DIVERSITY OF SPIDERS (ARANEAE) IN TEA

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IN

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By

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CERTIFICATE - I

This is to certify that the thesis entitled **"Diversity of Spiders (Araneae) in Tea"** submitted to the Faculty of Agriculture, Assam Agricultural University, in partial fulfilment for the degree of **Doctor of Philosophy (Agriculture) in Entomology** is a record of Research work carried out by **Somar Hazarika**, under my personal supervision and guidance.

All help received by him have been duly acknowledged.

No part of this thesis has been reproduced elsewhere for any degree.

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CERTIFICATE - II

This is to certify that the thesis entitled **"Diversity of Spiders (Araneae) in Tea"**submitted by **Somar Hazarika, Regd. No. 14-ADJ-34** to the Assam Agricultural University in partial fulfilment of the requirements for the degree of **Doctor of Philosophy (Agriculture) in Entomology** in the discipline of **Entomology** has been examined and approved by the Student's Advisory Committee after viva-voce on the same, in collaboration with an External Examiner.

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ABSTRACT

A survey was conducted to study the diversity of spiders in different tea gardens *viz.,* conventional, organic and small grower tea gardens of Jorhat district from May, 2016 to April, 2017. The results revealed a total number of 2954 specimens of spiders collected under 16 genera, 8 families and 20 species *viz., Cyrtophoracicatrosa, Nephila kuhlii, Argiope pulchella, Cyclosa mulmeinensis, Neoscona* sp, *Cyclosa spirifera, Cyclosa bifida, Araneus mitifica, Oxyopes sitae, Oxyopes shweta, Oxyopes* sp, *Rhene danieli, Phintella vittata, Telamonia dimidiata, Tetragnatha* sp, *Leucauge decorata, Heteropoda ventoria, Xysticus* sp and *Perdosa peaudoannulata.* Among all the species, *Castianeira furva* has been recorded for the first time from this region. Species richness (R = 3.07) and evenness (E = 0.96) was recorded the highest in Deha T.E. (organic garden) and was found lowest for Saikia T.E (small grower garden) *i.e.,* 2.51 and0.89 respectively. However, species diversity was recorded highest in conventional garden, Dhloi T.E. (H’ = 2.88). The correlation studies revealed that the spider population exhibited significant positive correlation with total rainfall (r = 0.776) and non-significant for maximum temperature, minimum temperature and evening relative humidity while, a significant negative correlation was observed with morning relative humidity (r = -0.797) and bright sunshine hour (r = -0.676).

Some morphological and biochemical characters of seven selected tea clones (TV 1, TV 2, TV 7, TV 9, TV 12, TV 18, TV 23) in the Experimental Garden of Plantation crops, Assam Agricultural University, Jorhat were examined to determine their effects on common insect pests and spider population. The results showed that all the clones were susceptible to the pests, TV 23 being more susceptible compared to others (*H. theivora* 6.22 no/bush, *O. coffeae* 18.35 no/leaf, *Hyposidra* sp 3.43 no/bush). However, no significant difference for spider populations was found to exist amongst the clones. With respect to morphological characters, the examined clones showed significant difference for total number of branches, leaf area and

trichome densities. The differences in leaf moisture contentwere also significant. Moreover, it was found that the phenol content of examined clones gradually decreased due to pest infestation and the reduction was highest in TV 23 (22.43%). The linear correlation among morphological and biochemical attributes of selected tea clones with pests showed that total no of branches and leaf area had a non significant negative correlation with *H. theivora* (r = - 0.664, - 0.333), *O. coffeae* (r = -0.277, -0.175) and *Hyposidra* sp (r = -0.156, -0.179) while trichome density had significant negative correlation with *H. theivora* (r = -0.643) *O. coffeae* (r = -0.475) and *Hyposidra* sp (r = - 0.493). However, the moisture content showed a non-significant positive correlation for *H. theivora* (r=0.064) but established a negative association with *O. coffeae* (r = -0.446) and *Hyposidra* sp (r = -0.370). Regarding insect pests, both the reduction in phenol content and spider population exhibited a significant positive association.

A field experiment was conducted in the Experimental Garden of Plantation crops, Assam Agricultural University, Jorhat, during 2016 and 2017 to investigate the effect of pesticides on common insect pests and spider population in tea plantation. On the basis of the pooled data of two year observations recorded at 1^{st}, 5^{th} and 10^{th} days after application and revealed that all the treatments showed significant differences over control. Among the treatments thiomethoxam 25% WG @ 0.01% was found to be most effective against *H. theivora* followed by deltamethrin 2.8 EC @ 0.02% and azadirachtin @ 0.003%, whereas spiromesifen 240 SC @ 0.2% was found to be least effective against *H. theivora* population. The pooled data on the efficacy of different pesticides on *O. coffeae* revealed that spiromesifen 240 SC @ 0.2% was most effective followed by ethion 50EC @ 0.25%, deltamethrin 2.8 EC @ 0.02% and azadirachtin @ 0.003% whereas thiomethoxam 25% WG@ 0.01% @ was found to be least effective against *O. coffeae* population. Among all the treatments ethion 50EC @ 0.25% was found to be most toxic on spider population followed by deltamethrin 2.8 EC @ 0.02% and *B. bassiana* @ 2% was found safer to spider population which was followed by azadirachtin 5 EC 0.003%.

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ABBREVIATION USED

Abbreviation	Meaning
	Percentage
˚C	Degree centigrade
@	At the rate
AAU	Assam Agricultural University
cm	Centimeter
DAS	Day after Spray
Fig.	Figure
cm_2	
IRRI	International Rice Research Institute
mm	Millimeter

CHAPTER I
INTRODUCTION

Tea, *Camellia sinensis* (L.) O. Kuntze, is an evergreen plant of the family theaceae that is native to China and North east India (Willson, 1999). It is an intensively managed perennial monoculture crop cultivated on large and small scale plantation. Tea plays a major role in the economy of several countries of Asia and Africa. India is one of the leading producers of tea (1,233.14 million kg per year) and approximately 52 per cent of the total tea produced in India comes from Assam (Tea board of India, 2016). In Assam tea is mainly confined to three main varieties *viz.* Assam indigenous variety (*Camellia sinensis* var. *assamica* Masters), China variety (*C. sinensis* var. *sinensis* L) and Cambod variety (*C. assamica* sub sp. *Lasiocalyx* Planch). Besides these varieties the hybrids developed through crossing between the three varieties and selected parents from seed jats with mixed taxonomic characters are also widely used almost in all the tea growing areas.

Tea, being a perennial monoculture crop is exposed to many pests and diseases. It provides a suitable condition for the development of a wide variety of insect pests. More than one thousand species of arthropods are known to attack tea (Hazarika *et al.*, 2009). Among them, about three hundred species of insect and mites are reported from India (Chakravarthya and Sridhara, 2016). Every part of a tea plant *i.e.* leaf, stem, root, flower and seed are attacked by pests, which may result on an average 5 to 55 per cent yield loss (Hazarika *et al.*, 2009). A wide range of pests have been associated with tea plantations., only a few of these like tea mosquito bug, *Helopeltis theivora* (Waterhouse); red spider mite, *Oligonychus coffeae* (Nietner); jassids, *Empoasca flavescens* (Fabricius); red slug caterpillar, *Eterusia magnifica* (Butler); common looper, *Hyposidra* sp and termites are economically important (Rahman *et al*., 2005).

The composition of various planting materials and management strategies in tea gardens play a very crucial role in the infestation of a particular pest. The tea pests also show preference to some of the clones/varieties compared to others due to their wide genetic variability. Thus, different clones/varieties differ in their susceptibility to infestation by various pests.

It has been found that chemical control measures are effective in controlling pests in tea, but the per hectare consumptions of pesticides is excessively high and equally expensive. Injudicious use of long persistent insecticides/ acaricides has harmful effects such as residue problem, pest resurgence and development of resistance, and become a major concern to the tea industry (Chakravartee and Hazarika, 1995)

Spiders are a diverse arachnid order. According to the World Spider Catalogue (2016), 45,945 species of spiders belonging to 3982 genera under 114 families are known from the world and 1442 species of spiders belonging to 361 genera in 59 families are known from India. Spider families are recognized under two suborders - (i) Mesothelae - includes only family - Liphistiidae and Opisthothelae includes two infra orders - (a) Mygalomorphae and (b) Araneomorphae spider (Platnick, 1995). Spider maintains the ecological structure of a habitat as a top predator of many insects and arthropods. They can kill a large number of insects per unit time and hence of great importance in reducing and even in preventing outbreaks of insect pests in agriculture (Sunderland *et al.*, 1986). Spiders can lower insect densities, as well as stabilize populations, by virtue of their top-down effects, prey selection, polyphagy, functional responses, numerical responses, and obligate predatory feeding strategies. In addition to killing pest by direct attack, they also cause pest mortality by dislodging them from the plants or trapping them in the webs (Landis *et al*., 2000). Spider may kill as many as fifty times the number of prey it consumes (Riechert and Lockley, 1984). Therefore, it is assumed to have a significant role in tea plantation.

In Assam, the Tocklai Tea Research Institute released clones are widely grown on large and small-scale plantation. Since the behaviour and physiology of natural enemies are generally influenced by both the plant and the phytophagous host, the patterns of plant and herbivore population on different clones/varieties would lead to the understanding of tritrophic interaction in tea plantation.

In the past 10 years, new insecticide chemistry have been introduced that provide a diversity of novel mode of action and routes of activity for effective pest management (Gulya, 2014). However, in view of the undesirable effect due to excessive dependence on chemicals, recent advances in research are directed towards increased interest in alternate control agents along with safer and effective insecticides which are relatively safe to natural enemies and environment. Thus, spiders being identified as an effective component of natural enemy complex in tea plantation, their study and encouragement in particular tea ecosystem may lead to development of a management plan that would limit pesticide usage and increase economic return. Hence, attempt has been made to study spiders in tea. The outcome of the present study would also generate the baseline data for the researchers working on tea entomology.

The main objectives of the present study are:

- ❖ To record the diversity of spiders in tea
- ❖ To study the effect of tea cultivars/clones on tea spider communities
- ❖ To determine the effects of commonly used pesticides on spider communities

CHAPTER II
REVIEW OF LITERATURE

The studies on 'Diversity of spiders in tea' and target pest management has been reviewed and discussed in this chapter.

2.1 Spider diversity

Spiders are one of the most diverse groups of animals, which constitute the seventh largest order. The pioneering works in spider taxonomy around the globe were mainly done by Latreille (1804), Leach (1815), Koch (1846), Simon (1864) and Cambridge (1885).

In India, pioneering work on the taxonomy of Indian spiders was done by European Arachnologists before which, practically little was known about them. The earliest contributions to Arachnology were made by Stoliczka (1869),Cambridge (1898) and Karsch (1873) who reported many interesting accounts on the spiders of India, Sri Lanka and Minicoy islands. Thereafter, systematic studies on spiders developed rapidly with increasing knowledge. Beginning in 1960, Tikader's works occupied a prominent portion of Arachnology in India. He described 1,066 species belonging to more than 43 families, distributed throughout the country including Darjeeling, Ladakh, Madhya Pradesh, Andaman and Nicobar Islands, Sikkim and Nepal (Tikader, 1987) and these works are good field manuals for both professionals and other workers.

Studies on spiders of agricultural field have been published across the globe (Hibbert and Buddle, 2008; Mukhtar, 2012) and most of the works on the spiders in agricultural fields are confined to spider diversity, impact of disturbing factors and predatory role of spiders in agricultural fields (Oberg, 2007). In India, extensive studies relating to agro-ecosystem have been done by different authors (Gupta *et al.,* 1986, Sudhikumar *et al.* 2005; Jayakumar and Sankari 2010; Jeyaparvathi *et al.*, 2013; Keswai and Vankhede 2014).

The spider diversity in coffee plantation with organic and conventional management practices was studied by Randon *et al.* (2006) and they reported 2261 individuals among which 992 from the organic management site, 485 from the control site and 784 from the conventional management site. The collected spiders represented 20 families, 56 genera and 98 species and conventional management site recorded the highest species richness, higher spider diversity and highest value of cody diversity index both in dry and rainy season.

In 1997, Mason *et al.* studied the patterns of spider abundance during an outbreak of Western Spurce budworm (Lepidoptera; Tortricidae) and they reported 47.30 per cent of web spinner and 52.70 per cent of hunting spiders. The Saltacid species *Pelegrina aeneola* was the dominant predator of western Spurce budworm.

The distribution and diversity patterns of ground dwelling spiders were studied in Mexico by Bizeut- Flores *et al.* 2015 and they found that the families Gnaphosidae, Lycosidae and Saltacidae were most abundant with 29 families and 144 morphospecies. The most common species were *Gnaphosa* sp and *Gnaphosa hirsutipes.* The rarefied richness was highest at dense vegetation and high humidity site. Dominance was high, and richness was low in sparsely vegetated site. The wandering hunters were dominant in all sites, but the spider diversity was higher in sites with high plant complexity.

The information regarding the diversity and distribution of spider species from Assam, India is scarce. A few earlier works on the distribution and diversity of spiders in rice field ecosystem has been done from Barak Valley (Pathak and Saha, 1999). Ahmed *et al.* 2015 also studied the orb web spiders fauna of agroecosystem of Sonitpur district, Assam and categorised them under family Araneidae, Nephilidae, Tetragnathidae and uloboridae.

2.2 Role of spider in biological control

Riechert and Lockley (1984) brought attention to spider as potential agents of biological pest control. Spiders exhibit the ability to both lower and stabilize pest population making them excellent biological pest management candidates (Sunderland, 1999).

Studies from Japan, India, China, Taiwan, Korea, Thailand, and the Philippines provided evidence that spiders, because of their high population densities in rice fields have a damping influence on the populations of insect pests (IRRI Annual report 1973). A diverse group of spiders might be effective at biological control because they differ in hunting strategies, habitat preferences and active periods. Predation by spider was density dependent which was affected by two characteristics of predator i.e. feeding and hunting behaviour (the functional response) and densities (the numerical response). In functional response the rate of consumption of food increased or decreased in response to an increased or decreased food supply. In numerical response spiders move from decreasing prey density to one that are offering higher densities. If the prey population increased, they reproduced more in numbers to kill more number of preys. The extent of prey population controlled by spider was limited due to disruptive effects of the application of insecticides and the annual agronomic practices (Dondale and Redner 1978).

Encouraging spiders within the IPM programme for the control of insect pests of tea incited Hazarika *et al.* (2001) to remark the necessity of generating baseline data on the predators and parasites mainly the spider.

2.3 Distribution of spiders in tea gardens

Takashige (1978) reported 124 spider species belonging to 15 families from Japanese tea gardens when he studied spider fauna in tea field.

Zhang (1993) conducted survey on spiders in China and identified a few species of salticids and liocranids as predators of leaf hoppers and marked *Evancha albaria*, *Jotus minutes* and *Telamonia bifurcilinea* as dominant salticids and *Clubiona comgata, C. japonica* as dominant clubionids in tea plantation.

Huong (1999) experienced small black spider, a potential biocontrol agent of tea pests and accordingly recommended conservation of such spiders.

Yinfang *et al.* (2000) conclusively stated that most spiders in Chinese tea gardens belong to families araneidae, linyphiidae, agelenidae, tiidiidae, salticidae, tetragnathidae, clubionidae etc and around 290 species of spiders belonging to 28 families were found in chinese tea garden.

Qingmei *et al.* (2013) investigated the spider resources in tea plantations in Enshi region, China and identified 51 species of spiders belonging to 22 families.

Hazarika and Chakraborty (1998) recorded 28 species of spiders from various tea gardens of Jorhat belonging to eight families.

Roy *et al.* (2009) surveyed spiders in the Tea Ecosystem of Dooars, West Bengal and reported the existence of 31 typical Orb-weaving species belonging to 11 genera and the spider species *Cyrophora exanthematica* reported for the first time in India.

Roy *et al*. (2010) surveyed orb-weaving spiders in tea plantations in Assam and found different araneid species belonging to 15 genera along with new record of *Tukaraneus patulisus* after the report of Barrion and Listinger 1995. They also compared the species richness with the spiders of tea ecosystem of Dooars and Assam and found that richness was more in Dooras areas than Assam.

Saha *et al.* (2016) studied the spider species assemblage from both conventional and organic tea ecosystem of Darjeeling, West Bengal and documented 85 species under 52 genera distributed over 18 families. They further grouped the decreasing order of the groups as Orb weavers (48.24%) > Ambushers (22.35%) > Ground dwellers (11.76%) ≥ Stalkers (11.76%) > Foliage hunters (9.41%) > Sheet web weavers (2.35%) > Space web builders (1.18%), araneids and salticids being the dominant groups.

2.4 Pest complex in tea

The pest and disease of tea plant was seriously dealt with as early as late 19thcentury (Watt and Mann, 1903) and due to the influence of climate, altitude, nature of cultivation and age of plantation each geographic region may have its own distinctive pest complex (Muraleedharan, 1992). In India only 300 species of insects belonging mainly to the orders Lepidoptera, Hemiptera and Coleoptera and mites (Acari) were recorded as tea pests. Among these only a few were economically important (Rahman *et al.*, 2005).

2.4.1 Red Spider Mite

Mites are the most serious and persistent pests of tea in almost all tea producing countries (Hazarika *et al.*, 2009).The mites species were distributed in almost all tea-growing countries and its seasonal occurrences on tea plants were reported from various plantations of India (Radhakrishnan., 2004). Among twelve species of mites recorded on tea, *Oligonychus coffeae* Nietner is the major one in north east India which has beenestimated 6-20 per cent yield loss of tea crop in certain parts of north-east India (Awasthy and Venkatakrishnan, 1977). RSM normally infests the upper surface of mature tea leaves imparting them a reddish bronze colour and impairing their photosynthetic capacity leading to their nutritional deficiency and shedding (Das *et al.*, 2017).

2.4.2 Tea mosquito bug

The incidence of *H. theivora* Waterhouse, the tea mosquito bug (TMB) pest is found almost throughout the year mostly severe during the months of May-September. Both, nymphs and adults of the TMB suck the sap from tender leaves, buds and young shoots, which results in heavy crop losses and nymphs often cause heavier damage than adults because the nymphs move less than the adults. It has been estimated that they could result 25 to 60 per cent damage to its pluckable shoots in different tea growing areas of Assam (Deka *et al.*, 2001).

2.4.3 Tea Looper

Different species of looper are predominant in different tea growing regions.Das (1965) reported occurrence of *Biston bengaliaria* Guen, *Boarmia selenaria* Hbn, *B. Acaciaria* Boisd, *Medasina strixaria* Guen, *Erebomorpha fulgurita*

Wlk, Abraxas *sylvata* Scop. and *Euschema mililtaris* L. on tea. A few more loopers species including *Hyposidra talaca*, *H. injixaria*, *Aseotis* and *Eetropis* species has alsobeen reported (Chutia *et al*., 2012). Tea looper caterpillar, *Buzura suppressaria* are considered to be one of the major defoliators from Darjeeling area of West Bengal causing magnificent losses to the tea crop. The young caterpillar usually make holes along the margin of the leaf by nibbling, but the late instars, feed the whole tea causing maximum damage during pre-monsoon period (Gope, 1991).

2.4.4 Bunch caterpillar

It is a common and serious pest causing considerable loss to tea cultivation in North-East India. The young caterpillars of bunch caterpillar (*Andraca bipunctala* walker) are found in congregation on the lower surface of leaves and from third instar stage they form clusters on the branchduring day time and feed during night. In extreme cases, isolated bushes may be completely stripped off of the leaves During tea leaf consumption, they were also found to destroy tea leaves by cutting petiole parts, half of leaves, a portion of leaves, a succulent shoot part and sometimes made several fragments of leaves which dropped down from the tea shoots (Gope, 1991).

2.4.5 Termites

Two species of termites *viz*., *Microtermes* sp. and *Odontotermes* sp. are observed both in tropical and subtropical locations andare of importance as pests of tea in India. The incidence of termites *viz*., *Odontotermes assamensis* and *Microcerotermes bessoni* have been also reported from tea plantations of Assam (Rahman *et al*., 2005) which cause serious damage to tea plantations especially during the dry season (*i.e.* September-March) (Choudhury *et al.*, 2005) and accounts near about 22.56 per cent of crop loss (Anonymous, 2007-08).

2.5 Morphometric and biochemical attributes of different varieties to insect pests

Saito (1985) screened thirty TV clones against *O. coffeae* and were grouped into moderately resistant and susceptible owing to the presence of more depressions on the upper surface and concluded that depressions may provide shelter and protection from predators because the mite constructs a woven roof over leaf depressions for feeding and resting.

Sachan and Sachan (1991) conducted an experiment to know the relation of some biochemical characters of mustard to susceptibility to *Lipaphis erysimi* (Kalt.) and reported that significantly higher phenolic contents were observed in resistant varieties followed by moderately resistant varieties and low in susceptible aphid population and phenol content.

Zhu (1992) reported that tea varieties with the character of late sprouting were resistant to tea green leafhopper *Empoasca vitis* (Göthe) and those with leaves curled downward and long distances between buds were susceptible. He concluded that the thicknesses of palisade tissue and thick horny cells were key factors for the resistance to the leafhoppers.

Sannigrahi and Mukhopadhyay (1993) studied distribution and incidence of some of the tea pests (like aphids, thrips and red spiders) on different tea cultivars (i.e., TV1, TV 18, TV 25 and TV 26) in their respective habitat and the incidence was correlated with weather factors like maximum and minimum temperature, humidity and rainfall and observed significant correlation between pest population and weather factors.

Ramdhari *et al.* (1995) analysed biochemical traits of some mustard cultivars at flower bud initiation stage against *L. erysimi* (Kalt.). It was observed that the high level of total and reducing sugars and protein was positively correlated with average aphid population, while phenol was negatively correlated with average aphid population.

Chen *et al.* (1996) reported that chinese varieties were preferred by tetranychids such as *T. kanzawai* and *O. coffeae* and tenuipalpids such as *B. phoenicis* because of their higher rhodoxanthin and l-arginine content and lower tannin content; whereas, Assam jats, which are attacked by eriophyids such as *A. theae*, have less pubescence, stronger cuticularization on the under surface of leaf, lower stomatal density, and low sugar, but were rich in total antioxidant activity, theamine, gibberellic acid and caffeine.

Kalita *et al.* (1999) studied the feeding response of second and fourth instar nymphs of *H. theivora* to different tea genotypes *viz*. TV-1, TV-6, TV-9, TV-18, TV-20, TV-23, TV-25, TV-28, TS-491 and TS-520 and found that in both choice or no-choice conditions both instars preferred TV-1, TS-520, TS-491 and TV-9 while least preferred genotypes were TV-6 and TV-18.

Kalita *et al.* (2003) studied morphological resistance of certain genotypes of tea *viz*. TV-1, TV-6, TV-9, TV-18, TV-20, TV-23, TV-25, TV-28, TS-491 and TS-20 to tea mosquito bug in Assam and observed that out of ten genotypes studied, TV-6 and TV-18 showed resistance to pest. They further suggested that the thickness of cuticle of upper leaf surface had significant association with certain life parameters of pest.

Sharma (2004) studied the effect of physical and biochemical parameters on the incidence of aphid, *M. persicae* infesting cumin (*Cuminum cyminum* L) and found that variety RZ-19 had more height, primary branches per plant, higher amount of total phenols and lower amount of free amino acids and proved least susceptible for the aphid infestation. Whereas, entry UC-198 proved to be most susceptible, which had these parameters contrary to variety RZ-19.

Wang *et al.* (2006) studied the correlation between leaf structure or biochemical components in new tea shoots and their resistance to the black spiny whitefly (*A. spiniferus* Quaint) and found that the fecundity of the whitefly was positively correlated with stoma density and thickness of spongy tea tissue and negatively correlated with thickness of palisade tissue and some biochemical compositions in new shoots.

Naqvi *et al*. (2008) correlated four leaf characters of different varieties of brinjal, *viz*., leaf area, leaf thickness, trichome density and chlorophyll content with leafhopper and whitefly population. The data indicated that leaf area, leaf thickness and chlorophyll content exerted no effect on leafhopper population, while trichome density had negative correlation. The trichome density in different varieties ranged between 550.8 to 1068.5/cm^2. The leaf area had positive significant effect on whitefly population, whereas leaf thickness, trichome density and chlorophyll content had non-significant effect.

Roy *et al.* (2009) screened 28 tea cultivars common in North East India for susceptibility to *H. theivora* attack and found that tea cultivars TV1, TV12, TV23, TS653 and TV16 were the most susceptible, where as clones TV4, TV11, TV28, TV29 and ST449 were less susceptible, and the clones TV2, TV9, TV17, TV18, TV20, TV25, TV26, TV30, Teenali 17, TS652, TS491, P126, TV7, TV10, TV14, TV19, TV22 and TS426 were marked as moderately susceptible. No clone was found resistant to infestation by *H. theivora.*

Singh and Jat (2011) screened fifteen genotypes of barley for their comparative resistance to aphid, *R. maidis.* Out of them, none was found completely free from aphid attack. Among the morphological characters, the plant height, tillers per meter row and days to maturity had negative correlation, whereas, days to earing had positive correlation with aphid population. In biochemical characters, total phenols had negative correlation, whereas, total soluble sugars and total free amino acids had positive correlation with aphid population.

Yin Ye *et al.* (2013) reported that substantial morphometric and genetic variability exists among tea cultivars, to which pests react differentially. Such diversity has facilitated host plant resistance selection and development.

Shah *et al.* (2014) studied the biochemical defence mechanism of tea plants against *H. theivora* and found that all the varieties *viz.,* TV1, TV23, S3A3, Tinali have varying levels of infectivity and concluded that biochemical changes in host might be the outcome of oxidative stress and biochemical defence mechanism of *Helopeltis* infested tea leave.

Dutta (2015) studied certain morphological attributes of tea leaf varieties TV1, TV6 and TV10 towards red spider mite and concluded TV1 to be highly palatable by the mite in comparison to TV6 and TV10.

2.6 Relationship between spiders and pest population

Singh *et al.* (2000) studied the correlation between population of spiders and insect pest population and concluded that usually when the population of pest increases, the population of spiders also increases.

Yinfang *et al*. (2005) also reported that the population of pests in tea garden influences the population of spiders and as the population of pests increased, the population of spiders also increased. They also classified two main groups of spiders: one was netting spiders (Linyphiidae, Agelenidae, Araneidae and Tetragnathidae) and the other was hunting-spiders (Oxyopidae, Salticidae, Lycosidae and Pisauridae) that prey on harmful pests in tea gardens like *Burzura suppressaria, Empoasca formosana, Caloptilia theivora, Polvphaotaronemus latus*, *Acaphylla theae, Calacarus carinatus* and *Etctropis oblique.*

2.7 Pest management in tea

Pest control in tea is mainly achieved by the use of synthetic pesticides, provided their application is synchronized with most vulnerable stage of the pest. Tea pest control incorporates almost all groups of insecticides, including those with new chemistries such as neonicotinoids, spinosyns, avermectins, pyrazoles, and oxadizine (Hazarika *et al.,* 2009).

Muraleedharan and Selvasundran (1996) conducted field experiments in south India and assessed crop losses in tea caused by *Acaphylla theae* (Eriophyidae: Acarina), *Scirtothrips bispinosus* (Thripidae: Thysanoptera), *Heloptelis theivora* (Miridae: Hemiptera) and *Ewallacea fornicatus* (Scolytidae: Coleoptera) to the extent of 5.55, 9.83, 16.0 and 9.0 per cent, respectively. They used neem-based formulations in combination with chemical pesticides to manage mites and insect pests with cost benefit ratio of 1:2.93 (for *H. theivora*), 1:1:79 (*A. theae*), 1:1.69 (*S. bispinosus*) and 1:1.18 (*E. fornicatus*).

Ramesh and Selvasundram (2001) studied the effect of *Beauveria bassiana* on natural enemies of tea pests in Tamil Nadu by applying spore suspension of different concentration *viz.* 10^5, 10^6, 10^7 and 10^8 spores/ml to various natural enemies (*Jauravia pubescens, Menochilus sexmaculatus, Betayrphus serarius, Ischiodon scutellarins* and *Paragus tibialis*). They recorded no adverse effect of *B. bassiana* on these natural enemies after 3 weeks of treatment.

Sharma and Kashyap (2002) studied the impact of pesticidal spray on seasonal availability of predators and parasitoids in the tea ecosystem in Himachal Pradesh by applying insecticides and biopesticides on tea pests and their natural enemies. They found deltamethrin at 0.005 per cent, cypermethrin (0.01%) and ethion (0.1%) to be highly toxic to larva and adults of syrphids and *Coccinella septempunctata* whereas, Neemark (*Azadirachta indica*) at 0.3 per cent, Achook (0.3%) and *Bacillus thuriengiensis* formulation (Dipel 8L at 0.3%) were observed quite safe to these natural enemies. According to them endosulfan was relatively safe to syrphids but highly toxic to *C. septempenctata.*

Ramarethinam *et al.* (2004) reported neem as an effective biocontrol agent for tea pests in Tamil Nadu due to its action of repellency, feeding and oviposition deterrency, growth regulation and sterilant effect on pests.

Subaharan and Regupathy (2006) evaluated the neem formulations *viz.*, TNAU neem 0.03 and Neem gold 0.15 EC for bio- efficacy against purple mite *Calacarus carinatus* under laboratory and field conditions. They observed that in laboratory conditions both of the neem formulations exhibited 66-68 per cent mortality in 72 hours after treatment whereas, in field trials the population of mite was reduced up to 70 per cent after 7 days of application.

Kalita *et al.* (2007) compared the efficacy of spiromesifen (Oberon 240SC) against the red spider mite, *O. coffeae* on tea in comparison to the conventional acaricides and found that treatment with Oberon 240SC @400 ml/ha resulted 99.23% reduction of mites on tea, which was found to be superior to sulphur 80WP (65.50%), dicofol 18.5EC (58.53%), ethion 50EC (49.45%) and endosulfan 35EC (26.15%), respectively.

Sarmah *et al.* (2009) conducted field efficacy of thiomethoxam 25 WG and botanical pesticides against tea mosquito bug and found that higher doses of thiomethoxam (25.0, 37.5 and 50 g. a.i./ha) were superior in reducing the infestation of *H. theivora* over its lowest dose (12.5 g. a.i./ha), deltamethrin, cypermethrin, profenofos,endosulfan and azadirachtin 5% after 7 and 14 days of first and second spray.

Sara *et al*. (2013) conducted an experiment to test the bioefficacy of newer insecticides against the sucking pests of chilli and safety of these insecticides to natural enemy population in chilli ecosystem and concluded that spiromesifen 45 SC and propargite 57 EC at 570 g a.i. ha^{-1} were found to be effective in reducing chilli mite population whereas acetamiprid 20 SP at 20 g a.i. ha^{-1} along with spiromesifen were found to be effective against chilli thrips.

Smitha and Pushpalatha (2014) tested efficacy of different insecticides against tea mosquito bug, *H. antonii* Signoret (Hemiptera: Miridae) on cashew and found that amongst the insecticides thiamethoxam, λ-cyhalothrin-neem oil and λ-cyhalothrin were most effective in reducing the damage by tea mosquito bug.

2.8 Effects of pesticides on spiders

Nanda *et al.* (1996) tested the bioefficacy of neem derivatives against the predatory spiders, wolf spiders (*L. pseudoannulata*), jumping spider (*Phidippus* sp), lynx spider (*Oxyopes* sp.), dwarf spider (*Callitrichia formosana*), orb spider (*Argiope* sp.), damselflies (*Agriocnemis* sp.) and mirid bug (*C. lividipennis*) and found that the neem kernel extract and oil were relatively safer than the conventional insecticides to *Lycosa pseudoannulata*, *Phidippus* sp. and *C. lividipennis* in field conditions.

Ganesh kumar and Velusamy (1996) from Tamil Nadu, Coimbatore found that accephate, BPMC and ethofenprox were safe to *L. pseudoannulata, Tetragnatha javana* and *Oxyopes javanus*, whereas carbaryl was found more toxic to *T. javana* and *O. javanus.*

Markandeya and Divakar (1999) reportedthat spiders such as the wolf spider *P. pseudoannulata* are highly tolerant of botanical insecticides such as Neem-based chemicals and are generally more tolerant to organophosphates and carbamates than of pyrethroids, organochlorines and various acaricides.

Tanka *et al.* (2000) from China reported that deltamethrin was the most toxic to the spiders followed by ethofenprox in the paddy fields in Japan. They also found that spiders were susceptible to synthetic pyrethroids.

Giribabu (2002) revealed the toxicity of insecticides in the order of chlorpyriphos >triazophos>monocrotophos> SIL- 942 >betacyfluthrin> abamectin > neem to predatory spiders of watermelon.

Han (2005) reported 14 species of eight families of spiders in tea systems treated with 10-15 pesticide sprays, 16 species of eight families in plantations treated seven or eight spray times and 29 species of 12 families found in an organic tea garden. Among 295 spider species belonging to 26 families representatives of three families, Araneidae, Salticidae and Theridiidae were dominant, accounting for 23 per cent, 13 per cent and 9 per cent of the total.

Solangi and Lohar (2007) conducted a field study to determine the efficacy of different insecticides against different insect pests and their predators on okra crop. The results showed that in controlling jassid, all the insecticides were significantly ($p<0.01$) effective but Confidor proved to be more effective as compared to Sundaphos, Polo and Mospilan, where jassid mean population was 1.20 plant^{-1} as compared to pre-treatment population of 7.78 plant^{-1}, thrips 1.16 plant^{-1} as compared to pre-treatment population of 6.52 plant^{-1}, whitefly 1.18 plant^{-1} as compared to pre-treatment population of 8.31 plant^{-1}, mites controlled to the level of 2.42 plant^{-1} as compared 8.56 plant^{-1} (control). All the insecticides were almost equal in effects on the spiders and the mean spider population was 0.31, 0.30, 0.31, 0.38 plant^{-1} in plots sprayed with Confidor, Sundaphos, Polo and Mospilan, respectively and similar was the situation with population of ants where mean population was 0.33, 0.38, 0.35 and 0.35 plant^{-1} in plots sprayed with Confidor, Sundaphos, Polo and Mospilan, respectively. The insecticides sprayed all were harmful for the beetles and the mean population of beetles was 0.03, 0.06, 0.03 and 0.07 plant^{-1} in plots sprayed with Confidor, Sundaphos, Polo and Mospilan, respectively.

Tiwari *et al.* (2011) studied the effect of insecticides, bio-pesticides and botanicals on the population of natural enemies in brinjal ecosystem and found spraying of cypermethrin10 EC @ 0.016% as relatively most toxic having higher mortality of coccinellids (57.3, 58.1%); braconid wasp (54.6, 61.7%) and predatory spiders (64.58, 53.09%). However, the toxic effect of the insecticides and bio-pesticides decreased after 7 days of treatment application.

Sherawat *et at.* (2015) evaluated the toxicity of Confidor and Buctril-M on two dominant spiders of wheat ecosystem *i.e*., *Lycosa terrestris* and *Oxyopes javanus* and found that Buctril-M safer compared to Confidor for both species. It was future observed that mortality of both spider species declined with the increase of post sprayed time for both pesticides.

Muddasir *et al.* (2015) compared the effects of different biological insecticides extracts of *Azadirachta indica* and *Eucalyptus globulus,* and Spinosad on spider's population in a rice field and found that spider's population showed significantly higher resistance to botanicalthan microbial insecticide.

CHAPTER III
MATERIALS AND METHODS

The present investigation was conducted to assess the ‘Diversity of spiders in tea’. The details of materials used, procedures and techniques adopted for carrying out the study are presented in this chapter.

3.1Location, climate and weather condition

The investigations were carried out at Jorhat district, Assam during 2016-17. Jorhat of Assam is located at 26.75°N and 94.22°E and has an average elevation of 116 m above mean sea level. The district comes under semi-arid region with summer temperature 25°-35°C and winter temperature 22°-10°C. The vegetation structure of Jorhat comprises of wide types of agricultural land to forest areas. The district is spreading over 2851sq. km. with mean annual rainfall of 2029 mm.

3.2 Meteorological data

Meteorological data regarding minimum and maximum temperature, relative humidity (RH) and rainfall were obtained from Department of Agro meteorology, Assam Agricultural University- Jorhat 13, Assam, India.

3.3 Sampling and identification

Survey was conducted during May, 2016 to April, 2017 in different sections of six selected unpruned tea gardens with different management practices *viz*., conventional, organic and small grower gardens at monthly interval (Table 3.1 and Plate 1). The conventional type considered in the present study was gardens with proper recommended cultivation practices i.e. Dholi T.E. and AAU experimental Garden. Deha T.E. and Bordoloi T.E. were organically managed gardens where chemical pesticides were restricted, while Saikia T.E. and Gogoi T.E were small grower gardens with occasional pesticide usage and less vegetation. Collection of spiders was made mainly by hand picking or holding a tube close to the web, foliage,

trunk and branch of tea and grounds from an area of 900 meter square. The collected specimens were killed and preserved as per recommendations of Tikader (1987) and were preserved in 70% alcohol in glass tubes and labelled. Necessary field data for each of the samples were also noted in the field notebook. Different morphological characters present in the body of the collected specimens were studied under Stemi 2000-C and MS 24 microscope in the laboratory of Department of Entomology AAU, Jorhat. Measurements of the body parts were also taken. The spiders were identified with the help of available keys and literature *viz*., Handbook of spiders (1987) Spiders of India (2009) and Spider complex of tea ecosystem in Assam (1998). All sample spiders were not possible to identify because of large numbers of Juveniles. For identification of specimens, male padipalp and female epigyne was considered. For genitalia dissection the abdomen was cut and transferred to a test tube containing 4-5 ml of 10 per cent KOH which was placed in a beaker containing 100 ml of water. After that the genitelia containing every test tube was labelled immediately by giving a number and same number was also given to specimen from which genitalia was detached. Then the beaker was placed on an asbestos wire net and then the set was placed upon a tripod. A spirit lamp containing methylated spirit was put under the tripod and the lamp was light. After that the test tube containing the genitalia with KOH solution was put in the water bath. Depending upon the sclerotization the boiling time was 10-20 minutes. Then the soft connective tissues were removed with care until the abdomen become sufficiently transparent to see the internal structure. Further the abdomen and genitalia were examined under Stemi 2000-C and MS 24 microscope (x10) with suitable magnification. After observation drawings were made with the help of image analyser Leica M 165C microscope using ordinary pencil.Lastly,the specimens were sent to National Bureau of Agricultural important Insects (NBAIR), Bangalore for confirmation.

3.4Diversity Indices

3.4.1 Species diversity

The diversity was calculated by using "Shannon Wiener Index (1949)", which is defined as

$$H' (S) = -\Sigma pi \ln pi$$

Where, Pi = ni/N

ni = Number of individual of a species at a time i

N = Size of whole community

Σ = Number of species/ Number of seasons

S = Total number of species

3.4.2 Species richness

The Richness indices was calculated by using "Margalef index (1958)", which is defined as-

$$D = (S-1)/\ln (N)$$

Where, S = Number of species

N = Total number of individual of all the species

3.4.3 Species evenness

For calculating the evenness of species, "Pielou's Evenness Index (1966)" was used, which is defined as -

$$e = H / \text{In } S$$

Where, H = Shannon – Wiener diversity index

S = Total number of species in the sample

3.4.3 Correlation study with weather factors

The meteorological data and incidence of spiders obtained during the study period were subjected to simple correlation analysis using SPSS software20 version.

3.5 Distribution pattern of spiders

To determine the different parameters related to distribution pattern of spiders, the methods outlined by Atwal and Bains (1974) and Southwood (1978) were followed.

3.5.1 Variance to mean ratio

Variance to mean ratio ($S^2/\bar{x}$) is the simplest approach for determination of distribution pattern. A variance to mean ratio greater than unity ($S^2/\bar{x} >1$) indicates contagious distribution while a smaller ratio ($S^2/\bar{x} <1$) indicates a regular distribution. For random distribution, the variance equals the mean, hence the ratio is equal to unity ($S^2/\bar{x}=1$).

3.5.2 Lloyds index of patchiness ($x^*/\bar{x}$)

Lloyd (1967) expressed the patchiness of distribution as the ratio of the mean crowding (x^*) to mean density ($\bar{x}$) i.e.

$$\text{Patchiness Index} = \frac{x^*}{\bar{x}}$$

If the value of this index is equal to unity, then it indicates random distribution and when the value of index is greater than or smaller than unity, then it signifies contagious and regular distribution, respectively.

3.6 Clonal preference of insect pests of Tea

3.6.1 Clones selected

To observe the variation in clonal preference, seven TV clones were selected inExperimental Plot for Plantation Crop, AAU-Jorhat. The experimental garden was maintained under proper recommended agronomic practices. Care was taken to avoid application of pesticides during the period. The clones screened are described below in Table 3.2.

Table 3.2 Description of different type of TV clone used during experiment

SlNo	Clone	Stock no	Type	Description
1.	TV 1	19/29/13	Assam x China	Leaves are boat shaped. The ends of the secondary veins near leaf margin almost merge with the lamina.
2.	TV 2	20/23/1	Assam type	Leaves are tapering towards the tip and base from the middle of the leaf lamina.
3.	TV 7	14/9	China type	Leaf size is small and bears a small depression at the tip of the dorsal side.
4.	TV 9	106/1	Assam type	The leaf petiole has a bent and in a branch the dorsal or ventral surface of all leaves faces downwards the same side. The leaf tip turned downward.
5.	TV 12	125/13	Assam type	The leaf is bigger in size and elliptical in shape.
6.	TV 18	107/4	Camboid hybrid	More or less of compact frame with glossy medium sized leaf. Leaves are lanceolate with pinkish petiole.
7.	TV 23	124/41/42	Cambod type	Leaves are lanceolate and light green. The wave of leaf margin of clone is deeper

3.6.2 Abundance of insect pests and spider population in different clones

The experiment was carried out in Experimental Plot for Plantation Crop, AAU-Jorhat, from May, 2016 to April 2017 (Plate 2, 3). Observations on the target pests and spider population were recorded for each clone at monthly interval. The major pests taken into consideration were *Oligonychus coffeae* Nietner (RSM), *Helopeltis theivora* Waterhouse (TMB) and *Hyposidra* sp (Looper).

3.6.2.1 Red spider mite

To determine the population of red spider mite, sample block (each comprising approximately 60 bushes) of each tea variety was selected in the said AAU Experimental Plot. Thirty leaves were randomly sampled from the block. The collected leaves were brought to the laboratory and the total number of red spider mite / leaf was counted under the microscope at 10x magnification.

3.6.2.2 Tea mosquito bug

To determine the number of tea mosquito bug population, observation on the total number of population was recorded by visual observation from 30 randomly selected bushes in the said AAU Experimental Plot.

3.6.2.3 Looper

The number of looper populations was also counted by visual observation and recorded on selected clones from 30 randomly selected tea bushes.

3.6.2.4 Spider

The presence of predatory spider population associated with all the selected tea clones were also observed by visually from 30 randomly selected tea bushes.

3.7 Morphometric and biochemical characters of different TV Clones

Sample block of each tea clone was selected in the said AAU Experimental Plot andmorphological characters such as total no of branches, leaf moisture content, trichome density and leaf area were recorded.

3.7.1 Number of branches

Variation among the clones in number of branches arising from the mother stem was recorded at the end of study period. For this side branches for ten bushes were counted at random (Ali *et al.,* 2012).

3.7.2 Trichome density

Young two leaf and a bud leaves which was preferred by Tea mosquito bugwere selected for this experiment. The leaves were cut in to 1cm square bits and boiled in water. Then few drops of dilute nitric acid and a pinch of potassium nitrate were added and continued boiling. While boiling, the epidermis came out as peels. The debris were removed with brush and observed under microscope at 10x magnification. The numbers of trichome present in a microscopic field were counted (Saikia, 1999). Count was replicated five times for each treatment and data were tabulated.

3.7.3 Leaf area

Leaf area of each clone was measuredusing a portable leaf area meter model Licor-3000C (Mahamat *et al.*, 2016). Each observation was replicated five times for each treatment.

3.7.4 Phenol content

The total phenols for healthy and infested leaves at the time of peak population were estimated following Gallic acid Equivalence method (Malik and Singh, 1980). Leaves infested by Tea mosquito bugwere selected for the study.One gm of leaves was homogenised with 10 time volume of 80% ethanol and the homogenate was centrifuged at 10,000rpm for 20min. Reagent mixture containing 1ml of the plant extract and Folin-Ciocalteau reagent was measured spectrophotometrically at 650nm for total phenol against a reagent blank. Gallic acid (1mg/ml) was used as standard for the assay. Phenol content expressed as gallc acid equivalent (mg/gm of leave tissue) was obtained from the standard curve.

3.7.5 Leaf Moisture

Leaf moisture content was determined by weighing fresh leaf and keeping those at 50°c in an incubator till a constant weight was obtained. The difference between initial and final weight gave an estimate of the moisture content (Baret and Fourty 1997). Observations were replicated five times for each treatment. The moisture percent was calculated according to the formula.

$$\text{Moisture percentage} = \frac{\text{Wt. of fresh leaves - Wt. of dry leaves}}{\text{Wt. of fresh leaves}} \times 100$$

3.7.7 Statistical analysis

Pearson correlation was used to investigate the relationship among the morphological parameters and biochemical characters in different clones with insect pests and spider population. For this statistical software SPSS 20 version was used.

3.8 Effect of pesticides on Spider population

Tea plants (TV-23 clone) from the Experimental Garden of Plantation crops, Assam Agricultural University, Jorhat, were used to study the efficacy of different pesticides on spiders. The whole experimental area was laid out in RBD with three replications, six plots along with a control plot in each replication. Individual plots measured 5m x 3m. Between each replication, 1.5m of distance was maintained. The treatment combinations compared were, foliar spray of pesticides and the control plants were sprayed with water only. Sprays were done with manually operated hydraulic knapsack sprayer. Population count for tea mosquito bug was made from 10 randomly selected bushes in each treated plot. Likewise, 10 plants were randomly selected and 30 leaf samples were collected from each plot for red spider mite count.

3.8.1 Experimental details

Location	: Experimental Garden of Plantation crops, AAU
Variety	: TV 23
Design	: Randomized Block Design

Replications :3

Treatments : 7

i. Ethion 50EC @ 0.25%

ii. Spiromesifen 240 SC (22.9 w/v) @ 0.02%

iii. Deltamethrin 2.8 EC @ 0.2%

iv. Thiomethoxam 25% WG @ 0.01%

v. Azadirachtin 5% @ 0.003%

vi. *Beauveria bassiana* @ 2%

vii. Control (Water spray)

CHAPTER IV
RESULTS AND DISCUSSION

The present study on "Diversity of spiders (Araneae) in tea" was carried out in selected tea gardens of Jorhat district during 2016-17. The findings of the study are presented and discussed below.

4.1. Occurrence and identification of predatory spiders in tea

The study area for the present work included six tea gardens *viz*. AAU Experimental garden, Dholi T.E, Deha T.E, Bordoloi T.E, Saikia T.E. and Gogoi T.E. The former two gardens were conventional type which follow recommended cultivation practices. Deha T.E. and Bordoloi T.E. were organically managed gardens while in Saikia T.E. and Gogoi T.E were small grower gardens and insecticides were irregularly applied. The results revealed a total of 2954 specimens of spiders (including juveniles and adults) collected from various tea gardens under 16 genera, 8 families and 20 species *viz.*, *Cyrtophora cicatrosa* (Stoliczka), *Nephila kuhlii* (Doleschall), *Argiope pulchella* (Thorell), *Neoscona* sp (Simon), *Cyclosa mulmeinensis* (Thorell), *Cyclosa spirifera* (Simon), *Cyclosa bifida* (simon), *Araneus mitifica* (Simon),*Oxyopes sitae* (Tikader), *Oxyopes shweta* (Tikedar), *Oxyopes* sp (Latreille), *Rhene danieli* (Tikader), *Phintella vittata* (Koch), *Telamonia dimidiata* (Simon), *Tetragnatha* sp (Latreille), *Leucauge decorata* (Blackwell), *Heteropoda ventoria (*Linnaeus), *Castianeira furva* (Sankaran, Malamel, Joseph and Sebastian), *Xysticus* sp (Koch) and *Perdosa peaudoannulata* (Boesenberg et Strand) (Table 4.1). Among these species *Castianeira furva* has been recorded for the first time from Assam.

The present study found 20 species of spiders belonging to 8 families. Earlier studies revealed the occurrence of 28 species of spiders from different tea gardens of Jorhat districts of Assam, India (Hazarika and

Chakraborty 1998). Further, the study conducted by Dhali *et al.* (2010) reported 36 species under 28 genera from Gibbon Wildlife Sanctuary in Jorhat Assam. Roy *et al*. (2010) also surveyed orb-weaving spiders in tea plantations in Assam and found different araneid species belonging to 15 genera. Similarly, Saha *et al.* 2016 also studied the spider species assemblage from both conventional and organic tea ecosystem from Darjeeling, West Bengal and documented 85 species under 52 genera distributed over 18 families. These figures stand higher in comparison to the number of spiders reported inthe present study. Past studies in the world have shown that different methods tend to complement one another (Russell-Smith, 1999; Kapoor, 2006). Furthermore, the habitat characteristics and different management practices also play a major role on the distribution and richness of spider in a given area (Bhattacharya *et al.,* 2017).

4.1.1 General description of spider species collected from tea gardens of Jorhat District

The description of different spider species given in this chapter was based on observed materials only. For identification of spiders mainly the pedipalps and epigyne characters were considered (Plate 4).

Family: Araneidae

4.1.1.1 *Cyrtophora cicatrosa* (Stoliczka)

Epeira cicatrosa Stoliczka, 1869

Cyrtophora cicatrosa (Stoliczka) Chrysanthus, 1960

Material examined: 10 Females, India: Assam: Jorhat, Tea garden, 5. VII. 2016

General description: Female

Cephalothorax longer than width, narrowing in front, very broad and rounded posteriorly, with a mid longitudinal and two lateral black patches and covered with hairs (Plate 5a). Femora I and II with longitudinal black stripes, rest of the segments with numerous small black spots. Black and white patches present on

dorsal side of abdomen with two pairs of humps (Plate 5b). This spider remains hanging downwards from the apex of the inverted bowl shaped web. Measurements of different body parts of *C. cicatrosa* are given in Table 4.2.

Epigyne: Epigyne provided with a broad rim (Plate 5c, 5d).

Table 4.2 Measurement of different body parts of *C. cicatrosa*

Body parts	Measurements (mm)± Sd
Total length	6.00 ±.115
Carapace length	2.22±.042
Carapace width	2.52±.056
Abdomen length	1.84±.049
Abdomen width	2.98±.102

* Average of 10 females

Present study revealed that in case of *C. cicatrosa*, the dorsal side of abdomenwas black in colour with white patches and provided with two pairs of humps and total body length measured 6.00±.115mm. Koh (1991) also reported similar description from Singapore where *C. cicatrosa* had four abdominal tubercles. Dhali *et al.,* (2010) also reported this species from Gibbon Wildlife Sanctuary, Jorhat Assam India. However, Chrysanthus (1960) reported that the male species of *C. cicatrosa*measured 2 mm only and the pattern of its cephalothorax and abdomen closely resembles that of the female.

4.1.1.2 *Nephila kuhlii* (Doleschall)

Epeira kuhlii Doleschall, 1859

Nephila kuhlii (Doleschall) Thorell, 1887

Material examined: 10 Females, India: Assam: Jorhat, Tea garden, 2. X. 2016

General description: Female

Cephalothorax black in colour, longer than width, narrowing in front than behind portion (Plate 6a). The front legs were about twice the length of the body. The first pair of legs is considerably longer than the 3rd pair. Abdomen black in colour, long and cylindrical, clothed with hairs, slightly overlapping on carapace with

a mid longitudinal greyish yellow patch on dorsum (Plate 6b) and ventrum dark brown in colour (Plate 6c). Measurements of different body parts of *N. kuhlii* are given in Table 4.3.

Epigyne: Epigyne heavily sclerotised and ducts of spermatheca originate posteriorly (Plate 6d, 6e).

Table 4.3 Measurement of different body parts of *N. kuhlii*

Body parts	*Measurements (mm)± Sd
Total length	30.20 ± .390
Carapace length	10.00 ± .056
Carapace width	7.60 ± .076
Abdomen length	20.00 ± .059
Abdomen width	9.04 ± .116

* Average of 10 females

From the present observations it was found that the body measurements for *N. kuhlii* was 30.20±.390 mm in total length, carapace 10.00±.056 mm long,7.60±.076 mm width and length and width of abdomen was 20.00±.059 mm and 9.04±.116 mm respectively. Similar findings were also reported by Arunkumar and Jayaprakash (2014) when they studied the morphometric of female *N. kuhlii*. They observed the mean length and width of carapace 12.09±0.05 mm, 8.23±0.05 mm and abdomen 35.24±2.90 mm, 10.80±0.06 mm respectively. They also reported that males were almost ten times smaller than females with carapace 2.14±0.09 mm long and 1.59±0.06 mm width. The mean length and width of abdomen was 3.80±0.06 and 1.51±0.06 mm respectively.

4.1.1.3 *Argiope pulchella* (Thorell)

Argiope pulchella Thorell, 1881

Material examined: 10 Female, India: Assam: Jorhat, Tea garden, 22. VIII. 2016.

General description: Female

Cephalothorax was longer and narrow in front, covered with thick white pubescence. Abdomen pentagonal, elongated, overlapping on the cephalothorax. Legs were long and strong with spines. Dorsal side of abdomen brownish in colour with brown transverse stripes but not forming any network in the posterior half (Plate 7a). Ventral side of abdomen was brownish and a pair of white longitudinal patches was present on it (Plate 7b). They build webs provided with two stabiliienta crossing each other (Plate 7c). Measurements of different body parts of *A. pulchella* are shown in Table 4.4.

Epigyne: Epigyne raised with two openings (Plate 7d)

Table 4.4Measurements of different body parts of *A. pulchella*

Body parts	* Measurements (mm)± Sd
Total length	14.32 ± .319
Carapace length	4.54 ± .025
Carapace width	4.38 ± .012
Abdomen length	9.38 ± .401
Abdomen width	8.76 ± .012

* Average of 10 females

These findings were in conformity with the findings of Bonnet (1955) who described the similar type of morphological characters of *A. pulchella*. They also reported that the species builds proportionately large coarse-meshed webs with stabilimenta. Biswas and Raychaudhuri (2015) also reported similar characteristics for *A. pulchella* from Bangladesh with total body length 20.10mm, carapace 8.30mm long, 6.20mm width and abdomen 11.10mm long and 8.00mm width.

4.1.1.4*Cyclosa mulmeinensis* (Thorell)

Epeira mulmeinensis Thorell, 1887

Cyclosa mulmeinensis (Thorell) Simon, 1909

Material examined: 10 Female, India: Assam: Jorhat, Tea garden, 5. IX. 2016.

General description: Female

Anterior portion of cephalothorax was narrow and the cephalicregion distinctly separated from thoracic region by an oblique groove. Ocular was quadrangle trapezium like and much narrower behind than in front. The abdomen was

with small and rounded protuberances (Plate 8a). Measurements of different body parts of *C. mulmeinensis* are presentedin Table 4.5.

Epigyne: Epigyne with thin flat scape present on it (Plate 8b, 8c).

Table 4.5 Measurements of different body parts of *C. mulmeinensis*

Body parts	* Measurements (mm) ± Sd
Total length	5.75 ± .001
Carapace length	3.12 ± .014
Carapace width	1.90 ± .016
Abdomen length	3.84 ± .019
Abdomen width	2.20 ± .014

* Average of 10 females

It was evident from the current findings that the total length of *C. mulmeinensis* was 5.75±001 mm. Tanikawa (1992) also described the species from Japanreported that total body length ranges from 3.42-5.00 mm. The present findings was similar to the findings of Hazarika and Chakraborty (1998) who observed and reported the species from Assam that measured about 4.25 mm in length with small and rounded protuberances. However, the male *C. mulmeinensis* reported from Bangladeshwas observed to be 3.00 mm in length (Okuma *et al.*, 1993).

4.1.1.5 *Cyclosa spirifera* (Simon)

Cyclosa spirifera Simon, 1889.

Material examined: 10 Female, India: Assam: Jorhat, Tea garden, 5. IX. 2016.

General description: Female

Cephalothorax blackish at anterior. Cephalic region distinctly separated from thoracic region by cephalic grooves. Abdomen long, provided with one small antero-median and one large postero-median tubercle. Dorsum of abdomen decorated with longitudinal blackish, silvery patches which runs downward (Plate 9a).

Ventrally the abdomen was brownish black with silvery yellowish or white patches. Measurements of different body parts of *C. spirifera* are given in Table 4.6

Epigyne: Epigyne with prominent, wrinkle scape with small, narrow, bent tip (Plate 9b, 9c).

Table 4.6 Measurements of different body parts of *C. spirifera*

Body parts	* Measurements (mm)± Sd
Total length	7.00 ± .056
Carapace length	2.30 ± .126
Carapace width	2.18 ± .010
Abdomen length	4.65 ± .082
Abdomen width	4.14 ± .120

* Average of 10 females

In the present study, *C. spirifera* observed was 7.00 ±.056 mm in length and blackish brown in colour with longitudinal silvery band in the abdomen. The present findings were more or less similar with the findings of Tikader (1982) who described *C. spirifera* with silvery and blackish patches measuring 7.10 mm in total body length. Dixit and Ade (2017) also reported the similar patterns for that species from Maharashtra. It has been reported that the male species of *C. spirifera* was 3.79 mm in length provided with one pair of small, sub posterior lateral tubercle, posterior tubercle absent (Keswani, 2013).

4.1.1.6 *Cyclosa bifida* (Doleschall)

Epeira bifida Doleschall, 1859

Cyclosa bifida (Doleschall) Simon

Material examined: 10 Female, India: Assam: Jorhat, Tea garden, 16. X. 2016.

General description: Female

The members of *C. bifida* had brownish colour cephalothorax which was longer than width, narrowing in front, covered with hairs (Plate 10a). Cephalic region was distinctly separated from thoracic region by a cephalic groove. Legs were long and covered with spines and hairs. Abdomen elongated, looked pulled upward at

the posterior end on tubercle. (Plate 10b). Epigynum was present ventrally at the anterior portion of abdomen (Plate 10c). Measurements of different body parts of *C. spirifera* are shown in Table 4.7.

Epigyne: Epigynal scape porrect, spermathecae bean-shaped, with ends converging towards the posterior epigynal margin (Plate 10d, 10e).

Table 4.7Measurements of different body parts of *C. bifida*

Body parts	* Measurements (mm)± Sd
Total length	12.02 ± .035
Carapace length	3.88 ± .116
Carapace width	2.96 ± .091
Abdomen length	5.95 ± .086
Abdomen width	3.90 ± .126

* Average of 10 females

It was found that the present species was 9.02±.035 mm in length and brownish in colour with elongated abdomen that looked pulled upward at the posterior end on tubercle. The present findings were inconformity with the findings of Barrion and Litsinger (1995) who observed *C. bifida* from rice fields with total length of 8.44 mm. Similarly, Petcharad *et al.* (2014) also recorded *C. bifida* from Thailand that ranged 4.00- 8.50 mm. They further described males which were smaller to females with four silvery spots forming x- shaped pattern on the abdomen.

4.1.1.7*Neoscona* sp (Simon)

Neoscona Simon,

Neoscona : Comstock, 1940

Material examined: 10 females, India, Assam: Jorhat, Tea garden, 5. VII. 2016.

General description: Female

Neoscona sp was a medium sized brown coloured spider (Plate 11a). A longitudinal groove was present on the thoracic region of female (Plate 11b, 11c). Ocular quad formed a trapezium and slightly longer than width (Plate 11d, 11e).

Abdomen subtriangular in shape. Measurements of different body parts of *Neoscona* sp are given in Table 4.8.

Table 4.8 Measurements of different body parts of *Neoscona* sp

Body parts	* Measurements (mm)± Sd
Total length	6.06 ± .085
Carapace length	2.55 ± .073
Carapace width	2.33 ± .084
Abdomen length	3.74 ± .046
Abdomen width	3.60 ± .077

* Average of 10 females

The female species observed in the current study was 6.06±.085mm in total length. Further, they had a longitudinal groove on the thoracic region. These findings are similar with earlier reports which illustrate; a longitudinal thoracic groove in females separates *Neoscona* from the members of *Araneus* (Gajbe 2005; Sonali and Raja 2015).

4.1.1.8*Araneus mitificus* (Simon)

Epeira mitifica Simon, 1886

Araneus mitificus (Simon) Simon, 1909

Material examined: 10 female, India: Assam: Jorhat, Tea garden, 2. X. 2017.

General description: Female

Cephalothorax and legs were yellowish in colour; dorsally the abdomen silver white and ventrally it was greenish colour (Plate 12a, 12b). Carapace was moderately convex andwithout anyhorny outgrowths. Legs long and moderately strong, yellowish colour. Abdomen nearly globular in shape but slightly narrow anterior than posteriorly, wider than long, clothed with pubescence. Dorsum provided with a pair of wing shaped large median black patch and two lateral black patches

(Plate 12c). Measurements of different body parts of *A. mitificus* are given in Table 4.9.

Epigyne: Epigyne was wrinkled andshort with a prominent scape, spermathecae rounded with their extensions fused. (Plate 12d, 12e).

Table 4.9 Measurements of different body parts of *A. mitificus*

Body parts	* Measurements (mm)± Sd
Total length	7.03 ± .01
Carapace length	2.30 ± .040
Carapace width	2.18 ± .016
Abdomen length	4.65 ± .019
Abdomen width	4.14 ± .014

* Average of 10 females

The present findings are similar with the findings of Hazarika and Chakraborty (1998) who described *A. mitificus* from Assam measuring 9.00 mm in total body length having wide black patch right on the middle of abdomen. Tanikawa (2009) also reported the species from Japan that ranged 8-10 mm in length, while in case of male he found it to be 5-6 mm in length.

Family: Oxyopidae

4.1.1.9*Oxyopes sitae* (Tikader)

Oxyopes sitae Tikader, 1970,

Material examined: Female 10, India: Assam: Jorhat, Tea garden, 25. VI. 2016.

General description: Female

Cephalothoraxlonger than width, broad posteriorly, cephalic region raised with distinct cervical furrows. A median longitudinal dark brown fovea present on thoracic region (Plate 13a). Posterior row strongly procurved and nearly equidistant to each other. Ventrally the femora of all legs with two longitudinal black lines (Plate 13b). Abdomen was elongate, oval in shape and posteriorly tapering with patches and bands. Measurements of different body parts aregiven in Table 4.10.

Epigyne: Epigyne with comma shaped spermatheca (Plate 13c, 13d).

Table 4.10 Measurements of different body parts of *O. sitae*

Body parts	*Measurements (mm)± Sd
Total length	12.02 ± .035
Carapace length	4.88 ± .116
Carapace width	2.96 ± .091
Abdomen length	6.95 ± .086
Abdomen width	3.90 ± .126

* Average of 10 females

It was observed that the studied species was 12.02 ±.035 mm in length having elongated abdomen with patches and bands. The findings are more or less similar with the findings of Gajbe (1999) who described *O. sitae* from Sikkim. Similarly, Biswas and Raychaudhuri (2015) also reported similar pattern for this spider with total body length of 11.50 mm.

4.1.1.10 *Oxyopes shweta* (Tikader)

Oxyopes shweta Tikader, 1970

Gajbe, 1999

Material examined: 10 Females, India: Assam: Jorhat, Tea garden, 18. IV. 2016

General description: Female

Cephalothorax longer than width and the ocular region whitish in colour (Plate 14a). Lateral side of cephalic region and clypeus with a narrow black line on either side. Legs were greenish brown in colour and spiny. Abdomen longer than width, tapering to posterior end. The mid dorsal area of abdomen was brownish and bordered in either side by a lateral white longitudinal band. Measurements of different body parts of *O. shweta* are presented in Table 4.11.

Epigyne : Epigyne with bilobed shaped spermatheca (14b).

Table 4.11 Measurements of different body parts of *O. Shweta*

Body parts	*Measurements (mm)± Sd
Total length	9.50±.014
Carapace length	3.60±.012
Carapace width	2.49±.01
Abdomen length	6.96±.089
Abdomen width	2.52±.014

* Average of 10 females

The present investigation revealed that the cephalic region and clypeus in the lateral side of *O. shweta* had a narrow black line on either side and was 9.50±.014 mm in total body length. The findings were more or less similar with the findings of Majumder (2007). Chutia *et al.* (2012) also reported similar species from Assam.The findings were also in line with Gajbe, (1999; 2008) who reported similarityof male, beings smaller in size than female.

4.1.1.11*Oxyopes* sp (Tikader)

Oxyopes Latreille, 1804

Oxyopes Simon, 1898

Oxyopes Tikader, 1970.

Material examined: 4 females, India, Assam: Jorhat, Tea garden, 5. VII. 2016.

General description: Female

The cephalothorax of the species had high carapace and convex in shape (Plate 15a). Anterior row of eyes recurved, and the anterior median eyes were smallest, much smaller than the anterior lateral eyes. Posterior row procurved. Posterior median eyes equal in size to posterior eyes (Plate 15b). Abdomen was elongate, widest immediately behind the base and narrowing to spinnerets. Legs were very long in comparison to body length and unequal in relative length. Legs IV was longer than III with numerous short spines (Plate 15c). Measurements of different body parts of this specieswere presented in Table 4.12.

Table 4.12 Measurements of different body parts of *Oxyopes* sp

Body parts	*Measurements (mm)± Sd
Total length	9.00 ± .014
Carapace length	3.73 ± .01
Carapace width	3.20 ± .011
Abdomen length	5.43 ± .015
Abdomen width	3.22 ± .014

* Average of 4 females

From the study, it was found that the present observation is in conformity with the description by several authors (Tikader 1969, 1970 and Biswas *et al.* 1996) who described the genus *Oxyopes* with posterior row of eyes strongly procurved and equidistant from each other and abdomen rounded and widest at the front and then tapering all the way to the spinnerets.

Family: Salticidae

4.1.1.12 *Rhene danieli* (Tikader)

Rhene danieli Tikader, 1973

Material examined: 10 males, India: Assam: Jorhat, Tea garden, 22. I. 2017.

General description: Male

Cephalothorax round, usually clothed with thick hairs, cephalic region flattened, nearly square (Plate 16a). Abdomen longer than wide, narrow behind. Dorsum decorated with transverse brownish band. Measurements of different body parts of this species are given in Table 4.13.

Male papal organ: Bulbous swollen, short with curved conductor (Plate 16b).

Table 4.13 Measurements of different body parts of *R. danieli*

Body parts	*Measurements (mm)± Sd
Total length	4.64±.021
Carapace length	2.12±.014
Carapace width	2.44±.014
Abdomen length	2.52±.011
Abdomen width	2.03±.018

*Average of 10 males

From the present study it was found that *R. danieli* was 4.64±.021mm long. Further, the dorsum had transverse brownish band. Similar trend of characteristics were also reported by Tikader (1973) and he identified *R. danieli* that measured 5.10 mm in length.

4.1.1.13 *Phintella vittata* (C.L. Koch)

Plexippus vittatus C. L. Koch, 1846

Phintella vittata (C.L. Koch) Zabka, 1985

Material examined: 10 male, 3 females India, Assam: Jorhat, Tea garden, 30. I. 2017.

General description: **Male**

Cephalothorax broad and high with black and golden stripes (Plate 17a). Legs light green in colour. Abdomen banded with black and golden stripes. Measurements of different body parts of this species are given in Table 4.15.

Male palpal organ: Embolus, short and thin and a well developed flaky out-growth present in the upper part of the bulbus (Plate 17b).

Female: The female are more or less similar to males in body coloration (Plate 17c). Measurement of different body parts are given in Table 4.14.

Table 4.14Measurements of different body parts of *P. vittata*

Body parts	*Measurements (mm)± Sd (Male)	*Measurements (mm)± Sd(Female)
Total length	3.34±.014	6.00±.085
Carapace length	1.02±.03	2.55±.073
Carapace width	1.75±.013	2.30±.084
Abdomen length	1.18±.174	3.72±.046
Abdomen width	3.30±.014	3.60±.077

* Average of 10 males and 3 females

In the present study it was found that *P. vittata* had a metallic body colour with legs light green in colour. Żabka (1985) also observed similar characters for *P. vittata*from Vietnam with carapace 2 .20 mm and abdomen 2 .50 mm in length.

Hazarika and Chakraborty (1998) also studied *P. vittata* from Assam that was more than 5mm in length and found females were comparatively larger than males.

4.1.1.14 *Telamonia dimidiata* (Simon)

Viciria dimidiata Simon, 1899

Telamonia dimidiata (Simon) Proszynski, 1984

Material examined: 10 male, 6 females, India, Assam: Jorhat, Tea garden, 3. III.

General description: Male

Male with dark brown cephalothorax having a white band along the lateral sides of the head. Middle of cephalothorax with deep white coloured fovea. Abdomen dark brown with a broad, elongated, roughly triangular, white band present along the mid dorsal line of it (Plate 18a). Measurement of different body parts are given in table 4.15.

Male palpal organ. Round bulbus, usually with a flap like process and long thin embolus encircling bulbus (Plate 18b).

Female: The female resembled similar as male in general body shape, differed in much lighter whitish yellow colouration of body and legs with two red strips along the abdomen (Plate 18c). Measurement of different body parts are given in Table 4.15.

Table 4.15 Measurement of different body parts of *T. dimidiata*

Body parts	*Measurements (mm)± Sd (Male)	*Measurements (mm)± Sd (Female)
Total length	12.02±.038	10.06±.08
Carapace length	4.50±.014	4.20±.04
Carapace width	3.10±.078	3.02±.08
Abdomen length	6.80±1.55	5.98±.50
Abdomen width	3.20±.010	2.80±.12

* Average of 10 males, 6 females

Current investigation revealed that mean male length *T. dimidiata* was 12.02±.038 with dark brown cephalothorax having a white band along the lateral sides of the head and a white patch in the middle of the ocular quadrangle. These findings were similar with the reports of Hazarika and Chakraborty (1998) who observed *T.*

dimidiata from Assam which measured 12 mm in lengthwith two black lines on the elongated abdomen.

4.1.1.15 *Tetragnatha (*Latreille)

Tetragnatha Latreille, 1804

Material examined: 10 male, India, Assam: Jorhat, Tea garden, 17. IV. 2017

General description: Male

Cephalothorax was oval, flat, apically straight, thoracic groove conspicuous (Plate 19a).Chelicerae very long and each margin with more than 4 teeth (Plate 19b, 19c). Legs were very long and provided with spines. The abdomen long, narrow usually two or three times as long as wide. Dorsum with dull silvery markings. Measurement of different body parts are given in Table 4.16.

Table 4.16 Measurement of different body parts of *Tetragnatha* sp

Body parts	*Measurements (mm)± Sd
Total length	10.54±.018
Carapace length	3.17±.10
Carapace width	2.12±.01
Abdomen length	8.25±.32
Abdomen width	2. 74±.081

* Average of 10 male

From the present findings it was observed that the body of *Tetragnatha* sp was 10.54 ±.018 mm long and several times longer than width, chelicerae was very long and each margin with more than 4 teeth. Basu and Raychaudhuri (2016) also observed similar characters in male *Tetragnatha* sp, especially chelicerae with numerous teeth and margins of fang furrow.

4.1.1.16 *Leucauge decorata* (Blackwall)

Tetragnatha decorata Blackwall, 1864.

Leucauge decorata (Blackwall) Simon, 1906

Material examined: 10 female, India, Assam: Jorhat, Tea garden, 12. V. 2017

General description: Female

Cephalothorax yellowish brown, longer than wide, cephalic region slightly higher than the thoracic region (Plate 20a). A pair of prominent black spots on anterior region of dorso-lateral part of abdomen just behind cephalothorax. Thoracic region provided with trifid deep groove. Legs very long and slender. Abdomen silvery white and elongated, both paired tubercles and median tubercles are highly prominent (Plate 20b). Measurement of different body parts are given in Table 4.17.

Epigyne: Scape broadly truncate towards posterior epigynal margin, with constrictions at midlength (Plate 20c).

Table 4.17Measurement of different body parts of *L. decorata*

Body parts	*Measurements (mm)± Sd
Total length	7.00±.016
Carapace length	2.87±.306
Carapace width	1.66±.238
Abdomen length	5.12±.14
Abdomen width	2.08±.11

* Average of 10 female

The result of present study revealed that *L. decorata* measured a total length of 7.00 ± .016 mm with a pair of prominent black spots on anterior region of dorso-lateral part of abdomen just behind cephalothorax. Hazarika and Chakraborty (1998) also reported similar type of characters for *L. decorata* from Assam. Yadav *et al.* (2012) also identified *L. decorata* with a pair of prominent black spots on anterior region of dorso-lateral part of abdomen. In addition, Barrion and Litsinger (1995) observed the male species of *L. decorata* from rice and found that the body length was comparative smaller than the female which measured 4.80 mm in length.

4.1.1.17 *Heteropoda venatoria* (Linnaeus)

Aranea venatoria Linnaeus 1767

Aranea regia Fabricius 1793

Heteropoda venatoria, Latreille 1804

Material examined: 10 female, 5 males, India, Assam: Jorhat, Tea garden, 15. VI. 2017

General description: Female

Cephalothorax brownish, as long as wide, thoracic furrow longitudinal and distinct (Plate 21a). Anterior row of eyes procurved, posterior row slightly recurved. Both, anterior and posterior laterals equal in size (Plate 21b). Legs long and strong. Abdomen elongated, tapering, at the posterior end. Measurement of different body parts are given in Table 4.18.

Epigyne: Epigyne provided with a pair of lobes, usually separated by a septum (Plate 21c, 21d).

Males: Adult males measured smaller than females with longer legs compared to females In addition, males have a dark, longitudinal stripe on the abdomen and a light-bordered pale area behind the eyes (Plate 21e). Measurement of different body parts are given in Table 4.18.

Table 4.18 Measurement of different body parts of *H. venatoria*

Body parts	*Measurements (mm)± Sd (Female)	*Measurements (mm)±Sd (Male)
Total length	24.90±.126	20.10±.12
Carapace length	13.99±.017	10.20±.07
Carapace width	5.97±.136	3.22±.16
Abdomen length	7.42±1.76	7.22±.60
Abdomen width	5. 10±.126	2.18±.26

* Average of 10 females and 3 males

From the current study it was found that the body colour of female *H. ventoria* was brown and had a flattened body structure that measured 24.90±.126 mm in length. The female genitalia were provided with a pair of lobes, usually at posterior side. Similar description has been made by Biswas and Raychaudhuri (2005) and Majumder (2007). These findings were also similar with the findings of Jager (2008) who described medium sized *Heteropoda* sp (18.80-20.30 mm in length) with similar structure of epigyne.

4.1.1.18 *Castianeira furva* (Sankaran, Malamel, Joseph and Sebastian)

Castianeira furva Sankaran, Malamel, Joseph and Sebastian, 2015

Material examined: 2 males, India, Assam: Jorhat, Tea garden, 5. VII. 2016

General description: Male

Adult were black in colour. Cephalothorax was flat and longer than width. Clypeus, chelicerae, labium, maxillae, sternum blackish with elongated abdomen (Plate 22a). Measurement of different body parts are given in Table 4.19.

Male palpal organ: Palpal segments were brownish-black colour. Embolus short, flat with median prominent twist, tip blunt, directed at 11-o'clock position (Plate 22b).

Table 4.19 Measurement of different body parts of *C. furva*

Body parts	*Measurements (mm)±Sd
Total length	9.00±.140
Carapace length	5.07±.170
Carapace width	2.97±.010
Abdomen length	3.97±.103
Abdomen width	2.00±.140

* Average of 2 males

The present finding reported here was a new distribution record for Assam, India. Similar description had also been made for a black morph of *C. furva* measuring 10.22 mm in long, carapace 5.30 mm long and 3.54 mm width and Abdomen 4.92 mm length and 2.66 mm width (Sankaran *et al.*, 2015).

4.1.1.19 *Xysticus (*Koch)

Xysticus Koch, 1835

Material examined: 10 females, India, Assam: Jorhat, Tea garden, 5. VII. 2016

General description: Female

Cephalothorax was light brown, legs greenish and abdomen light brown in colour (Plate 23a). Cephalothorax rather square fronted, clothed with simple isolated hairs and spines.Posterior eyes nearly equidistant, medians eyes smaller than laterals; the anterior medians usually little farther from each other than from the laterals (Plate 23b, 23c). Abdomen much wider behind than in front and legs were comparatively short, stout and spiny. Measurement of different body parts are given in Table 4.20.

Table 4.20 Measurement of different body parts of *Xysticus* sp

Body parts	Measurements (mm)± Sd
Total length	5.58±.12
Carapace length	1.79±.01
Carapace width	1.78±.01
Abdomen length	3.85±.16
Abdomen width	3.70±.01

* Average of 10 females

Current findings were found in agreement with the earlier studies who reported similar characters with posterior eyes nearly at equidistant, medians eyes smaller than lateral and the anterior medians usually little further from each other than from the laterals (Tikader, 1971 ; Gajbe 2005).

4.1.1.20 *Pardosa pseudoannulata* (Bosenberg and Strand)

Pardosa pseudoannulata Bosenberg and Strand, 1906

Material examined: 10 male India, Assam: Jorhat, Tea garden, 18. V. 2016

General description: Male

Cephalothorax was convex in shape and clothed with fine hairs. Cephalic region narrowing in front and slightly high. A short fovea was present in centre of thoracic region. Ocular region black and hairy (Plate 24a). Legs moderately

strong with spines and hairs. Abdomen longer than wide, decorated with minute light spots all over the dorsal side. Measurement of different body parts are given in Table 4.21.

Male palpal organ: Pedipalp brown tip of cambium without teeth, terminal margin sickle shaped with embolus coiled on top of median apophysis (Plate 24b, 24c)

Table 4.21Measurement of different body parts of *P. pseudoannulata*

Body parts	Measurements (mm) ± Sd
Total length	6.96±.10
Carapace length	3.95±.01
Carapace width	3.00±.14
Abdomen length	3.42±0.14
Abdomen width	3.40±.12

* Average of 10 males

P. pseudoannulata in current study measured 6.96 ± .10 mm in length with a short fovea on the thoracic region. The tip of cambium male papal organ without teeth and was sickle shaped with embolus slightly noticeable. The present findingswere in agreement with the findings of Sebastian and Peter (2009) who observed similar type of characters for *P. pseudoannulata.* They also observed and reported that the female of *P. pseudoannulata* measured around 8-10 mm in length and characteristically epigyne with well sclerotised medium septum.

4.2 Species richness, diversity and evenness

The diversity indices of spider species in different tea gardens of Jorhat district are presented in Table 4.22. Result showed that diversity indices *i.e.* species richness (R = 3.07) and evenness (E = 0.96) was recorded the highest in Deha T.E. followed by Bordoloi T.E (2.92, 0.93 respectively). Among all the gardens the species richness and evenness were found lowest in Saikia T.E. *i.e.* 2.51 and 0.89 respectively. The diversity index (H’) was recorded highest in Dholi T.E. (2.88). In the present study only minimal differences was recorded for the indices across

different tea gardens. This suggested that the variation on the diversity of spiders was not very drastic in the selected gardens of Jorhat, Assam. Deha T.E being an organically managed garden had overall higher species richness and evenness. Around small grower tea gardens the vegetation was scarce and the insecticides were irregularly applied, as a result richness and evenness were might be low. Comparative studies between organic and inorganic tea gardens reported elimination of natural enemies due to large-scale indiscriminate application of broad-spectrum organosynthetic insecticides (Wirsig 1999; Hazarika *et al.,* 2001). The higher spider densities in organic fields suggested a favorable habitat for spiders (Schmidt *et al.,* 2005). It is argued that organic systems are more diverse, and therefore more stable (Lampkin, 1990). However in the present study the spider species diversity was observed highest in case of Dholi T.E. which was a conventional tea garden as compared to organic garden. These results are contrary to what has previously been reported with high diversity index and uniformity in organic fields compared to conventional fields (Yardin and Edward 1998; Hazarika *et al.,* 2001; Schmidt *et al.,* 2005). This might be due to the existence of a favorable microclimate like shade tree density and diversity. Another possibility is that as relative diversity levels change between years (Rendon *et al.,* 2006).

It was found that members of the family Araneidae dominated in tea gardens accounting for 28.54 per cent of the total collected specimens (Fig. 4.1). Saltacidae formed the next dominant spider family with 26.46 per cent of the total collections. Oxyopidae was the third largest family where it for 19.43 per cent of the total collected specimens. Members of the families Tetragnathidae and Thomisidae were present in good number with 15.30 and 7.29 percent respectively of the total collected specimens. The other families were represented by a less number of specimens Lycosidae (2.27%), Sparassidae (1.02%) and Corinnidae (0.07%). Different author reported different family as the richest one in different region.Present study identified the family Araneidae (28.54%) as the dominant family in comparison to other families of the total collected specimens. This

was followed by Saltacidae (26.46%). Some previous studies reported similar kind of findings. In a study Quasin (2011) reported Araneidae as the most dominant family (18%) followed by Salticidae (11.5%), a study in Nanda Devi Biosphere Reserve, Dehradun, Uttarakhand. Kazim *et al.* (2014) found family Salticidae as the most common family that represented the highest species from Sindh province of Pakistan. Deshmukh and Raut (2014) also found Salticidae (19.23%) as the most abundant family followed by Araneidae (18.26%) and Thomisidae (12.05%) from Bangladesh. However, in a study conducted by Ghazanfar *et al.* (2016) reported Lycosidae to be the most dominant family. Thus, it indicated that there might be site specific variation in spider distribution pattern. This might be due to changes in the habitat structure, including habitat complexity, litter depth and microclimate characteristics (Downie *et al.*, 1999).

4.2.1 Seasonal incidence of spider population in relation to different weather parameters during May' 2016-April' 2017

Seasonal incidence of spider population during May' 2016-April' 2017 are presented in Fig. 4.2. During May, 2016 the mean population of spider recorded was 2 no/bush which increased gradually with a peak in June, 2016 (2.70 no/bush). However, the population trends fluctuated all-round the study period with no population during December 2016.

4.2.2 Correlation of spiders with different weather parameters

Different weather parameters such as temperature, relative humidity, total rainfall and bright sunshine hours were associated with spider incidence. Simple correlation studies were carried out between populations of spider with weather parameters. The coefficients of correlation are presented in Table 4.23. It was observed that the spider population exhibited significant positive correlation with total rainfall (r = 0.776) and non-significant for maximum temperature (r = 0.330), minimum temperature (r = 0.519) and evening relative humidity (r = 0.458). However, it was observed that spider population showed a significant negative correlation with morning relative humidity (r = -0.797) and bright sunshine hour (r = -0.676).

The above results were in accordance with the report of Kalita *et al*. (2015), where they found that natural enemies like spiders and dragonfly/damselfly showed significant positive relationship with total rainfall in rice field of Sikkim. Moreover the present results were similar to the findings of Subba *et al.* (2016) wherein they reported a significant negative correlation between spider population and morning relative humidity. Sidar *et al.* (2017) also reported negative impact of sunshine hour on abundance of spider densities.

4.2.3 Distribution pattern of spiders

For spatial distribution pattern of spiders, the distribution indices - Variance to mean ratio (S^2/X) and Lloyds index (X*/x) for different gardens types *i.e.*, conventional, organic tea gardens and small grower gardens are presented in Table 4.24, Table 4.25 and Table 4.26 respectively. It was found that both - Variance to mean ratio and Lloyds index for spiders exhibited significantly greater than 1.0, indicating clumped distribution pattern. However, only *Nephila kuhlii* showed a regular (< 0.1) distribution pattern. This might be due to several factors such as instinct behaviour of the individuals, response to prey and habitat resources distribution. In addition, a proper resource concentration in some areas has been proposed as the general cause of assemblage of most living things. (Ricklefs and Miller, 2000).

The result of the corresponding analysis of spider abundance in different tea gardens showed that there was a higher dominance of spider populations towards organic gardens then in conventional and small grower gardens (Fig. 4.3) Higher abundance of spiders in organic gardens might be due to increase in population of detrivores after addition of organic manures. This organism serves as alternate prey for spiders (Settle *et al*., 1996). Difference in species abundance between organic and conventional field had also been reported in other agroecosystems (Feber *et al*., 1998). Conventional management practices such as pesticides and tillage operations have numerous effects on the spider population.

Pesticide/ herbicides can reduce populations of phytophagous insects, which result in less prey availability for spiders (Amalin *et al.,* 2001).

4.4. Effects of tea clones on insect pests and spider population of tea

Seven different tea clones (TV 1, TV 2, TV 7, TV 9, TV 12, TV 18, TV 23) along with their morphological and biochemical characters were examined to determine their effects on common insect pests and spider population of tea. The results are described as under.

4.4.1 *H. theivora*

Population of *H. theivora* in different TV clones during 2016-17 are tabulated in Table 4.27. It was observed that the mean number of *H. theivora*, was significantly different among TV clones being varied from 2.12 to 6.22 no/bush. The highest mean number of *H. theivora* was recorded in TV 23 (6.22 no/bush) which was significantly higher from other TV clones, while the lowest number was recorded in TV 2 (2.12no/bush). This was followed by TV 1 (4.60 no/bush) which differed significantly from TV 18 (3.03no/bush), TV 2 (2.11no/bush), TV 7(2.15no/bush), TV 9 (2.60no/bush), but was found at par with TV 12 (4.22 no/bush). No significant difference was observed for TV 2 (2.12no/bush), TV 7(2.15no/bush), TV 9 (2.59 no/bush).

The present finding is in line with the findings of Roy *et al.* (2009) who screened 28 tea cultivars and reported that TV1, TV12, TV23, TS653 and TV16 were the most susceptible to *H. theivora* infestation. Further, the leaves of TV 23 were lanceolate and light green which generally attract *H. theivora.*

4.4.2 *O. coffeae*

The population of *O. coffeae* was found to be variable in all the tested TV clones (Table 4.27). It was observed that significantly highest mean number of *O. coffeae*was recorded in TV 23 (18.35 no /leaf). This was followed by TV 7 (13.87 no /leaf) which was found to be at par with TV 1 (13.71 no/leaf), TV 2 (12.74 no/leaf), TV 12 (12.52 no/leaf) and TV 18 (13.63 no/leaf). However, among all the clones the

lowest was recorded in TV 9 (11.75 no/leaf). Similar trend of findings was also reported by Choudhury *et al.* (2006) who assessed the variation in clonal susceptibility to red spider mite infestation for one year in Barak Valley Assam and found TV7, TV22, TV23 and TV24 to be fairly susceptible.

4.4.3 *Hyposidra* sp

The mean number of *Hyposidra* sp population showed a significant variation among the TV clones ranging from 1.99 to 3.43 (Table 4.27). The highest mean number of looper was observed in TV 23 (3.43 no/bush) followed by TV 1(3.03 no./bush) which differed significantly from TV 2 (2.63 no/bush), TV 9 (2.54 no/bush), TV 7 (2.38 no/bush), TV 12 (2.25 no/bush), while the lowest was recordedin TV 18 (1.99 no/bush). No significant difference was observed to exists between TV 2 (2.63 no/bush), TV 9 (2.54 no/bush), TV 7 (2.38 no/bush), TV 12 (2.25 no/bush) and TV 18 (1.99).

From the present findings it was observed that among all the clones, TV 23 a camboid variety with lanceolate leaf type was the preferred clone for *Hyposidra* sp. Such preference was noticed earlier by Majumder (2010) for Camboid variety TV 25. They also reported a lowest growth of *Hyposidra* sp. in the leaves of TV 1 which might be due to presence of high non-digestible matter and cellulose that render this clone comparatively less preferable to other clones.

4.4.4 Spiders

No significant difference was observed among different TV clones with respect to the spider populations found on them (Table 4.27). It was observed that the mean number of spiders ranged from 0.81 to 1.57 no/bush on different tested clones. However, the highest numbers of spiders were observed in TV 1 (1.57 no/bush) and the lowest number was found on TV 18 (0.81 no/bush) and there was no significant difference among the clones in respect of spider population. The current finding suggests that number of spider populations were more equally distributed with respect to all the TV clones.

4.5 Correlation between insect pests and plant characters

4.5.1 Number of branches

Significant differences were exhibited among the tea clones for number of branches, which ranged from 7.33 to 15.58 no/bush (Table 4.28). Maximum number of branches was recorded for TV 7, TV 18 and TV 23 with the highest count of branches of 15.58, 15.38 and 15.24 no/bush, respectively. The result further revealed that TV7 (15.58 no/bush) significantly differed from TV 1 (14.27 no/bush), TV 12 (8.40 no/bush) and TV 2 (7.33 no/ bush) and at par with TV 7 (15.58 no/bush), TV 23 (15.24no/bush), TV 18 (15.38no/bush) and TV 9 (15.21no/bush). Similar findings were also documented by Waheed *et al.* (2000) and they reported that cultivars of narrow leaves had more number of branches as compared to cultivars of broad leaves.

The correlation studies of *H. theivora, O. coffeae* and *Hyposidra* spwith total number of branches /bush established a non significant negative correlation (r = -0.664, r = -0.277 and r = -0.156 respectively) (Table 4.30).The present findings can be compared with findings of Iqbal *et al.* (2011) and they found a non significant correlation between numbers of branches with the incidence of *A. bigutulla* in okra. Similarly, Ali *et al.* (2012) also observed a non significant negative correlation between number of branches and the jassid population in brinjal.

4.5.2 Leaf area

Analysis of variance showed significant difference among the TV clones for leaf area (Table 4.28). Maximum leaf area was observed for TV 12, TV 2 and TV 23 with leaf area of 63.91, 50.95 and 47.03cm^2, respectively where as TV 7, TV 9, TV 18 and TV 1 had significantly less leaf area of about 23.21, 36.87, 41.84, 42.24cm^2 respectively. The present finding can be compared to the study of Rahman *et al.* (2010) who found that the leaf area for cu1tivars of narrow leaved group was significantly smaller (22.12- 42.40cm^2) than leaf area for broad leaved group (48.64- 62.49cm^2). Moreover, the correlation study demonstrated that leaf area had anon significant correlation with the insect pest incidence (Table 4.30). The correlation

study of *H. theivora* with leaf area showed a non significant negative correlation (r= -.333) while Javed (2012) reported that more leaf area cultivars of Brinjal recorded least pest population.The results in the correlation matrix for *O. coffeae* and *Hyposidra* sp population with leaf area also showed non significant negative correlation (r = -0.175, r = - 0.179, respectively). Ali *et al.* (2016) also found a non significant correlation between leaf area and grub of Hadda beetle in brinjal.

4.5.3 Trichome density

The data presented in the Table 4.28 showed that the maximum number of trichome was observed in case of TV 2 (93.33/cm^2) which was significantly different from rest of the clones examined. This was followed by TV 18 (82.67 /cm^2) which was found to be at par with TV 12 (79.33/cm^2), TV 7 (78.33 /cm^2) but differed significantly from TV 1 (68.67/cm^2), TV 9 (71.33/cm^2) and TV 23 (69.33/cm^2). However, it was observed that TV 7 (78.33/cm^2), TV 9 (71.33/cm^2) and TV 23 (69.33/cm^2) differed significantly from each other and the lowest number of trichome was observed in TV 1 (68.67/cm^2) which were at par with TV 23 (69.33/cm^2). The present findings are in line with the findings of Dutta (2015) who reported that trichomes density was more in TV 6 followed by TV10 and TV1.

The correlation study of *H. theivora* with trichome density established a strong significant negative correlation (r = -.643) (Table 4.30) and relationship between *O. coffeae* population and trichome density showed significant negative correlation (r = -.475). The present findings are in line with Dutta (2015) who reported that density of trichomes in TV clones to be negatively correlated with fecundityindicating partial fecundity and oviposition of *O. Coffeae.* Maluf *et al.* (2007) also reported that the genotype with more trichome densities showed higher levels of repellence to *Tetranychus urticae*. *Hyposidra* sp also showed a significant negative correlation (r = -.493) with trichome densities. It indicated that the pest preferred the clones with low trichome density. Similar results had been reported earlier by Wagh *et al.* (2012) who observed a negative impact of trichome density on the insect pests of brinjal.

4.5.4 Variation in phenol content

The variation in phenol contents in different TV clones are presented in Table 4.29. It was observed that the percent reduction of phenol content due to attack by *H. theivora* was maximum in TV 23 (22.43%). This was followed by TV 1 (18.46%), TV 18 (11.86%), TV 7 (9.71%), TV 2 (5.26%) and TV 12 (5.11%) and lowest percent reduction was in TV 9 (4.46%).

As far as correlation study concerned, there was significantly negative association between phenol content and insect pests *viz., H. theivora* (r=- *0*.766), *O. coffeae*(r = -*0*.866), *Hyposidra* sp (r=-*0*.760) respectively (Table 4.30). The secondary metabolite produced by the plants is the phenolics which defend themselves from the insect pests and pathogen.Similar trends in decreased of phenol content were also reported by Shah *et al.* 2014 and found that TV 1 and TV 23 clones were most susceptible to *H. theivora* infestation. Khattab (2007) also stated that phenol oxidation by antioxidant enzyme is a potential defence mechanism in plants against insect attack.

4.5.5 Leaf moisture content

Differences among the examined tea clones were significant for their leaf moisture content (Table 4.29). Maximum leaf moisture observed in TV 2 (89.32%) which was significantly differed from TV 1 (84.91%), TV 12 (83.61%), TV 23 (82.14%), TV 9 (80.77%) and TV 7 (37.50%). TV 18 (87.50 %) and TV 1 (84.91%) registered comparatively more leaf moisture and statistically at par with TV 2, but varied significantly from other clones. However, no significant difference was observed in between TV 12 (83.61%), TV 23 (82.14%) and TV 9 (80.77%). The results indicated that narrower leaves had comparatively less moisture content than those of broad leaves (TV 7 and TV 9 being narrower then rest of the clones).This resultbe compared with the findings of Waheed *et al.* (2000) who reported that narrow leaved group had high number of leaves but less fresh and dry leaf weight content.

The population of *H. theivora* established a weak non-significant positive correlation (r = 0.064) with leaf moisture (Table 4.30). Similar reports was

also laid by Hassan *et al.* (1999) who showed a non significant positive correlation between leaf moisture contents and sucking pests *viz.*, whitefly and jassid. In case of *O. coffeae*, it established a non significant negative (r = -0.446.) association with leaf moisture content. Earlier reports stated that population build up of mite population started in water shortage conditions (Kuepper, 2004). The present results also corroborate with that of Peter and Barrey (1980) who observed a delayed development of immature mites (*T. urtica*e) on the leaves with less moisture content

Further, the relationship between populations of *Hyposidra* sp was also non significant with moisture content (r = -0.458). The present results corroborate with the work done by Patel (2013) who computed non significant (r = -0.389) negative association between larvae of green semilooper (*Chrysodexis acuta*) and leaf moisture content of soyabean.

4.6 Correlation between spiders and major insect pest population in tea

The correlation coefficient value presented in Table 4.31, indicated that the spider population exhibited a significant positive correlation with all the three insect pests *viz., H. theivora* (r= 0.764), *O. coffeae* (r = 0.858) and *Hyposidra* sp (r = 0.919) respectively. Thus, population of spiders was found to increase with increase in pest population. The present findings are in line with several earlier works which report the predatory potency of spiders (Satpathi, 2004; Sudhikumar *et al.*, 2005; Sebastian 2005; Motobayashi *et al.*, 2006).

4.7 Efficacy of different pesticides against different insect pests of Tea

To investigate the effects of pesticides on major pests and spider population in tea, a field experiment was carried out during the peak pest period of June, 2016 and June, 2017 in the Experimental Garden of Plantation crops, Assam Agricultural University, Jorhat. Data were recorded at 1st, 5th and 10th days after application of different pesticides.

4.7.1 *H. theivora*

A. During 2016

The data on effect of pesticides on *H. theivora* during 2016 are presented in Table 4.32 and revealed that all treatments were found to be effective

over control in reducing *H. theivora* population. At one day, it was observed that minimum number of *H. theivora* (0.43no/bush) was recorded in the plot treated with thiomethoxam 25% WG @ 0.01% which was followed by deltamethrin 2.8 EC @ 0.02% (0.73 no/bush). However, azadirachtin a neem basedproduct @ 0.003% recorded 0.93 number of *H. theivora*. *Beauveria bassiana*@ 2% resulted in 2.40 no/bush after one day of treatment. The maximum number of *H. theivora* (6.10no/bush) was recorded in case of untreated control.The result further revealed that minimum no of *H. theivora* was recorded with treatment ofthiomethoxam 25% WG @ 0.01% (0.43no/bush) which differed significantly from *B. bassiana* @ 2% (2.40no/bush), while *B. bassiana* was found to be at par with ethion 50EC@0.25% (2.93no/bush) and spiromesifen 240 SC @ 0.2% (3.10no/bush).

The average number of *H. theivora* population at fifth days after spray revealed that though there was an increase in population number, same trend was observed in different treatments. It has observed that the lowest number of *H. theivora* population (2.00 no/bush) was recorded in thiomethoxam 25% WG @ 0.01% followed by deltamethrin 2.8 EC @ 0.02% (2.27 no/bush), azadirachtin @ 0.003% (2.57 no/bush), *B. bassiana* @ 2%, ethion 50EC@0.25% (3.40 no/bush) and spiromesifen 240 SC @ 0.2% (3.67 no/bush). The treatment thiomethoxam 25% WG @ 0.01% was significantly different from *B. bassiana* @ 2% (3.03 no/bush) which was at par with ethion 50EC @ 0.25% and spiromesifen 240 SC @ 0.2%.

Observation recorded on *H. theivora* at ten days after spraying showed that all the treatments reduced the population of *H. theivora*. Minimum number of *H. theivora* (2.50 no/bush) was recorded in thiomethoxam 25% WG @ 0.01% which was found significantly higher than all the treatments except control (7.00no/bush). Among all the treated plots, maximum number of *H. theivora* (4.07no/bush) was recorded in spiromesifen 240 SC @ 0.2%.

B. During 2017

It was observed that the efficacy of different pesticides during 2017 was in similar trend with 2016 (Table 4.33). At one day after spraying thiomethoxam

25% WG @ 0.01% was found to be most effective treatment with a minimumpopulation (0.20 no/bush) which differed significantly from *B. bassiana* @2%(2.07no/bush), while *B. bassiana* was found to be at par with ethion 50EC@0.25% (2.13no/bush) and spiromesifen 240 SC @ 0.2% (2.27no/bush).

Two year pooled data (Table 4.34) revealed that all the treatments were effective over the control in reducing the *H. theivora*. Among the treatments thiomethoxam 25% WG @ 0.01% was found to be most effective against *H. theivora* followed by deltamethrin 2.8 EC @ 0.02% and azadirachtin @ 0.003% whereas spiromesifen 240 SC @ 0.2% was found to be least effective against *H. theivora* population.Similar findings was also reported by Sarmah *et al.* 2009 who tested field efficacy of thiomethoxam 25 WG and botanical pesticides against tea mosquito bug, found that higher doses of thiomethoxam were more effective in reducing the infestation of *H. theivora*. Beside this, Tuck (1987) also recorded the effectiveness of deltamethrin against *H. theivora* on cocoa in Malaysia. Thus, in addition to regular updating of the strategy and tactics of *H. theivora* management with the introduction of new concepts and approaches together with new insecticides is required in order to have a better management of pests (Roy *et al.*, 2010).

4.7.2 *O. coffeae*

A. During 2016

The mean data on population of *O. coffeae* recorded at one day after treatment are presented in Table 4.35. It was found that, all the treatments were found to be effective in reducing *O. coffeae* population over control. The highest population 26.84 no/leaf was recorded in thiomethoxam 25% WG @ 0.01%, while the lowest of 2.35 no/leaf was recorded in spiromesifen 240 SC @ 0.2% followed by ethion 50EC@0.25% (6.56 no/leaf), azadirachtin @ 0.003% (14.37 no/leaf), deltamethrin 2.8 EC @ 0.02% (16.73 no/leaf) and *B. bassiana* @ 2% (22.84no/leaf). The treatment of spiromesifen 240 SC @ 0. % (2.35 no/leaf) was found to be significantly different from all other treatments except ethion 50EC@0.25% (6.56 no/leaf). Azadirachtin @ 0.003% (14.37 no/leaf) was found to be significantly different from *B. bassiana* @

2% (22.84 no/leaf), while *B. bassiana* @ 2% was at par with deltamethrin 2.8 EC @ 0.02% (16.73 no/leaf) in reducing *O. coffeae* population.

Data recorded at five days after spraying showed that the highest population (31.86 no/leaf) of *O. coffeae* was recorded in treatment with thiomethoxam 25% WG @ 0.01% and the lowest population (12.67 no/leaf) was recorded in spiromesifen 240 SC @ 0.2% followed by ethion 50EC@0.25% (17.55 no/leaf), azadirachtin @ 0.003% (21.74 no/leaf), deltamethrin 2.8 EC @ 0.02% (26.19 no/leaf) and *B. bassiana* @ 2% (26.56 no/leaf). The data also showed that among all the significantly minimum (12.67 no/leaf) population of *O. coffeae* population was observed in case of spiromesifen 240 SC @ 0.2% and the highest was observed in thiomethoxam 25% WG @ 0.01% (31.86 no/leaf), which differed significantly from azadirachtin @ 0.003% (21.74 no/leaf), deltamethrin 2.8 EC @ 0.02% (26.19 no/leaf) and *B. bassiana*@ 2% (26.56 no/leaf). However, thiomethoxam 25% WG @ 0.01% (31.86 no/leaf), was found to be statistically at par with, *B. bassiana* @ 2% (26.56 no/leaf). No significant difference was observed between azadirachtin @ 0.003% (21.74 no/leaf), deltamethrin 2.8 EC @ 0.02% (26.19 no/leaf) and *B. bassiana* @ 2% (26.56 no/leaf).

The data recorded at ten days after spray revealed that the lowest population of *O. coffeae* (20.00 no/leaf) was recorded in treatment with spiromesifen 240 SC @ 0.2% which differed significantly from all the treatments. The treatment of ethion 50EC@ 0.25% (24.23 no/leaf), deltamethrin 2.8 EC @ 0.02% (30. 34 no/leaf) and *B. bassiana* @ 2% (30.90 no/leaf) did not show any significant difference with each other which however, differed significantly from the treatment of thiomethoxam 25% WG @ 0.01% (36.12 no/leaf).

B. During 2017

The efficacy of different treatments recorded at one day after spray revealed a similar trend as in 2016 (Table 4.36). The treatment of spiromesifen 240 SC @ 0.2% (2.56 no/leaf) was found to be significantly different from all other treatments except ethion 50EC@0.25% (8.23 no/leaf). Azadirachtin @ 0.003% (13.56

no/leaf) was found to be significantly differed from *B. bassiana* @ 2% (22.88 no/leaf), while *B. bassiana* @ 2%was at par with deltamethrin 2.8 EC @ 0.02% (13.00 no/leaf) in reducing *O. coffeae* population.

At five days after spray minimum (12.48 no/leaf) population of *O. coffeae* population was observed in case of spiromesifen 240 SC @ 0.2% and the highest was observed in thiomethoxam 25% WG @ 0.01% (25.08 no/leaf), which differed significantly from azadirachtin @ 0.003% (19.01 no/leaf), deltamethrin 2.8 EC @ 0.02% (19.05 no/leaf) and *B. bassiana* @ 2% (23.96 no/leaf). However, Thiomethoxam 25% WG @ 0.01% (25.08 no/leaf), was found to be statistically at par with *B. bassiana* @ 2% (23.96 no/leaf). No significant difference was observed between azadirachtin @ 0.003% (21.74 no/leaf), deltamethrin 2.8 EC @ 0.02% (19.05 no/leaf) and *B. bassiana* @ 2% (23.96 no/leaf).

Observation recorded atten days after spray during 2017 revealed same trend as 2016. Lowest population of *O. coffeae* 20.00 no/leaf was recorded in spiromesifen 240 SC @ 0.2% which different significantly from all the treatments. The treatment of ethion 50EC@0.25% (22.84 no/leaf), deltamethrin 2.8 EC @ 0.02% (23.94 no/leaf) azadirachtin @ 0.003% (24.96 no/leaf),and *B. bassiana* @ 2% (27.01 no/leaf) did not show any significant difference with each other, however differed significantly from the treatment of Thiomethoxam 25% WG @ 0.01% (28.35 no/leaf).

The pooled data on the efficacy of different pesticides revealed significant differences (Table 4.37). Spiromesifen 240 SC @ 0.2% was found to be most effective against *O. coffeae* followed by ethion 50EC @ 0.25%, deltamethrin 2.8 EC @ 0.02% and azadirachtin @ 0.003% whereas thiomethoxam 25% WG@ 0.01% @ was found to be least effective against *O. coffeae* population.The present findings are in line with Kalita *et al.* (2007). They found that treatment with spiromesifen 240 SC @400 ml/haresulted 99.23% reduction of mites on tea, which was found to be superior to sulphur 80WP (65.50%), dicofol 18.5EC (58.53%), ethion 50EC (49.45%) and endosulfan 35EC (26.15%) respectively. The efficacy of spiromesifen over dicofol in reducing chilli mite was reported by Kavitha *et al.* (2006) and Nagaraj *et al.*

(2007) also found spiromesifen as the best treatment among all other chemicals examined.

4.7.3 Spider

A. During 2016

Observation recorded on spiders at one days after spraying is presented in Table 4.38. Results indicated that all the treatments were significantly differed over control. Highest number of spiders (0.47 no/bush) was recorded with treatment of *B. bassiana* @ 2%and lowest (0.13 no/bush) was recorded in ethion 50EC @ 0.25% followed by deltamethrin 2.8 EC @ 0.02% (0.20 no/bush), thiomethoxam 25 WG0.01% (0.23no/bush), spiromesifen 240 SC @ 0.2% (0.27 no/bush) and azadirachtin 5 EC 0.003% (0.40 no/bush) respectively. The treatment of ethion 50EC @ 0.25% (0.13 no/bush) significantly differed from the treatment azadirachtin 5 EC 0.003% (0.40 no/bush), while the treatment azadirachtin 5 EC 0.003% (0.40 no/bush) at par with the treatment of *B. bassiana* @ 2% (0.47 no/bush). The treatments of deltamethrin 2.8 EC @ 0.02% (0.20 no/bush), thiomethoxam 25 WG 0.01% (0.23no/bush) and spiromesifen 240 SC @ 0.2% (0.27 no/bush) did not showed at significant difference in reducing the population of spiders at three days after spraying. The data recorded at five days after spray revealed that the lowest population of spider 0.37 no/bush was recorded in treatment with ethion 50EC @ 0.25% which differed significantly from azadirachtin 5 EC 0.003% (0.50 no/bush) and *B. bassiana* @ 2% (0.57 no/bush). The treatment of ethion 50EC@0.25% (0.37 no/bush), deltamethrin 2.8 EC @ 0.02% (0.40 no/bush), thiomethoxam 25 WG 0.01% (0.43no/bush), spiromesifen 240 SC @ 0.2% (0.47 no/bush) did not show any significant difference with each other. Observation recorded at ten days after spray showed a gradual increase in spider population/bush. The highest number (0.67 no/bush) of spider was recorded in treatment with *B. bassiana* @ 2%, while the lowest number was recorded in treatment ethion 50EC @ 0.25% (0.40 no/bush) which differed significantly with azadirachtin 5 EC 0.003% (0.57 no/bush). However the treatment of azadirachtin 5 EC 0.003% (0.57 no/bush) was found to be at par with the

treatments of deltamethrin 2.8 EC @ 0.02% (0.47 no/bush), thiomethoxam 25 WG 0.01% (0.43 no/bush),and spiromesifen 240 SC @ 0.2% (0.53 no/bush) at ten days after treatment.

B. During 2017

The effect of different pesticides on spiders during 2017 was similar to that of 2016 (Table 4.39). At one day, ethion 50EC @ 0.25%was most harmful to spiders (0.03 no/bush) which was found to be at par with deltamethrin 2.8 EC @ 0.02% (0.17 no/bush), thiomethoxam 25 WG 0.01% (0.20 no/bush) and spiromesifen 240 SC @ 0.2% (0.27 no/bush) while highest number of spiders (0.40 no/bush) was recorded with treatment *B. bassiana* @ 2% followed by azadirachtin 5 EC 0.003% (0.30 no/bush). Observation recorded on five days after spray revealed lowest population of spider 0.27 no/bush was recorded in treatment with ethion 50EC @ 0.25% which differed significantly from azadirachtin 5 EC 0.003% (0.47 no/bush) and *B. bassiana* @ 2% (0.50 no/bush). Ethion 50EC@0.25% (0.27 no/bush) was most harmful for spiders, which was at par with deltamethrin 2.8 EC @ 0.02% (0.17 no/bush), thiomethoxam 25 WG0.01% (0.20 no/bush), spiromesifen 240 SC @ 0.2% (0.43 no/bush). Further at ten days, it was found that highest number (0.63 no/bush) of spider was recorded in treatment with *B. bassiana* @ 2%, while the lowest number was recorded in treatment ethion 50EC @ 0.25% (0.27 no/bush) which differed significantly with azadirachtin 5 EC 0.003% (0.47 no/bush). However no significant difference was found between azadirachtin 5 EC 0.003%, deltamethrin 2.8 EC @ 0.02% (0.47 no/bush, thiomethoxam 25 WG0.01% and spiromesifen 240 SC @ 0.2% (0.53 no/bush) in reducing the spider population.

Results of pooled data on effect of pesticides on spiders are present in Table 4.40. It revealed that all the treatments were significantly effective over the control. Among all the treatments ethion 50EC @ 0.25% was found to be most toxic on spider population followed by deltamethrin 2.8 EC @ 0.02%. However, *B. bassiana* @ 2% was found to safer to spider population which was followed by azadirachtin 5 EC 0.003%. The present investigation revealed pesticides of biological

origin found to be less toxic as compared to synthetic pesticide which is in line with the findings of Tiwari *et al.* (2011) and toxicity of ethion on spiders are in close conformity with the findings of Sara *et al.* (2013). The safety of spiromesifen (Oberon- 240 SC) in comparison to other acaricides was also reported by Sekh *et al.* (2007) and they observed that the chemical was very safe to predatory mites, coccinellid beetles and spiders.

CHAPTER V
SUMMARY AND CONCLUSION

1. A survey was conducted to study the diversity of spiders in different tea gardens *viz.*, conventional, organic and smallgrower gardens of Jorhat district from May, 2016 to April, 2017. Total of 2954 specimens of spiders were collected under 16 genera, 8 families and 20 species *viz.*, *Cyrtophora cicatrosa*, *Nephila kuhlii*, *Argiope pulchella*, *Cyclosa mulmeinensis*, *Neoscona* sp, *Cyclosa spirifera*, *Cyclosa bifida*, *Araneus mitifica*, *Oxyopes sitae*, *Oxyopes shweta*, *Oxyopes* sp, *Rhene danieli*, *Phintella vittata*, *Telamonia dimidiata*, *Tetragnatha* sp, *Leucauge decorata*, *Heteropoda ventoria*, *Xysticus*sp and *Perdosa peaudoannulata*. Among all species, *Castianeira furva* has been recorded for the first time from this region.

2. The highest species richness (R = 3.07) and evenness (E = 0.96) was recorded the highest in organic garden (Deha T.E) and lowest in small grower gardens (Saikia T.E) *i.e.*, 2.51 and0.89 respectively. However, species diversity was recorded highest in conventional garden, Dholi T.E. (H' = 2.88). It was found that members of the family Araneidae dominated in tea gardens accounting for 28.54 per cent of the total collected specimens. Saltacidae formed the next dominant spider family with 26.46 percent of the total collections followed by Oxyopidae (19.43%) Tetragnathidae (15.30 %), Thomisidae (7.29%), Lycosidae (2.27%), Sparassidae (1.02%) and Corinnidae (0.07%).

3. The periodical observation on incidence of spiders in tea during 2016-2017 was recorded a peak population in June, 2016 (2.70 no/bush). However, it was observed to fluctuate all round the study period with least population during December, 2016. The correlation studies revealed that the spider population exhibited significant positive correlation with total rainfall (r = 0.776) and non significant for maximum temperature (r = 0.330), minimum temperature (r = 0.519) and evening relative humidity (r = 0.458).However, it showed a

significant negative correlation with morning relative humidity (r = -0.797) and bright sunshine hour (r = -0.676).

4. For spatial distribution pattern of spiders it was observed that both - Variance to mean ratio and Lloyds index for spiders exhibited significantly greater than 1.0, indicating clumped distribution pattern. However, only *Nephila kuhli* showed a regular (< 0.1) distribution pattern. The result of the corresponding analysis of spider abundance in different tea gardens showed that there was a higher dominance of spider populations in organic gardens than in conventional and small grower tea gardens.

5. Certain morphological and biochemical charactersof seven different tea clones (TV 1, TV 2, TV 7, TV 9, TV 12, TV 18, TV 23) were examined to determine their effects on the incidence of common insect pests and spider population. Results revealed that the highest mean number of *H. theivora* was recorded in TV 23 (6.22 no/bush) which was significantly higher from other TV clones, while the lowest number was recorded in TV 2 (2.12 no/bush). This was followed by TV 1 (4.60 no/bush) which differed significantly from TV 18(3.03 no/bush), TV 2 (2.11 no/bush), TV 7 (2.15 no/bush), TV 9 (2.60 no/bush), but was found at par with TV 12 (4.22 no/bush). No significant difference was observed for TV 2 (2.12 no/bush), TV 7 (2.15 no/bush), TV 9 (2.59 no/bush).

6. The population of *O. coffeae* was also found to be variable in all the tested TV clones. It was observed that significantly highest mean number of *O. coffeae* was recorded in TV 23 (18.35 no /leaf). This was followed by TV 7 (13.87 no /leaf) which was found to be at par with TV 1 (13.71 no/leaf), TV 2 (12.74 no/leaf), TV 12 (12.52 no/leaf) and TV 18 (13.63 no/leaf). Among all the clones the lowest number of *O. coffeae* was recorded in TV 9 (11.75 no/leaf).

7. The mean number of *Hyposidra* sp population also showed a significant variation among the TV Clones. The highest mean number of *Hyposidra* sp population was observed in TV 23 (3.43 no/bush) which differed significantly

from TV 2 (2.63 no/bush), TV 9 (2.54 no/bush), TV 7 (2.38 no/bush), TV 12 (2.25 no/bush), while the lowest was recorded in TV 1 (1.99 no/bush). This was followed by TV 18 (3.03 no/bush), which was found similar with TV 23 (3.43 no/bush), TV 2 (2.63 no/bush) and TV 9 (2.54 no/bush), but differed significantly with TV 2 (2.63 no/bush), TV 12 (2.25 no/bush) and TV 18 (1.99). No significant difference was observed to exists between TV 2 (2.63 no/bush), TV 9 (2.54 no/bush), TV 7 (2.38 no/bush), TV 12 (2.25 no/bush) and TV 18 (1.99).

8. In case of spiders no significant difference was in numbers observed for all the examined TV clones. It was observed that the mean number of spiders ranged from 0.81 to 1.57 no/bush on different tested clones. However, the highest numbers of spiders were observed in TV1(1.57 no/bush) and the lowest number was found on TV 18 (0.81 no/bush).

9. Among the morphological characters, significant differences were exhibited among the tea clones for number of branches. The maximum number of branches was recorded for TV 7, TV 18 and TV 23 with the highest count of branches of 15.58, 15.38 and 15.24 no/bush, respectively. The result further revealed that TV7 (15.58 no/bush) significantly differed from TV1 (14.27 no/bush), TV 12 (8.40 no/bush) and TV 2 (7.33 no/ bush). However, no significant difference was observed between TV 7 (15.58 no/bush), TV 23 (15.24 no/bush), TV 18 (15.38 no/bush) and TV 9 (15.21 no/bush). Similarly, the clones also exhibited significant difference for leaf area. Maximum leaf area was observed for TV 12, TV 2 and TV 23 with leaf area of 63.91, 50.95 and 47.03 cm^2, respectively whereas TV 7, TV 9, TV 18 and TV 1 had significant less leaf area of about 23.21, 36.87, 41.84, 42.24 cm^2 respectively.

10. In case of trichome density, the maximum number of trichome was observed in case of TV 2 (93.33/cm^2) which was significantly different from rest of the clones examined. This was followed by TV 18 (82.67 /cm^2) which was found

to be at par with TV 12 (79.33/cm^2), TV 7 (78.33 /cm^2) but differed significantly from TV 1 (68.67 /cm^2), TV 9 (71.33 /cm^2) and TV 23 (69.33 /cm^2). However, it was observed that TV 7 (78.33 /cm^2), TV 9 (71.33 /cm^2) and TV 23 (69.33 /cm^2) differed significantly from each other and the lowest number of trichome was observed in TV 1 (68.67 /cm^2) which were at par with TV 23 (69.33 /cm^2).

11. While studying the biochemical response of the selected clones to attack by the insect pests with special reference to the total phenol content, it was found that the phenol content generally decreased, the reduction being more in TV 23 (22.43%). This was followed by TV 1 (18.46%), TV 18 (11.86%), TV 7 (9.71%), TV 2 (5.26%) and TV 2 (5.11%) with lowest in TV 9 (4.46%). The differences in leaf moisture content for the examined tea clones were significant. Maximum moisture content was observed in TV 2 (89.32%) which significantly differed from TV 1 (84.91%), TV 12 (83.61 %), TV 23 (82.14%), TV 9 (80.77%) and TV 7 (37.50%). It was followed by TV 18 (87.50%) which was at par with TV 1 (84.91%) but varied significantly with TV 12 (83.61%), TV 23 (82.14%), TV 9 (80.77%) and TV 7 (37.50%). However, no significant difference was observed in between TV 12 (83.61%), TV 23 (82.14%) and TV 9 (80.77%).
12. The linear correlation among morphological and biochemical attributes of selected tea clones with pests showed that total no of branches and leaf area had a non significant negative correlation with *H. theivora* (r = - 0.664, -0.333), *O. coffeae* (r = -0.277, -0.175) and *Hyposidra* sp (r = -0.156, -0.179) while trichome density had significant negative correlation with *H. theivora* (r = -0.643) *O. coffeae* (r = -0.475) and *Hyposidra* sp (r = - 0.493). However, the moisture content showed a non significant positive correlation for *H. theivora*(r=0.064) but established a negative association with *O. coffeae* (r = -0.446*)* and *Hyposidra* sp (r = -0.370). With respect to insect pests,both the

reduction in phenol content and spider population showed a significant positive correlation.

13. A field experiment was conducted during the peak pest period of June, 2016 and June, 2017 to investigate the effect of pesticides on common insect pests and spider population in tea plantation. On the basis of the average data of two years observations recorded at 1st, 5th and 10th days after application of different pesticides revealed that all the treatments showed significant differences over control. Among the treatments thiomethoxam 25% WG @ 0.01% was found to be most effective against *H. theivora* followed by deltamethrin 2.8 EC @ 0.02% and azadirachtin @ 0.003% whereas spiromesifen 240 SC @ 0.2% was found to be least effective against *H. theivora* population. The pooled data on the efficacy of different pesticides on *O. coffeae* revealed spiromesifen 240 SC @ 0.2% as most effective followed by ethion 50EC @ 0.25%, deltamethrin 2.8 EC @ 0.02% and azadirachtin @ 0.003% whereas thiomethoxam 25% WG@ 0.01% @ was found to be least effective against *O. coffeae* population. Among all the treatments ethion 50EC @ 0.25% was found to be most toxic on spider population followed by deltamethrin 2.8 EC @ 0.02%. However, *B. bassiana* @ 2% was found to safer to spider population which was followed by azadirachtin 5 EC 0.003%.

CONCLUSION

The present study depicted a diverse fauna of spiders associated with the tea ecosystem and can form the base line for exploring the factors influencing spider diversity in tea ecosystem, *viz.* management types, effects of pesticides and availability of prey species. The study also demonstrated that no single factor was responsible for abundance of the spider populations in tea ecosystem, as various factors worked in compliment with each other for the same. The morphological and biochemical plant characters are important factors affecting the incidence of insect pests and hence, likely to influence the spider performance. Moreover, the spiders are variably affected by application of synthetic pesticides compared to organic. Therefore, in order to conserve the biodiversity of tea ecosystem with sustainable quality production of tea, we may integrate azadirachtin and *Beauveria bassiana* as one criterion in integrated pest management module which will also have implications in retaining the greatest number of spider populations.

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APPENDIX

GLOSSARY

Abdomen	Posterior region of spider body
Carapace	Hard dorsal covering of the cephalothorax
Cephalothorax	The anterior body region of a spider which is formed by the combination of head and thorax
Chelicerae	First pair of post oral appendages
Clypeus	Area between front row of eyes and the edge of the carapace
Conductor	A semi-membranous structure in the male palp which supports and guides the embolus in insemination
Dorsal	Upper surface
Ebolus	The structure, in the male palp, containing the terminal part of the ejaculatory duct and its opening. It may be very small, or long, whip-like or coiled and is sometimes divided into several structures.
Epigyne	External female genitalia
Femur	Third segment of padipalp and legs
Fovea	Depression of cephalothorax for attachment of muscles
Procurved	An imaginary line drawn through the centers of four eyes in a row to produce an arc in which the arms point forward
Palpal bulbs	Copulatory organ of a male spider
Recurved	An imaginary line drawn through the centers of four eyes in a row to produce an arc in which the arms point backward
Scape	A finger, tongue, or lip-likes projection from the midline of the female epigyne.
Spinneret	Abdominal appendages through which the silk is liberated and span
Stabilimentum	Thick white zig-zag band of silk placed on the web in order to strengthen it
Tubercle	A knob like or rounded protuberance
Ventral	Lower, underside

Indigenous Assam variety (*Camellia sinensis* var. *assamica* Master)	This variety grows into a small tree with a ramifying branch system along with a distinct trunk and grows upto a height of 15 m. Leaves are very large in size, thin, glossy with more or less acuminate apex, and distinct marginal veins. Leaf blade is usually broadly elliptic, margin obscurely denticulate to bluntly wide serrulate, glabrous, or persistently hairy on the mid rib below. Flower are single or in pairs on the leaf axis. This variety is grown in the plains of Assam from which characteristic high quality Assam tea is produced
China tea plant (*Camellia sinensis* var.*sinensis* L)	This variety was originally introduced from China and now grown only in Darjeeling district of West Bengal, generally grow into a big shrub, about 1-3 m. high, with numerous stems arising from the base of the bush near the ground level, giving a dome shaped bush canopy. Leaves are erect, small, leathery and thick, marginal veins indistinct. This variety of tea produced the famous Darjeeling flavours and aroma which makes it popular among the consumers
Cambod form (*Camellia assamica* sub sp. *Lasiocalyx* Planch)	It is a medium size plant grows up to 8 m. height with several upright, almost equally developed branches. Leaves are erect glossy, yellowish green when young, light green at maturity, often turning into coppery yellow or pinkish red from autumn till the end of the season. This character becomes more prominent in the young leaves of seedlings. Petiole is pinkish red at the base, leaf size intermediate between the Assam and China varieties, broadly elliptic, marginal veins not very prominent

Table 3. 1 List of surveyed tea gardens of Jorhat district during 2016-17

Sl. No	Name of the garden	Management type	Location (Village)	Location (Latitude and longitude)
1	AAU Experimental garden	CG	AAU	26°71‘ N & 94°19‘ E
2	Dholi T.E.	CG	Titabar	26°77‘ N & 94°35‘ E
3	Deha T.E.	OMG	Ladoigarh	26°61‘ N & 94°23‘ E
4	Bordoloi T.E.	OMG	kachogaral	26°75‘ N & 94°25‘ E
5	Saikia T.E.	SM 1	Garaihabi	26°61‘ N & 94°20‘ E
6	Gogoi T.E.	SM 2	Titabar	26°78‘ N & 94°29‘ E

*** CG: Conventional garden, OMG: Organically managed garden, SM: Small-grower tea garden.**

Plate 1 Map of Jorhat showing study areas (Source: www.googleearth.com)

Plate 2 Ariel view of experimental plot for plantation crop AAU-Jorhat

Plate 3 Layout of Experimental plot for plantation crop AAU-Jorhat

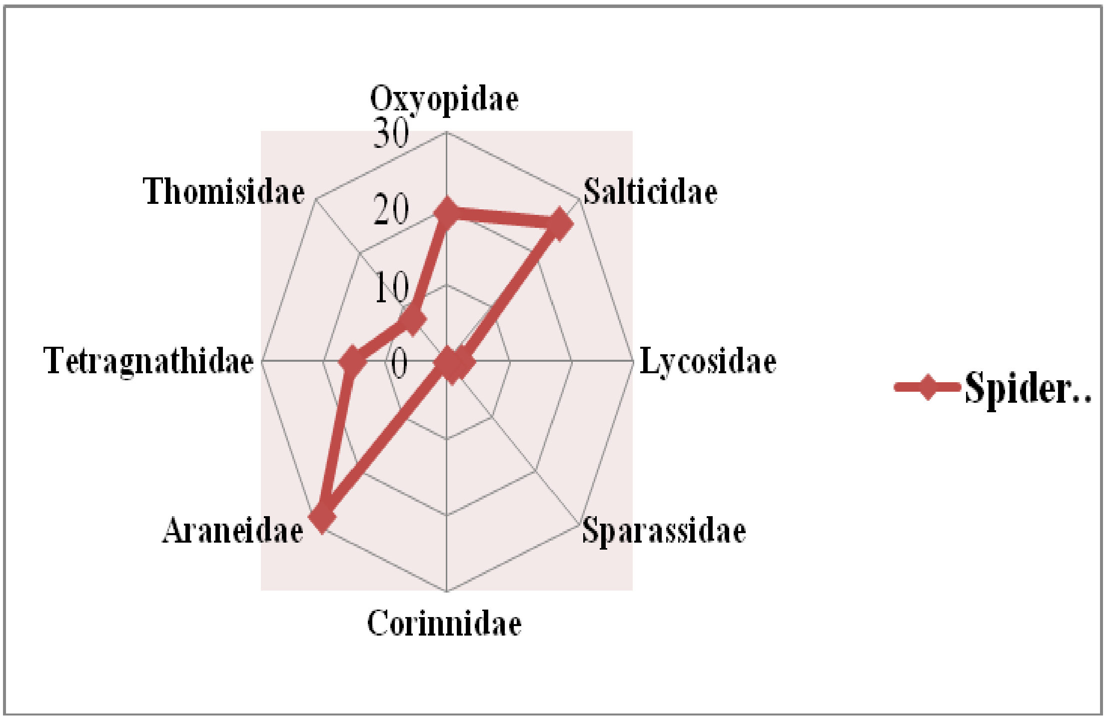

Fig.4.1 Relative abundance of different families of spider in tea gardens of Jorhat during May' 2016-April' 2017

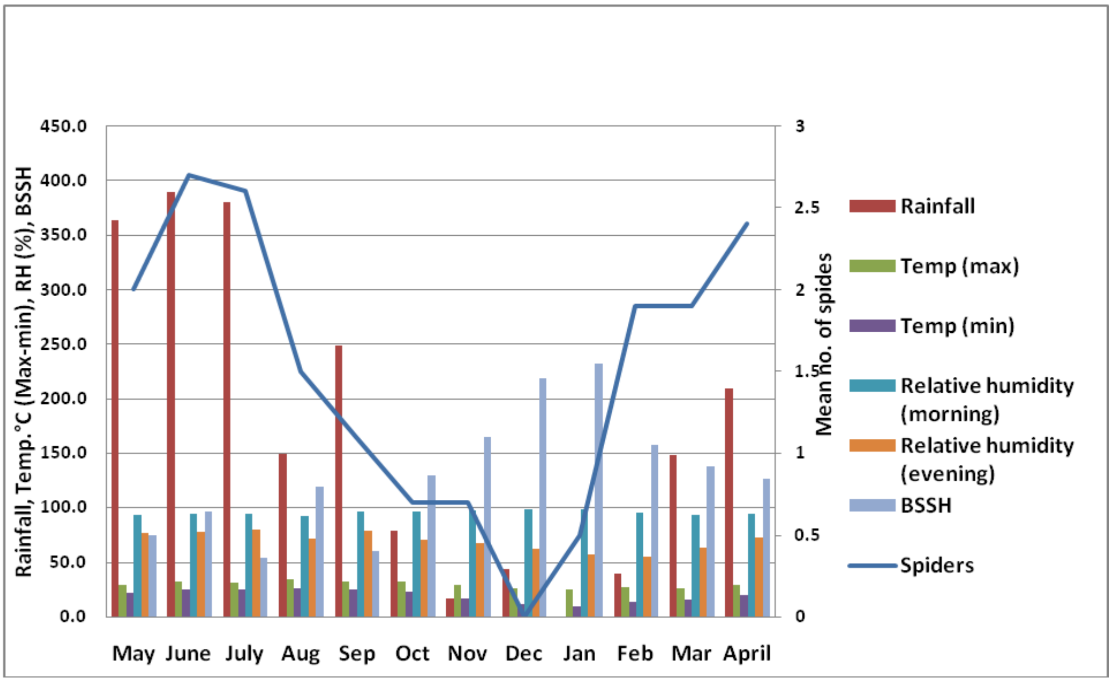

Fig.4.2 Seasonal incidence of spider population in relation to different weather parameters during May' 2016-April' 2017

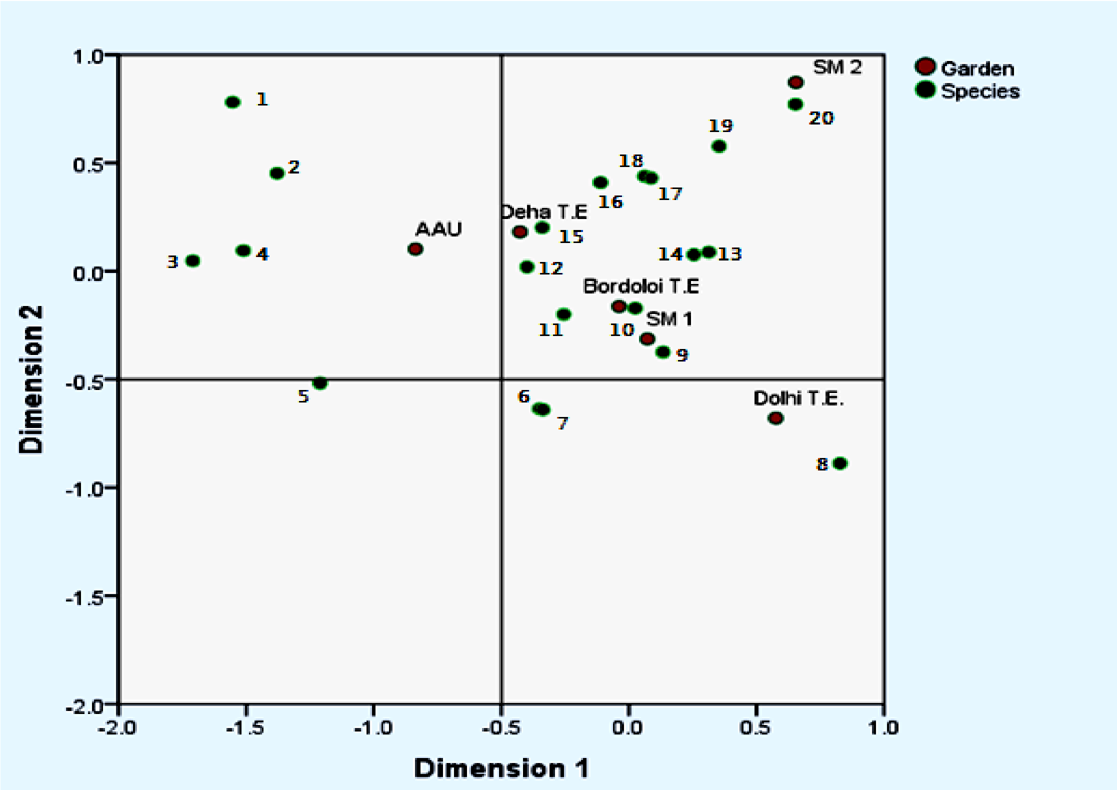

Fig.4.3 Correspondence Analysis of different tea gardens of Jorhat district

Key to species:

1. *Castianeira furva*
2. *Neoscona* sp
3. *Cyrtophora cicatrosa*
4. *Heteropoda ventoria*
5. *Nephila kuhuli*
6. *Cyclosa mulmeinensis*
7. *Araneus mitifica*
8. *Telamoniua dimidiata*
9. *Oxyopes* sp
10. *Rhene danieli*
11. *Perdosa peaudoannulata*
12. *Cyclosa bifida*
13. *Tetragnatha* sp
14. *Cyclosa spirifera*
15. *Argiope pulchella*
16. *Xysticus* sp
17. *Phintella vittata*
18. *Leucauge decorata*
19. *Oxyopes shweta*
20. *Oxyopes sitae*

Table 4.1 Collected spiders from tea plantation of Jorhat during 2016-17

Sl.No	Family	Species
1.	Araneidae	*Cyrtophora cicatrosa* (Stoliczka, 1869)
		Nephila kuhlii (Doleschall, 1859)
		Neoscona sp (Simon, 1864)
		Argiope pulchella (Thorell 1881)
		Cyclosa mulmeinensis (Thorell, 1887)
		Cyclosa spirifera (Simon, 1889)
		Cyclosa bifida (simon, 1895)
		Araneus mitifica (Simon, 1909)
2.	Oxyopidae	*Oxyopes sitae (*Tikader, 1970*)*
		Oxyopes shweta (Tikedar, 1970)
		Oxyopes sp (Latreille, 1804*)*
3.	Salticidae	*Rhene danieli* (Tikader, 1973)
		Phintella vittata (Koch, 1846)
		Telamonia dimidiata (Simon, 1899)
4.	Tetragnathidae	*Tetragnatha* sp (Latreille, 1804)
		Leucauge decorata (Blackwell, 1864)
5.	Sparassidae	*Heteropoda ventoria (*Linnaeus, 1767*)*
6.	Corinnidae	*Castianeira furva* (Sankaran, Malamel, Joseph & Sebastian, 2015)
7.	Thomisidae	*Xysticus* sp (Koch ,1835)
8.	Lycosidae	*Perdosa peaudoannulata* (Boesenberg et Strand, 1906)

Table 4.22 Diversity of spiders in different tea gardens of Jorhat district during 2016-17

Name of garden	Management type*	Species richness (R)	Species diversity (H')	Evenness (E)
Dholi T.E.	CG	2.89	2.88	0.95
AAU Experimental garden	CG	2.78	2.64	0.89
Deha T.E.	OG	3.07	2.84	0.96
Bordoloi T.E.	OG	2.92	2.79	0.93
Saikia T.E.	SM 1	2.51	2.55	0.89
Gogoi T.E.	SM 2	2.65	2.60	0.91

* CG: Conventional garden, OMG: Organic garden, SM: Small-grower tea garden.

Table 4.23 Correlation between spider population and weather parameters during May, 2016-April, 2017

Weather	Correlation coefficient
Total rainfall (mm)	0.776**
Maximum temperature (°C)	0.330
Minimum temperature (°C)	0.519
Morning Relative humidity (%)	-0.797**
Evening Relative humidity (%)	0.458
BSSH	-0.676*

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 4.26 Distribution pattern of different spider species in small grower garden

Species	Variance to mean ratio (S^2/X)	Lloyds index X*/x	Distributional pattern
Neoscona sp	3.42	4.23	Contagious
Tetragnatha sp	2.97	1.31	Contagious
Oxyopes sitae	5.32	1.57	Contagious
Nephila kuhuli	0.91	0.86	Regular
Oxyopes shweta	3.48	1.43	Contagious
Rhene danieli	4.76	1.54	Contagious
Argiope pulchella	2.71	1.43	Contagious
Cyclosa mulmeinensis	1.27	1.04	Contagious
Oxyopes sp	4.48	1.50	Contagious
Phintella vittata	4.73	1.63	Contagious
Heteropoda venatoria	10.25	2.04	Contagious
Leucauge decorate	10.25	2.04	Contagious
Xysticus sp	2.43	1.38	Contagious
Cyrtophora cicatrosa	2.64	7.54	Contagious
Cyclosa bifida	3.48	3.12	Contagious
Cyclosa spirifera	3.00	1.05	Contagious
Araneus mitifica	2.98	1.62	Contagious
Perdosa peaudoannulata	4.17	1.54	Contagious
Telamonia dimidiata	5.03	1.77	Contagious

Table 4.24 Distribution patterns of different spider species in conventional garden

Species	Variance to mean ratio (S^2/X)	Lloyds index X*/x	Distributional pattern
Neoscona sp	7.68	3.42	Contagious
Tetragnatha sp	3.94	1.54	Contagious
Oxyopes sitae	5.66	2.05	Contagious
Nephila kuhuli	0.77	0.91	Regular
Oxyopes shweta	3.65	1.64	Contagious
Rhene danieli	2.29	1.20	Contagious
Argiope pulchella	3.70	1.53	Contagious
Cyclosa mulmeinensis	4.69	2.03	Contagious
Oxyopes sp	5.81	1.79	Contagious
Phintella vittata	8.77	2.19	Contagious
Heteropoda ventoria	5.62	5.26	Contagious
Leucauge decorata	5.36	1.58	Contagious
Xysticus sp	3.24	1.51	Contagious
Cyrtophora cicatrosa	7.02	3.40	Contagious
Cyclosa bifida	5.82	3.88	Contagious
Cyclosa spirifera	4.28	1.67	Contagious
Castianeira furva	3.09	13.54	Contagious
Araneus mitifica	6.06	1.93	Contagious
Perdosa peaudoannulata	5.97	1.68	Contagious
Telamonia dimidiata	36.52	3.61	Contagious

Table 4.25 Distribution pattern of different spider species in organic garden

Species	Variance to mean ratio (S^2/X)	Lloyds index X*/x	Distributional pattern
Neoscona sp	2.78	2.42	Contagious
Tetragnatha sp	4.41	1.73	Contagious
Oxyopes sitae	3.92	1.94	Contagious
Nephila kuhuli	0.91	0.81	Regular
Oxyopes shweta	3.98	1.77	Contagious
Rhene danieli	3.23	1.54	Contagious
Argiope pulchella	2.53	1.35	Contagious
Cyclosa mulmeinensis	3.54	1.58	Contagious
Oxyopes sp	2.91	1.34	Contagious
Phintella vittata	5.30	1.72	Contagious
Heteropoda ventoria	4.78	4.48	Contagious
Leucauge decorata	6.13	2.09	Contagious
Xysticus sp	4.27	2.12	Contagious
Cyrtophora cicatrosa	3.03	2.14	Contagious
Cyclosa bifida	2.39	1.50	Contagious
Cyclosa spirifera	4.37	2.03	Contagious
Araneus mitifica	3.09	13.54	Contagious
Perdosa peaudoannulata	2.38	1.36	Contagious
Telamonia dimidiata	4.74	1.58	Contagious

Table 4.27 Mean population of insect pests and spider population in different TV clones during 2016-2017

Tea variety	**Number /bush/leaf**			
	H. theivora	***O. coffeae***	***Hyposidra* sp**	**Spider**
TV1	4.60	13.71	3.03	1.08
TV2	2.12	12.74	2.63	1.06
TV7	2.15	13.87	2.38	0.93
TV9	2.60	11.75	2.54	0.95
TV12	4.22	12.52	2.25	0.94
TV18	3.03	13.63	1.99	0.81
TV23	6.22	18.35	3.43	1.57
SEd	0.40	1.32	0.40	NS
CD (P=0.05)	0.91	2.82	0.87	NS

Mean of 30 Observations

Table 4.28 Comparison of different morphological parameters amongst the TV clones

Clones Physical Characters	No of branches/bush	Leaf area (cm2)	Trichome density (no/cm^2)
TV1	14.27	42.24	68.67
TV2	7.33	50.95	93.33
TV7	15.58	23.21	78.33
TV9	15.21	36.87	71.33
TV12	8.40	63.91	79.33
TV18	15.38	41.84	82.67
TV23	15.24	47.03	69.33
SEd	1.41	4.22	2.35
CD.05	3.03	9.03	5.03

Mean of five observations

Table 4.29 Comparison of biochemical parameters amongst the TV clones

Clones	Phenol content mg/gm leaf			Leaf moisture content (%)
	Healthy	Infested	Reduction%	
TV1	0.325	0.265	18.46	84.91
TV2	0.342	0.324	5.26	89.32
TV7	0.391	0.353	9.71	37.50
TV9	0.336	0.321	4.46	80.77
TV12	0.352	0.334	5.11	83.61
TV18	0.354	0.312	11.86	87.50
TV23	0.312	0.242	22.43	82.14
SEd	-	-	-	2.25
CD.05	-	-	-	4.82

*Mean of five observations**

Table 4.30 Correlation between insect pests incidence with morphological and biochemical characters of TV clone

Correlation matrix	No of Branches	Leaf area (cm^2)	Trichome density (no/cm^2)	Moisture content	Phenol content
H. theivora	-0..664	-0.333	-.643**	0.064	0.766*
O. coffeae	-0.277	-0.175	-.475*	-0.446	0.866*
***Hyposidra* sp**	-0.156	-0.179	-.493*	-0.370	0.760*

*__Correlation is significant at the 0.05 level (2-tailed).__

**** Correlation is significant at the 0.01 level (2-tailed).**

Table 4. 31 Correlation between spiders and major insect pests of tea

Correlation matrix	***H. theivora***	***O. coffeae***	***Hyposidra* sp**
Spider	0.764*	0.858*	0.919*

***Correlation is significant at the 0.05 level (2-tailed).**

Table: 4.32 Effect of pesticides on *H. theivora* in tea plantation during 2016

Treatments	Dose	Post Count (no./bush)			
		Precount	**1DAS**	**5DAS**	**10DAS**
Ethion 50EC	0.25%	6.97	2.93	3.40	3.53
Spiromesifen 240 SC	0.2%	6.00	3.10	3.67	4.07
Deltamethrin 2.8 EC	0.02%	5.83	0.73	2.27	2.96
Thiomethoxam 25% WG	0.01%	5.50	0.43	2.00	2.50
Biosona (*Beauveria bassiana)*	2%	5.80	2.40	3.03	3.50
Azadirachtin 5 EC	0.003%	6.07	0.93	2.57	3.26
Control	-	6.43	6.10	6.67	7.00
SEd	-	-	0.37	0.47	0.57
CD (P=0.05)	-	-	0.79	1.00	1.22

Mean of 3 replications

Table 4.33 Effect of pesticides on *H. theivora* in tea plantation during 2017

Treatments	Dose	Precount	Post Count (no/bush)		
			1DAS	**5DAS**	**10DAS**
Ethion 50EC	0.25%	4.93	2.13	2.73	3.00
Spiromesifen 240 SC	0.2%	4.73	2.27	3.20	3.73
Deltamethrin 2.8 EC	0.02%	5.13	0.47	2.67	2.33
Thiomethoxam 25% WG	0.01%	4.83	0.20	1.60	2.27
Biosona (*Beauveria bassiana)*	2%	4.80	2.07	2.60	3.60
Azadirachtin 5 EC	0.003%	4.97	0.67	2.47	2.80
Control	-	5.07	5.60	6.20	6.40
SEd	-	0.37	0.38	0.46	0.50
CD (P=0.05)	-	NS	0.83	0.99	1.07

Mean of 3 replications

Table 4.34 Effect of pesticides on *H. theivora* in tea plantation (Pooled)

Treatments	Dose	Precount	Post Count (no/bush)		
			1DAS	**5DAS**	**10DAS**
Ethion 50EC	0.25%	5.95	2.63	3.20	3.27
Spiromesifen 240 SC	0.2%	5.37	3.22	3.70	3.90
Deltamethrin 2.8 EC	0.02%	5.48	0.83	2.68	2.80
Thiomethoxam 25% WG	0.01%	5.17	0.48	2.13	2.38
Biosona (*Beauveria bassiana)*	2%	5.30	2.40	3.05	3.15
Azadirachtin 5 EC	0.003%	5.52	1.00	2.60	3.12
Control	-	5.75	5.52	5.90	6.40
SEd	-	0.37	0.19	0.23	0.27
CD (P=0.05)	-	NS	0.42	0.49	0.59

Mean of 3 replications

Table 4.35 Effect of pesticides on *O. coffeae* in tea plantation during 2016

Treatments	Dose	Post Count (no/leaf)			
		Precount	**1DAS**	**5DAS**	**10DAS**
Ethion 50EC	0.25%	38.88	6.56	17.55	24.23
Spiromesifen 240 SC	0.2%	39.86	2.35	12.67	20.00
Deltamethrin 2.8 EC	0.02%	41.55	16.73	26.19	30.34
Thiomethoxam 25% WG	0.01%	43.55	26.84	31.86	36.12
Biosona (*Beauveria bassiana)*	2%	42.26	22.84	26.56	30.90
Azadirachtin 5 EC	0.003%	42.75	14.37	21.74	28.14
Control	-	43.30	45.30	46.88	47.32
SEd	-	-	2.80	2.44	1.74
CD (P=0.05)	-	-	6.00	5.23	3.73

Mean of 3 replications

Table 4.36 Effect of pesticides on *O. coffeae* in tea plantation during 2017

Treatments	**Dose**	**Post Count (no/leaf)**		
		1DAS	**5DAS**	**10DAS**
Ethion 50EC	0.25 %	8.23	17.29	22.84
Spiromesifen 240 SC	0.2 %	2.56	12.48	16.59
Deltamethrin 2.8 EC	0.02 %	13.00	19.05	23.94
Thiomethoxam 25% WG	0.01%	19.77	25.08	28.35
Biosona (*Beauveria bassiana)*	2%	22.88	23.96	27.01
Azadirachtin 5 EC	0.003 %	13.56	19.01	24.96
Control	-	35.22	39.00	40.31
SEd	-	1.79	2.72	1.80
CD (P=0.05)	-	3.83	5.83	3.86

Mean of 3 replications

Table 4.37 Effect of pesticides on *O. coffeae* in tea plantation (pooled)

Treatments	Dose	Precount	Post Count (No./bush)		
			1DAS	5DAS	10DAS
Ethion 50EC	0.25%	38.22	7.40	17.42	23.53
Spiromesifen 240 SC	0.2%	39.06	2.46	12.58	18.29
Deltamethrin 2.8 EC	0.02%	39.39	8.80	20.43	26.60
Thiomethoxam 25% WG	0.01%	40.05	18.14	27.09	30.92
Biosona (*Beauveria bassiana)*	2%	40.19	22.86	25.26	29.75
Azadirachtin 5 EC	0.003%	43.35	13.96	20.38	28.06
Control	-	40.80	38.56	39.28	40.19
SEd	-	-	0.08	1.80	1.22
CD (P=0.05)	-	-	1.72	3.85	2.62

Mean of 3 replications

Table 4.38 Effect of pesticides on spiders in tea plantation 2016

Treatments	Dose	Post Count (No./bush)			
		Precount	**1DAS**	**5DAS**	**10DAS**
Ethion 50EC	0.25%	0.70	0.13	0.37	0.40
Spiromesifen 240 SC	0.2%	0.60	0.27	0.47	0.53
Deltamethrin 2.8 EC	0.02%	0.73	0.20	0.40	0.47
Thiomethoxam 25 WG	0.01%	0.67	0.23	0.43	0.50
Biosona (*Beauveria bassiana)*	2%	0.63	0.47	0.57	0.67
Azadirachtin 5 EC	0.003%	0.77	0.40	0.50	0.57
Control	-	0.70	0.73	0.80	0.83
SEd	-	-	0.08	0.08	0.09
CD (P=0.05)	-	-	0.18	0.18	0.19

Mean of 3 replications

Table 4.39 Effect of pesticides on spiders in tea plantation during 2017

Treatments	Dose	Precount	Post Count (No./bush)		
			1DAS	5DAS	10DAS
Ethion 50EC	0.25%	0.63	0.03	0.27	0.33
Spiromesifen 240 SC	0.2%	0.57	0.27	0.43	0.50
Deltamethrin 2.8 EC	0.02%	0.63	0.17	0.33	0.37
Thiomethoxam 25% WG	0.01%	0.60	0.20	0.37	0.40
Biosona (*Beauveria bassiana)*	2%	0.63	0.40	0.50	0.63
Azadirachtin 5 EC	0.003%	0.67	0.30	0.47	0.57
Control	-	0.63	0.67	0.73	0.73
SEd	-	-	0.06	0.05	0.06
CD (P=0.05)	-	-	0.14	0.12	0.14

Mean of 3 replications

Table 4.40 Effect of pesticides on spiders in tea plantation (pooled)

Treatments	Dose	Precount	Post Count (No./bush)		
			1DAS	**5DAS**	**10DAS**
Ethion 50EC	0.25%	0.67	0.08	0.37	0.37
Spiromesifen 240 SC	0.2%	0.58	0.27	0.43	0.52
Deltamethrin 2.8 EC	0.02%	0.68	0.18	0.38	0.40
Thiomethoxam 25% WG	0.01%	0.63	0.22	0.40	0.42
Biosona (*Beauveria bassiana)*	2%	0.65	1.03	0.58	0.65
Azadirachtin 5 EC	0.003%	0.72	0.50	0.47	0.57
Control	0.25%	0.67	0.70	0.77	0.78
SEd	-	-	0.16	0.05	0.06
CD (P=0.05)	-	-	0.35	0.11	0.13

Mean of 3 replications