

# STUDIES ON WHITE GRUB FAUNA OF CHUHAR VALLEY OF HIMACHAL PRADESH

## THESIS

*By*

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(A-2015-30-029)**

*Submitted to*



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## **CERTIFICATE – I**

This is to certify that the thesis entitled, “**Studies on white grub fauna of Chuhar valley of Himachal Pradesh**” submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the discipline of **Entomology** of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Balvir Kumar (Admn. No. A-2015-30-029)** son of Smt. Laxmi Devi and Shri Jagdish Chand, under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

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## CERTIFICATE- II

This is to certify that the thesis entitled “**Studies on white grub fauna of Chuhar valley of Himachal Pradesh**” submitted by **Balvir Kumar (Admission No. A-2015-30-029)** son of Shri Jagdish Chand to the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** in the discipline of **Entomology** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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## LIST OF ABBREVIATIONS USED

Sr. No.	Abbreviation/Symbols	Meaning
1.	Amsl	Above mean sea level
2.	E	East
3.	etc.	Etcetera
4.	<i>et al.</i>	<i>Et al.</i> (and others)
5.	Fig	Figure
6.	Ft	Feet
7.	<i>i.e.</i>	id est (that is)
8.	M	Meter
9.	Mm	Milimetre
10.	N	North
11.	no.	Number
12.	P	Page
13.	sp.	Species
14.	SE	Standard Error
15.	sq.	Square
16.	<i>viz.</i>	Vi delicet (namely)
17.	°	Degree
18.	"	Seconds
19.	'	Minutes
20.	=	Equal
21.	%	Per cent
22.	/	Per
23.	±	Plus or minus
24.	&	And
25.	*	Asterisk
26.	$\Sigma$	Summation
27.	>	More than
28.	<	Less than
29.	≥	More than equal to
30.	H'	Shannon's index of diversity
31.	D	Simpson's index of diversity
32.	1/D	Simpson's reciprocal index
33.	J'	Pielou's evenness index

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**ABSTRACT**

The diversity of scarabaeid beetles was assessed using light traps and by collecting beetles directly from their host trees. The light trap studies were carried out at Badagaon and Barot during May to August, 2016. A total of 1819 beetles representing nine genera and 13 species were collected by light traps during the monitoring period. The subfamily Melolonthinae is represented by seven species and maximum species diversity was recorded in genus *Melolontha* having four species. The cumulative trap catch of scarabaeid beetles was maximum in July (35.8-36.74%). *Trichoserica umbrinella* was the most predominant species comprising 70.42 to 86.8 per cent of total catch. Other three species which accounted for 5.63-6.11 per cent at Badagaon were *Anomala rufiventris*, *Melolontha cuprescens* and *Mimella passerinii*. At Barot, *M. passerinii*, *B. coriacea*, *A. rufiventris* and *H. holosericeus* constituted 1.02-2.04 per cent on light trap. On host trees, 14 species belonging to seven genera were collected. *M. passerinii* was most preponderant species, and it contributed 24.77 per cent of total scarab beetles collected at Barot. At Badagaon, beetle activity was found to be very low during June to August, 2016. *T. umbrinella* was the most predominant species and it constituted 29.79 per cent of total beetle catch. *M. indica* and *B. coriacea* constituted 17.02 and 14.89 per cent of total beetle catch respectively. At Badagaon, *T. umbrinella* displayed decided preference for walnut, whereas *B. coriacea* was recorded chiefly on apple. The value of Simpson's index of diversity (D) was quite high (0.83-0.86), whereas Simpson's reciprocal index (1/D) was quite low (1.16-1.21). The values for Shannon index (H') at Barot and Badagaon were calculated to be 2.26 and 1.92. A comparison of light trap and host tree data revealed that *T. umbrinella* constituted 79.98 per cent on light trap, whereas on host trees, it constituted nearly 11.56 per cent of total catch. Contrary to this, *B. coriacea* and *M. passerinii* were more abundant species on host trees, but less abundant on light trap. To study the population of white grubs, soil sampling was done from January to December 2016. *M. virescens* was found to be the predominant species comprising about 80.0 per cent of the grub population in soil. During January and February, very low population of grubs was recorded in Chuhar valley because of downward movement of *M. virescens* grubs. There was significant increase in the activity of white grubs during April to September. In July, maximum population of white grubs was recorded at Badagaon with mean population of  $5.6 \pm 0.54$  grubs per ft<sup>3</sup>. At Barot,  $2.3 \pm 0.5$  grubs per ft<sup>3</sup> were recorded. In Chuhar valley, rajmash, potato and cabbage were found to be damaged by grubs of *M. virescens*. The plant infestation in rajmash and cabbage varied from 7.5 to 16.3 and 23.00 and 36.5 per cent, respectively. In potato, very high tuber infestation ranging from 16.0 to 32.1 per cent was recorded. The present study revealed that it was only the grubs of *M. virescens* which caused economic damage, whereas species like *T. umbrinella* which was taken in large numbers on light trap and host trees was of lesser significance.

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# 1. INTRODUCTION

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The superfamily Scarabaeoidea contains an immense number of species whose larvae live in the soil and are commonly known as white grubs. It constitutes a large distinct group of highly specialized beetles, which could easily be recognized by their lamellate antennae (Mehta *et al.* 2010). Since many species of white grubs are root feeders, they are also called as root grubs, but all white grubs are not root grubs. Most of the white grubs are similar in shape and colour and have fleshy curved bodies with brown heads and have well developed legs which are hardly used for locomotion (Mehta *et al.* 2010). They can be easily distinguished from similar looking grubs by the presence of two rows of minute hairs on the ventral surface of the last segment (Khan and Ghai 1974).

White grubs are chiefly found in grasslands feeding on roots of many plants, while others develop on decaying organic matter (Chandel *et al.* 2015a). They live concealed and suddenly increase their population in place having enough food and least disturbance of soil. White grubs are favoured by light soil, fibrous rooted plants and high particulate organic matter content and are not abundant in waterlogged, compacted, stony soil or land lacking vegetation (Mehta *et al.* 2008). Beetles usually remain unnoticed throughout the year and their appearance in large number occurs just after a break in monsoon for a month or two, and feed on the foliage of different fruit and forest trees. Many species are crepuscular or nocturnal, rarely seen by casual observers except when the beetles are attracted to light. Some are diurnal, occasionally found feeding on flowers and fruits. There are many destructive species of white grubs which occur singly or in association and destroy crops in different regions of Himachal Pradesh.

Among the soil macrofauna, the white grubs form a major component both in number of species and diversity of habits in Indian sub-continent (Veeresh 1988). The world fauna of white grubs exceeds 30,000 species (Mittal 2000), and the maximum number occurs in the tropical areas of world, particularly in African and Oriental regions. The fauna of Indian sub region is very rich and diverse, but it is yet to be fully explored (Mishra and Singh 1999). Ali (2001) reported that family Scarabaeidae represents about 2500 species from Indian sub region.

In India, white grubs are pests of national importance and their economic importance is primarily due to feeding activity of third instar grubs (Mehta *et al.* 2010).

This is a polyphagous pest both in grub and adult stage and inflicts heavy damage on various fruit/forest trees, their nurseries, vegetables and field crops (Chandel and Kashyap 1997). In many parts of north western Himalaya, larvae of Melolonthinae cause extensive damage to roots of grasses, legumes, small fruit plants, shrubs and trees. Larvae of greatest economic importance belong to the tribe Melolonthini (Ritcher 1958). Grubs prefer to feed on fibrous roots for normal growth and the crops with tap root system suffer more as compared to adventitious root system. In general, underground parts of all plants are subjected to grub feeding and show different types of damage (Yadava and Vijayvergia 2000). The symptom of injury is root pruning by grubs showing varying degrees of wilting, yellowing, browning and eventually death. In crops like potato and ginger, large holes are made in the tubers/rhizomes rendering them unfit for marketing (Mehta *et al.* 2010).

More than 35 species of scarabaeid beetles have been reported to cause damage to fruit trees in Himachal Pradesh (Bhalla and Pawar 1977), out of which *Holotrichia longipennis* Blanchard, *Brahmina coriacea* (Hope), *Holotrichia sikkimensis* Brenske, *Anomala dimidiata* (Hope), *Melolontha* spp and *Lepidiota stigma* Fabricius are the key pest species attacking different crops in Himachal Pradesh (Chandel *et al.* 2010). In Himachal Pradesh, adults of *B. coriacea*, *H. longipennis*, and *A. lineatopennis* severely attack the leaves of apple (Mehta *et al.* 2008). In Uttarakhand, adults of *H. longipennis* feed on the leaves of walnut, chestnut, apple and plum (Mishra 2001).

The problem of white grubs is quite serious in high hills where potatoes are grown during summer season as rainfed crop under long day conditions (Misra and Chandel 2003). In Himachal Pradesh, grubs of *B. coriacea*, *H. longipennis* and *Melolontha* spp cause widespread damage to potato, rajmash, peas, ginger, cabbage *etc.* In potato, the tuber damage often exceeds 50 per cent in endemic areas (Chandel *et al.* 2003). In forest nurseries up to 30 per cent infestation due to grubs of *B. coriacea* has been reported in mid hills of Himachal Pradesh. In Chuhar valley, white grubs are highly destructive in crops like potato, peas and rajmash and their infestation often exceeds 30 to 40 per cent (Chandel *et al.* 2015a). The information on scarabaeid fauna of Kullu and Shimla region is available to some extent (Barwal, 1998; Kumar *et al.* 2005; Kumar *et al.* 1996; Chandel *et al.* 1997; Pathania *et al.* 2015a), but in Chuhar valley, no systematic studies have been carried out as far as white grubs are concerned. Most of the species occurring in Chuhar valley are still unidentified and there exists lot of variation in their behaviour and biology. This poses problem in development of integrated pest management programme against this pest. To

combat the burgeoning problem of white grubs it is imperative to understand species distribution in the region and also their hosts so that a focused strategy may be formulated for their management. Keeping these points in view, it was planned to undertake the present study with the following objectives:

**Objectives:**

- i) To identify the white grubs of Chuhar valley.
- ii) To study the relative abundance and population build up of predominant species of white grubs.
- iii) To study the damage caused by white grubs in different crops.

## 2. REVIEW OF LITERATURE

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In India, the insect fauna appears to be diverse as can be inferred from the published literature. Every exploration of a new habitat or a slightly intensive sampling of a common habitat, continues to yield new faunal elements. India accounts for 6.08 per cent entomofauna of the total species recorded so far in the world (Ali 2001). In India, Coleoptera contributes 4.37 per cent of the total world beetle fauna (Ghosh 1996), and the superfamily Scarabaeioidea accounts for 8.5 per cent of total world scarab beetles (Sengupta *et al.* 1991; Ghosh 1994, 1996). The white grubs in Himachal Pradesh show varied zoo geographical links with the fauna of other regions. Most of the representatives generally show their affinity with the fauna of various adjoining sub-regions like Indo-China and Indian Peninsula and very few species also share the distribution of Palaerctic, Australian and European regions (Chandel *et al.* 2015a). In this chapter, we have reviewed the work on distribution of scarabaeid beetles mainly from the Indian sub-continent.

### 2.1 Relative abundance and diversity of scarabaeid beetles on light traps

Insects are positively phototropic and use of light traps for insect catches produce valuable faunistic data. The light trap studies indicate biodiversity of an area and show period of maximum activity of insects. Nath *et al.* (1978) carried out light trap studies in Uttar Pradesh and reported maximum attraction of adults to light traps between 20:30 to 22:30 hours and the peak attraction period was recorded to be 21:30 hours. When light traps were placed near *neem* trees, maximum beetles were collected. Tripathi and Gupta (1985) collected 33 species of beetles at Chaubattia in Uttarakhand from June 1983 to September 1985. On the basis of mean number of beetles collected, predominant species were *Adoretus bimarginatus* Ohaus (101.66), *A. versutus* Harold (150.0), *Anomala rufiventris* Redtenbacher (116.33), *Melolontha furcicauda* Ancy (73.66) and *Hilyotrogus holosericea* Redtenbacher (233.66). Shah and Garg (1988) carried out light trap studies from April to October to determine the peak emergence of scarabaeid beetles at Hawalbagh in Almora district of Uttarakhand. *Anomala dimidiata* Hope, *H. longipennis*, *Mimela fulgidivittata* Blanchard were among the predominant beetles collected on light trap. Maximum catch of *H. longipennis* (103 beetles) was recorded during third week of June.

In Nilgiri hills of Tamil Nadu, there was 53 per cent emergence of *Holotrichia excisa* Moser, and 82 per cent emergence of *Holotrichia repetita* Sharp within a fortnight of first rain on light trap (Chandramohan and Nanjan 1991).

In Himachal Pradesh, Devi *et al.* (1994) identified 20 species of beetles on light trap between March to October during 1992-93 at Palampur. *Anomala lineatopennis* Blanchard was abundant in June, whereas *Holotrichia cavifrons* Brenske appeared in July. Bhagat and Kashyap (1997) recorded 10 species of beetles belonging to six genera on light trap from May to September at Palampur. The beetles of *Holotrichia sikkimensis* Brenske and *H. longipennis* were recorded in May on light trap and their emergence continued till September. The relative abundance of these two species was recorded to be 40.35 and 12.74 per cent, respectively. In a similar study, Chandel *et al.* (1994b) collected 16 species of defoliating beetles showing photo-positive response at Solan. Maximum percentage of the total catch in a year was for that of *Brahmina coriacea* Hope (13.40-18.90%), followed by *H. longipennis* (11.20-13.20%). *Holotrichia microsquamosa* and *Holotrichia seticollis* Moser comprised 7.6-7.8 per cent and 7.8-8.5 per cent of total catch, respectively. *H. seticollis* appeared from May to June, *H. microsquamosa* from June to August, and *H. longipennis* appeared from June to September on light trap. Kumar *et al.* (1996) also recorded 16 species during 1992-93 on light trap in Kullu valley, between March to September. Maximum beetles were represented by *Maladera insanabilis* Brenske (38 beetles), followed by *B. coriacea* (29 beetles), *Adoretus* sp. (22 beetles) and *Phyllognathus dionysius* Fabricius (18 beetles). **Barwal (1998) studied the diversity of scarabaeids at Katrain in Kullu valley of Himachal Pradesh, and reported occurrence of *Brahmina crinicollis* Burmeister, *H. longipennis*, *M. furcicauda*, *Melolontha nepalensis* Blanchard, *A. rufiventris*, *Adoretus lithobius* Ohaus, *Anomala stoliezkoe* Ohaus, *Popillia cyanea* Hope, *Oryctes nasicoris* Linnaeus, *Clinteria spilota* Hope, and *Gametis jucunda* Faldermann. In general, emergence of the beetles from soil was recorded from June to September at Katrain.**

In Gharwal region of Uttarakhand, light trap studies were conducted at Tehri, Chamoli, and Uttarkashi starting from May to September during 1990-91. Of the 25 species of beetles recorded in Gharwal region, *H. longipennis* was predominant species occurring from valley areas to high hills ranging from 800 to 2200 m amsl (Mishra and Singh 1996). In Kumaon region, 14 species of beetles were captured on light trap during

1995-96, and *A. dimidiata* was the predominant species. *H. seticollis* and *H. longipennis* constituted 15.73 and 7.56 per cent of total catch, respectively (Mishra and Singh 1997).

Mishra and Singh (1999) installed a light trap with 20 watt fluorescent tube at Ranichauri in Uttarakhand. They captured 26 species of scarabaeid beetles on light trap with a total catch of 1238 beetles. *H. longipennis* constituted 39.57 per cent of total catch, followed by *B. coriacea* (17.85%).

Sushil *et al.* (2004) monitored seasonal abundance of beetles at Almora by using light traps. Maximum and minimum temperature, relative humidity and rainfall during July produced maximum catches of beetles. Higher temperature during May to June, low temperature during December, January and February favoured beetle emergence, whereas rains during April, October and November reduced beetle emergence. According to Sushil *et al.* (2006), *H. seticollis* constituted 9.08 and 8.80 per cent of total catch on light trap during 2002 to 2004 in Kumaon hills.

Viraktamath and Kumar (2005) made comparison of two types of light traps in attracting insect-pests of economic importance at Dharwad. Fine trap (India) fitted with 120 watt bulb producing bluish light attracted three times more beetles of *Anomala* spp. and *H. serrata* as compared to modified ICRISAT light trap fitted with 160 watt mercury vapour lamp emitting white light. The joint trap catch of *Anomala varicolor* (Gyllenhal), *A. dorsalis*, *Anomala singularis* Arrow was 234.0 in fine trap (India) over 70.63 beetles in modified ICRISAT trap. The respective trap catch for *H. serrata* was 133.0 and 40.96 beetles. Ashfaq *et al.* (2005) studied the effect of different colours on light trap catches. The highest number of insects was observed in container placed under the black light (UV light), while the lowest in that of red light. The common insect orders frequented among all colour lights were, Diptera, Coleoptera and Lepidoptera.

Kumar *et al.* (2007) carried out light trap studies at three locations in Kullu valley of Himachal Pradesh and captured 29 species of defoliating beetles. *H. longipennis*, *B. coriacea*, *Maladera* sp., *A. dimidiata*, *Adoretus simplex* Sharp and *Adoretus* sp. were among the predominant beetles species. The trap catch for *H. longipennis* ranged from 4.22-18.43 beetles at different locations over different years. Irrespective of species, maximum percentage of total catch was recorded in June-July. In Haryana, emergence of beetles begins during 18<sup>th</sup> standard week after the first pre-monsoon showers of the season and maximum emergence was recorded in the month of July. A total of 1998 beetles

belonging to 13 species were captured on light trap. *H. consanguinea* being most predominant, followed by *H. serrata* (Dashad *et al.* 2008). Ramamurthy *et al.* (2010) used Mercury, Black and Ultra-violet light traps for insect capture and found that Coleopterans dominate the catches followed by Hemipterans, Hymenopterans and Lepidopterans. Black light was more efficient for Coleoptera, Orthoptera, Isoptera, and Dictyoptera.

In Chhattisgarh, Chandra and Gupta (2012) conducted biodiversity surveys for scarabaeids at many locations of Achanakmar-Amarkantak Biosphere Reserve in the years, 2004-2008. The specimens were collected using light trap with 160 watt mercury bulb. They captured 426 phytophagous scarabs. The six most common species were *Anomala ruficapilla* Burmeister (31.52%), *Apogonia proxima* Waterhouse (19.5%), *Anomala biharensis* Arrow (9.41%), *A. bimarginatus* (8.70%), *A. rugosa* (5.88%) and *A. varicolor* (5.64%). Bhawne *et al.* (2012) used light traps to collect beetles from north western ghats of Kolhapur district of Maharashtra. They captured 18 species from six sampling sites and the most predominant species were *Holotrichia karschi* Brenske, *Holotrichia fissa* Brenske, *H. serrata*, *Maladera castanea* (Arrow), *Adoretus lasiopygus* Burmeister and *Adoretus versutus* Harold.

Dhoj *et al.* (2009) monitored the abundance and diversity of scarabaeid beetles on light traps in Nepal. A total of 4708 scarabaeid beetles of 29 genera and 77 species were trapped. The five most common species were *Adoretus coronatus* Burmeister, *Maladera thomsoni* (Brenske), *Anomala bilobata* Arrow, *Holotrichia nigricollis* Brenske and *A. dimidiata*. In genus *Holotrichia*, six species were collected with *H. nigricollis* as most predominant constituting 5.39 per cent of total catch, followed by *H. seticollis* (3.59%), *H. sikkimensis* (2.40%), *Holotrichia pruinosa* Wiedemann (1.20%) and *Holotrichia anthracina* Brenske (0.60%). White grubs are economically important pests in Nepal, while their management strategy is limited. Dhoj *et al.* (2012) conducted a survey to study the abundance and distribution of white grubs in Makawanpur, Tanahu and Chitwan districts of Nepal during June–July 2010. The dominant species in Chitwan were *Anomala dimidiata* Hope (24%) followed by *Maladera affinis* Blanchard (23.75%), *Anomala varicolor* (Gyllenhal) Rutelinae (23%), *Heteronychus lioderus* Redtenbacher (14%) and *Holotrichia* spp (7%).

Gite *et al.* (2015) recorded 16 species under eight genera from Sangli, Satara, Solapur, and Kolhapur districts of Maharashtra. The most predominant species was *Holotrichia serrata* comprising 26.55 per cent of total catch, followed by *Phyllognathus*

*dionysius* with relative abundance of 16.58 per cent. The species *Adoretus versutus*, *Anomala ruficapilla*, *Sophrops karschi* were newly recorded in western Maharashtra.

Pathania *et al.* (2015b) conducted a study on preliminary ecology of invasive scarabaeid species of north-western Himalayan region. A total of 85 invasive species phytophagous scarabaeids under 25 genera, belonging to five subfamilies of family Scarabaeidae were recorded. Among these, 55 species were recorded on light trap and 78 species occurred on host trees. Melolonthinae being most dominated subfamily representing 13 genera and 51 species, Rutelinae represents 24 species belonged to four genera. *B. coriacea*, *H. longipennis*, *A. phthisica*, *M. insanabilis* and *Schizonycha* sp. 1 were recorded as the leading species of north western Indian hills. *B. coriacea* and *H. longipennis* were the most dominant and very common species in terms of number and damage potential. The scarabaeid species composition (richness and diversity) was significantly higher in the mid hill areas of Himachal Pradesh as compared to higher hills. Palampur area situated in the mid hills with long rainy seasons had the maximum Shannon Weiner index (3.03) with 39 species recorded from the region.

## 2.2 Relative abundance and diversity of scarabaeid beetles on host trees

The scarabaeid beetles become active during May-June and feed on foliage of different fruit/forest trees (Chandel *et al.* 2015a). Chandel and Kashyap (1997) reported that chafer beetles are quite serious and regular pests of fruit trees in hilly parts of north-western Indian sub-continent and about 35 species have been reported to cause damage on fruit/forest trees in Himachal Pradesh. In Rajasthan, Srivastava and Khan (1963) recorded adults of *Holotrichia insularis* Brenske feeding on the foliage of 13 different plants including *Moringa oleifera* Lam., *Carandus plum* Linnaeus, *Psidium guajava* Linnaeus, *Azadirachta indica* A. Juss., *Eugenia jambolana* Lam., *Lawsonia inermis* Linnaeus, *Zizyphus jujube* Mill., *Tamarindus indica* Linnaeus, *Acacia Arabica* Lam., *Punica granatum* Linnaeus, *Mangifera indica* Linnaeus, *Grewia asiatica* Linnaeus and *Crataeva religiosa* Forst. Amongst these host plants, adults showed a clear cut preference for *M. oleifera*.

Sharma and Bhalla (1964) reported *L* (= *H.*) *longipennis*, *L* (*B.*) *coriacea*, and *L* (*B.*) *crinicollis* Burmeister, feeding on apple, apricot, peach, plum and other stone fruits in Himachal Pradesh during June-July. Sharma *et al.* (1971) recorded *B. coriacea*, *H. longipennis*, *A. flavipes*, *A. lineatopennis*, *A. rufiventris* and *H. holosericeus* causing

damage to fruits and foliage of apple, pear, plum, cherry, peach and apricot during May-June at Kwagdhara. Bhalla (1972) reported that *B. coriacea*, *H. longipennis* and *A. dimidiata* occur all over Himachal Pradesh. In addition to fruit damage, *H. longipennis* beetles cause complete defoliation of pome and stone fruits in endemic areas.

During October 1969, falsa bushes, *G. asiatica* at PAU, Ludhiana were reported to be damaged by scarabaeid beetles. The beetles responsible for causing this defoliation were identified as *Anomala bengalensis* Blanchard, *Apogonia uniformis* Blanchard, *H. consanguinea* and *Schizonycha* sp. The beetles completely devoured young leaves, whereas the old leaves were damaged on the margins only (Verma and Bindra 1972). Verma (1975) noticed an outbreak of *H. longipennis*, *A. ruficapilla*, *Anomala dorsalis* Fabricius, *A. bengalensis* and *H. problematica* in Haryana. These beetles severely defoliated peach trees.

In Chaubattia area of Uttarakhand, *A. versutus*, *A. dimidiata*, *A. polita*, *A. lineatopennis*, *A. rugosa*, *A. rufiventris*, *H. holosericeus*, *Popillia complanata* Newman, *Popilla cyanea* Hope, *B. coriacea*, *L. longipennis*, *M. furcicauda*, *M. indica*, *Catharsius molasus* and *Xylotrupes gideon* Guerin-Meneville were recorded to feed actively on apple, peach, plum, apricot, pear, rose and walnut from April to August. Peak period of abundance was from first week of June to fourth week of July for *H. longipennis* (Gupta *et al.* 1977). Bhalla and Pawar (1977) reported *H. longipennis* as most common species of white grubs in Himachal Pradesh soils. It occurs all over the state causing severe defoliation of pome and stone fruits in addition to attacking the fruits (Bhalla 1972). In Kumaon hills of Uttar Pradesh, a survey was conducted from 1972-78, to identify insect-pests of fruit crops. Among scarabaeids, *Brahmina* spp., *L. longipennis*, *Melolontha* spp., *A. versutus*, *Anomala* spp., and *Serica* spp. were found to defoliate apple, apricot, walnut and cherry (Joshi and Joshi 1980).

Shah and Garg (1985) conducted survey in Kumaon hills of Uttarakhand and recorded *H. seticollis*, *Lepidiota* sp., *Anomala xanthoptera* Blanchard, *Mimela fulgidivittata* Blanchard, *Oxycetonia* sp. and *Clinteria spilota* (Hope) defoliating apricot, peach, plum, apple and other temperate fruits. Out of these, *H. seticollis* and *A. dimidiata* were serious, whereas other species were either moderate or sporadic in their occurrence. Sharma and Tara (1985) conducted survey on insect-pests of mulberry in Jammu region of Jammu & Kashmir. Among scarabaeids, *S. ruficollis*, *M. insanabilis*, *Lepidiota bimaculata* (Saunders) and *Holotrichia* sp. were recorded as major pests of mulberries. Mahal *et al.*

(1991) studied adult emergence of *H. consanguinea* in Punjab. The adults settled on mango, *Iberis amara* and *Lagerstroemia indica* for mating immediately after emergence.

Chandel *et al.* (1997) collected 21 species of defoliating beetles on apple, pear, plum and apricot at Solan. *B. coriacea*, *H. seticollis* and *H. longipennis* were the leading species comprising 42.5 - 51.7, 14.3 - 20.1 and 8.2 - 19.9 per cent of total catch during 1990 - 1991, respectively. On olive, *H. problematica* was predominant (40.9 - 49.4%) with peak activity in first fortnight of April. Maximum activity of *H. longipennis* was observed from first week of July to first week of August, whereas *H. seticollis* had peak activity on fifth June. *Thuja orientalis* (Linn.) was also observed to be an important host of beetles of *B. coriacea* and *H. longipennis* at Nauni in Solan district of Himachal Pradesh (Chandel *et al.* 1994a).

In Garhwal hills, peak emergence of *H. longipennis* occurs in fourth week of June and adults congregate in large numbers on *Rubus ellipticus* for mating and feeding (Mishra *et al.* 1998). According to Singh *et al.* (2002) atleast 57 species are known to occur in Uttarakhand and the predominant species were *A. dimidiata*, *H. longipennis* and *H. seticollis*. Important hosts of adult beetles include apple, pear, peach, plum, apricot, cherry, almond, walnut, ber, guava, *karanda*, mango, *jamun*, phalsa, grape, pomegranate, chestnut and other plants. Singh *et al.* (2003) sampled 51 host plants to collect defoliating beetles from Tehri, Uttarkashi, Pauri and Chamoli districts of Uttarakhand. *H. longipennis*, *B. coriacea*, *A. lineatopennis*, *A. dimidiata* and *Pentodon bengalense* Arrow were observed to be occurring in tropical, subtropical and temperate zones. *H. seticollis*, *A. lasiopygus*, *Pachyrhinadoretus funtatus*, *A. varicolor* and *A. rugosa* occurred commonly in tropical and subtropical locations. *Heterorychus lioderes* Fabricius was tropical in distribution. *Sophrops problematica* (Fabricius) and *Oxycentonia versicolor* were found only in subtropical zone, whereas *Melolontha nepalensis* Hope was exclusively a temperate species.

Chandra (2005) reported about 88 species of phytophagous scarabaeids from Himachal Pradesh. In genus *Holotrichia*, 11 species viz. *H. problematica*, *H. anthracina*, *H. semihirta*, *H. sikkimensis*, *H. serrta*, *H. longipennis*, *H. gradalatifrons*, *H. nubiliventris*, *H. batillariae* and *H. occipitalis* have been collected. *H. longipennis* was recorded in Chamba, Kinnaur, Shimla, Sirmaur and Solan districts, whereas *H. sikkimensis* occurred only in Chamba and Sirmaur districts. *H. problematica*, *H. anthracina* and *H. serrta* were confined to Solan district. *H. gradalatifrons*, *H. problematica*, *H. nubiliventris*, and *H.*

*occipitalis* were recorded only in Kullu district. Bhagat and Singh (2006) conducted survey to identify the pests associated with seabuckthorn in Lahaul valley of Himachal Pradesh. It was found that beetles of *B. coriacea* and *H. longipennis* caused extensive damage to foliage.

Kumar *et al.* (2006) studied faunal composition of scarabaeids on rose and recorded 13 species from different parts of Bangalore. *H. seticollis*, *S. ruficollis*, *A. versutus* caused severe defoliation of leaves, whereas *A. bengalensis* damaged flowers severely. *Hylamorpha elegans* Burmeister, *Oxycentonia versicolor* Fabricius, and *Popillia cinarea* Hope also damaged flowers. Rose, apple, *Delbergia*, guava and mango were the other hosts on which the scarabaeids were recorded. The population of *H. serrata* was around 8.14-8.66 per cent on rose (Kumar *et al.* 2009).

Anitha *et al.* (2006) reported that *H. reynaudi* predominated in the central deccan area, while *H. serrata* was most abundant in the south and west. A new undescribed, *Holotrichia* sp. near *H. consanguinea* was collected in south and south-west of Hyderabad in mixed population with *H. reynaudi*. *H. reynaudi* was collected predominantly from ber and *Acacia*, whereas *H. serrata* was collected almost exclusively from *neem*. In Gujarat, Kapadia *et al.* (2006) collected 14 species of scarabaeid beetles from *neem*, *Acacia* sp and ber trees. The beetles were identified as *Holotrichia fissa* Brenske, *H. consanguinea*, *H. serrata*, *S. ruficollis*, *Adoretus bicolor*, *Adoretus deccanus* Ohaus, *A. versutus*, *A. bengalensis*, *A. dorsalis*, *A. varicolor*, *Apogonia rauca*, *Phyllognathus* sp. and *Maladera* sp. *A. rauca* was predominant (80.0%), followed by *H. consanguinea* (12.0%).

In Kinnaur district of Himachal Pradesh, sampling of fruit trees in Sangla valley revealed the abundance of nine species of beetles. *B. coriacea* and *H. longipennis* were the predominant species comprising 39.53 to 46.38 and 31.88 to 41.49 per cent of the total catches, respectively, on walnut, apple and apricot (Sood *et al.* 2009). Kulkarni *et al.* (2009) reported occurrence of *H. rustica* and *Holotrichia mucida* (Gyllenhal) from Nagpur in Central India. The beetles emerged after pre-monsoon showers and the feeding/mating was recorded on *Zizyphus jujuba*, *Zizyphus mauritiana* Lam., *Zizyphus xylopyra* Willd, *Acacia leucophloea* (Roxb.) and *Acacia catechu*.

Chandel *et al.* (2010) conducted survey during 2005-2009 in Himachal Pradesh and reported that beetles of *H. longipennis* occurred predominantly on 'toon' at Palampur. *B. coriacea* constitutes 90 per cent of the total beetle population, whereas in Uttarakhand, *H. longipennis* constitutes 55.80 per cent of total population (Mehta *et al.* 2010). Kumar *et al.*

(2009) investigated the faunal composition of scarabaeids associated with rose cultivation in Bangalore. They recorded thirteen species belonging to nine genera representing three sub families viz. Melolonthinae, Rutelinae, and Cetoniinae. Among the identified species, *Holotrichia serrata*, *Schizonycha ruficollis*, *Anomala bengalensis*, and *Adoretus versutus* were found to be the most dominant leaf feeders and *Maladera* sp. and *Apogonia ferruginea* was found to be infesting more on flowers on rose. The degree of leaf damage caused by *H. serrata*, *S. ruficollis*, and *A. versutus* were significantly more on rose leaf irrespective of presence or absence of flowers.

Theurkar *et al.* (2012) studied the distribution and abundance of white grubs of Khed Taluka in western Ghats of Maharashtra. *H. consanguinea*, *H. serrata*, *H. fissa*, *Leucopholis lepidophora* Blanchard and *Anomala* were found to be distributed in this area. The adults were collected from *neem*, babul, ber and *khair*. The *H. serrata* was most abundant species found in Khed Taluka which form a part of north western Ghats in Maharashtra. *H. serrata* beetles were recorded mainly on '*neem*', whereas *H. fissa* adults were found only on ber.

In Kolhapur district of Maharashtra, a total of 29 species of beetles were identified. *L. lepidophora*, *H. fissa*, *H. karschi*, *H. serrata*, *A. versutus*, *A. lasiopygus*, *A. bengalensis* were reported as serious pests of agricultural, horticultural and silvicultural crops (Bhawane *et al.* 2012).

### **2.3 Distribution and abundance of white grubs in different crop-ecosystems**

First major epidemic of white grubs in India was reported in sugarcane from Bihar during 1956. The grubs of *H. consanguinea* were reported to feed mainly on sugarcane and '*Kans*', however, damage to groundnut was also noticed. In sugarcane, the damage was about 80 per cent (Gupta and Avasthy 1956). In Rajasthan, *H. consanguinea* is the dominant white grub species. During 1965, this grub was reported causing 21.50 per cent loss to groundnut crop from Lalsot area of Rajasthan (Joshi 1967). Vasu (1969) collected *Lachnosterma (Holotrichia) consanguinea* grubs feeding on the roots of castor at IARI, New Delhi and the incidence was reported to be 64.70 per cent. Nirula (1958) first reported the incidence of *Leucopholis coneophora* Burmeister from Kerala on coconut. As a result of grub's activity, the young and established roots were killed and the nut production was severely affected.

The problem of white grubs is quite serious in hilly states of India where potatoes are grown during summer season as rainfed crop under long day conditions (Misra and Chandel 2003). First record of white grubs causing damage to potato in India is from Himachal Pradesh by Sharma and Bhalla (1964). They mentioned two species viz. *B. coriacea* and *H. longipennis* causing damage to several crops including potato in Himachal Pradesh. The grubs of *B. coriacea* appeared in epidemic form in potato in Shimla hills during 1980's and there was up to 85 per cent tuber damage at Potato Development Station, Shillaroo located in Shimla hills of Himachal Pradesh (Misra and Chandel 2003).

In Karnataka, several species of white grubs are known to damage a wide range of crops and the most leading species is *H. serrata* (Khan and Ghai 1974). This pest is more predominant in Central and South India. Veeresh (1974) reported it as a serious pest on all cultivated crops like cereals, millets, pulses, vegetables, oilseeds, sugarcane and tobacco in all districts of Karnataka. Joshi *et al.* (1969) reported occurrence of *H. serrata* as a pest of tobacco at Central Tobacco Research Institute, Kateru (Andhra Pradesh). In Maharashtra, Raodeo (1974) reported *H. serrata* grubs feeding on the roots of jowar, bajra, sugarcane, groundnut, moong, arhar, chillies, paddy and wheat. In Kerala, tubers of *Dioscorea alata* and *D. esculenta* were damaged by grubs of *L. coneophora*. The damage was reported to be 9.07 and 4.03 per cent, respectively, and such tubers were not acceptable to the consumers (Lal and Pillai 1977).

Bhattacharjee and Bhatia (1981) observed larvae of *H. consanguinea* causing serious damage to soybean in Maharashtra and New Delhi. Sharma and Shukla (1991) also recorded grubs of *H. consanguinea* on soybean in Madhya Pradesh. In Sehore area of Madhya Pradesh, infestation of *H. consanguinea* in soybean ranged from 15.90-58.20 per cent during September. As a result of root feeding by grubs, there was reduction of 27.84 per cent in grain yield (Singh and Singh 1994). In Punjab, heavy losses occurred due to incidence of white grubs in groundnut. Bakheta (1982) estimated avoidable losses ranging from 28.74 to 40.34 per cent in groundnut due to grubs of *H. consanguinea*.

Mammen (1981) reported infestation of *S. ruficollis* on sugarcane in Alleppey district of Kerala. The incidence was maximum during March-April on 1 to 3 month old seedlings. In eastern parts of Uttar Pradesh, the white grubs (mainly *Anomala* spp.) were recorded from sugarcane, groundnut, bajra, sunhemp and sesame fields (Nath and Singh 1981). Patel *et al.* (1982) conducted survey in summer groundnut in Kupadwanj Taluka (Gujarat) and found infestation of *Maladera (Autoserica) nathani* Frey with an average of

1.50 grubs/plant. These larvae were also observed feeding on the roots of castor, maize, sweet potato, fennel and brinjal.

In Uttarakhand, severe outbreaks of white grubs mainly *A. dimidiata barbata*, *H. seticollis* and *H. lioderes* occurred over large areas in paddy and more than 50 per cent of the paddy crop was damaged. Maximum damage was recorded in August (Garg and Shah 1983).

Patil *et al.* (1986) recorded larvae of *L. lepidophora* from sugarcane and rice fields for the first time in Maharashtra. The damage was caused by third instar larvae up to the end of September and in heavily infested fields, 14 to 15 larvae/sugarcane stool were observed. In Marathwada region of Maharashtra, *H. serrata*, *P. dionysius*, *O. rhinoceros*, *O. versicolor* and *C. orientalis* are the economically important species of white grubs which attacked roots of various crops including wheat, groundnut, potato, tomato and sugarcane (Raodeo and Deshpande 1987).

Rajendran and Chandla (1986) recorded high incidence of grubs of *B. coriacea*, *L. longipennis* and *M. indica* to potato in certain villages of Shimla, Mandi and Kullu districts of Himachal Pradesh. Veeresh (1988) reported that 10 to 20 per cent of the tubers in the harvested potatoes in upper Shimla hills of Himachal Pradesh are half eaten tubers due to damage of white grubs. Chandla *et al.* (1988) also reported that potatoes are being severely attacked by *B. coriacea* grubs in Shimla hills of Himachal Pradesh and found 56.30 per cent tuber damage on number basis. Misra and Chandla (1989) reported that eight species of white grubs *viz.* *A. dimidiata*, *A. polita*, *A. rugosa*, *L. longipennis* and *B. coriacea* are the predominant species in hilly tracts where potatoes are grown during summer season as rainfed crop. Misra (1995) recorded incidence of white grubs in potato in different villages of Shimla and Sirmaur districts of Himachal Pradesh. The tuber damage ranged from 15.50 to 80.00 per cent. Maximum damage was recorded at Shillaroo and lowest damage occurred at Shimla. In Sirmaur district, 50.9 per cent tuber damage was recorded. Besides potato, the grubs of *B. coriacea* also damaged ginger in Shimla district of Himachal Pradesh. The grubs produced large, deep and circular holes on damaged rhizomes and the per cent damage varied from 5.7 to 26.5 per cent at harvest (Misra 1992).

Gowda *et al.* (1990) carried out a survey of the scarabaeids (*Leucopholis* spp.) in arecanut plantations in hill region of Karnataka during 1988. The results indicated that the white grubs were first noticed in 1964 and by 1988, 47.12 per cent plantations were affected. The reduction in average yield was estimated at 101.12 kg/acre. In western Maharashtra, *L. lepidophora* was observed causing damage to 25 to 100 per cent of

sugarcane, paddy, maize, groundnut and vegetables. In summer groundnut, plant mortality at different locations ranged from 56 to 89 per cent with an average of 80.56 per cent (Adsule and Patil 1990).

Nath and Singh (1987) found 14 species of white grubs attacking groundnut in eastern Uttar Pradesh with *Apogonia* spp, *S. ruficollis* and *A. ruficapilla* being the most prevalent. Deol and Sekhon (1993) recorded larvae of *Maladera* sp. feeding on 3 to 4 week old wheat seedlings in Punjab for the first time. Kumawat and Saxena (1993) evaluated arhar, pearl millet, chilli, cowpea, groundnut and gaur for their relative tolerance to the grubs of *M. insanabilis* in Rajasthan. Groundnut was found to be least tolerant crop followed by chillies and pearl millet. Maximum tolerance and least damage were recorded in arhar. In Debijhora (West Bengal), the grubs of *Rhinyptia meridionous* Arrow damaged young rhizomes and roots of *Boehmeria nivea*. The grubs were found up to a depth of one meter (Pandit 1995). During a survey of vegetable pests in Kumaon hills of Uttarakhand, *A. rufiventris* was recorded for the first time as a pest of brinjal (Arif and Joshi 1994). In Jammu, the incidence of *Anomala* and *Adoretus* grubs was recorded in tomato (Bhat *et al.* 1994).

Mishra and Singh (1996) recorded population of white grubs at two locations in Uttarakhand. During August, very high population of grubs was recorded at Gwaldam (19.8 grubs/pit) and Ranichauri (11.2 grubs/pit) in potatoes and barnyard millet, respectively. In Uttarakhand, the white grubs pose serious problem at elevations ranging from 600-2000 meters. Three species *viz.*, *A. dimidiata*, *H. longipennis* and *H. seticollis* are predominant in the state, damaging almost all vegetable crops like cabbage, cauliflower, brinjal, tomato, capsicum, cucurbits, okra, pea, potato, garlic, and ornamentals *viz.*, rose, carnation, gladiolus, chrysanthemum and marigold grown during August-April (Singh *et al.* 2002). Singh *et al.* (2003) recorded the incidence of *H. longipennis* in various rainy season crops under different farming situations of Uttarakhand. Maximum damage ranging from 5.67 to 65.16 per cent occurred under mid hill farming situations. The observations were recorded in 15 crops and severe infestation was noticed in upland rice, barnyard millet, finger millet, potato, and chillies.

Padmanaban and Daniel (2003) reported *L. burmeistri* as major pest of arecanut plams in Karnataka and Kerala causing significant yield losses. Grub feeding on roots resulted in yellowing of leaves and stem tapering. In Satpura plateau of Madhya Pradesh, the roots of *Withania somnifera* Linnaeus were damaged by grubs of *H. serrata* for the first

time. The grubs damaged roots and rootlets and about 20 per cent incidence of this pest was recorded (Meshram 2005).

In Paonta valley of Himachal Pradesh, strawberry c.v. Chandler was attacked by grubs of *H. insularis* (Singh *et al.* 2004). Kumar *et al.* (2005) identified the species of white grubs associated with maize and paddy in Kullu and Mandi districts of Himachal Pradesh. It was revealed that *M. furcicauda*, *M. nepalensis*, *A. dimidiata*, *A. rufiventris*, *A. lineatopennis*, *P. dionysius*, *Heteronychus robustus* Arrow, *H. longipennis*, *X. gideon* and *B. coriacea* caused damage in maize. In upland paddy, *B. coriacea*, *Maladera* spp, *H. robustus*, *A. rufiventris* and *Adoretus* spp. were found associated. In maize crop, on an average 28.53 and 36.58 per cent plant damage was recorded in Kullu and Mandi districts with mean population of 6.70 and 7.30 grubs/m<sup>2</sup>, respectively. The respective damage recorded in paddy was 22.42 and 16.40 per cent.

Anitha *et al.* (2006) studied the distribution and abundance of white grubs on groundnut in southern India. *Holotrichia* spp especially *H. reynaudi* and *H. serrata* were the major species associated with groundnut. A new undescribed *Holotrichia* sp near *H. consanguinea* was collected in south and south west of Hyderabad in mixed populations with *H. reynaudi*. In survey data, densities of *Holotrichia* larvae were highly correlated with the percentage of damaged groundnut plants. In sub-Himalayan tarai region of West Bengal, two species of white grubs viz., *A. varicolor* and *A. commonalis* were found to cause considerable damage to roots of arecanut palms in North Bengal (Chenchaiah 2006).

In Saurashtra region of Gujarat, 14 species of white grubs were collected in groundnut fields. These species were identified as *Phyllognathus* sp., *Apogonia rauca* Fabricius, *H. consanguinea*, *H. fissa*, *H. serrata*, *Maladera* sp., *S. ruficollis*, *A. bicolor*, *A. deccanus*, *Adoretus* sp., *A. bengalensis*, *A. dorsalis* and *A. varicolor*. The grubs feed on the nodules and rootlets and immature pods. Infested plants did not die, but remained stunted due to poor growth. Infestation by *A. rauca* was observed throughout the groundnut season from July to October (Kapadia *et al.* 2006).

Kulkarni *et al.* (2007) recorded incidence of *S. ruficollis* in a teak nursery at Ramdongari, Nagpur. The white grub infestation ranged from 14 to 52 per cent. Joshi and Meshram (2008) recorded damage of whitgrubs (*Holotrichia* sp.) in bamboos grown in sandy soils in nurseries and plantations at Angul in Bhubneshwar and Cuttack from July to September. In Kuio Reserve forest of Angul, upto 30 % incidence was recorded in an area of 360 hectares. Kulkarni *et al.* (2009) reported two species of white grubs viz. *H. rustica*

and *Holotrichia mucida* (Gyllenhal) damaging teak seedlings at Nagpur in Central India. Mean density of grubs in nurseries varied from 6.70 to 8.60 grubs/m<sup>2</sup> over different years. The mortality of seedlings was noticed between July and September.

Thakur *et al.* (2008) observed up to 62.0 per cent tuber damage in potato at Shillaroo in Shimla hills due to feeding of grubs of *B. coriacea*. In Sangla valley, white grubs are reported to cause 8 to 10 per cent plant mortality in rajmash (Sood *et al.* 2007) and 11.0 to 47.0 per cent plant mortality in 'off-season' peas (Sood *et al.* 2009). Sood *et al.* (2010) found increase in grub population from June to August in kidney bean fields in Sangla valley. The average grub population of *B. coriacea* and *H. longipennis* in soil was maximum (1.665 grubs/ft<sup>3</sup> area) in the month of August. Similar trend in grub population in adjoining pea and buckwheat fields was noticed.

Bhawane *et al.* (2012) studied host range of white grubs from Kolhapur district, Maharashtra. Grubs of *L. lepidophora*, *H. fissa*, *H. karschi*, *H. serrata*, *A. versutus*, *A. lasiopygus* and *A. bengalensis* were recorded as serious pests of several crops. The grubs of *H. karschi* damaged roots of *Cinnamomum tamala* (Buch.-Ham) T. Nees and C.H. Ebrems and severe infestation was noticed at Amba Reserve Forest. The larvae of *H. fissa* were collected from the fields of sugarcane and saplings of teak in the nursery. The grubs of *H. serrata* were found to damage the roots of sugarcane, jowar, maize, paddy and groundnut at Panhala, Karveer, Shahuwadi and Ajara. The sugarcane cultivated area at the bank of river Kumbhi Kasari is an endemic pocket of *L. lepidophora*. The grubs were also found in rice fields. *A. lasiopygus* and *A. versutus* were found to damage *Curcuma aromatica* Salisb. and grasses. Pathania *et al.* (2012) recorded six species of white grubs viz., *B. coriacea*, *B. flavosericea*, *M. indica*, *H. longipennis*, *P. dionysius* and *A. dimidiata* causing damage to potato in Himachal Pradesh. There was 42.5 per cent tuber infestation of *B. coriacea* grubs at Shillaroo in Shimla hills.

### 3. MATERIALS AND METHODS

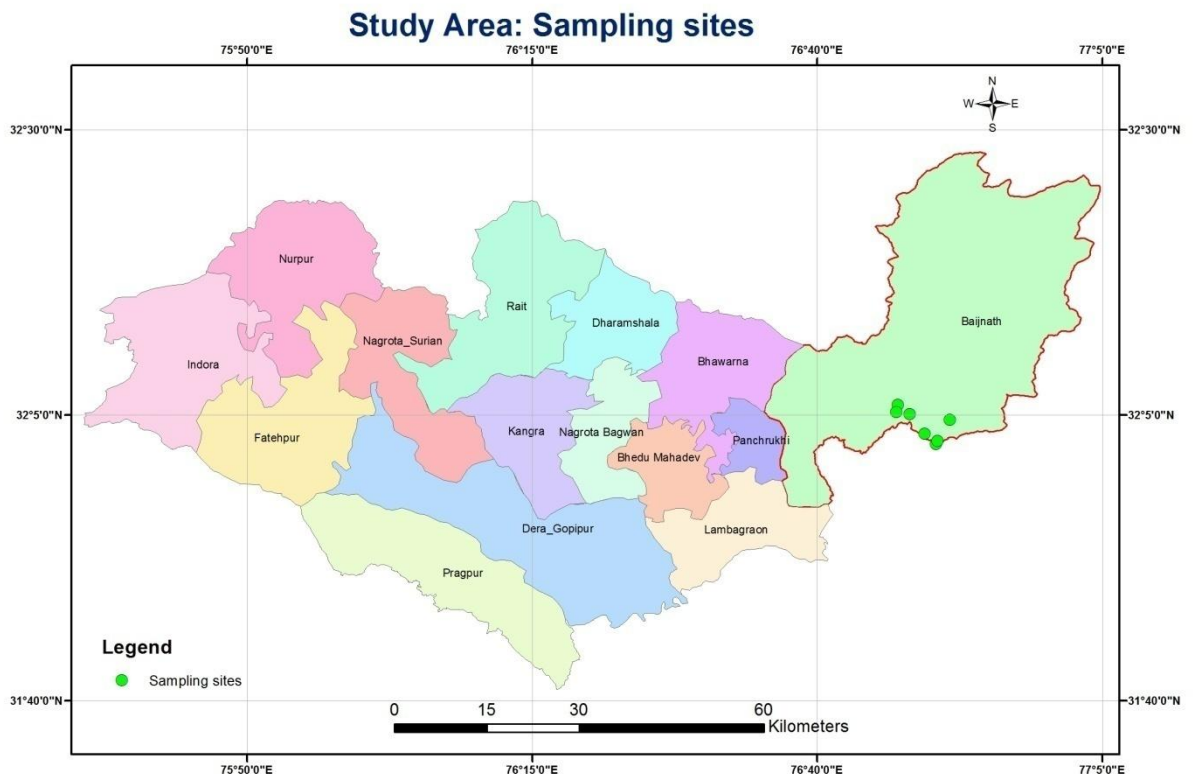
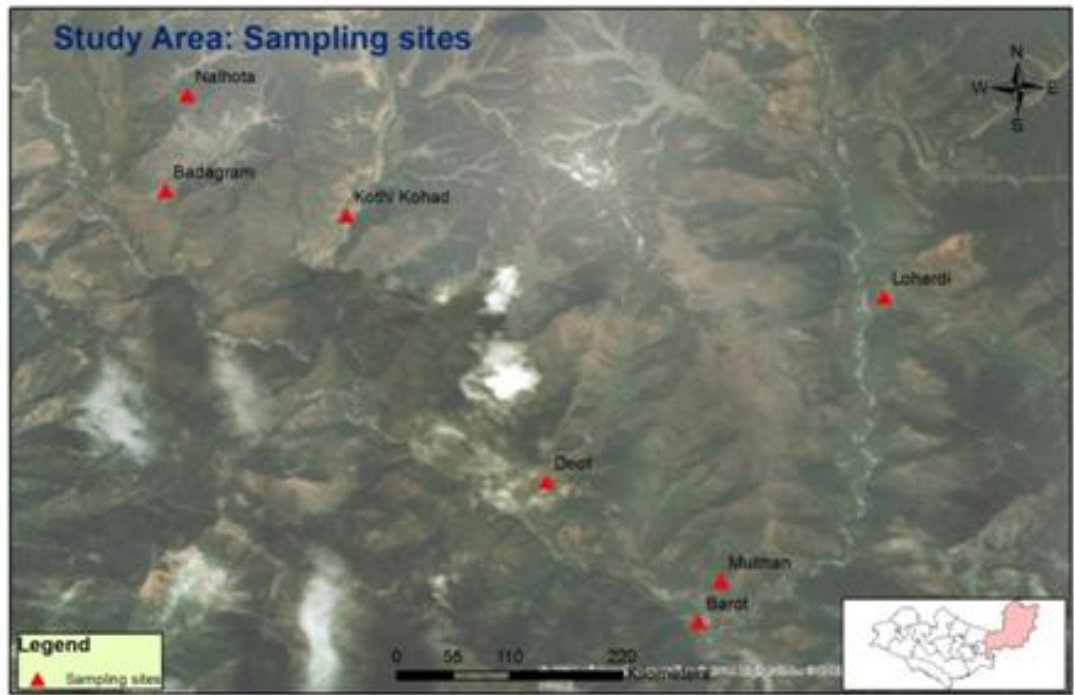
The emergence of scarab beetles occurs during May to July in high hills of Himachal Pradesh and the grubs remain active in the soil from June to November. The field survey work related to the present study was initiated in May, 2016 to collect different stages of phytophagous scarabs. The survey work continued for about one year at Barot, Badagaon, and adjoining areas. To corroborate the field studies, the culture of predominant species was maintained separately in the white grub laboratory, Department of Entomology, CSK HPKV, Palampur (latitude N 32<sup>o</sup>05.985' and longitude E 76<sup>o</sup>32.831').

**3.1 Collection of adult beetles on light trap:** The population of scarabaeid beetles was monitored through UV light trap installed at different locations in Chuhar valley (Zone-III wet temperate high hills) of Himachal Pradesh during 2016. Both the study areas were either farm lands with different cropping patterns or forest areas. The details of study sites are given in table 3.1 and shown in Fig. 3.1. The light traps were used for about four months, and beetles were monitored once a week. The UV light traps used in the present study were supplied by M/S Himalayan Industries, Baddi, Solan, Himachal Pradesh.

**Table 3.1 Description of sampling locations for beetles on light trap/host trees**

District	Location	Zone	Latitude	Longitude	Altitude(m)	Crop Habitat
Kangra	Badagaon	III	E 77 <sup>o</sup> , 07.907'	N 31 <sup>o</sup> , 58.957'	2268	Apple, walnut, wildrose and pear
Mandi	Barot	III	E 76, 50.415'	N 32 <sup>o</sup> , 02.647'	1847	Apple, walnut, apricot, wildrose and pear

The body of the light trap was made of red coloured PVC plastic. The plastic funnel was 25 cm in height having top diameter of 30 cm and bottom diameter of 5-6 cm. The rain shed cone for the protection of bulb was fixed about 17 cm above the funnel with the help of three white metal sheets. The diameter of the rain shed cone was 20 cm. The special features of this trap are the baffles, which are three in number and placed at a uniform distance of 10 cm around the circumference of funnel. The baffles are white in colour, made of M.S. sheet, 30 cm long and 11 cm wide. They were fixed in such a way so that light rays are emitted uniformly in all the directions without any interference; however, the beetles attracted to light collided with these baffles and fell into the trap. An efficient bag was attached to the bottom of this funnel. The light source consisted of hard glass bulb with choke of copper wire. The capacity of bulb was 120 watt and it was with UV radiation with visible spectrum having bluish light (Plate 3.1).



**Fig 3.1** Maps showing different sampling locations for beetles and white grubs

These light traps were installed at two locations and there was one trap at each location. The light trap was placed in the centre of the field at a height of about 10 feet and operated from 7:00 PM to 11:00 PM to attract chafer beetles, being positively heliotactic in nature. The trapped beetles were collected and separated species-wise and cumulative count of each species was determined at each location. These beetles were grouped on the basis of relative abundance and frequency values for the purpose of investigating the relative importance of different species of white grubs. The frequency data were grouped into four categories as suggested by Tischler (1949) and the abundance values were grouped into two as suggested by Weis-Fogh (1948).

**3.2 Collection of beetles on host trees:** Adult surveys to determine species occurrence and relative abundance on host trees were conducted at Badagaon and Barot in Chuhar valley of Himachal Pradesh during the rainy seasons of 2016. Both these areas are well known to be endemic to white grubs. Generally the scarabaeid beetles are nocturnal in behaviour and come out of soil at dusk. Chandel *et al.* (1995) reported that beetles come out of soil around 7:50 PM at light intensity of 3 lux and settle on host trees for mating and feeding. Therefore, it was ensured to reach at the collection site by 7:30 PM on the day of collection. After suitable rainfall events, representative samples of beetles were collected during May to September from trees *viz.*, apple, apricot, walnut, peach, pear. In these areas, trees of 3-5 m height were commonly selected. Five plants were marked at random in each orchard/farm in all the surveyed localities and three branches of almost equal length were selected. The beetles were collected between 18:30 and 19:30 hours using a powerful flash light. This collection was done during the peak emergence months of May and September for different species followed by fortnightly observations during the entire monsoon season. A simple umbrella method was used for collecting beetles from trees as suggested by Chandel *et al.* (1997). On each sampling date, an umbrella was spread below each tree and the branches were shaken one by one to dislodge the beetles. The beetles dislodged thus were handpicked and transferred to metal cages containing shoots of host trees on which collection was done.



**Plate 3.1 UV light trap used for monitoring of beetles**

The beetles collected at various locations were brought to the laboratory and further were sorted out at species level to compile a list of scarabaeid fauna of each location. For the purpose of this survey, any tree on which scarabaeid adults could be collected feeding and/or mating was considered to be a host tree. Trees in and around a selected location, were sampled in a semi-systematic manner to ensure that all the tree species in the locality were examined.

### 3.3 Identification of beetles

The scarab adults collected during the survey and the adults emerging from larval collections were identified to species level based on the keys and character lists given by Veeresh (1977), Mittal and Pajni (1977), Khan and Ghai (1982) and Ahrens (2005). The identity of adult beetles was confirmed by Dr. K. Sreedevi, Indian Agriculture Research Institute, New Delhi. Some of the samples were compared with scarabaeid collection available in Department of Entomology, CSKHPKV Palampur.

**3.4 Determination of Diversity indices:** Richness (number of species), abundance (number of individuals) and four diversity measures were used in this study.

i) Shannon index

$$H' = - \sum_{i=1}^s (p_i) (\log_2 p_i)$$

ii) Simpson's index of diversity

$$D = \frac{1}{\sum_{i=1}^s (p_i)^2}$$

iii) Simpson's reciprocal index = 1/D

iv) Pielou's evenness index (J')

$$J' = H' / H_{max}$$

Where

$H'$ = Shannon diversity index

$p_i$ = Proportion of total sample belonging to the  $i^{\text{th}}$  species.

$S$ = Number of species.

$\Sigma$ = Sum from species 1 to species  $S$

$D$ = Simpson's index of diversity.

$N$ = Total percentage cover or total number of organisms.

$n$ = Percentage cover of a species or number of organisms of a species

$J'$ = Evenness of allotment of individuals among the species.

$H_{max}$  = Maximum species diversity ( $H'$ ) =  $\text{Log}_2 S$

**3.5 Estimation of leaf defoliation by beetles on different hosts:** The leaf defoliation was calculated in apple, walnut, apricot, pear and wild rose. To study the extent of leaf defoliation, randomly selected 100 leaves of a selected branch of a plant were monitored for healthy and damaged leaves and per cent defoliation was thus calculated. To calculate the leaf injury index, the per cent defoliation was visually scored using 1-5 scale.

Score	Rate of defoliation (%)
1	1-20
2	21-40
3	41-60
4	61-80
5	>80

The leaf injury index was calculated using the following formula

$$\text{Leaf injury index (I)} = \frac{\sum n}{N}$$

Where

$n$ = Per cent defoliation in each sample

$N$ = Total number of samples

### **3.6 Estimation of white grub population in soil and their extent of infestation**

The locations selected for beetle collection during 2016 and 2017 were also surveyed for larvae from January 2016 to December 2016. The sampling was done at least once in a month and during each sampling atleast 10 samples were taken at each location. In crops like rajmash and cabbage, the wilting plants and the plants that had died prematurely were uprooted and the soil around these plants was searched for larvae. In crops like potato, or in fallow fields, sampling sites were selected randomly by throwing a one square feet quadrant over ones shoulder, with no two sampling pits overlapping. Pit sampling was done and a sample consisted of one cubic feet of soil, carefully dug by a shovel and searched for larval, pupal and adult stages. Eggs were too small and thus too tedious to be sampled. Ten samples in each crop were taken during all the observations. Larvae were transferred to the laboratory for rearing to the adult stage and to facilitate identification as the knowledge of adult-larval association was incomplete for white grub species occurring in Himachal Pradesh.

The time when larval samples were collected, the data on damage in crops like potato, cabbage and rajmash were also assessed. The averages of all observations made were worked out and plotted to draw conclusions. To collect information on natural enemies associated with white grubs, data were recorded with respect to the total number of grubs collected and the resulting healthy, infested/diseased grubs. Thus the percentages of infected/diseased grubs were calculated from this data.

## 4. RESULTS AND DISCUSSION

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Chuhar valley mainly represents Chhota Bhangal area which is southern half of Bhangal and it is located in Kangra and Mandi districts of Himachal Pradesh (Plate 4.1). Chhota Bhangal is divided into two parts by a branch range of over 10,000 feet in height thrown out to the south by the Dhauladhar. This is the range which runs above Bir and Kamand and by Futakal to Mandi. The area to the east of this range is known as Kodhswar, or Andarla and Bahirlagarh, and contains the head waters of the Uhl river. The slope of the ground is very steep everywhere and lower part of the valley has a scattering of about eighteen to nineteen villages (Anonymous 1884). The climatic conditions are wet and temperate. The valley is popular for the production of potato, rajmash, and off season vegetable crops. The present work on diversity of white grubs in Chuhar valley of Himachal Pradesh was carried out during the year 2016-2017. The diversity of scarabaeid beetles was assessed using light traps and also by collecting beetles directly from their host trees. To study the population dynamics of white grubs in soil, pit sampling was done and collected larvae were brought to laboratory for further rearing and identification. The results obtained on these aspects are presented and discussed in this chapter in light of existing literature.

### **4.1 Species diversity and seasonal abundance of scarabaeid beetles on light trap in Chuhar valley**

The light trap studies were carried out at two locations *viz.*, Badagaon and Barot during the rainy season of 2016. The altitudes of these locations are 1847 and 2268 m amsl. Rainfall varied from 118.7 to 2032.5 mm during the year 2016, whereas in the year 2017 it was found to range from 130.4 to 2037.6 mm. The latitude of study sites ranged from  $76^{\circ}, 50.415' E$  to  $77^{\circ}, 07.907' E$ , and longitude from  $32^{\circ}, 02.647' N$  to  $31^{\circ}, 58.957' N$ . A total of 1819 scarabaeid beetles representing nine genera and 13 species were collected by light traps during the monitoring period. The observations recorded on population of scarabaeid beetles which were attracted to light traps have been analysed for their relative abundance and emergence frequency separately and discussed further location-wise. The beetles were grouped on the basis of relative abundance and frequency values, for the purpose of investigating relative importance of different species of white grubs. The check list of the scarabaeid beetles collected on light trap in Chuhar valley is given in table 4.1. The frequency data were further grouped in four categories as suggested by Tischler

(1949), and the abundance values were grouped into two as suggested by Weis-Fogh (1947-48).



**Plate 4.1 View of Chuhar valley**

**Table 4.1 Check list of scarabaeid beetles collected on light trap in Chuhar valley**

Species	Badagaon	Barot
<b>Subfamily: Melolonthinae</b>		
<i>Brahmina coriacea</i> Hope	+	+
<i>Brahmina flavosericea</i> Brenske	+	-
<i>Hilyotrogus holosericeus</i>	+	+
<i>Holotrichia longipennis</i> Blanchard	+	-
<i>Melolontha cuprescens</i> Blanchard	+	+
<i>Melolontha furcicauda</i> Ancey	+	+
<i>Melolontha indica</i> Hope	+	+
<i>Melolontha virescens</i> Brenske	+	+
<i>Trichoserica umbrinella</i> Brenske	+	+
<b>Subfamily: Rutelinae</b>		
<i>Anomala rufiventris</i> Redtenbacher	+	+
<i>Anomala stoliezkoe</i> Hope	-	+
<i>Mimela passerinii</i> Hope	+	+
<i>Popillia cyanea</i> Hope	-	+
<b>Subfamily: Dynastinae</b>		
<i>Xylotrupes gideon</i> Linnaeus	+	-

(+) Present (-) Absent

**4.1.1 Relative abundance of scarabaeid beetles on light traps at Badagaon:** Badagaon area of Chhota Bhangal is located in Kangra district at an altitude of 1829 m amsl and the light trap was installed near to fields where intensive cultivation of potato, rajmash and off-season vegetables is done. Altogether 841 specimens of scarab beetles were collected from Badagaon during the study period in 2016. Light trap data indicated that at least twelve species belonging to eight genera were present in this area. In subfamily Melolonthinae, four genera were identified. Maximum species diversity was recorded in genus *Melolontha* which is represented by four species as shown in table 4.2. Bhagat and Kashyap (1997) collected four species of Melolonthinae and three species each of Rutelinae and Dyanstinae on light traps at Palampur. However, Chandra (2005) recorded 11 species of scarabaeids and from Kangra district all belonged to subfamily Rutelinae.



*Anomala rufiventris*



*Brahmina comata*



*Anomala stoliezkoe*



*Mimella passerinii*



*Trichoserica umbrinella*



*Hilyotrogus holosericeus*



*Popillia cyanea*



*B. coriacea*



*Melolontha furcicauda*



*M. virescens*



*M. cuprescens*



*H. longipennis*

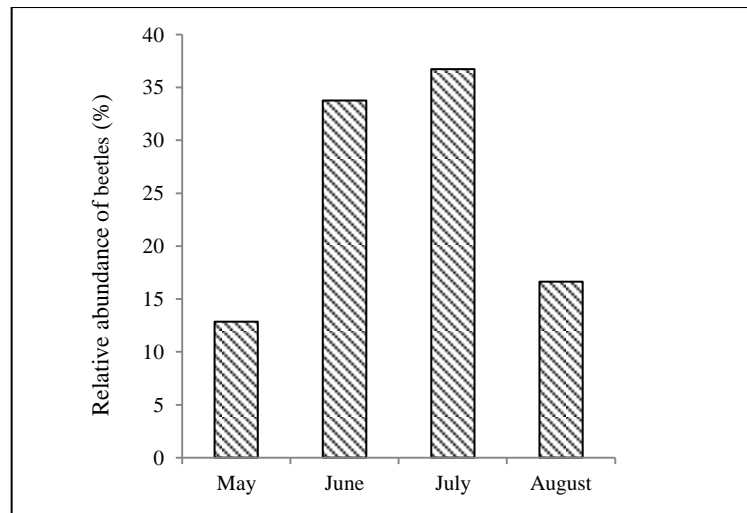


*Xylotrupes gideon*



*Mimella sp*

**Plate: 4.2 Scarabaeid beetles collected in Chuhar valley during 2016**



**Fig 4.1 Month-wise occurrence of scarabaeid beetles at Badagaon**

During May, among the four species collected, *Trichoserica umbrinella* Brenske was found the predominant. This species was recorded from May to August. All species shown in table 4.2 were recorded on light trap in July. During June 12 species whereas in August 10 species were collected. *Xylotrupes gideon* Linnaeus was recorded during the month of July only. *Anomala rufiventris* Redtenbacher, *Brahmina coriacea* Hope, *Mimella passerinii* Hope and *Trichoserica umbrinella* Brenske were observed right from May till August during 2016.

The month-wise trap catches during the year 2016 at Badagaon was calculated to be 12.84, 33.76, 36.74 and 16.64 per cent, during May, June, July and August, respectively. The cumulative trap catches of beetles was maximum in July (36.74%), followed by June (33.76%) and August (16.65%) as shown in Fig 4.1. The present results are contrary to those of Kumar *et al.* (2007) who reported peak emergence of scarabaeid beetles during June on light traps in Kullu valley of Himachal Pradesh. Pathania *et al.* (2015) also collected maximum number of beetles in June under mid hill conditions of Kangra district at Palampur. This variation in the emergence pattern is attributed to the changing temperature at different locations. Svestka (2006) reported that the emergence of beetles begins at the time when average daily temperature reaches more than 10 - 12°C and maximum swarming takes place on the days when the average daily temperature reaches 20°C. According to Svestka and Drapela (2009), maximum numbers of *Melolontha hippocastani* Fabricius swarm when average temperature was 17.37°C, and during 15 days of peak swarming, the average temperature was 18.22°C. Our findings find support from

Pathania (2014), who reported that in Kinnaur district the beetle emergence typically begins in June and peak emergence of scarabaeid beetles occurs in July on light trap.

*Trichoserica umbrinella* was found to be the only species predominant in this area which constituted 70.42 per cent of total catch during the year 2016. In mid hills of Kangra district, *T. umbrinella* constituted 0.23-0.67 per cent of total light trap catch at Palampur (Pathania *et al.* 2015a). Other three species which accounted for more than 5 per cent were, *Melolontha cuprescens* (6.11%), *A. rufiventris* (5.87%) and *Mimella passerinii* Hope (5.63%) as shown in table 4.2. *Anomala rufiventris* had been recorded on light trap in Sirmaur district by Chandra (2005). Kumar *et al.* (2007) collected *A. rufiventris* on light trap in Kullu valley. In Kumaon hills of Uttarakhand, *A. rufiventris* comprised 0.18-0.31 per cent of total beetle catch on light trap (Sushil *et al.* 2006). According to Pathania (2014), *M. cuprescens* was fairly common on light trap at Kheradhar, Sangla and Kullu. It is said by Chandra (2005) to occur from Chamba, Kinnaur and Kullu districts of Himachal Pradesh. *M. passerinii* had been collected earlier on light trap from Shillaroo, Kheradhar, Bharmour and Reckong Peo and it constituted 1.05 to 6.21 per cent of total beetle catch in these areas (Pathania *et al.* 2015b). The altitude of Shillaroo, Kheradhar, Bharmour and Reckong Peo ranges between 2032 and 2479 m amsl, whereas our study area *i.e.* Badagaon is located at an altitude of 2268 m amsl. Therefore, the present observations are in conformity with the scarab fauna recorded at other locations, had more or less similar geographical features.

**Table 4.2 Abundance and frequency of scarabaeid beetles on light trap at Badagaon during the year 2016**

Species	Number of beetles collected during				Total catch	Dominance (%)	Frequency (%)
	May	June	July	August			
<i>Anomala rufiventris</i>	3	21	17	8	49	5.87	100.0
<i>Brahmina coriacea</i>	1	9	7	2	19	2.28	100.0
<i>Brahmina flavosericea</i>	0	2	6	2	10	1.20	75.0
<i>Hilyotrogus holosericeus</i>	0	8	6	0	14	1.68	50.0
<i>Holotrichia longipennis</i>	0	2	4	3	9	1.08	75.0
<i>Melolontha cuprescens</i>	0	15	28	8	51	6.11	75.0
<i>Melolontha furcicauda</i>	0	8	1	1	10	1.20	75.0
<i>Melolontha indica</i>	0	5	3	2	10	1.20	75.0
<i>Melolontha virescens</i>	0	6	2	5	13	1.56	75.0
<i>Mimella passerinii</i>	2	18	20	7	47	5.63	100.0
<i>Trichoserica umbrinella</i>	102	185	205	96	588	70.42	100.0
<i>Xylotrupes gideon</i>	0	0	6	0	6	0.71	25.0

Others	0	5	4	6	15	1.80	100.0
<b>Total</b>	<b>108</b>	<b>284</b>	<b>309</b>	<b>140</b>	<b>841</b>		

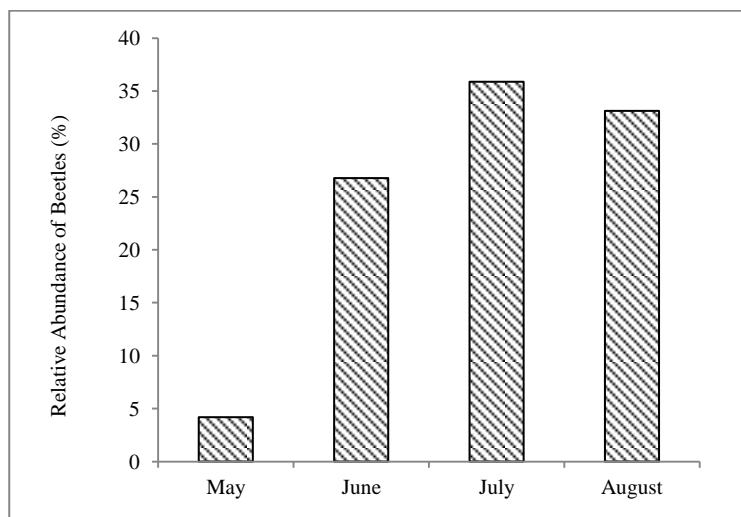
A cursory look on the data in table 4.3 indicated that *A. rufiventris*, *M. cuprescens*, *M. passerinii* and *T. umbrinella* were the dominant species ( $\geq 5.0\%$ ) collected most frequently (75-100% frequency) on light trap at Badagaon. Six species viz., *Brahmina coriacea* Hope, *Brahmina flavosericea* Brenske, *Holotrichia longipennis* Blanchard, *Melolontha furcicauda* Ancy, *Melolontha indica* Hope and *Melolontha virescens* Brenske were recorded to be influent and these species occurred at regular interval, but the frequency of occurrence was recorded to be 75 to 100 per cent. *Hilyotrogus holosericeus* Redtenbacher was also categorized as influent, but this species occurred at regular interval with lesser frequency (50-75% frequency). *Xylotrupes gideon* was of lesser significance (influent) and its frequency of occurrence ranged between 25 to 50 per cent.

**Table 4.3 Category-wise frequency distribution of scarabaeid beetles on light trap in Chuhar valley**

Sites →		Badagaon (2016)		Barot (2016)	
Categories of frequency (%)	Accidental (0-25)	Categories of relative abundance		Categories of relative abundance	
		Dominant ( $\geq 5\%$ )	Influent ( $< 5\%$ )	Dominant ( $\geq 5\%$ )	Influent ( $< 5\%$ )
		-	-	-	-
	Accessory (25-50)	-	<i>X. gideon</i>	-	<i>P. cyanea</i>
	Constant (50-75)	-	<i>H. holosericeus</i>	-	<i>A. stoliezkoie</i> <i>B. coriacea</i> <i>M. indica</i> <i>X. gideon</i>
Absolute (75-100)	<i>A. rufiventris</i> <i>M. cuprescens</i> <i>M. passerinii</i> <i>T. umbrinella</i>	<i>B. coriacea</i> <i>B. flavosericea</i> <i>H. longipennis</i> <i>M. furcicauda</i> <i>M. indica</i> <i>M. virescens</i>	<i>T. umbrinella</i>	<i>A. rufiventris</i> <i>H. holosericeus</i> <i>M. cuprescens</i> <i>M. furcicauda</i> <i>M. virescens</i> <i>M. passerinii</i>	

**4.1.2 Relative abundance of scarabaeid beetles on light trap at Barot:** Barot is located in Mandi district at an altitude of 1847 m amsl, where the light trap was installed at the centre of a fruit orchard. The species diversity of scarabaeids at Barot was almost the same as recorded at Badagaon. At Barot, 12 species were collected on light trap during the year 2016, and maximum species diversity was recorded in subfamily Melolonthinae which is

represented by seven species. In subfamily Rutelinae, four species were collected and Dynastinae was represented by a single species only. Kumar *et al.* (2007) recorded 29 species of scarabaeids on light trap in Kullu valley. They noted that 11 species represented Melolonthinae and in Rutelinae nine species were recorded. In the present study, total trap catch during the year 2016 consisted of 978 beetles. In May, trap catch was low (4.19%) and represented four identified species. During June, more than 12 species were collected and the trap catch accounted for 26.78 per cent of total beetle catch for the entire season (Fig. 4.2). Maximum beetle activity on light trap was recorded in July and the trap catch accounted 35.88 per cent of total catch in July. Similarly in August, the total trap catch of beetles was found to be 33.12 per cent.



**Fig 4.2 Month-wise occurrence of scarabaeid beetles on light trap at Barot**

In July, eleven identified species were collected, while in August, five identified species only were observed as indicated in table 4.4. In mid hills of Himachal Pradesh, peak emergence of beetles on light trap occurs in June (Kumar *et al.* 2007; Kumar *et al.* 1996; Chandel *et al.* 2010; Chandel *et al.* 1994), whereas in Rekongpeo, maximum scarab beetles on light trap were recorded in July (Pathania *et al.* 2015a).

**Table 4.4 Abundance and frequency of scarabaeid beetles on light trap at Barot during the year 2016**

Species	Number of beetles collected during				Total catch	Dominance (%)	Frequency (%)
	May	June	July	August			
<i>Anomala rufiventris</i>	6	4	2	0	12	1.23	75.0
<i>Anomala stoliezkoe</i>	0	2	3	0	5	0.51	50.0
<i>Brahmina coriacea</i>	3	9	5	0	17	1.74	75.0
<i>Hilyotrogus holosericeus</i>	1	5	4	0	10	1.02	75.0
<i>Melolontha cuprescens</i>	0	1	3	1	5	0.51	75.0
<i>Melolontha furcicauda</i>	0	2	4	1	7	0.72	75.0
<i>Melolontha indica</i>	0	2	3	0	5	0.51	50.0
<i>Melolontha virescens</i>	0	2	2	1	5	0.51	75.0
<i>Mimella passerinii</i>	0	6	8	6	20	2.04	75.0
<i>Popillia cyanea</i>	0	5	0	0	5	0.51	25.0
<i>Trichoserica umbrinella</i>	30	220	305	312	867	88.65	100.0
<i>Xylotrupes gideon</i>	0	2	7	0	9	0.92	50.0
Others	1	2	5	3	11	1.12	100.0
<b>Total</b>	<b>41</b>	<b>262</b>	<b>351</b>	<b>324</b>	<b>978</b>		

*Trichoserica umbrinella* was the most predominant species, and it comprised 88.65 per cent of total beetle catch during the year 2016. *Mimella passerinii*, *B. coriacea*, *A. rufiventris* and *H. holosericeus* constituted 2.04, 1.74, 1.23 and 1.02 per cent at Barot on light trap. The relative abundance of all other species was < 1 per cent during the period of this study. According to a number of workers, *B. coriacea* has been found to be predominant on light trap in mid and high hills of Shimla, Kullu, Solan and Sirmour districts (Chandel *et al.* 1994b; Chandel *et al.* 2010; Chandel *et al.* 2003; Gupta 2012). *Hilyotrogus holosericeus* has also been recorded in Chamba, Mandi, Sirmour and Solan districts by Chandra (2005). *Trichoserica umbrinella* was found to be the dominant ( $\geq 5\%$ ) occurring most frequently (75-100% frequency) on light trap (Table 4.3). *Anomala rufiventris*, *H. holosericeus*, *M. cuprescens*, *M. furcicauda*, *M. virescens* and *M. passerinii* were of lesser significance (influent), but appeared frequently (75-100%) on light trap during the year 2016.

Simpson's index of diversity (D) was calculated to be 0.50 at Badagaon and 0.21 at Barot, and the values of Simpson's reciprocal index (1/D) were computed to be 2.00 and 4.76, respectively. Declining values of Simpson's index of diversity (D) and increasing values of Simpson's reciprocal index (1/D) are clear indicators of low diversity in Chuhar

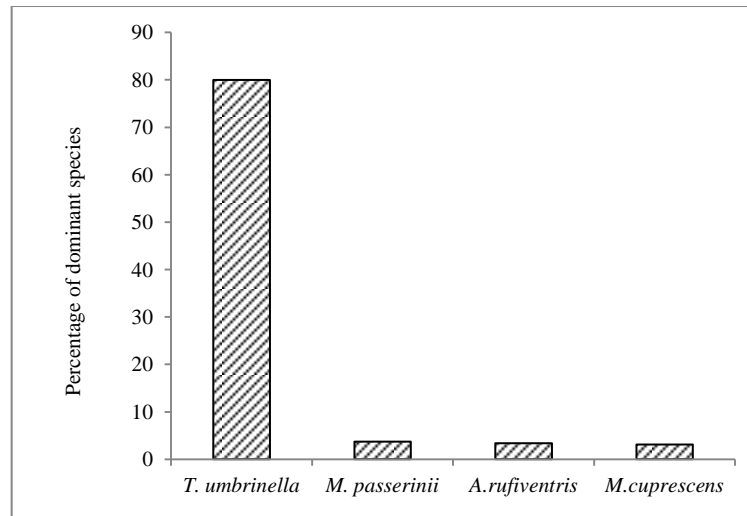
valley. The values of Shannon index (H') are near to 1.0 (1.17 at Badagaon and 0.76 at Barot) and Pielou's evenness index (J) was calculated to be 0.46 at Badagaon and 0.30 at Barot during the year 2016. As shown in table 4.5, the values of Shannon index (H') and Pielou's evenness index (J) are extremely low which showed poor species richness and greater variation in community between the species.

**Table 4.5 Diversity indices calculated for light trap catches of scarabs at Badagaon and Barot**

Diversity indices	Badagaon	Barot
Shanon index (H')	1.17	0.76
Simpson's index (D)	0.50	0.21
Simpson's reciprocal index (1/D)	2.00	4.76
Pielou's evenness index (J)	0.46	0.30

The data showed that the beetle community in Chuhar valley was numerically less diverse at both the study sites. There is complete dominance of *T. umbrinella* constituting about 70.42 and 88.65 per cent of total beetle catch at Badagaon and Barot respectively, which explains the low values of Simpson's index of diversity (D) and Pielou's evenness index (J) at these two study sites during the year 2016. Dhoj *et al.* (2009) reported that a community dominated by few species is considered to be less diverse than one with a high species richness and evenness. In the present study, less variation in the scarabaeid beetle's diversity was observed at Badagaon and Barot. Several workers have observed that in Himachal Pradesh the scarabaeid beetle species diversity and abundance varies considerably with locations (Chandel *et al.* 1994; Anonymous 2008; Anonymous 2009; Anonymous 2010).

The light traps were operated for four months from May to August and the maximum percentage of total scarab fauna was recorded in July. Overall pooling of data from both the locations revealed that 36.28 per cent of the beetles were captured only in the month of July. The average trap catch of beetles during May, June and August was recorded to be 8.19, 30.01 and 25.50 per cent, respectively. The three most common scarabaeid species in Chuhar valley on light traps were *T. umbrinella*, *M. passerinii*, and *A. rufiventris*. They accounted 87.02 per cent of all beetles collected (Fig 4.3). In *T. umbrinella*, 1455 beetles were observed, contributing to 79.98 per cent of total number of scarabaeid beetles collected.



**Fig. 4.3 Dominant species of scarabs on light trap during the year 2016 in Chuhar valley**

#### 4.2 Species diversity and seasonal abundance of scarabaeid beetles on host trees in Chuhar valley

The check list of the scarabaeid beetles collected on host trees during the year 2016 at Badagaon and Barot is given in table 4.6.

**Table 4.6 Check list of scarabaeid beetles collected on host trees in Chuhar valley**

Species	Badagaon	Barot
<b>Subfamily: Melolonthinae</b>		
<i>Brahmina coriacea</i> Hope	+	+
<i>Brahmina flavosericea</i> Brenske	+	+
<i>Brahmina comata</i> Blanchard	-	+
<i>Holotrichia longipennis</i> Blanchard	-	+
<i>Melolontha cuprescens</i> Blanchard	+	-
<i>Melolontha furcicauda</i> Ancy	-	+
<i>Melolontha indica</i> Hope	+	+
<i>Melolontha virescens</i> Brenske	+	+
<i>Trichoserica umbrinella</i> Brenske	+	+
<b>Subfamily: Rutelinae</b>		
<i>Anomala dimidiata</i> Hope	-	+
<i>Anomala rufiventris</i> Redtenbacher	+	+
<i>Anomala stoliezkoe</i> Hope	-	+

<i>Mimela passerinii</i> Hope	-	+
<i>Popillia cyanea</i> Hope	+	-

(+) Present (-) Absent

**4.2.1 Relative abundance of defoliating beetles on host trees at Barot:** The data collected on scarab fauna at Barot on different fruit/forest trees and ornamental plants during the year 2016 are contained in table 4.7. In total, twelve species belonging to six genera were collected on different fruit and forest trees. *Mimella passerinii* was collected from apple, apricot, pear and wild rose and contributed to 24.77 per cent of total scarab beetles collected during the year 2016 (Table 4.7). It was regarded to be leading species in Barot area of Chuhar valley on host trees. There are several reports which clearly underline the importance of *M. passerinii* in mid and high hills of Himachal Pradesh (Pathania 2014; Chandra 2005). The other species that were ample in adult collection, were *Anomala stoliezkoe* Hope (19.27%) and *B. coriacea* (11.93%). *A. stoliezkoe* was collected on apple, walnut, apricot and pear and maximum preference under field condition to the tune of 33.33 per cent was recorded for pear leaves, followed by apple = apricot (23.8%). Pathania (2014) had recorded *A. stoliezkoe* on apple, pear, peach and apricot from Reckong Peo which showed higher feeding preference for apple.

*Brahmina coriacea* constituted 11.93 per cent of total beetle catch and it was recorded on apple, walnut, apricot and rose. Maximum occurrence of *B. coriacea* (30.76%) was recorded on apple and apricot (Table 4.8). According to Chandel *et al.* (2010), *B. coriacea* constituted 99.10 per cent of total beetle catch at Shillaroo. Gupta (2012) reported that *B. coriacea* accounted for 98.51 per cent of total beetle population at Shillaroo. Similarly, in Jubbal, Thanedar and Matiana areas of Shimla district, *B. coriacea* comprised 100 per cent population in 10 different day catches (Anonymous 1977). Chandel *et al.* (2015) reported that *B. coriacea* beetles exhibit distinct preference for a specific host in a particular locality. The beetles of *B. coriacea* display a decided preference for apple at Kullu, walnut at Shillaroo, apricot at Nauni, *Polygonum* at Fagu and *Indigofera* at Kheradhar (Pathania 2014). Chandel *et al.* (2010) also recorded varied host preference of *B. coriacea* in Shimla, Sirmaur, and Solan districts of Himachal Pradesh.

*Holotrichia longipennis*, *A. rufiventris*, *B. flavosericea*, *M. furcicauda*, *M. virescens* and *Anomala dimidiata* Hope were collected in low numbers on different fruit trees. *Holotrichia longipennis* constituted 8.26 per cent of total beetle catch on different fruit trees. Pathania (2014) reported that *H. longipennis* has a wide distribution, becoming most

numerous in Palampur, Kullu, Dallash and Nauni areas. It was also recorded in moderate numbers from Bharmour, Reckong Peo, Kheradhar, Kwagdhar and Shimla areas. In Palampur and Nauni areas, *toon* is apparently the preferred host. In Kullu, maximum beetles of *H. longipennis* occurs on apple (Pathania 2014).

*Brahmina flavosericea*, *M. furcicauda*, and *M. virescens* comprised 5.50 per cent each on different fruit trees in the present study (Table 4.7). Chandel *et al.* (2010) reported that *B. flavosericea* is one of the leading species in Janjheli area of Mandi district. Pathania (2014) recorded *B. flavosericea* in low to moderate numbers in Shillaroo, Bharmour, Nauni, Sangla and Kalpa areas. Mehta *et al.* (2008) reported occurrence of *M. furcicauda* up to an altitude of 3000 m amsl in Himachal Pradesh with adults feeding on stone fruits during second fortnight of June. Beeson (1941) reported that *M. virescens* occurs at low levels in Himalaya breeding in moist sandy soil permeated by roots of grasses and herbs. According to Pathania (2014), *M. virescens* is an important pest of almost all crops grown during summer season in Chuhar valley of Himachal Pradesh. The relative abundance of *A. dimidiata* and *A. rufiventris* was found to range from 4.59 to 6.42 per cent, respectively. Bhalla and Pawar (1977) reported *A. dimidiata* to be a serious defoliating beetle pest of temperate fruits in Himachal Pradesh. Chandra (2005) has recorded *A. dimidiata* from Kangra, Chamba, Kullu and Shimla districts of Himachal Pradesh. *Anomala rufiventris* has been recorded earlier at Kullu, Dallash and Kheradhar on apple, pear, apricot, and peach (Pathania, 2014). *Holotrichia longipennis* was recorded on apple, walnut, apricot and wild rose, but maximum preference under field was observed for apple foliage. *Brahmina flavosericea* beetles displayed distinct preference for apple and pear and 33.33 per cent of the beetles were collected each on apple and apricot. On walnut and rose each 16.66 per cent was observed. *Melolontha furcicauda* and *M. virescens* were observed on apple, walnut and apricot. Beetles of *M. furcicauda* to the maximum extent of 50 per cent were recorded on walnut, whereas in the case of *M. virescens*, 50 per cent of the beetles occurred on apricot.

**Table 4.7 Abundance and distribution of scarabaeids on various host trees at Barot during the year 2016**

Species	Number of beetles collected feeding on different hosts			
	June	July	August	Total
<i>Anomala dimidiata</i>	1	3	1	5
<i>Anomala rufiventris</i>	5	2	0	7
<i>Anomala stoliezkoe</i>	6	9	6	21
<i>Brahmina coriacea</i>	4	6	3	13
<i>Brahmina comate</i>	1	1	0	2

<i>Brahmina flavosericea</i>	2	3	1	6
<i>Holotrichia longipennis</i>	2	4	3	9
<i>Melolontha furcicauda</i>	1	4	1	6
<i>Melolontha indica</i>	2	0	1	3
<i>Melolontha virescens</i>	4	2	0	6
<i>Mimella passerinii</i>	10	12	5	27
<i>Trichoserica umbrinella</i>	3	1	0	4
<b>Total</b>	<b>41</b>	<b>47</b>	<b>21</b>	<b>109</b>

Three species of *Anomala* viz., *A. dimidiata*, *A. rufiventris* and *A. stoliezkoe* were collected on apple, walnut, apricot and rose. Maximum occurrence of *A. dimidiata* was recorded each on apple and apricot (40% on each host), whereas *A. rufiventris* comprised 57.14 per cent on apricot. *Anomala stoliezkoe* showed maximum preference for pear (33.33 %) as shown in table 4.8.

**Table 4.8 Host tree preference by adult beetles at Barot during the year 2016**

Species	Prevalence(%) of different scarabs on host tree				
	Apple	Walnut	Apricot	Pear	Rose
<i>Anomala dimidiata</i>	40.00	20.00	40.00	0.00	0.00
<i>Anomala rufiventris</i>	14.28	28.57	57.14	0.00	0.00
<i>A. stoliezkoe</i>	23.80	19.04	23.80	33.33	0.00
<i>B. coriacea</i>	30.76	23.07	30.76	0.00	15.38
<i>B.comate</i>	0.00	50.00	50.00	0.00	0.00
<i>B. flavosericea</i>	33.33	16.66	33.33	0.00	16.66
<i>H. longipennis</i>	33.33	22.22	11.11	0.00	22.22
<i>Melolontha furcicauda</i>	16.66	50.00	33.33	0.00	0.00
<i>M. indica</i>	33.33	0.00	0.00	66.66	0.00
<i>M. virescens</i>	16.66	33.33	50.00	0.00	0.00
<i>Mimella passerinii</i>	29.68	0.00	37.04	18.51	14.81
<i>Trichoserica umbrinella</i>	0.00	25.00	50.00	25	0.00

**4.2.2 Relative abundance of defoliating beetles on host trees at Badagaon:** The observations recorded on the diversity and abundance of scarabaeid beetles during the year 2016 at Badagaon are presented in table 4.9. Among the collected beetles, eight species were identified. The population data were analysed for their relative abundance on apple, walnut wildrose and pear. Earlier, Chandra (2005) has reported eight species from Kangra and eleven species of phytophagous scarabs from Mandi district of Himachal Pradesh. The beetle activity was found to be very low as recorded from June to August at Badagaon. In total 47 beetles belonging to eight species were collected during the study period in the year 2016. *Trichoserica umbrinella* was the most predominant species, and it constituted 29.79 per cent of total beetle catch. *Melolontha indica* and *B. coriacea* constituted 17.02 and 14.89 per cent of total beetle catch, respectively. Chandra (2005) had recorded *M.*

*indica* from Kullu, Shimla and Solan districts of Himachal Pradesh. According to Chandel *et al.* (1997), *B. coriacea* comprised 42.50-51.70 per cent of total beetle catch on different fruit trees at Nauni. *Melolontha virescens* and *P. cyanea* comprised only 6.38 and 4.25 per cent of total beetle catch at Badagaon during the year 2016. Chandel *et al.* (2010) reported *M. virescens* as most damaging in Badagaon area of Chuhar valley and observed its beetles feeding on wheat spikes in the first week of July. According to Pathania (2014), this species was preponderant in Badagaon area of Kangra district at an altitude of 2268 m amsl. Almost all crops grown during rainy season were found to be damaged by *M. virescens* in Chuhar valley. *Popillia cyanea* had been recorded earlier in Chamba district causing extensive damage to rajmash. The beetles destroyed flowers, buds and newly formed pods of rajmash (Thakur *et al.* 1996).

**Table 4.9 Abundance and distribution of scarabaeids on various host trees at Badagaon during the year 2016**

Species	Number of beetles collected on different hosts			
	June	July	August	Total
<i>Anomala rufiventris</i>	0	3	2	5
<i>B. coriacea</i>	2	4	1	7
<i>B. flavosericea</i>	1	3	0	4
<i>Melolontha cuprescens</i>	0	3	1	4
<i>M. indica</i>	2	4	2	8
<i>M. virescens</i>	0	2	1	3
<i>Popillia cyanea</i>	0	1	1	2
<i>Trichoserica umbrinella</i>	4	7	3	14
<b>Total</b>	<b>9</b>	<b>27</b>	<b>11</b>	<b>47</b>

At Badagaon, *T. umbrinella* beetles were collected on apple, walnut and wild rose, however there was decided preference for walnut. *Trichoserica umbrinella* constituted 57.14 per cent of total catch on walnut and it was maximum. *Brahmina coriacea* was recorded chiefly on apple and its population was found to be 57.14 per cent of the total catch. Pathania (2014) reported 16.20 – 18.18 per cent population of *B. coriacea* beetles feeding on apple at Nauni. *Melolontha cuprescens*, *M. indica* and *M. virescens* were found frequently on walnut and wild rose and both these host trees showed at par attraction of *Melolontha* spp. In case of *B. flavosericea*, 50 per cent of the beetles were recorded on walnut, whereas *P. cyanea* beetles were recorded only on walnut at Badagaon (Table 4.10).

**Table 4.10 Host tree preference by adult beetles at Badagaon during the year 2016**

Species	Prevalence (%) of different scarabs on different host trees
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	Apple	Walnut	Wildrose	Pear
<i>Anomala rufiventris</i>	40.00	20.00	40.00	0.00
<i>B. coriacea</i>	57.14	42.85	0.00	0.00
<i>B. flavosericea</i>	0.00	50.00	25.00	25.00
<i>Melolontha cuprescens</i>	0.00	50.00	50.00	0.00
<i>M. indica</i>	25.00	37.50	37.50	0.00
<i>M. virescens</i>	0.00	33.33	33.33	33.33
<i>Popillia cyanea</i>	0.00	100.00	0.00	0.00
<i>Trichoserica umbrinella</i>	14.28	57.14	28.57	0.00

**4.2.3 Diversity indices of scarabaeids on host trees:** The value of Simpson's index of diversity (D) was quite high, whereas the value of Simpson's reciprocal index (1/D) was quite low. At Barot, the value of Simpson's index of diversity (D) was calculated to be 0.86, and at Badagaon it was computed to be 0.83 (Table 4.11). The values of Simpson's reciprocal index (1/D) were calculated to be 1.16 and 1.21, respectively. The values for Shannon index (H') at Barot and Badagaon were calculated to be 2.26 and 1.92 during the year 2016. These low values are attributed to lesser number of species (12) recorded at Barot and Badagaon combined with dominance of *M. passerinii* at Barot, and *T. umbrinella* at Badagaon. These species contributed 29.78 and 24.77 per cent of total catch during the year 2016 at Barot and Badagaon, respectively. The Pielou's evenness index (J=0.91 at Barot and 0.93 at Badagaon) revealed lesser evenness in community between the species in Chuhar valley of Himachal Pradesh. The little low value of Simpson's index of diversity (D) is attributed to the fact that *T. umbrinella*, *M. indica*, and *B. coriacea* constituted 60.71 percent of total scarab fauna. Dhoj *et al.* (2009) also reported that a community dominated by few species is considered to be less diverse than one with a high species richness and evenness. In mid hills of Kangra district at Palampur, Pathania (2014) also calculated moderately high values of Shannon index (H'=2.12-2.41), Simpson's index of diversity (D=0.85-0.86) and Pielou's evenness index (J=0.73-0.76). These values are in line with our findings.

**Table 4.11 Diversity indices calculated for host tree catches of scarabs at Barot and Badagaon in the year 2016**

Diversity indices	Barot	Badagran
Shanon index(H')	2.26	1.92
Simpson's index (D)	0.86	0.83
Simpson's reciprocal index (1/D)	1.16	1.21
Pielou's evenness index(J)	0.91	0.93

A comparison of light trap with host tree data revealed that *T. umbrinella* constituted 79.98 per cent on light trap, whereas on host trees, it constituted nearly 11.56 per cent of total catch. *Mimella passerinii* comprised 17.30 per cent on host trees, whereas on light trap its percentage was calculated as 1.97 per cent. This clearly showed that *B. coriacea* and *M. passerinii* were more abundant on host trees, but less abundant on light trap because of their poor phototactic nature. Pathania (2014) has also recorded less number of beetles of *B. coriacea* on light trap as compared to host trees and also reported that *B. coriacea* beetles were less phototactic in nature. However, *T. umbrinella* were less abundant on host trees but highly abundant on light trap, suggesting thereby strong phototactic response of these beetles.

#### 4.3 Leaf defoliation by scarab beetles in Chuhar valley during the year 2016

The adult scarab beetles have been found to be the common defoliating pests and they damaged large number of fruit crops and forest trees. They devour plant tissue, especially leaves, flowers or growing fruits (Chandel *et al.* 2015). At Badagaon, the leaf defoliation was examined on apple, pear, walnut and wildrose. Maximum leaf defoliation was recorded on walnut (12.5%), followed by apple (9.3%), wildrose (7.3%) and pear (5.8%). The values of leaf injury index were low (1.0-1.25) in case of apple, wildrose and pear indicating lesser degree of damage to leaves. In case of walnut, the value of leaf injury index (I) was calculated to be 1.75 which showed marginally higher degree of damage to walnut leaves as compared to apple and pear leaves (Table 4.12).

**Table 4.12 Leaf defoliation by scarab beetles at Badagaon during the year 2016**

Host	Defoliation (%)	Leaf Injury Index
Apple	9.3	1.25
Walnut	12.5	1.75
Wildrose	7.3	1.25
Pear	5.8	1.00
CD (P=0.05)	3.86	

At Barot, leaf defoliation data were recorded on apple, walnut, apricot and wildrose. The extent of defoliation was very low on all observed plants (Table 4.13). As observed at Badagaon, maximum defoliation (5.0 %) was recorded on walnut, followed by apricot (3.3%) and apple (2.3%). According to earlier reports, walnut leaf defoliation due to feeding of *B. coriacea* beetles was recorded upto 85 per cent at Shillaroo, whereas in case of apple, extent of leaf defoliation was only 10 per cent (Anonymous, 2010). At Kwagdhara, *A. lineatopennis* caused severe defoliation of apple plants (Pathania, 2014).

According to Sharma *et al.* (1971), *A. lineatopennis* caused extensive damage to fruits and foliage of pome and stone fruits at Kwagdhur. On wildrose and pear, 1.0 and 0.8 per cent defoliation was noticed as indicated in table 4.13. The values of injury index (I) ranged between 1.0 to 1.25 on apple, apricot and pear which indicated very low amount of injury to the leaves of these plants as shown in table 4.13. The leaf injury index was 1.50 and 1.75 in case of wildrose and walnut respectively, which showed moderate amount of injury to walnut and wildrose leaves. Pathania (2014) calculated values of leaf injury index as 4.75 and 2.35 on walnut and apple at Shillaroo. High values of leaf injury index ranging from 2.28 to 4.00 have been reported earlier on *toon*, apricot and peach at Palampur, Reckong Peo and Kullu (Pathania, 2014). Low values of leaf injury index in the present study indicated that beetle damage to fruit trees was of lesser significance and did not warrant any control measures in the present scenario.

**Table 4.13 Leaf defoliation by scarab beetles at Barot during the year 2016**

Host	Leaf Defoliation (%)	Leaf Injury Index
Apple	2.3	1.00
Walnut	5.0	1.75
Apricot	3.3	1.25
Wildrose	1.0	1.50
Pear	0.8	1.00
CD (P=0.05)	1.17	

#### 4.4 Population dynamics of white grubs in soils in Chuhar valley

The white grub sampling in soils of Chuhar valley was done throughout the year from January to December 2016. The sampling was done at five locations in Chuhar valley at monthly intervals. During this period of one year, total 360 number of samples were taken and total 793 number of grubs were collected in the valley. These grubs were separated into five species *viz.*, *Anomala* spp, *M. virescens*, *M. cuprescens*, *B. coriacea* and *H. longipennis* on the basis of their raster pattern. Predominant species on the basis of population of white grubs in soil was *M. virescens*, which constituted 70 per cent of the grub population in the soil. During January and February very low population of white grubs was recorded at Badagaon, Barot, Kothikohar and Kothiswar. The population of grubs during January to February ranged from 0 to 3 grubs per ft<sup>3</sup>. The collected grubs during January to February belonged to *B. coriacea* and *Anomala* spp and none of the grubs belonging to *M. virescens* was collected during January to February. Chandel *et al.* (2003) reported that fully fed grubs of *B. coriacea* overwintered inside earthen cells in

upper 4-6 inches of soil. According to Pathania (2014), fully fed third instar grubs moved very deep into the soil and constructed large earthen chambers in which hibernating larvae rested throughout the winter months. Litsinger *et al.* (2002) reported that white grubs descended in the soil profile to lower depths when they were about to enter a resting stage and the selected depth appeared to be a function of soil type, body size and prevailing climate. Those that dug deeper tended to be in lighter soils, colder climates, and were larger in size. In the present sampling, the soil was dug upto 1 ft of soil. Ritcher (1958) also reported that larger the species the more deeper they moved into the soil during winter which confirmed our findings. As the grubs of *M. virescens* were 55 mm in length (Pathania, 2014), it therefore could be hypothesized that these grubs moved deep into the soil beyond the depth of 1-2 feet because of their large size. The fully fed third instar grubs of *H. longipennis* also moved downward to a considerable depth and constructed earthen cells for overwintering during winter months (Haq, 1962; Shah and Shah, 1990). Kalpana (2015) reported that earthen cells provided protection against biotic and abiotic factors throughout the winter months in north-western Himalayas. In Chuhar valley, *M. virescens* was the leading species in soil sampling, and all *M. virescens* grubs moved very deep into the soil during winter months which explained the very low population of grubs during soil sampling in winter months.

During March, there was little increase in the activity of white grubs and 1 to 2 grubs per ft<sup>3</sup> were recorded at Badagaon, Barot and Lohardi. There was significant increase in the activity of white grubs during April to September 2016 as evidenced by the data given in table 4.14. During April, average population of grubs in Chuhar valley ranged from 0.4±0.22 to 1.8±0.63 grubs per ft<sup>3</sup>. During May, comparatively lesser number of white grubs were observed as compared to April and this was due to the reason that the grubs transformed into pupae during April to May. During June, average population of grubs in Chuhar valley ranged from 0.5±0.16 to 1.8±0.53 per ft<sup>3</sup>. There was significant increase in grub population in soil between July to September.

In July maximum population of white grubs was recorded at Badagaon with a mean population of 5.6±0.54 grubs/ft<sup>3</sup>. At Barot, 2.3±0.5 grubs per ft<sup>3</sup> were recorded. At Kothikohar, Kothiswar and Lohardi, the grub population ranged from 0 to 4 grubs per ft<sup>3</sup>. Maximum population of grubs was recorded during August irrespective of location. At Badagaon 5.6±0.54 grubs per ft<sup>3</sup> whereas at Barot, Kothikohar, Kothiswar and Lohardi 1.0±0.42, 1.3±0.37, 1.7±0.65 and 1.3±0.45 grubs/ft<sup>3</sup> were recorded. Earlier workers have reported 8.3 and 4.8 grubs of *M. virescens* per m<sup>2</sup> at Badagaon and Barot (Anonymous

2016), and this confirmed our present findings. After August, a gradual decline in population of white grubs was observed in entire Chuhar valley as shown in table 4.14. In November, low population of grubs was observed at Badagaon, Barot, Kothikohar and Kothiswar with population ranging from 0 to 2 grubs per ft<sup>2</sup>. Very low activity of white grubs was recorded in December.

**Table 4.14 Population of white grubs in Chuhar valley during the year 2016**

Month	No of grubs/ft <sup>3</sup> area									
	Badagaon		Barot		Kothikohar		Kothiswar		Lohardi	
	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE
January	0-1	0.2 ±0.11	0-1	0.1 ±0.02	0-2	0.1 ±0.05	0-1	0.1 ±0.05	0-3	0.4 ±0.13
February	0-2	0.3 ±0.09	0-2	0.2 ±0.08	0-1	0.2 ±0.06	0-2	0.2 ±0.05	0-1	0.1 ±0.02
March	0-2	0.7 ±0.21	0-1	0.3 ±0.15	0.00	0.00	0-4	1.1 ±0.40	0-1	0.5 ±0.16
April	0-3	1.3 ±0.36	0-2	1.0 ±0.25	0-2	0.4 ±0.22	0-6	1.8 ±0.63	0-4	0.8 ±0.42
May	0-1	0.4 ±0.16	0-4	1.0 ±0.42	1-4	2.0 ±0.40	0-3	0.6 ±0.30	0-2	0.4 ±0.22
June	1-5	1.8 ±0.53	0-5	1.6 ±0.54	0-5	1.8 ±0.64	0-1	0.5 ±0.16	0-3	1.2 ±0.38
July	4-8	5.5 ±0.47	0-5	2.3 ±0.55	1-4	1.6 ±0.31	0-2	0.8 ±0.24	0-2	0.7 ±0.26
August	3-9	5.6 ±0.54	0-4	1.0 ±0.42	0-3	1.3 ±0.37	0-6	1.7 ±0.65	0-4	1.3 ±0.45
September	2-8	5.0 ±0.68	1-6	2.2 ±0.57	1-4	1.7 ±0.33	0-4	1.1 ±0.41	0-3	0.6 ±0.31
October	0-5	2.5 ±0.50	0-4	1.1 ±0.43	0-2	1.0 ±0.25	0.00	0.00	0-2	0.9 ±0.27
November	0-2	0.8 ±0.24	0-1	0.5 ±0.16	0.00	0.00	0-1	0.5 ±0.16	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

**4.5 Natural enemies of white grubs:** During sampling in the year 2016, 793 white grubs were collected in Chuhar valley, but none of the grubs showed any infection of fungi, bacteria, nematodes or viruses. In Himachal Pradesh, Chandel (2000) isolated *Entomophthora* spp from full fed grubs of *B. coriacea* collected from Shimla region. Sharma *et al.* (2012) isolated 16 species belonging to 9 genera from cadavers of white grubs and adult beetles in Himachal Pradesh. Kalia (2013), isolated *B. brongniartii* from grubs of *B. coriacea*, and reported Shillaroo strains to be highly virulent in nature against potato white grubs. The overwintering inactive grubs of *M. virescens* were attacked by mites under laboratory conditions. The attacked larvae developed blackish angular spots on their body and head before death. Chandel (2000) also reported the association of mites with grubs of *B. coriacea* from Solan area of Himachal Pradesh.

## 4.6 Distribution and abundance of white grubs in different crops

**4.6.1 Infestation of white grub in rajmash in Chuhar valley:** In rajmash, field surveys were carried out at five locations in Chuhar valley of Himachal Pradesh during the years 2016 and 2017. The incidence of white grubs was noticed at the time of emergence in June. The 10-15 days old plants were more prone to their attack during May-June. Perusal of data in table 4.15 indicated negligible incidence of white grubs in Lohardi area during the years 2016 and 2017. Maximum damage i.e. 16.3 per cent in the year 2016 and 13.8 per cent in the year 2017 was recorded at Badagaon in Kangra district. The mean population of grubs was estimated to be  $5.0 \pm 0.68$  per ft<sup>3</sup> area during the years 2016 and 2017. In Barot area, plant mortality ranged from 7.5 to 8.8 per cent during the years 2016 and 2017. Density of grubs in rajmash fields in Barot area varied from 0-5 grubs per ft<sup>3</sup> during 2016-17. In Kothiswar area of Chuhar valley,  $0.5 \pm 0.16$  grubs per ft<sup>3</sup> area were recorded which resulted in 10.0 per cent plant mortality during the years 2016 and 2017. In Kothikoher area, the incidence of white grubs ranged from 7.5 to 8.8 per cent and the density of white grubs averaged  $2.5 \pm 0.50$  grubs per ft<sup>3</sup> area, respectively. Earlier workers have recorded white grub infestation up to 30 per cent in rajmash at Badagaon (Anonymous, 2010). Sood *et al.* (2007), reported 8 - 10 per cent plant mortality due to the attack of white grubs in rajmash in Sangla valley. Sood *et al.* (2010) found significant increase in grub population from June to August in rajmash fields in Sangla valley and reported 1.66 grubs/ft<sup>3</sup> area of *B. coriacea* and *H. longipennis* from that area.

**Table 4.15 Incidence of white grubs in rajmash in different locations of Chuhar valley**

Location	Number of grubs/ft <sup>3</sup> area		Frequency (%)	Plant mortality due to grubs (%)	
	Range	Mean±SE		2016	2017
Badagaon	2-8	$5.0 \pm 0.68$	100.0	16.3	13.8
Kothikoher	1-5	$2.5 \pm 0.50$	100.0	7.5	8.8
Barot	2-6	$3.5 \pm 0.48$	100.0	13.8	12.0
Lohardi	0-3	$1.2 \pm 0.38$	50.0	1.0	1.3
Kothiswar	0-1	$0.5 \pm 0.16$	50.0	10.0	10.0
CD(P=0.05)				9.69	NS

In all these surveyed areas, the grubs of *M. virescens* were observed to damage root system of rajmash plants, causing sudden wilt and death of plants (Plate 4.3). Maximum mortality in rajmash was observed during May-June when plants were highly tender at 5 to 6 leaf stage. A typical behaviour of these grubs is that they were present at a depth of about

10 cm in soil and had least disturbance during inter-cultural operations. Deeper the grubs, more difficult would be their control because of poor translocation of

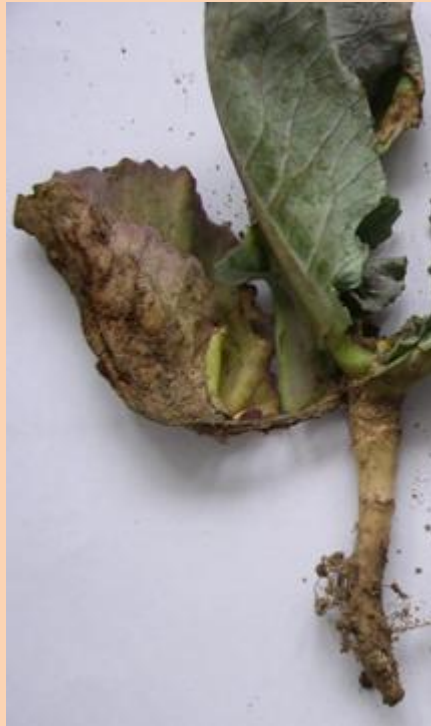


**Plate 4.3 Root pruning by white grubs in rajmash**

insecticides beyond 5 cms of soil depth (Mehta *et al.* 2010). Therefore, an alternate strategy was needed to be formulated for the management of white grubs in rajmash in Chuhar valley of Himachal Pradesh.

**4.6.2 Infestation of white grubs in cabbage in Chuhar valley:** In cabbage, the incidence of white grubs in Chuhar valley was noticed during May-June. In Chuhar valley cabbage is grown as off-season crop from May to September and the field observations were recorded at Badagaon, Barot, Kothikohar, Kothiswar and Lohardi during the year 2016 and 2017. The damage was most severe during July – August. The symptom of injury was root pruning by the grubs and the infested plants resulted in wilting, yellowing, browning and death eventually (Plate 4.4). Maximum damage was recorded at Badagaon (Table 4.16). At Badagaon, 23.0 and 36.5 per cent cabbage plants were found to be damaged by the white grubs where the population was recorded to be  $5.5 \pm 0.47$  grubs per  $\text{ft}^3$  area, followed by Barot ( $2.3 \pm 0.55$  grubs per  $\text{ft}^3$ ). At Barot, 18.1 and 17.5 per cent of the cabbage plants showed infestation of white grubs. Density of grubs in cabbage fields at Kothiswar ranged from 0 to 2 grubs per  $\text{ft}^3$  area and the resulting damage was 18.7 and 12.3 per cent during the years 2016 and 2017, respectively.

In Kothikohar, 11.7 per cent of the cabbage plants were found to be attacked by white grubs, but during the year 2017, comparatively higher infestation (17.1%) was observed. The average grub population at Kothikohar was found to be  $1.6 \pm 0.30$  grubs per  $\text{ft}^3$  area. Mehta *et al.* (2008) observed total failure of cabbage due to the attack of white grubs in Chhota Bhangal area of Kangra district during July - August. In Palampur area, earlier workers had reported 8 to 10 per cent incidence of *Holotrichia* spp grubs in cabbage fields (Anonymous, 2010). These reports lend support to our results and corroborate our findings. In Lohardi  $0.8 \pm 0.79$  grubs per  $\text{ft}^3$  area were observed, but cabbage plants did not show any white grub infestation. In all these areas except Lohardi, the leading species responsible for plant mortality in cabbage was *M. virescens*. In Lohardi area, the collected grubs were smaller in size and did not belong to *M. virescens*. These grubs were kept in laboratory for rearing, but all grubs died during rearing, hence their identity could not be ascertained.



**Plate 4.4 Root pruning by white grubs in cabbage**

**Table 4.16 Incidence of white grubs in cabbage at different locations of chuhar valley**

Location	Number of grubs/ ft <sup>3</sup>		Frequency (%)	Plants showing white grub infestation (%)	
	Range	Mean±SE		2016	2017
Badagan	4-8	5.5±0.47	100.0	23.00	36.50
Kothikohar	1-4	1.6±0.30	100.0	11.70	17.10
Barot	0-5	2.3±0.55	70.00	18.10	17.50
Lohardi	0-2	0.8±0.79	60.00	0.00	0.00
Kothiswar	0-2	0.7±0.26	50.00	18.70	12.30
CD(P=0.05)				14.02	12.58

**4.6.3 Infestation of white grubs in potato in Chuhar valley:** In Himachal Pradesh, the problem of white grubs has been very serious as potato growing is practiced during summer season as rainfed crop under long day conditions (Chandel *et al.* 2015). Altogether five locations were surveyed in Chuhar valley during the year 2016 to ascertain the magnitude of losses inflicted by white grubs in potato. Maximum tuber damage was recorded at Badagaon (23.7 - 32.1 %) during the year 2016. Density of white grubs in potato fields at Badagaon was 5.6±0.54 grubs per ft<sup>3</sup> area. At Kothikohar, the tuber infestation was registered to be 23.7 and 12.0 per cent on number and weight basis respectively, with corresponding average grub population of 1.7±0.33 grubs per ft<sup>3</sup> area (Table 4.17). In Barot area, the white grub damage ranged from 14.3 to 16.0 per cent during the year 2016, and the grub population was found to range between 0 and 4 grubs per ft<sup>3</sup> area. Pathania (2014) had reported 2.20 to 3.20 grubs per ft<sup>3</sup> area at Barot and 6.10 to 6.50 grubs per ft<sup>3</sup> area at Badagaon in potato fields. The corresponding tuber damage was 12.0 to 14.8 and 28.0 to 30.60 per cent at these two locations and these observations were in agreement with our findings. In Lohardi area, very low population of grubs was observed in potato fields (0.97±0.27) and the tuber damage was also found to be low, ranging between 3.4 and 5.4 per cent during the year 2016, respectively.

**Table 4.17 Incidence of white grubs in potato in different locations of Chuhar valley in the year 2016**

Location	Number of grubs/ft <sup>3</sup>		Frequency (%)	Tuber infestation due to white grubs (%)	
	Range	Mean±SE		Number basis	Weight basis
Badagan	3-9	5.6±0.54	100.0	32.1	22.8
Kothikohar	1-4	1.7±0.33	100.0	23.7	12.0
Barot	0-4	1.0±0.42	50.0	16.0	14.3
Lohardi	0-2	0.9±0.27	60.0	3.4	5.4
CD(P=0.05)				11.25	NS





**Plate 4.5** Potato tubers damaged by white grubs

In the entire Chuhar valley, except Lohardi, *Melolontha* spp grubs predominated in potato fields. These grubs were large in size and ranged from 50 to 55 mm. They produced single large cavity in the tubers which was found filled with soil (Plate 4.5). There was synchronization between damaging stage of the pest vis-à-vis susceptible stage of potato crop (tuber bulking stage) which added to huge losses of potato crop. Chandel *et al.* (2015) reported that white grubs were responsible for causing 40 to 90 per cent losses in potato in endemic areas situated in higher hills of Uttar Pradesh, Himachal Pradesh and Jammu and Kashmir. Singh and Verma (1982) reported that in some worst affected areas located in dry temperate zones, even the seed tubers were eaten away before they gave rise to plants.

## 5. SUMMARY AND CONCLUSIONS

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The survey studies on white grub fauna of Chuhar valley of Himachal Pradesh were carried out during the year 2016. Chuhar valley lies in southern half of Bhangal and is wet and temperate in climate. The diversity of scarabaeid beetles was assessed using light traps and by collecting beetles directly from their host trees. The light trap studies were carried out at two locations *viz.*, Badagaon and Barot during May to August, 2016.

A total of 1819 beetles representing nine genera and 13 species were collected by light traps during the monitoring period. At Badagaon, 12 species belonging to eight genera were collected on light traps, and maximum species diversity was recorded in genus *Melolontha* having four species. In subfamily Melolonthinae, four genera were identified. The cumulative trap catch of scarabaeid beetles was maximum in July (36.74%) followed by June (33.76%) and August (16.65%). *Trichoserica umbrinella* Brenske was the only species found predominant in this area and constituted 70.42 per cent of total catch at Badagaon during the year 2016. Other three species, which accounted for > 5 per cent, were *Anomala rufiventris* Redtenbacher (5.87%), *Melolontha cuprescens* Blanchard (6.11%) and *Mimella passerinii* Hope (5.63%). *Trichoserica umbrinella* was the dominant ( $\geq 5\%$ ) species collected more frequently (75-100%) on light traps at Badagaon. *Brahmina coriacea* Hope, *B. flavosericea* Brenske, *Holotrichia longipennis* Blanchard, *M. indica* Hope and *M. virescens* Brenske were recorded to be influent and these species occurred at regular intervals, but the frequency of occurrence was recorded to be 75 to 100 per cent.

At Barot, 12 species were collected on light traps during the year 2016 and maximum species diversity was recorded in subfamily Melolonthinae which is represented by seven species. A total of 978 beetles were collected and maximum beetle activity was recorded in July, comprising 35.8 per cent of total beetle catch. In August, the total trap catch of beetles was found to be 33.12 per cent, followed by 26.78 per cent in June. *Trichoserica umbrinella* was the most predominant species comprising 86.8 per cent of total beetle catch. *Mimella passerinii*, *B. coriacea*, *A. rufiventris* and *H. holosericeus* constituted 2.04, 1.74, 1.23 and 1.02 per cent at Barot on light traps. *Trichoserica umbrinella* was found to be dominant (>5%) and occurred most frequently (75-100%). Simpson's index of diversity (D) was calculated to be 0.50 at Badagaon and 0.21 at Barot, and the values of Simpson's reciprocal index (1/D) were computed to be 2.00 and 4.76,

respectively. The values of Shannon's index were 1.17 at Badagaon and 0.76 at Barot. The Pielou's evenness index (J) were calculated to be 0.46 at Badgaon and 0.30 at Barot. Overall pooling of data from both the locations revealed that the three most common scarabaeid beetles on light traps were *T. umbrinella*, *A. rufiventris* and *M. passerinii*.

In order to collect beetles from host trees, the sampling was done at night. At Barot, 12 species belonging to six genera were collected on different fruit and forest trees. *Mimella passerinii* was regarded to be leading species on host trees in Barot area, and it contributed 24.77 per cent of total scarab beetles collected at Barot. *Brahmina coriacea* constituted 11.93 per cent of total beetle catch when recorded on apple, walnut, apricot and rose. Maximum occurrence of *B. coriacea* (30.76%) was recorded on apple and apricot. At Badagaon, beetle activity was found to be very low as recorded from June to August, and in total eight species were identified. *Trichoserica umbrinella* was the most predominant species which constituted 29.79 per cent of the total catch. *Melolontha indica* and *B. coriacea* constituted 17.02 and 14.89 per cent of total beetle catch respectively.

At Badagaon, *T. umbrinella* displayed decided preference for walnut, whereas *B. coriacea* was recorded chiefly on apple. The value of Simpson's index of diversity (D) was quite high (0.86) at Barot and 0.83 at Badagaon, whereas Simpsons's reciprocal index (1/D) was quite low (1.16) at Barot and 1.21 at Badgaon. The values for Shannon index (H') at Barot and Badagaon were calculated to be 2.26 and 1.92 during the year 2016. A comparison of light trap and host tree data revealed that *T. umbrinella* constituted 79.98 per cent on light trap, whereas on host trees it constituted nearly 11.56 per cent of total catch. Contrary to this, *B. coriacea* and *M. passerinii* were more abundant species on host trees, but less abundant on light trap. The beetles were found to feed on leaves of apple, walnut, and wild rose, but the leaf defoliation was insignificant at both the locations.

To study the populations of white grubs in soil, soil sampling was done at five locations in Chuhar valley at monthly intervals from January to December 2016. A total of 793 grubs were collected in Chuhar valley during soil sampling and these grubs were separated at least into five species viz., *M. virescens*, *M. cuprescens*, *Anomala* spp, *B. coriacea*, *H. longipennis* on the basis of their raster pattern. Predominant species of white grubs in soil was *M. virescens* which constituted 80.0 per cent of the grub population. During January and February 2016, very low population of grubs was recorded in Chuhar valley because of downward movement of *M. virescens* grubs which is

predominant species in the valley. There was significant increase in the activity of white grubs during April to September. In July, maximum population of white grubs was recorded at Badagaon with mean population of  $5.6 \pm 0.54$  grubs per  $\text{ft}^3$  area. At Barot,  $2.3 \pm 0.5$  grubs per  $\text{ft}^3$  area were recorded.

In Chuhar valley, rajmash, potato and off season cabbage are leading crops. All these crops were found to be badly damaged by white grubs, especially *M. virescens*. There was root pruning in rajmash and cabbage however in potato, the infested tubers showed large cavities which were filled with soil. The major white grub endemic areas were Badagaon, Barot, Kothiswar, and Kothikohar. The white grub population in endemic areas ranged from 0 to 9 grubs per  $\text{ft}^3$  area in rajmash, cabbage and potato fields. In rajmash, the plant mortality due to white grubs was recorded to vary from 7.5 to 16.3 at different locations during 2016 and 2017. In cabbage, 23.0 and 36.5 per cent plants were found to have infestation of white grubs during the years 2016-17 at Badagaon. At Kothikohar, Barot and Kothiswar, the plant infestation in cabbage ranged from 11.7 to 18.7 per cent. In potato, very high tuber infestation, ranging from 16.0 to 32.1 per cent, was recorded at Barot, Kothikohar and Badagaon. There was synchronization between the damaging stage of pest vis-à-vis susceptible stage of potato which adds huge losses to potato crop in Chuhar valley.

**Conclusion:** A total of 14 species were recorded on light trap and host trees in Chuhar valley. *Trichoserica umbrinella* was the predominant species on light traps. On host trees, very low activity of beetles was noticed. However, *B. coriacea* and *M. passerinii* were more abundant on host trees as compared to light traps. *Brahmina coriacea* and *M. passerinii* were found to be less phototactic, whereas *T. umbrinella* was more heliotactic in nature. The diversity indices indicate poor species diversity and less evenness in abundance of scarab beetles. In soil surveys, predominance of *M. virescens* caused huge losses to almost all crops cultivated in Chuhar valley. During sampling of beetles on host trees and light traps, *M. virescens* beetles were observed in very few numbers which confirmed that the beetles were less phototactic. Thus, it was likely that they did not feed actively and their mating was taking place on some other plants in the forest area. *Trichoserica umbrinella* predominated on light trap and host trees, but its damage was not seen either in adult or in grub stage. Therefore, the present study revealed that *M. virescens* grubs only caused economic damage to almost all crops in Chuhar valley. The species like *T. umbrinella* cannot be regarded as pests in spite of their higher adult population, but they

certainly play a crucial role in the local biodiversity. The biological study for such species could explain the role they play in the local ecology. During field sampling of grubs, third instar grubs were present in soil at the time of sowing during May to June. Thus, deep ploughing followed by thorough application and mixing of insecticide in soil would be helpful in reducing losses due to white grubs.

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