2. REVIEW OF LITERATURE

The origin of world *Scarabaeus* is attributed either to the Latin or to the Greek. According to Macleay (1819), it was originally used by the Romans to designate the Coleoptera and as such is used by Pliny, who also used it in a definite description of the sacred beetles of Egypt. Linnaeus (1758) was the first who applied the term properly. He included all that we now know as 'Lamellicorns'. Scopoli (1763) separated the genus *Lucanus* from *Scaraboeus* and *Scaraboeus* became known as the *Lamellicornia,* a term which was first used by either Lamark (1817) or Latreille (1817), but it is more generally attributed to Latreille. The family Scarabaeidae according to Leng (1920) includes 14 commonly recognized subfamilies, namely the Coprinae, Aegialiinae, Aphodiinae, Ochodaeinae, Hybosorinae, Geotrupinae, Pleocominae, Glaphyrinae, Acanthocerinae, Troginae, Melolonthinae, Rutelinae, Dynastinae and Cetoniinae arranged as far as possible in phylogenetic sequence. Only four families *viz.* Melolonthinae, Rutelinae, Dynastinae and Cetoniinae are considered in this study. The family Scarabaeidae alone represents about 2500 species from the Indian sub-region to which the majority of the phytophagous scarabs belong. The economically most important sub families are Melolonthinae, Rutelinae, Dynastinae and Cetoniinae each representing 1958, 412, 46 and 24 species, respectively (Ali 2001). As a part of the present study we have reviewed work on representatives of four of the subfamilies considered here.

2.1 Relative abundance and diversity of scarabaeid beetles on light traps

Insects as a class respond to electromagnetic radiations from approximately 2537 A^0-7000 A^0 *i.e.* from ultraviolet to the infrared. At the long end of the spectrum the maximum effective wavelength for most insects is of the order of 6500 A^0 (Detheir 1953). Based on light as an attractant a variety of insect traps have been developed and used. Light traps have been used for many years to monitor long term population changes in nocturnal flying insects. They also provide information on the time of arrival of a particular species of an insect in a particular locality (Saini and Verma 1991). The major problem with light traps is that sometimes large number of non-target species which may include useful ones also, get trapped which not only make sorting cumbersome but also

disturb ecological balance (Saini and Yadav 2007). Light traps have been most widely employed for sampling and mass trapping of scarabaeid beetles in different parts of the world.

Sanders and Fracker (1916) used Lantern traps to collect the beetles. The trap consisted of coleman gasoline arc lantern, from 300-400 candle power, set into galvanized refrigerator pans, 5 inches deep and 24 inches in diameter. The pans were filled about 2/3rd full of water and little kerosene was poured on this and renewed when necessary. Seventeen out of 19 species known to occur in Wisconsin were taken in the traps. *Lachnosterna fusca* (Froelich) was most widely distributed at Lancaster and Dodgeville. *Lachnosterna rugosa* Melsh. was dominant at north east station and *Lachnosterna implicta* (Horn.) at Ripon. Morofsky (1933) collected 16 species of *Lachnosterna* (*Phyllophaga*) occurring in Michigan. *L.* (*P.*) *rugosa* and *Lachnosterna* (*Phyllophaga*) *hirticula* Knoch were the most numerous species. Of the 10,000 adults of all the species taken at electric lights, 89 per cent was found to be males, except in the case of *Lachnosterna* (*Phyllophaga*) *anxia* Lec., the most widely distributed, of which 75 per cent were females.

Stearns (1937) operated light trap in north of Delaware during the spring and summer of 1937, and captured 79 beetles belonging to 8 species of *Lachnosterna* (*Phyllophaga*). To gather information on the flying heights of insects associated with tobacco and some other crops, two traps installations were operated during 1967 in Wilson County, North Carolina. In one installation, insect trap equipped with UV lamps were mounted at about 11 feet intervals to 99 feet above ground with the lowest trap at ground level. Height distribution in the traps was reported for *Lachnosterna* (*Phyllophaga*) *crenulata* (Froelich) and *Lachnosterna* (*Phyllophaga*) *luctuosa* Horn. (Stewart and Lam 1968).

Gruner (1975) investigated flight activity of scarabaeids with the aid of light traps on Guadeloupe Island in the West Indies during 1970-73. He recorded activity of *Bothynus ebenus* (Deg.), *Bothynus* (*Lachnosterna*) *cuniculus* (Fabricius), *Dyscinetus picipes* (Burm.), *Lachnosterna* (*Phyllophaga*) *plaei* (Blanchard), *Lachnosterna* (*Phyllophaga*) *patrueloides* (Paulian) and *Cyclocephala insulicola* Arrow most of which are pests of sugarcane. Petty (1977) recorded observations on beetle pests of pineapples

at East London, South Africa, during 1974-77. Three scarabaeids *viz. Adoretus tessulatus* Burmeister, *Trochalus politus* Moser and *Heteronychus arator* (Fabricius) were most abundant. There was variation in numbers from year to year, the time of peaks in numbers of adults in light traps changed little from year to year.

Pal (1977) carried out light trap studies on relative abundance of scarabaeieds in Jodhpur area of Rajasthan during 1971-72. *Rhinyptia meridionous* Arrow was the most common species followed by *Schizonycha ruficollis* (Fab.), *Adoretus lasiopygus* Burmeister and *Maladera assamensis* (Brenske). In Uttar Pradesh, adults of *Holotrichia consanguinea* (Blanchard) were most attracted 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 (Nath et al. 1978). Bakhetia and Sohi (1982) collected 14 species of scarabaeids belonging to 10 genera on light trap from Punjab. Maximum trapping (32.84%) was on UV light, followed by blue light (24.36%), orange (13.98%), plain bulb (12.92%), yellow (8.68%) and green light (7.20%).

Tripathi and Gupta (1985) conducted studies on the collection of scarabaeid beetles on light trap from June 1983 to September 1985 at Chaubattia in Almora district of Uttrakhand. During these three years of survey, 33 species of beetles were collected, however, total catch ranged from 1-18 beetles per night per light trap. 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-October to find the peak period of emergence of positively heliotactic 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 catches of *H. longipennis* (103 beetles) and *A. dimidiata* (985 beetles) were recorded during third and fourth week of June, respectively. *Melolontha indica* Hope beetles appeared during August-September. *A. rugosa, Anomala polita* Blanchard, *Melolontha furcicauda* Ancy and *Brahmina* sp. were observed on light trap in small numbers.

In Korea Republic, UV light trap was used to examine the species distribution and seasonal occurrence of chafers in groundnut fields in Kyunggi-do. In all, 13 species were collected with *Anomala rufocuprea* Motschulsky, *Holotrichia morosa* Waterhouse, *Holotrichia diomphalia* (Bates) and *Maladera orientalis* Motschulsky being the most abundant (Cho et al. 1989). In Georgia, Forschler and Gardner (1991) captured over 60,000 beetles of phytophagous scarabaeids in UV light traps operated at two sites in 1988 and four sites in 1989. In total, 31 species in 8 genera were represented. Adults of the genus *Cyclocephala* were the most numerous. The genus with the most species was *Phyllophaga* with 22 species. However, these *Phyllophaga* collections represented only 4 per cent of total numbers collected at four sites in 1989. In the Appalachian mountains of north western North Carolina, *Phyllophaga anxia* (LeConte), *Phyllophaga fusca* (Froelich) and *Polyphylla comes* Casey were recorded on light trap. Multiple flights by *P. anxia* and *P. fusca* occurred over period of 10 and 12 weeks, respectively, while multiple flights by *P. comes* lasted for 6 weeks. The peak flight densities occurred 3-4 weeks after initial flights. Males and females of the both *Phyllophaga* species were captured in large numbers, but very few females of *P. comes* were caught. Most individuals of *Phyllophaga* species were captured before mid night, while most individuals of *P. comes* were caught between mid night and 04:00 hours (Kard and Hain, 1990).

Vora and Rama Krishnan (1991) exposed beetles of *H. consanguinea* to different intensities of light (0.83-36.67 C.P.) simultaneously in a cubicle. They reported that *H. consanguinea* beetles were positively phototactic towards lower intensity of light. The light intensity of 0.83 C.P. was preferred over total darkness. In Nilgiri hills of Tamil Nadu, around 70 per cent emergence of *Anomala communis* Burmeister and *Anomala nathani* Frey occurred within a week of first summer rain on light trap. In case of *Holotrichia excisa* Moser, 53 per cent emergence, and in *Holotrichia repetita* Sharp 82 per cent of the emergence occurred within a fortnight of first rain (Chandramohan and Nanjan 1991).

In Himachal Pradesh, Devi et al. (1994) identified 20 species of beetles on light trap between March-October during 1992-93 at Palampur. *Anomala lineatopennis* Blanchard was abundant in June, whereas *Holotrichia cavifrons* Brenske appeared in July. *Melolontha melolontha* Fabricius was recorded during July-August. Bhagat and Kashyap

(1997) recorded 10 species of beetles belonging to 6 genera on light trap from May-September at Palampur. The beetles of *Holotrichia sikkimensis* Brenske, *H. longipennis* and *Xylotrupes gideon* Guerin-Meneville were recorded as early as May on light trap and their emergence continued till September. The relative abundance of these three species has been recorded to be 40.35, 12.74 and 33.0 per cent, respectively. In a similar study, Chandel et al. (1994) 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 *B. coriacea* (13.40-18.90%) followed by *H. longipennis* (11.20-13.20%). The *B. coriacea* appeared as early as March and trapping continued till August, whereas *H. longipennis* appeared during June to September. Kumar et al (1996) also recorded 16 species during 1992-93 on light trap in Kullu valley. During both the years, a total of 177 beetles were collected 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).

In Gharwal region of Uttrakhand, 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 800-2200 m amsl (Mishra and Singh 1996). In Kumaon region, 14 species of beetles were captured on light trap and *A. dimidiata* was the predominant species constituting 61.05 per cent of total catch during 1995-96. *H. seticollis, B. coriacea* and *H. longipennis* constituted 15.73, 9.00 and 7.56 per cent of total catch, respectively (Mishra and Singh 1997).

In Australia, detection of flight activity of African black beetle, *H. arator* by light traps suggested that light trap catches were consistently female dominated (Matthiessen and Learmonth 1998). Rodriguez Jimenez et al. (2002) carried out experiments in the plantation of the Ciego de Avila Pineapple Enterprise to control whitegrubs using light traps. They reported that it is possible to manage them using light traps. The analysis of energy cost showed that substitution of the incandescent light traps by the fluorescent lights for the trapping of scarabaeids is economic, effective, reliable and feasible.

Patel and Patel (1999) made collection of new species of whitegrubs using light trap from Gujarat. They recorded *Apogonia* sp., *Autoserica calcuttae* Brenske, *Autoserica*

nagporeana Brenske, *Cyphochelus sp., H. reynaudi, Holotrichia tetarana* Brenske, *Schizonycha ruficollis* Fabricius, *Adoretus bicolor* Brenske, *A. versutus* Harold, *Anomala bengalensis* Blanchard, *Adoretus dorsalis* (Fabricius), *Anomala* sp. and *Mimela macleoyana* (Vigros) during *kharif* season of 1997-1998. Mishra and Singh (1999) installed a light trap with 20 watt fluorescent tube at Ranichauri in Uttrakhand. 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%) and *Maladera* sp. (7.27%). Bhagat and Kashyap (1999) operated light trap at Shillaroo in Shimla hills of Himachal Pradesh. Data on beetle catch were recorded from June 16-18 and July 18-19, 1998. A total of 95 beetles of *B. coriacea* were captured during this period.

Zahoor et al. (2003) obtained data on scarabaeid beetles by netting, handpicking and light traps in Faislabad, Pakistan. The species richness, species evenness and species diversity by Shanon diversity index for two habitats revealed more diversity of scarab beetles in forest area (57 species) as compared to the cropped area (41 species). Pinto et al. (2004) collected Coleoptera on light traps in *Eucalyptus urophylla* (S.T. Blake) plantation in the municipality of Almerin, State of Para, Brazil. The collection was done during one night every fifteen days from September 1995 to August 1996. Among scarabaeids, *Anomala* sp., *Leucothireus* sp. and *Cyclocephala laminata* Burmeister were the most abundant species. *Anomala* sp. and *Leucothireus* sp. jointly constituted 93.40 per cent of the individuals. However, in the county of Santa Barbara, Minas Gerais, Brazil, family Scarabaeidae constituted only 10.12 per cent of total coleopteran insects collected on light trap. Among scarabs, most species captured were *Isonychus albicinctus* Mannerheim and *C. laminata* (Freitas et al. 2002).

Sushil et al. (2004) monitored seasonal abundance of beetles at Hawalbagh, Almora by using light traps. Maximum and minimum temperature, RH 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. In Kumaon hills, *A. dimidiata* was the most predominant species constituting 12.78-51.96 per cent of light trap catches during 2002 to 2004. *H. longipennis, Lepidiota stigma* (Fabricius), *H.*

seticollis and *X. gideon* represented 9.08, 15.32, 8.80 and 15.01 per cent of total scarabaeid fauna captured on light trap during this period (Sushil et al. 2006). Bhat et al. (2005) collected beetles on light trap from April-September, 2004 in Srinagar district of Jammu and Kashmir. They captured 9 species of beetles and *M. indica, A. rufiventris, Lasiotropus ponnesis* and *Oryctes nasicornis* (Linnaeus) have been claimed as new records from Kashmir.

Pardo et al. (2005) installed light traps weekly throughout one year in agro-ecological systems of Northern Cauca, Columbia. They captured 12,512 adults on light traps belonging to 45 species of Scarabaeidae. Members of sub family Dynastinae predominated with 48 per cent of the species (mostly *Cyclocephala*) followed by Melolonthinae (35%) and Rutelinae (15%, principally *Anomala* spp.). In Melolonthinae, *Plectris* spp. comprised 59.50 per cent of the species and 35.90 per cent of the beetles belonged to *Phyllophaga* spp.

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. Chenchaiah (2006) recorded seasonal adult emergence using modified Robinson light trap in North Bengal. The light trap collection indicated that emergence of *A. varicolor* and *Anomala commonalis* Arrow takes place from April to July and again in October every year.

Kumar et al, (2007) carried out very detailed 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 ranged from 4.22-18.43, 4.00-20.55, 10.74-26.67, 4.33-12.68, 10.21-16.22 and 8.89-20.73 per cent, respectively, at different locations over different years. Irrespective of species, maximum percentage at total scarabaeid catch was recorded in June-July. In Haryana, emergence of

beetles begin during 18th 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 (60.76%), followed by *H. serrata* (19.12%) (Dhasad et al. 2008).

Gracia et al. (2008) used fluorescent light traps for management of whitegrubs in maize in Puebla, State of Spain. They obtained 91,486 adult beetles belonging to 19 species. *Phyllophaga ravida* (Blanchard) was the most abundant species comprising about 98.69 per cent of total beetle population in that area. 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), *Anomola bilobata* Arrow, *Holotrichia nigricollis* Brenske and *A. dimidiata*. They accounted for 58.81 per cent of all individuals collected. Khanal et al. (2012) installed two light traps for two nights in two locations each of Makawanpur, Tanahu and Chitwan districts and a season long light trap at Mangalpur of Chitwan district from April to September, 2010 in Nepal. The flight activity and species composition of scarab beetles in these three districts was observed to be different. The dominant species in Chitwan area were *A. dimidiata* (24%) followed by *Maladera affinis* (Blanchard) (23.75%), *A. varicolor* (23%), *Heteronychus lioderus* Redtenbacher (14%) and *Holotrichia* sp. (7%).

Kishimota et al. (2011) compared the species diversity of phytophagous scarabaeids in six forest sites in Malaysia. The beetles were collected by light trapping among 20 study plots in primary forest's, isolated primary forests, rubber gardens, old fallows, young fallows and new fallows. Estimated species richness did not differ significantly among the forest types. However, evenness values of new fallows were remarkably lower than those of the other forest type. The results suggested that rubber gardens and old fallows at various stages, with the exception of new fallows, tend to maintain phytophagous scarabaeid diversity at the level found in primary forest or atleast in isolated primary forest.

In Chhattisgarh, Chandra and Gupta (2012) conducted biodiversity surveys for scarabaeids at many locations of Achanakmar Amarkantak Biosphere Reserve (AABR) 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%). Thakare and Zade (2012) conducted survey on the coleopteran diversity from the vicinity of Semadoh-Makhala Road, Sipna, Melghat, Tiger Reserve in Maharashtra during October-November 2009. Among scarabaeids, *Chiloloba acuta* (Weidemann) was the only species collected on the light trap. Bhawne et al. (2012) used light traps to collect beetles from north western ghats of Kolhapur district of Maharashtra. They captured 18 species from 6 sampling sites and the most predominant species were *Holotrichia karschi* Brenske, *Holotrichia fissa* Brenske, *H. serrata*, *Maladera castanea* (Arrow), *A. lasiopygus* and *A. versutus.*

2.2 Relative abundance and diversity of scarabaeid beetles on host trees

Based on the food habits of adult beetles, scarabaeids are broadly divided into lamellicorn scavengers and lamellicorn leaf chafers (Comstock 1950). The phytophagous scarabs have great ecological impact by directly feeding on green plants causing extensive damage to both cultivated and forest plants. The beetles become active during May-June and feed on the foliage of different fruit and forest trees (Mehta et al. 2008). Beetles of the sub family Melolonthinae and Rutelinae are pre-eminently leaf feeders (Arrow 1917). The majority of the adults of Cetoniinae feed on flowers and fruits, therefore the cetoniid beetles are popularly referred as flower beetles.

Beeson (1921) reported *B. coriacea* on pear and apple in north western Himalaya. Later this species was recorded as a pest of *Quercus* sp. and *Rubus* sp. (Beeson 1941). Pruthi and Batra (1960) reported *B. coriacea* beetles feeding on leaves of apple, peach, plum, fig and grapevine in Kullu valley of Himachal Pradesh. Haq (1962) reported *Lachnosterna* (*Holotrichia*) *longipennis* beetles as important defoliators of apple, walnut, cherry and strawberry in the hilly districts of Uttar Pradesh. This species is widely distributed in Uttrakhand from Jeolikote (4000feet) to Chaubattia (7000 feet).

In Rajasthan, Srivastava and Khan (1963) recorded adults of *H. insularis* feeding on the foliage of 13 different plants including soanjna (*Moringa oleifera* Lam.), *karanda* (*Carandus plum* Linnaeus), guava (*Psidium guajava* Linnaeus), *neem* (*Azadirachta*

indica A. Juss.), *jamun* (*Eugenia jambolana* Lam.), mehndi (*Lawsonia inermis* Linnaeus), ber (*Zizyphus jujube* Mill.), imli (*Tamarindus indica* Linnaeus), babul (*Acacia arabica* Lam.), anar (*Punica granatum* Linnaeus), mango (*Mangifera indica* Linnaeus), falsa (*Grewia asiatica* Linnaeus) and barna (*Crataeva religiosa* Forst.). Amongst these host plants, adults showed a clear cut preference for soanjana and these plants were completely defoliated by beetles during rainy season.

Sharma and Bhalla (1964) reported *Clinteria spilota* Arrow defoliating apple plants as well as growing apple fruits during June in Kotgarh. *Mimela passerinii* Hope, *Oxycetonia jucunda* Faldermann, *Protaetia neglecta* (Hope), *Autoserica* sp., *Lachnosterna* (*Holotrichia*) *longipennis*, *Lachnosterna* (*Brahmina*) *coriacea, Lachnosterna* (*Brahmina*) *crinicollis, Microtrichia* sp., *Adoretus epipleuralis* Arrow, *A. dimidiata, Anomala flavipes* Arrow, *A. lineatopennis* and *A. rufiventris* were recorded feeding on apple, apricot, peach, plum and other stone fruits in Himachal Pradesh during June-July. However, *Heteronychus lioderes* Redtenbacher was found to damage paddy by adult beetles in Khepu-Khakhar area.

Singh (1964) in his book 'Entomology in India' has described scarabaeid beetles as important pests of temperate fruits. As many as 35 species are mentioned causing damage to many fruit and forest trees. Important species include *B. coriacea, Brahmina crinicollis* Burmeister, *L. (H.) longipennis, M. furcicauda, A. polita, A. rugosa, A. lineatopennis, A. rufiventris, A. dimidiata, A. bimarginatus, A. versutus, Adoretus duvauceli* Blanchard, *Cephaloserica thomsoni* (Brenske), *Hilyotrogus, holosericeus* Redtenbacher and *Mimela fulgidivittata* Blanchard which feed and cause damage to leaves of apple, apricot, cherry and walnut. However, *A. rufiventris* and *M. fulgidivittata* also feed on flowers of apple and apricot, respectively. Among sub family Cetoniinae, *Heterorrhina nigritarsis* (Hope), *O. versicolor* and *Oxycetonia albopunctata* (Fabricius) are important flower eating beetles of temperate fruits. *C. spilota* and *Macronata* 4-*lineata* have fruit eating habits and cause direct damage to fruits.

During 1963, there was an outbreak of beetles on pome, and stone fruits at Government PCDO, Kwagdhar in Himachal Pradesh. Therefore, regular surveys were conducted for four years between 1964-67, to monitor the population of scarabs and *A. flavipes, A. lineatopennis, A. rufiventris, H. holosericeous, L. longipennis, B. coriacea*

and *Macronata* 4-*lineata* were collected and identified on fruit trees. All these species were recorded causing damage to leaves of apple, peach, plum, apricot and pear. At lower elevations, where stone fruits mature early, even fruits are also attacked (Sharma et al. 1969; Chowdhuri and Verma, 1979). At Solan, *H. seticollis, A. lineatopennis, A. polita, B. coriacea, L. longipennis* and *Microtrichia cotesi* Brenske represented 6.79, 3.96, 5.59, 25.87, 44.06 and 13.75 per cent, respectively. However, in Shimla district, 100 per cent beetles of *B. coriacea* were observed at Jubbal, Matiana and Thanadhar in 10 different day catches (Anon. 1977).

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 Kwagdhar. Kashyap and Adlakha (1971) reported *Popillia gemma* Krautz as minor pest of soybean feeding on foliage during July-August in Kangra valley. It was also reported to feed on maize foliage in Kangra valley (Bhalla and Pawar 1977). 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.

Viswanathan and Shamanna (1972) carried out surveys in 35 coffee estates collecting 5 melolonthids and 3 rutelinids which were associated with the coffee crop. Of these, *Holotrichia nilgiria* (Arrow) was found to be widely distributed. Adults were active from July-November feeding at night on the leaves of coffee and other plants. During October 1969, falsa bushes, *Grewia asiatica* at Punjab Agricultural University, Ludhiana were reported to be damaged by scarabaeid beetles. The beetles responsible for causing this defoliation were identified as *A. bengalensis*, *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). Khan and Ghai (1974) reviewed work on Indian whitegrubs and reported that most destructive species of whitegrubs in India are *H. consanguinea* in Bihar, Uttar Pradesh and Rajasthan; *H. serrata* in Mysore, Uttar Pradesh, Maharashtra and Tamil Nadu; *H. insularis* in Rajasthan and Punjab, *Schizonycha ruficollis* in Uttar Pradesh, Punjab and Rajasthan; *Anomala* spp., in Rajasthan and Uttar Pradesh. The adults feed on foliage and

fruits of ornamental and fruit plants causing profuse defoliation. Verma (1975) noticed an outbreak of *Lachnosterna* (*Holotrichia*) *longipennis, A. ruficapilla, Anomala dorsalis* Fabricius, *A. bengalensis* and *Holotrichia problematica* Brenske in Haryana. These beetles severely defoliated peach trees.

In Chaubattia area of Uttrakhand, *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, X. gideo*n were recorded to feed actively on apple, peach, plum, apricot, pear, rose and walnut from April-August. Peak period of abundance was from first week of June to first week of July for *B. coriacea* and up to fourth week of July for *L. longipennis* (Gupta et al. 1977). Bhalla and Pawar (1977) compiled a book on "Survey study of insect and non-insect pests of economic importance in Himachal Pradesh". About 30 species of scarabaeid beetles are reported in this book causing damage to apple, pear, plum, apricot, peach, fig, grapevine, tea, loquat, cherry, soybean and maize in the state.

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). Nath and Singh (1981) surveyed Varanasi and Mirzapur districts of eastern Uttar Pradesh. They collected and identified *A. bengalensis, A. dorsalis, A. ruficapilla, Anomala* sp. *S. ruficollis, Apogonia ferruginea* Fabricius, *Apogonia rouca, Apogonia uniformis* Blanchard, *Autoserica nathani* Frey, *Autoserica* (*Maladera*) *insanabilis* (Brenske), *Dyscinetus trachipygus, Alissonotum* spp. on different host trees. These beetles were found feeding on *neem,* babul, and rose plants. The leaves were eaten up from the margins. The severely attacked trees were completely defoliated and looked like skeletons.

Bhadauria and Nigam (1982) studied food preference of *H. consanguinea* beetles to 12 plants. Maximum preference was recorded for guava followed by *neem*. It was least for mango. Rohilla et al. (1981) reported *H. serrata* as predominant species in Haryana. Shah (1983) recorded *Anomala nainitali* as a new species of defoliating beetle collected from a shrub in Nanital. Garg et al. (1983) found more than 15 species of scarabaeid beetles attacking fruit and forest trees in Uttar Pradesh. *A. dimidiata* var. *barbata*

Burmeister and *H. seticollis* being the most abundant ones. Shah (1986) observed serious attack of *Bhatula* beetles, *H. liioderes* in low-lying irrigated as well unirrigated rice fields in Uttrakhand. The beetles burrow in the base of rice plants and cut the stems from the ground level below the soil surface. Maximum damage was reported in June-July when the crop was in vegetative growth stage.

Singh and Dogra (1984) identified 17 species of phytophagous scarabs attacking apple cultivars at Mashobra in Shimla hills. The population of *B. coriacea* beetles exceeded 90 per cent and was responsible for inflicting maximum defoliation of apple cultivars during May-June. Chander and Singh (1985) reported *B. coriacea* as a common pest of apple and potato in Himachal Pradesh. Shah and Garg (1985) conducted survey in Kumaon hills of Uttrakhand during 1980-1982 and recorded about 20 species of defoliating beetles over a period of three years. *H. seticollis, Lepidiota* sp., *Anomala xanthoptera* Blanchard, *Mimela fulgidivittata* Blanchard, *Oxycetonia* sp. and *C. spilota* were recorded defoliating apricot, peach, plum, apple and other temperate fruits. Out of these, *H. seticollis* and *A. dimidiata* were serious, whereas other species were moderate/sporadic in their occurrence. Sharma and Tara (1985) conducted survey on insect-pests of mulberry in Jammu region of Jammu and Kashmir. Among scarabaeids, *S. ruficollis, M. insanabilis, Lepidiota bimaculata* (Saunders) and *Holotrichia* sp. were recorded as major pests of mulberries.

In Campania, Italy, *Anomala juni* Duftschmid, *Haplidia etrusca* Kraatz**,** *Melolontha pectoralis* Megerle and *Pentodon punctatus* Villers have been described as damaging to hazelnuts (Bianco and Viggiani 1988). In China, there was an outbreak of adults of *Brahmina potanini* (Semenov) in Wang Kui and Lanxi counties. The beetles fed on young plants of *Ulmus pumila* Linnaeus, *Ulmus macrocarpa* Hance, *Larix gmelinii* (Rupr.), *Larix olgensis* var. *koreana* Henry, and *Larix principis-rupprechtii* (P.R. Larch) (Dong and Yuan 1987). Zhou et al. (1990) reported beetles of another species, *Brahmina amurensis* Brenske feeding on leaves of *Ulmus* spp in China.

Chandla et al. (1988) reported that emergence of *B. coriacea* takes place in June in Shimla hills and adults feed on *Acacia* sp., peach, plum, apricot, pear and apple trees. In addition to above host trees, roses, *kathi* (*Indigofera sp.*), *khair* (*Acacia catechu* (Roxb.)Willd.) and several ornamental plants served as hosts for adult beetles (Misra and

Chandla 1989). Tewari et al. (1991) compiled information on 47 species of scarabaeids commonly occuring in Himachal Pradesh. They reported about 99 per cent damage to apple leaves by adults of *B. coriacea.*

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. Vora and Ramakrishnan (1991) studied attraction of *H. consanguinea* to different host plants by hanging their branches at different places in a cage. The highly attractive host plants were *Acacia arabica* and *Azadirachta indica.* The relative percentages of beetles on these plants were 34.10 and 30.76 per cent, respectively.

Chandra (1992) studied the host-pest relationship in Pleurostict Scarabaeidae of North-West India. *Popillia cyanea* Hope damaged roses and other wild flowers during day time in Almora. Among cetoniid beetles, *Torynorrhina spalina* and *Jumnos ruckeri* Saunders were found in large numbers clinging to the trunks of poplar trees in Almora. They damaged bark of the trunk while sucking the plant sap in poplars. *Protaetia alboguttata* Vigors also damaged sunflower in Almora area. *Clinteria acuta* (Wiedemann) was also found in abundance in Kurukshetra causing considerable damage to *kharif* crops. *O. versicolor, O. albopunctata, Oxycetonia jucunda* Faldermann and *C. spilota* were observed feeding on wild and ornamental flowers at Kalesar forest. *P. alboguttata* and *Heterorrhina elegans* Fabricius defoliated *Delbergia* trees in Kurukshetra very frequently. *Popillia pilosa* Arrow was observed feeding on lawn plantation at Chail in Himachal Pradesh. *A. dimidiata, A. duvauceli* and *A. lasiopygus* caused considerable damage to grapes by devouring the leaves at Naya Nangal in Punjab. *A. lasiopygus* and *A. duvauceli* were observed feeding on the leaves of *Casia tori* in Kurukshetra.

In Tamil Nadu, the scarabaeid beetles caused heavy defoliation of *neem* trees in some areas (Annamalai et al. 1993). In Punjab, the beetles of *C. acuta* severely attacked sorghum seed crop. The appearance of beetles coincide with the emergence of earheads from August end to first week of September. Freshly emerged earheads were found to be highly attractive to the adults for feeding. Peak population of the beetles occured during fourth week of September (Dhaliwal and Mehndiratta 1994).

Yadava and Sharma (1995) reported that there are about 50 species of whitegrubs in Indian subcontinent, of which about a dozen species are the key pests attacking different crops in different regions of the country. *H. consanguinea* is a dominant species in Rajasthan, Gujarat, Haryana, Punjab, Uttar Pradesh and Bihar and the adults prefer to feed on ber, *neem*, gular, *jamun* and drumstick. The beetles of *H. serrata* are attracted to *neem*, palas, babul, guava and grapes in southern parts of India. In Karnataka, the beetles of *Leucopholis* spp., feed on mango, guava, *Atrocarpus hetrophyllus, Ficus asperrima, Ficus racemosa, Syzygium zealanicum, Grewia microcos, Atrocarpus hirsutum* and *Anacardium occidentale*. The beetles produce peculiar step wise pattern on the cut edges. Around Mandya region, the beetles of *Popillia pulchripes* Arrow damaged newly emerging leaves of local banana (*Yelakki bale*) during September, 1996. The beetles congregate on the top most leaf as they were tender and palatable. The infested leaves gave a burnt appearance. It is reported that brinjal plots adjacent to banana served as a source of infestation (Thyagaraj and Gubbaiah 1996). In Buxa Tiger Reserve, Jalpaiguri, West Bengal, *Adoretus ariel* Arrow, *Adoretus bicaudatus* Arrow, *Adoretus boops* (Weidemann), *Adoretus flavus* (Nees), *Adoretus lemniscus* Arrow, *Adoretus minutus* Brenske, *Adoretus serratipes* Arrow, *Adoretus testaceus* (Hope), *A. versutus*, *Oxyadoretus nasutus* Arrow and *Parastasia sulcipennis* Gestro were reported. Out of these, *A. ariel* and *O. nasutus* were reported for the first time from West Bengal, whereas *A. lemniscus* is a new record from India (Saha and Raychaudhuri 1998).

Misra and Singh (1996) recorded data on number of *H. longipennis* beetles feeding on different host plants during peak period of emergence in Garhwal region of Uttrakhand. At elevations ranging from 800-2200m amsl, *Rubus ellipticus* Smith (29.4 beetles/branch) and walnut (21.0 beetles/branch) were the most preferred hosts, however, in valley areas, the beetles were observed to feed on ber. In Chamba district of Himachal Pradesh, a rutelinid beetle, *P. cyanea* was observed to cause extensive damage to rajmash during July-August, 1991. The beetles caused damage to flowers, buds and newly formed pods of rajmash (Thakur et al. 1996). Chandel et al. (1997) collected 21 species of defoliating beetles on apple, pear, plum and apricot at Solan. *B. coriacea* was the predominant species constituting 42.50-51.70 per cent of total catch in 1990-1991. *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. 1994).

Bhagat and Kashyap (1997) conducted preliminary survey on whitegrubs of Dhauladhar foot hills of Himachal Pradesh by direct collection of beetles from their host plants and the beetles of *Adoretus* sp. were observed on plum plants. However, the beetles of *Clinteria* sp. preferred apple fruits for feeding. In Mandi district of Himachal Pradesh, adults of *Clinteria* sp. were found feeding on apple fruits causing severe damage. It was observed that the beetles attacked only red fruits of apple (Bhagat and Kashyap 1998). Bhagat and Kashyap (1999) worked out light trap:host tree (LT:HT) ratio for *B. coriacea* beetles. They collected 381 beetles of *B. coriacea* on wild rose (*Rosa moschata*) between 16.06.1998 to 19.07.1998 and the corresponding catch on light trap consisted of 85 beetles. The LT:HT ratio ranged from 1:3.13 to 1:4.92. In case of *H. longipennis*, the LT:HT ratio has been computed to be 1:1.17 at Ranichauri using walnut as most preferred host (Mishra and Singh 1999). Mishra et al. (1998a) observed peak emergence of *A. lineatopennis* during first fortnight of June at Ranichauri in Uttrakhand. The adults preferred to mate and feed on chestnut, *Castanea sativa* Mill. At Nauni, *H. problematica* damaged olive plants severely during March-April. Its maximum activity was recorded during March-April and it constituted 40.90-40.4 per cent of total catch on olive (Chandel and Verma 1998).

In Garhwal hills of Uttar Pradesh, 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. 1998b). Singh et al. (1999) studied host preference of *H. longipennis* beetles under laboratory conditions using 15 hosts. *Rubus ellipticus* and *C. sativa* were found to be the most preferred hosts, whereas chamlai (*Desmodium tiliaefolium* D. Don), poplar (*Populus deltoides* Marsh), wild rose (*Rosa brunonii* Lindley), ban oak (*Quercus leucotricophora* A. Camus), apple (*Malus domestica* Borch) and plum (*Prunus domestica* L.) were least preferred. There was moderate preference for walnut (*Juglans regia* L.), *khirak* (*Celtis australis* L.), *bhimal* (*Grewia optiva* Burret), black raspberry (*Rubus niveus* Wallich) and dahlia (*Dahlia imperialms* R. Ortgies). Mishra and Singh (1999) reported that emergence of *S. ruficollis* starts by the May end with peak population occurring during second week of June. *Melia azedarach* was the most preferred tree for the beetles.

In Tamil Nadu, a cetoniid beetle, *O. versicolor* was observed to cause serious damage to brinjal crop in Cudalore district during 1999. The adult beetles congregate on arial parts and cause damage to tender shoots by nibbling the soft tissues of stem closer to the branches and leaf axils by thrusting their heads inside. As a result of beetle feeding, there was withering and drying of terminal and side shoots (Ambethgar 2000). Shekhar et al. (2000) collected four cetoniid beetles *viz. C. acuta, O. versicolor, P. alboguattata* and *Cetoniinae* gen. sp. *indet*. from maize fields in New Delhi. These beetles were found infesting maize tassels during *kharif*, of which *C. acuta* and *O. versicolor* were the predominant species. The distribution of these species was aggregated on maize. Khader Khan and Nagaraju (2005) observed beetles of *O. versicolor* attacking cashew apple in Kolar district of Karnataka during the month of May. The beetles attacked in large numbers having preference for uniformly yellow coloured fruits. At Mudigere in Karnataka, *H. liioderes* caused damage to local banana (*Putta bale*) and areca seedlings. Large number of beetles (300-400/sucker) congregated at the base of banana suckers and 5-6 beetles on the rootlet of areca seedlings. On banana, beetles bore into the stem for feeding and a gummy liquid oozed out. On areca, the entire root mass was damaged. The infested plants of both areca and banana produced yellowing symptoms on leaves (Thyagaraj 2003).

Singh et al. (2002) compiled information on species composition of whitegrubs as recorded in Uttrakhand. Atleast 57 species are known to occur in Uttrakhand 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. The adults of *A. dimidiata* have also been reported to be diurnal in their feeding habit. Singh et al. (2003) sampled 51 host plants to collect defoliating beetles from Tehri, Uttarkashi, Pauri and Chamoli districts of Uttrakhand. *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. *H. liioderes* was tropical in distirbution. *Sophrops problematica* (Fabricius) and *O. versicolor* were found only in subtropical zone, whereas *Melolontha nepalensis* Hope was exclusively a temperate species. About 70 per cent of

the recorded species had their host plants belonging only to family Rosaceae. In Kanpur, adult beetles of *Heteronychus annulatus* Bates have been reported feeding on the underground portion of 2-3 month old shoots of sugarcane, resulting in the drying of the central portion of the spindle, forming dead hearts (Mukunthan and Nirmala 2002). At Fagu in Shimla hills, collection of adults from host trees, revealed a complex of five species. *B. coriacea* was the best known of the five species having preference to feed on *Polygonum* (Chandel et al. 2003).

In talukas of Dakshina Kannada and Chickmagalur, the adult emergence of palm whitegrub, *Leucopholis burmeistri* Brenske takes place during second week of May to fourth week of May. The host range of *L. burmeistri* include areca, banana, coconut, sweet potato, cashew, rubber and coffee (Padmanaban and Daniel 2003). Sharma et al. (2004) conducted preliminary survey in Kalatop-Khajjiar wild life sanctuary situated on the western extremity of Dhauladhar range of western Himalaya. They collected 7 species of scarabaeid beetles including *B. coriacea, Brahmina* sp., *Clinteria* sp., *Mimela pectoralis* Blanchard , *Mimela* sp., *Oxycetonia* sp., and *Popillia* sp. Sushil et al. (2006) conducted host preference studies for 25 known hosts using choice method for economically important species of whitegrubs in Uttrakhand. *A. dimidiata* had a maximum preference for walnut with mean daily leaf consumption of 131.50 mm^2/beetle/ day. *H. seticollis* preferred *Rosa* sp. and a single beetle consumed 204 mm^2 of leaf area per day. In case of *M. indica*, maximum preference was recorded for *Alnus nepalensis*, although mean leaf area consumption per beetle was very low (31.00 mm^2/day).

Chandra (2005) reported about 88 species of phytophagous scarabaeids from Himachal Pradesh. In genus *Anomala,* 13 species and in genus, *Holotrichia,* 11 species have been recorded. In genera *Brahmina* and *Popillia* each, six species have been reported. Other important genera include *Melolontha* and *Mimela* having 4 species under each. The distribution of phytophagous beetles in Himachal Pradesh indicated that genera *Popillia, Mimela, Melolontha, Brahmina* and *Clinteria* are confined to hilly regions and forests only, whereas genera *Anomala, Adoretus, Serica, Maladera, Apogonia* and *Oxycetonia* are found in higher elevations as well as in the plains. Bhagat and Singh (2006) conducted survey to identify the pests associated with seabbuckthorn in Lahaul valley of Himachal Pradesh. It was found that beetles of *B. coriacea* and *H. longipennis* caused extensive damage to foliage.

From Ladakh region of Jammu and Kashmir, *Adoretus* spp., *Brahmina* spp., and *Holotrichia* spp. have been reported by Pandey and Sharma (2006). Kumar et al (2007) recorded observations on host plants of scarabaeid beetles in lower Kullu valley of Himachal Pradesh. Wild apricot (*Prunus armeniaca* Linnaeus) and Chinar (*Platanus orientalis* Linnaeus) were most preferred hosts of *B. coriacea* beetles, whereas *H. longipennis* showed preference for wild rose (*Rosa moschata)* and pomegranate. *A. simplex* preferred *Hibiscus malvaviscus* Cav., willow (*Salix alba* Linnaeus), amlok (*Diospyros lotus* Linnaeus) and plum (*Prunus saliciana* Lindley), *beul* (*Grewia oppositifolia* Linnaeus) and poplar (*P. deltoides*) for mating and feeding. *A. duvacueli* also showed preference for willow (*Salix alba*). *M. furcicauda* and *A. rufiventris* were recorded on *koish* (*Alnus nitida* Mill.). Some unidentified species of *Maladera* exhibited distinct preference for *koish* and peach for feeding and mating. In Uttrakhand, peak emergence of *A. dimidiata* takes place during second fortnight of June and they settle on *Juglans regia* Linnaeus, which is their most preferred host for mating and feeding (Mishra and Singh 2006).

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. *H. elegans, O. versicolor,* and *Popillia cinarea* Hope also damaged flowers. Besides rose, *neem,* tamarind, roseapple, *Delbergia,* guava and mango were the other hosts on which the scarabaeids were recorded. Brinjal plants were damaged by *O. versicolor* and *P. cinerea. S. ruficollis* constituted 21.98-29.40 per cent of total scarabaeid on rose at different locations around Bangalore. *A. versutus* represented 14.68-19.29 per cent and the population of *A. bengalensis* varied from 6.52-12.53 per cent. 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.* The number of beetles observed on and collected from various tree species indicated that distinct host preference occurs among the species encountered. *H. reynaudi* was collected predominantly from ber and

Acacia, few were found on *neem* and drumstick. *H. serrata* was collected almost exclusively from *neem* and occasional specimens taken from *Acacia* and ber. *S. ruficollis* was mostly found on *Acacia* and ber with little collection 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, A. bicolor, Adoretus deccanus* Ohaus, *A. versutus, A. bengalensis. A. dorsalis, A. varicolor, A. rauca, Phyllognathus* sp. and *Maladera* sp. *A. rauca* was predominant (80%), 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 39.53-46.38 and 31.88-41.49 per cent of the total catches, respectively, on walnut, apple and apricot. *M. furcicauda* and *Anomala* sp. constituted 5.99-8.69 per cent of total catch on different fruit trees (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 naturally growing bushes of *Zizyphus jujuba, Zizyphus mauritiana* Lam., *Zizyphus xylopyra* Willd., *Acacia leucophloea* (Roxb.) and *A. catechu.*

Chandel et al. (2010) conducted survey during 2005-2009 in Himachal Pradesh and reported *B. coriacea* as the most predominant species in mid and high hills of Himachal Pradesh. The beetles of *B. coriacea* exhibited distinct preference for a specific host in a particular locality. The beetles preferred apricot at Nauni, *Polygonum* at Fagu, *Indigofera* at Kheradhar and walnut at Shillaroo. *H. longipennis* beetles were observed on *toon* at Palampur. *M. insanabilis* beetles were collected on trees of *Grewia optiva* in large numbers at Bajaura. *Lepidiota stigma* beetles settled on *Delbergia sissoo* Roxb. trees for mating. The beetles of *M. indica* were observed to feed on wheat spikes in Barot area of Himachal Pradesh.

In northern Pakistan, recent collection revealed the presence of several species of scarabaeids. These include *P. cyanea, Oryctes elegans* Prell, *Clinteria confinis pseudoconfinis* Hope, *Gametis jucunda* (Falderman) *and Clinteria klugi* Hope (Ratcliffe and Ahmed 2010). Mehta et al. (2010) reviewed the distribution and species diversity of

scarabaeids in north western Himalaya. A total of 116 species have been reported, out of which 82 species belong to subfamilies Melalonthinae and Rutelinae. *Anomala, Holotrichia, Adoretus, Popillia, Brahmina, Melolontha* and *Mimela* constitute important genera. Maximum diversity has been reported in genera *Anomala* and *Holotrichia.* The most destructive species causing economic losses are *B. coriacea, H. longipennis, A. dimidata, P. dionysius, L. stigma, H. seticollis* and *Melolontha* spp. In Himachal Pradesh, *B. coriacea* constitutes 90 per cent of the total beetle population, whereas in Uttrakhand, *H. longipennis* contstitutes 55.80 per cent of total population. The important hosts of beetles have been reported as apple, pear, apricot, walnut, *bhimal*, *uttish*, *toon*, *sisham*, yellow raspberry, *Robina, Polygonum,* wild rose and *Berberris.* In upper Himalaya of Jammu and Kashmir, flower eating beetle, *P. alboguattata* was found associated with rain fed maize at intermediate zone of Jammu and Kashmir (Ahad et al. 2011).

In Assam, *X. gideon, Adoretus* sp. and *Apogonia* sp. infested som (*Persea bombycina* Mill.) and soalu (*Litsaea monopetala* (Roxb.)) which are two primary hosts of muga silk worm. As a result of beetle feeding, there was reduction in leaf yield which indirectly influences the production of muga silk (Reddy 2011). Taggar et al. (2012) reported the occurrence of flower beetle, *O. versicolor* damaging flowers of pigeonpea and mungbean for the first time in Punjab. During peak flowering period, 15-17 beetles/10 plants were recorded on both these grain legumes. Adult beetles devoured the flowers and buds, thereby greatly reducing the pod setting. Theurkar et al. (2012) studied the distribution and abundance of whitegrubs of Khed Taluka in western ghats of Maharashtra. *H. consanguinea, H. serrata, H. fissa, Leucopholis lepidophora* Blanchard and *Anomala* species were found to be distributed in this area. The adults were collected from host plants like *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 (Theurkar et al 2012).

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 pest of agricultural, horticultural and silvicultural crops. The main hosts of adult beetles include guava (*Psidium guajava*), teak (*Tectona grandis*

Linnaeus), tamarind (*Tamarindus indica* Linnaeus), arjun (*Terminalia arjuna* (Roxb.)), babul (*Cassia fistula* Linnaeus), *Jamun* (*Syzygium cumini* Linnaeus), amla (*Emblica officinalis* Linnaeus), ber (*Zizyphus jujube*), *neem (Azadirachta indica*), Ficus *(Ficus* sp.) sisham (*Dalbergia latifolia* Roxb.) and palas (*Butea monosperma* Lam.) (Bhawane et al. 2012).

2.3 Distribution and abundance of whitegrubs in different crop-ecosystems

The larvae of scarabaeids are chiefly found in grasslands feeding on roots of many plants and are commonly known as 'whitegrubs'. Being polyphagous, the whitegrubs feed on roots of a wide variety of cultivated plants. During sixties, the whitegrubs assumed serious proportion as a pest of several crops in various parts of our country, especially in the states of Assam, Gujarat, Haryana, Himachal Pradesh, Karnataka, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh; the whitegrubs were recognized as pest of national importance in 1975 (Raodeo and Deshpande 1987). The whitegrubs have always existed in nature feeding on roots of both weeds and crops. The earliest record of damage to crops by whitegrubs in India is that of Stebbing (1902) from Punjab.

Whitegrubs were reported earlier on forest plants (Beeson 1941). There exists no record of any serious whitegrub damage until the later part of 1950's. First major epidemic of whitegrubs in India was reported in sugarcane from Bihar during 1956 (Gupta and Avasthy 1956). It was in Dalmianagar area of south Bihar in August, 1956 that grubs of *H. consanguinea* appeared in epidemic form in sugarcane. This tract was sandy and *Kans saccharum spontaneum* grew in the vicinity. The grubs 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). Nearly during the same period, *H. consanguinea* was reported to appear in severe form in 1957 causing heavy damage to groundnut and jowar in localized pockets of Amerli district of Gujrat (Desai and Patel, 1965). In Rajasthan, *H. consanguinea* is the dominant whitegrub species. The infestation of this species existed in the soil well before it was first reported from the fields of sorghum and maize by Ritcher in 1961 (Ritcher, 1961). During 1965, this grub was reported causing 21.50 per cent loss to groundnut crop from Lalsot area of Rajasthan (Joshi, 1967). Vasu (1969) collcted *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. *H. insularis* was reported to cause damage to *kharif* crops in Rajasthan by Srivastava and Khan (1963). Nirula (1958) first reported the incidence of *Leucopholis coneophora* Burmeister from Kerala on coconut. Subsequently, Johnson and Nair (1966) reported heavy losses to coconut by same species of whitegrubs in the state. As a result of grub's activity, the young and established roots were killed and the nut production was severely affected.

The problem of whitegrubs is quite serious in hilly states of India where potatoes are grown during summer season as rainfed crop under long day conditions (Mishra and Chandel 2003). First record of whitegrubs 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 to potato tubers at Potato Development Station, Shillaroo located in Shimla hills of Himachal Pradesh (Mishra and Chandel 2003).

In Karnataka, several species of whitegrubs 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 the districts of Karnataka. Joshi et al. (1969) reported occurrence of *H. serrata* as a pest of tobacco at Central Tobacco Research Institute, Kateru (Andhara Pradesh). There was wilting and drooping of the plants as a result of feeding by the grubs. In Maharashtra, Raodeo (1974) reported *H. serrata* grubs feeding on the roots of jowar, bajra, sugarcane, groundnut, moong, arhar, chillies, paddy and wheat. There were three conspicuous endemic pockets in Maharashtra *viz.* Nanded, Buldhana and Sangli districts and inspite of heavy application of insecticides, the problem was not under check and it was found to be spreading to adjoining areas. In Kerela, 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. In a food selection experiment with 6 species of leguminous and graminaceous plants, soybean and groundnut were more found to be preferred as compared to blackgram, greengram and jowar. Arhar was least infested than any of the other crops. 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 whitegrubs in groundnut. Bakhetia (1982) estimated avoidable losses ranging from 28.74-40.34 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 highest during March-April on 1-3 month old seedlings. The root system of seedlings was completely eaten by these grubs. In eastern parts of Uttar Pradesh, the whitegrubs (mainly *Anomala* spp.) were recovered from sugarcane, groundut, bajra, sunhemp and sesame fields. The population of grubs was more in ratoon crop of sugarcane as compared to fresh sown crop. The heavily infested sugarcane shoots were yellowish in colour and stunted in growth (Nath and Singh 1981). Patel et al. (1982) conducted survey of summer groundnut in Kupadwanj taluka (Gujarat) and found infestation of *Maladera* (*Autoserica*) *nathani* Frey with an aveage of 1.50 grubs/plant. These larvae were also observed feeding on the roots of castor, maize, sweet potato, fennel and brinjal.

In Uttrakhand, severe outbreaks of whitegrubs mainly *A. dimidiata barbata, H. seticollis* and *H. liioderes* 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). Paharia (1982) investigated the factors which led to the decline of groundnut yield in Uttar Pradesh during the period 1950-1980. He listed, drought, low fertility of sandy soils and increased incidence of whitegrubs (*H. consanguinea* and *H. serrata*) as three important factors which contributed to decline of groundnut yield in the state.

Patil et al. (1986) recorded larvae of *L. lepidophora* from sugarcane and rice 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, 14-15 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 whitegrubs which attacked roots of various crops including wheat, groundnut, potato, tomato and sugarcane (Raodeo and Deshpande 1987). Nehru and Jayarathnam (1988) reported damage of *H. serrata* grubs on rubber seedlings during 1985-1987, in South India.

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 10-20 per cent of the tubers in the harvested potatoes in upper Shimla hills of Himachal Pradesh are half eaten tubers due to damage of whitegrubs. 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 8 species of whitegrubs *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. Mishra (1995) recorded incidence of whitegrubs in potato in different villages of Shimla and Sirmaur districts of Himachal Pradesh. The tuber damage ranged from 15.50-80.00 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. Higher incidence was noticed in late harvested crop. Besides potato, the grubs of *B. coriacea* also damaged ginger in Shimla district of Himachal Pradesh. The grubs produced large, deep, circular holes on damaged rhizomes and the per cent damage varied from 5.7-26.5 per cent at harvest (Mishra 1992). Chandel et al. (1996) conducted survey of whitegrubs on potato in Lahaul valley of Himachal Pradesh and recorded low incidence of *H. longipennis* in the valley.

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 whitegrubs 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 Maharashra, *L. lepidophora* was observed causing damage to 25-100 per cent of sugarcane, paddy, maize, groundnut and vegetables. In summer groundnut, plant mortality at different locations ranged from 56-89 per cent with an average of 80.56 per cent (Adsule and Patil 1990).

Nath and Singh (1987) found 14 species of whitegrubs attacking groundnut in eastern Uttar Pradesh with *Apogonia* spp., *S. ruficollis* and *A. ruficapilla* being the most prevalent. Kalra et al. (1991) studied population of *H. consanguinea* grubs in 7 field crops in Haryana. The grubs were most numerous under groundnut, followed by moong, beans, pearl millet and cowpea. Deol and Sekhon (1993) recorded larvae of *Maladera* sp. feeding on 3-4 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 1 meter (Pandit 1995). During a survey of vegetable pests in Kumaon hills of Uttrakhand, *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).

Suhartawan (1995) reported *L. stigma* as an important pest of rainfed sugarcane at Madukismo Sugar Estate in Indonesia. In Vanuatu (Japan), *A. versutus* has become the biggest threat to cocoa plantations since its accidental introduction (Beaudoin et al. 1995).

Mishra and Singh (1996) recorded population of whitegrubs at two locations in Uttrakhand. 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 Uttrakhand, the whitegrubs 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 vegetables like cabbage, cauliflower, brinjal, tomato, capsicum, cucurbits, okra, pea, potato, garlic, rose, carnation, gladiolus, chrysanthemum, and marigold grown during August-April (Singh et al. 2002). Singh et al. (2003) recorded the incidence of whitegrubs (*H. longipennis*) in various rainy season crops under different farming situations of Uttrakhand. Maximum damage ranging from 5.67-65.16 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 Kerela causing significant yield losses. Grub feeding on roots results 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 whitegrubs 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^2, respectively. The respective damage in paddy was 22.42 and 16.40 per cent.

Anitha et al. (2006) studied the distribution and abundance of whitegrubs 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 whitegrubs *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 whitegrubs 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-October (Kapadia et al. 2006).

Kulkarni et al. (2007) recorded incidence of *S. ruficollis* in a teak nursery at Ramdongari, Nagpur. The whitegrub infestation ranged from 14-52 per cent. The whitegrubs caused major damage by feeding on root system with symptoms of wilting and mortality of seedlings in nursery beds. Joshi and Meshram (2008) recorded damage of whitgrubs (*Holotrichia* sp.) in bamboos *viz. Bambusa arundinacea* (Retz.), *Bambusa nutans* (Linnaeus) and *Dendrocalamus strictus* Nees grown in sandy soils in nurseries and plantations at Angul in Bhubneshwar and Cuttack from July-September. In Kuio Reserve forest of Angul, maximum incidence (30%) was recorded in an area of 360 hectares. Kulkarni et al. (2009) reported two species of whitegrubs *viz. H. rustica* and *Holotrichia mucida* (Gyllenhal) damaging teak seedlings at Nagpur in Central India. The grubs were recorded near the roots of teak seedlings, feeding on fine rootlets and main roots of young and mature seedlings, causing wilting and consequently mortality in case of sever infestation. Mean density of grubs in nurseries varied from 6.70-8.60 grubs/m^2 over different years. The mortality of seedlings was noticed between July-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.* Chandel et al. (2008) reported that most critical period in the dynamics of whitegrub infestation lies between August-September and timely harvest can avoid huge losses. There exists highly positive correlation (r = 0.948) between population of third instar larvae for *B. coriacea* and tuber damage and third instar grubs are responsible for nearly 90 per cent tuber damage in potato fields. Regression analysis revealed that with unit increase in population of third instar grubs of *B. coriacea,* the tuber damage will increase by 12.17 per cent.

In Sangla valley, whitegrubs are reported to cause 8-10 per cent plant mortality in rajmash (Sood et al. 2007) and 11.00-47.00 per cent plant mortality in ‘off season’ peas (Sood et al. 2009). Sood et al. (2010) found increase in grub population from June-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^3) 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 whitegrubs 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. Ebrem 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 (2012) recorded six species of whitegrubs *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.

2.4 Biology and morphometrics of phytophagous whitegrubs

Information on scarabaeid biology is exceedingly voluminous because of the world wide distribution of the group and its diverse habits and because of the importance of many genera as crop pests (Ritcher 1958). Most species complete their life cycle in one year and all scarabaeids without exception undergo three larval stages and spend more than half of their life time as larvae (Mehta et al. 2010). Emden Van (1941) states that the larvae of the lamellicornia moult thrice, the third ecdysis releasing the pupa.

Scarabaeids life cycle varies with the climate, being longest in more temperate regions. The shortest life cycles are to be found in tropical areas with no climatic seasons (Gressitt 1953). In the subfamilies, Melolonthinae, Rutelinae, Dynastinae and Cetoniinae the life cycles may be one, two or three years or in the case of Melolonthinae, even four or five years in northern latitudes (Ritcher 1958). In Melolonthinae, most species of the tribe Melolonthini, have rather long life cycles, especially in temperate regions. In the United States, many species of *Phyllophaga* (=*Holotrichia*) have a two or three year life cycle (Hayes 1925; Hayes, 1929; Reinhard 1940; Reinhard 1941). Some of the species having a two year life cycle in the northern states, have only a one year cycle in Texas (Reinhard 1940; Reinhard 1941).

In Europe *Melolontha hippocastani* Linnaeus requires three to five years to complete its life cycle (Korschefsky, 1940), while *M. melolontha* requires three to four years depending upon latitude (Regnier, 1950). Species belonging to Melolanthini tribe Sericini have a one year life cycle, but some species in more temperate climate have a two year life cycle. Schread (1953) states that *Autoserica castanea* Arrow also has a one year life cycle. According to Murayama (1954), *Serica orientalis* Motschulsky has a one year life cycle in Manchuria and Korea. In New Zealand, *Costelytra zealandica* (White) also has a one year life cycle (Dumbleton, 1943). *Popillia japonica* Newman and *Anomala orientialis* Waterhouse have one year life cycle in the United States (Ritcher, 1958). Friend (1929) states that a few larvae of *A. orientalis* have a two year life cycle in Connecticut.

The earliest available record on the biology of Indian scarabs is by Lefroy (1900) who included the detailed biology of *Anomala varians* Oliver in his monograph on the life history of Indian insects. Srivastava and Khan (1963) worked on the biology of *H. insularis* in Rajasthan. The female makes selection of the oviposition spots by digging several holes in the field and the single hole may contain 2-4 eggs. Eggs are generally laid towards the end of July and about 30.0 eggs were laid by one female. The incubation period varies from 8-12 days. The life cycle is completed in 11-16 weeks. The adults as well as pupae hibernate in the soil till the break of monsoon next season.

The biology of the most important and widespread pest species, *H. serrata* from Indian sub-continent has been investigated by many workers. Majumdar and Teotia (1965) reported the field biology of *H. serrata* under north Indian conditions. In North India, the adult emergence begins in late May and the beetles are active until August. Veeresh (1977) gave a detailed account of its biology under Karnataka conditions. The beetles start emerging from first week of April and the adult activity stops before the end of May. Egg laying starts, the day after copulation and on an average a female laid 26 eggs. According to Majumdar and Teotia (1965), the average fecundity of *H. serrata* was 64.4 eggs/female. Veeresh (1977) reported that freshly laid eggs were 3.0 mm long and 1.7 mm broad, however, eggs swell up to 4.0 mm in diameter before hatching. The eggs hatch in 10-12 days and first, second and third larval instars last for 30.2, 35.8 and 102.9 days, respectively. At Ranchi, the average periods of first to third instar larvae were

found to be 31.2, 36.5 and 81.0 days, respectively (Majumdar and Teotia, 1965). The prepupal period was of 7.0 days and pupal period 11.8 days in Bangalore. The population in the field occurs as early as September and continues up to March (Veeresh, 1977). At Ranchi, the average pupal period was 11.0 days (Majumdar and Teotia 1965). In Karnataka, adult formation begins in November, but adults remain confined in pupal cell until April (Veeresh 1977). This condition has been designated as hibernation by Mazumdar and Teotia (1965).

The biology of *H. serrata* under Marathwada conditions of Maharashtra has been studied by Raodeo and Deshpande (1987). They reported that larval period in Maharashtra persists for about 6-8 months and pupae are formed during early February. Pupal period lasts for about 2-3 days. The adults of *H. serrata* lives for about 2 weeks in Karnataka and total life cycle from egg to adult occupied 177.9 days (Veeresh 1977). At Ranchi, it was observed to be 170.60 days (Majumdar and Teotia 1965). Gardener (1935) and Ritcher (1961) described the third stage larvae of *H. serrata* but did not provide detailed description of all the structures of taxonomic importance. A detailed description of labrum, mandibles, maxillae, epipharynx clypeus and raster of third instar larvae are given by Veeresh (1977), Chandra and Kumar (1991) and Raodeo and Deshpande (1987). The male genitalia are discussed by Veeresh (1977), Khan and Ghai (1982), and Raodeo and Deshpande (1987).

H. consanguinea is a key pest on groundnut in Rajasthan, Gujarat, Maharashtra and Uttar Pradesh. It appears in serious form on sugarcane in Orissa, Bihar, Punjab and Uttar Pradesh. Rai et al (1969) worked on its bionomics on groundnut in Jaipur district of Rajasthan. The beetle emergence takes place in June, but egg laying begins in July. Pupal formation starts in October and the duration of pupal stage was about a fortnight. Adults are formed in November and remain in soil till they emerge in June next year. Brar and Sandhu (1982) also reported adult emergence of *H. consanguinea* during second fortnight of June in Punjab. The first instar larvae were observed in the first two weeks of July, the second instar larvae from mid July to mid August and third instar larvae from end of July to last week of September.

Nath and Srivastava (1982) studied the biology of *H. consanguinea* on groundnut in Uttar Pradesh. They observed average fecundity of 68.0 eggs/female. The incubation

period ranged from 4-8 days and hatching percentage was 81.20 per cent. The average duration of first, second and third instar was of 29.0, 31.0 and 71.0 days, respectively. The prepupal period lasted 3-5 days and the pupal period 16-20 days. The adult life span was of 200-250 days and the ratio of male to female has been reported to be 1:3.5. Bhattacharjee and Bhatia (1981) reported that eggs of *H. consanguinea* hatch in 2-3 weeks under Delhi conditions and second instar grubs become voracious feeders and they go on feeding and cutting the roots actively for 4-6 weeks up to prepupal stage.

The biology of *Holotrichia* sp. near *consanguinea* a sibling species of *H. consanguinea* has been reported on groundnut from northern districts of Karnataka, Andhra Pradesh, Gujarat and Rajasthan. Desai and Patel (1965) reported that grubs of *Holotrchia* sp. near *consanguinea* are active during monsoon and take about 8-10 weeks to attain full size in groundnut fields in Gujarat. After September, the larvae descend into the soil to a depth of 1.5 to 2 feet for pupation. The pupal period may be about 4-6 weeks. The biology of this species has also been studied by Patel et al (1967) in Gujarat. The beetles laid a total of 20 eggs and the incubation period was about 8 days. The larvae are present in soil from March to October. The pupation period was of 18 days and the beetles were observed in the soil from November onwards. The male genitalia of *H. consanguinea* are described by Khan and Ghai (1982). Gardner (1935) gave a detailed description of raster of third instar larvae of *H. consanguinea*.

The biology of *Maladera* spp. has also been worked out in Rajasthan (Kumawat 1992). Annually, two generations of *Maladera* spp. were reported in Israel, (Golberg et al. 1986; Golberg et al. 1989) and India (Kumawat 1992; Yadava and Sharma 1995). Golberg et al. (1989) while studying distribution, feeding habit, mating behaviour and life cycle of *Maladera matrida* found that the entire life cycle was completed in 102.2 days. They also reported that adults emerge during March, to May and disappear in October November. In India, two distinct peaks were recorded, first in the month of April/May and second in June/July, thereby, indicating two generations in a year (Kumawat 1992). The average duration of life cycle of first and second generations of *M. insanabilis* at room temperature was 60.0 and 224.0 days, respectively, in Rajasthan (Kumawat 1992). Yadava and Sharma (1995) reported incubation period of *M. insanabilis* varying from 4-8 days. The duration of instars I-III was 13.0, 31.0 and 20-30 days in first generation. The third instar during second generation is prolonged for about 182.0 days. The pupal period ranges from 5-10 days.

H. reynaudi is now being recognized as one of the major pests on groundnut crop in peninsular India. Its detailed biology has been worked out by Wightman et al. (1990) and Anita (1997) in Hyderabad. Yadava and Sharma (1995) reported that adults of *H. reynaudi* emerge soon after the first rain in summer and remain active until the end of July. The grubs pupate by the first fortnight of October and become adult by the beginning of November. Vijaymohan Reddy (1977) gave a detailed biology of *H. nilgiria*, a major pest of coffee in parts of Chikmagalur and Coorg districts of Karnataka. Yadava and Sharma (1995) reported that peak damaging period of grubs of *H. nilgiria* is during August to October. The adults usually emerge during May-June in large numbers. A small percentage of the beetles also emerge during the month of October-November indicating the possibility of two separate broods. The longevity of adults has been reported to be of about 3 weeks.

L. coneophora, a major pest of coconut is found along the coastal belt of Kerala and Karnataka. The biology of this species was worked out by Abraham (1983) and Abraham and Mohandas (1988). In Kerala, the incubation period of *L. coneophora* averaged 23.0 days. The larval period averaged 266.0 and 270.0 days for males and females, respectively. Adults do not feed on vegetation (Abraham and Mohandas 1988). The biology of *L. burmeistri* was detailed by Kumar (1997). This species is a serious pest on arecanut, localized in parts of Sringeri, Chikmagalur district of Karnataka. It takes two years to complete its life cycle. Padamnaban and Daniel (2003) recorded beetle emergence of *L. burmeistri* during last week of April to first week of June in Dakshina Kannada. Duration of third instar grubs was of 129.2 days on arecanut.

L. lepidophora is a serious pest of arecanut in Malnad district of Karnataka. Bioecology of this species was provided by Veeresh et al. (1982). Distinguishing characters of the adults and larvae of *Leucopholis* spp. are also described. This species is also reported as a serious pest of sugarcane in parts of Kolhapur and Sangli districts, Maharashtra. Its incidence was also recorded in maize, groundnut, paddy and vegetables. The detailed biology of this species has been reported by various workers. Adsule and Patil (1994) studied biology of *L. lepidophora* in laboratory in western Maharashtra. The egg, larval and pupal periods were 21-33, 290-350 and 28-35 days, respectively, and adults lived for 17-32 days. Patil and Adsule (1991) observed total duration of

development as 284-507 days. Naik et al. (2009) recorded observations on biological parameters of *L. lepidophora* under green house conditions in Karnataka. The mean incubation period was 14.70 days and duration of instars I-III was 79.58, 82.15 and 129.71 days, respectively. Prepupal and pupal period ranged from 25-30 and 23-37 days and total life cycle from egg to adult requires 302-448 days.

In North Bengal, *A. varicolor* and *A. commonalis* damage roots of arecanut. The biology of both these beetles has been studied by Chenchaiah (2006). *A. varicolor* completed development from egg to adult within 151-202 days and *A. commonalis* took 157-180 days. Adult emergence of both species begins in April, peak emergence in May and emergence continues up to July. However, in case of *A. commonalis*, second peak of adult emergence has been reported in October, indicating that *A. commonalis* might have two overlapping generations in a year. In *A. varicolor*, egg, larval and pupal periods have been reported to be of 5-7, 135-178 and 11-17 days, respectively. The respective durations for *A. commonalis* are 6-10, 138-152 and 13-18 days in North Bengal (Chenchaiah 2006).

Rao (1993) studied biology of *H. liioderes* in Manipur. The pest completes two generations in a year and the adults are attracted to light in large numbers during March, and in September-October. The egg period was of 3-7 days and the grubs pupated in 52-61 days. Duration of pupal period was 10-12 days and total life cycle requires about 65-80 days. *Chililoba acuta* (Wiedemann) has been recorded in Punjab, Himachal Pradesh and Karnataka. Singh et al. (1997) reported this species as a serious pest of sorghum seed crop in Punjab and study its biology. The female beetles complete their oviposition in two batches from first week of September till third week of October. The average fecundity varies from 23-32 eggs and the eggs hatch in 14-18 days. The durations of instars I-III were 9.27, 20.05 and 205.52 days, respectively. The pest remains in pupal stage from June to August occupying 105-116 days. The female beetles lived for 64.20 days.

Another species, *C. orientalis* is of economic importance in Maharashtra on sorghum and maize. The biology of *C. orientalis* has been studied in Kolhapur by Kumbhar et al. (2012). The adults emerge during first week of September and emergence continues up to mid October. The females lay eggs within dung manure at a depth of 15-

20 cm. The average incubation period was 15.2 days. After hatching, the grubs feed greedily on decaying dung. The first, second and third instar occupy 22.7, 54.3 and 46.6 days and occurrence of grubs was recorded from September-January. The mean pupal period was 14.70 days. Newly hatched adults are formed in earthen cells in February and adults remain confined in pupal cell for 7 months. The adult longevity was short ranging from 8-10 days.

H. longipennis is one of the predominant species in hilly regions of Himachal Pradesh and Uttrakhand. The detailed biology of *H. longipennis* has been studied in Uttrakhand (Haq 1962; Shah and Shah 1990; Mishra and Singh 1993). The female beetles lay eggs in June-July (Mishra and Singh 1993), and the incubation period varies from 12-15 days. The first and second instar grubs occupy 41.80 and 45.60 days, respectively (Mishra 2001). Third instar grubs occupy 216-228 days and fully fed third instar grubs move downward for overwintering. Haq (1962) reported that third instar grubs of *H. longipennis* are present at a depth of 2-3 inches upto the middle of November and then they migrate deep into the soil up to a maximum of 10 inches and remain there till end of February. Total larval period varies from 294-323 days. Pupae are formed in April and adult emergence starts by the end of May (Mishra 2001). *A. lineatopennis* is distributed in Himachal Pradesh and Uttrakhand causing damage to potato. In Uttrakhand, *A. lineatopennis* completed a generation in about 320 days. Eggs hatch in 7-11 days and larval period varies from 276-313 days (Mishra et al. 1998a). Duration of third instar grubs ranged from 202-223 days and overwintering takes place deep into the soil in hard earthen cells. The hibernating grubs become active with the rise in temperature and pupa are formed in April (Mishra 2001).

A. dimidiata is distributed in Himachal Pradesh, Uttrakhand, Haryana, Punjab, West Bengal, Sikkim, Assam, Meghalaya and Manipur (Chandra and Uniyal 2007). The biology of *A. dimidiata* has been studied in Uttrakhand by Garg and Verma (1993) and Mishra (2001). According to Mishra (2001), the beetles of *A. dimidiata* emerge from the soil in the beginning of June, however, Garg and Verma (1993) noticed peak emergence in the first fortnight of July and maximum eggs were laid in soil during July. The incubation period varies from 12-21 days (Mishra 2001). The grubs are active during July-September and full fed grubs goes deep into the soil for overwintering from

October-March (Garg and Verma 1993). Duration of the instars is about 15 and 38 days for the first two stages and 256 days for the third instar overwintering grubs (Mishra 2001). *P. dionysius* is found in Himachal Pradesh, Uttar Pradesh, Haryana, Sikkim, West Bengal, Maharashtra, Tamil Nadu, Orissa and Karnataka (Chandra and Uniyal 2007). In Himachal Pradesh adult emergence takes place in May (Mehta et al. 2008). The eggs are laid during June and July and hatch in 5-8 days. The larvae feed during July, August and September. They then pupate, the pupal period being 8 days only. The beetle rests in the soil till May, when they become active, burrow out, fly, mate and lay eggs.

H. seticollis is another important species in hilly tracts of Uttrakhand (Mehta et al. 2010). The beetle emergence begins in the month of May and may continue till the end of August. Females lay 10-20 eggs and the incubation period ranges from 9-11 days. Fully fed third instar grubs transform into pupae in the beginning of October and pupal period ranges from 15-20 days (Yadava and Sharma 1995).

S. ruficollis is prevalent in Karnataka, Tamil Nadu and Uttrakhand (Ali 2001). Mishra and Singh (1999) worked on its biology in Uttrakhand. Peak adult emergence occurs during second week of June. Average fecundity was 12.16 eggs/female. Eggs hatched in 8-10 days and three larval instars were completed in 24.7, 34.2 and 179.5 days, respectively. Male and female beetles lived for 17.2 and 19.4 days, respectively, and total life cycle has been reported to be of 252.8 days.

B. coriacea is most important species in mid and high hills of Himachal Pradesh and some parts of Uttrakhand hills. Chandla et al. (1988) recorded preliminary observations on biology of *B. coriacea* in Himachal Pradesh. They reported that female beetles lay eggs in installments of 2-7 and hatching occurs in 7-12 days in June-July. The duration of instars I-III was 20.1, 29.6 and 74.4 days, respectively. The pupal period varied from 12-20 days. The longevity of laboratory reared adults has been reported to be 17.7 days. Misra and Chandla (1989) observed eggs and first instar grubs of *B. coriacea* between June-August in Shimla hills. Second and third instar grubs occur during August-October and third instar grubs feed voraciously on tubers in October. The fully fed grubs pupate during April-May and beetles emerge from soil between late May and early June. Chandel et al. (1995) studied the biology of *B. coriacea* at Solan in mid hill zone of Himachal Pradesh. Each female laid 17-26 eggs, which hatched in 9-12 days. They

observed change in shape of eggs from elongate (1.60 x 1.10 mm^2) to spherical (2.40 x 2.20 mm^2) with advancement in embryonic development. The three consecutive larval instars are completed in 14.40, 20.10 and 37.20 days, respectively. Pupation started as early as February in mid hills and the duration of pupal stage was 19-24 days. There is a single generation in a year which is completed in 305-452 days. Chandel et al. (2003) studied the field biology of *B. coriacea* under potato field conditions in Shimla hills. They reported that larvae are present in the soil form July-April. Third instar grubs cause damage through September-October and over wintering of full fed grubs occurs in earthen cells up to April followed by adults in May. Adult emergence begins in May and female beetles lay eggs throughout June. In Kashmir valley, the beetles of *Brahmina* sp. start appearing during third week of April. Incubation period varies form 20-27 days. The larval period lasted for about 9 months passing winter in grub stage. Pupae occupied 9-12 days only and adults survived for 15-30 days after emergence (Bhat et al. 2005).

H. rustica and *H. mucida* are serious pests of forest nurseries in central India. Their biology has been studied by Kulkarni et al. (2009) at Nagpur in Central India and both species have annual life cycle. *Lepidiota mansueta* Burmeister has been observed to cause substantial damage in Ganges basin of Uttrakhand and Uttar Pradesh. In Assam, this species has appeared as a key pest of potato in Brahmaputra basin areas (Mathur et al. 2010). Bhatacharyya et al (2011) reported its biennial life cycle from north eastern parts of India. The eggs hatch in 42-48 days. Duration of first and second instar grubs varies form 35-45 days and 55-63 days, respectively. The development of third instar is prolonged for about 2 years. Third instar grubs occupy 545-563 days. The pupal period is relatively short and adult comes out of pupae in 4-5 weeks. The adults have atrophied mouth parts. Both male and female beetles are non feeding in habit and they come out of ground only for mating. Another species, *L. stigma* is an important pest in Himachal Pradesh, Uttrakhand and North East India (Mehta et al. 2008; Ali 2001). This species has also been reported from Indonesia causing heavy damage to sugarcane. In Indonesia, the adults emerge at the beginning of rainy season, while serious damage occurs between February to June. The adults have been reported to feed on host plants and average fecundity was 13.78 eggs/female (Suhartawan 1995).