	0.25	0.25	0.19	0.19	0.19	2.25	2.03	2.01	2.38
	C.D. (5%)	NS	NS	0.76	0.75	0.58	0.57	0.76	0.75	0.75	0.58	0.58	0.58	6.74	6.08	6.02	7.13
	CV (%)	12.01	14.16	13.67	15.30	13.79	14.91	11.60	12.12	13.28	11.44	13.69	14.67	6.21	5.74	4.70	5.66

Figures in parentheses are √x+1 transformed values, means showing similar alphabets do not differ significantly by DMRT
DAT-Days After Treatment, NMC = Number of Millable Canes, UTC = Untreated check

Table 39: Pooled data (2011-12) on field evaluation of entomopathogens against white grub *Holotrichia serrata*

Sl. No.	Treatments	Mean grub load per m^2							
		Pre count	Post count						
			7DAT	14 DAT	28 DAT	45 DAT	60 DAT	NMC (000/ha)	Cane yield/(mt/ha)
1	*Metarhizium anisopliae* @ 25 k g/ha along with 125 kg FYM	12.98 (3.74)	12.42 a (3.60)	9.80 ab (3.29)	6.08 cd (2.66)	3.08 d (2.02)	2.24 de (1.80)	70.01	87.68
2	*Beauveria bassiana* @ 25 k g/ha along with 125 kg FYM	13.25 (3.77)	12.60 a (3.69)	9.99 ab (3.32)	7.86 bc (2.98)	4.18 cd (2.27)	3.19 cd (2.05)	68.37	84.83
3	*Metarhizium anisopliae* @ 12.5 k g/ha along with 62.5 kg FYM	12.98 (3.74)	12.90 a (3.73)	11.08 ab (3.47)	8.55 bc (3.09)	6.18 bcd (2.48)	4.19 bcd (2.28)	66.53	79.74
4	*Beauveria bassiana* @ 12.5 k g/ha along with 62.5 kg FYM	13.12 (3.76)	12.54 a (3.68)	11.53 ab (3.54)	8.89 bc (3.14)	6.97 bc (2.64)	5.25 bc (2.50)	63.79	79.15
5	*Metarhizium anisopliae* @ 12.5 k g/ha along with 62.5 kg FYM + *Beauveria bassiana* @ 12.5 k g/ha along with 62.5 kg FYM	12.83 (3.72)	12.55 a (3.68)	11.30 ab (3.51)	7.86 bc (2.98)	6.14bcd (2.47)	5.07 de (2.25)	65.14	77.50
6	*Metarhizium anisopliae* @ 25 k g/ha along with 125 kg FYM + *Beauveria bassiana* @ 25 k g/ha along with 125 kg FYM	13.15 (3.76)	12.55 a (3.68)	8.84 b (3.14)	4.85d (2.42)	2.70 de (1.92)	1.98 b (1.72)	72.12	89.62
7	Neem cake 500 k g/ha	12.72 (3.70)	12.27 b (2.64)	11.55 ab (3.54)	9.80 ab (3.29)	8.10 d (3.02)	6.72 b (2.78)	53.25	64.15
8	Chloropyriphos 10000 mlha	12.68 (3.70)	6.23 b (2.69)	3.13 c (2.03)	2.14 e (1.77)	0.89 e (1.37)	0.60 e (1.26)	74.53	93.45
9	UTC	13.06 (3.75)	12.90 a (3.73)	12.27 a (3.76)	13.18 a (3.76)	12.26 a (3.64)	12.35 a (3.65)	35.14	38.04
	SEm.±	0.25	0.26	0.19	0.20	0.19	0.19	2.14	2.19
	C.D. (5%)	NS	0.76	0.79	0.78	0.79	0.79	5.97	5.18
	CV (%)	11.80	12.33	10.14	11.50	13.74	14.79	6.41	6.57

Figures in parentheses are √x+1 transformed values, means showing similar alphabets do not differ significantly by DMRT
DAT-Days After Treatment, NMC = Number of Millable Canes, UTC = Untreated check

Kharif 2012

During *kharif* 2012, the grub population ranged from a minimum of 0.33 in soybean to maximum of 20.50 in sugarcane. Pooled population ranged from 0.50 (soybean) to 21.45 (sugarcane) and per cent infestation varied from 2.90 (soybean) to 40.50 (sugarcane) (Plate 16). Paddy recorded 6.17 grub load followed by capsicum and maize (3.83) with 25.75, 23.75and 15.75 per cent infestation in case of paddy, capsicum and maize respectively.

Rabi 2011

Grub population ranged from 6.66 to 7.00 per cent. Higher number of grubs was recorded in wheat followed by sorghum and bengal gram, respectively. Per cent infestation ranged from 16.30 (sorghum) to 28.50 (bengal gram).

Rabi 2012

During 2012, higher grub population was recorded and ranged from 11.60 (Bengalgram) to 16.60 (wheat) resulting in higher per cent infestation in different crops *viz.,* wheat (31.00), bengalgram (30.50) and sorghum (19.00). Pooled data also revealed trend similar to 2011 and 2012 with respect to grub load and per cent infestation.

4.5 Efficacy of entomopathogens and newer molecules of insecticides against *Holotrichia serrata*

4.5.1 Laboratory evaluation of entomopathogens against second instar *Holotrichia serrata* grub

Results obtained in the laboratory on evaluation of fungal pathogens against *H. serrata* are presented below (Table 37).

Chlorpyriphos 20 EC effected significantly higher per cent mortality of 61.90 and superior over all other treatments at 7DAT. All other treatments failed to effect any mortality.

At 14 DAT, chlorpyriphos 20 EC recorded 76.10 per cent mortality and was significantly superior over remaining treatments. This was followed by neem cake with 7.86 mortality and both chlorpyriphos and neem cake were significantly superior to control and entomopathogen treatments.

At 28 DAT, chlorpyriphos 20 EC was most effective with 83.71 per cent mortality and significantly superior to all other treaments. Among the different entomopathogens, *M. anisypliae* + *B. bassiana* each @ 4 x 10^8 conidia/g of soil (T_6) recorded 23.20 per cent mortality, *M. anisopliae* @ 4 x 10^8 conidia/g of soil (T_1) recorded 19.66 per cent mortality and was found next best. *B. bassiana* at higher dosage of 4 × 10^8 conidia/g recorded 17.61 per cent mortality and was on par with *M. anisopliae* @ 4 × 10^8 conidia/g. Remaining treatments *viz., M. anisopliae* @ 2 × 10^8/g, *B. bassiana* @ 2 × 10^8 conidia/g and *M. anisopliae* @ 2 × 10^8 conidia/g + *B. bassiana* @ 2 × 10^8 conidia/g respectively were significantly superior over neem cake by recording 16.81, 15.70 and 17.27 per cent grub mortality. However, neem cake was significantly superior to control.

At 45 DAT, chlorpyriphos 20 EC recorded 83.71 per cent mortality and was significantly superior over rest of the treatments. Among the entomopathogens, *M. anisopliae* @ 4 × 10^8 conidia/g + *B. bassiana* @ 4 × 10^8 conidia/g and *M. anisopliae* @ 4 × 10^8 conidia/g (Plate 17) were significantly superior over remaining treatments by recording 41.81 and 38.73 per cent mortality. However, *B. bassiana* at dosage of 4 × 10^8 conidia/g was the next best treatment by recording 34.73 per cent mortality and was significantly superior over T_2, T_4, T_5, T_7 and T_9.

At 60 DAT results obtained were similar to 45 DAT. Among the entomopathogens T_6 was effective by recording 591.40 per cent grub mortality and was significantly superior to T_1, T_2, T_3, T_4 and T_5, T_7 and T_9, except with chlorpyriphos. However, T_1 was the next best treatment with 46.65 per cent mortality and was superior to T_2, T_3, T_4, T_5, T_6 and T_7.

4.5.2 Field evaluation of entomopathogens

Results on field evaluation of two entomopathogens *M. anisopliae* (Plate 18) and *B. bassiana* (Plate 19) and their combination during 2011 and 2012 are presented in Tables 38-39.

2011

At 7 DAT, chlorpyriphos 20 EC @ 10 ml per l was most effective with least (chlorpyriphos @ 10000 ml/ha (T_8), 6.13) number of grubs and was significantly superior over all other treatments.

At 14 DAT, chlorpyriphos @ 10000 ml/ha (T_8) maintained its supremacy by registering only 3.12 grubs and was significantly superior over rest of the treatments. However, full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) was the next best with 8.74 grubs compared to full dose of *M. anisopliae* (T_1) and full dose of *B. bassiana* (T_2) with 9.24 and 9.32 grubs respectively. Entomopathogens at lower dosages *viz.,* half dose of *M. anisopliae* (T_3), half dose of *B. bassiana* (T_4) and half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) were the next best treatments with grub load of 10.89, 10.92 and 10.55 respectively, but were on par with neem cake @ 500 kg/ha (T_7) that recorded 11 grubs.

At 28 DAT, chlorpyriphos @ 10000 ml/ha (T_8) recorded least grub load of 2.16 and was significantly superior over all other treatments. Among the entomopathogens full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) was superior by recording 4.83 grubs exercising similar effect with full dose of *M. anisopliae* (T_1) and full dose of *B. bassiana* (T_2) that registered 5.50 and 5.58 grubs. However, next best treatment was half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) and was superior to half dose of *M. anisopliae* (T_3), half dose of *B. bassiana* (T_4) and neem cake @ 500 kg/ha (T_7).

At 45 DAT, chlorpyriphos @ 10000 ml/ha (T_8) maintained its superiority with only 0.91 grubs and was significantly superior to all other treatments. Among the entomopathogens, full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) was promising by recording 2.67 grubs and was on par with both full dose of *M. anisopliae* (T_1) and full dose of *B. bassiana* (T_2) which recorded 3.06 and 3.41 grubs and were significantly superior to half dose of *M. anisopliae* (T_3), half dose of *B. bassiana* (T_4), half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) and neem cake @ 500 kg/ha (T_7). However, entomopathogens at lower dosages half dose of *M. anisopliae* (T_3), half dose of *B. bassiana* (T_4) and half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) recorded 5.12 to 5.96 and 5.10 grubs and were significantly superior over neem cake (7.99) and control (12.05).

At 60 DAT, chlorpyriphos @ 10000 ml/ha (T_8) was most effective with least grub count (0.57) and was significantly superior over all other treatments. Among the entomopathogens full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) was superior with grub count of 1.96, but on par with full dose of *M. anisopliae* (T_1) which recorded 2.21 grubs. However, full dose of *B. bassiana* (T_2) was the next best treatment recording 3.16 grubs and was significantly superior over half dose of *M. anisopliae* (T_3), half dose of *B. bassiana* (T_4), half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) and neem cake @ 500 kg/ha (T_7). Combination of *M. anisopliae* @ 12.50 kg/ha + *B. bassiana*@ 12.50 kg/ha, recorded modest number of grub count (4.00) and was at par with half dose of *M. anisopliae* (T_3) which recorded 4.17 grubs. half dose of *B. bassiana* (T_4) was inferior to other entomopathogen treatments but significantly superior over neem cake and control.

Number of millable canes

During 2011, higher number of millable canes 75.72 (000/ha) were recorded in chlorpyriphos @ 10000 ml/ha (T_8) and was on par with full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6), full dose of *M. anisopliae* (T_1) and full dose of *B. bassiana* (T_2) with 72.42 (000/ha), 70.15 (000/ha) and 68.81 (000/ha) NMC's respectively.

Cane yield (t/ha)

Though higher cane yield of 95.66 t/ha was recorded in chlorpyriphos @ 10000 ml/ha (T_8) it was on par with both full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) and full dose of *M. anisopliae* (T_1) with 91.30 and 89.73 t/ha and these were significantly superior over all other treatments.

However, entomopathogens at lower dosages *i.e.,* half dose of *M. anisopliae* (T_3) @ 12.5 kg per ha, half dose of *B. bassiana* (T_4) @ 12.5 kg per ha and half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) @ 12.5 kg per ha + *B. bassiana* @ 12.5 kg per ha along with 62.5 kgs of FYM recorded 80.32, 78.66 and 83.12 t/ha and were significantly superior to neem cake @ 500 kg/ha (T_7) *i.e.,* neem cake @ 500 kg per ha.

2012

At 7 DAT, chlorpyriphos @ 10000 ml/ha (chlorpyriphos @ 10000 ml/ha, T_8) was most effective with 6.32 grubs and was significantly superior to all other treatments.

Results at 14 DAT again revealed the supremacy of chlorpyriphos @ 10000 ml/ha (T_8) over all other treatments with least larval count of only 3.14. Among the entomopathogens full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) was effective by recording 8.93 larvae followed by full dose of *M. anisopliae* (T_1) and full dose of *B. bassiana* (T_2) which recorded 9.40, 9.50 larvae and all these treatments *viz.,* full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6), full dose of *M. anisopliae* (T_1) and full dose of *B. bassiana* (T_2) were significantly superior to half dose of *M. anisopliae* (T_3), half dose of *B. bassiana* (T_4), half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) and neem cake @ 500 kg/ha (T_7). Half dose of *M. anisopliae* (T_3) recorded 11.26 grubs and found superior to half dose of *B. bassiana* (T_4) and half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5).

Results at 28 DAT, 45 DAT and 60 DAT revealed the superiority of chlorpyriphos @ 10000 ml/ha (T_8) over all other treatments. However, full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) was the next best to T_8 with grub load of 4.87, 2.72 and 1.99 respectively and was superior to both neem cake @ 500 kg/ha (T_7) and full dose of *B. bassiana* (T_2).

At 60 DAT full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) was found effective by recording lower grub count of 1.99, followed by full dose of *M. anisopliae* (T_1) and full dose of *B. bassiana* (T_2) which recorded 2.26 and 2.56 larval count and exercised similar effect but significantly superior to half dose of *M. anisopliae* (T_3), half dose of *B. bassiana* (T_4), half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) and neem cake @ 500 kg/ha (T_7).

Number of millable canes (000/ha)

Similar to 2011 chlorpyriphos @ 10000 ml/ha (T_8) recorded highest NMC of 73.33 (000/ha) but was on par with full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6), full dose of *M. anisopliae* (T_1) and full dose of *B. bassiana* (T_2). However, full dose of *B. bassiana* (T_2) was superior by recording 67.23 (000/ha) of NMC's followed by half dose of *M. anisopliae* (T_3) that recorded 65.86 (000/ha) and half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) with NMC's of 64.12 (000/ha) respectively.

Cane yield

Higher cane yield of 91.24 t/ha was recorded with chlorpyriphos @ 10000 ml/ha (chlorpyriphos @ 10000 ml/ha, T_8) exercising similar effect with full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) and full dose of *M. anisopliae* (T_1) with cane yield of 87.94 and 85.62 t/ha respectively. This was followed by half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) (82.87 t/ha) and full dose of *B. bassiana* (T_2) (82.74 t/ha). However, half dose of *M. anisopliae* (T_3) and half dose of *B. bassiana* (T_4) were the next best treatments with cane yield of 79.16 and 79.64 t/ha and were at par with full dose of *M. anisopliae* (T_1), full dose of *B. bassiana* (T_2) and half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) but superior to neem cake @ 500 kg/ha (T_7).

Pooled

Pooled data indicated that at 7 DAT, chlorpyriphos @ 10000 ml/ha (T_8) recorded significant superiority over all other treatments with least larval count of 6.23. At 14 DAT, chlorpyriphos @ 10000 ml/ha (T_8) maintained its significant superiority over all other treatments with only 3.13 grubs. Among the entomopathogens full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) recorded 8.84 larval count and was significantly superior over all other treatments. However, full dose of *M. anisopliae* (T_1) and full dose of *B. bassiana* (T_2) recorded 9.80 and 9.99 grubs and were at par with each other. Higher grub number was recorded in control plot and the order of superiority with respect to larval number was $T_8 < T_6 < T_1 < T_2 < T_3 < T_5 < T_4 < T_7 < T_9$.

Observations at 28, 45 and 60 DAT recorded supremacy of chlorpyriphos @ 10000 ml/ha (T_8) over rest of the treatments with 2.14, 0.89 and 0.60 grub load, respectively. However, among the entomopathogens full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) was significantly superior over all other treatments with grub load of 4.85, 2.70 and 1.98, respectively. Full dose of *M. anisopliae* (T_1) recorded 6.08, 3.08 and 2.24 grubs at 28, 45 and 60 DAT and was significantly superior over rest of the treatments.

Number of millable canes (000/ha)

Higher number of NMC's (74.53) were recorded in chlorpyriphos @ 10000 ml/ha (T_8) and was on par with full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) (72.12) and full dose of *M. anisopliae* (T_1) (70.01). However, full dose of *B. bassiana* (T_2) (68.13), half dose of *M. anisopliae* (T_3) (66.53), half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) (65.14) and half dose of *B. bassiana* (T_4) (63.79) were the next best treatments with respect to NMC count.

Cane yield (t/ha)

Higher cane yield of 93.45 t/ha was recorded in chlorpyriphos @ 10000 ml/ha (T_8) and was on par with full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6). Full dose of *M. anisopliae* (T_1) and full dose of *B. bassiana* (T_2) were the next best treatments with 87.68 and 84.83 cane yield. half dose of *M. anisopliae* (T_3), half dose of *B. bassiana* (T_4) and half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) recorded 79.74, 79.15 and 77.50 t/ha and were significantly superior to neem cake @ 500 kg/ha (T_7) (64.15) and untreated control (T_9) (38.04) t/ha.

Field evaluation studies revealed significant superiority of chlorpyriphos @ 10000 ml/ha (T_8) at all the intervals of observation by recording least larval number effecting higher NMC and cane yield. Among the entomopathogen treatments full dose of *M. anisopliae* + full dose of *B. bassiana* (T_6) was the most effective recording minimum number of grubs at all the intervals of observations and resulted in at par cane yield with chlorpyriphos @ 10000 ml/ha (T_8) followed by full dose of *M. anisopliae* (T_1) and full dose of *B. bassiana* (T_2). However, half dose of *M. anisopliae* + half dose of *B. bassiana* (T_5) recorded modest number of grub count and cane yield respectively.

4.5.3 Laboratory evaluation of newer molecules of insecticides against second instar grubs of *Holotrichia serrata* (2011)

The results of laboratory study presented in Table 40 revealed highest per cent grub mortality of 74.07 in T_4 which was significantly superior to all other treatments. However, the next best treatments were T_1, T_6, T_3 and T_2 effecting 61.66, 61.33, 60.35 and 60.32 per cent grub mortality without differing among themselves but superior to T_7 and T_9.

At 14 DAT, T_4 maintained its superiority with mortality of 87.07 per cent, followed by T_6, T_1 and T_3 which exercised similar effect among themselves but significantly superior over T_2, T_5, T_7 and T_9. However, T_2 was on par with T_7 and T_5 with respect to per cent mortality.

At 28 DAT, T_4 recorded highest mortality (93.74%). T_6 and T_1 with 88.77 and 86.11 per cent mortality were significantly superior over remaining treatments. However, T_3 and T_7 effected 81.33 and 81.24 per cent mortality and were significantly superior over T_2 and T_5 but on par with T_6.

At 45 DAT, highest mortality (94.14) was recorded with T_4 and was on par with T_6 (91.00). This was followed by T_1 (89.52), T_7 (84.33), T_3 (83.66), T_5 (82.89) and T_2 (82.54) respectively, with similar effect among themselves.

Irrespective of the insecticide, mortality of grub gradually increased from 7 DAT to 45 DAT and all insecticides recorded maximum mortality at 45^{th} DAT.

4.5.4 Field evaluation of newer molecules of insecticides

2011

The results of field study are presented in Table 41. The results at 7 DAT revealed that T_4 recorded minimum larval count of 1.54 followed by T_6 (1.87) and were significantly superior to T_1, T_2, T_3, T_5, T_7 and T_8. At 14 DAT, T_4 recorded 0.61 grubs followed by T_1 (0.77) and T_6 (0.89) and were significantly superior over remaining treatments.

At 28 DAT, T_4 was most effective with nil population. This was followed by T_3 (0.10) and found on par with T_1 but superior to all other treatments. At 45 DAT, all the insecticidal treatments except T_2, T_3, T_5 and T_7 recorded nil mortality (Plate 16).

Number of millable canes (ha)

All the insecticidal treatments (T_1 – T_7) were significantly superior over untreated check by recording higher number of millable canes. However, T_4 produced maximum NMC and was on par with all other insecticidal treatments.

Table 40: Laboratory evaluation of newer molecules of insecticides against second instar *Holotrichia serrata* grub

Sl. No.	Treatments	Per cent mortality			
		7 DAT	14 DAT	28 DAT	45 DAT
1	Imidacloprid17.8 SL @ 1000 ml/ha	61.66 b (51.72)	78.89 b (62.62)	86.11 b (68.09)	89.52 b (71.08)
2	Fipronil 5EC @ 1500 ml/ha	60.32 b (50.94)	71.07 c (57.44)	79.72 c (63.21)	82.54 c (65.27)
3	Lambda cyhalothrin 5 EC @ 1500 ml/ha	60.65 b (50.95)	74.33 bc (59.53)	81.33 c (64.37)	83.66 c (66.13)
4	Imidacloprid 40%, + Fipronil 40% 80 WG (500 g/ha)	74.07 a (59.36)	87.07 a (69.41)	93.74 a (75.48)	94.14 a (76.59)
5	Chlorpyriphos 20 EC @ 10000 ml/ha	52.33 c (46.32)	69.88 c (56.70)	74.07 d (59.46)	82.89 c (65.76)
6	Rynaxypyr 4 G @ 20 k g/ha	61.33 b (51.53)	81.15 b (62.24)	88.77 b (70.44)	91.10 ab (72.91)
7	Phorate 10 G @ 25 k g/ha	52.84 c (46.61)	70.37 c (57.01)	81.24 c (64.31)	84.33 c (66.77)
8	UTC	0.00 d (0.00)	0.00 d (0.00)	0.00 e (0.00)	0.00 d (0.00)
	SE.m .±	1.75	4.64	3.13	5.12
	C.D. at 1%	5.30	14.09	9.50	15.53
	C.V. (%)	5.73	13.19	8.16	12.81

Figures in parentheses are arc sine transformed values, means showing similar alphabets do not differ significantly by DMRT
DAT-Days After Treatment, UTC = Untreated check
15 second instar grubs/treatment (pre count)

Table 41: Field evaluation of newer molecules of insecticides against *Holotrichia serrata*

Sl. No.	Treatments	Pre-count		No./m² Post Count 7 DAT		14 DAT		28 DAT		45 DAT		NMC (000/ha)		Cane yield (t/ha)	
		2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
1	Imidacloprid 17.8 SL @ 1000 ml/ha (1 ml/l)	21.50 c (4.69)	19.16 a (4.43)	1.98 e (1.57)	1.89 de (1.55)	0.77 de (1.13)	0.74 de (1.13)	0.11 e (0.78)	0.19 c (0.83)	0 .00b (0.71)	0.10b (0.77)	68.67	67.85	98.33	97.67
2	Fipronil 5EC @ 1500 ml/ha (1.5 ml/l)	20.50ab (4.58)	17.98 a (4.30)	2.15 de (1.63)	2.22 c (1.65)	1.35 c (1.36)	1.66 c (1.36)	0.23 d (0.85)	0.31 c (0.88)	0.10 b (0.77)	0.00 b (0.71)	70.50	69.20	97.40	99.65
3	Lambda cyhalothrin 5 EC @ 1500 ml/ha (1.5 ml/l)	20.85 a (4.62)	17.80 a (4.28)	2.33 cd (1.68)	2.17 cd (1.63)	1.29 c (1.34)	1.30 c (1.34)	0.10 e (0.77)	0.22 c (0.85)	0.10 b (0.77)	0.00 b (0.71)	66.00	68.66	96.70	91.73
4	Imidacloprid 40%+Fipronil 40% 80 WG @ 500 g/ha (1g/l)	22.21 c (4.77)	17.65 a (4.26)	1.54 f (1.43)	1.72 e (1.49)	0.61 e (1.06)	0.59 e (1.05)	0.00 f (.071)	0.00 d (0.71)	0.00 b (0.71)	0.00b (0.71)	72.37	69.07	103.40	98.30
5	Chlorpyriphos 20 EC @ 10000 ml/ha (10 ml/l)	23.10 b (4.85)	18.05 a (4.29)	2.56 bc (1.75)	2.66 b (1.77)	1.56 b (1.44)	1.66 b (1.44)	0.66 c (1.08)	0.75 b (1.12)	0.15 b (0.80)	0.19 b (0.82)	63.87	63.51	94.40	93.40
6	Rynaxypyr 4 G @ 20 k g/ha	22.50 a (4.48)	17.94 a (4.29)	1.87 e (1.54)	1.93 de (1.56)	0.89 d (1.18)	0.91 d (1.18)	0.22 d (0.85)	0.20 c (0.84)	0.00 b (0.71)	0.10 b (0.71)	71.73	68.67	102.63	103.13
7	Phorate 10 G @ 25 k g/ha	22.40 a (4.79)	17.77 a (4.27)	2.89 b (1.84)	2.70 b (1.79)	0.96 d (1.21)	1.05 d (1.21)	0.88 b (1.17)	0.96 b (1.21)	0.11 b (0.78)	0.10 b (0.77)	65.83	63.53	94.33	92.75
8	UTC	22.05 a (4.75)	18.66 a (4.38)	22.41 a (4.79)	19.88 a (4.51)	23.10 a (4.86)	20.11 a (4.86)	22.86 a (4.83)	21.33 a (4.67)	21.66 a (4.71)	19.32 a (4.45)	34.67	32.20	48.87	46.33
	SEm. ±	0.37	0.38	0.11	0.11	0.10	0.10	0.06	0.08	0.05	0.05	3.14	2.70	2.99	4.26
	C.D.at (5 %)	NS	NS	0.33	0.33	0.30	0.30	0.17	0.24	0.14	0.14	9.54	8.18	9.06	12.93
	C.V.(%)	13.56	15.13	11.61	11.42	13.77	13.77	11.10	15.13	10.96	11.01	18.49	7.43	5.63	8.17

Figures in parentheses are $\sqrt{x+1}$ transformed values, means showing similar alphabets do not differ significantly by DMRT
DAT-Days After Treatment, NMC = Number of Millable Canes, UTC = Untreated check

Plate 19: Comparative field view of treated (imidacloprid + fipronil - 80 WG) and untreated plots of Co 86032

Table 42: Pooled data on field evaluation of newer molecules of insecticides against *Holotrichia serrata*

Sl. No.	Treatments	Pre-count	No./m^2 Post Count 7 DAT	14 DAT	28 DAT	45 DAT	NMC (000/ha)	Cane yield (t/ha)
1	Imidacloprid 17.8 SL @ 1000 ml/ha (1 ml/l)	20.33a (5.00)	1.94bc (1.89)	0.76de (1.37)	0.15cd (0.88)	0.00b (0.70)	68.26	98.00
2	Fipronil 5EC @ 1500 ml/ha (1.5 ml/l)	19.42a (4.90)	2.19d (1.47)	1.51bc (1.72)	0.27c (1.01)	0.05b (0.72)	69.85	98.53
3	Lambda cyhalothrin 5 EC @ 1500 ml/ha (1.5 ml/l)	20.01a (4.97)	2.25bc (2.00)	1.3bcd (1.64)	0.16e (0.16)	0.00b (0.70)	67.33	94.22
4	Imidacloprid + Fipronil 80 WG @ 500 gl/ha (0.5g/l)	20.38a (5.01)	1.63cd (1.77)	0.6e (1.27)	0.00d (0.70)	0.00b (0.70)	70.72	100.85
5	Chlorpyriphos 20 EC @ 10000 ml/ha (10 ml/l)	20.28a (4.97)	2.61b (2.11)	1.61b (1.76)	0.71b (1.34)	0.17c (0.41)	63.69	93.90
6	Rynaxypyr 4 G @ 20 k g/ha	20.17a (4.99)	1.9b (2.11)	0.9cde (1.44)	0.21cd (0.95)	0.00c (0.70)	70.20	102.88
7	Phorate 10 G @ 25 k g/ha	19.94a (4.96)	2.8 bc (1.87)	1.01bcde (1.49)	0.92b (1.45)	0.06b (0.74)	64.68	93.54
8	UTC	20.36a (5.01)	21.15a (4.98)	21.61a (5.14)	22.1a (5.20)	20.49a (5.02)	33.44	47.60
	SEm. ±	0.15	0.10	0.09	0.09	0.09	4.47	5.23
	C.D. at (5 %)	NS	0.30	0.29	0.28	0.27	13.55	15.85
	C.V. (%)	5.92	8.46	9.94	11.99	13.27	12.14	9.98

Figures in parentheses are $\sqrt{x+1}$ transformed values, means showing similar alphabets do not differ significantly by DMRT
DAT-Days After Treatment, NMC = Number of Millable Canes, UTC = Untreated check

Table 43: Cost economics of different entomopathogens

Sl. No.	Treatments	Cane yield (t/ha) (2011)	Cane yield (t/ha) (2012)	Total cost of cultivation (Rs/ha)	Gross returns (2011)	Gross returns (2012)	Net returns (2011)	Net returns (2012)	B:C (2011)	B:C (2012)
1	*M. anisopliae* @ 25 k g/ha along with 125 kg FYM	89.73	85.62	55287	224325	214050	169038	158763	3.05	2.87
2	*B.bassiana* @ 25 k g/ha along with 125 kg FYM	86.91	82.74	55287	217275	206850	161988	151563	2.92	2.74
3	*M. anisopliae* @ 12.5 k g/ha along with 62.5 kg FYM	80.32	79.16	52944	200800	197900	147856	144956	2.79	2.73
4	*B. bassiana* @ 12.5 k g/ha along with 62.5 kg FYM	78.66	79.64c	52944	196650	199100	143706	146156	2.71	2.76
5	*M. anisopliae* @ 12.5 k g/ha along with 62.5 kg FYM + *B. bassiana* @ 12.5 k g/ha along with 62.5 kg FYM	83.12	82.87	55287	207800	207175	152513	151888	2.75	2.74
6	*M. anisopliae* @ 25 k g/ha along with 125 kg FYM + *B.bassiana* @ 25 k g/ha along with 125 kg FYM	91.30	87.94	59975	228250	219850	168275	159875	2.80	2.66
7	Neem cake 500 k g/ha	64.50	63.80	51850	161250	159500	109400	107650	2.10	2.07
8	Chlorpyriphos 10000 mlha	95.66	91.24	52800	239150	228100	186350	175300	3.52	3.32
9	UTC	39.62	36.46	50000	99050	91150	49050	41150	0.98	0.82

B:C ratio: Benefit cost ratio, UTC = Untreated check

Table 44: Cost economics of different insecticidal treatments

Sl. No.	Treatments	Cane yield (t/ha) 2011	Cane yield (t/ha) 2012	Total cost of cultivation (Rs/ha)	Gross returns (2011)	Gross returns (2012)	Net returns (2011)	Net returns (2012)	B:C (2011)	B:C (2012)
1	Imidacloprid 17.8 SL @ 1000 ml/ha	98.33	97.67	53500	245825	244175	192325	190675	3.59	3.56
2	Fipronil 5EC @ 1500 ml/ha	97.40	99.65	51700	243500	249125	191800	197425	3.70	3.81
3	Lambda cyhalothrin 5 EC @ 1500 ml/ha	96.70	91.73	51730	241750	229325	190020	177595	3.67	3.43
4	Imidacloprid 40% + Fipronil 40%- 80 WG @ 500 g/ha	103.40	98.30	54800	258500	245750	203700	190950	3.71	3.48
5	Chlorpyriphos 20 EC @ 10000 ml/ha	94.40	93.40	52900	236000	233500	183100	180600	3.46	3.41
6	Rynaxypyr 4 G @ 20 k g/ha	102.63	103.13	53200	256575	257825	203375	204625	3.82	3.84
7	Phorate 10 G @ 25 k g/ha	94.33	92.75	52800	235825	231875	183025	179075	3.46	3.39
8	UTC	48.87	46.33	50000	122175	115825	72175	65825	1.44	1.31

B:C ratio: Benefit cost ratio, UTC = Untreated check

Cane yield (t/ha)

All the insecticidal treatments (T_1-T_7) were significantly superior over control with respect to cane yield. However, higher cane yield was obtained in T_4 (103.40 t/ha) and was on par with all except T_7, T_6 (102.63 t/ha).

2012

The results of field study conducted during 2012 are presented in Table 41. Larval population recorded at 7 days after treatment ranged from 1.72 to 19.88. T_4 recorded lowest number of grubs (1.72) followed by T_1 (1.89) and T_6 (1.93) and were on par with each other but significantly superior over rest of the treatments. This was followed by T_3 (2.17) and T_2 (2.22) and were significantly superior to T_5 (2.66) and T_7 (2.70).

Grub count recorded at 14 DAT varied from 0.59 to 20.11. Significantly lower number of grubs were recorded in T_4 (0.59) and T_1 (0.74) and were superior over T_6 (0.91), T_7 (1.05), T_3 (1.30) and T_2 (1.66).

At 28 DAT, T_4 with no population excelled over all other treatments but was statistically on par with T_1 (0.19), T_6 (0.20) and T_3 (0.22).

At 45 DAT, T_2, T_3 and T_4 recorded no grubs. T_1, T_6 and T_7 (0.10) were statistically at par with T_2, T_3 and T_4. However, T_5 with 0.19 larval count was on par with T_1, T_6 and T_7.

Number of millable canes (000/ha)

All the insecticidal treatments (T_1 – T_7) were significantly superior over control (T_9) but were on par with each other with respect to NMC's. However, maximum NMC's were produced in T_2.

Cane yield

All the insecticidal treatments effected significantly superior cane yield over control. However, T_6 recorded maximum cane yield of 103.13 t/ha and was on par with all other treatments.

Pooled

At 7 DAT, T_4 and T_6 were most effective by recording least grub count of 1.63 and 1.90 grub and were significantly superior over T_1 (1.94), T_2 (2.19), T_3 (2.25), T_5 (2.61) and T_7 (2.80) respectively (Table 42).

At 14 DAT, T_1, T_4 and T_6 were found to be equally effective by recording least larval population (0.60 – 0.90) and significantly superior over T_7 (1.01), T_3 (1.30), T_2 (1.51) and T_5 (1.61) respectively.

Both at 28 and 45 DAT all the insecticidal treatments were superior by recording least larval count. Significantly higher number (20.49/m^2) was registered in control.

Number of millable canes

All the insecticidal treatments T_1 - T_7 were significantly superior over control. Order of superiority for NMC was $T_4 > T_6 > T_2 > T_1 > T_3 > T_7 > T_5$ respectively.

Cane yield (t/ha)

Based on the pooled data analysis the order of superiority for cane yield was $T_6 > T_4 > T_2 > T_1 > T_3 > T_5 > T_7 > T_8$ (Table 42).

4.5.5 Cost economics

Entomopathogen

The average benefit for every rupee invested was Rs 3.52 and 3.32 and highest in chlorpyriphos 20EC @ 10ml/ l during 2011 and 2012 respectively (Table 43). Among the entomopathogens, *M anisopliae* @ 25kg per ha along with 125 kg FYM was next best with earning of Rs 2.92 and 2.74 followed by lower dosage of *M anisopliae* @ 12.5 kg along with 62.50kg FYM recording Rs 2.79 and 2.73 during 2011 and 2012, respectively.

Newer molecules of insecticides

The incremental benefit for every rupee invested was highest in rynaxypyr with Rs 3.82 and 3.84 followed by imidacloprid 40% + Fipronil 40% 80 WG with Rs 3.71 and 3.48 during 2012 as against Rs 3.46 and 3.39 in case of chlorpyriphos for 2011 and 2012, respectively (Table 44).

DISCUSSION

Sugarcane is an important commercial crop of Belagavi district of North Karnataka. The white grub *H. serrata* is a serious soil dwelling pest of sugarcane causing 40 to 80 per cent crop loss (Prasad and Thakur, 1959). In recent years the white grub has become a serious threat, not only to sugarcane but also on other agricultural and horticultural crops both under irrigated and rainfed ecosystems. The results on species composition, population dynamics, adult behavioural pattern, loss estimation in sugarcane crops, per cent infestation in non sugarcane crops, laboratory and field evaluation of entomopathogens and newer molecules of insecticides have been discussed below.

5.1 Species composition and abundance of *Holotrichia serrata*

In the present investigation totally four species of white grubs *Viz.*, *Holotrichia serrarta*, *Anomala bengalensis*, *Anomala ruficapilla* and *Phyllognathus dionysius* were recorded under irrigated (sugarcane) ecosystem. *H. serrata* was the dominant species, followed by *A. bengalensis*, *A. ruficapilla* and *Phyllognathus dionysius* (Fig. 1-4).

The present study is in line with the reports of Frey (1971) according to whom *Holotrichia* alone has more than 120 economically important species of which widely distributed and destructive species in India are *H. serrata* and *H. consanguinea*. *H. serrata* is found throughout India, whereas *H. consanguinea* is restricted to northern parts of India. Theurkar *et al.* (2012) reported distribution of five major species of white grubs in Maharashtra, *Holotrichia serrata, Holotrichia fissa, Holotrichia consanguinea, Leucopholis lepidophora* (Melolonthidae*)* and *Anomola* sp. (Rutelidae*).*This holds good with respect to record of *H. serrata*, *H.fissa* and *Anomola* spp. in the present study. Dashad *et al.* (2008) reported 13 species of white grubs from Haryana with maximum number of *Holotrichia consanguinea* (1214) followed by *H. serrata* (382 beetles) unlike in the present study where *H. serrata* dominated other species of white grubs. Further, it is in confirmation with the findings of Veeresh (1978), Dashad *et al.* (2008) and Adsule *et al.* (1990) who have reported the occurrence of *H. serrata* in irrigated ecosystems. Anitha *et al.* (2006) has reported the abundance of *H. serrata* in southern and western parts of India and is in partial agreement with respect to report of *H. serrata*. Further, Anitha *et al*. (2006) also reported that scarab adults were collected from neem trees on which they were feeding and/or mating while larvae were collected (white grubs) from groundnut fields. *Holotrichia* species, especially *H. reynaudi* and *H. serrata* were the major species associated with groundnut. *H. reynaudi* predominated in the central Deccan area, while *H. serrata* was most abundant in the south and west.

In the present investigation in irrigated sugarcane ecosystem the adult emergence of *H. serrata* varied from location to location. In Bellad Bagewadi emergence was observed from 7th MSW (February) and continued upto 16th MSW (April) whereas at Kadapur, Soundalga and Sankeshwar it commenced from 8th, 9th and 10th MSW (March) and continued upto 16th,17th (April) and 18th MSW (May) respectively. The per cent soil moisture and temperatures recorded during this period ranged from 18.75 to 25.40 per cent and 25.30 to 31.60 ^{o}C, respectively. At peak adult emergence more than 23 per cent soil moisture and 26 ^{o}C soil temperature were recorded.

Under rainfed ecosystem in non-sugarcane crops four species *viz.*, *Holotrichia fissa, Holotrichia serrata*, *A. bengalensis* and *A. ruficapilla* were recorded after receipt of monsoon showers. However, *H. fissa* was dominant followed by *H. serrata, A. bengalensis* and *A. ruficapilla* (Fig. 5) in the present study.

In rainfed ecosystem irrespective of species adult emergence commenced from 14th MSW (April) and continued up to 22 MSW (May) peak being recorded at higher moisture level of more than 20 per cent which coincided with the receipt of pre-monsoon rains. The present findings are in agreement with reports of Adsule *et al.* (1990) who reported 11 scarabaeid species from 4 sub-families of Coleoptera of which *H. fissa* was dominant and economically important. Further, he reported the relative abundance of scarabaeid beetles on light trap in western Maharashtra indicating the coincidence of adult emergence with the onset of rainfall especially under rainfed situations with maximum catch during May, June, September and October.

Lolage and Patil (1984) studied the diversity of white grub species in Konkan region and indicated *H. fissa* as predominant species causing economic loss in groundnut and is in line with the present finding with respect to dominance of *H. fissa.* under rainfed situations.

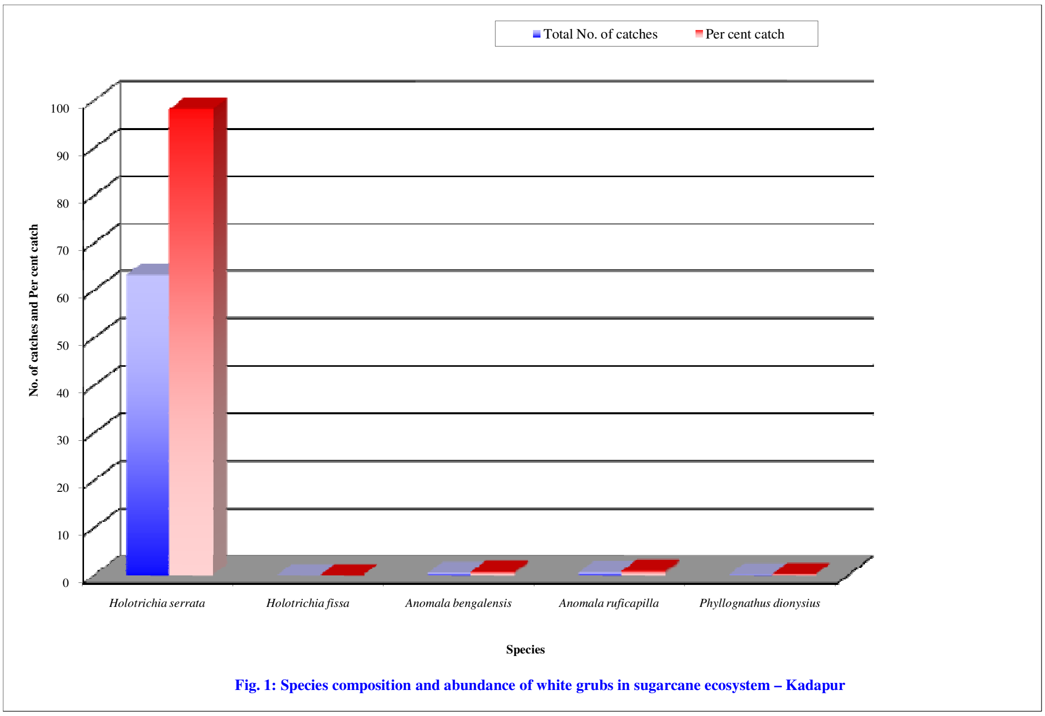


Fig 1: Species composition and abundance of white grubs in sugarcane ecosystem – Kadapur

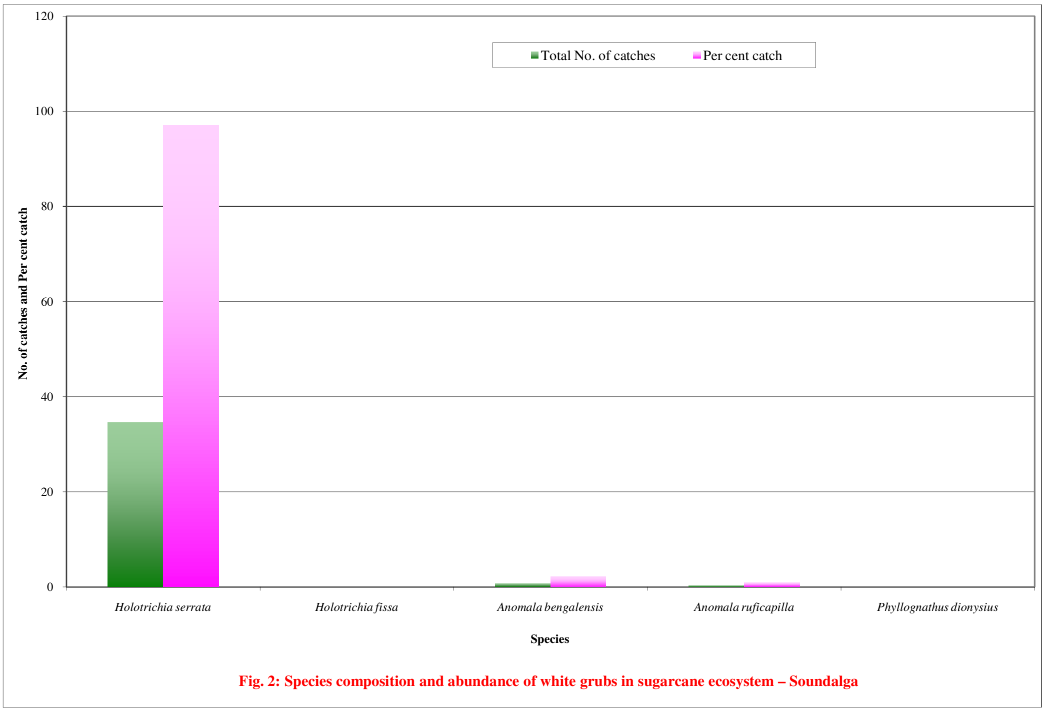


Fig 2: Species composition and abundance of white grubs in sugarcane ecosystem – Soundalga

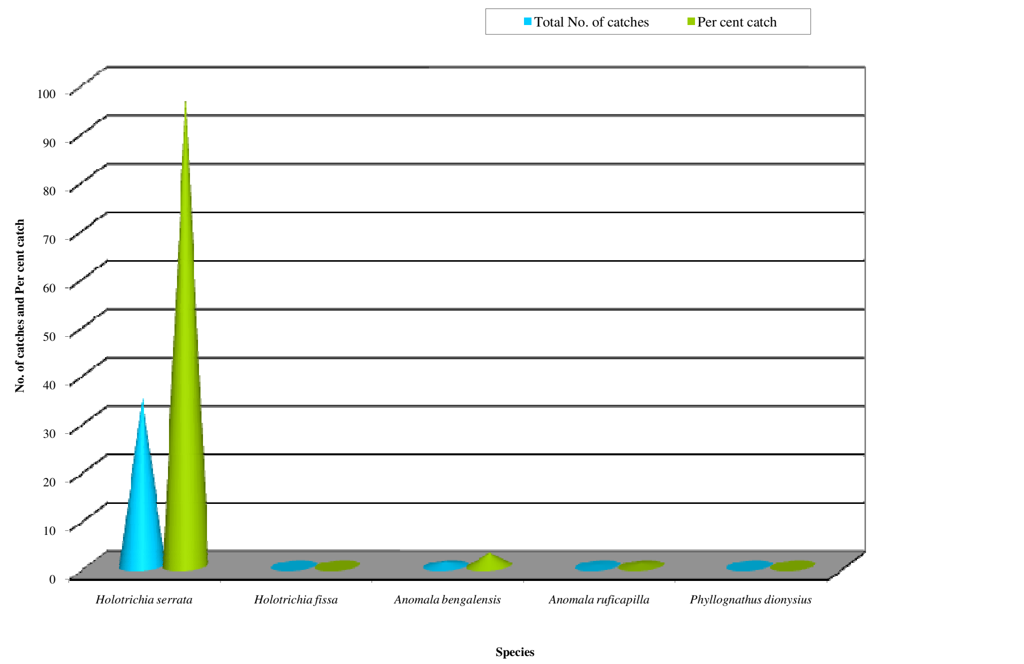


Fig. 3: Species composition and abundance of white grubs in sugarcane ecosystem – Bellad Bagewadi

Fig 3: Species composition and abundance of white grubs in sugarcane ecosystem – Bellad Bagewadi

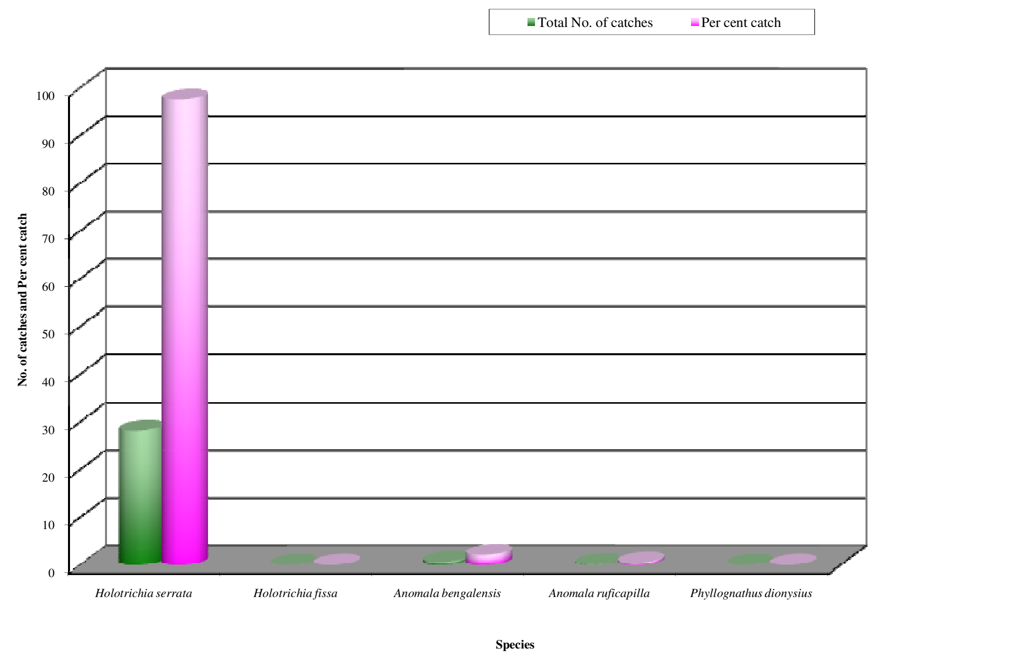


Fig. 4: Species composition and abundance of white grubs in sugarcane ecosystem – Sankeshwar

Fig 4: Species composition and abundance of white grubs in sugarcane ecosystem – Sankeshwar

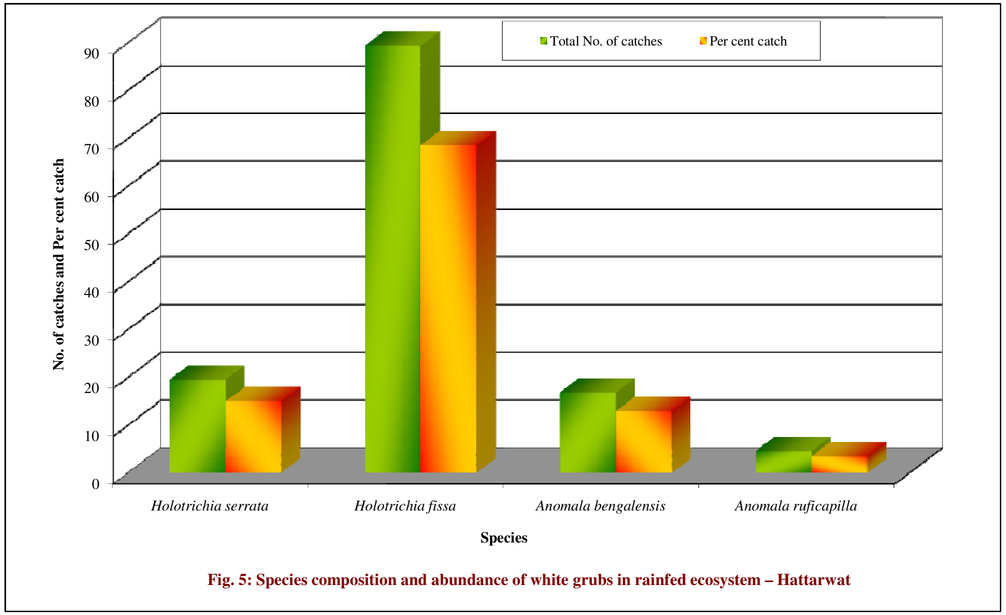


Fig 5: Species composition and abundance of white grubs in rainfed ecosystem – Hattarwat

Literature on adult emergence of *H. serrata* in irrigated sugarcane ecosystem is lacking. Location specific variation of *H. serrata* adult emergence under irrigated ecosystems in the present study is being reported for the first time. Probably in sugarcane ecosystem frequent irrigation from January to March months enhanced soil moisture to more than 23 per cent resulting in activation of the quiescent adult forcing adult emergence from February itself and continued upto April in different locations without waiting for the pre-monsoon showers indicating the changed behaviour of the insect.

5.2 Population dynamics of sugarcane white grub, *Holotrichia serrata*

In the present investigation in irrigated sugarcane ecosystem adult emergence was noticed from February to April in different locations resulting in presence of all the stages (pupae, adult and egg) during January - March; egg, first, second and third instars during May – August; third instar, pupae and quiescent adults from August to September indicating the overlapping nature of *H. serrata*. Whereas in rainfed ecosystem (non-sugarcane crops) the adult emergence was recorded only after the receipt of pre monsoon showers (April-May).

The literature on population density of white grub, *H. serrata* is lacking. However, the present study is in line with Kalra *et al.* (1984) who studied the population dynamics of the white grub, *H.consanguinea* in pits revealing that during June and July, due to paucity of rains, very less number of adults was noticed within the pits. Maximum number of adults (7 and 6 adults/pit) was recorded during August - September and grub population was more during June and July (4 to 7 grubs /pit), respectively. Further, Kalra *et al.* (1991) has reported the population build up of *H. consanguinea* on groundnut with less number of adult beetles during June - October and more from July to September.

In irrigated crop system, frequent irrigation to protect the crop enhanced the soil moisture to more than 20 per cent which might have triggered the quiescent adult to become active resulting in emergence right from February itself and presence of egg, larva and pupa during March, July, August and September months respectively. Secondly the availability of host (neem on field bunds) for the adults and sugarcane for grubs throughout the year has helped the insect to survive on the host plants leading to emergence of adults right from February.

5.3 Behavioural pattern of *Holotrichia serrata* adults in sugarcane

In the present investigation the results on peak adult emergence differed from location to location *i.e.*, from February (Bellad Bagevadi) to April (Sankeswar). No information is available with respect to adult emergence of *H.* serrata under irrigated sugarcane ecosystem. Adult emergence of *H. serrata* beetles is usually observed during the month of May and June, after the receipt of pre-monsoon showers, hence they are commonly known as May-June beetles. Veeresh (1978) reported the emergence of *H. serrata* adults after receipt of first summer showers during April and May months. Similar findings were also reported by Gangawar (1988), Patil and Hasabe (1979), Mishra and Singh, (1993) and Dashad *et al.* (2008).

However, during the period of present study emergence pattern of *H. serrata* adults under irrigated sugarcane ecosystem has changed from location to location resulting in overlapping stages of insect throughout the sugarcane growing season making the management of the pest more difficult. Further, in the areas of present study earlier sugarcane was grown only in traditional irrigated area but now rainfed area has been converted into sugarcane belt, wherein optimum soil moisture is available throughout the season resulting in varied time of adult emergence. Secondly, the availability of host plants (neem, acacia, ber etc on field bunds) for adults and sugarcane for grubs throughout the season across the locations and lack of regular rains during the past two years has further aggravated the white grub problem. These are the probable reasons attributed for changed behaviour of *H. serrata* in Belgaum district.

5.3.1 Adult trapping

Among the different adult trapping sources, light + neem was superior by trapping highest number of adults, followed by neem leaves alone (Fig. 6). However, light source was the next best with modest catches. Further, combination of neem leaves with other sources resulted in modest adult catches strongly indicating the adult attractant property of some of the sources used in the present study.

The present study is strongly supported by the finding of Gupta (1973) who utilized neem leaves in capturing 70,000 and 85,000 adults of *H. serrata* at Rampur during 1968 and 1969 and over 1,00,000 at Daurala in Meerut District in 1971. According to him the adults were attracted to neem smell and the exact chemical nature of the attractant is yet to be determined. The present study is also in full corroboration with Kesavan *et al.* (2012) who has reported that volatiles from neem, *Azadirachta indica* leaf extract elicited higher antennal response to adult *H. serrata* than other hosts like gulmohar and *Ailanthus excelsa*. However, Gangawar (1988) noticed that the light trap collection of white grub beetles at 950 meters MSL revealed the presence of 24 species of white grub occurring in Meghalaya, among which *Anomala* spp. dominated. The beetles started emerging from April and were observed up to October with a peak emergence in May indicating that light trap can be successfully used at medium altitude hills for survey and control of white grub beetles.

5.3.2 Adult trapping with chemicals with pheromone/kairomone activity

In the present investigation neem leaf extract @ 10 per cent was the only treatment effective in attracting *H. serrata* adults and is in line with report of Kesavan *et al.* (2012) who has reported that volatiles from neem, *Azadirachta indica* leaf extract elicited higher antennal response to *H. serrata* adults than other hosts tested. However, Robbins *et al.* (2003) identified sulphur containing long distance female produced sex pheromone for *Phyllophaga crinita* (Burmister) (Scarabaeidae: Coleoptera) as methyl 2 methoxy benzoate and succeeded in capturing 8,664 male beetles and no females. However, in the present study, Anisole (methoxy benzoate) the commonly used sex pheromone of *H. consanguinea,* failed to attract the adults of *H. serrata* since sex pheromones are highly species specific.

5.3.3 Grub load in different crops

In the present investigation grub count/population recorded in different crops *viz*., groundnut, soybean, capsicum, paddy, maize, turmeric, cabbage and brinjal (*Kharif*) and wheat, sorghum and bengalgram (*Rabi*) crops varied from 0.56 (soybean) to 12.40 (sugarcane) indicating the spread of *H. serrata* population from sugarcane ecosystem and increased crop diversity of the pest in recent years. Present findings are in corroboration with Veeresh *et al*. (1978) who reported the incidence of *H. serrata* on sugarcane and sorghum. Gupta and Avasthy (1957) reported *H.consanguinea* (Blanch) as a pest of sugarcane and many agricultural and horticultural crops in many parts of India. The present findings are also in line with reports of Chandramohan and Nanjan (1993) who noticed larval population of 10.81/m^2 of *H. excisa* on potato. Singh *et al.* (1999) recorded 1.66 to 2.33 per m^2 larval population of *H. longipennis* in upland rice and is in line with the grub load recorded on rainfed paddy in the present study. Singh *et al.* (2004) reported the incidence of *H. longipennis* in different crops like potato, ginger, finger millet, capsicum, *Amaranthus*, tomato, cabbage, blackgram and maize and is in confirmation of the grub load recorded on capsicum, cabbage and maize of the present study though the species studied is *H. serrata.*

5.4 Loss estimation in sugarcane due to *Holotrichia serrata* and per cent infestation in other crops

5.4.1 Varietal reaction and loss estimation in sugarcane

Under natural and protected plots variable grub load was recorded in different varieties *viz.,* CoM-265 (11.89 and 0.67), CoC-671 (11.81 and 0.57), Co-8011 (11.76 and 0.65), CoSnk 632 (10.79 and 0.63) and Co 86032 (10.74 and 0.62) for two consecutive years.

Literature on loss estimation due to *H. serrata* in different varieties of sugarcane (both quantitative and qualitative parameters) is lacking to compare the present finding. However, David *et al.* (1984) reported that 17 varieties *viz*., Co285, Co421, Co453, Co775, Co976, 6304, Co6311, Co6501, Co6512, Co6914, Co7313, Co7626, CoS510, CoL29, CoJ65, CoJ75 and Bo 92 were found resistant/tolerant to *H. serrata* under artificial infestation in pot experiments. Chirame *et al.* (2003) also reported that with grub load of 36 per m^2 and 74% crop damage resulted in yield of 23 t/ha due to *H. serrata* as against grub load of 1.5 per meter row and 2.5 per cent crop damage in treated plots recording 119 t/ha. Similarly, Sithanantham (1978) reported that *H. serrata* is predominantly associated with sugarcane causing considerable damage in Tamil Nadu, Maharashtra, Karnataka and Uttar Pradesh. The varieties Co453 and Co6304 can tolerate the damage considerably. In the present investigation number of roots, root length and total dry matter recorded in CoM 265 and CoSnk 03632 varieties both in protected and unprotected plots might have offered the tolerance in spite of grub attack resulting in significantly higher NMC's and cane yield (Fig. 7). Present finding are also in agreement with David and Ananthnarayana (1982), who reported one to two grubs per clump of sugarcane is known to have incremental effect on the cane but number more than this will cause damage. Veeresh (1977) noticed that white grubs can feed on any root or underground stem. No plant is completely resistant to white grub attack and certain crops can tolerate more than 50 per cent root damage as was observed in the present study for CoM 265 and CoSnk 03632 varieties.

5.4.2 Per cent infestation of *Holotrichia serrata* Fab. in different crops

In the present investigation per cent incidence of *H. serrata* observed in both *Kharif* (soybean, groundnut, chilli, capsicum, cabbage, turmeric, maize, brinjal *etc.*) and *Rabi* (wheat, sorghum and bengal gram) crops apart from sugarcane. Literature on per cent infestation in different *Kharif* and *rabi* crops is very scanty and is being reported for the first time. However, this is in agreement with Bakhetia (1982) who reported 10.7 per cent plant mortality of groundnut causing 28.74 - 40.34 per cent loss by *H. consanguinea.* John Rogers *et al.* (2005) reported that the *H. serrata* larva reduced the groundnut yield by an average of 7.52 g per larva and the provisional EIL is one larva in 7.1 m^2 area.

5.5 Efficacy of entomopathogens and newer molecules of insecticides against *Holotrichia serrata*

5.5.1 Laboratory evaluation of entomopathogens

In the present investigation the results on efficacy of entomopathogens carried out under laboratory condition indicated that combination of *M. anisopliae* and *B. bassiana* at higher dosage *i.e,* 4×10^8 conidia/ha was superior over remaining treatments followed by *M.anisopliae* @ 4×10^8 conidia/ha.

The present findings are in agreement with the report of Sajid Mohi-uddin *et al.* (2006) who found that entomopathogens *viz.*, *B. bassiona, B. brongniartii* and *M. anisopliae* were proved pathogenic to *Holotrichia* sp. at all the concentration levels *i.e.*, $1x10^8$, $1x10^6$, $1x10^4$ and $1x10^2$ spores per ml, but mortality in a shorter duration was observed at a spore concentration of 1×10^8, spores/ml. The enhanced mortality was observed with increase in inoculum dose. However, Easwarmoorthy *et al.* (2005) reported that *M. anisopliae* of varied concentration ranging from 10^4-10^9 spores/ml were more effective than *B. bassiana* and *B. brongniartii* against eggs of *H. serrata* under laboratory conditions. Samson *et al.* (1999) found that the number of white grubs of *Dermolepida* spp. on sugarcane was consistently reduced by more than 50 per cent when spores of *M. anisopliae* (F_1-1045) together with rice medium were applied @ 33 kgs per ha.

Rakesha *et al.* (2012) reported that *M. anisopliae* at higher dosage of 4×10^8 conidia/g recorded higher per cent mortality of *L. lepidophora* grubs (33.33) as compared to lower dosage of 2×10^8 conidia/g resulting in 14.81 per cent mortality.

5.5.2 Field evaluation of entomopathogens

In the present investigation *M. anisopliae @* 25 kg/ha and *B. bassiana* @ 25 kg/ha with FYM (250 kgs/ha) was effective by recording lower larval number resulting in higher cane yield followed by *M. anisopliae* and *B. bassiana* @ $4x10^8$ conidia /ha comparable with chlorpyriphos 20 EC @ 10 ml/1 (Fig. 8). Easwarmoorthy *et al.* (2005) reported that *B. brongniartii* when applied to the root zone of sugarcane crop @ 1.6 $x10^{14}$ spores/ha produced significantly higher infection rate in third instar grubs of *H. serrata* in treated plots. Similarly, Rachappa, (2003) reported that *M. anisopliae* @ $1x10^{13}$ conidia per ha was found as effective as chlorpyriphos in reducing *H. serrata* population in sugarcane resulting in higher cane yield

Present investigation is in agreement with Yadav *et al.* (2004) who reported the efficacy of both *M. anisopliae* and *B. bassiana* alone or with 5, 10 or 15 g compost in a pot culture experiment. The efficacy increased with increased rate of compost application. *M. anisopliae* in combination with compost resulted in higher mortality of *H. consanguinea* fully justifying the present study against *H. serrata.* However, Manisegaran *et al.* (2011) reported that application of *M. anisopliae* against sugarcane white grub, *H. serrata* @ 4×10^9 conidia/ha was found effective next to chlorpyriphos on 60^{th} DAT. Chlorpyriphos @ 3 lt/ha recorded higher cane yield of 110.5 t/ha and *M. anisopliae* @ 4×10^9 conidia/ha recording 100.6 t/ha and is in complete agreement with the present findings.

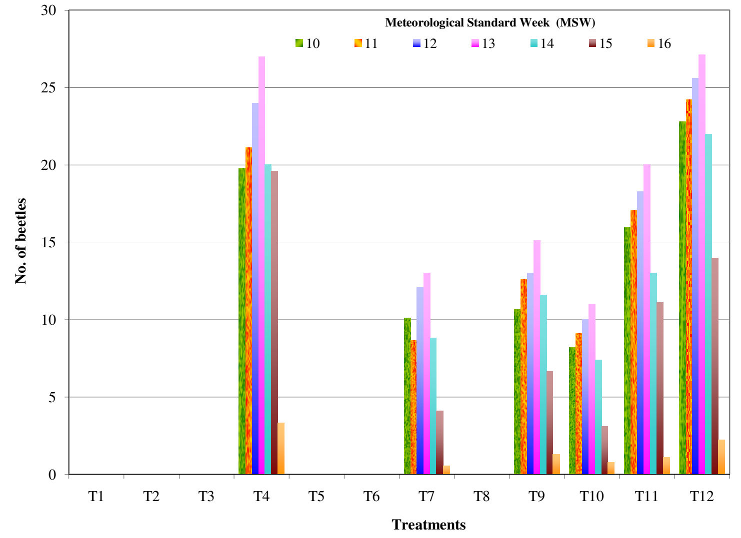


Fig. 6: Pooled data on evaluation of different trapping sources on mean number of *Holotrichia serrata* beetles caught under natural conditions

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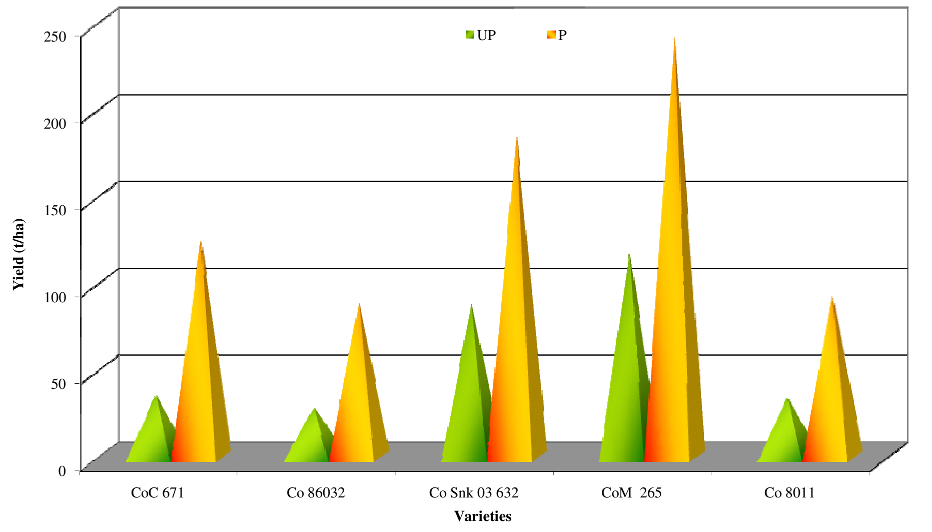

Fig. 7: Pooled data on varietal reaction and loss estimation of yield and yield related parameters due to *Holotrichia serrata* in different sugarcane genotypes

Fig 7: Pooled data on varietal reaction and loss estimation of yield and yield related parameters due to *Holotrichia serrata* in different sugarcane genotypes

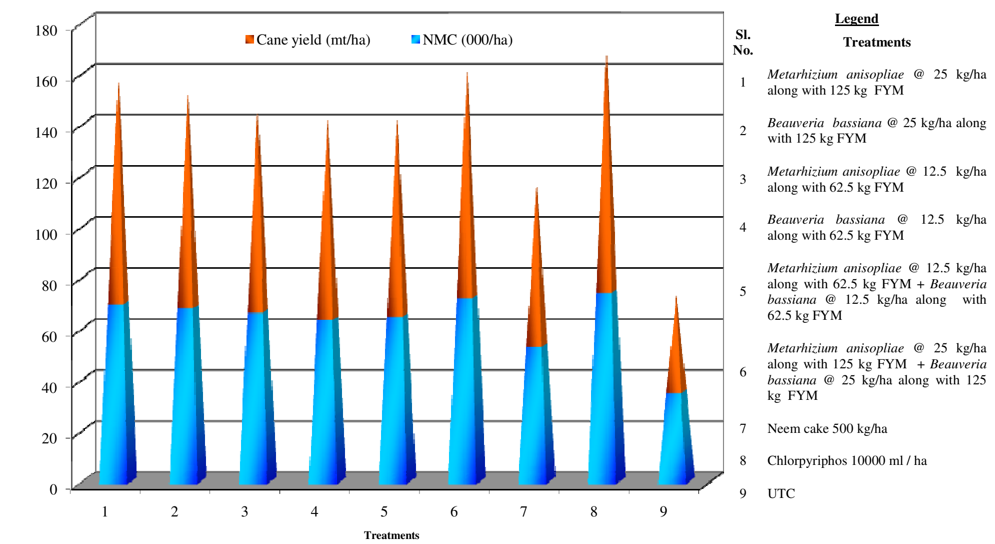

Fig. 8: Pooled data on NMC and cane yield as influenced by entomopathogens against white grub, *Holotrichia serrata*

Fig 8: Pooled data on NMC and cane yield as influenced by entomopathogens against white grub, *Holotrichia serrata*

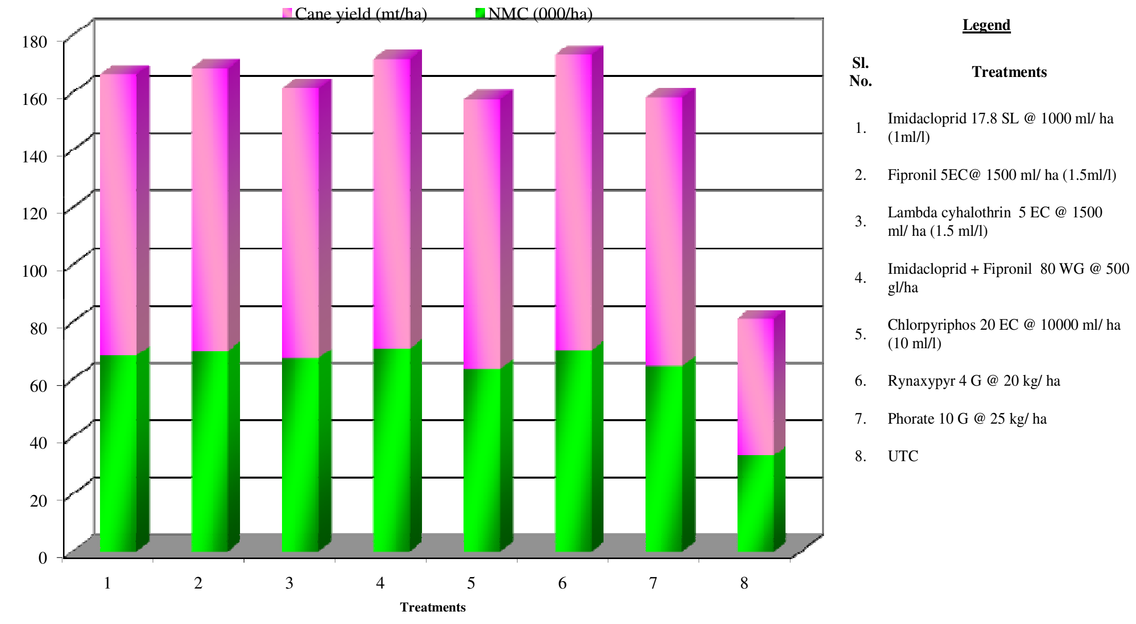

Fig. 9: Pooled data on NMC and cane yield as influenced by newer molecules of insecticides against white grub, *Holotrichia serrata*

Fig 9: Pooled data on NMC and cane yield as influenced by newer molecules of insecticides against white grub, *Holotrichia serrata*

5.5.3 Laboratory evaluation of newer molecules of insecticides

In the present investigation newer molecules of insecticides *viz*., imidacloprid+ Fipronil - 80 WG @ 1000g/ha followed by rynaxypyr 4 G @ 20 kg/ha were significantly superior to chlorpyriphos. Other molecules *viz*., imidacloprid 17.8 SL @ 1000 ml/ha, Fipronil 5EC @ 1500 ml/ha and lambdacyhalothrin 5 EC @ 1500 ml/ha were superior over chlorpyriphos 20 EC@ 10000 ml/ha.

The literature available on efficacy of newer molecules of insecticides against *H. serrata* is lacking and being reported for the first time. However, David *et al.* (1986) reported cent per cent and significantly superior mortality of eggs of *H. serrata* with phorate 10 G @ 38 mg/kg of soil. Further, phorate, sevidol, quinalphos and endosulfan were effective in killing the different instars of *H. serrata*.

5.5.4 Field evaluation of newer molecules of insecticides

Results of field evaluation of newer molecules of insecticides revealed that among the insecticide molecules imidacloprid + fipronil - 80 WG @ 1000 g/ha and rynaxypyr 4 G @ 20 kg/ha were significantly superior over chlorpyriphos 20 EC. Other traetments *viz*., imidacloprid 17.8 SL @ 1000 ml/ha, fipronil 5% SC @ 1500 ml/ha and lambdacyhalothrin 5% EC @ 1500 ml/ha were superior over chlorpyriphos 20 EC @ 10000 ml/ha (Fig. 9).

Veeresh (1977) also reported that organo-phosphorous insecticides *viz*., phorate 10 G, turbufos 5 G, quinalphos 5 G, carbofuron 3 G @ 1.0 kg a.i/ac and chlorpyriphos 0.5 kg a.i/ac were effective. Further, Veeresh (1978) reported that efficacy of insecticides will be enhanced under irrigated condition as compared to unirrigated conditions. The per cent control in unirrigated conditions was 31.0, 24.1, 27.5, 37.9 and 31.0 in chlordane, chlorpyriphos, aldicarb, torbophos and phorate respectively as compared to 53.1, 93.7, 0.0, 90.6 and 84.3 per cent control under irrigated condition respectively. Gajare *et al.* (1981) reported zero per cent plant mortality due to *H. serrata* in sugarcane and all the insecticides used *viz.,* fensulfothion 3 G, carbofuran 3G, quinalphos 5 G @ 2 kg a.i. /ha were highly effective.

Patil and Bhagat (2005) conducted field evaluation studies of insecticides against white grub *Holotrichia* spp. in maize and revealed that seed treatment with imidacloprid 70 WS @ 3.5 g a.i./kg seed, chlorpyriphos 20 EC @ 5 g a.i./kg seed, soil application of chlorpyriphos 10 G + NICAST (@ 2 kg a.i per ha + 500 kg per ha, respectively and chlorpyriphos 10 G @ 2 kg a.i. per ha resulted in decreased plant mortality in maize against white grub over control (75.85, 71.38, 66.67 and 56.59 per cent, respectively) and is in agreement with the present finding with respect to imidacloprid.

Swaroop Singh *et al.* (2012) studied efficacy of newer insecticide molecules as a seed dresser against *H. consanguinea* in groundnut and revealed that clothianidin 50 WDG at 2.0 g per kg seed, provided maximum protection (82.64%) with minimum plant damage (5.47%) followed by its higher dose 3.0 g per kg seed (82.39 per cent and 5.55 per cent, respectively) and imidacloprid 17.8 SL at 3 ml (80.36 per cent and 6.19 per cent, respectively) and is in full support of present finding with respect to efficacy of novel insecticides *viz.,* imidacloprid and fipronil. Maximum yield of 23.30 t per ha in 3.0 g per kg seed dose of clothianidin 50 WDG was recorded followed by its lower dose of 2.0 g per kg seed (22.24 q/ha) and imidacloprid 17.8 SL (20.93 q/ha). Further, Swaroop Singh *et al.* (2011) evaluated newer insecticides against *H. consanguinea* in ground nut and revealed superiority of imidacloprid 17.8 SL @ 33 ml/ha by recording least plant mortality (7.31) with pod yield (21.13 q/ha) followed by clothianidein 50 WDG @ 240 g/ha recorded (8.46) and pod yield (18.61 q/ha) and is in corroboration with the present finding with respect to imidacloprid and fipronil.

5.5.5 Cost economics

Entomopathogens

In the present investigation highest cost benefit ratio of Rs 3.52 and 3.32 was obtained with chlorpyriphos 20EC during 2011 and 2012 respectively. Among the entomopathogens, *M. anisopliae* @ 25 kg per ha along with 125 kg of FYM was best treatment earning Rs 3.05 and 2.87 followed by *B. bassiana* @ 25 kg along with 125 kg of FYM generating Rs 2.92 and 2.74 during 2011 and 2012 respectively. However, Manisegaran *et al.* (2011) who reported highest incremental benefit ratio of 7.58 with *M. anisopliae* @ 4×10^9 conidia/ha as against 6.09 in chlorpyriphos treatment, *M. anisopliae* even at 1×10^9 conidia/ha earned incremental ratio of 5.72.

Newer molecules of insecticides

In the present investigation the highest incremental benefit ratio of Rs 3.82 and 3.84 was obtained with rynaxypyr followed by fipronil 5% EC with Rs 3.70 and 3.81 and imidacloprid 40% + fipronil 40% -80WG obtained 3.71 and 3.48 during 2011 and 2012 respectively. Literature on cost economics of newer molecules against *H. serrata* in sugarcane ecosystem is lacking. However, Swaroop Singh *et al.* (2012) has reported highest incremental benefit ratio with imidacloprid 17.8 SL @ 333 ml/ha in groundnut against *H. consanguinea* which is in full agreement with the present finding though the species and the crop studied are different.

Future line of work

- Evaluation of different host plants, *viz.,* neem, acacia, ber *etc.* for their kairomone properties by identifying the volatiles of these plants.
- Studies on aggregation /sex pheromones for attracting adults.
- Evaluation of different formulations of fungal pathogens.
- Detailed and systematic study on field persistence of entomopathogens.
- Systematic studies on loss estimation due to *Holotrichia serrata* in major *Kharif* and *Rabi* crops and correlation between grub load and field infestation to work out crop loss as influenced by soil types.
- Loss estimation due to *Holotrichia serrata* as influenced by intercrops.

SUMMARY AND CONCLUSIONS

Investigations on species composition, population dynamics, behavioural pattern, loss estimation in sugarcane, per cent infestation in different crops, laboratory and field evaluation of entomopathogens and newer molecules of insecticides have been summarized below.

Studies on species composition in irrigated ecosystem clearly indicated that *H. serrata* was the dominant species occurring in different locations indicating overlapping generation whereas in rainfed ecosystem *H.fissa* was dominant followed by *H. serrata*.

Adult emergence of *H. serrata* commenced from 7^{th} MSW (February) and continued upto18th MSW (May). Irrespective of locations in irrigated ecosystem peak emergence was noticed during March and April. Where as in rainfed ecosystem adult emergence of *H. fissa* was recorded from 14^{th} MSW (April) and continued upto 22^{nd} MSW (May).

Adult emergence of *H. serrata* in irrigated ecosystem had positive correlation with soil moisture whereas under rainfed situations both soil temperature and moisture had positive correlation for *H. fissa.*

Behavioural studies of *H. serrata* conducted over two years indicated that in sugarcane ecosystem adult emergence was recorded from February and continued up to April in different locations. The peak emergence was observed during March and April months. Soil Moisture (>20%) and soil temperature (>23°C) favoured the adult emergence.

Studies on adults trapping with various sources indicated that neem was the best source to trap the adult *H. serrata*. Trapping efficiency of neem increased with light source.

Grub population recorded in non-sugarcane crops *viz.,* ground nut, soybean, maize, paddy, turmeric and vegetables (*Kharif*) and wheat, sorghum and bengalgram (*Rabi*) indicated spread of population from sugarcane to other crops with increased crop diversity.

Under laboratory condition among the fungal pathogens evaluated against *H. serrata* combination of *M. anisopliae* and *B. bassiana* at higher doses of 4 x 10^8 conidia/g was effective followed by *M. anisopliae* and *B. bassiana* @ 4 x 10^8 conidia/g alone.

Since higher dose of FYM could provide more moisture, natural multiplication and perpetuation of *Metarhizium* resulting in reduced grub population.

Both under protected and unprotected conditions variety CoM 265 emerged as tolerant to white grub attack followed by CoSnk 03632 and yielded significantly more cane yield in spite of white grub attack. Irrespective of varieties the grub population recoded was less in *M. anisopliae* applied plot resulting in better NMC and cane yield.

Among the novel insecticides evaluated against second instar grub of *H. serrata*. Imidacloprid + fipronil 80 WG was significantly superior but found on par with rynaxypyr 4G were superior to other insecticides recording highest larval mortality followed by imidacloprid 17.8 SL and lambda cyhalothrin 5 EC.

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Appendix Ia: Weather data for the year 2011

Month	Relative humidity (%)			Temperature (C^0)		Rainy Days	Rainfall (mm)	Average rainfall in 31years (mm)
	FN	AN	AV	Maxi.	Min.			
January	96.25	52.19	74.22	28.38	13.22	1	1.0	1.06
February	90.39	49.10	69.75	30.21	15.57	-	-	1.01
March	88.67	28.16	58.42	35.03	17.32	-	-	8.97
April	91.00	22.20	56.60	37.93	19.86	2	36.8	26.87
May	91.35	23.64	57.50	38.83	22.83	-	-	59.13
June	91.20	26.83	59.02	32.53	20.70	14	260.0	139.60
July	91.38	42.00	66.69	27.93	19.93	20	229.4	139.30
August	91.00	47.12	69.06	29.35	19.16	14	94.2	123.56
September	91.1	43.83	67.47	29.03	18.66	17	230.0	117.00
October	91.03	44.03	67.53	29.16	18.51	8	157.8	119.20
November	91.00	38.16	64.58	27.76	16.63	6	54.4	29.49
December	90.58	44.93	67.76	26.29	13.16	-	--	4.93
Total						82	1063.6	770.10

Appendix Ib: Weather data for the year 2012

Month	Relative humidity (%)			Temperature (^0C)		Rainy days	Rainfall (mm)	Average rainfall in 31 years (mm)
	FN	AN	AVG	Max.	Min.			
January	90.00	34.70	62.35	28.32	11.35	-	-	1.14
February	88.92	33.28	61.10	30.21	13.53	1	8.4	1.08
March	88.67	33.25	60.96	33.35	17.45	-	-	9.59
April	80.90	21.10	51.00	36.00	19.20	5	91.4	56.1
May	90.96	22.96	56.96	37.29	19.90	3	17.4	63.21
June	90.60	32.96	61.78	31.66	19.16	15	142.0	149.2
July	90.12	49.77	69.95	28.77	19.09	15	129.4	148.9
August	91.70	49.38	70.54	29.29	18.41	13	102.4	132.08
September	89.80	44.90	67.35	29.03	18.33	8	143.4	125.1
October	88.38	44.70	66.54	29.16	17.93	11	179.8	127.5
November	79.93	41.13	60.53	28.66	16.10	-	-	31.52
December	85.58	36.80	61.19	29.22	15.61	-	-	5.27
Total						71	814.2	850.69

STUDIES ON PRESENT STATUS OF WHITE GRUB, *Holotrichia serrata* (Fabricious) (COLEOPTERA; SCARABAEIDAE) IN BELAGAVI DISTRICT AND ITS MANAGEMENT

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ABSTRACT

Studies carried out in Belagavi district of Karnataka during 2011 and 2012 on species composition, population dynamics, behaviorual pattern of adult white grub, loss estimation, both laboratory and field evaluation of entomopathogens and newer chemical insecticides revealed that *Holotrichia serrata* and *Holotrichia fissa* were the dominant species in irrigated and rain fed ecosystem respectively.

Adult emergence of *H. serrata* commenced from 7th Meteorological Standard Week (MSW) (February) and continued upto 18th MSW (May), whereas in rainfed ecosystem adult emergence of *H. fissa* was recorded from 14th MSW (April) and continued upto 22 MSW (May).

Adult trapping with various sources indicated that neem (*Azadirichta indica*) was the best source to trap the adults of *H. serrata*. Studies on host range indicated the spread of white grub population from sugarcane to other crops namely, groundnut, soybean, maize, paddy, turmeric and vegetables under *kharif* and wheat, sorghum and bengalgram under *rabi* conditions. Fungal pathogens evaluated under laboratory conditions against second instar *H. serrata* grub revealed that the combination of *Metarhizium anisopliae* and *Beauuveria bassiana* @ $4x10^9$ conidia/g was most effective but on par with *M. anisopliae* and *B. bassiana* alone @ $4x10^9$ conidia/g. Similar to laboratory conditions field evaluation of fungal pathogens for two years (2011-2012) revealed that higher dosages of fungal pathogens @ 25 kg/ha and FYM @ 125 kg/ha were more effective in reducing grub population significantly.

Field evaluation of novel insecticide revealed that significant superiority of imidacloprid + fipronil 80 WG @ 1000 g/ha and on par with rynaxypyr 4G @ 20 kg/ha, lambda cylohothrin 5 EC @1500 ml/ha and imidacloprid 17.8 SL @1000 ml/ha were found superior to other insecticides by recording higher larval mortality. Among the five sugarcane genotypes screened both under protected (*M. anisoplieae*) and unprotected conditions against *H. serrata* grub. CoM 265 variety emerged as tolerant followed by CoSnk 03632.