Chapter II

Diversity of Pests and its Infestation in Agricultural Fields of Vadodara

2.1 Introduction

Biodiversity in agriculture refers to both plant and animal life in the farming areas. Crops, weeds, livestock, pollinators, natural enemies, soil fauna, and a wealth of other organisms, large and small, contribute to biodiversity. According to the biodiversity productivity hypothesis, biodiversity plays a significant role in maintaining a sustainable agronomic system. In order to gain better results, it is necessary to conserve biodiversity in agricultural ecosystems. Practices like overuse of pesticides, monoculture, grazing, low farming techniques, etc. are posing threats to biodiversity associated with the farming system. (Asghar *et al.,* 2013 and Ane and Hussain, 2015). Biodiversity is considered to be the origin of all crops and domesticated livestock and the variety within them. Conservation of this biodiversity is essential for the viable production of food and other agricultural products and the advantage these provide to humanity, including food security, nutrition, and livelihoods.

Adequate food production for a growing population has to be an issue of global challenges. It is considered that by 2050 the global population size will have increased by 46%, requiring increased agricultural production to ensure food security (FAO, 2018). The challenges we face are to produce crops and ensure food security in an environmental condition where insect and disease destruction and climate change are significant constraints (Godfray and Garnett, 2014; Sparks and Nauen, 2014; Sandhu *et al.,* 2015).The use of land for agricultural crop production affects large parts of the terrestrial area, which provides biodiversity is essential for successful future conservation (Tscharntke *et al.,* 2005). The fertile land is currently in use, and arable land areas cannot be expanded significantly. In addition to using large quantities of land, agriculture threatens natural biodiversity's stability and survival more than any human activity (Shah *et al.,* 2017). The clearing of natural ecosystems to increase food crops and livestock production, large quantities of water, and agricultural chemicals contribute to significant ecological systems (Pimentel, 2009). The common challenge is to secure high and quality yields and, at the same time, ensure that agricultural production is environmentally sustainable. Agriculture in India is majority monsoon dependent as a large part of the sub-continent does not have access to perennial sources of water. India is one of the most developed agricultural countries in the world. About 30-40% of the Indian population lives in urban areas, and the rest live in rural areas. The rural Indian people depend upon agriculture fields and their allied businesses such as apiculture, sericulture, lac culture, fish farming, emu farming, goat farming, and poultry farming. To attain this goal, one should reconsider the role of insects in our agricultural ecosystems.

Over the last century, loss of global biodiversity and species extinction has occurred at an unprecedented rate (Barlow *et al.*, 2016). One of the major drivers is agricultural Infestation (Tscharntke *et al.*, 2005; Gonthier *et al.*, 2014). Agricultural intensification is the striking change in land use, in which complex natural ecosystems have been converted to monocultural crop production ecosystems (Tscharntke, *et al.*, 2005). This agricultural intensification has multiple consequences for ecosystems, including a decline in natural biocontrol services (Symondson *et al.*, 2002), disruption of crop pollination (Kremen and Miles, 2012; Kovács-Hostyánszki *et al.*, 2017), and extensive damage to naturally-occurring species and the environment from the heavy use of agrochemicals (Tscharntke *et al.*, 2005; Gill *et al.*, 2012; Stehle and Schulz, 2015).

Intensive agriculture has achieved significant advances in terms of agroecosystem productivity. Growing systems currently employed prefer the simplified environment covering large areas of cultivated land, and replace the indigenous plant diversity with other cultivated plants or monocultures of specific cultivars. It leads to the loss of cultivated plant resources. It reduces the numerous benefits of biodiversity within agroecosystems, including those related to biological control, which further drives the imbalances and vulnerabilities of farms. Therefore, it is necessary to understand and respond to the mechanisms of diversification in agricultural systems that favor both disease management and increased yield (Dangles *et al.,* 2009; Amaral *et al.,* 2013; Ding *et al.,* 2015). Increasing crop diversity through intercropping is a simple and effective practice that offers advantages in reducing disease and pest population densities and severity (Li *et al.,* 2009; Ding *et al.,* 2015). Intercropping and mixed planting of different crops or varieties are traditional agricultural practices that have long been used for preventing disease and harmful pest infestations in different agricultural regions (Yang *et al.,* 2014). The plant components of the intercropping system are not sown at the same time. However, the substantial part of their growth periods, based on the specific crop combination, plays a crucial role in their growth and the ecological, environmental target of intercropping (Li *et al.,* 2009). Several patterns of crop arrangements in intercropping - such as row intercropping or strip intercropping, mixed planting crops, and relay intercropping - have been used for disease management.

Pests and Infestation are naturally related to the agricultural ecosystem. Farmers have fear high yield loss because of the outbreaks or epidemics. Worldwide, farmers have lost their annual harvest an average of 10-16% due to pests infestation and damage, but it varies widely by crop, region, and threat - farmers can lose 100% of crop yield in one season to a single pest or damage. Insects already infest 5 to 20% of significant grain yields. Both the number and appetite of insect boost by the increasing temperature and the researcher's project; they will destroy almost 50% more wheat than they do today with a 2C rise and 30% more maize. Agricultural pest insects damage or destroy more than 30% of crops worldwide. It is now becoming clear that climate variations are affecting virtually all aspects of life. One alarming dimension is the increased population of insect pests that are a risk to food production and security, particularly in developing economies such as India. It is estimated that in India, about 30-35% of the annual crop yield gets wasted because of pests, out of which 26% is due to insect pests (Dhaliwal *et al.,* 2015b). One of the significant challenges to humankind is a threat to food security due to emerging and invasive pests. Increased worldwide trade in agriculture has amplified the chances of the introduction of exotic pests. Pests reduce crop productivity in various ways; the loss may be quantitative and qualitative (Dhaliwal *et al.,* 2010; Dhaliwal *et al.*, 2015), various loss levels may be differentiated, e.g., direct and indirect losses, or primary and secondary losses, indicating that pests not only endanger crop productivity and reduce the farmer's net income but may also affect the supply of food and feed as well as the economies of rural areas as well as the country (De-Oliveira *et al.,* 2014; Deutsch *et al.,* 2018).

In India, pest damage varies considerably in different agro-climatic regions across the country mainly due to differential impacts of several abiotic factors such as temperature, humidity, and rainfall (Sharma *et al.*, 2005; Yadav *et al.,* 2010; Arora and Sandhu, 2017). This has a significant implication for the intensification of yield losses due to potential changes in crop diversity and increased incidence of insect-pests in the context of impending climate change. The Indian climate has undergone significant changes showing increasing annual temperature trends with an average of 0.56°C rise over the last 100 years (Solomon, 2007). Changes in climatic variables have led to increased frequency and intensity of outbreaks of insect-pests (Fand *et al.*, 2012). Gujarat state, which is located on India's western coast, has been considered one of the most developing states of India on industrial and agricultural fronts. It is endowed with abundant natural resources in terms of fertile land, river systems, good soil, and climatic conditions in many parts, which contribute significantly to Gujarat's vibrant agricultural zone. Agriculture is an essential sector in Gujarat, as it is one of the primary sources of livelihood for more than half (approximately 60%) of its workforce. Strengths of Gujarat’s agriculture sector are due to its diversified crops and cropping patterns.

Furthermore, its Climatic diversities have resulted in having eight agriculture climatic zones. Flexibility in adopting hi-tech agriculture technologies like tissue culture, greenhouses, and shed-net houses leading to higher yield and production has resulted in Gujarat being one of the significant agriculture export zones for mango and vegetables, sesame. However, loss due to pests has not spared the state. As to our knowledge, there is a lacuna as far as the pest status of Gujarat and Vadodara, in particular, is concerned except few of the studies where loss due to mealy bugs have been reported (Singh and Gandhi, 2012; Kataria and Kumar, 2012 Nagrare *et al.*, 2009). Agricultural biodiversity is an economically suitable and accessible option for farmers who may not afford chemical inputs. Using diversity for pest and disease management encourages farmers to maintain local diversity on their farms, a valuable source of genetic material that could be used for breeding resistant varieties in the future. ***Hence, the present work's objective was to have an insight into the pest population and the rate of Infestation and its severity in the agriculture fields of the Vadodara district.***

2.2 Materials and Methods

Data collection

The pest insect samples' collection and preservation were carried out as described in Chapter I. Pest belonging to four significant orders: Orthoptera, Coleoptera, Hemiptera, and Lepidoptera the present study. Collected insect pests were brought to the laboratory and identified using standard taxonomic keys and literature (Borror *et al.*, 1992; Maxwell-Lefroy & Harold, 1909; David & Ananthakrishnan, 2004). A stereomicroscope, Leica MPS 60 Ø28/8x/MPS, was used for identification and photographic record. The identified pest species were confirmed from Entomology Division, Anand Agricultural University, Anand, Gujarat. The host plant species' identification was carried out with the Department of Botany of The Maharaja Sayajirao University of Baroda. Economically important crops severely damaged by pests were examined; to know about the assessment of incidence and extent of damage to the crop. Fact sheets of the pests of four major orders were systematically made.

Assessment of Infestation rate/severity score of Pests:

The assessment of the infestation rate of insect pests on agricultural fields of selected sites on various crops was done following the scale given by Nagrare *et al.*, (2011)

Scale for Infestation rate/severity score for Pest

Grade: 0–20% of foliage consumed/ indecently seen

Grade:21–40% of foliage consumed/ Scattered appearance of few individuals on the plant

Grade: 41–60% of foliage consumed/ Severe Infestation of individuals on any one branch of the plant

Grade: 61–80% of foliage consumed/ Severe Infestation of individuals on more than one branch

Grade: 81–100% of foliage consumed/ Severe Infestation of individuals on the whole plant

The following formulas were used for estimations:

Percentage of Incidence was worked out by counting infested plants and dividing the plants' total number at each Site.

Percentage incidence (PI) = Number of infested plants / Total plant observed X 100.

Severity index (SI) = Sum of total grade points (1-5 infestation grade G-I to G-V, respectively) of the infested plants / Total number of infested plants observed (Berger et al., 1980)

Jaccard Similarity Index of Pest species on four Sites

Jaccard Similarity Index was calculated to compare the pest species of the sites concerning season to find out shared pest species between the sites and distinct pest species using software Past 3X.

2.3 Result

An annotated list of pest species found in the Agriculture fields of Site I, II, III, and IV are presented in Table 1.1 – 1.4. A total of 163 pest species belonging to four significant orders (Coleoptera, Hemiptera, Orthoptera, and Lepidoptera) were recorded during the study period (2017 - 2019).

Coleoptera	2017 -'18				2018 – '19			
	I	II	III	IV	I	II	III	IV
Lasioderma serricorne (Fabricius, 1792)	-	-	-	-	-	-	+	-
Formicomus sp.	+	-	-	-	-	-	-	-
Apion clavipes	+	-	-	+	+	-	-	+
Paratrachelophorus sp.	+	-	-	-	+	-	-	-
Acmaeodera sp.	+	-	-	-	+	-	-	-
Acmaeodera viridaenea (Eschscholtz, 1829)	+	-	+	-	+	-	+	-
Agrilus acutus (Thunberg, 1787)	-	+	-	-	-	+	-	-
Craspedophorus saundersi (Chaudoir, 1869)	-	+	-	-	-	+	-	-
Acanthophorus serraticornis (Olivier, 1795)	+	-	+	+	-	-	+	+
Batocera rufomaculata (De Geer, 1775)	+	-	-	+	+	-	-	-
Celosterna scabrator(Fabricius, 1793)	+	-	-	-	+	-	-	-
Dectes texanus	-	+	-	-	-	+	-	-
Derobrachus hovorei (Santos-Silva, 2007)	-	+	-	-	-	+	-	-
Niphona picticornis	-	-	-	+	-	-	-	+
Monochamus scutellatus	-	+	-	-	-	+	-	-
Trachysida sp.	+	+	-	-	-	-	-	-
Xylotrechus stebbingi (Gahan 1906)	+	+	-	-	-	-	-	-
Altica cyanea	-	-	+	+	-	-	+	+
Aspidomorpha miliaris (Fabricius, 1775)	+	-	-	+	+	-	-	+
Aulacophora indica	+	+	+	+	+	+	+	+
Aulacophora nigripennis (Motschulsky, 1857)	+	+	+	+	+	+	+	+
Aulacophora foveicollis (Lucas, 1849)	+	+	+	+	+	+	+	+
Cassida circumdata	+	-	+	+	+	-	+	+
Cassida sp.	-	+	+	+	-	+	+	+
Chiridopsis bipunctata (Linnaeus, 1767)	-	-	-	+	-	-	-	+
Chrysochus cobaltinus (LeConte, 1857)	-	+	+	-	-	+	+	-
Clytra laeviuscula (Ratzeburg, 1837)	+	+	-	-	+	-	-	-
Metriona bicolor (Fabricius,1981)	-	-	+	-	-	-	+	-
Monolepta signata	+	+	-	+	+	+	-	+
Oides bipunctata (Fabricus, 1781)	-	+	-	-	-	+	-	-
Oides palleata (Fabricius, 1781)	-	-	+	-	-	-	+	-
Podagrica fuscicornis (Linnaeus, 1767)	+	+	-	-	-	+	-	-
Sindia clathrata (Olivier,1808)	+	+	+	-	-	+	+	-
Epilachna ocellate (Redtenbacher, 1977)	+	+	+	+	-	-	+	+
Cleonus sp.	-	-	-	-	-	-	+	-
Cosmopolites sordidus (Germar, 1824)	-	+	-	+	-	+	-	+

Hypera postica (Gyllenhal, 1813)	-	-	+	-	-	-	+	-
Myllocerus dorsatus (Fabricius, 1798)	+	-	+	+	+	-	+	+
Myllocerus subfasciatus	-	+	+	+	-	+	+	+
Myllocerus undecimpustulatus (Faust,1891)	-	+	+	+	-	+	+	+
Myllocerus viridanus (Fabricius,1775)	+	+	+	+	+	+	+	+
Polydrusus formosus (Mayer, 1779)	-	+	-	-	-	+	-	-
Sitophilus oryzae(Linnaeus, 1763)	+	-	-	+	+	-	-	+
Lanelater fuscipes (Fabricius, 1775)	+	-	-	+	+	-	-	+
Cryptolestes pusillus (Schönherr, 1817)	+	-	-	-	-	-	-	-
Synhoria maxillosa	-	+	-	+	-	-	-	+
Lytta caragana (Pallas, 1798)	+	+	+	+	-	-	+	+
Mylabris cichorii (Linnaeus, 1767)	+	-	-	+	-	-	-	+
Mylabris pustulata (Thunberg, 1821)	+	+	+	+	+	+	+	+
Mylabris variabilis (Pallas, 1782)	-	+	+	-	-	-	-	-
Psalydolytta rouxi(Castelnau 1840)	+	-	+	+	-	-	+	+
Cetonia funesta (Poda, 1761)	-	+	-	-	-	-	-	-
Chiloloba acuta (Wiedemann, 1823)	+	+	+	+	+	-	-	+
Cyclocephala pasadenae (Casey, 1915)	+	-	-	-	+	-	-	-
Heliocopris gigas (Linnaeus, 1758)	-	-	-	-	-	-	+	+
Holotrichia reynaudi (Blanchard, 1851)	+	-	+	-	-	-	+	-
Oryctes nasicornis (Linnaeus, 1758)	+	+	-	-	+	-	-	-
Oryctes rhinoceros (Linnaeus, 1758)	+	+	-	-	+	+	-	-
Oxycetonia jucunda (Falderman, 1835)	-	+	+	+	-	-	+	-
Oxycetonia versicolor (Fabricius, 1775)	+	+	+	+	-	-	-	-
Phyllophaga nebulosi (Polihronakis, 2007)	+	-	-	-	+	-	-	-
Phyllophaga obsolete (Blanchard, 1851)	+	+	-	-	+	+	-	-
Phyllophaga sp.	-	+	-	-	-	-	-	-
Protaetia alboguttata (Vigors, 1826)	+	+	+	+	-	-	-	-
Protaetia aurichalcea (Fabricius, 1775)	-	-	+	-	-	-	+	-
Protaetia squamipennis (Burmeister, 1842)	+	+	+	+	+	+	+	+
Oryzaephilus surinamensis (Linnaeus, 1758)	+	-	-	-	-	-	-	-
Gonocephalum sp.	-	+	-	-	-	-	-	-
Tenebrio molitor (Linnaeus, 1758)	-	-	+	-	-	-	+	-

Table 2. 1: Presence (+) and absence (-) of Coleopteran pest species in the four Site

Members of order Coleopteran were found to be the most dominant with 69 pest species spread in 16 families, next in order of the number of representatives was Order Orthoptera with 34 species belonging to 4 families. Lepidoptera was recorded with 31 species spread in 12 families, and last in the order of the number of pest species was Hemiptera, with 29 species represented by 13 families. Site wise occurrence of the pests revealed that the Site II showed maximum followed by Site I, Site IV and Site III.

Orthoptera	2017 -'18				2018 – '19			
	I	II	III	IV	I	II	III	IV
Atractomorpha sinensis	+	-	+	-	+	-	-	-
Acrida conica (Fabricius, 1781)	+	+	+	+	-	-	-	-
Acrida exaltata (Walker, F., 1859)	+	-	-	+	+	-	-	+
Acrida ungarica (Herbst, 1786)	+	+	-	+	-	+	-	+
Acrida willemsei	-	-	-	-	-	+	-	-
Acrotylus humbertianus	+	-	-	+	+	-	-	+
Aiolopus thalassinus (Fabricius, 1781)	-	-	-	+	-	-	-	-
Aiolopus thalassinus tamulus	-	-	-	+	-	-	-	-
Phlaeoba infumata	-	-	-	+	-	-	-	-
Choroedocus robustus (Serville, 1838)	-	+	-	-	-	+	-	-
Chorthippus curtipennis	+	-	-	+	+	-	-	+
Hieroglyphus nigrorepletus (Bolivar)	+	-	-	+	+	-	-	+
Hieroglyphus banian (Fabricius, 1798)	+	-	-	+	+	+	-	+
Locusta migratoria (Linnaeus, 1758)	+	-	-	+	+	-	-	+
Melanoplus femurrubrum (De Geer, 1773)	+	+	+	+	+	+	+	+
Metaleptea brevicornis (Johannson, 1763)	+	-	-	+	+	-	-	+
Omecestus Sp	-	+	-	-	-	-	-	-
Omocestus viridulus (Linnaeus, 1758)	-	-	+	+	-	-	-	+
Orphulella pelidna (Burmeister, H., 1838)	-	-	-	+	-	-	-	+
Oxya hyla hyla (Serville, 1831)	+	+	-	+	+	+	-	+
Oxya hyla intricata (Stål, 1861)	+	+	-	-	-	-	-	-
Schistocera gregaria (Forskål, 1775)	-	+	+	-	-	+	+	-
Schistocera sp	-	-	-	-	-	+	-	-
Sphingonatus sp	-	-	-	+	-	-	-	+
Trilophidia annulata (Thunberg, 1815)	+	-	-	+	+	-	-	+
Xenocatantops humilis (Serville, 1838)	-	-	-	+	-	-	-	+
Acheta domesticus (Linnaeus, 1758)	-	+	-	-	-	+	-	-
Mecopoda elongate	-	-	-	+	-	-	-	+
Poekilocerus pictus (Fabricius, 1775)	-	+	-	-	-	+	-	-
Amblycorypha rotundifolia (Scudder, 1862)	-	-	-	+	-	-	-	-
Neoconocephalus velox (Rehn and Hebard, 1914)	-	-	-	+	-	-	-	+
Ducetia japonica (Thunberg, 1815)	-	-	+	-	-	-	+	-
Scudderia furcata (Wattenwyl, 1878)	-	-	-	+	-	-	-	+
Trigonocorypha unicolor (Stoll, 1787)	-	+	-	+	-	+	-	+

Table 2. 2: Presence (+) and absence (-) of Orthopteran pest species in the four Site

Lepidoptera Species	**2017 -'18**				**2018 – '19**			
	I	II	III	IV	I	II	III	IV
Cnaphalocrocis medinalis (Guenée, 1854)	+	+	-	-	-	-	-	-
Hellula undalis (Fabricius, 1794)	+	+	-	-	-	-	-	-
Leucinodes orbonalis (Guenée, 1854)	-	-	-	-	-	+	-	+
Noorda blitealis (Walker, 1859)	+	+	-	+	+	+	-	+
Scirpophaga incertulas (Walker, 1863)	-	+	-	+	-	-	+	+
Spoladea recurvalis (Fabricius, 1775)	-	+	-	+	-	+	+	+
Amsacta albistriga	-	+	-	+	-	-	+	+
Asota caricae (Fabricius, 1775)	-	-	-	-	-	-	-	-
Eudocima materna	+	+	+	-	+	+	+	-
Orgyia leucostigma	-	+	+	-	-	-	-	-
Orvasca subnotata	-	-	-	-	+	+	+	-
Spilarctia obliqua (Walker, 1855)	-	+	+	-	-	-	-	-
Eupterote germinate	-	+	-	+	-	-	-	+
Eupterote mollifera (Walker, 1865)	-	+	-	+	-	-	-	-
Pectinophora gossypiella (Saunders, 1844)	+	+	+	-	+	-	+	-
Euproctis lunata (Walker, 1855)	+	+	-	-	+	+	-	-
Helicoverpa armigera (Hübner, 1808)	+	+	+	+	+	+	+	+
Olene mendosa (Hübner, 1823)	+	+	-	-	+	+	-	-
Spodoptera sunia	-	+	-	-	+	+	-	-
Spodoptera frugiperda	-	+	-	+	-	-	+	+
Spodoptera litura (Fabricius, 1775)	+	+	+	+	+	+	+	+
Helicoverpa zea	-	-	-	-	-	+	+	-
Earias insulana (Boisduval, 1833)	+	-	+	-	+	-	+	-
Earias vitella	-	-	-	+	-	-	-	-
Ariadne merione (Cramer, 1777)	+	+	+	+	+	+	+	+
Trichoplusia ni	+	+	-	+	+	+	-	+
Hypolimnas misippus (Linnaeus, 1764).	+	+	+	-	+	+	+	-
Junonia almanac (Linnaeus, 1758)	+	+	+	-	+	-	+	-
Eurema hecabe (Linnaeus, 1758)	-	+	+	-	-	+	-	-
Plutella xylostella (Linnaeus, 1758)	+	+	+	+	+	+	+	+
Euzophera perticella (Ragonot, 1888)	-	+	+	-	-	-	-	-

Table 2. 3: Presence (+) and absence (-) of Hemipteran pest species in the four Site

Hemiptera	2017 -'18				2018 – '19			
	I	II	III	IV	I	II	III	IV
Aleurodicus disperses (Russell, 1965)	-	-	+	+	-	-	+	+
Melanaphis sacchari	-	-	+	+	-	-	+	+
Empoasca decipiens (Paoli, 1930)	+	+	+	+	+	+	+	+
Drepanococcus cajani (Maskell, 1891)	+	+	+	+	+	+	+	+
Phenacoccus madeirensis (Green, 1923)	+	+	+	+	+	+	+	+
Acanthocephala femorata (Fabricius 1775)	-	+	-	-	-	+	-	-
Cletomorpha benita (Kirby, 1891)	+	-	-	-	+	-	-	-
Cletus punctiger (Dallas, 1852)	+	+	+	+	+	+	+	+
Homoeocerus signatus (Walker, 1871)	+	-	-	-	-	-	-	-
Acanthuchus trispinifer	+	-	-	-	+	-	-	-
Proutista moesta (Westwood, 1851)	+	+	+	+	+	+	+	+
Rhynchomitra microrhina (Walker, 1851)	+	-	-	-	-	-	-	-
Coridius janus (Fabricius, 1775)	+	+	+	-	+	+	+	-
Pyrilla perpusilla (Walker, 1851)	+	+	-	+	+	+	-	+
Leptocentrus taurus	+	+	+	+	+	+	-	+
Acanthuchus trispinifer	-	-	-	+	+	-	-	-
Oxyrachis tarandus	+	-	+	-	+	-	+	-
Agonoscelis nubilis	-	+	-	+	-	+	-	+
Carbula insocia	-	+	+	+	-	+	+	+
Nezara mendax	+	-	-	-	+	-	-	+
Halyomorpha halys (Stål, 1855)	+	-	-	-	-	-	-	-
Nezara viridula (Linnaeus, 1758)	+	+	+	+	+	+	+	+
Nezara antennata	-	+	+	-	-	+	+	-
Palomena prasina (Linnaeus, 1761)	-	+	-	+	-	+	+	+
Megacopta cribraria (Fabricius, 1798)	-	-	+	-	+	-	+	-
Plautia affinis (Dallas, 1851)	+	+	+	+	+	+	+	+
Planococcus sp.	+	+	-	-	+	+	-	-
Dysdercus koenigii (Fabricius, 1775)	+	-	-	-	+	-	-	-
Dysdercus cingulatus (Fabricius, 1775)	-	-	+	+	-	-	+	+

Table 2. 4: Presence (+) and absence (-) of Hemipteran pest species in the four Site

The pests species representatives are depicted with its Infestation grading is shown with gradient colours at the end of the result.

Although Coleopteran pest's diversity was maximum, the highest Percentage incidence and the Severity Index were recorded maximum with Hemiptera and Lepidoptera's order compared to the other two orders years (Figure 2. 1 and 2. 2). During the Year 2017 – '18 the Site-wise percentage incidence range of pest varied from 26% - 57%, Site II from 25% - 39%, Site

III from 27% - 41% and Site IV from 40% - 58% (Table 2.5) and the order-wise Percentage incidence range varied for Orthoptera was from 26% - 40%, for Hemiptera was from 27% - 49%, for Coleoptera it was 25% - 49% and for

Lepidoptera was from 39% - 58% (Figure 2.1).

Sites	Orthoptera		Hemiptera		Coleoptera		Lepidoptera	
	PI	SI	PI	SI	PI	SI	PI	SI
I	35	1.2	45	1.5	41	1.4	41	1.5
II	30	1.1	32	1.5	28	1.5	35	1.5
III	18	1	32	1.1	38	1	39	1
IV	38	1.5	37	1.4	35	1.2	57	1.4
Mean		**1.2**		**1.4**		**1.3**		**1.4**

Table 2. 5: Percentage Incidence (PI) and Severity Index (SI)of four orders at four Sites in the year 2017- '18

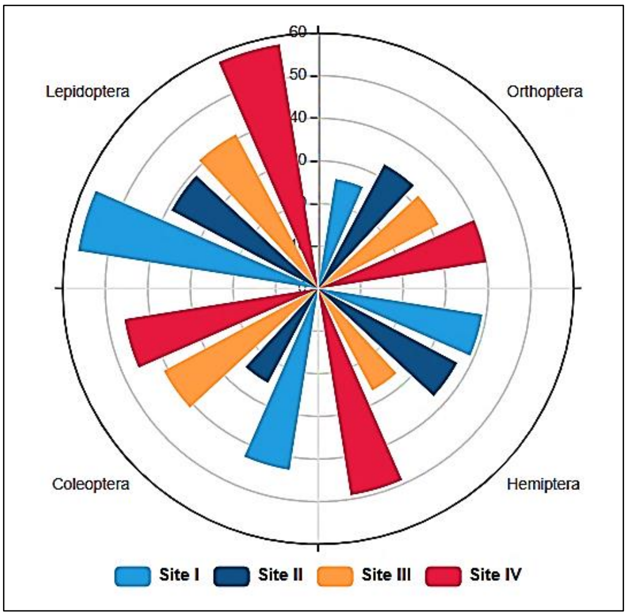


Figure 2. 1: Percentage Incidence of four orders at four Sites in the year 2017- '18

During the Year 2018 – '19 the Site-wise percentage incidence range of pest varied from 35% - 45%, Site II from 28% - 35%, Site III from 18% - 39% and Site IV from 35% - 57% (Table 2.6)and the Order-wise Percentage incidence range varied for Orthoptera from 18% - 38%, for Hemiptera from 32% - 45%, for Coleoptera 28% - 41% and for Lepidoptera from 35% - 57%

(Figure 2.2). The site-wise Percentage Incidence and Severity Index of pest depicted that Site IV had a higher occurrence of all the orders than the other three Sites. Year-wise Percentage Incidence and Severity Index of pests were recorded highly significant ($p<0.05$) during the year 2017 - '18 compared to 2018 - '19

Sites	Orthoptera		Hemiptera		Coleoptera		Lepidoptera	
	PI	SI	PI	SI	PI	SI	PI	SI
I	26	1	39	1.7	43	1.5	57	1.7
II	33	1.3	37	1.6	25	1	39	1.6
III	32	1	27	1.3	41	1.3	41	1.3
IV	40	2.1	49	1.9	46	1.5	58	2.1
Mean		**1.3**		**1.6**		**1.3**		**1.6**

Table 2. 6: Percentage Incidence (PI) and Severity Index (SI)of four orders at four Sites in the year 2018- '19

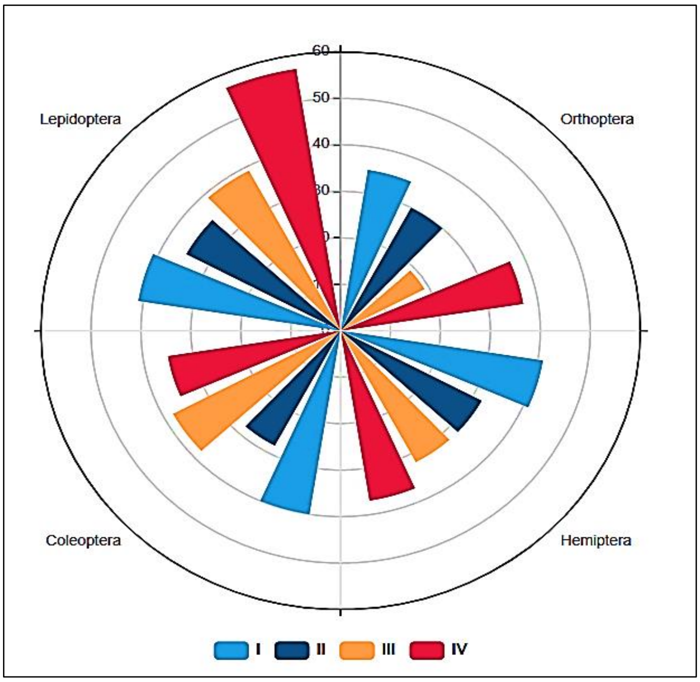


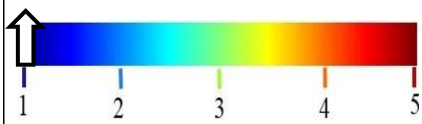
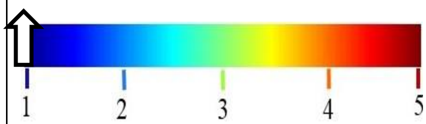
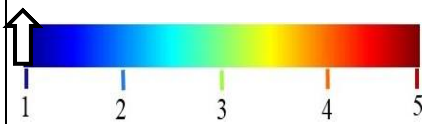
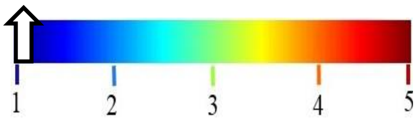
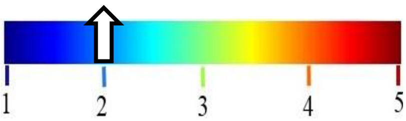
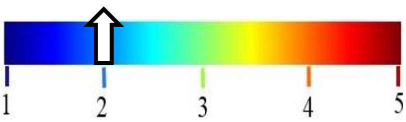
Figure 2. 2: Percentage Incidence of four orders at four Sites in the year 2018- '19

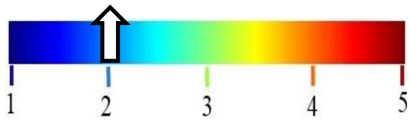
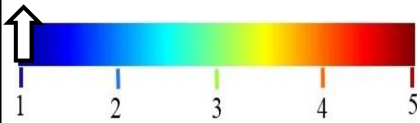
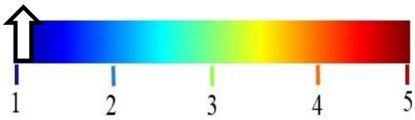
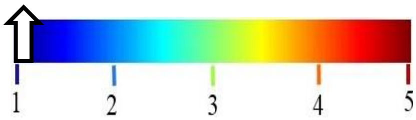
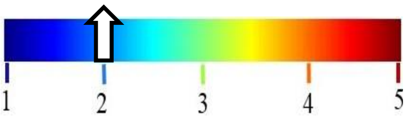
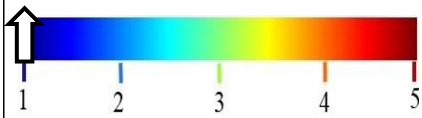
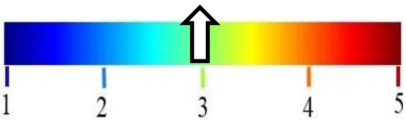
Sites	2017 - ‘18				2018 - ‘19			
	I	II	III	IV	I	II	III	IV
I	1	0.3803	0.352	0.4030	1	0.3421	0.3036	0.3879
II	0.3803	1	0.4016	0.3869	0.3421	1	0.3491	0.3621
III	0.352	0.4016	1	0.3471	0.3036	0.3491	1	0.3727
IV	0.4030	0.3869	0.3471	1	0.3879	0.3621	0.3727	1

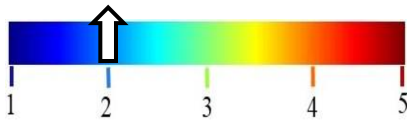
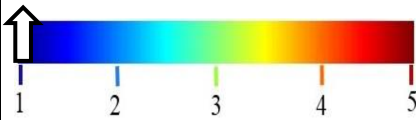
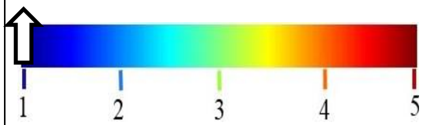
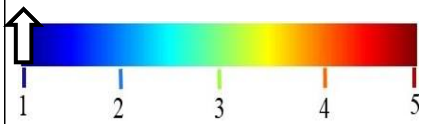
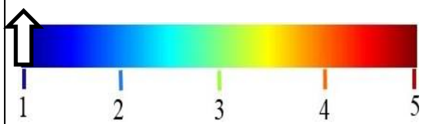
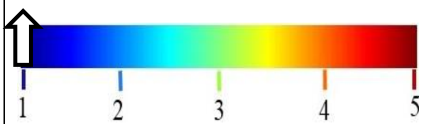
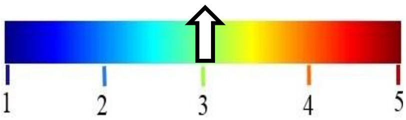
Table 2. 7: Jaccard Similarity Index of pest species at four Sites in both years

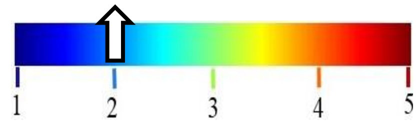
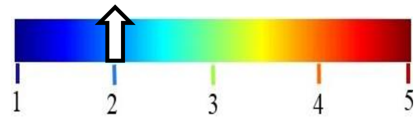
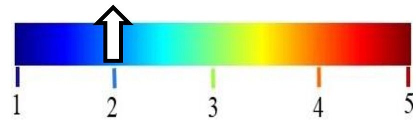
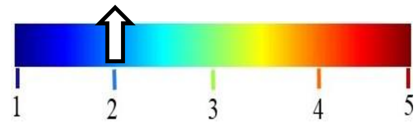
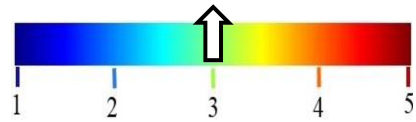
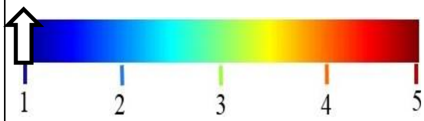
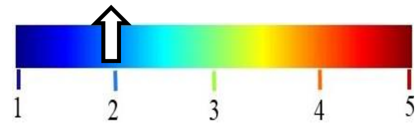
The Jaccard similarity index result revealed that in 2017-'18, the maximum similarity (40.83%) of pest species was seen between Site I and Site IV, and the minimum (35.45%) was between Site III and IV. One Way ANOVA analyses revealed that pest species between four Sites was highly significant ($F = 3.96$, $p = 0.008$) during the year 2017 - ‘18. Whereas in the year 2018-’19, the highest similarity (38.83%) was between Site I and Site IV, and the lowest (29.41%) was between Site I and Site III. One Way ANOVA analyses resulted that pest species between four Sites was significant ($F = 2.65$, $p = 0.048$) during the year 2018 - ‘19.

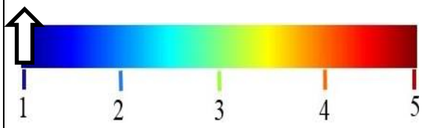
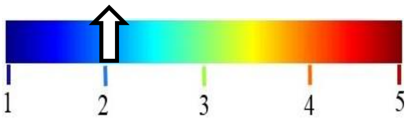
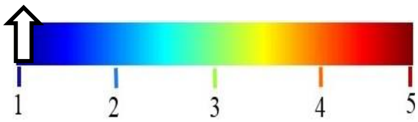
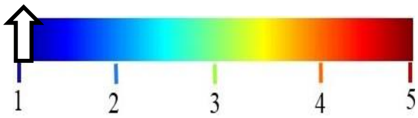
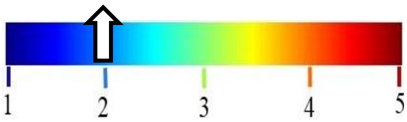
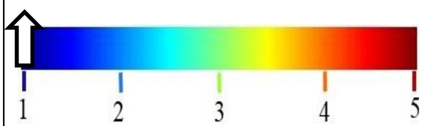
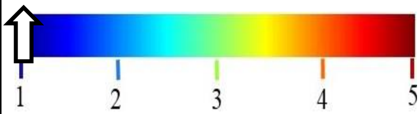
Following are the tables of four Orders representing pest species, host plant and its infestation rate

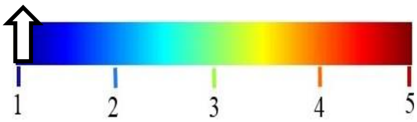
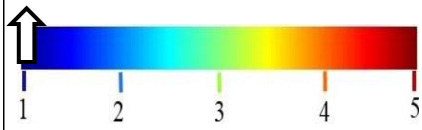
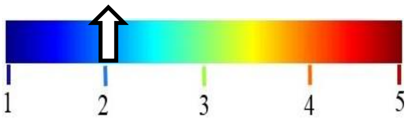
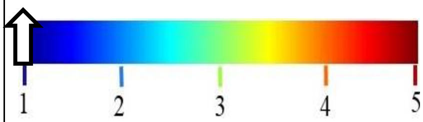
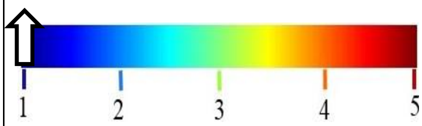
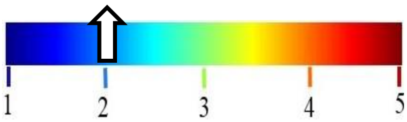
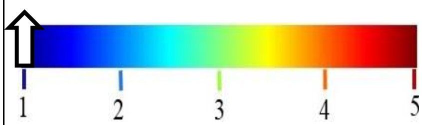
Order: Coleoptera			
Species	**Host Plant**	**Infestation Rate**	**Specimen**
Lasioderma serricorne	Tobacco, rice		
Acmaeodera viridaenea	Sunflower		
Agrilus acutus	Hibiscus		
Acanthophorus serraticornis	Mango tree		
Batoceraru fomaculata	Mango tree		
Dectes texanus	Soyabean		

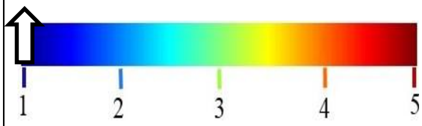
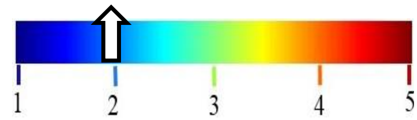
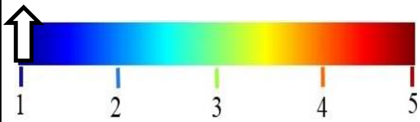
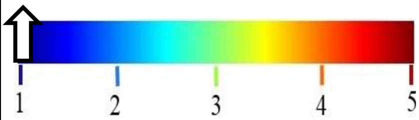
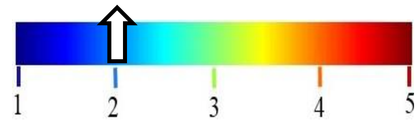
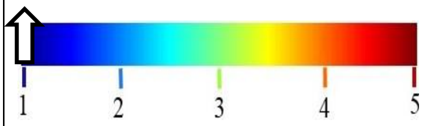
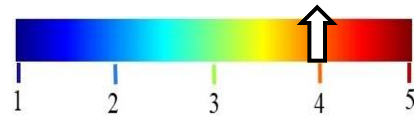
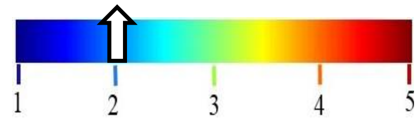
Derobrachus hovorei	Citrus plant		
Niphona picticornis	Mango		
Monochamus scutellatus	Fucus		
Xylotrechus stebbingi	Mulberry plant		
Altica cyanea	Cabbage Radish.		
Aspidomorpha miliaris	Sponge gourd		
Aulacophora indica	Sponge gourd, Cucumber		

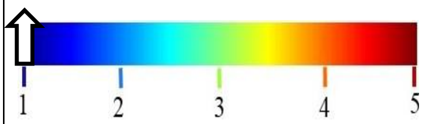
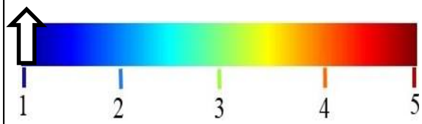
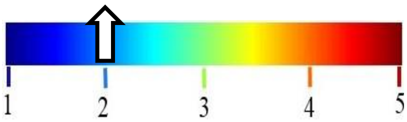
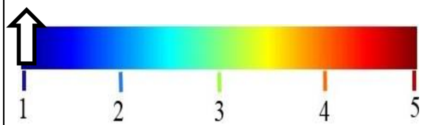
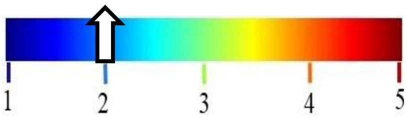
Aulacophora foveicollis	cucumber, bottle gourd, Sponge gourd		
Cassida circumdata	Sweet potato		
Chiridopsis bipunctata	Sweet potato		
Altica cyanea	Brinjal		
Clytra laeviuscula	Sweet potato		
Metriona bicolor	Sweet potato		
Monolepta signata	Maize, Ragi, Cowpea, Hibiscus		

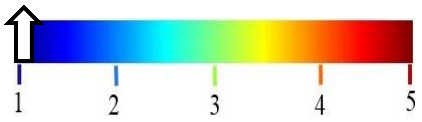
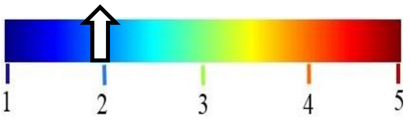
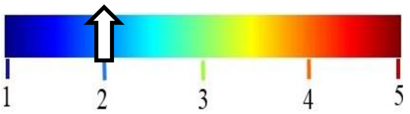
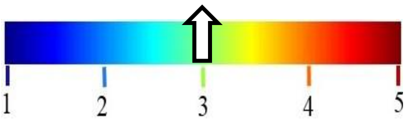
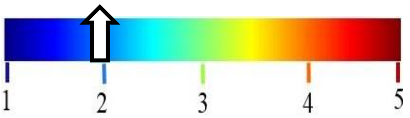
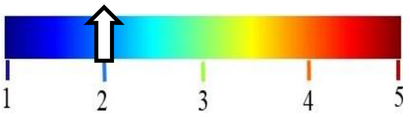
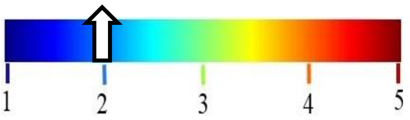
Oides bipunctata	*Cayratia trifolia*		
Oides palleata	*Cayratia trifolia*		
Podagrica fuscicornis	Brinjal		
Sindia clathrata	Climber		
Epilachna ocellata	Potato, Tomato, Brinjal, Okra, Cucumber, Radish		
Cosmopolites sordidus	Corn		
Hypera postica	Legume		

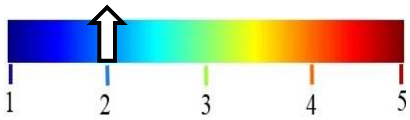
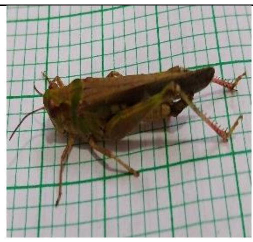
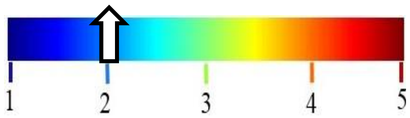
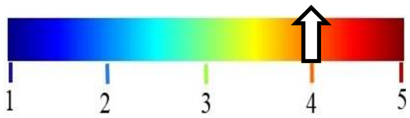
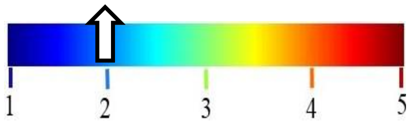
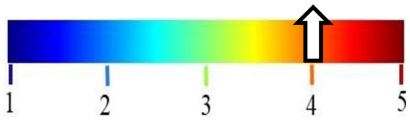
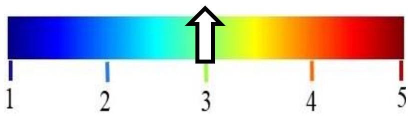
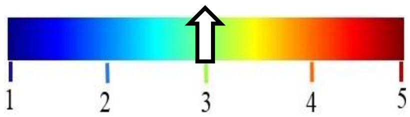
Myllocerus dorsatus	Bean, Cowpea, Pigeonpea, Cotton, Potato, Lemon.		
Myllocerus subfasciatus	Brinjal, Potato, Cotton		
Myllocerus undecimpustulatus	Pigeonpea, Cowpea, Maize, Rice, Cotton		
Myllocerus viridanus	Groundnut, Okra, Maize		
Polydrusus formosus	Mango		
Sitophilus oryzae	Maize, Rice, Wheat, Pulses		
Lanelater fuscipes	Potatoes, Cotton, Corn, Wheat, Carrots		

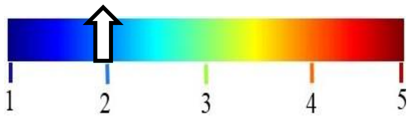
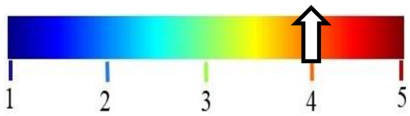
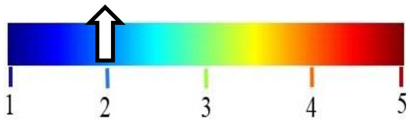
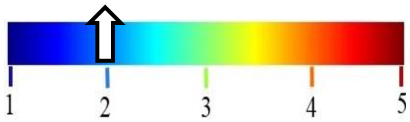
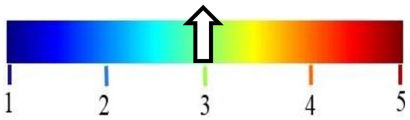
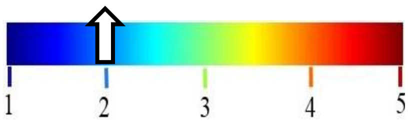
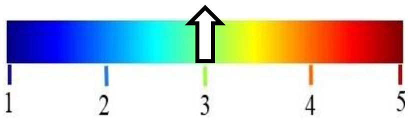
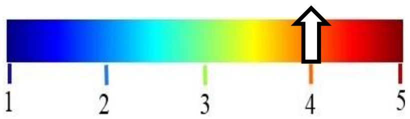
Synhoria maxillosa	Mango		
Lytta caragana	Green peas		
Mylabris cichorii	Sponge gourd		
Mylabris pustulata	Brinjal, Sponge gourd, Okra, Cow pea		
Mylabris variabilis	Brinjal, Sponge gourd		
Psalydolytta rouxi	Rice, Maize, Millet, Black Gram		
Cetonia funesta	Brinjal, Sponge gourd		

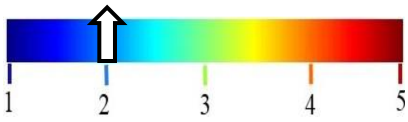
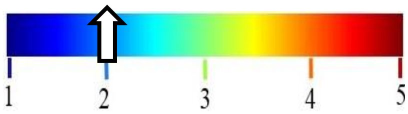
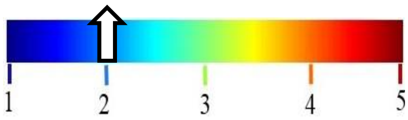
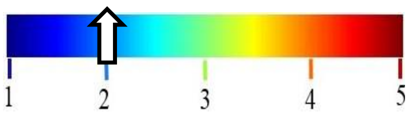
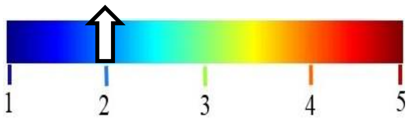
Chiloloba orientalis	Millet, Maize		
Cyclocephala pasadenae	Marigold		
Holotrichiareynaudi	Groundnut		
Oryctes nasicornis	Coconut		
Oryctes rhinoceros	Coconut		
Oxycetonia jucunda	citrus flower		
Oxycetonia versicolor	Brinjal, Pigeonpea, Sponge Gourd, Okra		
Phyllophaga nebulosa	Brinjal, Pigeonpea		

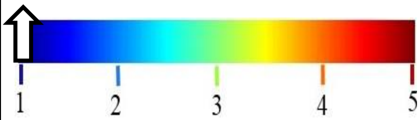
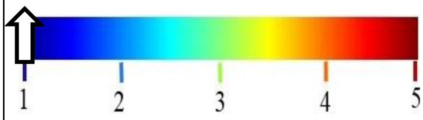
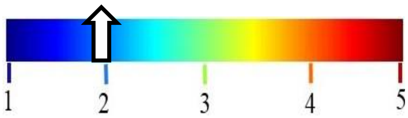
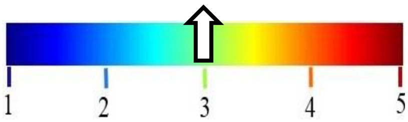
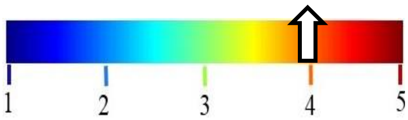
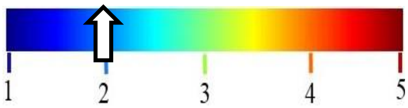
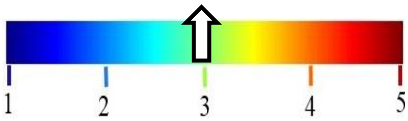
Phyllophaga obsoleta	Potato, Corn, Beans Vegetables		
Protaetia alboguttata	Maize, Brinjal Lantana		
Protaetia aurichalcea	Cluster Bean		
Protaetias quamipinnis	Maize, Brinjal		
Tenebrio molitor	Wheat, Rice		

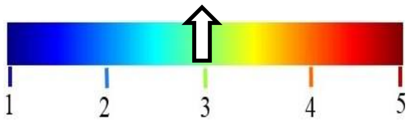
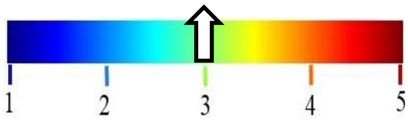
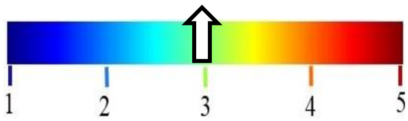
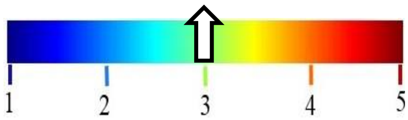
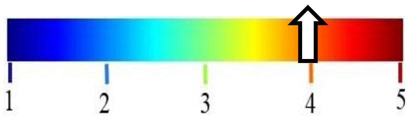
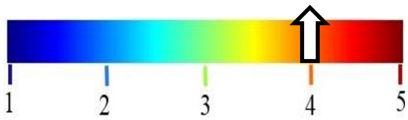
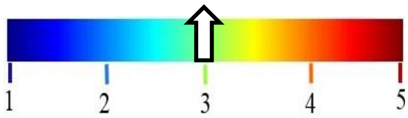
Order: Orthoptera			
Species	**Host Plant**	**Infestation Rate**	**Specimen**
Atractomorpha sinensis	Paddy, Wheat, Grass fodder		
Acrida conica	Wheat, Paddy, Grass fodder		
Acrida exaltata (Walker)	Paddy, Grass fodder		
Acrida ungarica (Herbst, 1786	Wheat, Paddy, Grass fodder, Maize		
Acrida willemsei	Paddy, Vegetables		
Acrotylus humbertianus	Maize, Vegetables		
Aiolopus thalassinus (Fabricius, 1781)	Rice, Maize, Millet, Grasses vegetables		

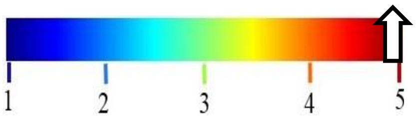
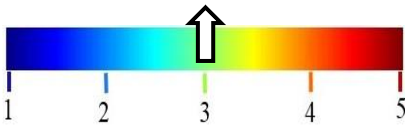
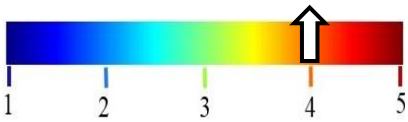
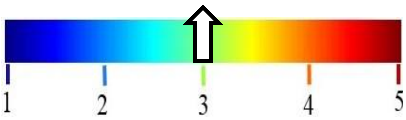
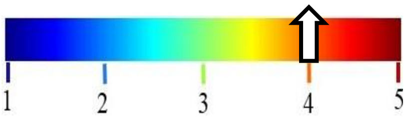
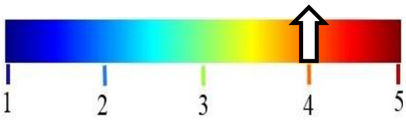
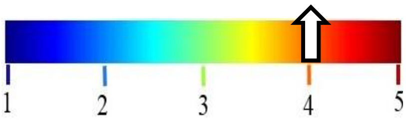
Aiolopus thalassinus tamulus	Maize, Rice, Ground nut, Millets Sugarcane		
Phlaeoba infumata	Maize, Rice, Ground nut, Millets Sugarcane		
Choroedocus robustus (Serville, 1838)	Maize, Banana, Sugarcane Millets		
Chorthippus curtipennis	Fodder grass, Sugarcane, Millets		
Hieroglyphus banian (Fabricius)	Rice, Maize, Sorghum, Sugarcane, Millet, Peas		
Hieroglyphus nigrorepletus (Bolívar	Maize, Sorghum, Millet, Grasses.		
Oxya hyla hyla (Serville)	Maize, Millet, Grasses.		

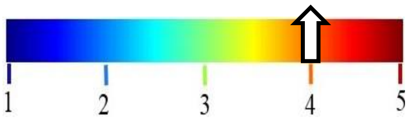
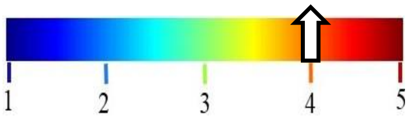
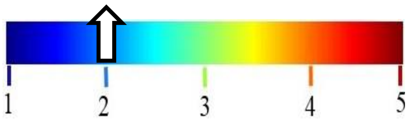
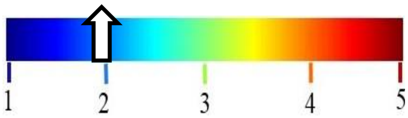
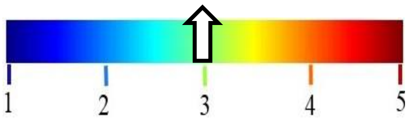
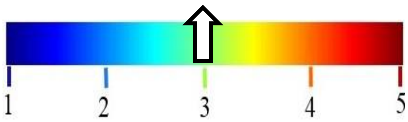
Poekilocerus pictus (Fabricius)	Calotropis, Vegetables		
Schistocerca gregaria (Forskål)	Wheat, Maize, Pigeonpea, Sugarcane, Cotton		
Mecopoda elongata (Linnaeus)	Sugarcane, Cotton, Vegetables		
Trigonocorypha unicolor (Stoll)	Fodder grass, Vegetables		
Locusta migratoria	Vegetable crops, Rice, Cotton,		
Oxya hyla intricate (Stål, 1861)	Paddy, Wheat		
Trilophidia annulata	Paddy, Sorghum, Maize, Millets		
Xenocatantops humilis	Paddy Fodder grass		

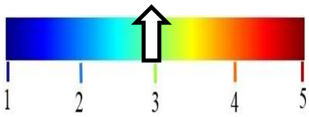
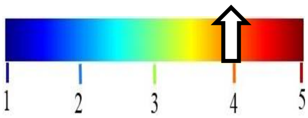
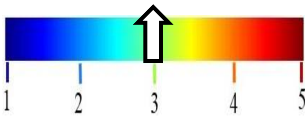
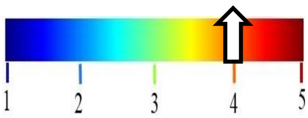
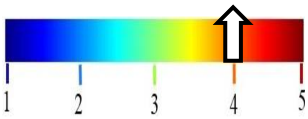
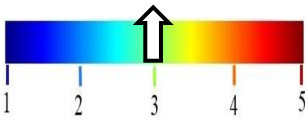
Acheta domesticus (Linnaeus, 1758)	Paddy		
Amblycorypha rotundifolia (Scudder, 1862)	Fodder grass		
Neoconocephalus velox (Rehn and Hebard, 1914)	Fodder grass, Vegetation		
Ducetia japonica (Thunberg, 1815)	Fodder grass, Vegetation		
Scudderia furcata (Brunner von Wattenwyl, 1878)	Fodder grass		

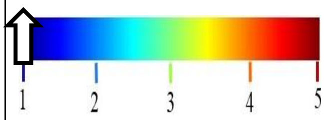
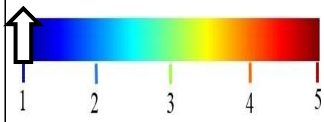
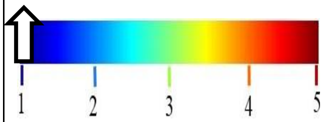
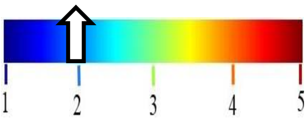
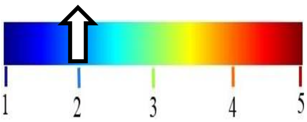
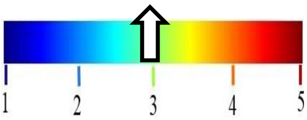
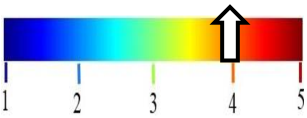
Order: Lepidoptera			
Species	**Host Plant**	**Infestation Rate**	**Specimen**
Cnaphalocrocis medinalis	Rice, Sugarcane, Maize, Sorghum, Ragi		
Hellula undalis	Cabbage, Cauliflower, Mustard, Radish		
Leucinodes orbonalis	Brinjal		
Scirpophaga incertulas	Rice, Fodder grass, Maize		
Spoladea recurvalis	Castor, Cucurbits, Raddish		
Amsacta albistriga	Castor, Cucurbits, Mulberry, Pulses, Millets		
Asota caricae	Ficus Spp., Mesua Sp., Shorea Robusta		

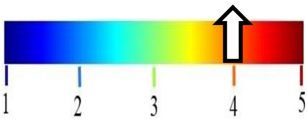
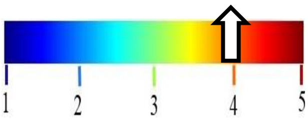
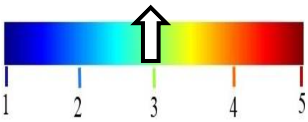
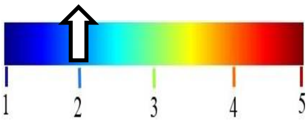
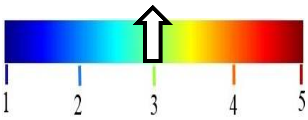
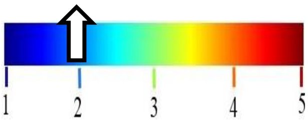
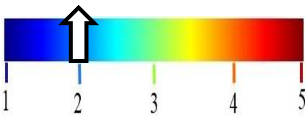
Eudocima materna	Banana, Citrus Mango Guava		
Orgyia leucostigma	Castor		
Orvasca subnotata	Thuver		
Spilarctia obliqua	Mulberry Bean		
Eupterote mollifera	Drumstick		
Pectinophora gossypiella	Hibiscus, Okra,		
Euproctis lunata	Hibiscus		

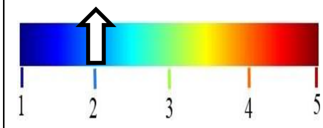
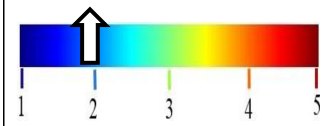
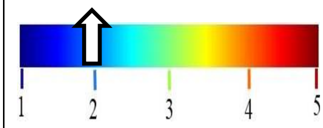
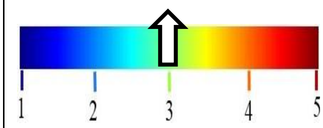
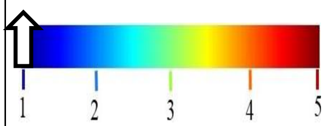
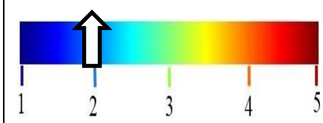
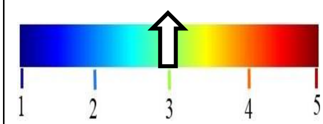
Helicoverpa armigera	Cotton Cabbage		
Olene mendosa	Castor		
Spodoptera sunia	Cotton, Cereals		
Spodoptera frugiperda	Maize, Rice, Sugarcane Wheat		
Spodoptera litura	Maize, Rice Cotton, Potatoes Cabbage, Cauliflower		
Helicoverpa zea	cotton, chickpeas, maize, millet tobacco		
Earias insulana	Cotton Okra		

Hypolimnas misippus	Moraceae, , Malvaceae, Fabaceae		
Plutella xylostella	Cabbage, Cauliflower		
Euzophera perticella	Brinjal, Potato, Chillies		
Earias vitella	Castor, Potato		
Ariadne merione (Cramer, 1777)	Castor		
Trichoplusia ni	cabbage, cauliflower		

Order: Hemiptera			
Species	**Host Plant**	**Infestation Rate**	**Specimen**
Aleurodicus dispersus	banana, citrus, mango, custard apple, guava		
Melanaphis sacchari	sweet potato, cotton, brinjal		
Empoasca decipiens	brinjal, cabbage		
Drepanococcus cajani	pigeonpea, guava, Okra		
Phenacoccus madeirensis	cotton, hibiscus, tomato, potato, brinjal		
Acanthocephala femorata	cotton vegetable		

Cletomorpha benita	Brinjal		
Cletus punctiger	Pigeonpea, Sugarcane, Rice		
Homoeocerus signatus	Spinach		
Proutista moesta	Coconut seedlings, maize, sugarcane		
Rhynchomitra microrhina	Hibiscus Vegetable		
Coridius janus	Bottle gourd, Brinjal		
Pyrilla perpusilla	Sugarcane, Wheat, Maize, Sorghum, Pearl Millet, Rice		

Leptocentrus taurus	Moringa		
Acanthuchus trispinifer	Moringa		
Oxyrachis tarandus	mulberry plants		
Agonoscelis nubilis	Sorghum, cumin, maize, coriander,		
Nezara mendax	Brinjal vegetable crops		
Carbula insocia	Rice Wheat		
Halyomorpha halys	pigeonpea, cotton, pomegranate, cowpea		

Nezara viridula	rice, pigeonpea, cotton, Okra, brinjal, castor,		
Nezara antennata	Brinjal, castor,		
Palomena prasina	Pigeon pea, field bean, cowpea, cotton, tomatoes		
Megacopta cribraria	Pigeonpea, cowpea, field bean, soybean		
Plautia affinis	Pigeon pea, field bean, cowpea, cotton		
Dysdercus koenigii	Cotton, Okra		
Dysdercus cingulatus	Cotton seeds		

2.4 Discussion

Occurrences of Pest species are known to be depending on the vegetation and cropping pattern of the agroecosystem. All four sites were enriched with a good cover of vegetation, different varieties of crops, and insects' abundant pest species. Pests belonging to all the four orders: Orthoptera, Hemiptera, Coleoptera, and Lepidoptera were present in all the study areas. The hierarchical number of pests’ species were found from order Coleoptera > Orthoptera > Lepidoptera > Hemiptera. Site wise hierarchical occurrence of pest revealed that the number of species was less in Site III<Site IV<Site I <Site II due to habitat diversifications that provide resources and environmental conditions suitable for natural enemies. Further, as Shrewsbury and Leather (2012) reported, flowers increase alternative prey and natural enemy abundance, translating into reduced pest insect survival. Vegetation cover, biomass, and plant diversity are essential drivers of below-ground ecosystem processes which influences the faunal diversity (Buchholz *et al.*, 2017), as it provides food and structure for many arthropod taxa, thereby influencing pest control by providing suitable habitats for increasing natural enemies of pests (Nicholls *et al.,* 2000; Altieri *et al.,* 2008; Danne *et al.,* 2010 ; Paredes *et al.,* 2013; Hall *et al.,* 2020). The observed fewer number of pests at Site III is probably because the agriculture fields at Site III had diversified flowering plants on the edges, and the farmers were found to follow the polyculture pattern of crops and the excellent usage of chemical pesticides. Our results follow the earlier work by Bianchi *et al.*, (2006); Lal Sharma and Singh, (2014); Sathe *et al.,* (2014); Sathe *et al.,* (2016) and Ul Ane and Hussain, (2016) working on the diversity of pests in various agriculture fields.

The variability observed between years in the proportional change of abundance of the pest species suggests an essential role of climatic conditions in modulating pest occurrence to their environment. Studies have identified several factors driving insect outbreaks, including climate (Marini *et al.*, 2017), induced responses in multiple predators' plants and densities. In the present study, it was observed that there was heavy rainfall in the year 2018 - ‘19 compared to 2017-’18 and so, pest species were recorded more in the year 2017

- ‘18. Hence, the climatic changes in temperature and humidity could have possibly altered pests and natural enemies' phenology and, therefore, influence insect population growth rate (Ekholm, 2019), which might have ultimately altered the effectiveness of natural enemies in controlling pest abundance. In perennial cropping systems, the presence of flowering undergrowth enhances the biological control of a series of insect pests. Several researchers have opined that introducing flowering plants as strips within crops enhances pollen and nectar availability, necessary for optimal reproduction, fecundity, and longevity of natural enemies of pests. However, the appreciable increase in the number of pest at the other three sites indicates that there is an increase in the number of links between crops, vegetable, and pest, the climatic suitability between pests and plants, and seasonal linkage between vegetation and pest as reported by Ramirez-cabral *et al.,* (2017) who have worked on Global alterations in areas of suitability for maize production from climate change and Grünig *et al.,* (2020) who have worked on increased linkage and suitability of crop pest and forest pest.

The Coleopterans include more species than any other order, constituting almost 25 % of all known types of animals, and among them, beetles are of 40% of all known insects (Patole, 2017). About 75 % of beetle species are polyphagous in both larval and adult stages and live in or on plants, wood, and various stored products (Bouchard *et al.*, 2017). Thus, directly or indirectly, beetles as pests cause significant damage to the agroecosystem (Diserud *et al.,* 2017). Coleopteran pests are equivocally adapted to feed on their host plants' roots, stems, leaves, or reproductive structures. In the present study, the coleopterans were mostly sighted in foliage, flowers, tree barks, and inside plant tissue in the form of galls. Hence, a sizeable number of Coleopteran pests in the present study is not surprising as all the sites had good vegetation cover. Our results are in accordance with the earlier reported work of Gullan and Cranston (2010), where they have reported Chrysomelidae devouring leaves, and of Banerjee (2014) and Singhal et al. (2018), who have reported some Scarabaeidae in agricultural fields. Further, Rossi et al. (2019) have opined that the leaf-miners (Chrysomelidae and Buprestidae) feed in narrow spaces between leaf surfaces. Many phytophagous species are pests of turfgrass, ornamental plants, agriculture, and rely on aggregation pheromones to coordinate performances and attacks on host trees and weakly defended hosts (Toffin *et al.,* 2018). The present study revealed that phytophagous beetles belonging to Chrysomeloidea, Carabidae, Coccinellidae, Cerambycidae, Meloidae, and Curculionoidea, which forage on the most parts of the host plant, probably have utilised the same strategy for their survival in the agriculture fields (Dedyukhin, 2015). Further, all phytophagous beetles show monophagy, oligophagy, and polyphagy (Raju *et al.,* 2016). The polyphagy practiced by the beetle is an adaptive benefit and ensures its survival and build-up of the population in different ecosystems (Hazarika and Kalita, 2018).

Many phytophagous Coleopterans cause extensive destruction to leguminous plants and lead to serious harm to field crops and fruits as well as to economically important crops like sugarcane, groundnut, pearl, millet, sorghum, paddy, chilies, and other vegetable crops (Popay and Thom, 2009; Chandra and Chandra, 2015) In the present study the agricultural fields comprised of a leguminous perennial plant and annual crops; this cultivated habitat harbors a succession of pest species that use the growing field as a passageway then establish themselves as the crop grows. Although there was a substantial temporal and spatial alteration in Coleoptera's pest species, it was comparatively less. There are two basic ways in which pest infestation is assessed; the incidence, which is usually expressed as a percentage, and the severity, a measure of the size of the pest population on the plants the possible are in agreement with the earlier reported works (Boivin and Hance, 2003; French *et al.,* 2004; Banerjee *et al.,* 2018). Rate of Infestation and severity are known to depend on a number of factors, such as cropping pattern, usage of chemical pesticides, number of individual pests, and the stage of their occurrence. Less infestation rates well as severity by Coleopterans compared to Hemiptera, Orthoptera, and Lepidoptera can thus be attributed to the fact that the cropping pattern at all the sites was not having much of the intercropping pattern and further it the larval and the grubs of the phytophagous beetles which are more damaging than the adults. Our results are parallel with the earlier work of Hassan (2009), and Kisetu Nassary and Nyasasi (2014), who have worked on the effect of intercropping on the Infestation and severity as well as the work of Dzemo et al. (2010) and Rehman *et al.,* (2014) have opined that the Infestation and severity are dependent on the spraying of the pesticides.

Orthopterans, including crickets and grasshoppers, are represented by more than 20,000 species with a worldwide distribution and include historically difficult pests such as the locust. Orthoptera is one of the most massive insect orders, including short-horned (Caelifera) and long-horned grasshoppers (Ensifera). Acrdoidea is one of the most important out of four superfamilies of Caelifera, which comprises five families out of which Acrididae, Catantopidae, and Pyrgomorphidae are widely distributed in India. Grasshoppers are of great economic importance because they constitute a significant group of pests and pose a constant threat to cereal crops, pulses, vegetables, orchards, grassland, and forest plantations all over the world (Rafi *et al.,* 2014). Most of the species are phytophagous, which forage on the Gramineae family and are considered agricultural pests of worldwide interest because of the crop losses linked with the crop yield (Hunter *et al.,* 2019).

Grasshoppers are polyphagous insects since they damage the crops, non-agricultural areas, and grasslands. Furthermore, the adverse effects of phytophagous orthopteran pests on crop production are often economically significant in crop yield (Bradshaw *et al.,* 2016; Yadav et.al, 2018a).In the present study, Orthoptera pest species were the second-highest in pest status, and most of the pest species belong to Acrididae, Tettigoniidae, Pyrgomorphidae, and Gryllidae. Many of the Orthopterans are important pests of crops that frequently are planted adjacent to or intermixed with grassland areas. It increases its population in adjacent rangelands, moves to the main crops, and causes severe damage to crops (Whipple *et al.*, 2012). Further, as reported by Chisté et al. (2016), many pest orthopteran species benefit from anthropogenically disturbed landscapes, and some acridid outbreaks are entirely natural events, effectively restricted to native grasslands and despite their large distributional ranges, the realized range in any given year may be remarkably limited. In the present study, the Orthopteran pests' occurrence was more prominent in the fodder growing fields, sugarcane, and Rice Fields. As far as Infestation is concerned, the Cereal crops growing fields had the maximum Infestation by the members of the Acrididae and Tettigoniidae, as both the groups are blessed with the strong mandibles this explains the activity. Paddy fields were also infested along with the wheat fields, and the leaves of paddy compared to wheat are more subtle because of more water content was commonly found to be infested by acridoids. In the case of vegetables, ladyfinger topped the list while gourd showed some signs of Infestation. Other vegetables in the area were nearly free of Acridoid pest infestation. Similar results have been obtained in various agriculture fields (Chitra *et al.,* 2000; Usmani *et al.,* 2010; Akhtar *et al.,* 2014; Ssakhi *et al.,* 2014; Kumar and Usmani, 2015; Diserud *et al.,* 2017; Mariod *et al.,* 2017; Pervaiz *et al.,* 2017; Mobin *et al.,* 2017). Jadhao and Khurad (2011), where they have reported the occurrence and Infestation by Orthoptera. In the present study, the infestation rate and severity index of Orthopterans were comparatively lesser than others. Some of the species act as minor pests, leaving holes in the leaf. However, some species like *Schistocerca gregaria, Choroedocus robust,* and *Hieroglyphus banian* cause heavy Infestation and damage to the crops, and the results obtained in the present study may be taken as in reasonably good agreement with the work of many groups who have worked on single species of orthopteran pests (Braman *et al.,* 2000; Liebhold and Tobin, 2008; Adjei *et al.,* 2009; Samin *et al.,* 2010; Silva *et al.,* 2011; Harris *et al.,* 2012; Gomez *et al.,* 2012; Harris *et al.,* 2013; Jonas *et al.,* 2015;Yadav *et al.,* 2018; Miao *et al.,* 2018).

Lepidoptera (moths and butterflies) are the second most diverse pest insect order over counted only by the beetles. There is hardly any cultivated plant that is not attacked by at least one Lepidopteran pest. Lepidoptera was found to be in the third position in pest status in the present study. Most of the Lepidopteran pests, especially the moths, are crop pests in their larval stage (Liu *et al.,* 2009; Adiroubane and Kuppammal, 2010) , and pest belonging families like Noctuidae, and Nymphalidae, cause severe destruction to crops and vegetables (Cordero-montoya *et al.,* 2019). Caterpillars are sthe most voracious feeder and feed on plant material, such as leaves, flowers, fruits, seeds, or roots (Ratnadass *et al.,* 2012). Further, it has been reported that they are vulnerable to stressors in agricultural landscapes because they are immobile compared with most adult moths and dependent on the availability of suitable host plants; hence, any change in the plant diversity or changes in plant communities most likely affects their occurrence (Hahn, 2015; Salunke and More, 2017).

In the present study, the caterpillars' occurrence was mostly sighted at the study sites where vegetables belonging to the cruciferous group were plenty. Moreover, the infestation rate and the severity were also more pronounced in this agriculture fields. Mixed cropping and intercropping are very common traditional cultivation practices; modern agriculture farmers give more preference to monocropping because, economically, it gives excellent benefits. However, monocrop destroys the soil in the long term and causes quick proliferation of phytophagous insects/pests(Sokame *et al.,* 2019). So the monocropping method leads to a massive population build-up of pest insects. The current investigation of the infestation rate and the severity of Lepidopteran pests were found to be influenced by cropping patterns. The monocrop vegetable field recorded a high infestation rate compared to the intercrop field, pointing to a good number of pest species higher in monocrops.

In addition to the vegetables belonging to the cruciferous group (Cauliflower, cabbage), sole brinjal and okra crops also showed a higher infestation rate. Abro *et al.,* (2004) have reported that okra intercropped with maize, mung, sesamum, and guar was infested significantly less than mono-crop of okra. Rao *et al.,* (2012) and Mahendran *et al.,* (2018) have spelled out that intercropping in castor and cauliflower significantly reduced the pest incidence, and Infestation was mainly due to the increased activity of natural enemies. Many investigators have experimentally proved that mixed cropping or intercropping practices can reduce the pest population level in the main crop by two ways: i) low density of the main crop in mixed cropping field cannot support a large number of pest species and ii) natural enemy/biocontrol agent population is always high in mixed cropping ecosystem since this type of habitat provides alternate prey, nectar, pollen, breeding grounds and favourable microclimate to the natural enemies. Our observation is in accordance with the results mentioned earlier, and despite the pest status, which is less in number, the infestation rate and severity were maximum due to the monoculture pattern in the vegetable fields. The high levels of Infestation and damage caused by the Lepidopteran larvae reported by several scientists support the present work(Taylor and Riley, 2008; Desneux *et al.*, 2010; Simmons *et al.*, 2017; Aslam *et al.*, 2019). In the present study, it was also noted that most of the vegetable crops were cultivated in two seasons per year and thus are available to the pest throughout the year. Among the 31 Lepidopteran pests recorded, many of them were found to infest more than a single crop, *i.e.*, and millets and castor, which were present throughout the year, probably ensuring the continuous availability of the host plants to the pest and thus the high infestation rate, our observations are parallel to work done on Lepidopteran pests by Bergé and Ricroch, (2010).

Hemiptera, which includes true bugs, are either plant feeders, and some species are a major agricultural pest. As plant feeders, some bugs - such as the aphids- are serious agricultural pests, not just because they damage crops but also because they can transmit viral diseases. Many hemipterans are considered major agricultural pests, causing significant economic losses to local agriculture (Seo *et al.*, 2011). Hemipteran feeds primarily on graminaceous plants such as rice, wheat, and sugarcane (Hill *et al.*, 2010). Other important hosts include many well-known weeds, such as millet, varieties of grass. Other reported hosts include mango, guava, jackfruit, and beans (Soria *et al.*, 2017). In the current inventory, the Hemipteran pest was less in number in species wise, and most of its pest species was belonging to Lygaeidea, Pentatomidae, Reduviidae, Membracidae, and Coreidae family. Our results are similar to Salunke and More, (2017), who have reported hemipteran pests from the agricultural fields of Kolhapur (Rice, Red gram, Brinjal, and Cowpeas).

Further, as Wetzel *et al.*, (2016) reported, bugs have narrow ranges of nutrient levels where they flourish. If the plants being fed on are too nutrient-rich or poor, the insects are less likely to thrive. Bugs surrounded by diverse plants are harmed much more by low-quality plants with the wrong nutrient levels than high-quality plants benefit them with high nutrient levels. Thus, a smaller number of Hemipterans could thus be for the mentioned reasons. As far as Infestation and severity of the Hemipteran pest are concerned, both the larval and the adults infest the plants, which results in a wide range of damage to the host plant. The severity of infestation increases when the nymphs and adults feed together on the same host plant, especially the sapsuckers, sucking the sap completely and damaging completely (Ujagir and Byrne, 2009; Ingegno *et al.,* 2016). Infestation by mealybugs has also been well explored by Nagrare *et al.,* (2009a) and has reported severe Infestation on cotton plants and Kataria and Kumar, (2012) and Singh and Gandhi, (2012) who have explored the Infestation by Hemipterans in the agricultural fields of Gujarat. In the present study, the Infestation of Hemiptera was observed more in the pre-monsoon, post-monsoon season, and winter, possibly the nymph and adult stages were more prevalent in those periods. Veeraragavan *et al.,* (2018) suggested that the Hemipteran pest frequency depends on season. The most noticeable observation in the present work despite the high infestation rate, none of the agriculture fields were seen to be damaged completely, probably the agriculture Plant self-defense against Hemipterans was operating physically, hindering insect feeding, and may some mechanisms be interfering with insect physiology and behavior (Shah *et al.,* 2017). Further, it has been reported that the synthesis of the new variety of chemical molecules to control diseases and insect infestation (Mitchell *et al.,* 2016; Stenberg and Muola, 2017)

Agricultural landscapes may be categorized as complex, simple, or cleared. In general, as the complexity of the landscape increases, biodiversity increases, although some species groups are insensitive to it (Tscharntke, *et al.,* 2005; Gonthier *et al.,* 2014). Previous work has shown that both local and landscape factors affect the biodiversity of semi-natural elements in agricultural areas and that the effectiveness of management for biodiversity depends on the landscape complexity (Kohler *et al.,* 2008; Tscharntke *et al.,* 2012). Agricultural landscapes may be manipulated in ways that benefit predatory insects by providing alternate food sources. Ecological theory predicts that complex plant communities support a more affluent community of natural enemies of pest insects than a simple plant community. Complex plant communities can directly enhance natural enemy populations by providing more niches, nectar, pollen as food, or indirectly by increasing prey. Left to its defenses, a farm field growing a variety of plants tends to attract fewer insect pests than a field growing just one type of crop. While scientists and farmers have noted this difference for years, the reasons behind it have been poorly understood.

The problem with monocultures is that if an insect likes the crop, that insect has a large food supply to draw from all in one place. Conversely, a field containing various plants does not offer a large block of food for the insect, so it will not get the nutrients it needs to survive and thrive. "A monoculture is like a buffet for plant-eating insects where every dish is delicious," and reverse to that, "A variable crop is like a buffet where every other dish is nasty" (Wetzel *et al.,* 2016). Hence, farmers include a diverse mixture of plants. In the same line to insight whether the pest population is dependent on the plant community, shared pest assemblage of all the study sites was performed by the Jaccard similarity index. The results revealed a 30 - 40% similarity among the space, i.e., Sites I and IV, on close observation of the plants' varieties at both the sites was almost similar. Further, at both the sites, the farmers were found to have polyculture farming patterns. At the same time, they are spraying the biopesticides at a regular interval as a significant alternative use of pesticides for conservation and promotion of natural enemies as part of the Integrated pest management program. Taking the explanation given by Wetzel *et al.,* (2016) however, the observations over time were found to be less in the year 2018-2019 compared to 2017-2018. The decline might be due to the low species richness or climate change and the massive flood. The similarity of habitat and cropping pattern and the crops has probably resulted in a maximum similarity between Site I and Site IV. Our result is parallel with the observation made by (Okrikata and Yusuf, 2016; Jemal and Getu, 2018; Mouhoub *et al.,* 2018; Deutsch *et al.,* 2018) who have opined that the similarity is dependent on the habitat and nature of plant cover and its density, type of soil as well as seasons.

2.5 Conclusion

This present study reports the pest species' distinct occurrence and its diversity in the Vadodara district's agricultural field. A maximum number of pest species were reported from order Coleoptera, followed by Orthoptera, Lepidoptera, and Hemiptera. However, Order Hemiptera and Lepidoptera showed more incidence and severity index and were highest in the 2017- ‘18 compared to the year 2018-‘19 due to extreme climate variation. The present study is the first of its kind where the pest status of the agriculture fields around Vadodara has been reported and hence can be interpreted as more of a baseline data which will help entomologists and agriculturalists to gain more insights and measures for better yield of the crops. However, there is a need to complement the existing information with additional studies where a detailed understanding of the trophic interaction and population dynamics will affirm how crop pests can be controlled with more directed measures. Further, one can adopt the alternative forms of vegetation diversity, and as an alternative for pest management, specific predators can be released, which reduce pest species abundance, and alleviates the cost of pest control measures.