

BIODIVERSITY AND IDENTIFICATION OF POTATO WHITE GRUBS IN HIGH HILLS OF HIMACHAL PRADESH

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ABSTRACT: The most challenging insect-pests of the potato crop in Himachal Pradesh are white grubs. Their diversity tends to fluctuate, depending on altitude, geography, ecosystems, and other environmental variables. The survey on white grubs of potato was carried out in 19 locations from five districts of Himachal Pradesh during 2021-22. The altitude of these locations varied from 1378-3279m amsl. In total, 13 species of white grubs were collected feeding on roots and tubers of potato crop. Out of 13 species, 8 species have been identified as *Brahmina crinicornis* Burmeister, *Brahmina coriacea* (Hope), *Brahmina flavosericea* Brenske, *Holotrichia longipennis* Blanchard, *Anomala rufiventris* Redtenbacher, *Melolontha fuscicauda* Ancey, *Melolontha cuprescens* Blanchard and *Polyphylla sikkimensis* Brenseke. We couldn't rear four species till adult emergence and hence this species remained unidentified. The raster patterns of all 13 species have been described with suitable pictures.

KEYWORDS: Potato, white grub, raster pattern, distribution

INTRODUCTION

Potato is cultivated in almost all states of India under diverse agro-climatic conditions and has wider adaptability. It is a high-volume crop and yields substantially more edible energy, protein and dry matter per unit area and time because of a short vegetative cycle than many other crops (Dhiman *et al.*, 2007). India produces about 7.72 per cent of the world's potato from 7.57 per cent of the total global potato growing area, with productivity levels higher than the world's average (Rana 2011). In Himachal Pradesh, potato occupies an area of 14407 hectares with production of about 1.97 lakh MT (Anonymous 2021).

Insect-pests cause variable and complex problems for potato farmers. India has a great diversity of insect-pests that attack potato. The significance of various insect-pests in potato production varies from region to region. According to Simpson (1977), potato

crop is attacked by more than 100 arthropod pests, and out of these 80 pests have been reported from India (Saxena and Misra 1983). Among different insect-pests, white grubs are more destructive and troublesome insects, impeding potato production especially in hilly states of India (Chandel *et al.*, 2015). White grubs are immature stages of scarab beetles popularly known as chaffer beetles or May-June beetles.

This is a polyphagous pest both in adult and grub stage and inflicts heavy damage on various fruit/forest trees, their nurseries, vegetables, lawns and field crops (Chandel *et al.*, 2010). Being polyphagous they feed on a wide variety of cultivated as well as uncultivated plants (Mehta *et al.*, 2010).

In India, no record exists of any white grub damage to potato tubers until the 1960s. The first record of white grubs causing damage to potato in India is from Himachal Pradesh by Sharma and Bhalla

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(1964). They mentioned two species viz., *Brahmina coriacea* (Hope) and *Lachnosterna* (= *Holotrichia*) *longipennis* Blanchard causing damage to several crops including potato in Himachal Pradesh. The problem of white grubs is quite serious in the entire north-western Himalaya, where potatoes are grown during summer season as a rainfed crop under long day conditions (Misra and Chandel 2003). In Himachal Pradesh, potato cultivation is done on sloppy lands with light and loose-textured soils and high rainfall. The potato fields are normally situated in the vicinity of fruit orchards in entire north-western Himalaya, and the adults of white grubs prefer to feed on fruit trees during night (Chandel *et al.*, 1997), and enter into nearby potato fields where they lay eggs in the soil during May-June (Chandel *et al.*, 1995). These conditions are conducive for development and multiplication of white grubs (Singh *et al.*, 2002). In India, 24 species of white grubs have been recorded to damage potato from the states of Himachal Pradesh, Uttarakhand, Jammu & Kashmir, Tamil Nadu, Karnataka and north-eastern hill states. The most widespread and destructive species are *B. coriacea*, *Brahmina flavosericea* Brenske, *Melolontha indica* Hope, *Anomala dimidiata* (Hope), *H. longipennis*, *Holotrichia sikkimensis* (Brenske), *Holotrichia seticollis* Moser, *Phyllognathus dionysius* (Fabricius) and *Lepidiota mansueta* Burmeister (Chandel *et al.*, 2013, Bhattacharyya *et al.*, 2011).

MATERIALS AND METHODS

Field survey for collection of white grubs from potato

The survey on potato white grubs was carried out in 19 locations from five districts, mainly in high hills areas of Himachal Pradesh (Table 1). The survey work continued for about one year, the sampling sites in a field were selected randomly by throwing

a 1 feet² quadrant over one's shoulder with no two sampling pits overlapping, the data on grub population were recorded by using pit sampling method with each pit consisting of 1 cubic feet area. At each location, at least 20 samples were taken. At each location sampling of soil was done by carefully digging field by shovel and different larval, pupal and adult stages were carefully collected. The collected white grubs were brought to the laboratory in polythene bags along with moist soil. The observations on raster pattern were taken under the stereo zoom microscope model LEICA S9i. The rearing of grubs was done in the white grub laboratory, Department of Entomology, CSK HPKV, Palampur for adult emergence, and their further identification from the relevant sources. In the laboratory, the grubs were sorted out species wise on the basis of their raster pattern. Some of the white grubs were preserved in 70 per cent alcohol and data on their length and breadth were also recorded. After through sorting of larvae, grubs were transferred to individual paper cups/glass jars having soil and FYM mixture (1:1). Potato tubers were given as food for developing larvae, and observations were recorded on their development up to May, 2022. After adult emergence, beetles were killed and sent to NBAIR, Bengaluru for identification.

RESULTS AND DISCUSSION

The survey on potato white grubs was carried out at 19 different locations in Himachal Pradesh, and 13 species of white grubs were collected as shown in table 1.

In Chamba district, *Brahmina crinicolis* was found to be the predominant species comprising 100 per cent population at Salooni and 68.18 per cent at Mani. At Shillaroo, Chidgaon, Matiana, Kufri and Fagu in Shimla district, only *Brahmina coriacea* grubs were

Table 1. Location-wise species distribution of white grubs in Himachal Pradesh

Sr. No.	Location	Altitude (m amsl)	Species	Relative abundance (%)
1.	Salooni	1734	<i>Brahmina crinicolis</i> Burmeister	100.00
2.	Mani	1514	<i>Brahmina crinicolis</i> Burmeister	68.18
			Unidentified sp. I	31.82
3.	Rohru	1965	<i>Brahmina coriacea</i> (Hope)	77.38
			Unidentified sp. II	17.26
			<i>Anomala rufiventris</i> Redtenbacher	4.17
			<i>Melolontha furcicauda</i> Ancey	1.19
4.	Chidgaon	1767	<i>Brahmina coriacea</i> (Hope)	100.00
5.	Khadrala	2603	<i>Melolontha cuprescens</i> Blanchard	100.00
6.	Tikkar	2244	<i>Brahmina Coriacea</i> (Hope)	56.20
			Unidentified sp. III	43.80
7.	Shillaroo	2479	<i>Brahmina coriacea</i> (Hope)	65.07
			<i>Holotrichia longipennis</i> Blanchard	34.93
8.	Matiana	2394	<i>Brahmina coriacea</i> (Hope)	100.00
9.	Kufri	2561	<i>Brahmina coriacea</i> (Hope)	100.00
10.	Fagu	2519	<i>Brahmina coriacea</i> (Hope)	100.00
11.	Nihri	2114	Unidentified sp. V	65.49
			<i>Brahmina coriacea</i> (Hope)	26.55
			<i>Anomala rufiventris</i> Redtenbacher	7.96
12.	Bagsiad	1849	<i>Brahmina crinicolis</i> Burmeister	100.00
13.	Janjheli	2095	<i>Brahmina crinicolis</i> Burmeister	62.50
			<i>Polyphyllasikkimensis</i> Brenske	32.24
			<i>Anomala rufiventris</i> Redtenbacher	5.26
14.	Barot	1807	<i>Polyphylla sikkimensis</i> Brenske	61.19
			<i>Brahmina crinicolis</i> Burmeister	38.81
15.	Karsog	1378	<i>Brahmina flavosericea</i> Brenske	100.00
16.	Benchi	1501	<i>Brahmina flavosericea</i> Brenske	57.75
			Unidentified sp. I	37.32
			Unidentified sp. IV	4.93
17.	Banjaar	1876	Unidentified sp. V	100.00
18.	Anni	2006	Unidentified sp. V	60.95
			Unidentified sp. III	39.05

found to cause damage to potato tubers. Maximum population of white grubs was recorded at Shillaroo with a mean of 11.45 ± 1.05 grubs/ft². At Rohru and Tikkar, *B. coriacea* comprised 77.38 and 56.20 per cent of total grub count, respectively.

The observations recorded on morphometrics and development of different species is discussed here under.

***Brahmina coriacea* (Hope):** The grubs caused heavy damage to potato ranging from 8.20 to 45.90 per cent in high hills of Shimla, Mandi

and Kullu districts of Himachal Pradesh. In Shimla district, *B. coriacea* grubs comprised 56.06 to 100.00 per cent at Tikkar, Rohru, Chidgaon, Shillaroo, Matiana, Kufri and Fagu. Chandel *et al.* (2003) also found *B. coriacea* to be a common species in Shimla hills of Himachal Pradesh, constituting about 90 per cent of the population. In Thanedhar, Kotgarh, Matiana and Jubbal areas, 100.00 per cent beetles of *B. coriacea* have been taken in different collections by various workers (Singh and Dogra 1984). In the present study, observations were recorded on grubs and pupae of *B. coriacea* under laboratory conditions at Palampur. The first instar grubs of *B. coriacea* were collected during July 2021 from potato fields located in Shillaroo, Matiana, Fagu and Kufri areas. The collected grubs were greyish white in colour, and their body length ranged from 6.2 to 7.3 mm. Mean head capsule width was recorded to be 1.64 ± 0.09 mm (range: 1.59-1.74 mm). The identity of grubs was confirmed based on their raster pattern as described by Pathania *et al.*, (2017). The raster pattern is given in fig. 1, and it is ornamented with two rows of palidia. There are 13 pali in each row. The pali of one side are crossing the corresponding pali from other side in the middle of septula. There is gradual narrowing of septula from posterior to anterior direction. The hemate setae are bold and short. The palidium was broad at the base, tapered gradually, with pointed tip. The hemate setae seems to be fitted in round socket like structure, comparatively less tapered, and terminal end is slightly curved to right side. Chandel *et al.* (1995) reported body length of fully fed first instar grubs of *B. coriacea* ranging from 11.0-12.7mm with an average head capsule width of 1.5 ± 0.03 mm, and these values are in the same range as recorded in the present study. The first instar grubs occupied 12.0-14.0 days under laboratory conditions at Palampur. Chandla *et*

al. (1988) reported somewhat higher duration of the first instar grubs of *B. coriacea* in Shimla hills. However, Chandel *et al.* (1995) reported first instar ranging from 11-20 days with an average of 14.4 ± 0.6 days at Nauni located in mid hill region of Himachal Pradesh.

To complete post eclosion development, the grubs of *B. coriacea* moulted twice having three distinct instars. The body length of second instar grubs was observed to range from 14.0-16.20 mm for fully fed second instar grubs. The width of head capsule varied from 2.30-2.44 mm. The second and third instar grubs did not show much difference in morphological characters, except that there was considerable increase in larval size in third instar. During this final instar, the grubs turned slightly yellowish to creamish white in colour, but the colour of the head capsule remained dark brown. The third instar grubs (Fig. 1) measured from 22.87-26.12 mm in body length, and 3.87-4.19mm in head capsule width. The head capsule width as reported by Chandel *et al.*, (1995) is 2.4 and 4.3 for instars II and III, and the grubs in successive instars were on an average 14.95 and 24.13mm long, respectively. Contrary to our findings, Chandla *et al.*, (1988) reported third instar grubs of *B. coriacea* ranging from 35-38mm in body length. Duration of the second instar was recorded to be 23-27 days (mean $\pm$ SE: 24.50 ± 0.89 days). The third instar was recorded to be the overwintering stage, thus required 184-214 days for maturity. Although the duration of the third instar was about six months (October 2021-March 2022), but the duration of active feeding of third instar grubs was for about 60-70 days through October-November.

The fully fed third instar grubs stopped feeding by November, and formed hard earthen cells for overwintering and subsequent development as pupa and adults. Contrary

to this, average duration of third instar at Shimla was found to be 74.4 ± 2.80 days (Chandla *et al.*, 1988). Possibly they have recorded observations only on active third instar grubs before formation of earthen cells. These observations are in line with those of Veeresh (1977) for *H. serrata*. The total larval period was found to be 219-255 days with an average of 244 ± 10.12 days. Gupta (2012) reported total larval period of 214-267 days under laboratory conditions at Palampur. The prepupal period in laboratory was short, ranging from 11-12 days. The pupation in laboratory was observed as early as fourth week of March 2022 in hard earthen cells. The pupa (Fig. 1) measured on an average 16.61 ± 0.38 mm long and 7.07 ± 0.31 mm wide. The average pupal period was 15.95 ± 0.82 days, the minimum and maximum being 14 and 18 days, respectively. The pupal duration as reported by earlier workers was 12-20 days at

Nauni and 19-24 days at Palampur (Chandel *et al.*, 1995; Gupta 2012). Adult formation in earthen cells was noticed in second week of April 2016 under laboratory conditions at Palampur.

The adult beetles are black in colour (Fig. 1). The body length of beetles ranged from 12.45-16.60 mm with a mean of 14.6 ± 0.40 mm, while the width ranged from 7.47-7.98 mm with a mean of 7.54 ± 0.35 mm as shown in table 2. The body length width of *B. coriacea* beetles as reported by earlier workers was in the range of 12-17.55 5.94-7.85 mm (Gupta 2012; Chandel *et al.*, 1995). Thus, our findings are in complete agreement with their results.

***Brahmina flavosericea* Brenske:** In the present study, maximum abundance of *B. flavosericea* was recorded in Karsog area at an altitude of 1492 amsl. Pathania (2014)

Table 2. Duration and morphometrics of different development stages of *B. coriacea*

Stage	Duration (Days)		Body Length (mm)		Width (mm)	
	Range	Mean $\pm$ SE	Range	Mean $\pm$ SE	Range	Mean $\pm$ SE
Grub I	12-14	13.15 ± 0.80	6.2-7.3	6.33 ± 0.35	1.59-1.74	$1.64 \pm 0.09^*$
II	23-27	24.50 ± 0.89	14.0-16.20	14.90 ± 0.55	2.30-2.44	$2.47 \pm 0.14^*$
III	184-214	207 ± 4.9	22.87-26.12	24.13 ± 0.15	3.87-4.19	$4.02 \pm 0.13^*$
Total larval period	219-255	244 ± 10.12	-	-	-	-
Prepupa	11-12	11.8 ± 0.87	-	-	-	-
Pupa	14-18	15.95 ± 0.82	16.12-17.07	16.61 ± 0.38	6.75-7.20	7.07 ± 0.31
Adult	-	-	12.45-16.60	14.6 ± 0.40	7.47-7.98	7.54 ± 0.35

*Refers to head capsule width.

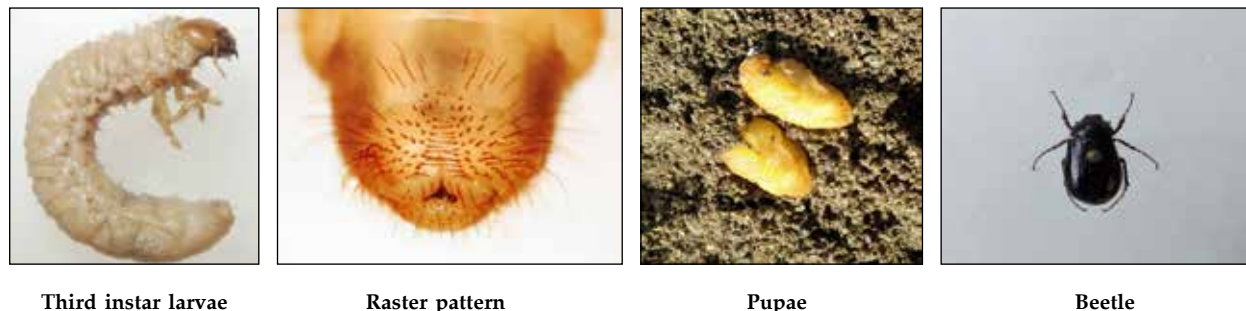


Fig. 1 Development stages and raster pattern of *B. coriacea*

has recorded this species in low to moderate numbers from Shillaroo, Bharmour, Nauni, Sangla and Kalpa areas. Chandel *et al.* (2010) reported that it is one of the leading species in Janjheli area of Mandi district. The young grubs were pearly white with a dark head. The fully fed first instar grubs were about 5.13 ± 0.04 mm long (range: 4.94 to 5.32 mm). The average head capsule width was recorded to be 1.16 ± 0.02 mm. The period of first instar larvae averaged 20.0 ± 2.13 days with extremes of 16 and 24 days. The average body length of second instar was noted to be 20.0 ± 0.83 mm (range: 19.20-22.10 mm). The second instar had extremes of 29 and 35 days with an average of 30.2 ± 0.12 days. The duration of third instar was found to be varying between 185 to 215 days, with an average of 203.50 ± 5.82 days. The length of fully grown third instar larvae ranged from 23.10 to 29.0 mm (mean: 27.38 ± 0.21 mm). Mehta *et al.* (2008) reported larval length of 22-24 mm in fully fed grubs of *B. flavosericea*. The average head capsule width was recorded to be 2.14 ± 0.02 and 3.29 ± 0.05 mm for second and third instar grubs, respectively. Pathania (2014) found head capsule width for first, second and third instar grubs of *B. flavosericea* as 1.16 ± 0.01 , 2.13 ± 0.03 and 3.30 ± 0.04 mm, respectively. These reports are well within the range observed from this species in the present study. The raster pattern is shown in fig.2. The septula is elongate, and palidia are arranged in two parallel rows. The number

of pali varied from 12 to 14, which are arranged in two parallel rows. The base of pali is spherical and the tip is pointed. The hemate setae had a circular flat base, more or less of same thickness from base to terminal end. The tip of hemate setae looks globular and is curved to right side.

The fully fed larva created a small earthen cell in the upper layer of soil in the month of November, and remained in the cell till adult emergence in next summer (Fig.2). Pupation occurred in earthen cells, and was observed as early as 17th April, 2022 in laboratory. The pupa measured from 15.74 to 17.46 mm with an average of 16.94 ± 0.52 mm. When freshly formed they were creamy white in colour, and darkened before emergence. There was a single generation in a year. Adult formation commenced on 3rd May, 2022, and newly transformed adults remained in earthen cells for a period of about 20 days. The adults are medium sized elongate beetles. The elytra are yellowish in colour. The head and legs are dark brown in colour (Fig. 2). The length of beetles ranged from 14.44 to 16.65 mm with a mean of 15.99 ± 0.21 mm, while the width ranged from 6.79 to 7.18 mm, with a mean of 7.05 ± 0.04 mm as shown in table 3. Mehta *et al.* (2008) recorded length as 13-14 mm, and breadth of 7-8 mm for beetles of *B. flavosericea*.

***Brahmina crinicornis* Burmeister:** The grubs of this species were collected in the month

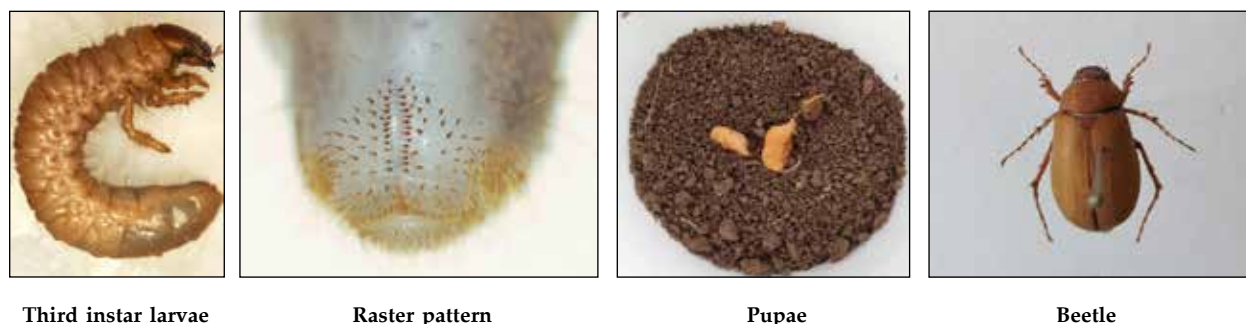


Fig. 2 Development stages and raster pattern of *B. flavosericea*

Table 3. Duration and morphometrics of different development stages of *B. flavosericea*

Stage	Duration (Days)		Length (mm)		Width (mm)	
	Range	Mean $\pm$ SE	Range	Mean $\pm$ SE	Range	Mean $\pm$ SE
Grub I	16-24	20.0 $\pm$ 0.83	4.94-5.32	5.13 $\pm$ 0.04	1.09-1.1.19	1.16 $\pm$ 0.02*
II	29-35	30.20 $\pm$ 0.12	19.20-22.10	20.0 $\pm$ 0.83	2.08-2.19	2.14 $\pm$ 0.02*
III	185-215	203.50 $\pm$ 5.82	23.10-29.0	27.38 $\pm$ 0.21	3.24-3.48	3.29 $\pm$ 0.05*
Total larval period	230-274	241 $\pm$ 11.20	-	-	-	-
Pupa	18-22	19.45 $\pm$ 0.64	15.74-17.46	16.94 $\pm$ 0.52	6.64-7.31	7.08 $\pm$ 0.42
Adult	-	-	14.44-16.65	15.99 $\pm$ 0.21	6.79-7.18	7.05 $\pm$ 0.04

*Refers to head capsule width.

of July at Salooni, Mani, Bagsiad and Janjheli in the present study. The head capsule width for third instar grubs ranged from 2.99 to 3.47 mm with an average of 3.25 $\pm$ 0.06mm. The fully fed third instar grubs measured on an average 26.24 $\pm$ 1.03mm in length (range: 23.51 to 29.8mm). The grubs continued feeding on potato tubers throughout August to October. The raster pattern (fig. 3) can be identified by two rows of palidia, each consisting of 18-20 pali. Each palidium runs parallel to each other from anterior to posterior direction upto 12 pali, but after 12 pali, each palidium diverge in opposite direction in a typical semi-circle forming J-shaped pattern as shown in fig.3. During November, fully fed third instar grubs constructed earthen cells and overwintering occurred in quiescent larval stage in these earthen cells from November to March. In the first week of April, grubs transformed into pupae inside the earthen cells. The pupation in laboratory

was observed as early as 4th April, 2022. The pupa measured on an average 16.53 $\pm$ 0.41mm long, and 7.08 $\pm$ 0.42mm wide. The average pupal period was 17.95 $\pm$ 0.74 days under laboratory condition, the minimum and maximum being 16 and 20 days, respectively. Total duration of third instar was calculated to 190 to 220 days (mean: 205.60 $\pm$ 5.7 days), and there was one generation per year.

Adult formation inside earthen cells was noticed as early as 18th April. Adult beetles are shiny black in colour, but the head and thorax are covered distinctly with brown hairs showing clear cut distinction from the rest of the body. The beetles measured 14.68 to 16.98mm in length, and 6.76 to 7.46mm (range: 6.76-7.46mm) in width.

***Holotrichia longipennis* Blanchard:** The grubs of *H. longipennis* were collected at Shimla in potato fields. According to Thakur (2000), this species usually occurs in northern India

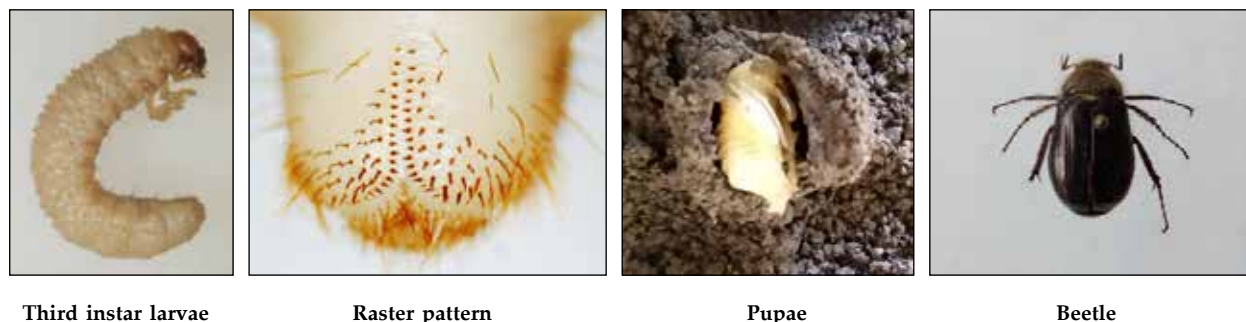


Fig. 3 Development stages and raster pattern of *B. crinicollis*

and Pakistan at altitude varying from 700-2500 amsl. The average density in potato fields was recorded to be 4.15 ± 0.17 grubs/ ft^2 (range: 2 to 6 grubs/ ft^2). The collected grubs were in first instar, and were further reared in laboratory till adult emergence. The field collected first instar grubs were creamy white in colour with light brown head which was prominently broader from rest of the body. The head capsule width of first instar averaged 1.73 ± 0.03 mm. Mean body length of fully fed first instar was recorded to be 8.88 ± 0.14 mm (range: 8.28 to 9.14 mm). Shah and Shah (1990) reported body length of early first instar grubs of *H. longipennis* as 6.92 ± 1.64 mm, and 1.97 ± 0.28 mm as width from first thoracic segment. Pathania et al. (2016) found body length of first instar larvae of *H. longipennis* to vary from 8.35 to 9.1 mm; and the average head capsule width has been reported to be 1.74 ± 0.01 mm. These reports are well within the range observed for this species in the present study. Under laboratory condition, the duration of first instar was recorded to be 14 to 18 days. Pathania et al. (2016) reported first instar of *H. longipennis* ranging from 21 to 26 days in Himachal Pradesh. However, in Uttarakhand, earlier workers have indicated higher duration ranging from 40.08-41.8 days for first instar grubs of *H. longipennis*.

The first instar grubs moulted into second instar by the end of August. The body colour of grubs in second instar was dirty white with dark brown head capsule. The body length ranged from 18.9 to 20.14 mm for fully fed second instar grubs. The head capsule width varied from 3.32 to 3.67 mm. Mishra et al. (1998) reported body length of second instar of *H. longipennis* ranging from 23.5 to 25 mm in Uttarakhand. The head capsule width reported by Pathania et al. (2016) is 3.15 ± 0.04 mm. These reports clearly substantiate our results. The duration

of second instar lasted for 26 to 32 days with an average of 29.20 ± 0.81 days. The second instar grubs of *H. longipennis* occurred from August to October. The second instar grubs constructed earthen cells and moulted inside these cells to the third instar. According to Kalpana (2015), the average duration for second instar of *H. longipennis* was 35.06 ± 0.52 days for this species at Palampur. During the final instar, the grubs turned greyish white in colour, measured from 32.88 to 34.31 mm in body length, and 5.03 to 5.13 mm in head capsule width. Shah and Shah (1990) reported that third instar of *H. longipennis* are 31.69 mm long indicating almost similar size of final instar grubs, whereas head capsule width reported by them is on higher side (8.91 mm). The raster pattern is given in fig. 4. Raster is equipped with two widely separated prominent palidia. The palidia (comb like structure) and hemate setae (lateral to palidia on each side -Tegillum) covered nearly half of the last ventral abdominal segment. Each palidium possessed long, sharp 13-14 pali. The septula (space between two palidia) is wide, linear and appears to be narrow 'V' shaped. Tegilla occupied nearly caudal half of the area between lower anal lip and the anterior margin of the last abdominal segment. The description of raster pattern matches with that of Kalpana (2015) and Pathania et al. (2016).

The duration of third instar ranges from 207-228 days with an average of 218 ± 3.12

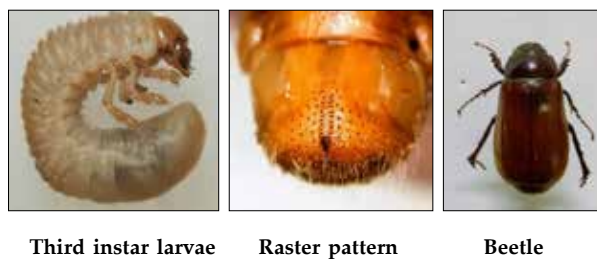


Fig. 4 Development stages and raster pattern of *H. longipennis*

days. The third instar grubs occurred from September to April. The average period of third instar of *H. longipennis* at Ranichauri was found to be 211.6 ± 3.14 days (Mishra *et al.* 1998). Haq (1962) reported that the duration of third instar grubs of *H. longipennis* in Uttarakhand ranges from 160-191 days with a mean value of 175.4 days. The fully fed third instar grubs moved downward, stopped feeding and constructed earthen cells. The formation of earthen cells by third instar grubs was noticed in the month of November. Third instar grubs produced large irregular cavities deep into the potato tubers, and such tubers are rendered totally unfit for marketing. Total larval period ranged from 247-303 days. The pupation in laboratory was observed as early as 14 April, 2022. The average pupal period was recorded to be 14.0 ± 0.86 days under laboratory condition. The minimum and maximum being 12 and 16 days. According to Shah and Shah (1990), the pupal period was of 22 to 28 days at Nainital for this species. It was of 15 to 23 days at Ranichauri (Mishra *et al.* 1998). In laboratory, the adult formation was noticed in the first week of May. Pathania *et al.* (2016) also noticed adult formation of *H. longipennis* inside earthen cells as early as 7th May at Palampur. The adult beetles of *H. longipennis* are shining light chestnut brown in colour with light brown abdomen and dark brown legs. The average body length x width of beetle was recorded to be $21.61 \pm 0.34 \times 9.08 \pm 0.05$ mm. Kalpana (2015) recorded length of 21.29 to 21.49 mm and breadth of 8.94 to 9.27 mm for beetles of *H. longipennis* in Himachal Pradesh. There was one generation in year.

***Anomala rufiventris* Redtenbacher:** The grubs of *A. rufiventris* were collected at Janjheli and Nihri in Mandi district, and Rohru in Shimla district of Himachal Pradesh. *A. rufiventris* has been recorded on light trap in Sirmour 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). The grubs were further reared in laboratory at Palampur. The fully fed third instar grubs averaged 42.06 ± 1.93 mm in their body length with a range of 40.13 to 43.98 mm. The head capsule width of third instar grubs averaged 4.29 ± 0.12 mm (range: 4.17 to 4.4 mm). The raster pattern is given in fig.5. The raster is characterised by very long and thin pali. The pali of each side overlap corresponding pali of other side in the centre, and pali are arranged in a clustered manner. The grubs did not inflict much damage, but superficial scrapping was seen on potato tubers. The fully-fed larvae made a small earthen cell in deep layer of soil (about 6 to 8 cm deep) on first November, and remained in the cell till adult emergence in next summer. The grubs remained active for about 90 days before constructing earthen cells. They spent about 180 days in earthen cells before transforming into pupae. Pupa was observed as early as 2 May, 2002 in laboratory. The length of pupal stage was found to vary from 24 to 27 days with an average of 25.33 ± 0.88 days. The adult formation commenced on 26 May, 2022. There was single generation per year, and the total average duration of the third instar and pupa was observed to be 288 ± 2.13 days. The adults are medium sized, elongate beetles. Their body is smooth, shining, very dark bronzy-green, sternum and legs greenish black and



Third instar larvae

Raster pattern

Beetle

Fig. 5 Development stages and raster pattern of *A. rufiventris*

ventral abdominal segments mahogany red. Pronotum thinly and very minutely punctate. The length of beetles ranged from 16.10 to 22.00 mm, while the width varied from 10 to 11mm. Rai and Joshi (1988) has reported *A. rufiventris* causing damage to potato in Uttarakhand. According to Chandra and Uniyal (2007), *A. rufiventris* distributed in Himachal Pradesh, Uttar Pradesh, West Bengal, Manipur, Meghalaya, Sikkim and Bhutan.

***Melolontha cuprescens* Blanchard:** The grubs of *M. cuprescens* were collected from potato fields in Khadrula area of Shimla district. It is said by Chandra (2005) to occur from Chamba, Kinnaur and Kullu district of Himachal Pradesh. Pathania (2014) has reported *M. cuprescens* in Holi, Kheradhar, Dalash and Sangla. The average population of grubs in soil was recorded to be 7.82 ± 0.50 grubs/ft². The grubs were large in size, and measured 58.74 ± 1.28 mm (range: 51.98-68.02mm) in body length. The average head capsule width was recorded to be 6.5 ± 0.15 mm (range: 51.98-68.02 mm). The grubs were collected in the month of November and were maintained in laboratory for about two months. The grubs inflicted large holes in potato tubers during feeding. The grubs stopped feeding by the end of November and hibernated in large earthen cells. There was no pupa formation in the laboratory. The raster pattern is given in fig. 6. The raster is prominently conspicuous with two

widely separated and prominent palidia in central region. The paired palidia are nearly parallel each consisting of 28-29 pali, pointed downward especially in the lower region. The anal slit is Y shaped, depressed and hooked in the centre, slightly raised on both sides and gradually tapering laterally in a semi-circular fashion. The anal cleft is straight, touching the base of septula. Rana *et al.* (2022) also revealed similar features in his description of raster pattern of *M. cuprescens*.

***Melolontha furcicauda* Ancey:** The grubs of *M. furcicauda* were collected from potato fields at Rohru during November. The grubs were collected in very few numbers in potato fields. The head capsule width was recorded to be 6.89 mm, and the body length averaged 59.03 mm. *M. furcicauda* has been reported to be an important pest infesting oats during seedling stage in northern Kashmir (Kumar *et al.*, 2019). Gupta *et al.* (1977) has reported *M. furcicauda* as a major pest of different fruit crops including apple, apricot and cherry in different regions of north-western Himalaya. The raster pattern is given in fig. 7. The raster pattern of *M. furcicauda* has been described by Rana *et al.* (2022), and it matches with our picture. Each palidium consisted of 26 pali. The anal slit is raised in the centre and gradually tapers to both sides uniformly.

***Polyphylla sikkimensis* Brenske:** The grubs of *P. sikkimensis* were collected from Barot and Janjheli in Mandi district inflicting



Third instar larvae

Raster pattern

Fig. 6 Development stages and raster pattern of *M. cuprescens*



Third instar larvae

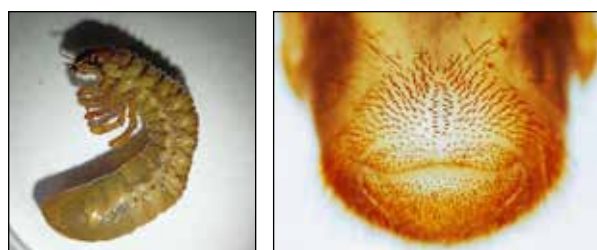
Raster pattern

Fig. 7 Development stages and raster pattern of *M. furcicauda*

considerable damage to potato tubers. The head capsule width measured 7.6 ± 0.17 mm (range: 7.32 to 7.98 mm), and body length was recorded to be varying from 58.3 to 63.12 mm (59.8 ± 1.2 mm). The grubs were collected from Janjheli in the month of July, 2021, and were reared in laboratory on potato tubers upto November. The grubs constructed earthen cells in November for hibernation. Pupa formation was not recorded under laboratory condition. The raster pattern is given in fig. 8. The palidia is short and each palidium consisted of 12 pali. The pali pointed inward and upward in the upper region with septula indistinct. Anal cleft is absent. The V shape anal slit, more or less flat in the centre, equal gradually on both side and becomes almost flat for considered end on both sides. Rana (2020) has described the raster pattern of *P. sikkimensis* in a similar manner. In *Polyphylla disoniata*, the anal opening is broadly V shape and rasterly too short, nearly parallel, longitudinal palidia each sparsely set with 7-12 cylindrical pali whose tips frequently touching those of opposite palidium (Ritcher 1966).

Unidentified Species I-V: The grubs of unidentified species I were collected at Mani, and Benchi areas. The head capsule width of grubs averaged 4.92 ± 0.14 mm (range: 4.87-5.12 mm), and body length was 33.78 mm (range: 31.98-39.53 mm). The raster pattern is given in fig. 9. The unidentified species II was collected at Rohru in the beginning of November. The head capsule width of grubs averaged 3.72 ± 0.19 mm (range: 3.50 to 4.11mm), and mean body length measured 41.2 ± 1.2 mm (range: 39.2 to 45.10 mm). The raster pattern is given in fig. 10.

The grubs of unidentified species III were collected at Tikkar (2244 m amsl) in Shimla district and Anni (2006 m amsl) in Kullu district. The head capsule width was recorded to be 3.45 ± 0.13 mm (range: 3.29 to 3.67 mm)



Third instar larvae

Raster pattern

Fig. 8 Development stages and raster pattern of *P. sikkimensis*



Third instar larvae

Raster pattern

Fig. 9 Development stages and raster pattern of unidentified sp. I



Third instar larvae

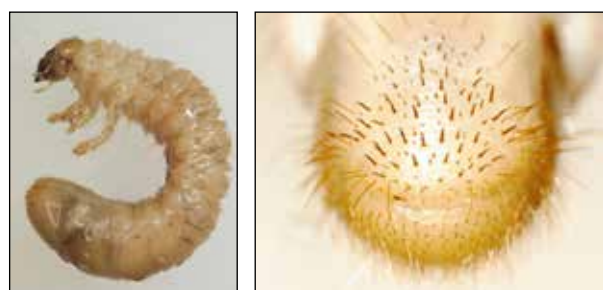
Raster pattern

Fig. 10 Development stages and raster pattern of unidentified sp. II

with body length ranging from 38.94-42.16 mm (mean: 39.74 ± 0.98 mm) (Fig. 11).

The unidentified species IV was collected at Benchi. The head capsule width of grubs was recorded to be 3.81 mm, and body length averaged 32.36 mm. The raster pattern is given in fig. 12.

The grubs of unidentified species V were collected at Nihri in Mandi district, and Banjaar and Anni in Kullu district. The fully fed third instar grubs averaged 28.98 ± 0.52 mm in their body length with a range of 27.36-31.23mm. The head capsule width of



Third instar larvae

Raster pattern

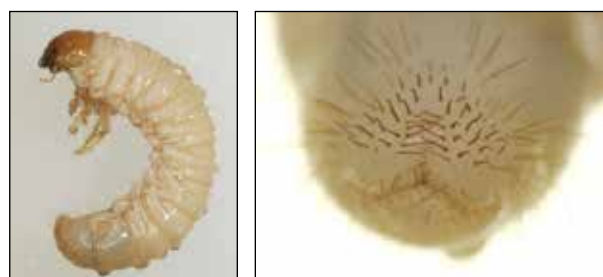
Fig. 11 Development stages and raster pattern of unidentified sp. III



Third instar larvae

Raster pattern

Fig. 12 Development stages and raster pattern of unidentified sp. IV



Third instar larvae

Raster pattern



Pupae

Beetle

Fig. 13 Development stages and raster pattern of unidentified sp. V

third instar grubs averaged 3.31 ± 0.04 mm (range: 3.22-3.48 mm). The raster pattern is given fig. 13. They spent about 125 days in earthen cells before transforming into pupae.

The adults are medium sized elongate beetles. The elytra are shining brown in colour. The head and legs are dark brown in colour (Fig.13). The length of beetles ranged from 12.49-16.7 mm with a mean of 15.05 ± 0.94 mm, while the width ranged from 7.13-7.89 mm with a mean of 7.46 ± 0.16 mm.

CONCLUSION

Lot of diversity exists in white grubs causing damage to potato which is grown under rainfed condition in high hills of Himachal Pradesh, under long day conditions. In total, 13 species were recorded from potato fields, and frequency of their occurrence is very high. *B. coriacea* is a leading species in Shimla and Mandi, whereas in Chamba area, *B. crinicollis* constituted greater percentage. Similarly in Mandi district, *P. sikkimensis* also inflicted considerable damage and warrants control measures. The existing recommendation of white grubs is based on study conducted in Shimla hills where *B. coriacea* is the only species. Therefore, there is need to develop management practices for the control of other species like *B. crinicollis* and *P. sikkimensis*, in their respective areas of occurrence. There is also need to popularize the available technology with more emphasis on biointensive management as none of sample potato growers were found to use any biopesticide to control white grubs.

CONFLICT OF INTEREST

The authors confirm that this manuscript has no conflict of interest.

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ABBREVIATIONS

Abbreviation/ Symbol	Meaning
amsl	Above mean sea level
et al.	Et alii (and others)
ft	feet
Fig	Figure
i.e.	Id est (that is)
m	Meter
mm	Millimeter
No.	Number
P	Page
SE	Standard error
sp.	Species (Single)
vis-à-vis	In relation to
viz.	Vi delicet (namely)
=	Equal
%	Per cent
/	Per
±	Plus or minus
*	Asterisk
&	And