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Insect pest diversity of standing crops and traditional pest management in agricultural areas of the Mandakini Valley, Garhwal Himalaya, Uttarakhand, India

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***Abstract*—*The mountain farming communities of the Garhwal Himalaya rely on conventional agriculture to meet their subsistence needs. The resilience of local crop varieties plays a significant role in crop productivity in the indigenous agricultural system. In such circumstances, the protection of the crop from insect pests becomes paramount. Traditional ecological knowledge plays a crucial role in safeguarding standing crops from production losses in an environmentally benign and sustainable manner. The investigators in this study have surveyed the Mandakini valley to document the indigenous practices undertaken by the farming folks to protect the crops from pest infestation in the region. These practices are discoursed here and, further, look into the potential of natural predators as bio-control. The findings indicated that pests from the order Coleoptera had the most species, followed by Lepidoptera and Hemiptera. Most of the pests at the study site were serious defoliators, damaging the young foliage of the crops. Some entirely fed upon their roots-stems, while the rest were leaf miners and sapsuckers, thus compromising the overall well-being of the plant. In a developing country like India, there is a lack of reliable data that sheds light on the annual crop losses incurred by these pests. Thus, it becomes pertinent to compute an overall estimate of crop losses at various stages of crop production, from seed storage to post-harvest times.*

***Keywords*—*Crop loss, Insect pest, Mandakini Valley, Natural predators, Pest management*.**

I. INTRODUCTION

FAO/WHO (2014) has defined a pest as "any species, strain or biological type of plant, creature or pathogenic agent that damages plants or parts of them and incorporates vectors of parasites or pathogens of human and animal infections and creatures, causing a public health nuisance." Every year on June 6th, "World Pest Awareness Day" is observed to raise awareness about how pest management contributes to human well-being and survival. Insects are the most ubiquitous, diverse, and abundant animal group on the planet. These small, versatile beings are the major contenders for food and other useful resources for humans that are produced in the course of farming (Oerke & Dehne, 2004). The Food and Agriculture Organization (FAO) has labelled 2020 as the "International Year of Plant Health," with the purpose of raising awareness about how plant health may aid in hunger prevention, poverty alleviation, environmental protection, and economic development. Plants constitute at least 80 percent of our nourishment, yet they are constantly threatened by pests and diseases (FAO, 2019). Pests and diseases destroy up to 40% of the world's food crops each year. This incurs an annual agricultural trade loss of more than $220 billion, and results in hunger, and eventually interferes with rural income. It is reckoned that globally, food crops are harmed by over 10,000 insect species, 30,000 weed species, 100,000 diseases, and 1,000 nematode species (Dhaliwal et al, 2007).

The first systematic effort to assess crop losses due to different pests at a global level was accomplished by Cramer (1967), who projected total annual losses to be around 34% for major crops and vegetables. It was also specified explicitly that one-third of the total crop production worldwide is spoiled due to weeds, insects, and diseases. (Oerke, 2006). Losses due to insect pests in the context of Indian agriculture have also been reviewed in the past (Pradhan 1964; Krishnamurthy Rao & Murthy 1983; Atwal 1986; Jayaraj 1993; Lal 1996; Dhaliwal & Arora 1996, 2002; Dhaliwal et al 2003, 2004), and crop losses after the green revolution era were relatively higher than those recorded globally (Pradhan 1964; Dhaliwal et al, 2004). Crop losses increased from 7.2 percent in the early 1960s to 23.3 percent in the early 2000s, but then fell to 17.5 percent in the 21st (Dhaliwal et al 2007, 2010). Agriculture is the mainstay of the people residing in the rural areas of the Mandakini valley. Agriculture or allied practices employ more than 75% of the total population, which is substantially dominated by the subsistence mode of farming. The conventional method of mountain agriculture is the only way to meet the subsistence needs of the farming communities in the Garhwal Himalaya. Food grains like paddy, wheat, millet, barley, oil seeds, lentils, and vegetables such as *Solanum tuberosum*, *Solanum lycopersicum*, *Allium cepa*, *Allium sativum*, *Capsicum annum*, *Solanum melongena*, *Brassica oleracea*, *Cucurbits*, *Raphanus sativus*, *Pisum sativum*, *Zingiber officinale* etc., are widely grown in the region. Smallholders and marginal farmers feed more than 2/3^{rds} of the population, but pests destroy at least 30%-40% of the food crops they grow. However, the resilience of local crop varieties plays a significant role in overall farm productivity and, in such circumstances, crop protection from insect pests becomes paramount. Traditional ecological knowledge plays a crucial role in safeguarding standing crops from production losses in an environmentally benign and sustainable manner.

This investigation comprising insect pests of standing crops is a pioneer in the region. Earlier studies involving insect pests of stored grains were conducted and evaluated by research investigators in the Rudraprayag district. More than 50% of insect mortality for stored wheat grains was demonstrated using smoke generated from neem leaves and cow dung burning, which is both cost-effective and eco-friendly (Yadav & Tiwari, 2018).

Cutworms, root weevils, moth and beetle larvae, fruit flies, fruit or shoot miners, plant hoppers, and mealy bugs are major defoliators, pod damagers, sap suckers, shoot borers, and root feeders that destroy crops from seedling to maturity (Plate 1). The mechanism for averting the pest population explosion is crop diversification in the agro-ecosystem (Rao et al, 2015). The motive behind the study is to get a quick overview of insects as major crop pests, examine the extent of their damage to agricultural crops, review existing control measures, and describe potential natural predators as bio-control in the region. Scholars, scientists, researchers, and policymakers will benefit from the study since it sets the path for further investigation and development of a sustainable approach to protecting crops in mountain agro-biodiversity.

II. STUDY AREA

The research was conducted in the villages of the Mandakini valley, in the Rudraprayag district of the Garhwal region. These villages appear to occur in clusters or hamlets and lie between 1400-2100 metres, surrounded by forests. The detailed account of their geographical coordinates, area, population, and number of households as per census 2011 is specified below (Fig. 1).

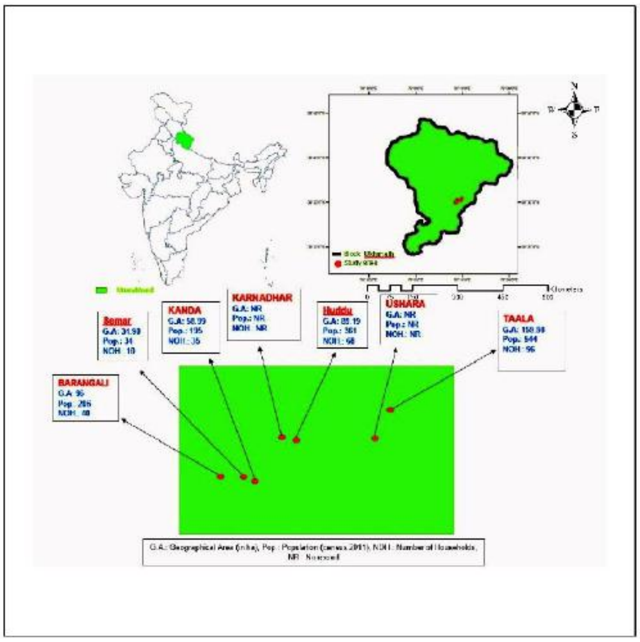

Fig 1: Study sites in the Mandakini valley

Broadly, the seasons are divided into three, viz., summer (April-June), the monsoon (July-September), and winter (November-March). Summers are pleasantly mild while winters are generally cold and prolonged with snowfall. Rains are mostly confined to the rainy season and heavy downpours in the rainy season frequently cause landslides and soil erosion. The maximum monthly temperature in the area varies from around 19º C to 28º C. The vegetation is a temperate broad leaf type (moist deciduous/ evergreen/ mixed) with dominant species such as Quercus, Rhododendron, Pinus, Aesculus, Acer, Juglans, Thamnocalamus, Daphniphyllum, Prunus, Myrica, and others. Despite feasible climatic conditions, coarse, and well-drained acidic soil, the net yield is low. Farmers are unable to meet their food needs due to erratic weather, a lack of irrigation facilities, mono-cropping, non-laboratory soil testing, insect pest attacks, and crop raiding by wild animals. As a result, the majority of people rely on local stores and the Public Distribution System (PDS) to meet their daily calorie needs.

III. METHODOLOGY

Three years of research was conducted on the farms of three Gram Panchayats in the Mandakini valley, which included seven villages. Periodical monitoring of insects pests of farmland, homesteads, kitchen gardens, and poly houses was carried out during the pre and post-monsoon seasons from 2017 to 2019. In this study, a random household survey was conducted in each village using a semi-structured questionnaire set, key respondents, and keen observation to enumerate the area under crop cultivation, crop composition, cropping pattern, crop pests, and diseases of cultivated crops. Informal dialogues with knowledgeable family members, particularly women, who are actively involved in agricultural activities, were used to gather the information.

A few community-based discussions were also held, mostly about recent farming trends, insecticide/pesticide use, traditional knowledge, and future aspects of farming related to climate change. Sampling methods such as opportunistic sampling and aerial sampling via sweep netting, handpicking, and ground digging were done as per the study needs. Specimens were documented either through photography or sample collection, and dry pinned for further identification and research. The information acquired from natives was analyzed in order to investigate scientific rationality.

IV. RESULT

A total of 187 respondents were interviewed and data was recorded from each village in the Ukhimath block. Obtained data was compiled and analyzed (Fig. 2 & Table 1). The residents of the Mandakini Valley were well aware of the insect pests present on their farmland, but they generally used traditional methods as control measures. Farmers used trap crops, cover crops, farmyard manure, and a mixture of salt-burnt fuel wood chullah ashes to thwart the advent of insect pest infestations on the standing crops.

Beetles are primarily crop pests of cereals, oilseeds, fruits, vegetables, and stored grains (Patole, 2017). The result exhibited major farm insects as pests, comprising 32 genera from 22 different families from the study area. Findings indicated that pests from the order Coleoptera (14 sp.) were the maximum in number, followed by Lepidoptera (07 species), Hemiptera (05 sp.), and Diptera (03 sp.) while Orthoptera, Thysanoptera, and Dermaptera contributed with single species respectively. Coleoptera (Beetles) were dominated by Chrysomelidae (05 sp.), Scarabaeidae (03), and Elateridae (02), while Nitidulidae, Meloidae, Brentoidae, and Curculionidae families each contributed a single species. Hemiptera (True bugs) have six families, including Coreidae (02 sp), Aphidae, Miridae, Pseudococcidae, Flatidae, and Pentatomidae, each with one sp. Lepidoptera (Butterflies and Moths) comes in second with four families of Noctuidae (04 species), while Erebidae, Sphingidae, and Papilionidae each have one species; Diptera has three families of Tipulidae, Psychodidae, and Tephritidae (one sp. each). A bar graph chart depicts a detailed account of these orders and families, along with the number of species (Fig. 2).

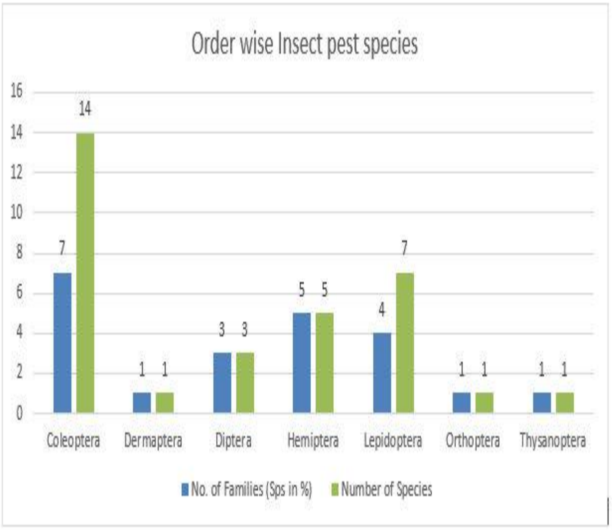

Fig.2: Bar graph showing the families belonging to various orders.

Larvae of the orders Lepidoptera, Coleoptera, and Diptera, are voracious feeders and are considered phytophagous pests. Braconids and Ichneumonidae are internal or external parasitoids of these pests that help in checking their population naturally (Plate 2). Birds, rodents, beetles, and earwigs are common predators of larval and adult insect pests. Beetles (larval stage) and weevils are generally root feeders and often damage the flowers and foliage while reaching for pollen and nectar. Most pests are serious defoliators, damaging the young foliage of the crops. Some entirely fed upon their roots-stems, while the rest were leaf miners and sapsuckers, thus jeopardising the overall well-being of the plant. *Altica himalayensis*, *Cotinis nitida*, Phyllophaga sp, Holotrichia sp, *Bactrocera cucurbitae*, Aphis sp, *Pieris brassicae*, Clavicoccus sp., Trichoplusia ni, *Agrotis ipsilon*, and *Thrips tabaci*, are the most common pests that severely affect standing crops and vegetables. The detailed accounts of the major pests of crops about their classification, host plants, and nature of damage are presented below (Table 1 & Plate 1).

V. DISCUSSION

Indigenous farming systems use Traditional Ecological Knowledge (TEK) to control insect pest infestations, such as deep ploughing to expose eggs and larvae of pests, spreading completely decomposed Farm Yard Manure (FYM) on prepared land, dusting of salt-burnt fuelwood chullah ash, mixture of cow dung-urine on standing crops, and stubble burning to clear leftover residues after harvesting to get rid of the exposed pests beneath the soil (Chandola et al, 2011). Leaf litter and livestock feed collected from forests are the primary sources of traditional FYM in the hill regions of Uttarakhand (Maikhuri et al, 2015). In the long run, narrow/selective spectrum chemical pesticides are preferred over broad-spectrum pesticides.

78.5 % of flowering plants in temperate habitats require an animal pollinator to successfully reproduce. Wild entomofauna and birds largely contribute to the productivity of crops through the provision of ecosystem services, such as pollination and natural pest control (Classen et al, 2014). There have been numerous reports of parasitic and predatory natural enemies being used to control agricultural insect pests (Van den Bosch et al, 1982). Spiders are regarded as important predators that aid in the regulation of insect pest population densities (Pickett et al 1946; Dondale 1956; Kajak et al 1968; Fox & Dondale 1972; Tanaka 1989). Biological control involves natural predators and parasitoids that are represented by the entomophagus groups (Sampaio et al, 2009). It is often used as a management tool in Integrated Pest Management (IPM), which is economically feasible and has a minimal environmental impact. Many insect pests have their natural enemies, like Braconids (Parasitoid- cutworm wasp), Micromus (Brown lacewing), Coccinellids (Ladybird beetles), Syrphidae (Hover flies), Soldier beetles, Spiders, and Capoletis (Parasitoid wasp-Ichneumonidae) (Plate 2).

Flea beetles can be deterred by several traps and companion plants (such as Basils, Beans, Brassica sp., Secale cereal, Zea mays, Cucurbits, Tagetes sp., Trifolium sp., wild Alliums, Mentha sp., Juglans sp.) that can be intercropped with the primary crop or planted at the periphery of cultivated land. The majority of insects provide direct or indirect benefits to humans (Peters, 1993), either in the form of pollinators, insect predators or parasites of pests. The wildflower strip elevates farmland biodiversity, enhances foraging opportunities for various insect pests and pollinators, and also ensures improved productivity (Matthias et al, 2016). Thus, pest control and pollination services are complementary in nature and essential for the sustainability of the mountain agroecosystem.

Recently, the locust invasion of the Rabi crops in Pakistan and the Middle East led to a total crop failure, while in Africa, the situation was so grave that Somalia declared a national emergency. A similar onslaught occurred in Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, and western Uttar Pradesh, galloping several lakh hectares of Rabi crop. Every year, an unprecedented amount of stored food grains, vegetables, and standing crops are destroyed by the infliction of these pests. In a developing country like India, there is a lack of reliable data that sheds light on the annual crop losses incurred by these pests. Thus, it becomes pertinent to compute an overall estimate of crop losses at various stages of crop production, from seed storage to post-harvest times. Emphasis should be given to different eco-friendly methods, such as the use of natural enemies, predators, cultural practices, bio-control, insect-resistant varieties, and the use of scientifically proven transgenic crops (Plate 2). The dissemination of farmer-friendly information about pest management via different platforms, such as Kisan web portal, KVKs (Krishi Vigyan Kendras), Krishi melas, social media, newsletters, pamphlets, and so on, ensures rapid adoption by rural folks and averts crop damage. Therefore, it is imperative to prioritize our food security program to contend with our limited resources and rising population.

VI. CONCLUSION

A total of 35 insect pest individuals from seven orders with a total of 23 families were documented from the study area. Pests from the order Coleoptera (14 species) were found to be the highest in number, followed by Lepidoptera and Hemiptera (07 sp. each), and Diptera (03 sp.). Coleoptera (07), with the maximum number of families, surpassed the others, followed by Hemiptera (06), Lepidoptera (04), and Diptera (03). Chrysomelidae dominated in terms of pest species number, followed by Noctuidae, Scarabaeidae, Acrididae, Elateridae, Coreidae, Brentidae, Curculionidae, Meloidae, Nitidulidae, Forficulidae, Psychodidae, Tephritidae, Tipulidae, and Aphididae. Globally, only 1% of all insects are pests (Triplehorn & Johnson, 2005), but they are responsible for the loss of 13% of crop productivity and 9% of forest production (Pimental et al, 2000). Moths and butterflies are beneficial as pollinators, but their larvae are potentially harmful. Cabbage White butterfly larvae, an invasive species, are serious pests of Brassicaceae plants (Snell-Rood & Papaj 2009; Cipollini 2002). The majority of the insect pests of standing crops were Coleopteran beetles, larvae of Lepidopterans and

Hemipterans, of which *Altica himalayensis*, *Cotinis nitida*, Phyllophaga sp, Holotrichia sp, *Bactrocera cucurbitae*, Aphis sp, Clavicoccus sp., Trichoplusia ni, Agrotis sp., and Thrips damaged the crops severely.

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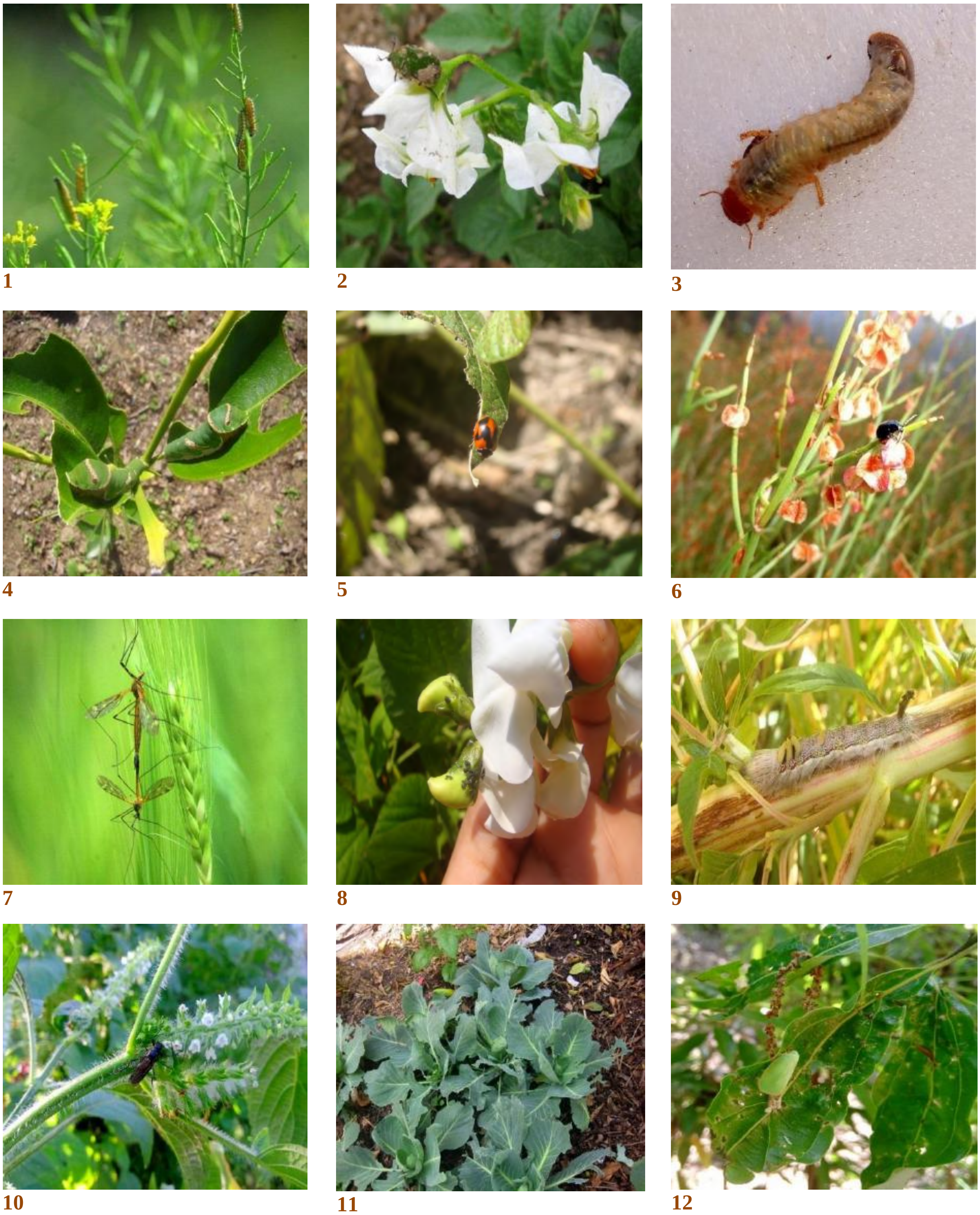
Table 1: Checklist of major Insect pests of standing crops

Order	**Family** (Number of species)	**Insects as pests** (Scientific name)	**Host plant**	**Parts Damaged**
Coleoptera	Brentidae (01)	Straight snouted weevil (Trichapion sp.)	Cereals, Vegetables	Root, flower, stem
	Chrysomelidae (05)	Cereal Leaf Beetle (Oulema sp.)	Cereals	Skeletonize leaves
		Flea beetle *(Altica himalayensis)*	Mustard, Lady's finger	Leaves, stems, petals
		Milkweed leaf beetle *(Labidomera clivicollis)*	Okra, Beans	Leaf, young foliage
		Red Pumpkin beetle *(Aulacophora foveicollis)*	Cucurbitaceae	Leaf, fruit, flower
		Spotted Cucumber beetle *(Diabrotica undecimpunctata)*	Cucurbitaceae	Roots, stem, leaf
	Curculionidae (01)	Knobbled Weevil *(Hadramphus tubuculatus)*	Vegetables, Cereals	Root, root hairs, fruit
	Elateridae (02)	Black Click beetle *(Agriotes gallicus)*	Wheat, Potatoes	Roots, tender stems
		Common Click beetle *(Agriotes spulator)*	Wheat, Potatoes	Roots, stems
	Meloidae (01)	Blister beetle (Hycleus sp.)	Beans, Tomatoes, Chilli, Amaranthus	Flower, leaf
	Nitidulidae (01)	4 Spotted Sap beetle *(Glischrochilus quadrisignatus)*	Corn, Peaches, Tomatoes	Fruits, young foliage
	Scarabaeidae (03)	Green June Beetle *(Cotinis nitida)*	Potatoes, Onion	Young foliage of shrubs, flowers

		May Beetle (Phyllophaga sp.)	Potatoes, Onion, Cucurbitaceae	Young foliage, shrub, flowers
		White Grubs (Holotrichia sp.)	Cole crops, Potatoes	Roots, tubers
Dermaptera	Forficulidae (01)	Earwigs (Forficula sp.)	Cole crops, Cucumber	Foliage, flowers
Diptera	Psychodidae (01)	Drain fly *(Psychoda alternata)*	Beefsteak	Leaf, inflorescence
	Tephritidae (01)	Melon fly *(Bactrocera cucurbitae)*	Bean, Tomato, Brinjal	Fruits, Pods
	Tipulidae (01)	Crane-fly *(Nephrotoma appendiculata)*	Beefsteak, Wheat,	Roots, crown, Leaf
Hemiptera	Aphididae (01)	Aphids (Aphis sp.)	Peach, Tomato, Beans, Pulses	Tender buds, stem flower
	Coreidae (02)	Coreid bug (Dalader sp.)	Malta, Squash, Pumpkin	Sap, young foliage
		Leaf footed bug (Leptoglossus sp.)	Cucurbits	Sap
	Flatidae (01)	Planthopper *(Siphanta acuta)*	Malta, Eggplant	Leaf, stem,
	Miridae (01)	Tarnished plant bug (Lygus sp.)	Beans, Soyabean	Flowers, fruit, leaves
	Pentatomidae (01)	Stink/Shield bugs *(Nezara viridulahg)*	Peach, Tomato, Lima beans	Leaf, fruits
	Pseudococcidae (01)	Mealybugs (Clavicoccus sp.)	Citrus plants, Mulberry	Leaf, buds, tender stems
Lepidoptera	Erebidae (01)	Tussock moth (Orgyia sp)	Amaranth, Maize	Tender stem, leaf
	Noctuidae (04)	Cabbage White *(Pieris brassicae)*	Cabbage, Cauliflower	Defoliation, leaf,
		Cabbage Semilooper *(Trichoplusia ni)*	Cole crops	Leaf scrabbling, Defoliation
		Fall armyworm *(Spodo frugiperda)*	Maize, Rice	Leaf, whole plant except roots
		Greasy Cutworm *(Agrotis ipsilon)*	Potato, Tomato, Maize	Leaf, Stem, Tubers
	Papilionidae (01)	Citrus Swallowtail (*Papilio demodocus)*	Sweet Orange	Leaves, young foliage
	Sphingidae (01)	Hornworm Caterpillar *(Manduca quinquemaculata)*	Potato, Tomato, Eggplant	Leaves, flower
Orthoptera	Acrididae (02)	Locust (Schistocerca sp)	Rice, Maize, Vegetables	Leaves, shoot, fruit, stem, bark
		Grasshopper *(Cyrtacanthacris tatarica)*	Cereals, vegetables	Young leaves
Thysanoptera	Thripidae (01)	Thrips *(Thrips tabaci)*	Onion, Chilli, Cucumber	Leaf, fruits

Plate 1: Major Insects as pests in the study site



1. *Pieris brassicae* larvae on *Brassica campestris* 2. Cotinis sp on *Solanum tuberosum* 3. Holotrichia sp. 4. Leaves of *Citrus sinensis* damaged by larvae of *Papilio demodocus* 5. *Labidomera clivicollis* 6. *Altica himalayensis* on *Rumex hastatus* 7. *Nephrotoma appendiculata* on *Triticum aestivum* 8. Aphis sp. on *Phaseolus vulgaris* 9. Orgyia sp on Amaranthus sp. 10. Bibio sp. on *Perilla frutescens* 11. Damaged leaves of *Brassica oleracea* 12. *Siphanta acuta*

Plate 2: Natural Enemies of pests in the study site

1. Coccinellidae sp. 2. Halzia sp. 3. *Coccinella septempunctata* 4. Odontocolon sp. (Ichneumonids) 5. Cryptus sp. 6. Braconid sp. 7. Thomisus sp 8. Mantis sp. 9. *Mantis religiosa*