



**SEASONAL ABUNDANCE AND DIVERSITY OF INSECT
PESTS AND THEIR NATURAL ENEMIES IN LOWLAND
RICE AGROECOSYSTEM UNDER DIMAPUR DISTRICT
OF NAGALAND**

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

By

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DISTRICT OF NAGALAND**

by

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Submitted

In partial fulfillment of the requirements for the Degree of Doctor of
Philosophy in
Entomology of Nagaland University.

Nagaland University
March 2025

I, J. Akato Chishi, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this Thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other University/Institute.

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CERTIFICATE – I

This is to certify that the thesis entitled **“Seasonal abundance and diversity of insect pests and their natural enemies in lowland rice agroecosystem under Dimapur district of Nagaland”** submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Entomology is the record of research work carried out by Mr. J. Akato Chishi, Registration No. Ph.D/ENT/00333, under my personal supervision and guidance.

The result of the investigation reported in the thesis has not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

**VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN
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This is to certify that the thesis entitled “**Seasonal abundance and diversity of insect pests and their natural enemies in lowland rice agroecosystem under Dimapur district of Nagaland**” submitted by Mr. J. Akato Chishi, Admission No. Ph-284/19 Registration No. Ph.D/ENT/00333 to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Entomology has been examined by the Advisory Board and External examiner on

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ABSTRACT

The study **"Seasonal abundance and diversity of insect pests and their natural enemies in lowland rice agroecosystem under Dimapur district of Nagaland"** was conducted across three locations: Singrijan, Medziphema, and Kuhoxu, during the rice-growing seasons of 2020 and 2021. The investigation observed 32 insect pest species from five insect orders and 57 natural enemies from 10 orders. Species diversity was quantified using Shannon-Weiner and Simpson's Diversity Indices, with Medziphema exhibiting the highest diversity for insect pests ($H' = 2.60$) and Singrijan for natural enemies ($H' = 2.06$). Beta diversity calculations confirmed substantial species overlap across locations, with minimal turnover in both insect pests and natural enemy populations. Dominant pests across the sites included *Nilaparvata lugens*, *Nephotettix virescens*, and *Sogatella furcifera*, while Hymenoptera, Coleoptera, and Arachnida emerged as the most abundant natural enemy groups. The relative abundance of pests and natural enemies fluctuated seasonally, with peak populations for pests like *Nilaparvata lugens* between weeks 30 and 45, and for natural enemies, particularly Hymenoptera, in late-season months. The study also examined the role of weather parameters in shaping pest dynamics, revealing that temperature and relative humidity had distinct impacts on pest populations, with several species showing strong negative correlations to temperature, while others thrived under warmer conditions. Rainfall showed mixed effects, with pests such as *Sitophilus oryzae* and *Cofana spectra* negatively impacted by excess moisture, while species like *Scirpophaga incertulas* and *Sogatella furcifera* responded positively under specific rainfall conditions. The findings highlight the intricate relationship between pest populations and their natural enemies. Significant positive correlations were observed between these pests and natural enemies groups, particularly Odonata (Zygoptera and Anisoptera) and Hymenoptera. These correlations indicate that predator abundance tends to increase in response to higher pest densities. The study further explored other predator groups, including Coleoptera, Orthoptera, and Arachnida, revealing varied interactions across different pest species and natural enemies. A comprehensive study was also carried out where

27 insect pest species and 48 natural enemies were examined for key morphometric traits including body lengths, wing lengths, head lengths and widths, thorax length and width, antennae length and leg morphology with comparisons to previous studies to ensure accuracy and account for geographic or ecological variation. The data provides a baseline reference for understanding species diversity and physical variations within rice field ecosystems in this region.

Keywords: Insect pests, natural enemies, diversity, seasonal abundance, Morphometric.

CHAPTER I

INTRODUCTION

INTRODUCTION

In India, 47.82 million ha is occupied for rice cultivation producing 137.83 million tonnes with a productivity of 2,882 Kg/ha (Agricultural Statistics at a glance, 2023). Rice is grown under diverse soil and climatic conditions in our country with the major being produced during *Kharif* season and occupies an important position as one of the most essential food crops feeding more than 60 per cent of India's population.

Agriculture is also a mainstay for the people of Nagaland with rich traditional practices and diverse history. Rice is the main crop cultivated with a production of 5.54 lakh metric tonnes from an area of 2.11 lakh ha (Nagaland statistical handbook, 2023). It is grown as both upland/*Jhum* under rainfed condition and wetland during the *kharif* season.

A cereal food plant of the family Poaceae, Rice (*Oryza sativa* L.) is cultivated under a wide range of climatic conditions of temperature and rainfall, mostly in South and South-East Asian countries. There are about 1,20,000 rice varieties grown across the world in an extensive range of climate, soil and water conditions (Babu *et al.*, 2006). It is also the only cereal crop that is known to thrive on standing water passing through three growth stages viz., vegetative (germination to panicle initiation), reproductive (panicle development to flowering) and ripening (milk grain to mature grain).

The vegetative and reproductive stages of rice crop are represented by the aquatic phase of the rice field while the semi-aquatic and terrestrial dry phases correspond to the grain ripening stage. Consequently, a rice field agro ecosystem goes through three major ecological phases: aquatic, semi-aquatic and terrestrial dry phase during a single crop cycle (Fernando, 1995) supporting a great biodiversity of flora and fauna, insect pests and their natural enemies being among them.

The eight states i.e; Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura make up the Northeast Hill Region (NEHR) and occupies 7.7 percent of India's total geographical area supporting 50 percent of

the flora (Rao 1994), of which 31.58 percent is endemic. This diversity in flora also supports great diversity of fauna, of which insects are the dominant.

Chatterjee *et al.* (2006) has described that due to the importance of the NEHR, Conservation International has up scaled the Eastern Himalaya Hotspot which initially covered the states of Arunachal Pradesh, Sikkim, Darjeeling Hills, Bhutan, and Southern China to the Indo Burma Hotspot (Myer *et al.*, 2000) which now includes all the eight states of North-East India, along with the neighboring countries of Bhutan, southern China and Myanmar.

Rice is the staple food crop for the people of this region and is grown extensively in valleys, terraces, uplands, hills and jhum. It is found that the rice crop in this region is host to many species of insects with a few causing severe economic damage leading from 20 percent yield losses to complete failure of the crop during epidemics (Thakur *et al.*, 2012). The major insect pests in the region has been described as yellow stem borer, leaf folder, case worm, hispa, gundhi bug, swarming caterpillar, thrips, gall midge, and army worm (Shylesha *et al.*, 2006). There is also a rich biodiversity of natural enemies in rice agroecosystem playing a major role in keeping a check on the population of these insect pests in the region.

Zhimomi and Ao, 2011, described 46 species of natural enemies belonging to 39 genera with 32 families of 9 taxa while carrying out trials on arthropod diversity in rice agroecosystem. The most dominant being from the families of Carabidae, Coccinellidae, Cicindellidae, libellulidae, Coenagrionidae, Lycosidae, Salticidae, Oxyopidae and Tetragnathida.

Identification of these specimens at the species level is necessary for understanding the diversity of the species, phylogenetic patterns, and evolutionary relationships (Platnick, 2014) for which morphological traits are used traditionally for the identification of insect pests (Jinbo, *et al.*, 2011) and continue to be widely practiced and accepted by the scientific community.

Insect pests of rice are known to be affected by climate change. Changes in temperature and precipitation as well as changes in the quality of host plants have

been known to have an effect on insects. Insect interactions with their host plants, competitors and natural enemies are altered by such changes in the environment and influence their ability to adapt to the changing climatic conditions. Rath *et al.* (2020) mentions that the insect pest scenario of the crop gradually changes with gradual changes in crop cultivation practices and climate change, especially the higher temperature and that several major pests have become minor and many minor pests attained the status of major pests. This has led to new pests shifting the host and also occurrence of some invasive pests due to change in their habitat.

Rice is the most important field crop in NEHR and exhibits a good example of changing insect pest scenario due to climate change and host alteration. This also results in alteration of their natural enemies which needs to be monitored on a time scale. Considering its importance to the people of NEHR and the ever-changing crop pest scenario, it is felt that documentation is necessary to study the seasonal abundance and diversity of insect pests and its natural enemies in the rice agro ecosystem. Consequently, the present investigation was undertaken with the following objectives:

1. To study the seasonal abundance and diversity of major insect pests in lowland rice agro ecosystem and their correlation with weather parameter,
2. To study the seasonal abundance and diversity of natural enemies and their correlation with insect pest population in lowland rice agro ecosystem,
3. To study the morphometric characteristics of major insect pests and natural enemies in lowland rice agro ecosystem.

CHAPTER II
REVIEW OF LITERATURE

REVIEW OF LITERATURE

This chapter reviews the literatures of work conducted by various researchers to highlights the present research investigation on **“Seasonal abundance and diversity of insect pests and their natural enemies in lowland rice agroecosystem under Dimapur district of Nagaland”**.

2.1. Diversity of insect pests and natural enemies in rice

Karim and Riazuddin (1999) presented a list of 52 insect pests from rice crops. They briefly described their identification, biology, control methods and future control strategies of major pests of rice.

Zahir *et al.* (2003) documented a total of 355 insect species associated with rice crops. These insects were categorized into plant feeders, non-rice plant feeders, predators, and parasitoids. Their study highlighted the significant role of non-rice plant feeders in sustaining natural enemies early in the crop cycle. They concluded that the rice ecosystem supports a highly diverse and abundant community of plant feeders and their natural enemies, fostering a stable ecological balance between them.

Bambaradeniya *et al.* (2004) conducted a survey in the rice field ecosystem, documenting 494 invertebrate species across 10 phyla and 103 vertebrate species. Arthropods were the dominant invertebrate group (405 species), including 55 rice insect pest species and 200 natural enemy species.

A survey of spiders in irrigated rice fields in central Kerala was conducted by Sebastian *et al.* (2005) and recorded a total of 1,130 individual spiders belonging to 92 species, 47 genera, and 16 families. Araneidae and Tetragnathidae were the dominant families, with *Tetragnatha mandibulata* Walckenaer 1842 (Tetragnathidae) being the most abundant species. Orb weavers were also dominant across all study sites.

Khan (2006) recorded a total of 39 species of spiders belonging to 18 genera under 9 families were recorded. Out of these, 11 species of Lycosidae, 5 species of Salticidae, 3 species of Clubionidae and 5 species of Oxyopidae were hunting spider. Four species of Thomisidae were ambushing spider. Five species of Araneidae, one species of Theridae, 4 species of Tetragnathidae, one species of Uloboridae were web building.

Wilby *et al.* (2006) conducted a series of studies to understand the land-use and management control crop-associated biodiversity. They reported on relationships between land-use variables and arthropod community attributes such as species diversity, abundance and guild structure across a diversification gradient in a rice-dominated landscape in the Mekong delta, Vietnam. They concluded that the rice habitats contained the most diverse arthropod communities, compared with other uncultivated and cultivated land-use types.

Zhimomi (2006) while recording predatory fauna of rice in Nagaland, observed 13 species of spiders, 4 damselflies/dragonflies, 3 predatory beetles and 1 predator belonging to order Diptera.

Rani *et al.* (2007) documented the occurrence of three rice leaf folder species: *Cnaphalocrocis medinalis* (Guenée), *Marasmia patnalis* (Bradley), and *Marasmia ruralis* (Walker), with *C. medinalis* being the most dominant. The incidence of *M. ruralis* was minimal but observed year-round. Several natural enemies were prevalent in the rice ecosystem, including the egg parasitoid *Trichogramma* spp.; larval parasitoids *Cardiochiles philippinensis* Ashm., *Apanteles* sp., *Goniozus* sp., *Copidosomopsis nacoieiae* Eady, and *Trichomma cnaphalocrocis* Uchida; the pupal parasitoid *Xanthopimpla flavolineata* Cameron; and *Brachymeria* sp., which parasitizes both larvae and pupae.

Nasiruddin and Roy (2012) conducted a survey of rice field insect pests during the rice growing seasons and recorded 35 species belonging to 30 genera under 13 families under four economically important insect orders. These were: order Hemiptera-five families with 14 species, order Orthoptera-four families with 9

species, order Lepidoptera-three families with 11 species and order- Coleoptera-one family with one species.

Ohwaki (2015) evaluated the ground arthropod communities in paddy fields during the dry early November and early May and recorded a total of 202 ground arthropods belonging to 18 taxa, with eight taxa identified at the species level. The most abundant taxa were two predator groups, spiders and carabid beetles. He suggested that during the dry period paddy fields contained abundant predatory arthropods, and that the communities and noted that these predators are important natural enemies of rice pests.

Bakar and Khan (2016) assessed insect pests and natural enemy diversity in the rice ecosystem, finding variations across treatments and crop growth stages. Among insect pests, the untreated control had the highest diversity index (1.67) at the maximum tillering stage, while the spray treatment (*Bipolar 55EC @ 10 ml/10 L water*) combined with perching at the early tillering stage showed the highest species richness (26.14). The highest evenness (0.921) was observed in the spray treatment at the seedling stage, and the highest reciprocal Berger-Parker's Dominance index ($D = 3.03$) was recorded in the untreated control at the maximum tillering stage. For natural enemies, perching resulted in the highest diversity index (1.88) at the reproductive stage. The early tillering stage under insecticide spray showed the highest richness (5.06), while perching at the seedling stage had the highest evenness (0.982). The highest dominance index ($D = 4.67$) for natural enemies was recorded in perching at the reproductive stage.

Chakraborty *et al.* (2016) investigated the occurrence of natural enemies of insect pests of paddy and recorded total of 49 predators and 7 parasitoid. In predatory guild, spiders were dominant group occupied over 41% which was followed by Coleoptera (29%), Hemiptera (8%), Odonata (8%), Diptera (5%), Hymenoptera (6%) and Neuroptera (2%).

Siregar *et al.* (2017) identified 1,365 individuals from 37 species, 24 families, and **8 orders**. The most abundant species were *C. medinalis* (178), *M. vittaticollis*

(83), *N. viridula* (81), *N. lugen* (78), *L. oratorius* (73), and *S. coarctata* (71). The highest numbers belonged to Crambidae (Lepidoptera), Gryllidae (Orthoptera), and Pentatomidae (Hemiptera). Biological indices calculated were Margaleff's richness (1.84), Menhinick's richness (0.79), Shannon-Wiener diversity index (2.26), evenness index (0.65), and Jaccard's similarity index (0.68). They found no significant differences between sampling sites or growth phases ($p>0.05$).

Borkakati *et al.* (2018) documented 16 spider species within the rice ecosystem. Among insect natural enemies, the dominant orders observed included Orthoptera, Coleoptera, Hemiptera, Diptera, Hymenoptera, and Dermaptera. Notable predatory species recorded were *Conocephalus longipennis*, *Agriocnemis femina*, *Micraspis crocea*, *Cicindela undulata*, and *Cicindela melancholica*, which preyed on various rice pests. Additionally, the larval parasitoid *Cotesia (Apanteles) angustibasis* and the egg parasitoid *Trichogramma japonicum* were found to be more abundant in the rice ecosystem.

Meena *et al.* (2018) recorded 8 insect pests of paddy viz., Army worm, *Mythimna separate* (Walker); rice leaf folder, *Cnaphalocrocis medinalis* (Guenee), rice butterfly, *Melanitis leda ismene* (Cramer), rice gundhi bug, *Leptocorisa acuta* (Thunberg), green leaf hopper, *Nephotettix virescens* (Distant), short horned grass hopper, *Tetrix subulata* (Linnaeus), field cricket, *Euscyrtus concinnus* (de Haan), and mole cricket, *Gryllotalpa orientalis* (Burmeister).

Kathirvelu (2019) assessed the diversity of parasitic fauna in a conventional rice ecosystem and recorded a total of 889 parasitoids collected through net sweeps, 631 using a Malaise trap, 534 in a yellow pan trap, and 308 in a UV light trap. A total of thirteen agriculturally important parasitic families were identified, with Ichneumonidae, Braconidae, Scelionidae, and Chalcididae being the most predominant.

Rahaman and Stout (2019) recorded *Micraspis discolor*, *Lycosa pseudoannulata*, *Ophionea indica*, *Forticula auricularia*, *Cyrtorhinus lividipennis* and *Agriocnemis pygmaea* as predators and *Trichogramma japonicum*, *Telenomus*

rowani and *Tetrastichus schoenobii* as important parasitoids of *Scirpophaga incertulas* (Walker).

Shyamrao *et al.* (2019) recorded a total of 2,605 spiders belonging to fifteen species across six families. The family Araneidae (orb weavers) had the highest species composition with five species, followed by Tetragnathidae with four species, and Oxyopidae and Salticidae with two species each. The dominant spider species observed were *Neoscona theisi* (Walckenaer) accounting for 34%, *Neoscona mukerjei* (Tikader) at 12%, and *Leucauge decorata* (Blackwall) at 10%.

Anbalagan *et al.* (2020) observed the diversity of phytophagous and entomophagous insects in rice. In total, 45 species of phytophagous, and 70 species of entomophagous were recorded. Lepidopterans were in maximum number among phytophagous insects. Hymenoptera and Odonata were found to be the most important predatory insects.

A survey was conducted in different farmer's field by Das (2020) and recorded seven insect species viz., *Cnaphalocrocis medinalis* (Guenée), *Scirpophaga incertulas* (Walker), *Mythimna separata* (walker), *Leptocorisa* spp., *Nilaparvata lugens* (Stål), *Nephotettix nigropictus* (Stål) and *Nephotettix virescens* (Distant) as major pests. Leaf folder (*C. medinalis*) and yellow stem borer (*S. incertulas*) were found as highly abundant and dominant pest species.

Lisha *et al.* (2020) documented the presence of several insect pests in rice fields, including the yellow stem borer, leaf folder, grasshopper, green leafhopper, ear head bug, and white leafhopper. Additionally, the study recorded various natural enemies belonging to the families Braconidae, Ichneumonidae, Trichogrammatidae, Platygasteridae, Eulophidae, Chalcididae, and Pteromalidae.

Pathak *et al.* (2020) identified 29 species of predators belonging to 20 genera under 15 families of 6 orders in rice. Damselflies, dragon flies, long horned grasshopper, lynx spiders, plant and leaf bugs and wolf spiders were recorded in high numbers, whereas ground beetles, lady bird beetles, long jawed spiders, orb spiders, ripple bugs and sword bearing crickets were recorded in moderate numbers. Earwigs,

rove beetles and sac spiders were recorded low in numbers. He also identified 26 species and 4 unidentified species of parasites belonging to 18 genera under 10 families of Hymenopterans. Genus *Apanteles*, *Telenomus*, *Trichogramma* and *Xanthopimpla* were recorded in high numbers, whereas *Amauromorpha*, *Anagyrus*, *Anastatus*, *Bracon*, *Cotesia*, *Stenobracon*, *Temelucha* and *Tetrastichus* were recorded in moderate numbers. Genus *Aphanogmus*, *Brachymeria*, *Elasmus*, *Gonatocerus*, *Isotima* and *Oligosita* were recorded low in number.

Rath *et al.* (2020) described numerous insect pests of rice which were known to be affected by climate change directly through physiological changes in temperature and precipitation which includes stem borers, plant hoppers, gall midge, leaf folder, cutworms, swarming caterpillar, rice hispa, mealy bug caseworm, blue beetle, white grubs and termites.

Edde (2022) discussed some common arthropod pests associated with rice, namely *Cnaphalocrocis medinalis*, *Diopsis longicornis*, *Laodelphax striatellus*, *Leptocorisa oratorius*, *Lissorhoptrus oryzophilus*, *Nephotettix nigropictus*, *Nilaparvata lugens*, *Orseolia oryzae*, and *Paraponyx stagnalis*.

Ravi *et al.* (2022) examined the diversity of spider fauna (Arachnida: Araneae) in a rice agro-ecosystem using multiple sampling methods, resulting in the collection of 622 spider specimens representing 9 species, 7 genera, and 4 families. Spider species richness exhibited a gradual increase throughout the crop's growth stages, reaching its peak at the ripening stage (6.8). Diversity indices were highest during the reproductive and ripening phases, with the Shannon diversity index (H') recorded at 1.76 and the evenness index (E) at 0.92, indicating a more uniform distribution of species. Conversely, the Simpson index (D) was lowest (0.11) at the ripening stage, reflecting greater species diversity at this phase.

Moses *et al.* (2023) recorded 16 species of predatory spiders from six families in rice fields. The non-web-forming group included *Lycosa pseudoannulata*, *Arctosa tanakai* (Lycosidae); *Oxyopes lineatipes*, *Oxyopes javanus*, *Oxyopes salticus* (Oxyopidae); *Bianor spp.* and *Hasarius adansoni* (Salticidae); and *Thomisius spp.*

(Thomisidae). Web-weaving spiders included *Tetragnatha maxillosa*, *Tetragnatha mandibulata*, *Tetragnatha javana* (Tetragnathidae); *Leucauge decorata*, *Leucauge celebesiana* (Araneidae); *Neoscona theisi*, *Neoscona mokerjei*, and *Araneus sp.* (Araneidae). Lynx spiders (Oxyopidae) were the most abundant, while wolf spiders (Lycosidae) were also prominent. In terms of species richness, long-jawed spiders (Tetragnathidae) were the most diverse, with five species recorded.

Priyadarshini and Mahapatra (2023) documented a total of 17 spider families in *Rabi*, while the *Kharif* season accounted for 13 families. Across 2,694 collected individuals, 60 genera and 93 species were identified. The population composition revealed that females constituted 67.6%, juveniles 18.8%, and males 13.6% of the total specimens. Among the families, Araneidae exhibited the highest species diversity with 28 species, whereas Tetragnathidae recorded the highest abundance with 1,106 individuals. The five most dominant families observed were Tetragnathidae, Araneidae, Lycosidae, Salticidae, and Oxyopidae.

2.2. Relative abundance of insect pests and natural enemies in rice

Heckman (1974) conducted a study on the community of organisms present in rice paddy in Vientiane, Laos. The major biological characteristics were noted including relative abundance of the 205 species observed. A few species were consistently common whenever there was sufficient water in the paddy, but most had well defined seasonal periods during which they were abundant and actively propagating.

Heong *et al.* (1991) described the arthropod community associated with irrigated rice. Homopterans, *Nephotettix virescens* (Distant), *N. nigropictus* (Stål) (Cicadellidae), and *Nilaparvata lugens* (Stål) and *Sogatella furcifera* (Horváth) (Delphacidae) represented 88% of phytophagous species with *Nephotettix* spp. Representing more than 70% of total leaf hoppers. Predators constituted 36-53% from different locations and were mainly Heteroptera with *Microvelia douglasi atrolineata* Bergoth (Veliidae), *Mesovelia vittigera* (Horváth) (Mesoveliidae), and *Cyrtorhinus lividipennis* Reuter (Miridae) as the most abundant species. *Pardosa*

pseudoannulata (Böesenberg & Strand) and three species of *Tetragnatha* were the most common Spiders. Parasitoids were recorded in low numbers, between 2 to 4% primarily represented by Hymenoptera, in particular the families Mymaridae, Braconidae, Diapriidae, Trichogrammatidae, and Pteromalidae.

Khan (2006) recorded species diversity of spider (1.2464) and species richness was 8.1102 in rice ecosystem. The relative abundance of *Lycosa pseudoannulata* was found highest followed by *Arctosa himalayensis*, *Araneus inustus* and *Tetragnatha mandibulata*.

Khan (2013) identified seven insect pests and seven natural enemies in rice fields. The green rice leafhopper (GLH) and spiders had the highest relative abundance. Green leafhoppers and short-horned grasshoppers were the most prevalent pests across rice growth stages, while damselflies, spiders, and ichneumonids dominated among natural enemies. Mirid bugs, ladybird beetles, and ground beetles were less prevalent. Diversity indices varied by habitat, with the rice-rice habitat showing the lowest Shannon's index (H) and evenness (J). The highest H and J values for pests and natural enemies were in rice-banana habitat, while Margalef's richness index peaked in rice-banana for pests and rice-vegetable for natural enemies. The highest D values for both groups were recorded in rice-banana habitat.

Mitra *et al.* (2014) reported that *Cofana spectra* was found in abundance in Indian rice fields, peaking during March-May and October-December, aligning with boro and aman rice crops. Environmental factors (temperature, rainfall, humidity) negatively correlated with its abundance and parasitization by *Halictophagus australensis*.

Morya and Kumar (2017) observed several species of predators and parasitoids on rice. They recorded 41 bioagent species, comprising of 13 bioagent groups (spiders, coccinellids, cicindelids, carabids, odonates, orthopterans, mantids, mirids, staphylinids, dermapterans, neuropterans, dipterans, and hymenopterans). The highest abundance of ground beetles at seedling stage, lady bird beetles and spiders at transplanting stage and mirid bugs at flowering stage and ranked them as:

hymenopterans > spiders > coccinellids > carabids > cicindelids > odonates > orthopterans > dermapterans > dipterans > mantids > mirids > neuropterans > staphylinids and parasitoids > predators.

Rahman *et al.* (2017) documented a diverse range of beneficial insects and spiders in rice fields, including ladybird beetles, carabid beetles, ground beetles, damselflies, mirid bugs, ants, wasps, dipteran flies, lynx spiders, wolf spiders, jumping spiders, and long-jawed spiders, all abundant across rice growth stages. The relative abundance ranked as ladybird beetle > damselfly > ant > wolf spider > jumping spider > ground beetle > wasp > tachinid fly > lynx spider > carabid beetle > mirid bug. Araneae had the highest diversity, evenness, and richness indices, while Coleoptera recorded the lowest. The study concluded that rice ecosystems serve as important reservoirs of beneficial species, supporting natural biological control.

Studies by Mukherjee and Khan (2017) examined arthropod pests and natural enemies in rice fields across growth stages. Leafhoppers were most abundant at the seedling (94.25) and maximum tillering (122.5) stages, while rice bugs peaked at panicle initiation (334.00). Among natural enemies, ladybird beetles (45.27) and damselflies (16.73) were most abundant in the rice-rice habitat, ichneumonid wasps (57.53) in the rice-tree habitat, and ground beetles (28.80) in the rice-sesame habitat. Ladybird beetles peaked at maximum tillering, while ichneumonid wasps and ground beetles were highest at the seedling stage. No significant variation was found in dragonflies, spiders, and dipteran flies across habitats and growth stages.

Moses *et al.* (2019) reported 23 insects including spiders preying on various stages of insect pests belonging to 7 orders and 18 families was prominently. Spiders, lady bird beetle, staphylinid beetle, green mirid bug, dragonfly and damselfly were the important predators. They recorded the relative abundance as Spider (18.64%), Lady bird beetle (31.69%), Staphylinid beetle (13.76%), Green mirid bug (09.90%), Dragonfly (12.94%) and Damselfly (13.04).

Adhikari *et al.* (2021) identified the rice gundhi bug, short-horned grasshopper, and black bug as the most prevalent insect pests in rice fields. Out of the total insects, 40% dominance was shown by the short-horned grasshopper followed by the black bug (19%) and rice gundi bug (12%).

Mishra *et al.* (2021) revealed that the lynx spider, *Oxyopes javanus* and the ground-dwelling wolfspider, *Pardosa sumatrana* were the most abundant arboreal hunting spiders, while *Neoscona theisi* and *Tetragnatha javana*, were the most abundant arboreal web-making spiders.

2.3. Seasonal abundance of insect pests and natural enemies in rice

Sabir *et al.* (2006) found that *Cnaphalocrocis medinalis* and *Scirpophaga incertulas* populations peaked in September at 74 and 7.75 larvae per 20 hills, respectively. In October, *Sogatella furcifera*, *Nephotettix cincticeps*, and *Cofana spectra* reached 88.25, 25.50, and 1.50 insects per 10 net sweeps, respectively. Temperature and rainfall significantly influenced insect populations, with stem borers and green leafhoppers responding positively to temperature and rainfall, respectively. Relative humidity positively affected all species. Environmental factors accounted for 85.30%, 82.99%, 78.09%, 66.50%, and 57.00% of population changes in these pests.

Borath *et al.* (2011) reported significant variation in the rice borer population between two study years. In 2007, three damage peaks were recorded during the fourth week of August, the third week of September, and October, coinciding with the active tillering, maximum tillering, and reproductive stages of the crop. In contrast, in 2008, infestation levels remained low during the early vegetative stage until the first half of September. Multiple regression analysis indicated that weather factors accounted for only 40 to 60 percent of the variation in borer incidence. The combined influence of weather factors on borer incidence was 43.93 percent in 2007 and 51.80 percent in 2008. The study further noted that none of the weather factors contributed significantly to variations in borer incidence

Zhimomi and Ao (2011) studied the seasonal abundance of the major insect pests and observed that they were most active from the month of May-November. They observed that temperature played an important role as it affects the activities of arthropods, causes increase or decrease in their population where both insect pests and natural enemies population were recorded maximum during the tillering stage of the crop, similarly the temperature also recorded maximum 32.8°C and minimum 26.3°C during the peak period of arthropod population. The correlation coefficient value had revealed a positive effect of natural enemies on all the population of major insect pests.

Parasappa *et al.* (2017) reported that the yellow stem borer, plant hoppers, gall midge, and leaf folder were the most severe pests, while mirids and spiders were the most important natural enemies among predators. The population of the yellow stem borer showed a significant positive correlation with Hymenopterans, Odonata, and Staphylinids. Similarly, the brown planthopper (BPH) exhibited a positive correlation with mirids ($r = +0.770^{**}$), spiders ($r = +0.440^{*}$), Odonata ($r = +0.700^{**}$), coccinellids ($r = +0.476^{*}$), carabids ($r = +0.779^{**}$), and cicindelids ($r = +0.417^{*}$). Additionally, white-backed planthopper, skipper, caseworm, hispa, blue beetle, and grasshopper showed both significant and non-significant positive correlations with predators and parasitoids.

Sulagitti *et al.* (2017) documented that yellow stem borer incidence commenced in late July, peaking in the second week of October. Brown planthopper (BPH) first appeared in early August, reaching its maximum population in the second week of October before declining as the crop approached harvest. Leaf folder infestation emerged in early August, with larval populations progressively increasing until the 38th week, reaching 10 larvae per 10 hills. Gundhi bug was initially detected in the second week of September.

Meena *et al.* (2018) recorded armyworm activity starting in the 34th Standard Meteorological Week (SMW), with peaks in the 40th and 44th SMW, the highest in the 44th. Rice leaf folder, first noted in the 38th SMW, remained active from September to December, reaching peak infestations in the 40th and 44th SMW. Rice

butterfly, observed in the 33rd SMW, peaked in the 39th, 42nd, and 45th SMW, with the highest in the 45th. Rice gundhi bug emerged in the 31st SMW, showing peak populations in the 36th and 42nd SMW, the latter being the highest. Green leafhopper, first recorded in the 27th SMW, was active from July to mid-November, peaking in the 34th and 42nd SMW, with the highest in the 42nd. Short-horned grasshopper, appearing in the 26th SMW, peaked in the 32nd and 38th SMW, reaching its highest in the 32nd. Field cricket, documented in the 26th SMW, displayed peak activity in the 33rd and 42nd SMW, with the highest in the 33rd. Mole infestation, recorded in the 26th SMW, peaked in the 32nd, 36th, and 39th SMW, reaching maximum levels in the 39th SMW.

Seni and Naik (2018) reported that the infestation of yellow stem borer (*S. incertulas*) was initiated from the 3rd week of August (34 SMW) and peaked (8.38 per cent DH) during 2nd week of October (41 SMW). *C. medinalis* first appeared on 3rd week of August (34 SMW) and the peak activity of the pest was found in 4th week of September (39 SMW). The number of plant hoppers (both *N. lugens* and *S. furcifer*) per hill was found initially low (0.4/hill) during 2nd week of September (36 SMW), which gradually increased during successive standard weeks and reached at the maximum level (18.40/hill) during 1st week of November (44 SMW) and thereafter hopper population declined to 9.0/hill during 49th standard week.

Bisen *et al.* (2019) observed that the yellow stem borer appeared from mid to late September, while the leaf folder population began increasing from mid-September. They also noted a rise in the green leaf hopper population from mid-August to early October.

Deshwal *et al.* (2019) recorded *Scirpophaga incertulas* to appear in the beginning of July and remained active throughout the crop season peaking from beginning of August to September end. *Cnaphalocrocis medinalis*, leaf hoppers and plant hoppers were recorded during August-September. *Hieroglyphus banian* and *Oxya fuscovittata* were found active throughout the crop season.

Sawai and Kothikar (2019) examined seasonal pest incidence in rice fields. Dead heart incidence was initially low at 4.95% in the 42nd SMW and peaked at 6.77% in the 44th SMW. Armyworm populations ranged from 0.28 to 3.43 per hill, while cutworm populations varied between 1.04 and 4.0 per hill from the 29th to 44th SMW, with minimal influence from weather conditions. Brown planthopper, white-backed planthopper, and green leafhopper were recorded between the 39th and 44th SMW. Leaf folder infestation reached its highest level in the 40th SMW (15.63% damage), followed by the 44th SMW (10.88%) and the 38th SMW (10.87%), with the lowest incidence observed in the 36th SMW (1.28%).

Studies were conducted by Dumra and Srivastav (2019) and observed that adults of caseworm started appearing in 3rd week of July (29 SW). The highest peak of caseworm was noted during 2nd week of August (32 SW) with 23.5 adults per five sweeps. Thereafter, the population of pest decreased and the activity ceased during 4th week of September (38 SW). At Farmer's field, adults of caseworm started appearing in 4th week of July (30 SW) with population level of 7.4 adults per five sweeps. The highest peak of caseworm was obtained during 2nd week of August (32 SW) with 18.4 adults per five sweeps. Thereafter, the population of pest decreased and the activity ceased during 3rd week of September (37 SW).

Moses *et al.* (2019) reported that the predatory spider population reached its peak in the 29th standard week of July before declining. The ladybird beetle population peaked in the 33rd standard week of August, with a second peak in the 34th standard week of August. The highest population of staphylinid beetles was recorded in the 39th standard week of October, with a secondary peak in the 35th standard week of September. The green mirid bug population was initially low but peaked in the 36th standard week of September. Dragonfly numbers were highest in the 29th standard week of July, with a secondary peak in the 32nd standard week of August. The damselfly population initially peaked in the 30th standard week of July, followed by a second peak in the 31st standard week of August, after which it declined.

According to Kalita *et al.* (2020), the leaf folder population reached its highest density in the 38th SMW, while rice hispa infestation was most pronounced between the 33rd and 34th SMW. Green leafhopper activity fluctuated from the 38th to the 43rd SMW, whereas white-backed planthopper peaked between the 38th and 41st SMW. Greenhorn caterpillars remained active from the 36th to the 43rd SMW, while Gundhi bug populations surged between the 43rd and 46th SMW. The incidence of stem borer varied by rice variety, with peak infestations occurring between the 32nd and 38th SMW. Additionally, natural enemies such as spiders, dragonflies/damselflies, and coccinellid beetles were found in significant numbers, with their populations peaking in the 38th-40th, 38th, and 38th SMW, respectively.

Kumar *et al.* (2020) observed that major insect pests of rice became active from the 31st SMW and persisted until the 49th SMW. The leaf folder infestation peaked in the 49th SMW, recording 17.6 larvae per 10 hills. Dead heart incidence was highest in the 42nd SMW at 6.23%. Rice white ear infestation reached its maximum in the 49th SMW at 10.93%, while the rice brown planthopper population peaked in the 41st SMW with 19.33 insects per 10 hills.

Patil *et al.* (2020) recorded brown planthopper (*Nilaparvata lugens*) incidence starting in the first week of September (32nd MW), peaking in the third week of October (42 MW). Its population steadily increased from the 36th to the 42nd MW. Leaf folder infestation began in the second week of September, reaching its highest level in the first week of October. Yellow stem borer appeared in the third week of August, peaking in the second week of September.

Singh *et al.* (2020) while studying the population dynamics of rice insect-pests revealed that pest activity commenced from 34th SMW and continued to 49th SMW. Highest yellow stem borer was recorded in the 39th SMW. The 44th SMW registered the highest population of leaf folder and green leaf hopper. Grass hopper's population peaked between 41st to 42nd SMW. The maximum population of gundhi bug was recorded at 43rd. The 39th to 42nd SMW saw highest spider population. dragon fly was highest at 39th-41st SMW while of damsel fly was recorded at 42nd SMW. The 39th to 44th SMW recorded the maximum ladybird beetle population.

Lisha *et al.* (2020) reported that pest activity commenced in the 35th SMW and continued until the 41st SMW in 2018. The highest white ears incidence of *Scirpophaga incertulas* was observed in the 41st SMW, while the maximum population of *Cnaphalocrocis medinalis* peaked in the 37th SMW. The population of *Nephotettix* spp. also reached its highest in the 37th SMW, whereas the maximum number of *Leptocorisa acuta* was recorded in the 41st SMW.

An investigation was carried out by Nishanthini and Kandibane (2021) on the seasonal incidence of rice insect pests using a light trap during *Kharif* 2019 and *Rabi* 2019-2020. The yellow stem borer (*Scirpophaga incertulas*) was first observed in the 28th MSW at a population of 0.14, with its activity increasing from August to November (*Kharif*) and again from January to February (*Rabi*), reaching a peak of 2.86 in the 43rd MSW. Green leafhopper (*Nephotettix virescens*) was initially recorded in the 47th MSW (1.43), showing peak infestations in the 1st MSW (4.86) and 4th MSW (5.29). Brown planthopper (*Nilaparvata lugens*) appeared later, first detected in the 50th MSW (0.29), with its highest densities recorded in the 1st MSW (2.29) and 3rd MSW (1.86). White leafhopper (*Cofana spectra*), emerging in the 48th MSW (0.29), reached its maximum population of 1.71 in the 3rd MSW during *Rabi* 2019-2020. Vennila *et al.* (2021) also stated that population of the brown planthopper (*Nilaparvata lugens*) is influenced by prevailing weather conditions.

Saikia *et al.* (2022) observed the lowest population (0.05 gundhi bug hill-1) on 40th SMW and the highest (0.9) on 46th SMW. Population build-up of gundhi bug showed significant positive correlation with morning relative humidity ($r=0.734$) and bright sunshine hour ($r= 0.661$).

An investigation by Selvam *et al.* (2022) examined the seasonal incidence of pests and their natural enemies in rice fields using light traps. Trap catches commenced in the 34th SMW, with the highest number of insects (113 adults) recorded in white light traps in the 36th SMW, followed by the 35th and 37th SMW. The catches subsequently declined, reaching their lowest in the 44th SMW (36 adults). In yellow light traps, the maximum catches occurred in the 37th SMW (62 adults), while the lowest count was recorded in the 43rd SMW (23 adults). Natural enemies,

including predators and parasitoids, were first noted in the 35th SMW (22 individuals in both traps), with populations gradually increasing and peaking in the 40th SMW in white light traps and the 39th SMW in yellow light traps, aligning with peak pest activity.

Sreelatha *et al.* (2022) recorded the yellow stem borer incidence to start from 2nd week of July and the pest population reached its highest level during the 4th week of September. The leaf folder and gundhi bug infestation reached its highest level during 4th week of August and 4th week of September, respectively. Brown plant hopper and green leaf hopper appeared in rice crop from August to October and the population gradually decreased as the crop reached the harvesting stage. Grass hopper observed in rice crop during 2nd week of August and gained highest level during 1st week of October. Rice butterfly was first observed during 4th week of July and reached its highest level during 4th week of September.

Varsha *et al.* (2022) studied the seasonal occurrence of major insect pests in rice. Fortnightly observations of pest populations in relation to meteorological parameters revealed that rice leaf folder (*Marasmia medinalis*, Crambidae: Lepidoptera) caused the highest leaf damage (2.95%) in the second fortnight of September when the crop was more succulent. The yellow stem borer (*Scirpophaga incertulas*, Crambidae: Lepidoptera) first appeared in the first fortnight of August, with peak damage (2.62% dead hearts) occurring in the second fortnight of September. The brown planthopper (*Nilaparvata lugens*, Delphacidae: Hemiptera) reached its highest population (4.97 hoppers per hill) in the first fortnight of October, coinciding with the panicle initiation stage of the crop.

Weekly observations by Hemanth *et al.* (2024) showed that yellow stem borer incidence as dead hearts peaked at the vegetative stage during SMW 38 (5.56%) and was lowest at SMW 30 (0.30%). At the reproductive stage, white ears incidence was highest at SMW 44 (2.20%) and lowest at SMW 42 (0.33%). Rice leaf folder infestation peaked at SMW 39 (9.21%) and was lowest at SMW 44 (1.00%). The brown planthopper population was highest at SMW 39 (9.60 hoppers/hill) and lowest at SMW 31 (0.20 hoppers/hill). Similarly, white-backed planthopper populations

peaked at SMW 38 (3.70 hoppers/hill) and were lowest at SMW 32 (0.40 hoppers/hill).

2.4. Correlation coefficient of insect pests of rice with weather parameters

Environmental factors played a significant role in insect pest population fluctuations, as reported by Sabir *et al.* (2006). Stem borer (*Scirpophaga incertulas*) exhibited a positive response to temperature, while green leafhopper (*Nephotettix cincticeps*) was influenced positively by rainfall. Relative humidity generally favored pest populations. Maximum and minimum temperatures, along with rainfall, contributed notably to these variations, with environmental factors explaining 85.30%, 82.99%, 78.09%, 66.50%, and 57.00% of the population changes in green leafhopper, leaf folder (*Cnaphalocrocis medinalis*), stem borer, white-backed planthopper (*Sogatella furcifera*), and white leafhopper (*Cofana spectra*), respectively.

Kalita *et al.* (2015) reported that stem borer infestation peaked during August-September, with dead heart incidence ranging from 6.82% to 7.62%. The highest occurrence of white ear head was recorded in the second fortnight of October, reaching 7.56% in 2007 and 8.14% in 2008. Leaf folder populations were at their maximum between late August and early September, causing 14.50-16.75 damaged leaves per 10 hills. Gundhi bug infestation was most prominent during the milky stage of the crop in early October, with a density of 14.80-16.40 bugs per 10 hills. Among natural enemies, spiders, *Apanteles*, and dragonflies were most abundant in August and September, while ladybird beetles peaked in the last fortnight of September. Correlation analysis indicated that weather parameters significantly influenced the population dynamics of pests and their natural enemies in both study years.

Sulagitti *et al.* (2017) reported that yellow stem borer exhibited a significant positive correlation with evening and average humidity, while its correlation with morning humidity and rainfall was positive but non-significant. Brown planthopper showed a non-significant positive correlation with rainfall, temperature, and relative

humidity. Leaf folder had a significant positive correlation with evening relative humidity, whereas gundhi bug displayed a non-significant positive correlation with morning relative humidity and a non-significant negative correlation with temperature.

Kafle *et al.* (2018) examined the influence of weather factors on insect pest incidence in rice, identifying rice hispa, white-spotted leaf beetle (*Monolepta signata*), and gundhi bug as widely distributed pests. Rice hispa showed a positive correlation with minimum temperature ($r = 0.155$) and average relative humidity ($r = 0.285$). In contrast, the white-spotted leaf beetle exhibited a negative correlation with all weather parameters, including temperature, rainfall, and relative humidity. Similarly, gundhi bug demonstrated a significant negative correlation with minimum temperature ($r = -0.600$), maximum relative humidity ($r = -0.590$), minimum relative humidity ($r = -0.612$), and average relative humidity ($r = -0.581$).

Meena *et al.* (2018) studied the seasonal incidence and population dynamics of major insect pests of paddy using a Jawahar light trap (80-watt mercury vapor lamp) at the Krishi Nagar experimental farm, Adhartal, during the *kharif* 2014 season. The study identified eight regularly occurring paddy pests from light trap catches: Armyworm (*Mythimna separata* Walker), rice leaf folder (*Cnaphalocrocis medinalis* Guenée), rice butterfly (*Melanitis leda ismene* Cramer), rice gundhi bug (*Leptocorisa acuta* Thunberg), green leaf hopper (*Nephotettix virescens* Distant), short-horned grasshopper (*Tetrix subulata* Linnaeus), field cricket (*Euscyrtus concinnus* de Haan), and mole cricket (*Gryllotalpa orientalis* Burmeister).

Seni and Naik (2018) reported that yellow stem borer incidence showed a non-significant correlation with maximum temperature ($r = 0.072$) and minimum temperature ($r = -0.209$) but had a significant negative correlation with morning relative humidity ($r = -0.506$), evening relative humidity ($r = -0.680$), and rainfall ($r = -0.488$). The incidence of *C. medinalis* was significantly positively correlated with maximum temperature ($r = 0.749$) and minimum temperature ($r = 0.654$), while its correlations with rainfall ($r = 0.216$), evening relative humidity ($r = 0.150$), and morning relative humidity ($r = -0.365$) were non-significant. Plant hopper populations

in rice exhibited a significant negative correlation with maximum temperature ($r = -0.619$), minimum temperature ($r = -0.755$), evening relative humidity ($r = -0.788$), and rainfall ($r = -0.583$), whereas the correlation with morning relative humidity ($r = 0.015$) was negative but non-significant.

Sawai and Kothikar (2019) studied paddy pest dynamics, observing activity from the 29th to the 44th Standard Meteorological Week (SMW). The highest dead hearts (6.77%) caused by yellow stem borer (*Scirpophaga incertulas*) occurred in the 44th SMW. Peak populations of armyworm (3.43 per hill) and cutworm (1.71 per hill) were recorded in the 36th SMW, while leaf folder (*Cnaphalocrocis medinalis*) caused the highest leaf damage (15.63%) in the 40th SMW. Brown planthopper (*Nilaparvata lugens*) (7.43 per hill) and white-backed planthopper (*Sogatella furcifera*) (9.14 per hill) peaked in the 44th SMW, whereas green leafhopper (*Nephotettix cincticeps*) reached its highest population (3.86 per hill) in the 43rd SMW. Gall midge incidence was absent. Temperature and morning relative humidity positively influenced yellow stem borer, brown planthopper, white-backed planthopper, green leafhopper, and leaf folder. In contrast, armyworm and cutworm populations showed positive correlations with rainy days, total rainfall, and both morning and evening relative humidity. Meanwhile, evening relative humidity, rainfall, and rainy days suppressed yellow stem borer, brown planthopper, white-backed planthopper, green leafhopper, and leaf folder but favored armyworm and cutworm.

Kalita *et al.* (2020) reported that the population buildup of case worm, whorl maggot, and leaf folder showed a positive correlation with maximum temperature (Tmax), minimum temperature (Tmin), and rainfall (RF). In contrast, rice hispa and stem borer exhibited a positive correlation with Tmax and Tmin but a negative correlation with morning relative humidity (RHm). Meanwhile, gundhi bug displayed a negative correlation with Tmax and Tmin but a positive correlation with RHm.

Kumar *et al.* (2020) analyzed the correlation between climatic factors and rice pest infestations, noting that yellow stem borer-induced dead heart had a significant positive correlation with relative humidity, a non-significant negative correlation with the highest temperature, and a significant negative correlation with minimum

temperature and rainfall. The percentage of white ears showed a non-significant negative correlation with rainfall and a significant negative correlation with maximum temperature, minimum temperature, and relative humidity. Rice leaf folder exhibited a non-significant negative correlation with rainfall, a significant positive correlation with relative humidity, and a non-significant positive correlation with both the highest and lowest temperatures. Meanwhile, rice brown planthopper displayed a non-significant negative correlation with rainfall, highest temperature, and lowest temperature.

Patil *et al.* (2020) reported a significant negative correlation between Brown Planthopper incidence and both rainfall ($r = -0.488$) and morning relative humidity ($r = -0.614$), while a positive correlation was observed with maximum temperature. Leaf Folder exhibited a significant positive correlation with maximum temperature, whereas Stem Borer showed a significant negative correlation with evening humidity.

An investigation by Lisha *et al.* (2020) revealed that yellow stem borer, leaf folder, green leafhopper, and grasshoppers showed a positive correlation with both maximum and minimum temperatures. In contrast, pollen feeders and earhead bugs exhibited a negative correlation with maximum and minimum temperatures, respectively. Relative humidity (RH) favored earhead bugs, grasshoppers, and pollen feeders, all of which showed a positive correlation, whereas yellow stem borer, leaf folder, and grasshoppers did not.

Singh *et al.* (2020) reported that maximum temperature and relative humidity favored the populations of yellow stem borer, leaf folder, grasshopper, green leafhopper, gundhi bug, spider, dragonfly, damselfly, and ladybird beetles, whereas rainfall and minimum relative humidity were unfavorable for both insect pests and their natural enemies.

Adhikari *et al.* (2021) reported that the population dynamics of the rice gundhi bug showed a non-significant negative correlation with maximum temperature ($T_{\max}$, $r = -0.319$) and average temperature (T_{avg} , $r = -0.099$), while a non-significant positive correlation was observed with minimum temperature ($T_{\min}$, $r = 0.188$). A similar pattern was noted for relative humidity (maximum, minimum, and average) and average rainfall, where all correlations remained statistically insignificant. In contrast, the black bug exhibited a significant positive correlation with $T_{\max}$ ($r = 0.622$) and a positive but non-significant correlation with all other weather parameters.

Nishanthini and Kandibane (2021) analyzed the correlation between weather parameters and rice insect pests during *kharif* 2019 and *rabi* 2019-2020. In *kharif* 2019, yellow stem borer exhibited a significant negative correlation with maximum (-0.58) and minimum temperature (-0.55) but a non-significant positive correlation with morning (0.07) and evening relative humidity (0.11) and rainfall (0.14). During *rabi* 2019-2020, yellow stem borer and green leafhopper had a non-significant positive correlation with maximum temperature (0.46, 0.08), whereas brown planthopper and white leafhopper showed a non-significant negative correlation (-0.16, -0.29). A significant negative correlation was recorded between white leafhopper and minimum temperature (-0.71), while yellow stem borer (-0.41), green leafhopper (-0.11), and brown planthopper (-0.31) displayed non-significant negative correlations. Green leafhopper had a significant positive correlation with morning relative humidity (0.73), whereas yellow stem borer (-0.65) showed a significant negative correlation with evening relative humidity. Additionally, yellow stem borer had a significant negative correlation with rainfall (-0.57), whereas green leafhopper (0.12), brown planthopper (0.24), and white leafhopper (0.21) exhibited significant positive correlations with rainfall.

In a study on the population dynamics of insect pests and their natural enemies in rice, Selvam *et al.* (2022) found a positive correlation with maximum and minimum temperatures, while relative humidity and rainfall showed a negative correlation.

Sreelatha *et al.* (2022) analyzed the correlation between rice pest incidence and meteorological factors, reporting varied relationships across species. Yellow stem borer incidence showed a positive but non-significant correlation with morning, evening, and average relative humidity, as well as minimum temperature ($r = 0.189, 0.412, 0.375$, and 0.220), while exhibiting a negative but non-significant correlation with rainfall, maximum, and average temperatures ($r = -0.036, -0.460$, and -0.194). Leaf folder infestation correlated positively with humidity and temperature ($r = 0.282, 0.353, 0.348, 0.371$, and 0.040) but negatively with rainfall and maximum temperature ($r = -0.159$ and -0.255). A significant negative correlation was observed for gundhi bug with rainfall, humidity, and temperature ($r = -0.102$ to -0.300). The brown planthopper population declined as the crop matured, showing a positive but non-significant correlation with maximum temperature ($r = 0.026$) and a negative correlation with other factors ($r = -0.064$ to -0.326). Similarly, green leafhopper and rice butterfly exhibited negative but non-significant correlations with rainfall, humidity, and temperature ($r = -0.078$ to -0.214).

Morsheda *et al.* (2023) observed that rice Yellow Stem Borer, Caseworm, Green Leafhopper, Field Cricket, Carabid Beetle, and Ladybird Beetle were the most prominent species throughout the rice seasons. Insect population abundance was strongly influenced by maximum temperature, whereas rainfall had a negative impact.

Spider abundance was strongly positively correlated with relative humidity, while rainfall and wind speed influenced colonization but did not show a significant correlation with abundance, as reported by Priyadarshini and Mahapatra (2023).

The yellow stem borer exhibited a non-significant negative correlation with maximum temperature and rainfall but a non-significant positive correlation with minimum temperature and relative humidity. Similarly, the rice leaf folder showed a non-significant negative correlation with minimum temperature while responding positively, though non-significantly, to other weather factors. The brown planthopper also displayed a non-significant negative correlation with temperature and rainfall but a non-significant positive correlation with relative humidity. In contrast, the white-backed planthopper had a significant positive correlation with morning relative

humidity, while all other correlations remained non-significant, as reported by Hemanth *et al.* (2024).

2.5. Correlation coefficient of insect pests of rice with natural enemies

Heong *et al.* (1991) found that veliid densities were positively correlated with hopper densities, indicating a close link between veliid and mesoveliid populations and planthopper and leafhopper abundance. In contrast, the mirid egg predator *Cyrtorhinus lividipennis* did not exhibit a strong positive response to hopper densities, likely due to its preference for hopper eggs. Spider populations also showed a positive correlation with hoppers.

As hopper density increased, spider populations also grew, indicating a direct relationship between pest population and predator abundance. Khan and Misra (2003) attributed spider abundance and decline in the rice ecosystem to prey insect maturity, disappearance, and unfavorable abiotic conditions.

Zhimomi and Ao (2011) reported that odonates (dragonflies and damselflies) played a crucial role as predators, showing a highly significant correlation with Orthoptera, Hemiptera, and Lepidoptera. Spiders (Araneida) also contributed significantly, maintaining a strong correlation with Lepidoptera and Orthoptera but showing no significant impact on Isoptera and Hemiptera. In contrast, ground beetles had no significant effect on pest populations, except for Hemiptera.

Rahaman *et al.* (2014) found strong positive associations between stem borers-including pink stem borer, dark headed stem borer, yellow stem borer, white stem borer, and stripped stem borer-and key predators such as damselflies, ladybird beetles, long-jawed spiders, and wolf spiders, emphasizing their role in natural pest control. Among these, damselflies exhibited the highest positive correlation (up to 0.999), indicating their significant impact on stem borer populations. In contrast, carabid beetles and earwigs consistently showed negative correlations, suggesting a minimal role in stem borer suppression.

Mondal & Chakraborty (2017) observed a positive correlation between yellow stem borer infestations and the abundance of natural enemies, indicating that predator populations tend to fluctuate in response to pest incidence.

Parasappa *et al.* (2017) found that yellow stem borer, gall midge, brown planthopper, and leaf folder showed significant positive correlations with key natural enemies, particularly odonates, spiders, staphylinids, coccinellids, and carabids. They recorded brown plant hopper to have the strongest associations with multiple predators, including odonates, mirids, and carabids, while leaf folder was strongly correlated with spiders, odonates, and coccinellids. Additionally, spiders exhibited positive correlations with several rice pests, including gall midge, brown planthopper, and leaf folder.

Kalita *et al.* (2020) observed that natural enemies such as spiders, Dragonflies and damselflies, and coccinellid beetles exhibited a strong positive correlation with morning relative humidity. Evening relative humidity also positively influenced spiders and dragonflies and damselflies. In contrast, temperature had a negative impact on coccinellid beetles and spiders.

Rani *et al.* (2022) recorded that yellow stem borer showed a significant positive correlation with the spider guild in both wet and dry seasons but a negative correlation with preying mantids and carabid beetles in the dry season. Pink stem borer had a negative correlation with most predators, except damselflies and long-jawed spiders. White stem borer correlated negatively with long-jawed spiders, lynx spiders, and mantids in the wet season, while in the dry season, it was negatively linked to wolf spiders and carabid beetles but positively to other predatory groups. Dark-headed stem borer showed negative correlations with wolf spiders, long-jawed spiders, and mirid bugs in the wet season but positive correlations with damselflies, mantids, and tiger beetles in the dry season, indicating seasonal shifts in predator-prey dynamics.

2.6. Morphometric characteristics of major insect pests of rice and their natural enemies

Prasad and Ghosh in 1983 observed the morphometric measurements of *Brachythemis contaminata*. They observed the abdomen length inclusive of anal appendages to be between 18 to 21.5 mm long, forewing lengths between 22 to 22.5 mm, hindwing lengths between 21.5 to 24.5 mm, hindwing width between 8 to 9.5 mm and pterostigma length was 3 mm.

Daly (2003) stated that morphometrics is the measurement and analysis of form and are reviewed in connection with the external structures of insects and their relations with life history, genetics, ecology and systematics.

Amir *et al.* (2015) while studying the morphological species variability in stem borers on gramineous crops, observed various morphological characters of *Scirpophaga incertulas* among other species. They observed the head length from 0.7 to 1.3 mm, head width from 1.25-1.8 mm, and the forewing length and width between 10 to 13.25 mm and between 3-4 mm respectively.

A study on taxonomy and genetic diversity of rice earhead bugs was undertaken by Lahari *et al.* (2024) from India. They recorded various morphological parameters of *Leptocorisa acuta*. They observed that the Insect length measured 15.7 ± 0.50 , Head length was recorded at 4.8 ± 0.02 , rostrum or mouthpart was measured at 4.7 ± 0.02 , antenna length was 14.0 ± 0.50 , forewing length was 11.8 ± 0.02 and finally Hindleg length was recorded as 13.1 ± 0.02 on male specimens.

Matsukura *et al.* (2006) while comparing the morphological characteristics of the two populations of *Chilo suppressalis*, used ten non-genital traits in adults for its morphometric studies. The ten non-genital traits were length of the forewing (FWL), distance between the first and seventh (last) black spots along the side-margin of the forewing (DBS), length of the hindwing (HWL), fore femur (FFL), fore tibia (FTL), mid femur (MFL), mid tibia (MTL), hind femur (HFL), hind tibia (HTL), and head width (HW).

Fedor *et al.* (2008) studied 17 quantitative morphometric characters on different parts of the thrips body to study the use of a supervised artificial neural network (ANN) model for semi-automated identification of 18 common European species of Thysanoptera *viz.*, head width, head length (dorsal side), head length (ventral side, including mouthcone), clavus length, clavus width, forewing length, forewing basal width, total body length (excluding antenna and penis), pronotum width, pronotum length, eye length, ovipositor length, ovipositor width, antennal segment V length, antennal segment VI length, distance between the posterior pair of ocelli and distance between an anterior and posterior pair of ocelli.

Das and Deveci (2017) observed leaf hopper morphology in Jorhat, Assam during 2012-14. They observed *Nephotettix virescens* body length: 4.57 mm, length of head: 0.42 mm, inter ocular distance: 0.75 mm and length of wing: 3.77 mm. In *Nephotettix nigropictus*, they observed the body length: 3.64 mm, length of head: 0.36mm, inter ocular distance: 0.53 mm and length of wing: 3.08 mm while in and *Cofana spectra*, body length was 9.74 mm, length of head: 0.79 mm, inter ocular distance: 1.73 mm and length of wing: 7.74 mm. *Maistas dorsalis* measured body length of 3.24 mm, length of head: 0.24 mm, inter ocular distance: 0.43 mm and length of wing: 2.39 mm.

Rashid *et al.* (2017) reported that brown planthopper (BPH), *Nilaparvata lugens* (Stål) (Hemiptera: Delphacidae), is a notorious insect pest of rice. Nutrient supplementation can alter plant biochemical compositions which may indirectly affect on ecological fitness parameters of its insect pest. N inputs improved all ecological fitness traits of BPH providing greater survival, shorter generation time, and larger body size.

Setyawati *et al.* (2017) revealed that the measurements in *Orthetrum pruinatum* were; abdominal length and thorax 42 mm, the length of the abdomen was 30 mm, the front wing length was 37 mm, the front wing width was 8.5 mm and the rear wing was 11.25 mm.

Sharma and Srivastava (2017) observed the morphometric of rice hispa from egg to adult and observed the adult body length of males as 4.03 ± 0.047 mm while in females it was 4.45 ± 0.056 mm. The head width recorded in males was 0.60 ± 0.006 mm and 0.70 ± 0.011 mm in females.

Sazali *et al.* (2018) conducted extensive studies on the Morphometric traits of Palm Weevils, *Rhynchophorus vulneratus* and *R. ferruginous* (Coleoptera: Curculionidae) in Malaysia to identify their unique characteristics. Twenty three characters were linearly measured-Snout length (SL), snout width (SW), scape of antenna length (SAL), antenna length (AL), antenna width (AW), distance between eyes (ED), pronotum length (PL), pronotum width (PW), elytra length (EL), elytra width (EW), total length (without snout) (TL), profemur length (F1L), protibial length (F1Tb), protarsus length (F1Ta), mesofemur length (F2L), mesotibia length (F2Tb), mesotarsus length (F2Ta), metafemur length (F3L), metatibia length (F3Tb), metatarsus length (F3Ta), mesocoxal distance (MSD), metacoxal distance (MTD) and meso-metacoxal distance (MMD).

Mahdi *et al.* (2018) while carrying out an experiment to assess the species diversity, seasonal abundance and morphometric characteristics of grasshopper (Orthoptera: Caelifera) in Bangladesh recorded a total number of 286 individuals of grasshopper which were studied for inter-specific variations and the morphometric analysis of nine parameters were taken *viz.* length of body, antenna, foreleg, midleg, hindleg, forewing and hindwing; width of forewing and hindwing was evaluated. Similarly, Milach *et al.* (2015) took the following measurements: body length, pronotum length, pronotum width, head width, interocular distance, tibia III length, femur III length, metanotal gland length, metanotal gland width, area of metanotal gland, and scutellar cavity area while identifying a new species of tree crickets *Oecanthus* (Orthoptera, Gryllidae, Oecanthinae) in tobacco plantation from Southern Brazil. Likewise, Romero *et al.* (2014) also examined six morphometric traits *viz.* total length, third femur length, third tibia length, thorax length, thorax height, and tegmen length. Morphometric while studying the differentiation in *Cornops aquaticum* (Orthoptera: Acrididae).

The body parameters of male specimens of *Orthetrum sabina* were recorded by Shaikh *et al.* (2018) across various morphological traits. The antennae measured 2.34 ± 0.027 mm in length, while the head was 4.62 ± 0.026 mm long and 5.37 ± 0.033 mm wide. The pronotum measured 8.03 ± 0.021 mm in length and 4.71 ± 0.044 mm in width. The abdomen had a length of 29.46 ± 0.033 mm, whereas the femur and tibia measured 5.48 ± 0.052 mm and 4.26 ± 0.037 mm, respectively. The forewings and hindwings measured 26.70 ± 0.063 mm and 28.02 ± 0.013 mm, respectively. Overall, the total body length of males averaged 42.04 ± 0.024 mm.

Tatsuta *et al.* (2018) expressed that the recent expansion of a variety of morphometric tools have brought about a revolution in the comparison of morphology in the context of the size and shape in various fields including entomology.

Ahmed and Kareem (2019) described morphological to identify three native species belonging to the family Libellulidae (Odonata: Anisoptera) from Basrah Governorate-South of Iraq. They reported *Crocothemis servilia* as medium sized body with total length of 36-40 mm in male and 32-36 mm in female, hind wing: 30-32 mm and 26-28 mm, in male and female respectively. From the pictures of male specimen (with measurement scale) provided by them, it is evident that the abdomen length is about 26 mm, thorax length is about 9mm, head width is about 5 mm, head length about 4.5 mm and the pterostigma length was measured about 3 mm. They also described *Orthetrum Sabina* with large body with a total length: 45-49 mm in male and 42-48 mm in female, hindwing: 32-34 mm and 31-33 mm, in male and female respectively. From the male photograph that is shown with measurement scale, it can be seen that abdomen length is about 35 mm, thorax length is about 10 mm, head width is about 6 mm, head length about 4.5 mm and the pterostigma length was measured about 3 mm.

Alvial *et al.* (2019) while observing the effects of geographical isolation on population genetic structure and wing morphology, 281 individuals of the cosmopolitan odonate *Pantala flavescens* were collected were characterize by genetic diversity and genetic structure between and within locations. 8 Linear and geometric

morphometry were used to evaluate differences in the size and shape of wings. For linear morphometry, the parameters recorded body length (BD), abdomen length (AL), thorax length (TL), head width (HW), forewing length (FWL), forewing height (FWH), forewing width (FWW), hindwing length (HWL) and hindwing height (HWH).

Manurung *et al.* (2019) reported on the morphometric studies of *Cofana spectra* in three locations and reported body length from 7.35 to 9.07 mm, body width of 1.92 to 2.08 mm, head length was 0.45 to 0.69 mm, head width of 1.74 to 2.08 mm. The thorax length reported was 2.06-2.36 mm; abdomen length measured 2.22 to 3.77 mm. The forewing length was 5.97 to 7.81 mm, with a width of 1.28 to 1.42 mm. The hind leg length measured 6.52 to 7.51 mm. The stylet length was recorded as 0.54 to 0.67 mm.

Oyerinde *et al.* (2019) while studying the morphometric variations of species of tsetse fly (Diptera: Glossinidae) considered the following parameters for its morphometric measurements: Head / Eyes, Body Length, Antenna, Length of Femur, Tibia length, Tarsal, Abdomen, Wing Length and Thorax.

Jaskuła *et al.* (2021) while studying the geographic variation in morphology and sexual dimorphism in *Lophyra flexuosa* (Fabricius, 1787) (Coleoptera, Cicindelidae) in desert countries report on the following body parameters - right mandible length (RML), length of head (LH), width of head (WH), length of pronotum (LP), pronotum width (WP), length of elytra (LE), maximum elytra width (MEW) and total body length (TBL). Acal *et al.* (2024) also took the same morphometric parameters while quantifying data of sexual dimorphism in semi-arboreal *Therates* from the Philippine biodiversity hotspot.

Priyadarshini *et al.* (2021) while studying the brownplant hopper, reported the macropterous male to exhibit a body length of 2.316 ± 0.24 mm and a body width of 1.023 ± 0.02 mm. The abdominal length measured 1.333 ± 0.02 mm, while the abdominal width was 0.992 ± 0.05 mm. The antennal length was recorded as 0.940 ± 0.01 mm. The inter-ocular distance was found to be 0.255 ± 0.03 mm. The length of

the tibial spur measured 0.353 ± 0.03 mm, and the length of the rostrum was 0.852 ± 0.09 mm. The wing length was 3.060 ± 0.1 mm, with a wing width of 0.602 ± 0.09 mm.

Six dimensional parameters were assessed by Sukhodolskaya *et al.* (2021) to study the Morphometric measurements of ground beetles. The parameters used were elytra length, elytra width, pronotum length, Pronotum width, head length and distance between eye. Similarly, Ribera *et al.* (1999) took 13 linear quantitative measurements of the body, hind legs, eyes and antennae to study the morphological diversity of ground beetles (Coleoptera: Carabidae) in Scottish agricultural land. The measurements taken were width of the head, diameter of the eye, length of the antenna, length of the Pronotum, maximum width of the pronotum, maximum height of the pronotum, length of the elytra, maximum width of the elytra, length of the metafemur, length of the metatrochanter, length of the metatibia, length of the metatarsi, maximum width of the metafemur and the total length.

Mahdi *et al.* (2022) conducted investigation of the morphometric traits of the dark evening brown butterfly, *Melanitis phedima* (Lepidoptera: Nymphalidae) and considered 14 morphometric traits for the study viz., Total length, antenna length, forewing base-apex, forewing base-tornus, forewing apex-tornus, hindwing base-apex, hindwing base-tornus, hindwing apex-tornus, total foreleg, total hindleg, vein forewing cubitus2, vein forewing anal, vein hindwing radius2, and vein hindwing cubitus2.

Paul *et al.* (2022) while studying the Sexual and developmental variations of ecto-parasitism in damselflies recorded the morphometrics of *Agriocnemis pygmaea*. The observations they made were body size: 19.84-22.68 mm; abdomen length: 15.03-17.62 mm; thorax length: 1.92-2.45 mm; abdomen width: 0.17-0.36 mm; thorax width: 1.20-1.54 mm.

Hassan and Liuthe (2022) while studying and re-describing the faunal diversity of lacewings in Pakistan, recorded their measurements on the various parameters such as forewing length, forewing width, hindwing length, hindwing

width, body length, head length, antennae length, in addition to other morphological characteristics.

Triaswanto *et al.* (2022) while describing the Sexual dimorphism (SD) in Rice ear bugs [*Leptocorisa oratorius* Fabricius (Hemiptera: Alydidae)] analyzed 22 morphometric descriptors viz., Body length, body width, body height, antennae length, mouthpart length, left forewing length, right forewing length, left hindwing length, right hindwing length, left forewing width, right forewing width, left hindwing width, right hindwing width, femur length, tibia length, tarsus length, prothorax leg length, mesothorax leg length, metathorax leg length, head length, abdomen length and thorax length.

Suhriani *et al.* (2023) while studying the morphology and of stored grain weevils, recorded that *Sitophilus oryzae* (males) possessed the a total body length of 3.190 mm abdomen length was recorded as 1.120 mm, abdomen width was 0.700 mm, pronotum length was 1.055 mm while pronotum width was recorded as 0.630 mm. The average head size recorded was 1.105 mm while the length of the rostrum to insertion of the antennae was 0.580 mm.

The description of *Neurothemis intermedia* in Indian Biodiversity portal in 2024, describes the male abdomen size as 22-24 mm and a hindwing size as 25-28 mm. Similarly, the measurements of Male *Neurothemis tullia* are given as abdomen ranging between 16-20 mm and hind wings between 19-23 mm. Male *Orthetrum pruinatum* was recorded as abdomen: 28-31 mm and hind wing:32-36 mm. The male specimens of *Palpopleura sexmaculata* are described with 14-16 mm abdomen and with a hind wing of 15-21 mm. Damselflies are also briefly described with abdomen length of male *Agriocnemis pieris* ranging from 16-18 mm and hind wing length between 9-10 mm. At the web portal “Odonata of Bangladesh”, the data on *Palpopleura sexmaculata* (Fabricius, 1787) - Asian widow or blue-tailed yellow skimmer recorded the male abdomen size as 15 mm with wing size of 18 mm. *Agriocnemis pieris* is recorded with 17 mm and wing length of 9.5 mm in male specimens.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The experimental study entitled “**Seasonal abundance and diversity of insect pests and their natural enemies in lowland rice agroecosystem under Dimapur district of Nagaland.**” was undertaken in three prominent lowland rice growing areas of Nagaland. The study was conducted during two rice-growing seasons from June to December of 2020 and 2021.

3.1. Geographical location

The experiment was conducted at three lowland rice growing locations: Singrijan and Medziphema, now part of the newly formed Chümoukedima district, and Kuhoxu, which currently falls under Niuland district. At the time of the study, all these locations were under erstwhile Dimapur district.

Medziphema Geo-coordinates	: 25.744576, 93.860705
Singrijan Geo-coordinates	: 25.835184, 93.716652
Kuhoxu Geo-coordinates	: 25.905405, 93.990827

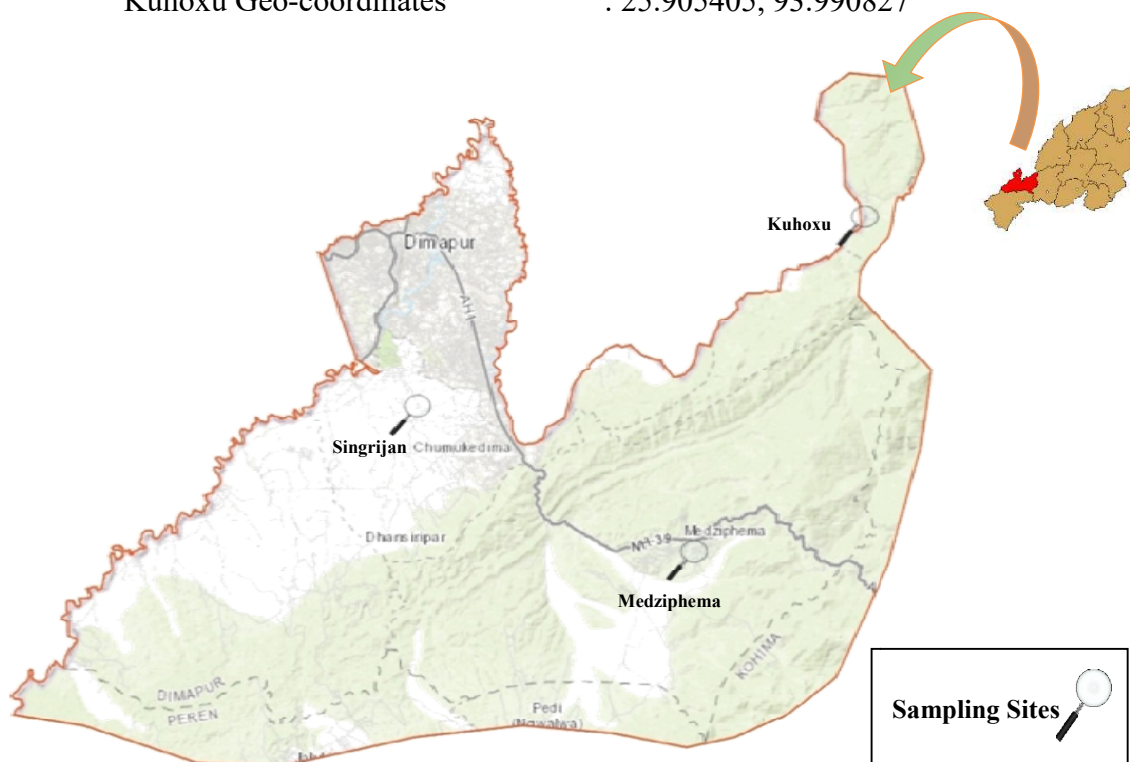


Fig 3.1: Map indicating sampling sites under erstwhile Dimapur district (Source: Bharat Maps, www.bharatmaps.co.in)



Plate 1. Study locations

3.2 Meteorological data

The weather parameters of different standard meteorological weeks (SMW) during the crop growth were obtained from ICAR-NEHR Jharnapani for Medziphema; office of the Soil and Water Conservation for Singrijan and office of the Sub-Divisional Agriculture officer, Niuland for Kuhoxu.

3.3 Sampling methods used:

The following sampling methods were used to study the diversity of insect pests and their natural enemies under lowland rice agroecosystem, with an objective to draw maximum result from different methods adopted under field condition.

3.3.1. Sweep net: A standard sweep net of 30 cm diameter was used. Five sweeps per sq. meter area at five random places was done at weekly interval. The collected samples were killed by carbon tetra-chloride in killing bottle and stored at 70% ethanol for later sorting and identification. The moths were, however, pinned and stored in wooden insect boxes (Cameron *et al.*, 1981).

3.3.2. Light trap: For nocturnal flying insects, light traps having potassium cyanide bottle or carbon tetra-chloride at the bottom as killing agent, equipped with 60 watts electric bulb was operated in proper location from dusk to dawn and insect specimens were collected at weekly intervals from nurseries and crop field.

3.3.3. Pitfall trap: For terrestrial insects, pitfall traps were used. Wide mouth plastic jars (11 cm deep and 7.5 cm in diameter) were permanently buried in the field bunds (at end of cropping season when water dried from the fields, the traps were shifted into the rice field). Twenty traps were installed at 10 feet interval in an alternating pattern along the length of field bunds. The traps were filled (2-3 cm) at the bottom with 95% ethylene glycol with few drops of detergent or 5% formaldehyde solution to kill and preserve the insects. The insects were sorted in the laboratory under a stereoscopic binocular microscope and then transferred into 70% alcohol until further identification (Oraze *et al.*, 1988).

3.3.4. Quadrat method: For the study of rice thrips, it was difficult to record their presence with other sampling methods. Hence, a quadrat sampling method comprising of 5 quadrats was deployed for accurate observation of the pest.

3.4. Documentation and Preservation of specimen

The insect pests and their natural enemies were photographed in the field with the help of a DSLR camera equipped with a macro lens (Nikon D7500 + 85mm micro nikkor lens) which enabled to take good quality photographs. Dead specimens were brought back to the laboratory which was photographed under a stereozoom microscope (Zeiss stemi 305).

The collected specimens were sorted, pinned, labelled and mounted in collection boxes and minute specimens in glass vials in 70% ethyl alcohol. These specimens were then used for identification.

3.5. Morphometric studies of the collected specimens:

Relevant literatures were referred for taking the morphometric studies of rice insect pests and their natural enemies. Three replicates were used for each morphometric measurement in millimeter (mm) on a Zeiss stemi 305 stereomicroscope with Mosaic 2.4 software. The following parameters for morphometric studies were taken:

3.5.1. Hemiptera - Cicadellidae and Delphacidae (Manurung *et al.*, 2019)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Body length	BL
2.	Body width	BW
3.	Head length	HL
4.	Head width	HW
5.	Thorax length	TL
6.	Abdomen length	AL
7.	Stylet length	SL
8.	Fore wing length	WL
9.	Fore wing width	WW
10.	Hind leg length	LL

11.	Hind wing width	HWW
12.	Ovipositor length	OL
13.	Antennae Length	AL
14.	Inter ocular distance	IOD

3.5.2. Lepidoptera - Crambidae and Pyralidae (Matsukura *et al.*, 2006)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Length of the forewing	FWL
2.	Distance between the first and seventh (last) black spots along the side-margin of the forewing	DBS
3.	Length of the hindwing	HWL
4.	Fore femur length	FFL
5.	Fore tibia length	FTL
6.	Midfemur length	MFL
7.	Mid tibia length	MTL
8.	Hind femur length	HFL
9.	Hind tibia length	HTL
10.	Head width	HW
11.	Total Body Length	TBL
12.	Labial Length	LL
13.	Proboscis Length	PbL
14.	Antennal Length	AL
15.	Abdomen Length	AbL
16.	Thorax Length	TL

3.5.3. Hemiptera - Alydidae, Coreidae, Reduviidae, Miridae (Triaswanto *et al.*, 2022)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Body Length	BL
2.	Body Width	BW
3.	Body Height	BH
4.	Antennae Length	AnL
5.	Mouthpart Length	ML
6.	Left Forewing Length	LfL
7.	Right Forewing Length	RfL
8.	Left Hindwing Length	LhL
9.	Right Hindwing Length	RhL
10.	Left Forewing Width	LfW
11.	Right Forewing Width	RfW

12.	Left Hindwing Width	LhW
13.	Right Hindwing Width	RhW
14.	Femur Length	FL
15.	Tibia Length	TiL
16.	Tarsus Length	TarL
17.	Prothorax Leg Length	Pro. Leg L
18.	Mesothorax Leg Length	Mes. Leg L
19.	Metathorax Leg Length	Met. Leg L
20.	Head Length	HL
21.	Abdomen Length	AbL
22.	Thorax Length	ThL

3.5.4. Lepidoptera - Nymphalidae and Hesperidae (Mahdi *et al.*, 2022)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Total Length	TL
2.	Antenna Length	AL
3.	Forewing Base-Apex	FWBA
4.	Forewing Base-Tornus	FWBT
5.	Forewing Apex-Tornus	FWAT
6.	Hindwing Base-Apex	HWBA
7.	Hindwing Base-Tornus	HWBT
8.	Hindwing Apex-Tornus	HWAT
9.	Total Foreleg	TFL
10.	Total Midleg	TML
11.	Total Hindleg	THL
12.	Vein Forewing Cubitus2	VFCU2
13.	Vein Forewing Anal	VFA
14.	Vein Hindwing Radius2	VHR2
15.	Vein Hindwing Cubitus2	VHCU2
16.	Proboscis Length	PbL
17.	Abdomen Length	Ab.L
18.	Thorax Length	Th. L

3.5.5. Orthoptera - Acrididae, Pyrgomorphidae, Gryllidae and Pyrgomorphidae (Mahdi *et al.*, 2018; Milach *et al.*, 2015 and Romero *et al.*, 2014)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Body length	BL
2.	Pronotum length	PL
3.	Pronotum width	PW
4.	Head width	HW

5.	Interocular distance	IOD
6.	Antenna length	AL
7.	Thorax height	TxH
8.	Tegmen length	TegL
9.	Forewing length	FWL
10.	Forewing width	FWW
11.	Hindwing length	HWL
12.	Hindwing width	HWW
13.	Foreleg length	FLL
14.	Midleg length	MLL
15.	Hindleg length	HLL
16.	Third femur length	FL
17.	Third tibia length	TiL
18.	Metanotal gland length	MGL
19.	Metanotal gland width	MGW

3.5.6. Coleoptera - Curculionidae (Sazali *et al.*, 2018)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Snout length	SL
2.	Snout width	SW
3.	Scape of antenna length	SAL
4.	Antenna length	AL
5.	Antenna width	AW
6.	Distance between eyes	ED
7.	Pronotum length	PL
8.	Pronotum width	PW
9.	Elythra length	EL
10.	Elythra width	EW
11.	Total length (without snout)	TL
12.	Profemur length	F1L
13.	Protibia length	F1TB
14.	Protarsus length	F1TA
15.	Mesofemur length	F2L
16.	Mesotibia length	F2TB
17.	Mesotarsus length	F2TA
18.	Metafemur length	F3L
19.	Metatibia length	F3TB
20.	Metatarsus length	F3TA
21.	Mesocoxal distance	MSD
22.	Metacoxal distance	MTD
23.	Meso-metacoxal distance	MMD

3.5.7. Coleoptera - Chrysomelidae (Muntha *et al.*, 2024)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Antennal length	AL
2.	Length of Head	HL
3.	Width of Head	HW
4.	Length of Pronotum	PL
5.	Width of Pronotum	PW
6.	Elytral length	EL
7.	Elytral width	EW
8.	Total body length	BL
9.	Inter ocular distance	IoD
10.	Fore femur length	FFL
11.	Fore tibia length	FTL
12.	Midfemur length	MFL
13.	Mid tibia length	MTL
14.	Hind femur length	HFL
15.	Hind tibia length	HTL

3.5.8. Thysanoptera - Thripidae (Fedor *et al.*, 2008)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Head width	HW
2.	Head length (dorsal side)	HL
3.	Head length (ventral side, including mouthcone)	HLiMC
4.	Clavus length	CL
5.	Clavus width	CW
6.	Forewing length	FL
7.	Forewing basal width	FbW
8.	Total body length (excluding antenna and penis)	TL
9.	Pronotum width	PW
10.	Pronotum length	PL
11.	Eye length	EL
12.	Ovipositor length	OL
13.	Ovipositor width	OW
14.	Antennal segment V length	ALV
15.	Antennal segment VI length	ALVI
16.	Antenna length	AL
17.	Distance between the posterior pair of ocelli	
18.	Distance between anterior and posterior pair of ocelli	
19.	Hind wing width	HWW

20.	Hind wing Length	HWL
21.	Inter ocular distance	IoD

3.5.9. Odonata - Libellulidae and Coenagrionidae (Alvial *et al.* 2019)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Body length	BD
2.	Abdomen length	AL
3.	Thorax length	TL
4.	Head width	HW
5.	Head Length	HL
6.	Forewing length	FWL
7.	Forewing height	FWH
8.	Hindwing length	HWL
9.	Hindwing height	HWH
10.	Pterostigma length	PtL
11.	Foreleg length	FLL
12.	Midleg length	MLL
13.	Hindleg length	HLL

3.5.10. Hymenoptera - Scelionidae, Ichneumonidae and Braconidae (Khan *et al.* 2020)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Antennal length	AL
2.	Inter ocular distance	OD
3.	Flagellum length	FL
4.	Flagellum width	FW
5.	Head length	HL
6.	Head width	HW
7.	Eye width	EW
8.	Fore wings length	FWL
9.	Fore wings width	FWW
10.	Length of hind tibia	HTL
11.	Width of hind tibia	HTW
12.	Ovipositor length	OL
13.	Thorax length	TL
14.	Thorax width	TW
15.	Prtiole length	PL
16.	Foreleg length	FLL
17.	Midleg length	MLL
18.	Hindleg length	HLL
19.	Petiole width	PW

20.	Gaster length	GL
21.	Gaster width	GW
22.	Hind wings length	HWL
23.	Hind wings width	HWW
24.	Body Length	BL

3.5.11. Coleoptera - Caribidae (Ribera *et al.*, 1999 and Sukhodolskaya *et al.*, 2021)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Width of the head	HW
2.	Diameter of the eye	YW
3.	Length of the antenna	AL
4.	Length of the pronotum	PL
5.	Maximum width of the pronotum	PW
6.	Maximum height of the pronotum	PH
7.	Length of the elytra	EL
8.	Maximum width of the elytra	EW
9.	Length of the metafemur	FL
10.	Length of the metatrochanter	TR
11.	Length of the metatibia	BL
12.	Length of the metatarsi	RL
13.	Maximum width of the metafemur	FW
14.	Total length	TL

3.5.12. Coleoptera - Cicindelidae (Jaskuła *et al.*, 2021 and Acal *et al.*, 2024)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Right mandible length	RML
2.	Labrum length	LL
3.	Length of head	LH
4.	Width of head	WH
5.	Length of pronotum	LP
6.	Width of pronotum	WP
7.	Length of elytra	EL
8.	Width of elytra	WE
9.	Length of foreleg	FLL
10.	Length of middle leg	MLL
11.	Length of hind leg	HLL
12.	Total body length	TBL

3.5.13. Coleoptera - Coccinellidae

Sl. No.	Characteristics (mm)	Abbreviation
1.	Length of whole body	TBL
2.	Breadth of body	BB
3.	Length of head	HL
4.	Breadth of head	HB
5.	Distance between compound eyes	DBE
6.	Breadth of compound eye	EB
7.	Length of Antenna	AL
8.	Length of Pronotum	PL
9.	Breadth of Pronotum	PB
10.	Length of scutellum	SL
11.	Breadth of scutellum	SB
12.	Breadth of elytra	EB
13.	Length of elytra	EL
14.	Length of foreleg	FLL
15.	Length of middle leg	MLL
16.	Length of hind leg	HLL
17.	Length of Abdomen	AbL
18.	Breadth of Abdomen	AB

3.5.14. Neuroptera - Chrysopidae (Hassan and Liuthe. 2022)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Head length	HL
2.	Head width	HW
3.	Body length	BL
4.	Dist.between tentoria	DBT
5.	Frons length	FL
6.	Clypeus length	CL
7.	Antenna length	AL
8.	Pronotum length	PL
9.	Pronotum width	PW
10.	Forewing length	FWL
11.	Forwing width	FWW
12.	Hindwing length	HLW
13.	Hindwing width	HWW

3.5.15. Neuroptera - Ascalaphidae (Alvial *et al.* 2019)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Body length	BD

2.	Abdomen length	AbL
3.	Thorax length	TL
4.	Head width	HW
5.	Forewing length	FWL
6.	Forewing width	FWW
7.	Hindwing length	HWL
8.	Hindwing height	HWH
9.	Fore wing Pterostigma length	FWPtL
10.	Hind wing Pterostigma length	HWPtL
11.	Antenna length	AL
12.	Interocular distance	IOD
13.	Eye width	EW

3.5.16. Diptera - Tachinidae (Oyerinde *et al.*, 2019)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Head / Eyes	HE
2.	Interocular distance	IOD
3.	Body Length	BL
4.	Antenna	AN
5.	Arista Length	ArL
6.	Fore leg Length of Femur	FFL
7.	Fore leg Tibia length	FTiL
8.	Fore leg Tarsal	FTaL
9.	Meta Length of Femur	MFL
10.	Meta Tibia length	MTiL
11.	Meta Tarsal	MTaL
12.	Hind Length of Femur	HFL
13.	Hind Tibia length	HTiL
14.	Hind Tarsal	HTaL
15.	Abdomen	AB
16.	Wing Length	WL
17.	Thorax	TH
18.	Proscutulum/scutellum	

3.5.17. Arachnida - Araneae (Arunkumar and Jayaprakash. 2014)

Sl. No.	Characteristics (mm)	Abbreviation
1.	Length of head	HL
2.	Width of head	HW
3.	Length of abdomen	AL
4.	Width of abdomen	AW
5.	Total length	TL

6.	1 st pair of legs	1 st LL
7.	2 nd pair of legs	2 nd LL
8.	3 rd pair of legs	3 rd LL
9.	4 th pair of legs	5 th LL

3.6. Statistical analysis

3.6.1. Diversity Studies

- The insect pests and their natural enemies' diversity were calculated using the Shannon-Wiener diversity index (Shannon and Wiener, 1949)

$$H = - \sum_{i=1}^S P_i \log P_i$$

Where,

H = Measure of Shannon and Wiener Diversity

S = Total no. of species in a sample.

P_i = Proportion of the total number of individuals occurring in species i .

- In addition, Simpsons diversity was also calculated as per the formula below:

$$D = \sum_{i=1}^S \left(\frac{n_i}{N} \right)^2$$

Where:

D = Simpson's Index of Diversity.

n_i = Number of individuals of species i .

N = Total number of individuals of all species.

S = Total number of species

- Indices for Alpha (α), Beta (γ) and Gamma (β) diversity among the three locations of investigation were calculated as per Whittaker (1972) using the PAST (Paleontological Statistics) program version 3:04 (Hammer, 2014)

3.6.2. Relative abundance

The relative abundance of insect pest and their natural enemies were worked out statistically by following the methods as suggested by Singh and Rai, 2000.

$$R = \frac{a}{n} \times 100$$

Where,

R = Relative abundance (%).

a = No. of individuals present on date of sampling.

n = Total population of all species.

3.6.3. Correlation

For correlation studies, a simple correlation was calculated between the insect pests values and weather parameters; and between insect pests' values and natural enemies from the formula calculations options available at Microsoft Excel 2016.

In addition to correlation, multiple linear regression analysis was also calculated and formulated on Microsoft Excel 2016 to assess the relationship between pest incidence and weather parameter and for future pest scenario of the study locations.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The present study entitled “**Seasonal abundance and diversity of insect pests and their natural enemies in lowland rice agroecosystem under Dimapur district of Nagaland**” was carried out at three locations: Singrijan and Medziphema, now part of the newly formed Chümoukedima district, and Kuhoxu, which currently falls under Niuland district. At the time of the study, all these locations were under Dimapur district. The study was conducted during the rice-growing seasons from June to December of 2020 and 2021, and the findings are presented and discussed as follows.

4.1. DIVERSITY AND ABUNDANCE OF INSECT PESTS AND THEIR NATURAL ENEMIES IN LOWLAND RICE AGROECOSYSTEM IN NAGALAND

4.1.1. DIVERSITY OF INSECT PESTS AND THEIR NATURAL ENEMIES IN LOWLAND RICE AGROECOSYSTEM IN NAGALAND

During the course of the study, 32 insect pests associated with rice crops were observed (Table 4.1a, plates 1-8), belonging to 28 genera, 16 families and 5 insect orders *viz.*, Hemiptera (8 species), Lepidoptera (12 species), Orthoptera (9 species), Coleoptera (2 species) and Thysanoptera (1 species) as described in table 4.1a. These findings align with Nasiruddin and Roy (2012), who documented 35 pest species across four major orders, and Karim and Riazuddin (1999), who listed 52 pest species from rice crops. Bambaradeniya *et al.*, (2004) observed 55 rice pest species within a highly diverse rice field ecosystem. Similarly, Das (2020) identified seven dominant pest species, including *Cnaphalocrocis medinalis* and *Scirpophaga incertulas*, which were also recorded in the present study. Edde (2022) confirmed the presence of *C. medinalis*, *N. lugens*, and *Leptocorisa oratorius*, reinforcing their widespread occurrence in rice agroecosystems. Rath *et al.* (2020) highlighted that climate change has influenced the population dynamics of several rice pests, including stem borers, plant hoppers, gall midges, leaf folders, cutworms, and swarming caterpillars, many of which were also recorded in the present investigation. The recorded pest

Table 4.1a: Diversity of insect pests in lowland rice agroecosystem

Sl.no.	Insect pest species	Common name	Order	Family
1.	<i>Nephotettix virescens</i> Distant	Rice green leafhopper	Hemiptera	Cicadellidae
2.	<i>Nephotettix nigropictus</i> Stål	Rice green leafhopper		Cicadellidae
3.	<i>Cofana spectra</i> Distant	White Leafhopper		Cicadellidae
4.	<i>Maistas dorsalis</i> Motchulsky	Rice zigzag leafhopper		Cicadellidae
5.	<i>Nilaparvata lugens</i> Stål	Brown planthopper		Delphacidae
6.	<i>Sogatella furcifera</i> Horvith	White-backed planthopper		Delphacidae
7.	<i>Leptocorisa acuta</i> Thunberg	Paddy earhead bug		Alydidae
8.	<i>Cletus punctiger</i> Dallas	Rice stinkbug		Coreidae
9.	<i>Scirpophaga incertulas</i> Walker	Yellow stem borer/Rice yellow stem borer	Lepidoptera	Crambidae
10.	<i>Chilo suppressalis</i> Dudgeon	Asiatic rice borer/Striped rice stemborer		Crambidae
11.	<i>Scirpophaga</i> spp.	Stem borer		Crambidae
12.	<i>Scirpophaga nivella</i> Fabricus	White rice borer		Crambidae
13.	<i>Cnaphalocrocis medinalis</i> Guenée	Rice leafroller		Crambidae
14.	<i>Melanitis leda ismene</i> Linnaeus	Rice butterfly/ Rice horned caterpillar		Nymphalidae
15.	<i>Mycalesis mineus</i> Linnaeus	Dark-branded bushbrown		Nymphalidae
16.	<i>Orsotriaena medus</i> Fabricus	Medus brown		Nymphalidae
17.	<i>Spodoptera litura</i> Fabricius	Tobacco cutworm/Cotton leafworm		Noctuidae
18.	<i>Leucania loreyi</i> Duponchel	False army worm		Noctuidae
19.	<i>Nymphula depunctalis</i> Guenée	Rice caseworm		Pyrilidae
20.	<i>Pelopidas mathias</i> Fabricius	Rice skipper		Hesperiidae
21.	<i>Oxya</i> spp.	Rice grasshopper	Orthoptera	Acrididae
22.	<i>Melanoplus bivittatus</i> Say	Two striped grasshopper		Acrididae
23.	<i>Dociostaurus</i> spp.	Grasshopper		Acrididae
24.	<i>Phlaeoba infumata</i> Brunner von Wattenwyl	Silent slant-faced grasshopper		Acrididae
25.	<i>Atractomorpha</i> spp.	Grasshopper		Pyrgomorphidae
26.	<i>Euscyrtus concinnus</i> de Haan	Field cricket		Gryllidae
27.	<i>Gryllus bimaculatus</i> De Geer	Field cricket		Gryllidae
28.	<i>Gryllus</i> spp.	Field cricket		Gryllidae
29.	<i>Gryllotalpa orientalis</i> Burmeister	Oriental mole cricket		Gryllotalpidae
30.	<i>Sitophilus oryzae</i> Linnaeus	Rice weevil	Coleoptera	Curculionidae
31.	<i>Dicladyspa armigera</i> Olivier	Rice hispa		Chrysomelidae
32.	<i>Stenchaetothrips biformis</i> Bagnall	Rice thrips	Thysanoptera	Thripidae

species in the present investigation also align with Lisha *et al.* (2020), who documented *Scirpophaga incertulas*, *Cnaphalocrocis medinalis*, grasshoppers, green leafhoppers, ear head bugs, and white leafhoppers, many of which were among the dominant pests in the present study. Additionally, Meena *et al.* (2018) recorded *Mythimna separata*, *Cnaphalocrocis medinalis*, *Melanitis leda ismene*, *Leptocorisa acuta*, *Nephotettix virescens*, *Euscyrtus concinnus*, and *Gryllotalpa orientalis*, which were also observed in the present study, reinforcing the consistency of pest occurrence across different rice-growing regions. Siregar *et al.* (2017) and Rani *et al.* (2007) also recorded similar pest species with *C. medinalis*, *N. lugens*, *L. oratorius* and *S. incertulas* as the most dominant.

As evident from table 4.1b, 57 natural enemies of insect pests were also observed which belonged to 42 genera, 19 families from 10 orders and 2 classes viz., Hymenoptera (10 species), Odonata (15 species), Coleoptera (10 species), Neuroptera (5 species), Diptera (2 species), Hemiptera (5 species), Mantodea (2 species), Orthoptera (1 species), Arachnida (Araneae: 6 species) were identified. 8 insect specimens remained unidentified (Plates 9-12).

These results are consistent with Chakraborty *et al.* (2016), who recorded 49 predator species, with spiders forming the most abundant group (41%), followed by Coleoptera (29%) and Hymenoptera (6%). The diversity of spiders in the present investigation aligns with Borkakati *et al.* (2018), who documented 16 spider species in rice fields, and Moses *et al.* (2023), who recorded 16 predatory spider species across six families. In the present investigation, the recorded spider diversity is also supported by Sebastian *et al.* (2005), who surveyed irrigated rice fields in Kerala and recorded 1,130 individual spiders belonging to 92 species, 47 genera, and 16 families. The abundance of spiders in the present study corresponds with the findings of Shyamrao *et al.* (2019), who reported 2,605 spiders in rice fields, with Araneidae and Tetragnathidae as the most abundant families. Further supporting this, Priyadarshini and Mahapatra (2023) documented 93 spider species across 17 families in the Rabi season and 13 families in the Kharif season, with Araneidae exhibiting the highest

Table 4.1b: Diversity of natural enemies of insect pests in lowland rice agroecosystem

Sl.no.	Natural enemy species	Common name	Class/Order	Family /Class
1.	<i>Brachythemis contaminata</i> Fabricius	Asian groundling/Ditch jewel	Odonata	Libellulidae
2.	<i>Crocothemis servilia</i> Drury	Scarlet skimmer or ruddy marsh skimmer		Libellulidae
3.	<i>Orthetrum sabina</i> Drury	Slender skimmer or green marsh hawk		Libellulidae
4.	<i>Crocothemis nigrifrons</i> Kirby	Black-headed skimmer and blue-scarlet dragonfly		Libellulidae
5.	<i>Neurothemis intermedia</i> Rambur	Paddy field parasol		Libellulidae
6.	<i>Diplacodes trivialis</i> Rambur	Blue ground skimmer		Libellulidae
7.	<i>Neurothemis tullia</i> Drury	Pied paddy skimmer		Libellulidae
8.	<i>Orthetrum pruinsum</i> Burmeister	Crimson-tailed marsh hawk		Libellulidae
9.	<i>Palpopleura sexmaculata</i> Fabricius	Blue-tailed yellow skimmer		Libellulidae
10.	<i>Agriocnemis pieris</i> Laidlaw	Indian white dartlet		Coenagrionidae
11.	<i>Agriocnemis pygmaea</i> Rambur	Pygmy dartlet		Coenagrionidae
12.	<i>Agriocnemis argentea</i> Tillyard	Silver wisp		Coenagrionidae
13.	<i>Ischnura rubilio</i> Selys	Western golden dartlet		Coenagrionidae
14.	<i>Ceriagrion cerinorubellum</i> Brauer	Orange-tailed marsh dart		Coenagrionidae
15.	<i>Ceriagrion coromandelianum</i> Fabricius	Coromandel marsh dart/ Yellow wax tail		Coenagrionidae
16.	<i>Macrocheilus bensoni</i> Hope	Ground beetle	Coleoptera	Caribidae
17.	<i>Ophionea nigrofasciata</i> Schmidt-Goebel	Long-neck ground beetle		Caribidae
18.	<i>Chlaenius</i> spp.	Vivid metallic ground beetle		Caribidae
19.	<i>Pheropsophus</i> spp.	Asian bombardier beetle		Caribidae
20.	<i>Cicindela sexpunctata</i> Fabricius	Tiger beetle		Cicindelidae
21.	<i>Cylindera venosa</i> Kollar	Tiger beetle		Cicindelidae
22.	<i>Micraspis discolor</i> Fabricius	Discolored ladybird beetle		Coccinellidae
23.	<i>Micraspis univittata</i> Hope	Ladybird beetle		Coccinellidae
24.	<i>Coccinella septempunctata</i> Linnaeus	Seven-spot ladybird beetle		Coccinellidae
25.	<i>Harmonia</i> spp.	Asian ladybird beetle		Coccinellidae

26.	<i>Peirates atromaculatus</i> Stål	Assassin bug	Hemiptera	Reduviidae
27.	<i>Oncocephalus</i> spp.	Assassin bug		Reduviidae
28.	<i>Rhynocoris fuscipes</i> Fabricius	Assassin bug		Reduviidae
29.	<i>Ectomocoris atrox</i> Stål	Assassin bug		Reduviidae
30.	<i>Cyrtorhinus lividipennis</i> Reuter	Mirid bug		Miridae
31.	<i>Telenomus</i> spp.	Parasitic wasp	Hymenoptera	Scelionidae
32.	<i>Ophion</i> spp.	Ichneumonid wasp		Ichneumonidae
33.	<i>Xanthopimpla</i> spp.	Ichneumonid wasp		Ichneumonidae
34.	<i>Xanthopimpla punctata</i> Fabricius	Yellow ichneumon wasp		Ichneumonidae
35.	<i>Agonocryptys discoidaloides</i> Viereck	Ichneumonid wasp		Ichneumonidae
36.	<i>Ischnojoppa luteator</i> Fabricius	Ichneumonid wasp		Ichneumonidae
37.	<i>Aleiodes</i> spp.	Braconid wasp		Braconidae
38.	<i>Brachymeria scutellocarinata</i> Joseph	Chalcid wasp		Chalcidoidea
39.	<i>Cardiochilinae</i> spp.	Braconid wasp		Braconidae
40.	<i>Agrypon flaveolatum</i> , Gravenhorst	Ichneumonid wasp		Ichneumonidae
41.	<i>Apochrysa</i> spp.	Delicate lacewing	Neuroptera	Chrysopidae
42.	<i>Ankylopteryx</i> spp.	Green lacewing		Chrysopidae
43.	Unidentified	Green lacewing		Chrysopidae
44.	<i>Ascalaphus prothoracicus</i> Kimmins	Owlfly		Ascalaphidae
45.	Unidentified	Mantisfly/ mantid lacewing		Mantispidae
46.	Unidentified	Robber fly	Diptera	Asilidae
47.	Unidentified	Tachinid fly		Tachinidae
48.	Unidentified	Earwig	Dermaptera	--
49.	Unidentified	Preying mantid	Mantodea	--
50.	Unidentified	Preying mantid		--
51.	Unidentified	Long horned grasshopper	Orthoptera	--
52.	<i>Oxyopes birmanicus</i> Thorell	Burmese lynx spider	Arachnida/ Araneae	Oxyopidae
53.	<i>Peucetia viridana</i> Stoliczka	Green lynx spider		Oxyopidae
54.	<i>Argiope aemula</i> Walckenaer	Signature spider		Araneidae
55.	<i>Argiope bruennichi</i> Scopoli	Wasp spider		Araneidae
56.	<i>Tetragnatha straminea</i> Emerton	Long-jawed orb weaver		Tetragnathidae
57.	<i>Neoscona theisi</i> Walckenaer	Orb spider		Araneidae

species diversity (28 species) and Tetragnathidae having the highest abundance (1,106 individuals). Ravi *et al.* (2022) also observed spider diversity similar to the trends observed in the present investigation. Similarly, **Zhimomi (2006)** recorded 13 species of spiders, 4 species of Zygoptera/Anisoptera, 3 predatory beetles, and 1 predatory Dipteran in rice fields in Nagaland. In the present study, the diversity of parasitoids was high, with families such as Ichneumonidae, Braconidae, Scelionidae, and Chalcididae being the most dominant. These results align with **Kathirvelu (2019)**, who recorded a total of 889 parasitoids. Additionally, Pathak *et al.* (2020) recorded 26 species of parasitoids, with *Apanteles*, *Telenomus*, *Trichogramma*, and *Xanthopimpla* being the dominant genera, which corroborates the findings of the present investigation. The diversity of predatory species in the present investigation aligns with **Rahaman and Stout (2019)**, who recorded *Micraspis discolor*, *Lycosa pseudoannulata*, *Ophionea indica*, *Forticula auricularia*, *Cyrtorhinus lividipennis*, and *Agriocnemis pygmaea* as key predators and *Trichogramma japonicum*, *Telenomus rowani*, and *Tetrastichus schoenobii* as parasitoids in rice fields, which is in agreement with the present investigation.

Table 4.1c: Diversity of insect pests and their natural enemies in lowland rice agroecosystem at Medziphema, Singrijan and Kuhoxu in Nagaland

	Medziphema		Singrijan		Kuhoxu	
	Insect pests	Natural enemies	Insect pests	Natural enemies	Insect pests	Natural enemies
Shannon-Weiner Diversity Index (H')	2.60	1.99	2.32	2.06	2.25	2.04
Species Richness (S)	29	54	30	52	31	52
Species Evenness (E_h)	0.81	0.83	0.72	0.86	0.70	0.85
Simpson's Diversity Index (D)	0.87	0.84	0.82	0.85	0.81	0.84

Table 4.1c reveals that Medziphema has the highest insect pest diversity ($H'=2.60$) compared to Singrijan ($H'=2.32$) and Kuhoxu ($H'=2.25$). This indicates a more balanced and diverse insect pest population in Medziphema. In terms of natural enemies, diversity remains fairly consistent across locations, with Singrijan recording

the highest value ($H'=2.06$), followed by Kuhoxu ($H'=2.04$) and Medziphema ($H'=1.99$). Bakar and Khan (2016) reported a similar trend, where diversity indices varied across locations based on environmental factors and crop management practices. The diversity indices observed in the present investigation were slightly higher than those reported by Siregar *et al.* (2017), who found a Shannon-Wiener diversity index ($H' = 2.26$) and evenness (0.65). Such variations may be attributed to differences in environmental conditions and pest management practices, as noted by Bakar and Khan (2016), who reported significant diversity variations across different treatments.

The highest diversity (Simpson's Diversity Index) was observed in Medziphema ($D=0.87$), followed by Singrijan ($D=0.82$) and Kuhoxu ($D=0.81$) which indicates that Medziphema has a more balanced insect pest population, while Singrijan and Kuhoxu exhibit a slightly higher dominance of specific pest species. For Natural enemies, it remained relatively stable across locations, with values ranging between 0.84 and 0.85. This suggests a consistent and well-distributed population of natural enemies in the lowland rice agroecosystems of all three locations.

Across all locations, natural enemies exhibit higher species richness than insect pests, ranging from 52 to 54 species, compared to 29 to 31 insect pest species. Among insect pests, Kuhoxu has the highest species richness (31), followed by Singrijan (30) and Medziphema (29). The species richness of natural enemies remains relatively stable, indicating a consistent presence of predators and parasitoids in all three locations. Wilby *et al.*, (2006) highlighted that natural enemies exhibited higher species richness than pests, which aligns with the current findings where natural enemies were consistently more diverse across all locations.

Species evenness is highest among natural enemies across all locations, particularly in Singrijan ($E_h=0.86$) and Kuhoxu ($E_h=0.85$), suggesting a well-balanced distribution of individuals among species, with no single species dominating. Among insect pests, Medziphema exhibits the highest evenness ($E_h=0.81$), whereas Singrijan

($E_h=0.72$) and Kuhoxu ($E_h=0.70$) display slightly lower values. This suggests that in Singrijan and Kuhoxu, certain pest species are more dominant compared to others.

In the present investigation, species richness and evenness of natural enemies remained stable across locations, with minimal species turnover. These findings align with that of Zahir *et al.* (2003), who emphasized the role of non-rice plant feeders in sustaining natural enemy populations. Anbalagan *et al.* (2020) also reported 70 entomophagous insect species, reinforcing the high diversity of natural enemies recorded in the present investigation.

4.1.2. ALPHA (α), BETA (γ) & GAMMA (β) DIVERSITY OF INSECT PESTS AND THEIR NATURAL ENEMIES IN LOWLAND RICE AGROECOSYSTEM AT MEDZIPHEMA, SINGRIJAN AND KUHOXU IN NAGALAND

Table 4.1d describes the Alpha (α), Beta (β) and Gamma (γ) diversity of major insect pests and their natural enemies in lowland rice agroecosystem of the three locations. The Alpha diversity (Shannon-Weiner Diversity) represents the diversity of a single location which are recorded as 2.6, 2.32 and 2.25 in case of insect pests at Medziphema, Singrijan and Kuhoxu respectively and 1.99, 2.06 and 2.04 in case of natural enemies at Medziphema, Singrijan and Kuhoxu, respectively. Gamma diversity is the total diversity across all locations which are recorded as 2.308 and 2.05 for insect pests and natural enemies, respectively. Beta diversity measures species turnover between locations and using Whittaker's formula resulted in very low values of 0.028 and 0.00 for insect pests and natural enemies, respectively which confirms that most species were shared among the three locations.

Based on the results of the analysis with the Whittaker beta diversity index (Whittaker's index), the change in species composition from one location to another is negligible, as seen from the values that are almost 0. The value of the beta diversity index ranges from 0-1. If beta diversity = 0, then the change in species composition from location to location is small or there is no change.

Table 4.1d: Alpha (α), Beta (β) and Gamma (γ) diversity of insect pests and their natural enemies in lowland rice agroecosystem at Medziphema, Singrijan and Kuhoxu

Insect pests diversity:	Location		
	Medziphema	Singrijan	Kuhoxu
Alpha Diversity α	2.6	2.32	2.25
Beta Diversity β	0.028		
Gamma Diversity γ	2.308		
Natural enemies diversity:	Location		
	Medziphema	Singrijan	Kuhoxu
Alpha Diversity α	1.99	2.06	2.04
Beta Diversity β	0.00		
Gamma Diversity γ	2.05		

Khan (2006) similarly observed that species turnover in rice ecosystems was minimal, suggesting that dominant species remain consistent across regions. Ohwaki (2015) found that predatory arthropods, especially spiders and beetles, maintained stable populations across different rice fields, which aligns with the uniform presence of natural enemies in the study area.

4.1.3. RELATIVE ABUNDANCE OF INSECT PESTS AND NATURAL ENEMIES IN LOWLAND RICE AGROECOSYSTEM IN NAGALAND

The analysis of Table 4.1e reveals the relative abundance of insect pests in the lowland rice agroecosystem. At Medziphema, it revealed that *N. lugens* is the most dominant species, accounting for 30.72 percent of the total pest population followed by *N. virescens* and *L. acuta* contributing 10.92 percent and 8.22 percent, respectively. Other notable species include field crickets (5.11%) and *D. armigera* (4.67%), while the remaining pests had lower relative abundance with *S. litura*, green horned caterpillars, *P. mathias* and *C. suppressalis* at 0.02 percent, 0.42 percent, 0.59 percent and 0.89 percent, respectively showing the least abundant while *S. nivella* was not recorded during the investigation at Medziphema.

Table 4.1e: Relative abundance (%) of insect pests (Pooled data of two years, 2020-2021) recorded in Nagaland

Insect Pest Species	Medziphema	Singrijan	Kuhoxu
<i>Nephotettix virescens</i> Distant	10.92%	16.80%	16.51%
<i>Nephotettix nigropictus</i> Stål	3.20%	4.54%	5.87%
<i>Cofana spectra</i> Distant	2.24%	2.05%	1.81%
<i>Maiestas dorsalis</i> Motchulsky	2.20%	2.82%	1.84%
<i>Nilaparvata lugens</i> Stål	30.72%	34.93%	37.32%
<i>Sogatella furcifera</i> Horvith	4.22%	11.30%	11.37%
<i>Leptocorisa acuta</i> Thunberg	8.22%	2.18%	1.84%
<i>Cletus punctiger</i> Dallas	1.88%	1.39%	1.38%
<i>Scirpophaga incertulas</i> Walker	2.83%	3.41%	2.96%
<i>Chilo suppressalis</i> Dudgeon	0.89%	0.64%	0.61%
<i>Scirpophaga</i> spp.	1.90%	2.20%	2.37%
<i>Scirpophaga nivella</i> Fabricus	Nil	Nil	0.91%
<i>Cnaphalocrocis medinalis</i> Guenée	1.42%	1.10%	1.10%
<i>Melanitis leda ismene</i> Linnaeus	1.27%	0.51%	0.52%
Green horned caterpillars: • <i>Mycalesis mineus</i> Linnaeus • <i>Orsotriaena medus</i> Fabricus	0.42%	0.33%	0.27%
<i>Spodoptera litura</i> Fabricius	0.02%	0.12%	0.29%
<i>Leucania loreyi</i> Duponchel	1.05%	1.26%	1.01%
<i>Nymphula depunctalis</i> Guenée	3.07%	0.98%	0.74%
<i>Pelopidas mathias</i> Fabricius	0.59%	0.29%	0.31%
Short horned grasshoppers: • <i>Oxya</i> spp. • <i>Melanoplus bivittatus</i> Say • <i>Dociostaurus</i> spp. • <i>Phlaeoba infumata</i> Brunner von Wattenwyl • <i>Atractomorpha</i> spp.	4.17%	2.08%	2.00%
Field crickets: • <i>Euscyrtus concinnus</i> de Haan • <i>Gryllus bimaculatus</i> De Geer • <i>Gryllus</i> spp.	5.11%	4.92%	3.89%
<i>Gryllotalpa orientalis</i> Burmeister	2.30%	0.68%	0.53%
<i>Sitophilus oryzae</i> Linnaeus	3.43%	0.90%	0.81%
<i>Dicladispa armigera</i> Olivier	4.67%	1.55%	1.31%
<i>Stenchaetothrips biformis</i> Bagnall	3.26%	3.03%	2.43%

The investigation in the lowland rice agroecosystem at Singrijan village revealed similar results with *N. lugens* as the most dominant species, comprising 34.93 percent of the total pest population. *N. virescens* followed with 16.80 percent, while *S. furcifera* contributed 11.30 percent. Among other pests, Field crickets (4.92%) and *N. nigropictus* (4.54%) had moderate abundance, whereas *S. incertulas* (3.41%) and *S. biformis* (3.03%) were also notable. *S. litura* (0.12%), *P. mathias* (0.29%), Green horned caterpillars (0.33%), *M. leda ismene* (0.51%), *C. suppressalis* (0.64%) and *G. orientalis* (0.68%) were the least abundant among insect pests. *S. nivella* was also not recorded at Singrijan.

The analysis of relative abundance of insect pests at Kuhoxu village revealed that *N. lugens* was the most dominant species, accounting for 37.32 percent of the total pest population followed by *N. virescens* (16.51%) while *S. Furcifera* contributed 11.37 percent. Moderately abundant species included *N. nigropictus* (5.87%), field crickets (3.89%), and *S. incertulas* (2.96%). Least abundant pests were *C. suppressalis* (0.61%), *M. leda ismene* (0.52%), *G. orientalis* (0.53%), *P. mathias* (0.31%), *S. litura* (0.29%) and green horned caterpillars (0.27%). *S. nivella* was recorded only at Kuhoxu with a relative abundance of 0.91 percent. The area was earlier under sugarcane cultivation which might explain its presence.

The present findings align with Heong *et al.* (1991), who reported that *Nilaparvata lugens*, along with *Nephotettix virescens*, *Nephotettix nigropictus*, and *Sogatella furcifera*, represented 88 percent of the phytophagous insect population in irrigated rice fields, with *Nephotettix* species alone comprising more than 70 percent of the total leafhopper population. Similarly, Mukherjee and Khan (2017) documented leafhoppers as the most abundant insect group in rice fields, particularly during the seedling and maximum tillering stages.

Among the other insect pests recorded in this study, *Nephotettix virescens* was the second most dominant species, contributing 10.92 percent in Medziphema, 16.80 percent in Singrijan, and 16.51 percent in Kuhoxu. This is consistent with previous findings by Khan (2013) who identified seven insect pests and reported green leafhoppers and short-horned grasshoppers as the most prevalent pests. Mitra *et al.*

(2014) also reported high *Cofana spectra* abundance in Indian rice fields, particularly during March-May and October-December, aligning with the *boro* and *aman* rice cropping seasons. Additionally, Adhikari *et al.* (2021) found that the rice gundhi bug, short-horned grasshopper, and black bug were among the most prevalent rice pests, with short-horned grasshoppers contributing 40 percent to the total pest population.

At the lower end of the abundance spectrum, *Scirpophaga incertulas*, *Chilo suppressalis* and horned caterpillars exhibited relatively low abundance across all three locations. Similar findings were reported by Heckman (1974), who observed that while some species was consistently present in rice paddies, most had well-defined seasonal peaks of abundance and reproduction. This seasonal fluctuation might explain the variations in insect pest populations across study sites.

Examination of Table 4.1f illustrates the relative abundance of natural enemies at lowland rice agroecosystem. At Medziphema, it reveals that Hymenoptera (23.02%) was the most dominant, followed closely by Coleoptera (22.09%), Arachida (17.93%), Odonata-Zygoptera (10.38%) and Orthoptera (9.05%). Odonata-Anisoptera (8.06%) show a slightly lower presence followed by Hemiptera (4.51%). The least abundant groups include Dermaptera (1.75%), Neuroptera (1.03%), Mantodea (1.47%), and Diptera (0.70%).

The observation at Singrijan highlighted the dominance of Hymenoptera (25.48%). This was followed by Coleoptera (18.61%), Arachnida (13.50%), Orthoptera (12.86%), Hemiptera (9.43%), Odonata-Zygoptera (6.47%), and Anisoptera (5.37%). Meanwhile, Neuroptera (4.25%), Diptera (1.55%), Dermaptera (1.35%), and Mantodea (1.13%) were less abundant.

In Kuhoxu, it highlighted similar trend with Hymenoptera (28.62%) followed by Coleoptera (18.29%), Arachnida (13.04%) and Orthoptera (11.81%). Hemiptera (9.00%) and Odonata, which consists of Zygoptera (6.12%) and Anisoptera (3.36%), were moderately abundant. Meanwhile, Neuroptera (4.36%), Diptera (2.49%), Dermaptera (1.78%), and Mantodea (1.12%) had lower representation with least abundance.

Table 4.1f: Relative abundance (%) of natural enemies (Pooled data of two years, 2020-2021) recorded in Nagaland.

Natural Enemies Species	Medziphema	Singrijan	Kuhoxu
Odonata-Anisoptera • <i>Brachythemis contaminata</i> Fabricius • <i>Crocothemis servilia</i> Drury • <i>Orthetrum sabina</i> Drury • <i>Crocothemis nigrifrons</i> Kirby • <i>Neurothemis intermedia</i> Rambur • <i>Diplacodes trivialis</i> Rambur • <i>Neurothemis tullia</i> Drury • <i>Orthetrum pruinosum</i> Burmeister • <i>Palpopleura sexmaculata</i> Fabricius	8.06%	5.37%	3.36%
Odonata-Zygoptera • <i>Agriocnemis pieris</i> Laidlaw • <i>Agriocnemis pygmaea</i> Rambur • <i>Agriocnemis argentea</i> Tillyard • <i>Ischnura rubilio</i> Selys • <i>Ceriagrion cerinorubellum</i> Brauer • <i>Ceriagrion coromandelianum</i> Fabricius	10.38%	6.47%	6.12%
Coleoptera • <i>Macrocheilus bensoni</i> Hope • <i>Ophionea nigrofasciata</i> Schmidt-Goebel • <i>Chlaenius</i> spp. • <i>Pheropsophus</i> spp. • <i>Cicindela sexpunctata</i> Fabricius • <i>Cylindera venosa</i> Kollar • <i>Micraspis discolor</i> Fabricius • <i>Micraspis univittata</i> Hope • <i>Coccinella septempunctata</i> Linnaeus • <i>Harmonia</i> spp.	22.09%	18.61%	18.29%
Hymenoptera • <i>Telenomus</i> spp. • <i>Ophion</i> spp. • <i>Xanthopimpla</i> spp. • <i>Xanthopimpla punctata</i> Fabricius • <i>Agonocryptys discoidaloides</i> Viereck • <i>Ischnojoppa luteator</i> Fabricius	23.02%	25.48%	28.62%

• <i>Aleiodes</i> spp. • <i>Brachymeria scutellocarinata</i> Joseph • <i>Cardiochilinae</i> spp. • <i>Agrypon flaveolatum</i>, Gravenhorst			
Neuroptera • <i>Apochrysa</i> spp. • <i>Ankylopteryx</i> spp. • Unidentified species • <i>Ascalaphus prothoracicus</i> Kimmins • Unidentified mantis fly	1.03%	4.25%	4.36%
Hemiptera • <i>Peirates atromaculatus</i> Stål • <i>Oncocephalus</i> spp. • <i>Rhynocoris fuscipes</i> Fabricius • <i>Ectomocoris atrox</i> Stål • <i>Cyrtorhinus lividipennis</i> Reuter	4.51%	9.43%	9.00%
Diptera • Unidentified robber fly • Unidentified tachinid fly	0.70%	1.55%	2.49%
Dermaptera • Unidentified earwig	1.75%	1.35%	1.78%
Mantodea • Unidentified preying mantid • Unidentified preying mantid	1.47%	1.13%	1.12%
Orthoptera • Unidentified long horn grasshopper	9.05%	12.86%	11.81%
Arachida • <i>Oxyopes birmanicus</i> Thorell • <i>Peucetia viridana</i> Stoliczka • <i>Argiope aemula</i> Walckenaer • <i>Argiope bruennichi</i> Scopoli • <i>Tetragnatha straminea</i> Emerton • <i>Neoscona theisi</i> Walckenaer	17.93%	13.50%	13.04%

The results of the present investigation is consistent with findings from Morya and Kumar (2017), who ranked hymenopterans as the most abundant bioagents in rice fields, followed by spiders, coccinellids, and carabids. Rahman *et al.* (2017) also reported that wasps and parasitoids played a key role in controlling pest populations,

ranking them after ladybird beetles, Zygoptera, and ants in relative abundance. Similarly Moses *et al.*, (2019) found ladybird beetles (31.69%) to be the most abundant predators in rice fields, followed by spiders (18.64%), staphylinid beetles (13.76%), Zygoptera (13.04%), and Anisoptera (12.94%). Additionally, Khan (2013) identified damselflies, spiders, and ichneumonids as more dominant among natural enemies, while mirid bugs, ladybird beetles, and ground beetles were less prevalent.

Similar to the present investigation, Mukherjee and Khan (2017) also reported significant populations of Zygoptera and ichneumonid wasps in rice habitats. Meanwhile, Heong *et al.* (1991) found that predatory Hemipterans (*Microvelia douglasi*, *Mesovelia vittigera*, and *Cyrtorhinus lividipennis*) were abundant, comprising 36–53 percent of the predator community across different locations. They also observed that *Tetragnatha* species and *Pardosa pseudoannulata* were the most common spiders in rice agroecosystems, agreeing with the present findings. Similarly, Mishra *et al.* (2021) documented *Oxyopes javanus* (lynx spider) and *Pardosa sumatrana* (wolf spider) as the most abundant ground-dwelling predators, preying heavily on leafhoppers and adult Lepidopteran pests.

4.2. SEASONAL ABUNDANCE OF MAJOR INSECT PESTS AND THEIR NATURAL ENEMIES IN LOWLAND RICE AGROECOSYSTEM IN NAGALAND

This part of the chapter provides a comprehensive analysis of the seasonal abundance of insect pests and their natural enemies in the rice agroecosystem at Medziphema, Singrijan and Kuhoxu. The findings are based on data collected over two years from June to December of 2020 and 2021, focusing on key pest species, their population trends, and the potential for biological control through natural enemies.

4.2.1. SEASONAL ABUNDANCE OF INSECT PESTS IN LOWLAND RICE AGROECOSYSTEM

4.2.1.1. SEASONAL ABUNDANCE OF INSECT PESTS IN LOWLAND RICE AGROECOSYSTEM AT MEDZIPHEMA

The examination of Table 4.2a reveals that there is considerable variation and seasonal abundance of insect pests in lowland rice agroecosystem at Medziphema. The study of the pooled data revealed highest abundance was recorded by *N. lugens* (663.25) followed by *N. virescens* (235.75), *L. acuta* (177.40), *D. armigera* (100.80), Field crickets (110.35), *S. furcifera* (91.08), short-horned grasshoppers (90.00), *S. oryzae* (74.00), *S. biformis* (70.38), *N. nigropictus* (69.10), *N. depunctalis* (66.35), *S. incertulas* (61.10), *G. orientalis* (49.59), *M. dorsalis* (47.58), *C. spectra* (48.41), *Scirpophaga* spp. (41.10) and *C. punctiger* (40.70). Least abundant insect species recorded were *C. medinalis* (30.60) followed by *M. leda ismene* (27.44), *L. loreyi* (22.77), *C. Suppressalis* (19.27), *P. mathias* (12.70), green horned caterpillars (9.10), and *S. litura* (0.50).

The population of *N. virescens* showed a steady increase from meteorological week 25 onwards, peaking between weeks 38 and 43 (Fig. 4.1a). The total recorded numbers were 192.59 in 2020 and 222.58 in 2021, indicating a higher infestation in 2021. Pooled data suggests a gradual mid-season rise in population.

Table 4.2a: Seasonal abundance and diversity of major insect pests in lowland rice agro ecosystem at Medziphema

Insect Pests	SMW	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	Total
<i>Nephotettix virescens</i> Distant	2020	0.00	0.00	0.66	2.33	4.66	2.66	2.33	3.66	5.00	2.33	3.33	8.66	9.00	12.33	13.66	20.00	28.00	36.33	21.00	17.33	11.66	9.66	9.00	12.33	8.00	7.33	7.33	192.59
	2021	0.00	0.00	2.00	1.66	3.33	5.66	2.66	2.00	1.33	1.33	4.33	2.00	4.66	8.33	10.66	17.00	22.33	26.33	34.00	21.66	15.66	10.00	7.66	4.00	4.66	5.33	4.00	222.58
	Pooled	0.00	0.00	1.33	2.00	4.00	4.16	2.50	2.83	3.17	1.83	3.83	5.33	6.83	8.33	12.16	18.50	25.17	26.33	27.50	21.66	13.66	9.83	8.33	8.17	6.33	6.33	5.67	235.75
<i>Nephotettix nigropictus</i> Stål	2020	0.00	0.00	0.00	0.00	0.00	0.66	0.33	0.33	1.00	1.33	1.33	3.00	2.66	3.66	6.00	4.66	5.00	4.33	5.33	5.66	4.33	4.00	4.33	2.00	2.33	2.66	2.66	67.59
	2021	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.66	0.33	2.00	2.33	2.33	3.33	3.00	4.66	4.33	6.33	7.00	4.66	5.33	3.33	3.66	4.00	2.66	3.00	3.33	4.00	70.60
	Pooled	0.00	0.00	0.00	0.00	0.00	0.50	0.17	0.50	0.67	1.67	1.83	2.67	3.00	3.33	5.33	4.50	5.67	5.67	5.00	5.50	3.83	3.83	4.17	2.33	2.67	3.00	3.33	69.10
<i>Cofana spectra</i> Distant	2020	0.00	0.00	0.00	0.33	0.00	1.00	1.33	1.66	0.33	0.66	1.00	1.66	1.33	0.33	1.33	1.66	2.00	3.33	2.66	3.66	4.00	3.66	4.66	5.66	4.33	2.66	1.66	50.90
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66	1.00	0.66	0.66	1.33	2.00	1.00	2.33	2.66	1.66	3.00	3.33	3.33	2.66	4.00	3.66	4.33	4.66	0.66	2.33	45.92
	Pooled	0.00	0.00	0.00	0.17	0.00	0.50	0.67	1.16	0.67	0.66	0.83	1.50	1.67	0.67	1.83	2.16	1.83	3.17	3.00	3.50	3.33	3.83	4.16	5.00	4.50	1.66	2.00	48.41
<i>Maistas dorsalis</i> Motchulsky	2020	0.00	0.00	0.33	0.33	0.00	0.33	1.00	0.33	0.66	2.00	2.66	3.00	3.00	1.66	3.66	4.00	3.66	4.33	4.33	4.66	2.66	1.66	0.33	0.33	0.33	0.00	0.66	45.91
	2021	0.00	0.00	0.00	0.00	0.33	0.33	0.33	2.00	1.66	2.33	2.33	2.66	4.33	3.66	4.00	4.33	4.00	4.66	3.66	2.33	2.66	2.00	0.33	0.33	0.33	0.33	0.33	49.25
	Pooled	0.00	0.00	0.17	0.17	0.17	0.33	0.67	1.17	1.16	2.17	2.50	2.83	3.67	2.66	3.83	4.17	3.83	4.50	4.00	3.50	2.66	1.83	0.33	0.33	0.33	0.17	0.50	47.58
<i>Nilaparvata lugens</i> Stål	2020	0.00	0.00	0.33	2.00	0.66	2.33	3.33	4.66	4.33	6.33	8.66	12.66	16.00	20.36	35.66	42.33	50.66	60.00	68.33	62.33	57.66	47.00	40.66	34.66	12.66	11.66	14.33	619.59
	2021	0.00	0.00	0.00	1.00	1.66	0.66	2.66	6.00	8.66	12.66	18.33	20.00	29.33	43.66	41.33	58.66	56.33	72.00	64.66	56.33	40.66	32.66	38.00	39.66	20.66	21.33	20.00	706.90
	Pooled	0.00	0.00	0.17	1.50	1.16	1.50	3.00	5.33	6.50	9.50	13.50	16.33	22.67	32.01	38.50	50.50	53.50	66.00	66.50	59.33	49.16	39.83	39.33	37.16	16.66	16.50	17.17	663.25
<i>Sogatella furcifera</i> Horvith	2020	0.00	0.00	0.00	0.00	0.00	0.33	0.33	1.00	1.66	0.66	2.00	2.66	4.00	4.00	4.66	6.33	8.33	10.00	8.33	6.33	4.33	4.66	2.33	2.33	1.33	2.66	2.66	80.92
	2021	0.00	0.00	0.00	0.33	0.33	0.00	0.33	2.00	2.33	1.66	2.33	3.33	2.66	6.33	6.00	4.66	6.66	8.33	7.66	9.00	12.66	8.33	4.33	4.66	2.66	2.33	2.33	101.24
	Pooled	0.00	0.00	0.00	0.17	0.17	0.17	0.33	1.50	2.00	1.16	2.17	3.00	3.33	5.17	5.33	5.50	7.50	9.17	8.00	7.67	8.50	6.50	3.33	3.50	2.00	2.50	2.50	91.08
<i>Leptocorisa acuta</i> Thunberg	2020	0.00	0.00	0.00	0.00	2.20	3.80	6.00	6.80	5.00	5.80	4.80	3.00	2.80	6.00	6.60	6.80	9.00	9.80	12.20	16.80	14.60	15.60	16.00	8.80	9.00	6.40	6.20	184.00
	2021	0.00	0.00	0.00	2.00	2.60	4.00	8.20	6.20	7.80	6.00	6.80	4.00	2.40	2.60	2.20	3.60	6.80	12.00	11.60	14.60	14.00	16.20	11.80	7.60	6.00	7.20	4.60	170.80
	Pooled	0.00	0.00	0.00	1.00	2.40	3.90	7.10	6.50	6.40	5.90	5.80	3.50	2.60	4.30	4.40	5.20	7.90	10.90	11.90	15.70	14.30	15.90	13.90	8.20	7.50	6.80	5.40	177.40
<i>Cletus punctiger</i> Dallas	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.80	2.60	0.80	0.60	2.60	0.60	2.00	3.60	4.40	4.60	2.80	2.60	2.00	2.00	2.20	1.60	1.40	1.00	1.00	1.00	40.80
	2021	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20	1.00	1.20	1.00	0.80	1.80	1.60	2.80	2.20	5.00	5.60	4.80	3.80	2.00	2.00	2.20	1.00	1.20	0.20	0.00	40.60
	Pooled	0.00	0.00	0.00	0.00	0.00	0.10	0.30	0.50	1.80	1.00	0.80	1.70	1.20	1.80	3.20	3.30	4.80	4.20	3.70	2.90	2.00	2.10	1.90	1.20	1.10	0.60	0.50	40.70

<i>Scirpophaga incertulas</i> Walker	2020	0.00	0.00	0.00	0.00	0.00	1.00	0.66	1.66	2.00	2.66	3.00	4.33	4.33	6.66	5.00	6.66	7.00	4.66	4.66	3.00	3.66	3.33	2.00	0.33	0.33	0.00	0.00	66.93
	2021	0.00	0.00	0.00	0.00	0.33	0.00	1.33	1.00	1.66	1.00	2.66	3.00	5.00	5.33	6.66	8.00	5.33	5.66	4.66	2.33	0.66	0.00	0.33	0.33	0.00	0.00	0.00	55.27
	Pooled	0.00	0.00	0.00	0.00	0.17	0.50	1.00	1.33	1.83	1.83	2.83	3.67	4.67	6.00	5.83	7.33	6.17	5.16	4.66	2.67	2.16	1.67	1.17	0.33	0.17	0.00	0.00	61.10
<i>Chilo suppressalis</i> Dudgeon	2020	0.00	0.00	0.00	0.00	0.33	0.00	0.66	0.33	1.00	0.66	0.00	0.33	0.00	2.00	0.66	2.00	2.66	2.66	0.33	0.33	0.33	0.00	0.33	0.00	0.00	0.00	0.00	14.61
	2021	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.66	0.66	0.33	1.00	1.33	2.66	2.33	3.00	3.66	3.00	2.66	0.33	0.33	0.33	0.33	0.00	0.33	0.00	0.00	0.00	23.93
	Pooled	0.00	0.00	0.00	0.00	0.33	0.17	0.50	0.50	0.83	0.50	0.50	0.83	1.33	2.17	1.83	2.83	2.83	2.66	0.33	0.33	0.33	0.17	0.17	0.17	0.00	0.00	0.00	19.27
<i>Scirpophaga</i> spp.	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	1.00	1.66	2.00	2.66	2.66	3.33	2.00	4.66	6.00	4.66	4.33	2.00	0.33	0.33	0.00	0.00	0.00	0.00	38.61
	2021	0.00	0.00	0.00	0.00	0.00	0.66	1.00	1.00	1.66	0.66	2.00	2.33	0.66	2.33	2.66	4.66	5.66	5.33	6.00	3.66	1.66	1.00	0.33	0.33	0.00	0.00	0.00	43.59
	Pooled	0.00	0.00	0.00	0.00	0.00	0.33	0.67	0.67	1.00	0.83	1.83	2.17	1.66	2.50	3.00	3.33	5.16	5.67	5.33	4.00	1.83	0.67	0.33	0.17	0.00	0.00	0.00	41.10
<i>Cnaphalocrocis medinalis</i> Guenée	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.66	0.33	0.00	0.66	1.00	1.33	2.00	2.66	3.33	4.33	4.66	3.66	2.66	1.00	0.66	0.00	0.00	29.93
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.33	0.33	0.66	1.00	1.33	1.66	1.33	2.33	4.00	3.66	0.66	2.66	3.66	2.66	2.33	2.00	0.33	31.26
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.33	0.17	0.50	0.33	0.33	0.83	1.17	1.50	1.67	2.50	3.67	4.00	2.66	3.16	3.16	1.83	1.50	1.00	0.17	30.60
<i>Melanitis leda ismene</i> Linnaeus	2020	0.00	0.00	0.00	0.00	0.00	0.33	0.33	1.00	1.00	0.66	1.66	2.33	2.00	2.66	0.66	1.00	1.66	2.66	2.33	2.00	1.00	0.66	1.00	1.33	0.00	0.00	0.00	26.27
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.66	0.33	2.00	2.33	2.33	1.66	1.66	1.66	1.33	1.66	2.00	2.33	2.00	2.00	1.33	1.33	1.33	0.00	0.00	28.60
	Pooled	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.83	0.83	0.50	1.83	2.33	2.17	2.16	1.16	1.33	1.50	2.16	2.17	2.17	1.50	1.33	1.17	1.33	0.67	0.00	0.00	27.44
Green Horned caterpillars	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.20	0.40	0.80	1.00	1.80	1.80	1.40	0.20	0.20	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.60
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.40	0.60	0.20	0.80	1.00	1.00	1.80	1.40	1.20	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.60
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.30	0.30	0.50	0.50	0.90	1.40	1.40	1.60	0.80	0.70	0.50	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.10
<i>Spodoptera litura</i> Fabricius	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.33	
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.66	
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.00	0.50	
<i>Leucania loreyi</i> Duponchel	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.33	1.33	1.00	1.66	1.33	2.66	2.66	2.33	2.00	1.66	1.66	2.00	1.33	0.33	0.00	0.00	0.00	23.27
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.33	1.00	0.33	0.33	0.66	1.00	0.66	2.00	2.66	3.00	1.66	2.66	2.00	1.33	1.33	0.66	0.33	0.00	0.00	22.27
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.33	0.67	0.33	0.83	0.83	1.33	1.00	2.33	2.66	2.67	1.83	2.16	1.83	1.67	1.33	0.50	0.17	0.00	0.00	22.77
<i>Nymphula depunctalis</i> Guenée	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	1.66	4.00	4.66	8.00	8.33	6.66	4.66	4.00	4.33	2.33	3.00	2.00	2.33	2.66	0.00	0.00	0.33	60.95
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.66	2.80	6.00	8.00	8.33	7.00	7.66	5.00	5.33	3.66	3.00	3.66	2.00	1.66	2.00	0.66	0.33	0.00	71.75
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	2.33	2.23	5.00	6.33	8.17	7.67	7.16	4.83	4.67	4.00	2.67	3.33	2.00	2.00	2.33	0.33	0.17	0.17	66.35

<i>Pelopidas mathias</i> Fabricius	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.20	0.60	0.80	1.00	1.40	1.80	1.40	1.80	1.20	0.80	0.80	0.20	0.00	0.00	0.00	0.00	12.60
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.40	0.20	0.40	1.00	0.80	0.80	1.60	1.60	1.60	1.00	1.00	1.20	0.80	0.00	0.00	0.00	0.00	12.80
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.10	0.10	0.30	0.20	0.50	0.90	0.90	1.10	1.70	1.50	1.70	1.10	0.90	1.00	0.50	0.00	0.00	0.00	0.00	12.70
Short horned grasshoppers	2020	1.00	1.60	2.00	2.40	2.60	3.00	1.60	1.20	1.60	2.00	3.00	4.20	2.00	3.80	4.20	4.20	6.00	4.80	4.20	3.80	3.20	2.00	1.80	4.00	6.20	3.20	4.00	83.60
	2021	1.20	1.00	1.80	1.60	2.00	2.00	2.20	2.20	1.80	6.00	4.60	6.00	4.20	4.00	3.60	4.80	4.20	5.80	5.20	3.20	2.00	2.20	2.00	4.80	6.80	6.00	5.20	96.40
	Pooled	1.10	1.30	1.90	2.00	2.30	2.50	1.90	1.70	1.70	4.00	3.80	5.10	3.10	3.90	3.90	4.50	5.10	5.30	4.70	3.50	2.60	2.10	1.90	4.40	6.50	4.60	4.60	90.00
Field crickets	2020	0.33	0.66	2.00	0.66	1.66	2.66	2.33	4.33	3.66	3.66	2.66	4.66	5.33	5.00	4.33	5.33	4.66	4.33	6.66	6.00	4.33	4.66	2.66	7.00	10.00	5.00	3.00	107.56
	2021	0.66	0.33	0.66	0.33	1.00	1.66	2.66	2.66	4.00	4.66	5.66	4.00	5.33	2.66	3.00	3.66	6.66	5.00	7.33	7.00	6.55	6.00	4.00	11.00	8.00	6.66	2.00	113.13
	Pooled	0.50	0.50	1.33	0.50	1.33	2.16	2.50	3.50	3.83	4.16	4.16	4.33	5.33	3.83	3.67	4.50	5.66	4.67	7.00	6.50	5.44	5.33	3.33	9.00	9.00	5.83	2.50	110.35
<i>Gryllotalpa orientalis</i> Burmeister	2020	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.66	2.00	1.66	2.00	3.33	3.33	2.66	3.00	2.00	2.33	2.66	4.66	6.66	4.00	4.33	3.33	1.00	0.00	0.00	0.00	50.27
	2021	0.00	0.00	0.00	0.00	0.33	0.66	0.33	2.00	1.66	1.66	1.66	2.66	4.66	2.33	2.66	4.33	3.33	2.66	2.66	4.33	3.66	2.66	2.00	1.66	1.00	0.00	0.00	48.90
	Pooled	0.00	0.00	0.00	0.00	0.17	0.50	0.33	1.33	1.83	1.66	1.83	3.00	4.00	2.50	2.83	3.17	2.83	2.66	3.66	5.50	3.83	3.50	2.67	1.33	0.50	0.00	0.00	49.59
<i>Sitophilus oryzae</i> Linnaeus	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	2.00	4.20	4.20	6.80	8.00	8.80	12.00	10.80	12.00	69.60
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.60	3.00	9.80	12.00	10.60	11.80	14.00	16.40	78.40
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	1.10	2.40	3.60	8.30	10.00	9.70	11.90	12.40	14.20	74.00
<i>Dicladispa armigera</i> Olivier	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.60	3.00	4.60	8.00	8.80	8.00	8.80	7.80	7.60	8.20	3.00	3.80	3.60	3.60	3.20	3.40	2.00	0.60	0.00	0.00	88.80
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	2.00	3.40	6.80	4.60	4.80	5.80	9.60	9.80	14.80	16.80	13.00	8.20	4.80	2.20	2.80	2.60	0.00	0.00	0.00	112.80
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.70	2.50	4.00	7.40	6.70	6.40	7.30	8.70	8.70	11.50	9.90	8.40	5.90	4.20	2.70	3.10	2.30	0.30	0.00	0.00	100.80
<i>Stenchaetothrips biformis</i> Bagnall	2020	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.50	4.00	6.25	5.50	8.25	6.50	6.75	4.25	2.00	2.75	2.00	2.00	3.25	1.25	1.25	1.00	2.00	1.75	2.00	0.25	67.50
	2021	0.00	0.00	0.00	0.00	0.00	1.50	1.25	2.00	2.75	4.00	3.75	6.75	8.25	7.00	6.50	4.00	3.25	3.00	1.75	2.00	2.50	2.75	2.50	2.50	2.25	2.50	0.50	73.25
	Pooled	0.00	0.00	0.00	0.00	0.00	0.75	1.63	2.25	3.38	5.13	4.63	7.50	7.38	6.88	5.38	3.00	3.00	2.50	1.88	2.63	1.88	2.00	1.75	2.25	2.00	2.25	0.38	70.38

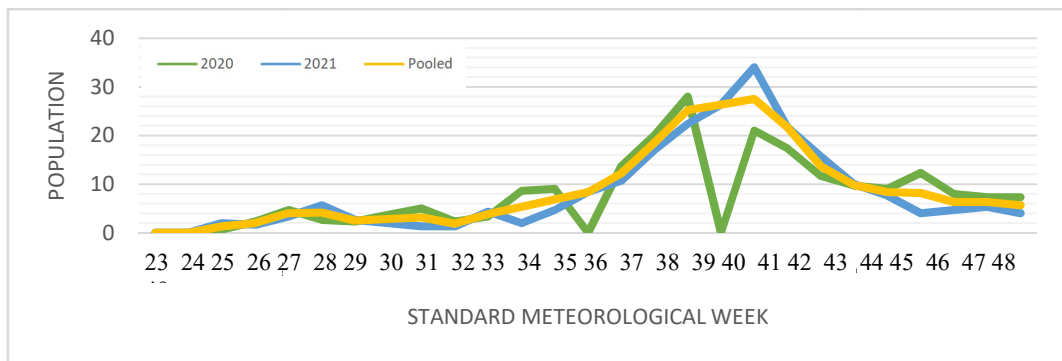


Fig.4.1a: Seasonal abundance of *Nephotettix virescens* Distant from June to December, 2020 & 2021 at Medziphema

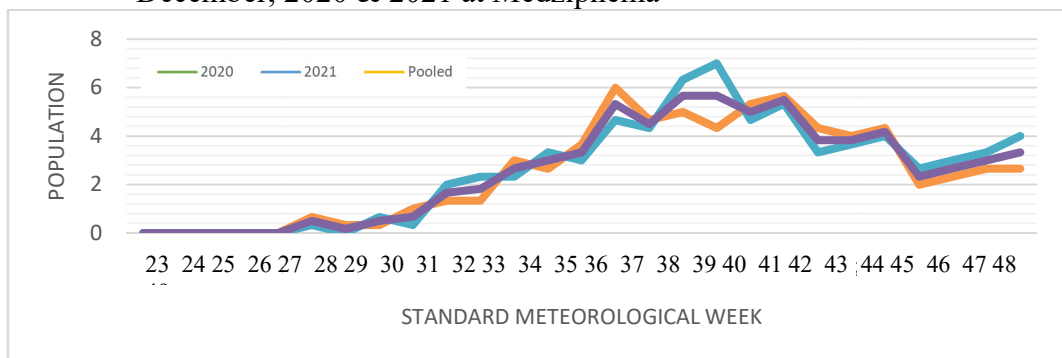


Fig.4.1b: Seasonal abundance of *Nephotettix nigropictus* Stål from June to December, 2020 & 2021 at Medziphema

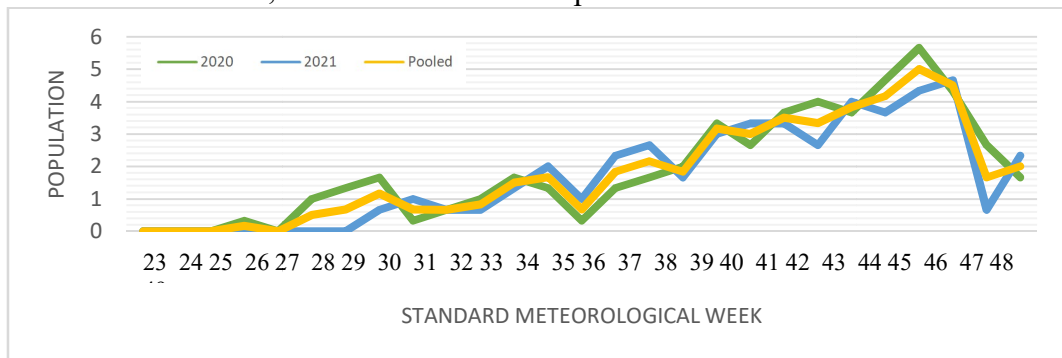


Fig.4.1c: Seasonal abundance of *Cofana spectra* Distant from June to December, 2020 & 2021 at Medziphema

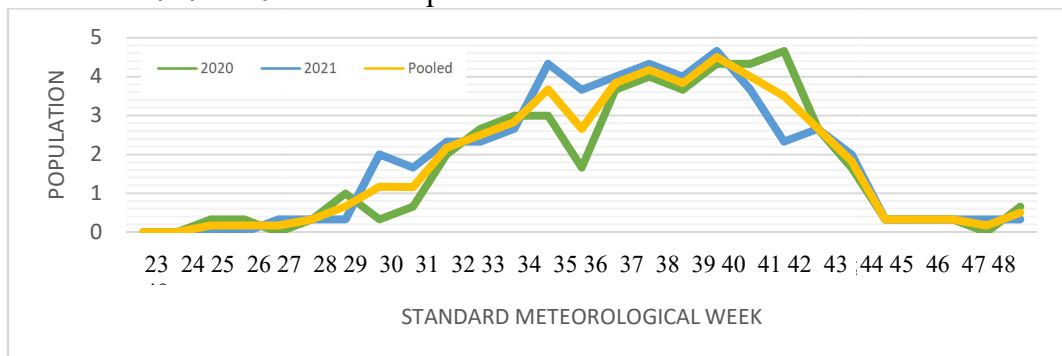


Fig.4.1d: Seasonal abundance of *Maiestas dorsalis* Motchulsky from June to December, 2020 & 2021 at Medziphema

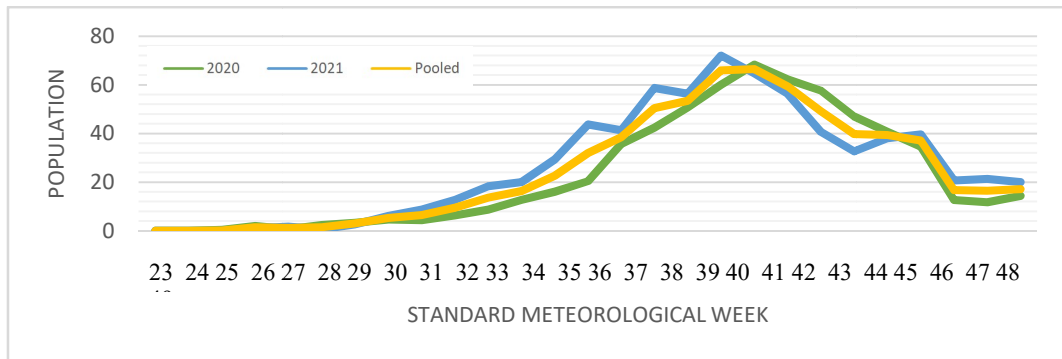


Fig.4.1e: Seasonal abundance of *Nilaparvata lugens* Stål from June to December, 2020 & 2021 at Medziphema

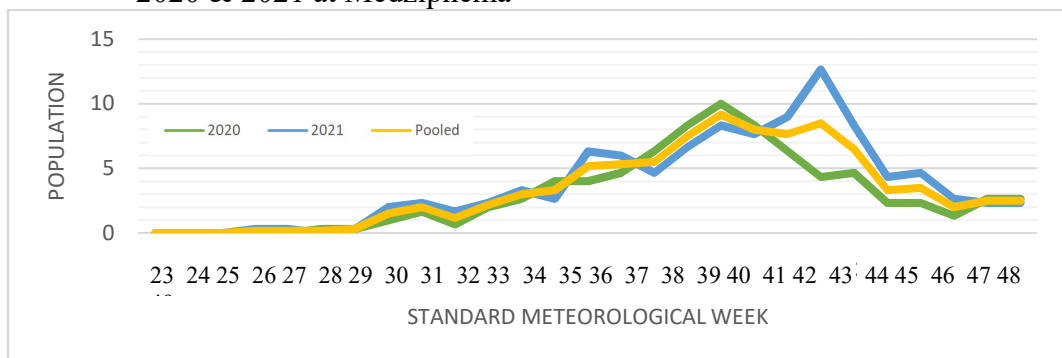


Fig.4.1f: Seasonal abundance of *Sogatella furcifera* Horvith from June to December, 2020 & 2021 at Medziphema

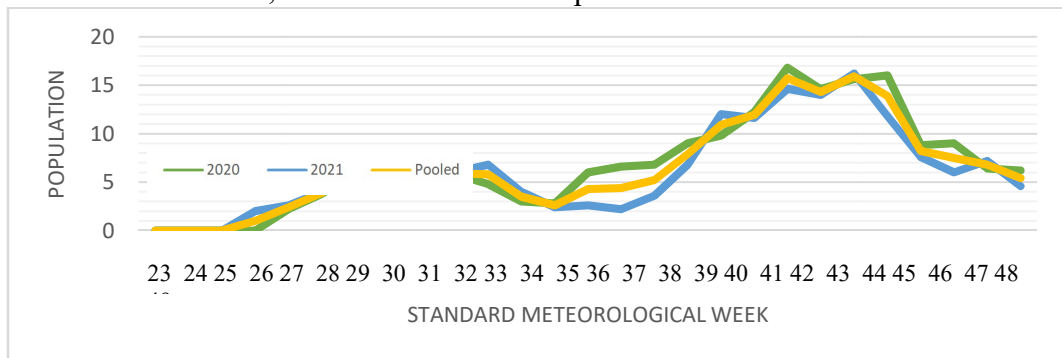


Fig.4.1g: Seasonal abundance of *Leptocorisa acuta* Thunberg from June to December, 2020 & 2021 at Medziphema

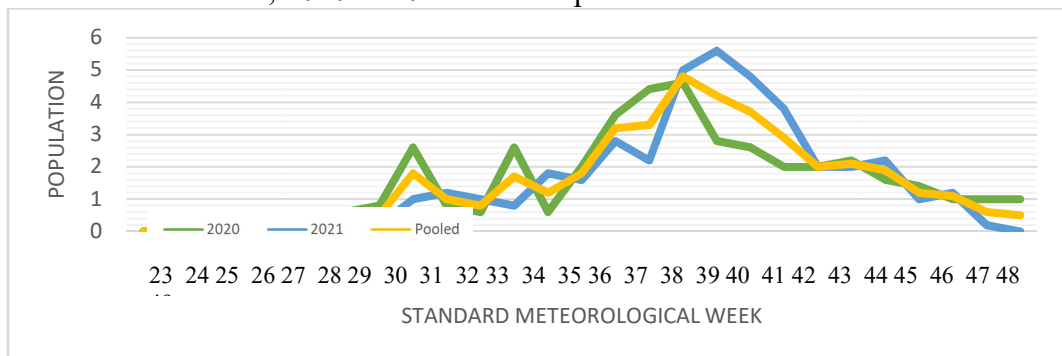


Fig.4.1h: Seasonal abundance of *Cletus punctiger* Dallas from June to December, 2020 & 2021 at Medziphema

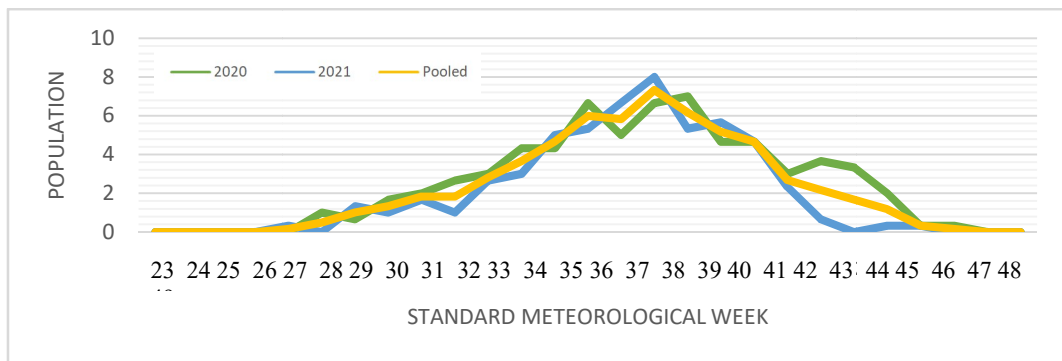


Fig.4.1i: Seasonal abundance of *Scirpophaga incertulas* Walker from June to December, 2020 & 2021 at Medziphema

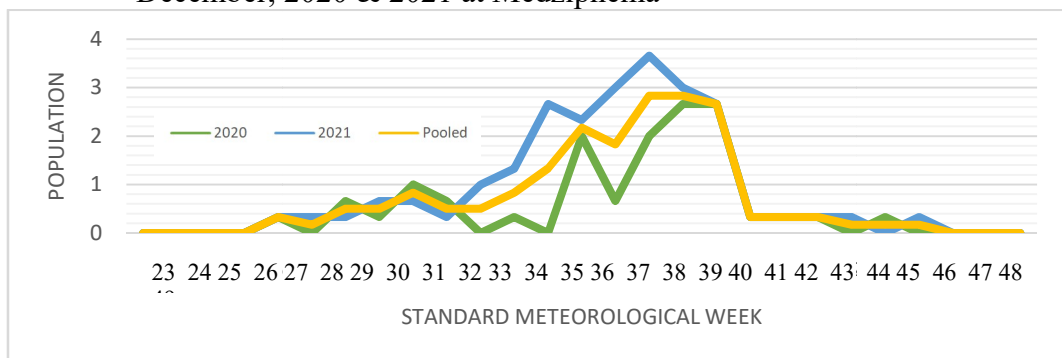


Fig.4.1j: Seasonal abundance of *Chilo suppressalis* Dudgeon from June to December, 2020 & 2021 at Medziphema

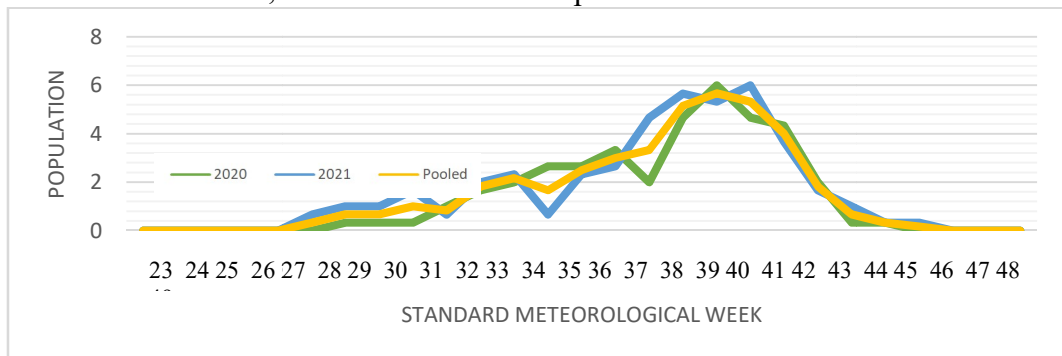


Fig.4.1k: Seasonal abundance of *Scirpophaga* spp. from June to December, 2020 & 2021 at Medziphema

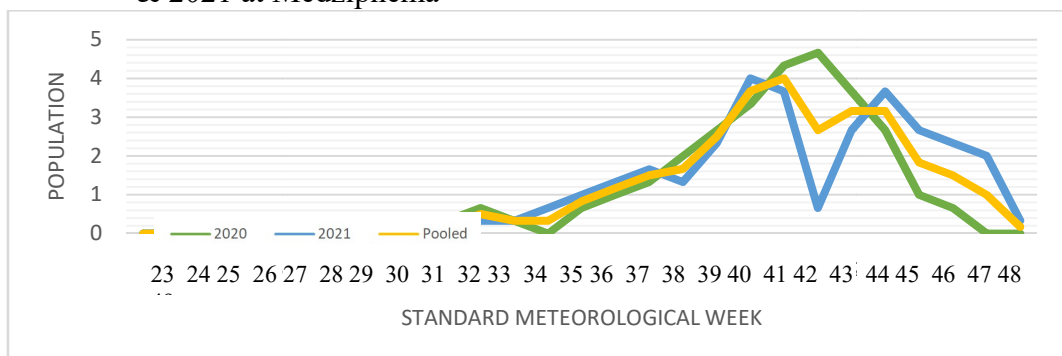


Fig.4.1l: Seasonal abundance of *Cnaphalocrocis medinalis* Guenée from June to December, 2020 & 2021 at Medziphema

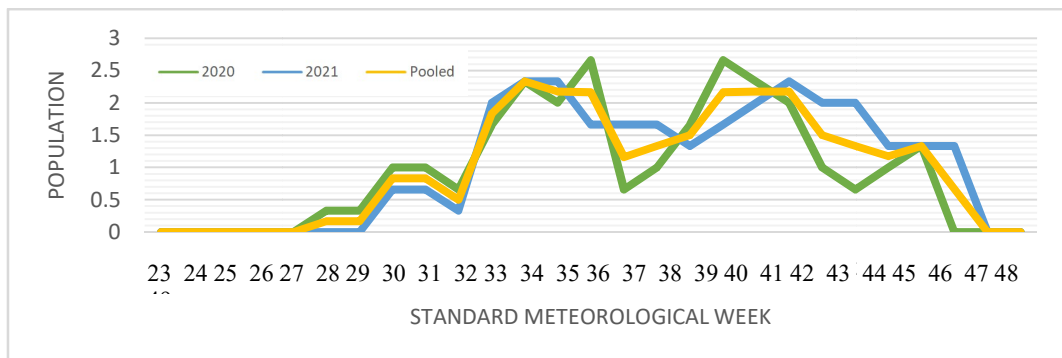


Fig.4.1m: Seasonal abundance of *Melanitis leda ismene* Linnaeus from June to December, 2020 & 2021 at Medziphema

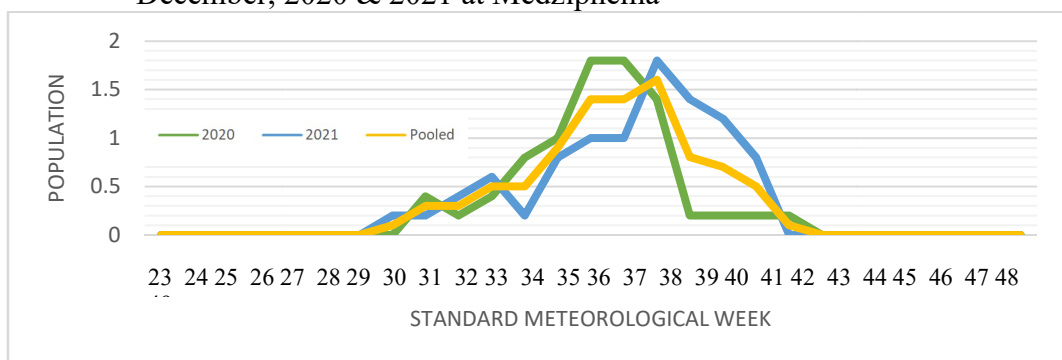


Fig.4.1n: Seasonal abundance of green horned caterpillars from June to December, 2020 & 2021 at Medziphema

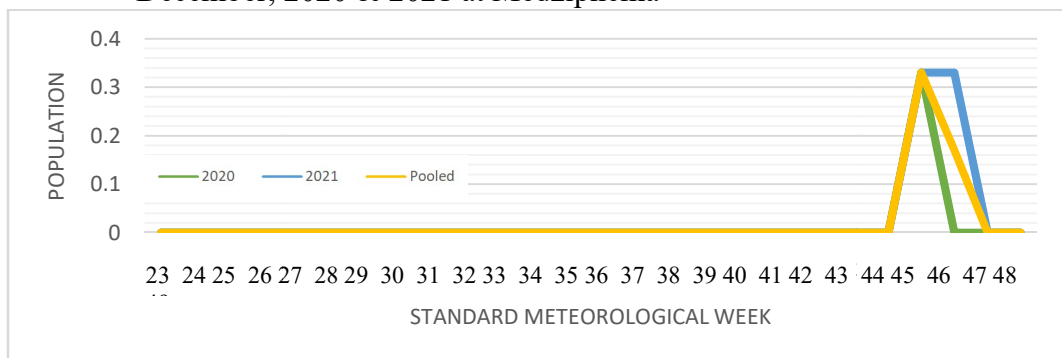


Fig.4.1o: Seasonal abundance of *Spodoptera litura* Fabricius from June to December, 2020 & 2021 at Medziphema

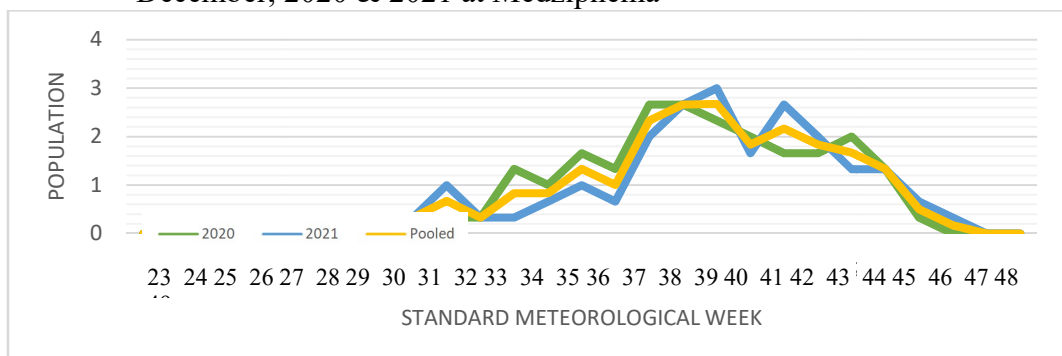


Fig.4.1p: Seasonal abundance of *Leucania loreyi* Duponchel from June to December, 2020 & 2021 at Medziphema

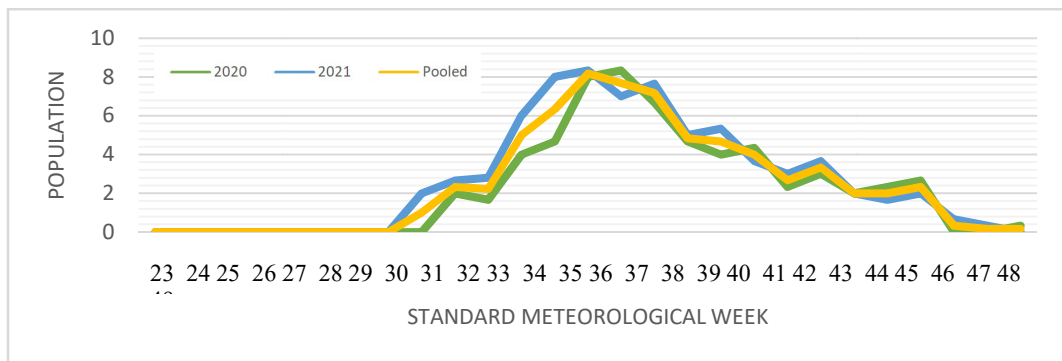


Fig.4.1q: Seasonal abundance of *Nymphula depunctalis* Guenée from June to December, 2020 & 2021 at Medziphema

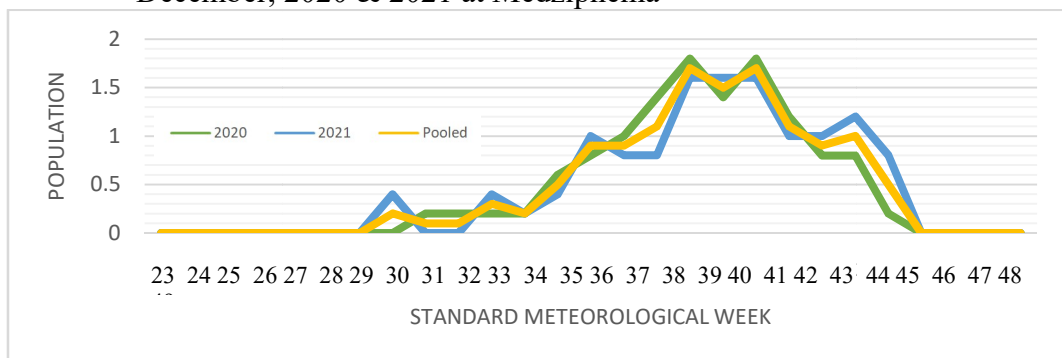


Fig.4.1r: Seasonal abundance of *Pelopidas mathias* Fabricius from June to December, 2020 & 2021 at Medziphema

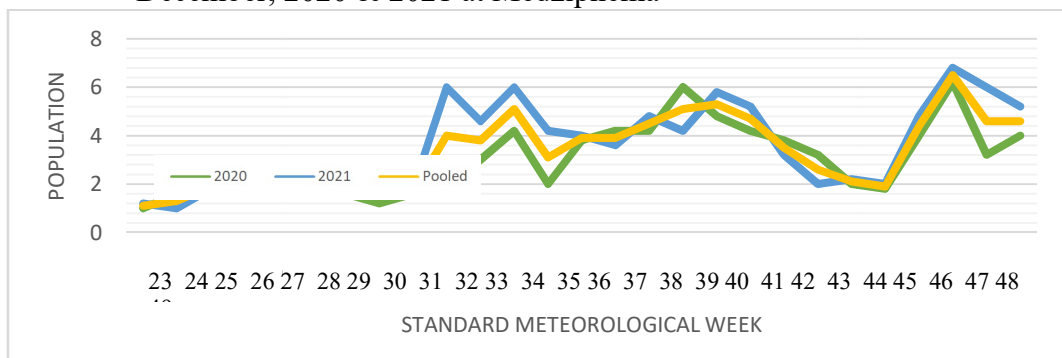


Fig.4.1s: Seasonal abundance of short horned grasshoppers from June to December, 2020 & 2021 at Medziphema

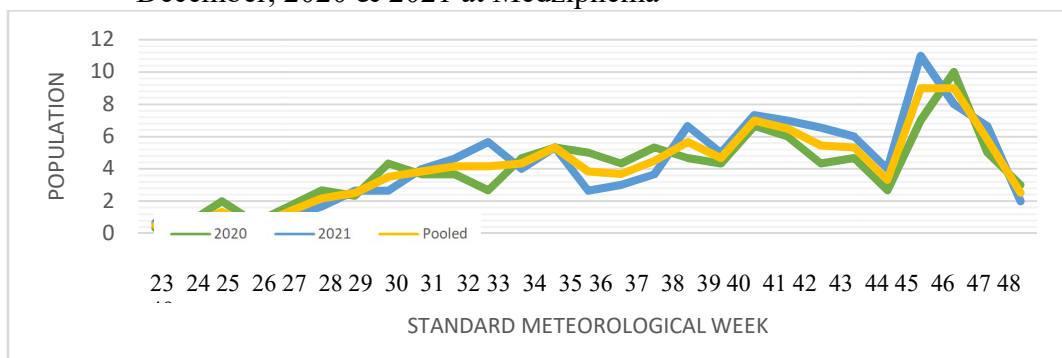


Fig.4.1t: Seasonal abundance of field crickets from June to December, 2020 & 2021 at Medziphema

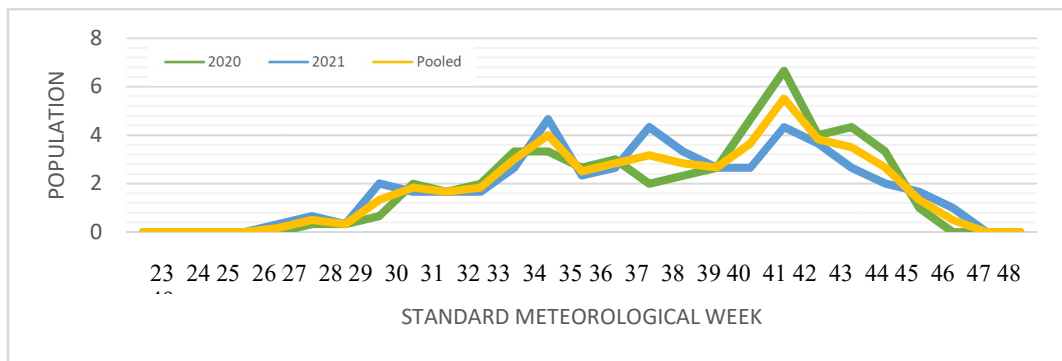


Fig.4.1u: Seasonal abundance of *Gryllotalpa orientalis* Burmeister from June to December, 2020 & 2021 at Medziphema

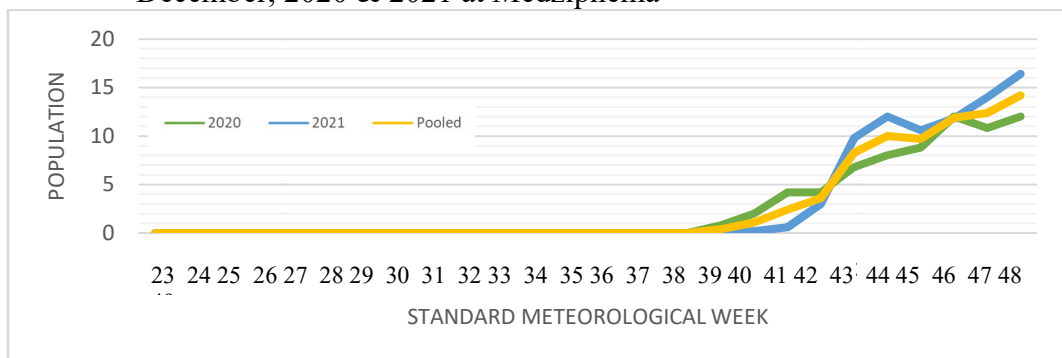


Fig.4.1v: Seasonal abundance of *Sitophilus oryzae* Linnaeus from June to December, 2020 & 2021 at Medziphema

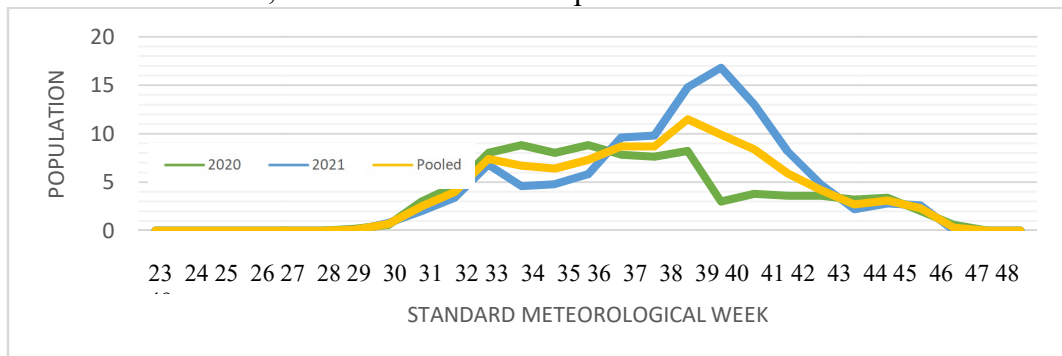


Fig.4.1w: Seasonal abundance of *Dicladispa armigera* Olivier from June to December, 2020 & 2021 at Medziphema

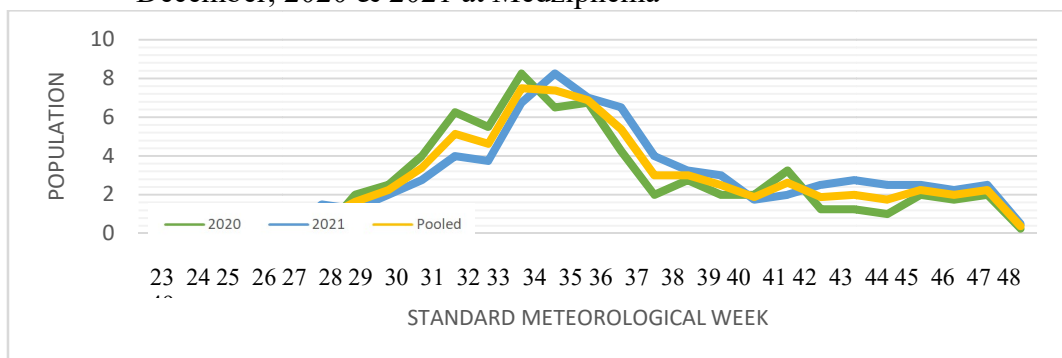


Fig.4.1x: Seasonal abundance of *Stenchaetothrips biformis* Bagnall from June to December, 2020 & 2021 at Medziphema

N. nigropictus had a lower population compared to *N. virescens*. Their numbers started increasing from week 32, with a significant peak between weeks 37-42 (Fig. 4.1b). The total population in 2020 was 67.59, whereas in 2021, it was 70.60. The pooled total population was 69.10.

C. spectra showed a gradual increase in population from week 28 onward. The highest population densities were observed between weeks 40 and 47 (Fig. 4.1c). In 2020, the total recorded population was 50.90, while in 2021, it was 45.92, resulting in a pooled population of 48.41.

The population of *M. dorsalis* showed a peak between weeks 37-42 (Fig. 4.1d). In 2020, the total population was 45.91, while in 2021, it was 49.25. The pooled total recorded was 47.58.

N. lugens, a major rice insect pest, exhibited an explosive population growth with peak densities between weeks 38 and 46 (Fig. 4.1e). The total recorded numbers were 619.59 in 2020 and 706.90 in 2021, indicating a higher infestation in 2021. The pooled total was recorded as 663.25.

The population of *S. furcifera* remained low in the early season but spiked significantly between weeks 36 and 44 (Fig. 4.1f). The total recorded numbers were 80.92 in 2020 and 101.24 in 2021, leading to a pooled total of 91.08.

Infestation levels of *L. acuta* were relatively low, with numbers peaking between weeks 40 and 45 (Fig. 4.1g). The total recorded numbers were 184.00 in 2020 and 170.80 in 2021, leading to a pooled total of 177.40, with peak densities occurring late in the season.

The population of *C. punctiger* peaked between weeks 37 and 41 (Fig. 4.1h). The total recorded population was 40.80 in 2020 and 40.60 in 2021, leading to a pooled total of 40.70.

S. incertulas Walker showed a steady increase from week 27 onwards, peaking between weeks 35 and 41 (Fig. 4.1i). The total population recorded in 2020 was 66.93, while in 2021, it was 55.27, with a pooled total of 61.10.

C. suppressalis had low population densities throughout the season, with a peak between weeks 36 and 40 (Fig. 4.1j). The total recorded population in 2020 was 14.61, whereas in 2021, it was 23.93, leading to a pooled total of 19.27.

The population of *Scirpophaga* spp. steadily increased from week 28 onwards, peaking between weeks 39 and 42 (Fig. 4.1k). The total recorded numbers were 38.61 in 2020 and 43.59 in 2021, leading to a pooled total of 41.10.

C. medinalis exhibited a low population in early weeks but increased from week 33 onwards, peaking between weeks 41 and 45 (Fig. 4.1l). The recorded population was 29.93 in 2020 and 31.26 in 2021 with a total pool population 30.60.

The population of *M. leda ismene* remained consistently low throughout the season, with a minor peak between weeks 34-37 and between 40-42 (Fig. 4.1m). The total recorded numbers were 26.27 in 2020 and 28.60 in 2021, with a pooled total of 27.44.

Green horned caterpillars were one of the least abundant species, peaking between weeks 36 and 40 (Fig. 4.1n). The total recorded population was 8.60 in 2020 and 9.60 in 2021, with a pooled total of 9.10.

S. litura remained at very low levels through out the study period, with a slight increase towards the end of the season (Fig. 4.1o). The total pooled recorded population was 0.50.

The population of *L. loreyi* remained low in early weeks with highest density recorded between weeks 38 and 42 (Fig. 4.1p). In 2020, the total population recorded was 23.27, while in 2021, it was 22.27, with a pooled total of 22.77.

The population of *N. depunctalis* was noticed after week 31, peaking between weeks 34 and 38 (Fig. 4.1q). The total population recorded in 2020 was 60.95, while in 2021, it was 71.75, with a pooled total of 66.35.

A fairly low population buildup was observed in *P. mathias* with the highest numbers seen between weeks 38 and 42 (Fig. 4.1r). In 2020, the total population was 12.60, whereas in 2021, it was 12.80, leading to a pooled total of 12.70.

Short-horned grasshoppers exhibited seasonal fluctuations, with peak infestations occurring between weeks 34 and 40 and another spike at the end of the season (Fig. 4.1s). In 2020, the recorded population was 83.60, while in 2021, it was 96.40, leading to a pooled total of 90.00.

Field crickets remained relatively stable throughout the season, with peak populations between weeks 38 and 44 (Fig. 4.1t). The recorded numbers were 107.56 in 2020 and 113.13 in 2021, resulting in a pooled total of 110.35.

G. orientalis gradually increased from week 27 onwards, with peak densities observed between weeks 41 and 44 (Fig. 4.1u). The total population recorded in 2020 was 50.27, while in 2021, it was 48.90, with a pooled total of 49.59.

S. oryzae was mostly prevalent towards the end of the season due to its preference for feeding on grains. Its population peaked between weeks 45 and 49 (Fig. 4.1v). The total population in 2020 was 69.60, while in 2021, it was 78.40, with a pooled total of 74.00.

The population of *D. armigera* rose gradually from week 30, peaking between weeks 37 and 41 (Fig. 4.1w). The total recorded numbers were 88.80 in 2020 and 112.80 in 2021, resulting in a pooled total of 100.80.

The population growth of *S. biformis* was observed from week 28 onwards, peaking between weeks 34 and 37 (Fig. 4.1x). The total population recorded in 2020 was 67.50, while in 2021, it was 73.25, with a pooled total of 70.38.

4.2.1.2. SEASONAL ABUNDANCE OF INSECT PESTS AT SINGRIJAN

The population dynamics of insect species in the lowland rice agroecosystem at Singrijan village revealed significant variations in abundance (Table 4.2b). *N. lugens* (1961.41) emerged as the most dominant species, followed by *N. virescens*

Distant (943.40) and *S. furcifera* (634.24), indicating their major presence in the ecosystem. *N. nigropictus* (254.76) and field crickets (276.28) also exhibited higher populations. *S. incertulas* (191.58), *S. biformis* (170.00), *M. dorsalis* (158.23), and *Scirpophaga* spp. (123.59) were moderately abundant and were followed by *Cofana spectra* Distant (114.92), short horned grasshoppers (116.80), *L. acuta* (122.30), *C. punctiger* (78.30), *L. loreyi* (70.77) and *D. armigera* (87.00).

N. depunctalis (54.94), *C. medinalis* (61.61), *S. oryzae* (50.30), *G. orientalis* (38.08), *C. suppressalis* (35.77), *M. leda ismene* (28.42), green horned caterpillars (18.70), *P. mathias* (16.10), and *S. litura* (6.97) were the least abundant among all the species recorded at Singrijan.

N. virescens showed a significant increase in population from meteorological week 35 onwards, reaching peak abundance between weeks 39 and 45 (Fig. 4.2a). The total number recorded in 2020 was 1018.24, while in 2021, it was 868.55, indicating a higher infestation in 2020. The pooled data suggests a gradual rise in population during mid-season.

N. nigropictus had a much lower population compared to *N. virescens*. Their numbers started increasing from week 32, with a significant peak between weeks 41-44 (Fig. 4.2b). In 2020, the population reached 414.59, whereas in 2021, it was only 94.93. The pooled total population was recorded as 254.76.

The population of *C. spectra* was initially low, with a gradual increase from meteorological week 27 onward. The highest population densities were observed between weeks 39 and 46 (Fig. 4.2c). In 2020, the total recorded population was 90.92, while in 2021, it was 138.91, indicating a higher incidence in 2021. The pooled population was 114.92, with peak densities recorded during weeks 39-45.

The population of *M. dorsalis* showed a gradual increase from week 27 onwards. In 2020, the total population was 187.56, while in 2021, it was 128.89. The pooled total was 158.23, with the highest densities occurring between weeks 32-38 (Fig. 4.2d).

A major rice pest, *N. lugens* showed explosive population growth from week 30 onwards with maximum levels between weeks 38 and 45 (Fig. 4.2e). The total recorded numbers were 1962.90 in 2020 and 1959.91 in 2021, indicating almost equal levels of infestation in both years. The pooled total was recorded as 1961.41.

S. furcifera had low early-season numbers but spiked significantly between weeks 39 to 45 (Fig. 4.2f), reaching over 70 individuals per observation. The total population recorded was 597.23 in 2020 and 671.24 in 2021, indicating higher pest pressure in 2021, with a pooled total of 634.24.

The population of *L. acuta* had relatively lower infestation levels, with numbers peaking between weeks 41 and 44 (Fig. 4.2g). The total recorded numbers were 126.40 in 2020 and 118.20 in 2021. The pooled data reveals a total population of 122.30.

C. punctiger maintained low population levels in early weeks peaking between weeks 36 and 40 (Fig. 4.2h). The recorded total was 88.00 in 2020 and 68.60 in 2021, leading to a pooled total of 78.30.

S. incertulas showed a population increase after week 30, peaking between weeks 36 and 42 (Fig. 4.2i). The recorded numbers were 202.91 in 2020 and 180.24 in 2021, resulting in a pooled total of 191.58.

The population of *C. suppressalis* exhibited relatively low densities throughout the season. A gradual increase was observed from week 29 onwards, reaching peak densities between weeks 36 and 39 (Fig. 4.2j). The total recorded population in 2020 was 41.60, whereas in 2021, it was 29.94, indicating a lower infestation in 2021. The pooled total population was recorded as 35.77.

Scirpophaga spp. showed a steady increase in population from week 27 onwards, peaking between weeks 37 and 42 (Fig. 4.2k). The total population recorded in 2020 was 125.26, while in 2021, it was 121.92, with a pooled total of 123.59. The infestation levels were similar in both years.

Table 4.2b: Seasonal abundance of insect pests in lowland rice agro ecosystem at Singrijan

Insect Pests	SMW	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	Total
<i>Nephotettix virescens</i> Distant	2020	3.33	7.66	7.66	9.33	10.00	8.66	14.00	8.66	10.00	10.33	16.00	21.66	36.33	38.00	42.66	44.33	60.66	66.66	67.00	79.66	89.00	76.33	82.00	70.33	62.33	45.66	30.00	1018.24
	2021	2.33	4.33	4.66	7.66	12.66	12.00	13.33	16.33	16.66	8.33	19.66	24.00	28.66	28.00	38.66	56.33	59.66	52.00	55.33	61.66	73.33	68.66	56.33	42.66	31.66	38.00	35.66	868.55
	Pooled	2.83	6.00	6.16	8.50	11.33	10.33	13.67	12.50	13.33	9.33	17.83	22.83	32.50	33.00	40.66	50.33	60.16	59.33	61.17	70.66	81.17	72.50	69.17	56.50	47.00	41.83	32.83	943.40
<i>Nephotettix nigropictus</i> Stål	2020	0.00	0.00	1.00	0.33	0.33	1.33	2.66	2.00	2.00	4.33	8.66	6.33	8.66	8.00	17.33	22.66	20.66	30.00	39.00	44.33	63.33	39.33	32.66	18.00	22.33	13.33	6.00	414.59
	2021	0.00	0.00	0.00	0.33	1.00	1.33	2.33	3.33	1.66	2.00	1.33	3.33	4.00	4.33	6.00	8.00	4.33	6.33	8.66	6.33	12.33	8.66	2.00	1.33	0.66	4.00	1.33	94.93
	Pooled	0.00	0.00	0.50	0.33	0.67	1.33	2.50	2.67	1.83	3.17	5.00	4.83	6.33	6.17	11.67	15.33	12.50	18.17	23.83	25.33	37.83	24.00	17.33	9.67	11.50	8.67	3.67	254.76
<i>Cofana spectra</i> Distant	2020	0.00	0.00	0.00	0.00	0.00	0.33	1.33	2.66	1.00	0.33	0.66	0.33	0.66	2.00	1.33	3.66	6.66	5.33	6.00	6.66	8.33	9.33	11.00	10.33	6.66	4.33	2.00	90.92
	2021	0.00	0.00	0.00	0.33	3.66	2.33	3.33	1.00	0.33	2.66	2.00	1.66	3.33	3.33	5.66	4.66	9.00	8.66	12.33	12.00	9.33	10.66	10.66	8.33	9.00	7.33	7.33	138.91
	Pooled	0.00	0.00	0.00	0.17	1.83	1.33	2.33	1.83	0.67	1.50	1.33	1.00	2.00	2.67	3.50	4.16	7.83	7.00	9.17	9.33	8.83	10.00	10.83	9.33	7.83	5.83	4.67	114.92
<i>Maistas dorsalis</i> Motchulsky	2020	2.00	2.66	1.66	2.33	4.66	8.33	6.00	9.66	7.33	12.66	15.33	14.33	10.66	8.00	8.66	12.00	7.33	7.33	9.66	10.00	6.66	4.66	4.66	2.33	4.00	3.66	1.00	187.56
	2021	0.33	0.33	1.00	1.66	1.33	2.66	2.66	5.33	6.66	9.00	8.33	7.66	6.00	8.33	10.33	11.66	9.00	6.66	5.66	5.33	5.33	6.66	2.66	1.00	1.66	1.66	0.00	128.89
	Pooled	1.17	1.50	1.33	2.00	3.00	5.50	4.33	7.50	7.00	10.83	11.83	11.00	8.33	8.17	9.50	11.83	8.17	7.00	7.66	7.67	6.00	5.66	3.66	1.67	2.83	2.66	0.50	158.23
<i>Nilaparvata lugens</i> Stål	2020	6.33	4.00	2.66	4.66	6.33	8.66	6.33	19.66	46.66	56.00	58.33	82.33	83.00	90.66	49.33	110.33	150.66	180.66	160.33	188.66	165.00	149.66	89.33	93.33	64.00	34.00	52.00	1962.90
	2021	4.00	2.33	4.00	4.33	6.00	2.66	8.66	22.33	36.66	73.00	79.00	87.66	63.33	60.33	82.00	99.66	130.33	168.66	200.33	166.66	130.33	175.66	120.00	76.33	45.33	52.00	58.33	1959.91
	Pooled	5.17	3.17	3.33	4.50	6.17	5.66	7.50	21.00	41.66	64.50	68.67	85.00	73.17	75.50	65.67	105.00	140.50	174.66	180.33	177.66	147.67	162.66	104.67	84.83	54.67	43.00	55.17	1961.41
<i>Sogatella furcifera</i> Horvith	2020	0.00	0.00	0.00	0.00	3.33	8.66	6.66	8.33	10.66	6.33	14.00	18.66	7.33	10.66	18.66	24.33	30.66	47.33	59.66	72.66	68.66	54.00	56.33	30.66	22.00	9.66	8.00	597.23
	2021	0.00	0.00	1.00	0.00	1.33	6.33	4.66	9.00	12.66	12.66	9.33	21.66	24.00	16.00	20.66	28.66	45.33	34.33	70.66	72.66	79.00	68.66	64.00	18.66	12.33	21.00	16.66	671.24
	Pooled	0.00	0.00	0.50	0.00	2.33	7.50	5.66	8.67	11.66	9.50	11.67	20.16	15.67	13.33	19.66	26.50	38.00	40.83	65.16	72.66	73.83	61.33	60.17	24.66	17.17	15.33	12.33	634.24
<i>Leptocorisa acuta</i> Thunberg	2020	0.00	0.00	1.20	3.20	5.60	5.80	7.20	2.00	4.60	3.40	2.40	3.20	4.20	4.00	0.80	4.20	8.60	8.80	12.80	16.20	12.60	6.60	6.00	1.80	0.20	1.00	0.00	126.40
	2021	0.20	1.60	0.20	1.20	2.20	2.60	5.60	3.80	4.20	2.00	2.60	1.80	2.20	2.40	1.00	0.20	4.60	6.20	14.20	9.20	16.40	16.40	9.20	6.00	2.00	0.20	0.00	118.20
	Pooled	0.10	0.80	0.70	2.20	3.90	4.20	6.40	2.90	4.40	2.70	2.50	2.50	3.20	3.20	0.90	2.20	6.60	7.50	13.50	12.70	14.50	11.50	7.60	3.90	1.10	0.60	0.00	122.30
<i>Cletus punctiger</i> Dallas	2020	0.00	0.20	1.40	2.20	2.60	3.00	2.20	2.80	2.80	4.20	1.20	2.00	2.60	4.00	6.00	8.00	8.40	6.60	4.00	4.20	4.40	2.20	5.00	1.00	2.60	2.40	2.00	88.00
	2021	0.00	0.00	0.20	3.20	1.40	2.20	4.60	3.00	2.00	2.80	2.20	1.20	1.20	6.20	4.60	5.40	6.40	6.00	2.00	1.20	2.20	2.60	2.20	1.20	1.00	2.40	1.20	68.60
	Pooled	0.00	0.10	0.80	2.70	2.00	2.60	3.40	2.90	2.40	3.50	1.70	1.60	1.90	5.10	5.30	6.70	7.40	6.30	3.00	2.70	3.30	2.40	3.60	1.10	1.80	2.40	1.60	78.30

<i>Scirpophaga incertulas</i> Walker	2020	0.00	0.00	0.00	0.00	0.66	2.33	0.66	4.66	3.33	6.33	8.66	12.66	14.00	16.66	16.66	20.33	19.66	20.66	23.00	14.00	6.66	8.00	3.00	0.66	0.33	0.00	0.00	202.91
	2021	0.00	0.00	0.00	0.33	0.33	1.66	2.66	2.66	4.00	2.33	6.66	8.00	10.66	12.33	14.66	16.66	20.00	19.00	14.66	17.66	12.33	6.66	4.33	2.66	0.00	0.00	0.00	180.24
	Pooled	0.00	0.00	0.00	0.17	0.50	2.00	1.66	3.66	3.67	4.33	7.66	10.33	12.33	14.50	15.66	18.50	19.83	19.83	18.83	15.83	9.50	7.33	3.67	1.66	0.17	0.00	0.00	191.58
<i>Chilo suppressalis</i> Dudgeon	2020	0.00	0.00	0.00	1.00	0.00	0.66	2.66	0.33	0.33	3.66	1.00	0.66	4.00	6.33	2.00	6.66	8.66	0.33	0.66	2.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	41.60
	2021	0.00	0.00	0.00	0.00	0.33	0.33	0.66	1.00	2.00	1.66	2.00	3.33	3.66	4.33	1.66	2.33	4.00	1.66	0.33	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.94
	Pooled	0.00	0.00	0.00	0.50	0.17	0.50	1.66	0.67	1.17	2.66	1.50	2.00	3.83	5.33	1.83	4.50	6.33	1.00	0.50	1.50	0.17	0.00	0.00	0.00	0.00	0.00	0.00	35.77
<i>Scirpophaga</i> spp.	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.66	2.33	4.33	3.66	6.33	6.66	5.66	8.33	14.00	8.66	12.66	15.33	10.33	12.00	6.66	0.33	4.33	3.00	0.00	0.00	0.00	125.26
	2021	0.00	0.00	0.00	0.00	1.33	2.66	1.00	1.66	2.33	6.33	4.00	4.66	6.33	2.66	9.66	12.66	14.66	18.00	13.66	8.33	2.00	5.33	1.66	1.00	2.00	0.00	0.00	121.92
	Pooled	0.00	0.00	0.00	0.00	0.67	1.33	0.83	2.00	3.33	5.00	5.17	5.66	6.00	5.50	11.83	10.66	13.66	16.67	12.00	10.17	4.33	2.83	3.00	2.00	1.00	0.00	0.00	123.59
<i>Cnaphalocrocis medinalis</i> Guenée	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	2.33	1.66	4.00	3.33	6.66	8.33	6.66	10.66	11.33	2.00	3.33	0.66	1.33	0.00	62.61
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	1.00	0.33	1.66	0.33	2.66	1.33	4.66	3.33	6.00	7.33	9.66	5.33	8.66	6.33	1.00	0.66	0.00	60.60
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.50	0.17	1.00	1.33	2.16	2.67	4.00	5.00	7.17	7.00	10.16	8.33	5.33	4.83	0.83	1.00	0.00	61.61
<i>Melanitis leda ismene</i> Linnaeus	2020	0.00	0.00	0.00	0.00	0.00	0.66	1.66	0.33	0.33	2.00	1.66	1.33	0.66	2.00	1.33	2.66	2.33	1.66	0.66	3.66	1.00	0.66	1.00	1.33	0.00	0.00	0.00	26.92
	2021	0.00	0.00	0.00	0.00	0.66	2.00	0.66	2.66	1.33	1.66	1.66	2.33	1.33	2.66	1.00	1.66	1.33	1.66	1.33	0.00	0.66	0.66	2.00	1.33	1.33	0.00	0.00	29.91
	Pooled	0.00	0.00	0.00	0.00	0.33	1.33	1.16	1.50	0.83	1.83	1.66	1.83	1.00	2.33	1.17	2.16	1.83	1.66	1.00	1.83	0.83	0.66	1.50	1.33	0.67	0.00	0.00	28.42
Green Horned caterpillars	2020	0.00	0.00	0.00	0.00	0.60	1.20	2.20	1.00	0.60	1.20	2.80	1.20	1.80	2.80	1.80	1.60	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.20
	2021	0.00	0.00	0.00	0.00	0.00	0.20	1.40	1.80	1.20	0.20	1.00	2.20	1.20	1.40	2.80	1.60	2.20	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.20
	Pooled	0.00	0.00	0.00	0.00	0.30	0.70	1.80	1.40	0.90	0.70	1.90	1.70	1.50	2.10	2.30	1.60	1.20	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.70
<i>Spodoptera litura</i> Fabricius	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66	1.00	1.33	0.33	1.33	1.00	1.33	0.66	0.00	0.33	0.00	0.00	0.00	7.97
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	1.00	1.66	0.66	0.66	0.33	0.66	0.33	0.33	0.00	0.00	5.96
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.50	0.83	0.67	1.50	0.83	1.00	0.50	0.33	0.33	0.17	0.00	0.00	6.97
<i>Leucania loreyi</i> Duponchel	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66	2.00	1.66	6.66	6.66	8.33	7.00	8.66	10.33	7.66	4.33	3.33	2.33	3.66	0.00	0.00	0.00	73.27
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.33	0.66	2.33	4.66	6.00	9.66	12.33	8.66	6.33	7.66	5.00	1.66	1.66	1.00	0.00	0.00	68.27
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.33	1.17	1.16	4.50	5.66	7.17	8.33	10.50	9.50	7.00	6.00	4.17	2.00	2.66	0.50	0.00	0.00	70.77
<i>Nymphula depunctalis</i> Guenée	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	6.66	12.66	9.66	10.00	8.66	2.33	1.33	0.66	2.33	0.33	0.33	0.66	0.33	0.00	0.33	0.66	0.00	58.26
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	6.33	8.00	4.33	9.66	8.00	6.66	2.66	1.33	1.33	1.66	0.33	0.33	0.33	0.00	0.00	51.61
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	3.50	6.50	8.00	9.00	6.50	6.00	4.67	3.66	2.50	0.83	0.83	1.16	0.33	0.17	0.33	0.33	0.00	54.94

<i>Pelopidas mathias</i> Fabricius	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	1.20	1.60	2.40	3.60	1.20	2.80	1.00	0.20	2.20	0.20	0.00	0.00	0.00	0.00	0.00	16.60
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.40	1.00	1.20	2.20	2.40	1.80	1.40	1.40	0.60	1.00	0.20	0.00	0.00	0.00	0.00	15.60
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.50	1.30	1.30	1.80	2.90	1.80	2.30	1.20	0.80	1.40	0.60	0.10	0.00	0.00	0.00	0.00	16.10
Short horned grasshoppers	2020	2.60	4.40	4.20	3.20	2.00	6.80	4.80	2.60	2.40	6.00	4.60	3.20	3.00	8.60	2.60	2.60	6.20	8.80	4.00	2.40	6.60	2.40	2.40	4.00	6.20	3.20	4.00	113.80	
	2021	3.80	2.00	3.00	2.80	4.80	3.00	2.60	2.60	2.60	4.00	6.40	4.40	4.00	6.40	4.40	3.60	8.00	7.00	6.40	4.60	5.60	1.20	3.80	4.80	6.80	6.00	5.20	119.80	
	Pooled	3.20	3.20	3.60	3.00	3.40	4.90	3.70	2.60	2.50	5.00	5.50	3.80	3.50	7.50	3.50	3.10	7.10	7.90	5.20	3.50	6.10	1.80	3.10	4.40	6.50	4.60	4.60	116.80	
Field crickets	2020	3.00	6.00	8.00	8.00	12.00	9.00	7.00	7.66	8.00	4.00	6.66	12.66	10.00	10.00	13.00	15.66	7.00	26.66	20.66	21.00	25.66	20.00	19.00	7.00	10.00	5.00	3.00	305.62	
	2021	2.00	3.00	3.00	3.00	4.00	6.66	8.00	5.66	6.00	9.66	2.00	8.66	8.00	15.00	10.66	8.00	16.00	20.66	16.00	14.00	15.00	23.66	10.66	11.00	8.00	6.66	2.00	246.94	
	Pooled	2.50	4.50	5.50	5.50	8.00	7.83	7.50	6.66	7.00	6.83	4.33	10.66	9.00	12.50	11.83	11.83	11.50	23.66	18.33	17.50	20.33	21.83	14.83	9.00	9.00	5.83	2.50	276.28	
<i>Gryllotalpa orientalis</i> Burmeister	2020	0.00	0.00	0.00	0.00	0.00	1.66	3.33	0.66	0.66	2.33	4.33	3.66	2.00	1.66	1.33	2.33	0.33	6.66	4.66	4.00	2.66	1.33	0.66	1.00	0.00	0.00	0.00	45.25	
	2021	0.00	0.00	0.00	0.00	0.33	0.66	1.00	1.33	1.66	2.66	1.33	2.33	1.00	1.66	1.66	1.33	1.66	2.33	3.00	2.66	0.33	0.66	0.66	1.66	1.00	0.00	0.00	30.91	
	Pooled	0.00	0.00	0.00	0.00	0.17	1.16	2.17	1.00	1.16	2.50	2.83	3.00	1.50	1.66	1.50	1.83	1.00	4.50	3.83	3.33	1.50	1.00	0.66	1.33	0.50	0.00	0.00	38.08	
<i>Sitophilus oryzae</i> Linnaeus	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	3.40	5.40	8.00	8.60	14.20	7.00	8.00	55.80	
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	6.80	7.00	9.60	12.20	9.00	44.80	
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	1.80	2.70	7.40	7.80	11.90	9.60	8.50	50.30	
<i>Dicladispa armigera</i> Olivier	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.20	2.20	4.40	5.40	4.60	6.60	5.40	10.60	9.80	10.80	2.60	6.60	3.20	1.20	3.00	2.60	2.00	1.20	1.20	0.40	0.00	84.00	
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.60	2.20	1.20	5.40	8.80	12.40	14.20	16.20	8.80	3.60	4.80	2.40	2.20	2.20	1.00	1.20	1.60	1.00	0.00	90.00	
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.10	1.20	2.50	3.80	2.90	6.00	7.10	11.50	12.00	13.50	5.70	5.10	4.00	1.80	2.60	2.40	1.50	1.20	1.40	0.70	0.00	87.00	
<i>Stenchaetothrips biformis</i> Bagnall	2020	0.00	0.00	2.00	4.25	8.50	6.25	8.75	12.50	12.25	14.25	14.75	12.00	13.75	10.25	12.50	6.25	8.75	8.50	4.50	7.25	8.75	6.25	2.25	2.00	1.75	2.00	0.25	190.50	
	2021	0.00	0.00	0.75	3.25	2.75	4.75	6.25	14.00	10.75	9.75	12.50	7.25	12.00	10.25	10.25	7.00	9.25	9.75	6.75	2.25	2.00	0.00	0.25	2.50	2.25	2.50	0.50	149.50	
	Pooled	0.00	0.00	1.38	3.75	5.63	5.50	7.50	13.25	11.50	12.00	13.63	9.63	12.88	10.25	11.38	6.63	9.00	9.13	5.63	4.75	5.38	3.13	1.25	2.25	2.00	2.25	0.38	170.00	

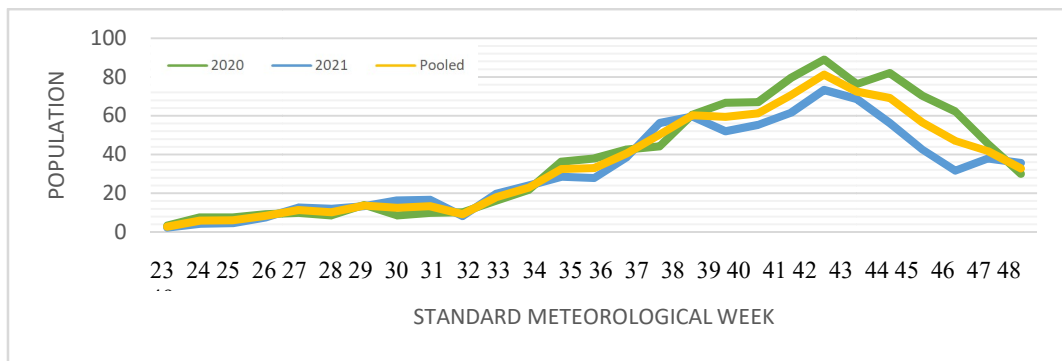


Fig.4.2a: Seasonal abundance of *Nephrotettix virescens* Distant from June to December, 2020 & 2021 at Singrijan

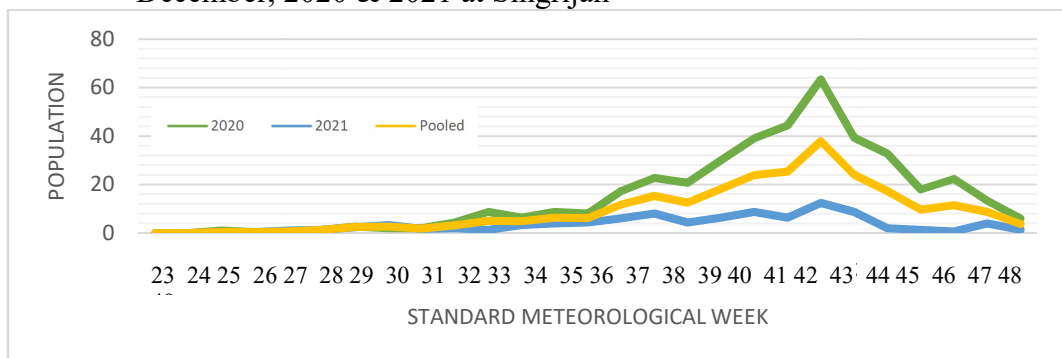


Fig.4.2b: Seasonal abundance of *Nephrotettix nigropictus* Stål from June to December, 2020 & 2021 at Singrijan

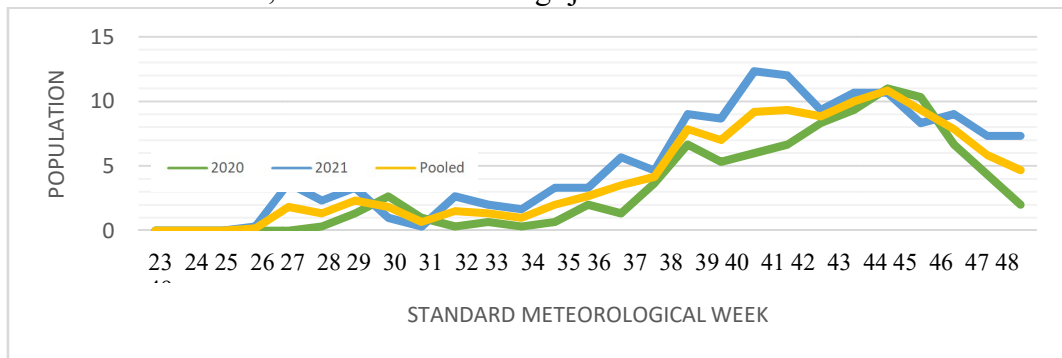


Fig.4.2c: Seasonal abundance of *Cofana spectra* Distant from June to December, 2020 & 2021 at Singrijan

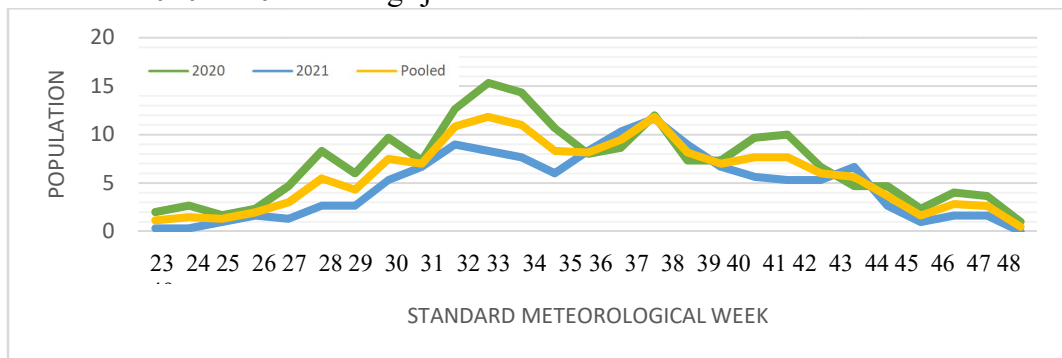


Fig.4.2d: Seasonal abundance of *Maiestas dorsalis* Motchulsky from June to December, 2020 & 2021 at Singrijan

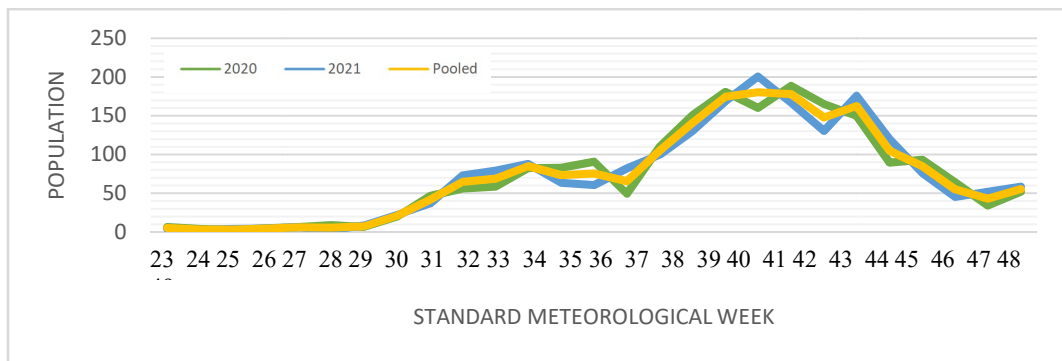


Fig.4.2e: Seasonal abundance of *Nilaparvata lugens* Stål from June to December, 2020 & 2021 at Singrijan

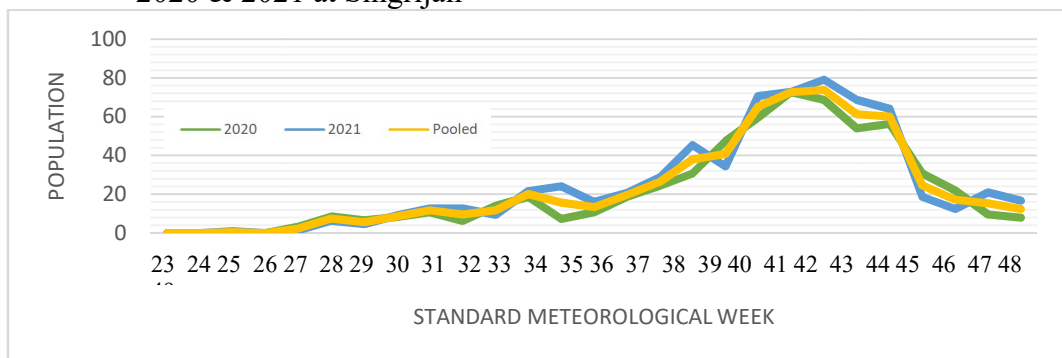


Fig.4.2f: Seasonal abundance of *Sogatella furcifera* Horvith from June to December, 2020 & 2021 at Singrijan

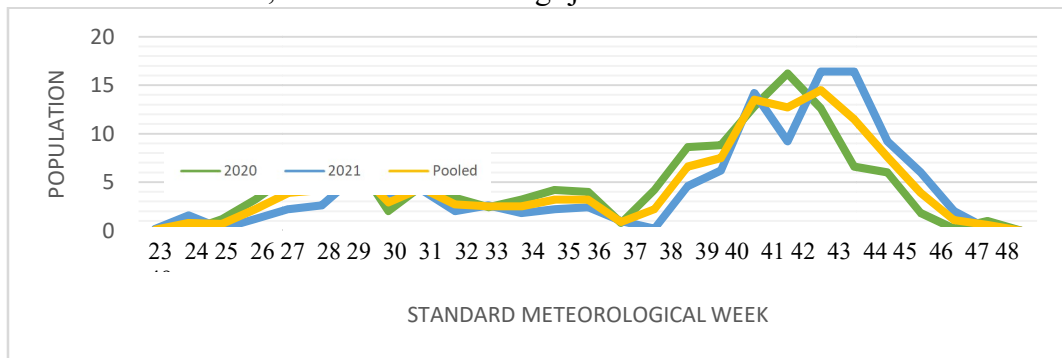


Fig.4.2g: Seasonal abundance of *Leptocorisa acuta* Thunberg from June to December, 2020 & 2021 at Singrijan

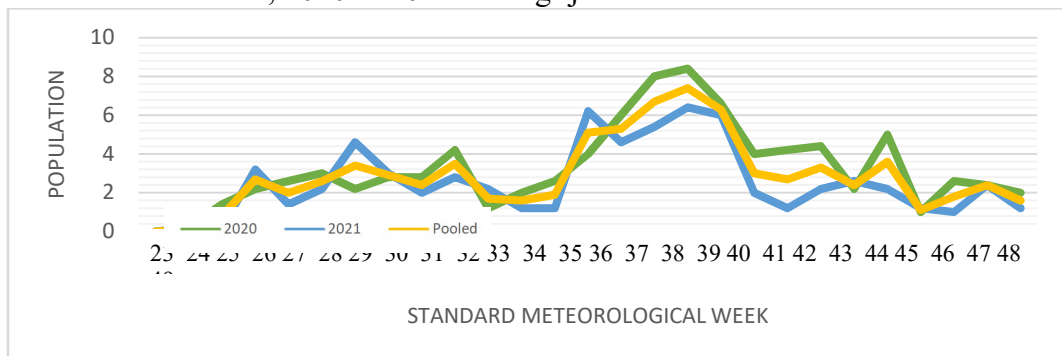
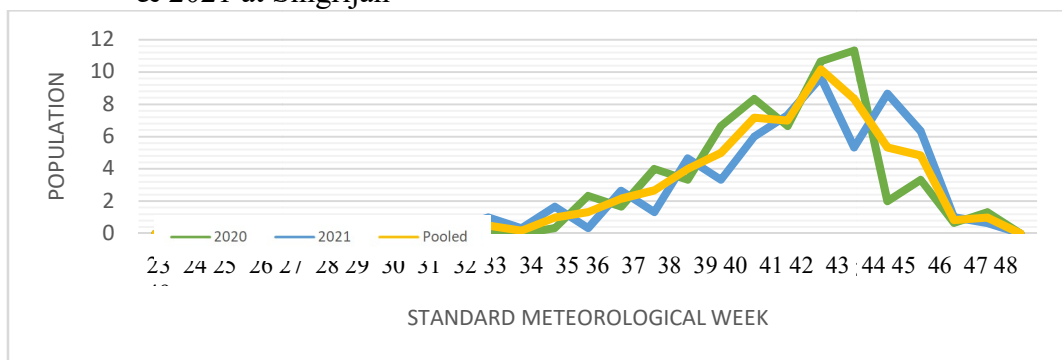
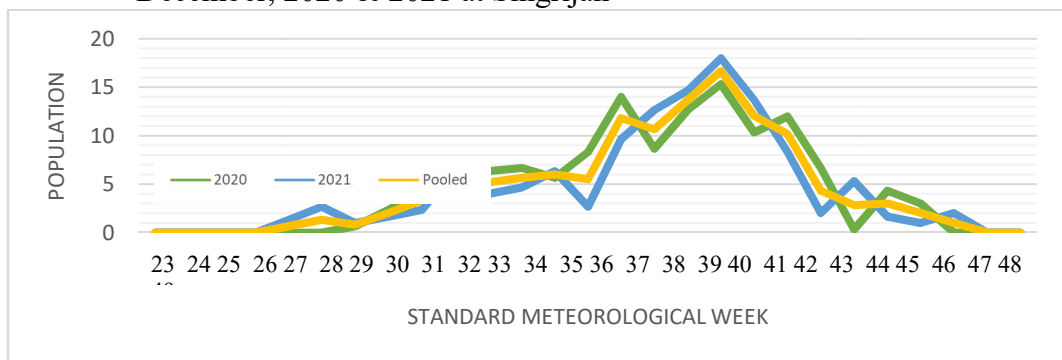
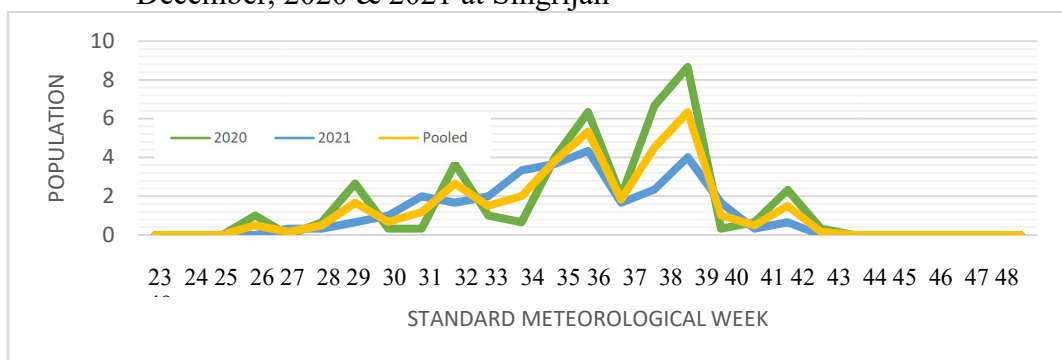
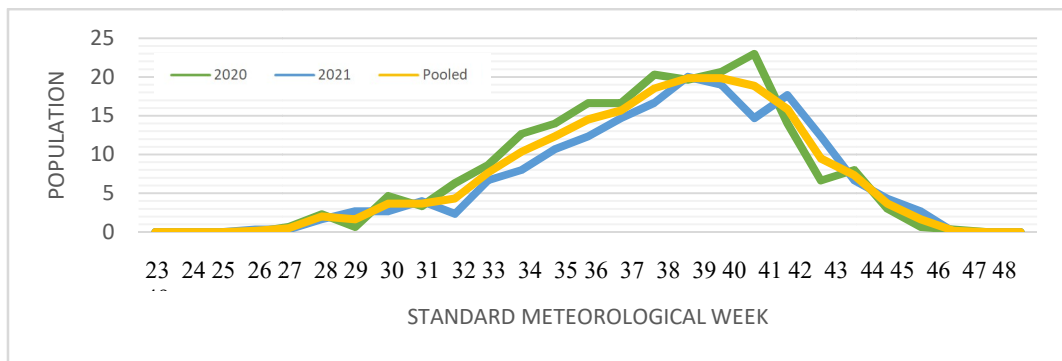


Fig.4.2h: Seasonal abundance of *Cletus punctiger* Dallas from June to December, 2020 & 2021 at Singrijan



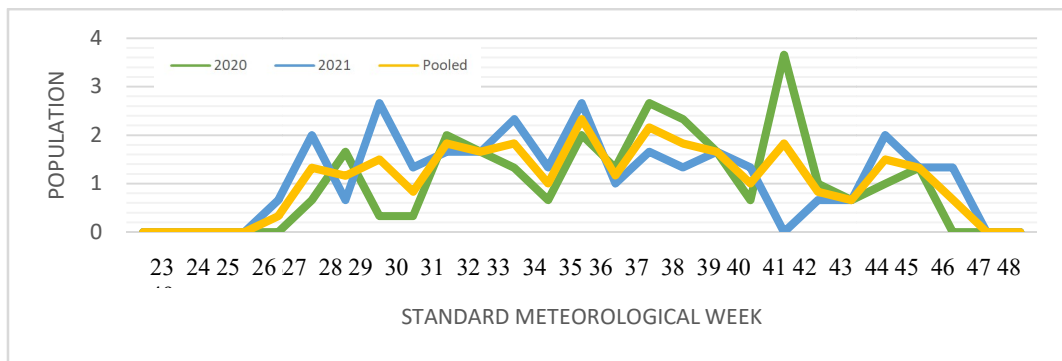


Fig.4.2m: Seasonal abundance of *Melanitis leda ismene* Linnaeus from June to December, 2020 & 2021 at Singrijan

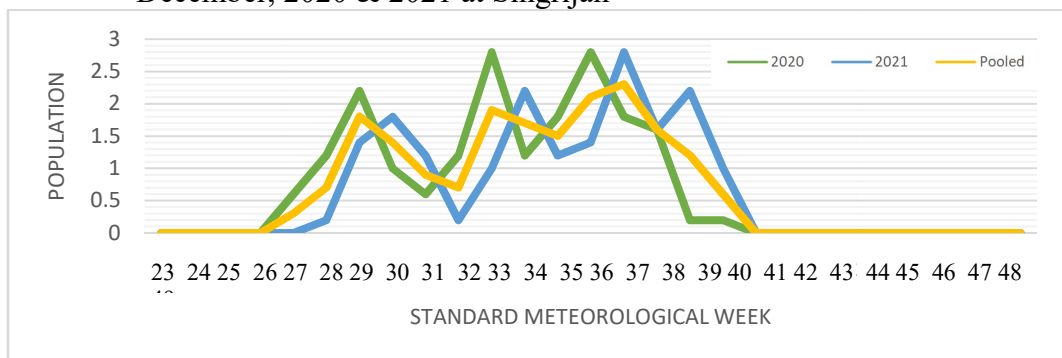


Fig.4.2n: Seasonal abundance of green horned caterpillars from June to December, 2020 & 2021 at Singrijan

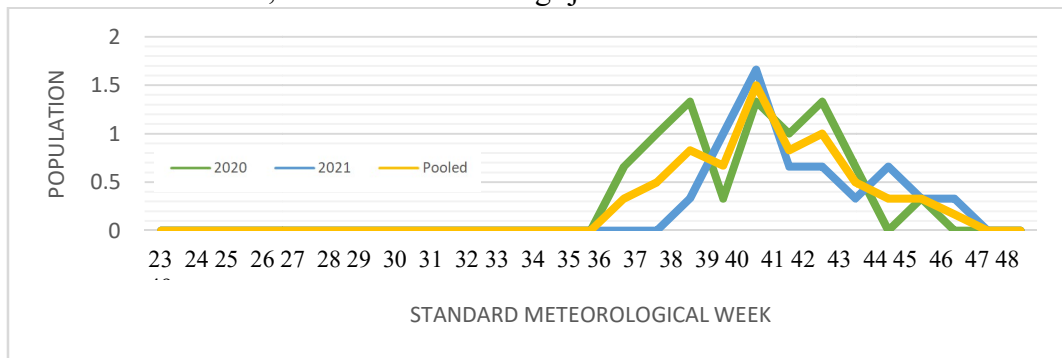


Fig.4.2o: Seasonal abundance of *Spodoptera litura* Fabricius from June to December, 2020 & 2021 at Singrijan

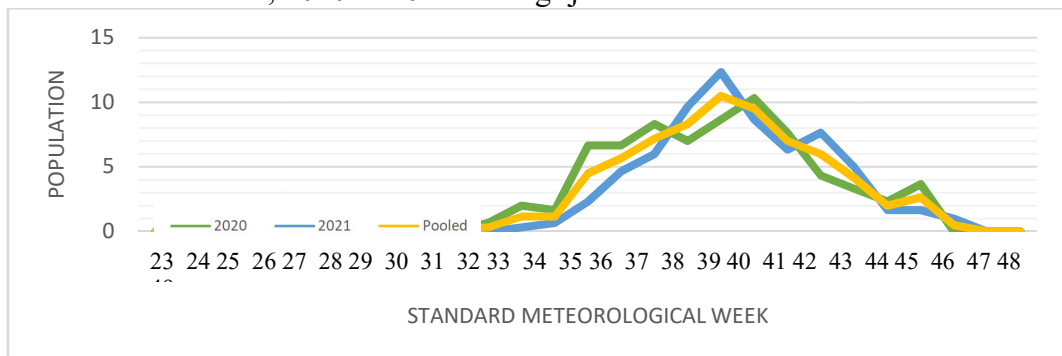


Fig.4.2p: Seasonal abundance of *Leucania loreyi* Duponchel from June to December, 2020 & 2021 at Singrijan

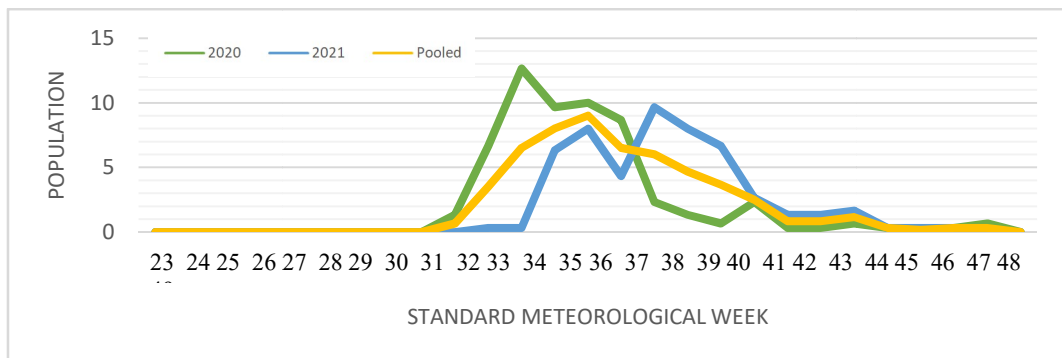


Fig.4.2q: Seasonal abundance of *Nymphula depunctalis* Guenée from June to December, 2020 & 2021 at Singrijan

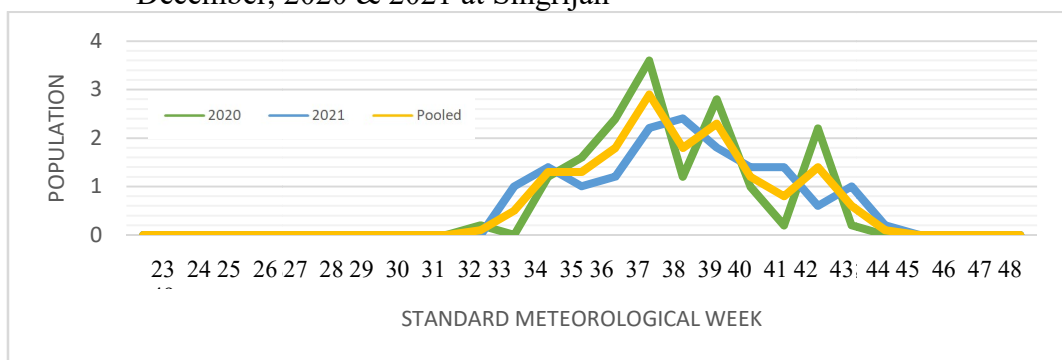


Fig.4.2r: Seasonal abundance of *Pelopidas mathias* Fabricius from June to December, 2020 & 2021 at Singrijan

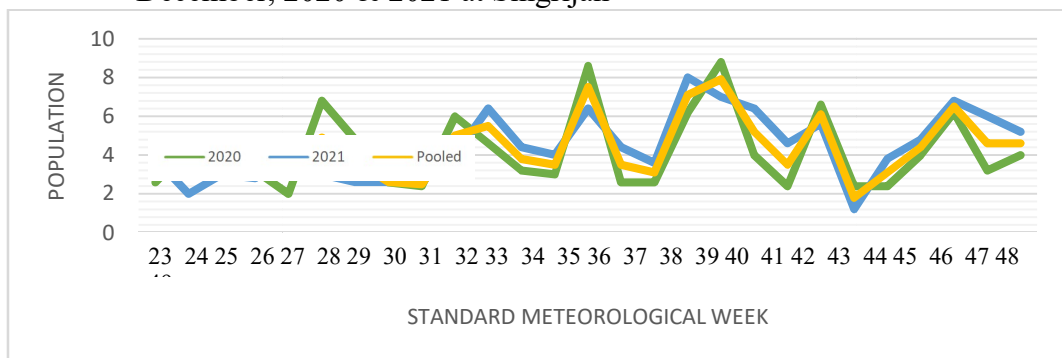


Fig.4.2s: Seasonal abundance of short horned grasshoppers from June to December, 2020 & 2021 at Singrijan

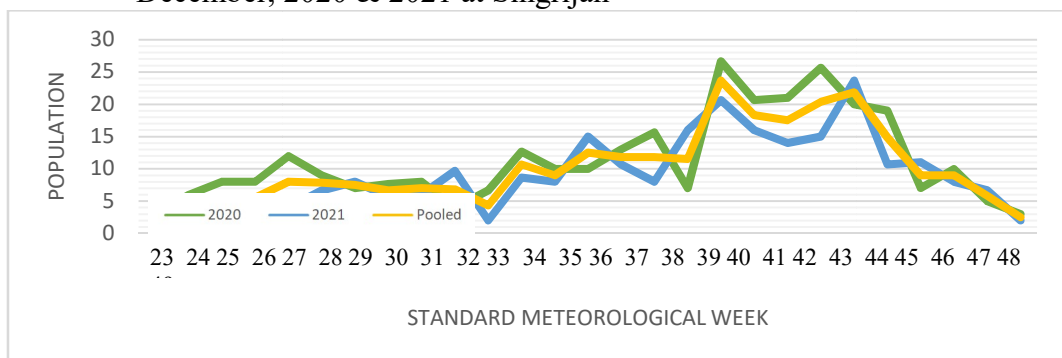


Fig.4.2t: Seasonal abundance of field crickets from June to December, 2020 & 2021 at Singrijan

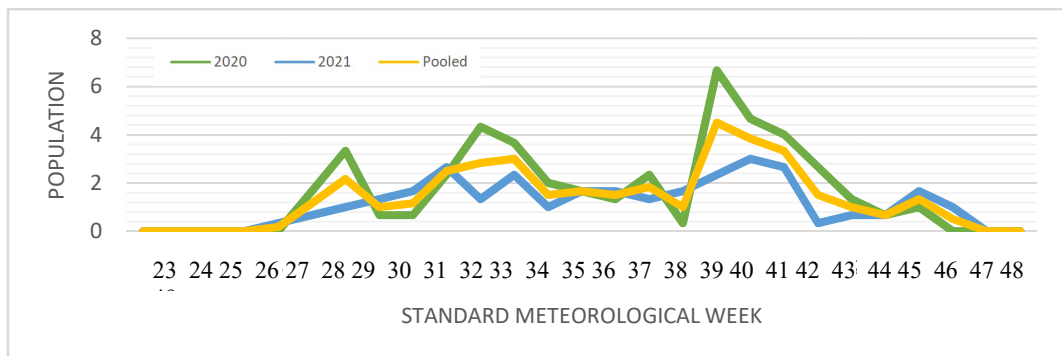


Fig.4.2u: Seasonal abundance of *Gryllotalpa orientalis* Burmeister from June to December, 2020 & 2021 at Singrijan

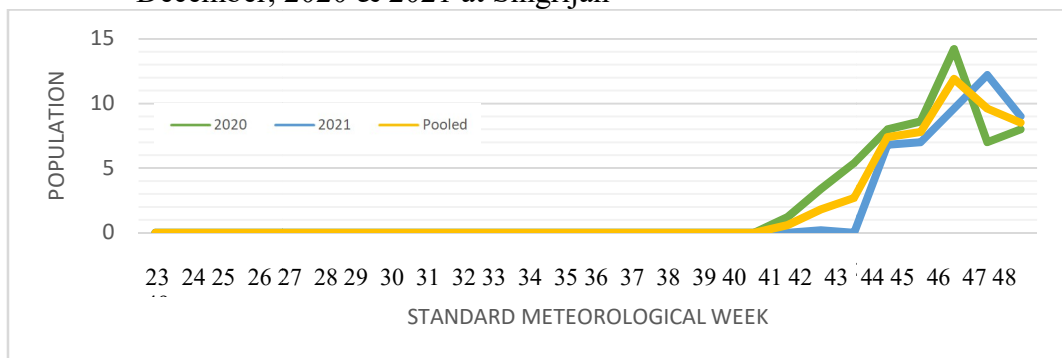


Fig.4.2v: Seasonal abundance of *Sitophilus oryzae* Linnaeus from June to December, 2020 & 2021 at Singrijan

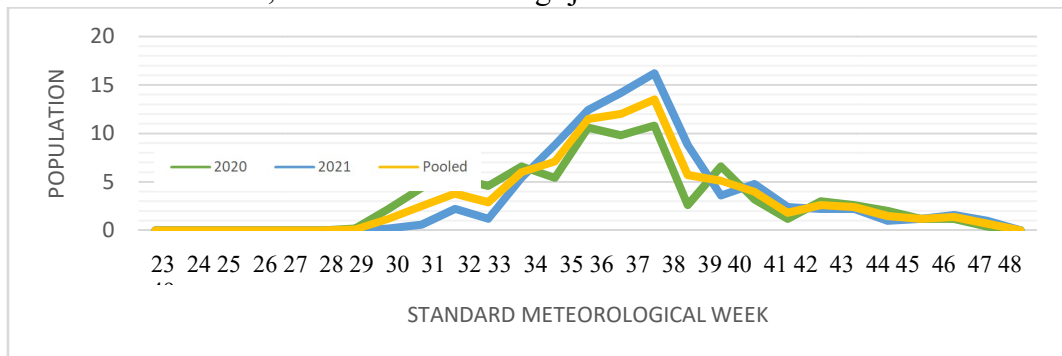


Fig.4.2w: Seasonal abundance of *Dicladispa armigera* Olivier from June to December, 2020 & 2021 at Singrijan

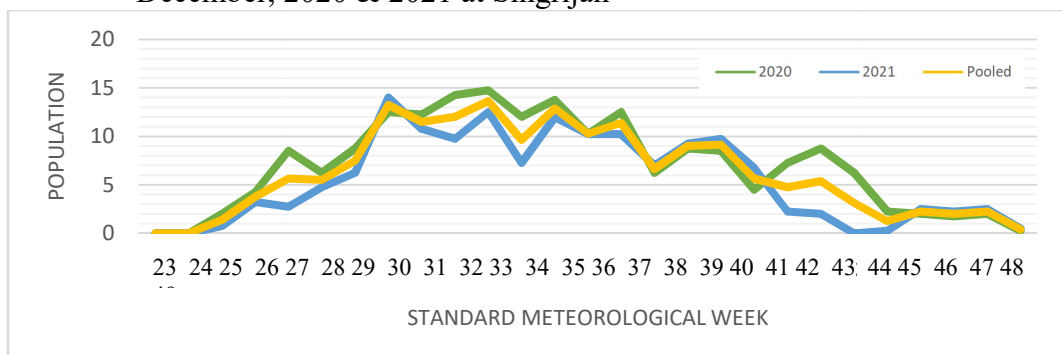


Fig.4.2x: Seasonal abundance of *Stenchaetothrips biformis* Bagnall from June to December, 2020 & 2021 at Singrijan

The population of *C. medinalis* remained low in the early weeks but showed a gradual increase from week 32 onwards. The highest densities were recorded between weeks 40 and 45 (Fig. 4.2l), coinciding with peak rice vegetative growth. The total recorded population was 62.61 in 2020 and 60.60 in 2021, with a pooled total of 61.61.

Consistently low population of *M. leda ismene* was observed throughout the season. A minor peak was observed between weeks 36 and 42 (Fig. 4.2m). The total recorded numbers were 26.92 in 2020 and 29.91 in 2021, with a pooled total of 28.42.

The population of green horned caterpillars was among the lowest recorded among all insect species. Peak densities were observed between weeks 33 and 37 (Fig. 4.2n), but overall infestation levels remained minimal. The total population recorded was 19.20 in 2020 and 18.20 in 2021, with a pooled total of 18.70.

S. litura remained significantly low level throughout the study period, with a peak occurring between weeks 39 and 42 (Fig. 4.2o). The total recorded population in 2020 was 7.97, whereas in 2021, it was 5.96, leading to a pooled total of 6.97.

The population of *L. loreyi* remained low in early weeks, but increased from week 32 onwards. The highest population density was recorded between weeks 38 and 43 (Fig. 4.2p). In 2020, the total population recorded was 73.27, while in 2021, it was 68.27, with a pooled total of 70.77.

N. depunctalis was mostly absent during early weeks, but population buildup was noticed after week 32, peaking between weeks 34 and 38 (Fig. 4.2q). The total population recorded in 2020 was 58.26, while in 2021, it was 51.61, with a pooled total of 54.94.

A relatively low population density was recorded for *P. mathias* with the highest numbers observed between weeks 37 and 40 (Fig. 4.2r). In 2020, the total population was 16.60, whereas in 2021, it was 15.60, leading to a pooled total of 16.10.

Short-horned grasshoppers showed seasonal fluctuations, with peak infestations occurring at week 36 with a second spike between 39 and 41 (Fig. 4.2s). The total recorded population was 113.80 in 2020 and 119.80 in 2021, with a pooled total of 116.80.

The field cricket population remained relatively stable throughout the season, with peak occurrences between weeks 40 and 44 (Fig. 4.2t). In 2020, the total recorded population was 305.62, while in 2021, it was 246.94, with a pooled total of 276.28.

G. orientalis showed a gradual increase from week 28 onwards, with peak densities observed between weeks 40 and 42 (Fig. 4.2u). The total population recorded in 2020 was 45.25, while in 2021, it was 30.91, with a pooled total of 38.08.

S. oryzae was mostly recorded towards the later part of the season, peaking between weeks 45 and 49 (Fig. 4.2v). The total population in 2020 was 55.80, while in 2021, it was 44.80, with a pooled total of 50.30.

D. armigera This species exhibited a gradual rise in population from week 30, with a peak between weeks 35 and 38 (Fig. 4.2w). The total population recorded in 2020 was 84.00, while in 2021, it was 90.00, leading to a pooled total of 87.00.

S. biformis showed steady growth in population from week 25, peaking between weeks 30 and 37 (Fig. 4.2x). The total population recorded in 2020 was 190.50, while in 2021 it was 149.50, with a pooled total of 170.00.

4.2.1.3. SEASONAL ABUNDANCE OF INSECT PESTS AT KUHOXU

From the study of table 4.2c, it is revealed that at Kuhoxu, the most abundant insect pest was *N. lugens* (2058.07), followed by *N. virescens* (910.40), *S. furcifera* (626.74), *N. nigropictus* (323.91), *S. incertulas* (163.10), *S. biformis* (134.13), *Scirpophaga* spp. (130.62), *M. dorsalis* (101.59), and *L. acuta* (101.30), with Short-horned grasshoppers ranking next in abundance, while pests with the least abundance included *P. mathias* (16.90), green horned caterpillars (15.10), *S. litura* (15.80), *S. oryzae* (44.70), and *N. depunctalis* (40.78).

N. virescens showed a steady increase from week 24, reaching peak abundance between weeks 41 and 47 (Fig. 4.3a). The total recorded population was 1030.23 in 2020 and 790.57 in 2021, resulting in a pooled total of 910.40.

Following a similar trend but at lower densities, *N. nigropictus* peaked between weeks 40 and 46 (Fig. 4.3b). The total population recorded was 379.58 in 2020 and 268.24 in 2021, bringing the pooled total to 323.91.

C. spectra exhibited moderate abundance, peaking between weeks 41 and 46 (Fig. 4.3c). The total recorded population was 89.27 in 2020 and 110.59 in 2021, leading to a pooled total of 99.93.

Gradual growth in population was observed for *M. dorsalis* starting from week 27, with peak occurrences between weeks 33 and 40 (Fig. 4.3d). The total recorded numbers were 118.25 in 2020 and 84.93 in 2021, resulting in a pooled total of 101.59.

N. lugens, a major rice pest, exhibited a rapid increase from week 30, reaching peak infestation between weeks 37 and 45 (Fig. 4.3e). The total population recorded was 2003.24 in 2020 and 2112.90 in 2021, leading to a pooled total of 2058.07.

S. furcifera had a low early-season presence but increased significantly between weeks 40 and 47 (Fig. 4.3f). The total recorded population was 548.23 in 2020 and 705.25 in 2021, with a pooled total of 626.74.

Lower in abundance, *L. acuta* peaked between weeks 40 and 45 (Fig. 4.3g). The total recorded numbers were 108.00 in 2020 and 94.60 in 2021, leading to a pooled total of 101.30.

A slow build-up in population was observed for *C. punctiger*, which reached peak abundance between weeks 37 and 40 (Fig. 4.3h). The species recorded a total of 81.00 in 2020 and 71.00 in 2021, bringing the pooled total to 76.00.

Table 4.2c. Seasonal abundance and diversity of major insect pests in lowland rice agro ecosystem at Kuhoxu

Insect pests	SMW	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	Total
<i>Nephotettix virescens</i> Distant	2020	1.33	3.66	5.66	6.33	7.33	6.66	7.33	6.66	8.00	12.33	12.00	12.66	15.66	24.66	28.00	37.66	56.66	52.33	69.00	87.66	102.00	97.33	90.66	84.33	76.00	60.00	58.33	1030.23
	2021	1.33	2.33	2.66	5.33	6.00	5.66	4.66	6.33	6.00	7.66	8.00	11.33	11.00	9.33	16.33	26.00	32.66	36.66	51.33	69.66	89.33	96.66	81.00	68.33	49.00	44.66	41.33	790.57
	Pooled	1.33	3.00	4.16	5.83	6.67	6.16	6.00	6.50	7.00	10.00	10.00	12.00	13.33	17.00	22.17	31.83	44.66	44.50	60.17	78.66	95.67	97.00	85.83	76.33	62.50	52.33	49.83	910.40
<i>Nephotettix nigropictus</i> Stål	2020	0.00	0.00	0.33	0.00	0.00	1.00	1.66	1.33	2.33	3.33	5.66	8.00	8.66	8.33	12.66	18.00	18.33	26.66	34.66	41.00	45.33	41.66	39.00	26.33	14.66	8.33	12.33	379.58
	2021	0.00	0.00	0.00	0.00	0.00	0.33	0.66	2.66	2.33	2.66	2.00	2.33	3.66	3.00	8.66	12.66	13.33	21.66	28.00	43.66	41.33	29.66	18.00	16.66	6.33	2.66	6.00	268.24
	Pooled	0.00	0.00	0.17	0.00	0.00	0.67	1.16	2.00	2.33	3.00	3.83	5.17	6.16	5.67	10.66	15.33	15.83	24.16	31.33	42.33	43.33	35.66	28.50	21.50	10.50	5.50	9.17	323.91
<i>Cofana spectra</i> Distant	2020	0.00	0.00	0.00	0.00	0.33	0.00	1.00	2.33	1.33	1.33	1.66	1.00	0.33	1.33	1.66	3.00	4.66	6.00	5.33	6.00	7.33	7.00	9.66	12.00	7.66	6.00	2.33	89.27
	2021	0.00	0.00	0.00	0.00	0.66	1.00	1.00	1.66	2.00	1.66	1.00	2.33	4.00	3.00	3.66	6.00	6.66	7.00	8.66	9.33	9.33	9.33	9.00	6.66	5.33	5.66	5.66	110.59
	Pooled	0.00	0.00	0.00	0.00	0.50	0.50	1.00	2.00	1.67	1.50	1.33	1.67	2.17	2.17	2.66	4.50	5.66	6.50	7.00	7.67	8.33	8.17	9.33	9.33	6.50	5.83	4.00	99.93
<i>Maiestas dorsalis</i> Motchulsky	2020	0.00	0.00	0.00	0.33	0.33	2.66	3.33	5.00	4.33	6.66	7.66	9.33	7.33	6.00	8.33	8.00	6.66	7.00	7.33	8.00	5.00	5.66	5.33	0.33	2.66	0.33	0.66	118.25
	2021	0.00	0.00	0.33	0.33	0.00	0.33	0.66	2.66	2.33	5.00	5.66	4.66	4.00	7.33	8.00	7.66	7.33	8.00	4.33	3.66	4.00	4.00	2.33	2.00	0.33	0.00	0.00	84.93
	Pooled	0.00	0.00	0.17	0.33	0.17	1.50	2.00	3.83	3.33	5.83	6.66	7.00	5.67	6.67	8.17	7.83	7.00	7.50	5.83	5.83	4.50	4.83	3.83	1.17	1.50	0.17	0.33	101.59
<i>Nilaparvata lugens</i> Stål	2020	0.00	0.00	4.66	3.66	4.00	7.33	8.33	21.00	52.33	63.00	52.66	74.66	102.33	89.66	94.00	98.66	128.66	168.00	193.33	186.00	180.66	163.00	107.66	82.00	56.33	32.66	28.66	2003.24
	2021	0.00	1.33	3.66	2.00	12.33	8.33	15.33	26.66	32.00	36.66	41.00	69.66	82.66	94.66	116.33	124.00	165.33	205.66	214.66	171.33	179.00	140.66	122.00	108.66	68.00	38.33	32.66	2112.90
	Pooled	0.00	0.67	4.16	2.83	8.17	7.83	11.83	23.83	42.17	49.83	46.83	72.16	92.50	92.16	105.17	111.33	147.00	186.83	204.00	178.67	179.83	151.83	114.83	95.33	62.17	35.50	30.66	2058.07
<i>Sogatella furcifera</i> Horvith	2020	0.00	0.00	0.00	1.00	2.33	7.33	7.66	7.66	11.66	7.33	12.33	16.66	12.66	9.33	15.66	20.66	28.00	40.33	62.33	68.00	53.33	45.66	46.66	28.66	24.00	12.33	6.66	548.23
	2021	0.00	0.00	0.00	0.66	2.00	4.66	7.00	6.00	8.33	9.66	12.00	20.33	21.00	14.66	18.33	24.66	30.33	38.33	47.33	61.66	72.00	78.33	73.33	56.66	46.00	31.66	20.33	705.25
	Pooled	0.00	0.00	0.00	0.83	2.17	6.00	7.33	6.83	10.00	8.50	12.17	18.50	16.83	12.00	17.00	22.66	29.17	39.33	54.83	64.83	62.67	62.00	60.00	42.66	35.00	22.00	13.50	626.74
<i>Leptocorisa acuta</i> Thunberg	2020	0.00	0.00	0.00	2.00	2.60	2.20	4.60	4.80	4.80	4.20	2.00	2.20	4.80	2.20	2.00	3.20	6.00	7.80	9.80	10.60	10.80	8.00	6.60	4.00	1.00	1.20	0.60	108.00
	2021	0.00	0.60	0.40	1.60	3.00	2.40	4.00	4.80	3.80	3.20	3.00	2.00	1.80	1.80	2.60	1.60	2.20	4.80	8.80	8.80	12.00	9.20	5.60	4.20	1.80	0.60	0.00	94.60
	Pooled	0.00	0.30	0.20	1.80	2.80	2.30	4.30	4.80	4.30	3.70	2.50	2.10	3.30	2.00	2.30	2.40	4.10	6.30	9.30	9.70	11.40	8.60	6.10	4.10	1.40	0.90	0.30	101.30
<i>Cletus punctiger</i> Dallas	2020	0.00	0.00	0.00	1.80	2.60	4.00	2.60	2.80	3.00	2.80	1.60	4.00	3.00	3.60	7.60	7.60	7.20	4.60	2.80	2.80	3.00	3.60	4.00	2.00	1.60	0.60	1.80	81.00
	2021	0.00	0.00	0.40	2.40	1.80	2.00	4.20	2.20	2.60	3.20	2.60	2.80	2.00	4.00	4.80	4.00	6.20	6.80	4.20	2.00	2.00	2.00	1.80	2.00	1.80	1.60	1.60	71.00
	Pooled	0.00	0.00	0.20	2.10	2.20	3.00	3.40	2.50	2.80	3.00	2.10	3.40	2.50	3.80	6.20	5.80	6.70	5.70	3.50	2.40	2.50	2.80	2.90	2.00	1.70	1.10	1.70	76.00

<i>Scirpophaga incertulas</i> Walker	2020	0.00	0.00	0.00	0.00	0.33	1.33	1.66	3.66	3.66	4.33	7.00	9.66	11.33	12.00	12.00	12.66	16.66	18.33	16.00	16.66	9.00	8.33	4.66	2.00	0.00	0.00	0.00	171.26	
	2021	0.00	0.00	0.00	0.00	0.00	0.66	4.00	3.33	2.66	3.33	5.33	5.66	8.00	9.33	9.66	10.00	15.33	15.66	18.00	13.33	13.00	9.66	5.00	3.00	0.00	0.00	0.00	154.94	
	Pooled	0.00	0.00	0.00	0.00	0.17	1.00	2.83	3.50	3.16	3.83	6.17	7.66	9.67	10.67	10.83	11.33	16.00	17.00	17.00	15.00	11.00	9.00	4.83	2.50	0.00	0.00	0.00	163.10	
<i>Chilo suppressalis</i> Dudgeon	2020	0.00	0.00	0.00	0.00	0.33	0.33	2.00	1.00	1.33	2.33	0.33	0.33	3.66	4.33	3.33	4.00	4.66	5.33	2.00	0.33	0.00	0.66	0.00	0.00	0.00	0.00	0.00	36.28	
	2021	0.00	0.00	0.00	0.00	0.00	1.00	1.33	0.66	1.66	2.00	1.66	2.00	2.66	2.66	2.00	3.33	3.33	2.00	2.66	1.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	30.61	
	Pooled	0.00	0.00	0.00	0.00	0.17	0.67	1.67	0.83	1.50	2.17	1.00	1.17	3.16	3.50	2.67	3.67	4.00	3.67	2.33	0.83	0.17	0.33	0.00	0.00	0.00	0.00	0.00	33.45	
<i>Scirpophaga</i> spp.	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	4.00	4.66	8.00	7.33	6.00	6.00	18.66	17.00	17.66	18.00	16.33	8.33	3.33	0.00	0.00	0.33	0.00	0.00	0.00	138.96	
	2021	0.00	0.00	0.00	0.00	0.00	0.33	0.33	1.00	1.33	2.66	7.66	8.33	5.00	5.66	5.33	11.00	11.99	16.33	12.00	12.33	6.00	6.33	4.00	2.33	2.33	0.00	0.00	122.27	
	Pooled	0.00	0.00	0.00	0.00	0.00	0.17	0.17	2.17	2.67	3.66	7.83	7.83	5.50	5.83	12.00	14.00	14.83	17.17	14.17	10.33	4.67	3.17	2.00	1.33	1.17	0.00	0.00	130.62	
<i>Scirpophaga nivella</i> Fabricus	2020	0.00	0.00	0.00	0.00	0.33	1.00	0.66	1.66	2.00	2.33	2.00	2.66	2.00	2.00	3.66	4.33	3.66	4.00	5.33	3.00	3.00	3.33	2.00	1.33	1.33	2.00	1.66	55.27	
	2021	0.00	0.00	0.00	0.00	0.00	0.66	1.00	1.33	1.66	1.33	1.66	1.00	2.33	0.66	5.00	3.66	3.33	2.66	2.33	2.66	3.00	2.66	1.00	1.66	2.33	1.66	2.00	45.58	
	Pooled	0.00	0.00	0.00	0.00	0.17	0.83	0.83	1.50	1.83	1.83	1.83	1.83	2.17	1.33	4.33	4.00	3.50	3.33	3.83	2.83	3.00	3.00	1.50	1.50	1.83	1.83	1.83	50.43	
<i>Cnaphalocrocis medinalis</i> Guenée	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.66	0.33	1.00	0.66	2.00	0.66	3.66	4.00	7.00	7.33	7.66	9.33	8.66	5.66	3.00	2.33	0.33	0.33	64.93	
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.33	0.66	2.00	1.66	3.00	2.33	4.66	3.33	5.66	8.00	8.66	6.33	6.00	2.33	0.66	0.00	0.00	55.94	
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.17	0.33	0.33	0.83	1.33	1.83	1.83	3.00	4.33	5.17	6.50	7.83	9.00	7.50	5.83	2.67	1.50	0.17	0.17	60.44	
<i>Melanitis leda ismene</i> Linnaeus	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.66	0.00	1.66	2.00	2.00	2.33	1.66	1.33	1.33	2.66	2.00	1.00	1.33	1.33	1.00	0.66	1.33	0.00	0.00	0.00	24.94	
	2021	0.00	0.00	0.00	0.00	0.00	0.33	1.00	1.33	1.00	1.00	1.66	2.00	2.00	2.33	2.00	2.00	1.66	2.00	2.33	2.00	1.66	1.66	1.66	1.33	1.33	0.00	0.00	32.28	
	Pooled	0.00	0.00	0.00	0.00	0.00	0.17	0.83	1.00	0.50	1.33	1.83	2.00	2.17	2.00	1.67	1.67	2.16	2.00	1.67	1.67	1.50	1.33	1.16	1.33	0.67	0.00	0.00	28.61	
Green Horned caterpillars	2020	0.00	0.00	0.00	0.00	0.00	1.00	1.20	1.60	0.80	0.60	0.80	2.00	2.00	2.20	0.60	1.00	0.40	0.40	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.80	
	2021	0.00	0.00	0.00	0.00	0.00	0.00	1.00	2.00	1.40	0.40	0.60	0.80	1.40	0.80	2.40	2.00	1.80	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.40	
	Pooled	0.00	0.00	0.00	0.00	0.00	0.50	1.10	1.80	1.10	0.50	0.70	1.40	1.70	1.50	1.50	1.50	1.10	0.60	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.10	
<i>Spodoptera litura</i> Fabricius	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	1.00	2.00	2.66	3.00	2.66	2.00	0.33	0.33	0.33	0.33	0.00	0.00	0.00	15.30	
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.33	0.66	1.66	2.66	2.33	2.33	2.00	1.66	1.00	0.33	0.33	0.00	0.00	16.29
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.67	0.67	1.33	2.16	2.83	2.50	2.17	1.17	1.00	0.67	0.33	0.17	0.00	0.00	15.80
<i>Leucania loreyi</i> Duponchel	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.33	1.66	2.00	5.33	5.66	9.00	6.66	7.33	6.33	6.33	8.00	4.33	0.66	2.00	0.33	0.00	0.00	66.28	
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	1.33	0.33	2.00	3.33	4.00	4.66	9.33	8.00	4.66	3.33	2.00	1.66	0.00	0.00	0.00	0.00	44.96	
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.33	1.50	1.17	3.67	4.50	6.50	5.66	8.33	7.17	5.50	5.67	3.17	1.16	1.00	0.17	0.00	0.00	55.62	

<i>Nymphula depunctalis</i> Guenée	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.33	6.66	6.33	6.33	4.33	2.33	2.00	2.33	1.33	0.66	0.33	0.33	0.33	0.66	0.33	0.33	0.33	0.00	37.27
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.33	4.66	3.66	6.00	7.33	6.00	4.00	2.00	2.66	2.00	0.66	0.66	0.66	1.00	0.66	0.00	0.00	0.00	0.00	44.28
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	3.50	5.16	6.17	6.83	5.17	3.17	2.00	2.50	1.67	0.66	0.50	0.50	0.67	0.66	0.17	0.17	0.17	0.00	40.78
<i>Pelopidas mathias</i> Fabricius	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.40	0.80	2.00	1.80	2.00	2.20	2.40	2.00	0.80	1.60	1.20	1.00	0.00	0.00	0.00	0.00	18.40
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.80	1.80	1.20	1.00	1.80	2.00	1.00	1.60	2.00	1.20	0.80	0.00	0.00	0.00	0.00	0.00	15.40
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.60	1.30	1.60	1.40	1.90	2.10	1.70	1.80	1.40	1.40	1.00	0.50	0.00	0.00	0.00	0.00	16.90
Short horned grasshoppers	2020	2.00	2.20	2.80	4.00	2.80	4.60	2.60	2.80	2.00	2.20	6.00	3.20	4.00	5.00	6.80	6.00	8.00	6.80	6.20	4.00	4.00	4.20	2.00	4.00	6.20	3.20	4.00	111.60
	2021	2.20	4.00	2.00	2.00	2.20	2.80	2.00	2.00	2.20	3.60	3.80	8.00	6.80	6.00	6.20	4.00	4.80	4.60	4.00	5.20	3.80	3.00	1.20	4.80	6.80	6.00	5.20	109.20
	Pooled	2.10	3.10	2.40	3.00	2.50	3.70	2.30	2.40	2.10	2.90	4.90	5.60	5.40	5.50	6.50	5.00	6.40	5.70	5.10	4.60	3.90	3.60	1.60	4.40	6.50	4.60	4.60	110.40
Field crickets	2020	1.00	2.33	6.00	6.33	8.66	7.33	4.66	8.00	9.33	6.33	7.66	9.33	7.00	6.00	9.33	8.66	9.66	12.00	16.66	14.00	18.33	18.00	15.33	7.00	10.00	5.00	3.00	236.93
	2021	0.00	2.00	2.33	2.33	4.66	4.00	7.66	6.66	7.33	7.00	6.00	6.33	6.00	6.00	7.33	7.00	7.33	9.00	9.66	12.33	10.66	16.33	16.66	11.00	8.00	6.66	2.00	192.26
	Pooled	0.50	2.17	4.17	4.33	6.66	5.67	6.16	7.33	8.33	6.67	6.83	7.83	6.50	6.00	8.33	7.83	8.50	10.50	13.16	13.17	14.50	17.17	16.00	9.00	9.00	5.83	2.50	214.60
<i>Gryllotalpa orientalis</i> Burmeister	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	1.00	0.66	2.66	2.66	2.33	1.00	2.00	1.66	0.66	4.00	3.00	3.66	2.00	1.66	1.66	1.00	0.00	0.00	0.00	31.94
	2021	0.00	0.00	0.00	0.00	0.00	0.33	0.66	0.66	1.33	2.00	2.00	2.66	0.66	0.33	0.33	1.66	1.33	0.33	2.00	2.33	2.00	1.66	1.33	1.66	1.00	0.00	0.00	26.26
	Pooled	0.00	0.00	0.00	0.00	0.00	0.17	0.33	0.50	1.17	1.33	2.33	2.66	1.50	0.67	1.17	1.66	1.00	2.17	2.50	3.00	2.00	1.66	1.50	1.33	0.50	0.00	0.00	29.10
<i>Sitophilus oryzae</i> Linnaeus	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	1.00	2.40	4.00	6.40	6.80	8.00	6.00	8.60	43.40
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	2.20	3.00	8.40	8.00	8.20	8.40	7.60	46.00
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.60	2.30	3.50	7.40	7.40	8.10	7.20	8.10	44.70
<i>Dicladispa armigera</i> Olivier	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	2.00	2.40	6.00	4.00	4.20	6.80	7.00	8.20	4.80	4.20	3.00	2.20	2.00	3.00	1.00	1.40	1.40	0.20	0.20	64.20
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	2.00	2.60	2.60	6.00	8.60	8.20	12.00	10.80	6.80	6.40	4.00	2.20	2.80	2.00	1.00	1.00	1.20	0.00	80.80
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	1.30	2.20	4.30	3.30	5.10	7.70	7.60	10.10	7.80	5.50	4.70	3.10	2.10	2.90	1.50	1.20	1.20	0.70	0.10	72.50
<i>Stenchaetothrips biformis</i> Bagnall	2020	0.00	0.00	0.00	3.25	4.50	4.00	6.25	8.00	10.50	10.75	12.00	14.25	10.75	8.75	8.00	4.25	6.25	4.50	6.50	6.25	6.00	4.75	2.00	2.00	1.75	2.00	0.25	147.50
	2021	0.00	0.00	0.00	0.25	0.75	2.00	4.75	6.25	6.75	6.75	10.00	10.25	10.75	8.25	8.50	6.00	6.50	6.25	6.00	4.00	4.50	2.00	2.50	2.50	2.25	2.50	0.50	120.75
	Pooled	0.00	0.00	0.00	1.75	2.63	3.00	5.50	7.13	8.63	8.75	11.00	12.25	10.75	8.50	8.25	5.13	6.38	5.38	6.25	5.13	5.25	3.38	2.25	2.25	2.00	2.25	0.38	134.13

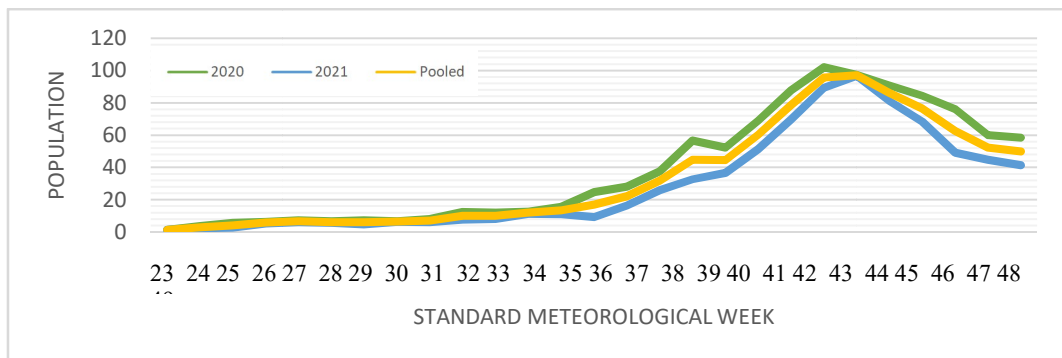


Fig.4.3a: Seasonal abundance of *Nephotettix virescens* Distant from June to December, 2020 & 2021 at Kuhoxu

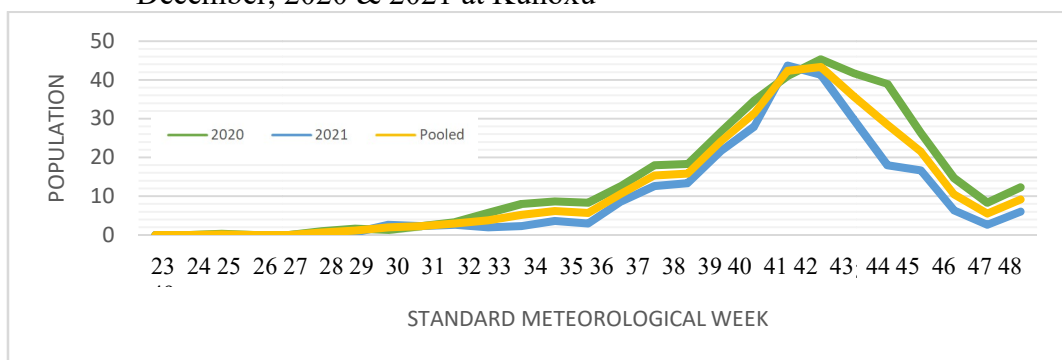


Fig.4.3b: Seasonal abundance of *Nephotettix nigropictus* Stål from June to December, 2020 & 2021 at Kuhoxu

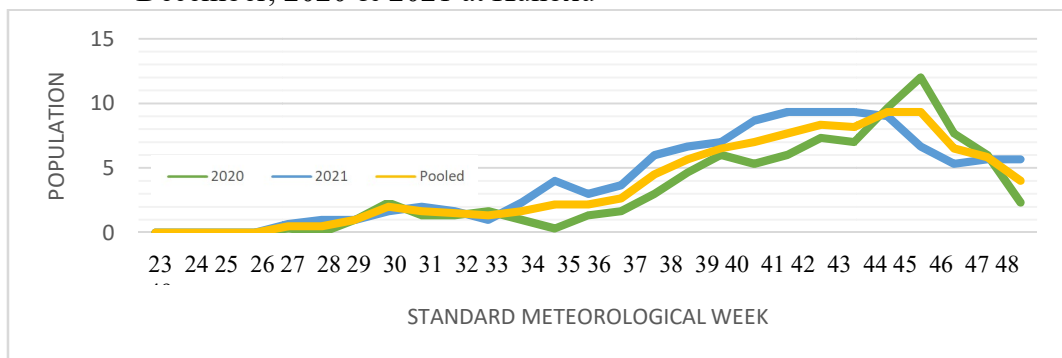


Fig.4.3c: Seasonal abundance of *Cofana spectra* Distant from June to December, 2020 & 2021 at Kuhoxu

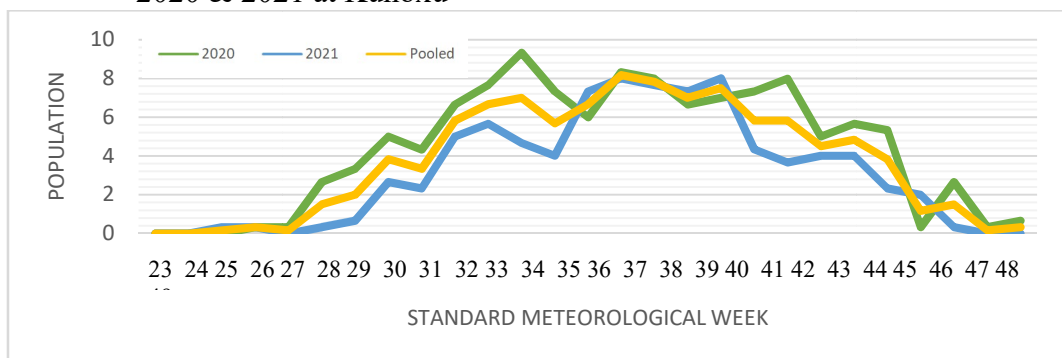


Fig.4.3d: Seasonal abundance of *Maiestas dorsalis* Motchulsky from June to December, 2020 & 2021 at Kuhoxu

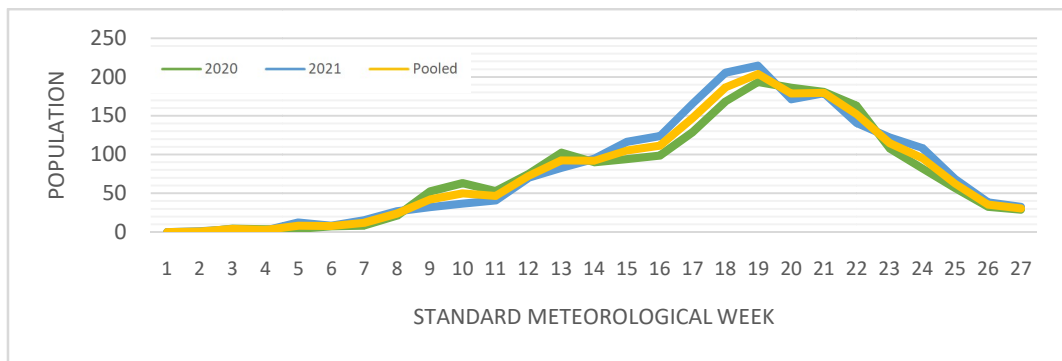


Fig.4.3e: Seasonal abundance of *Nilaparvata lugens* Stål from June to December, 2020 & 2021 at Kuhoxu

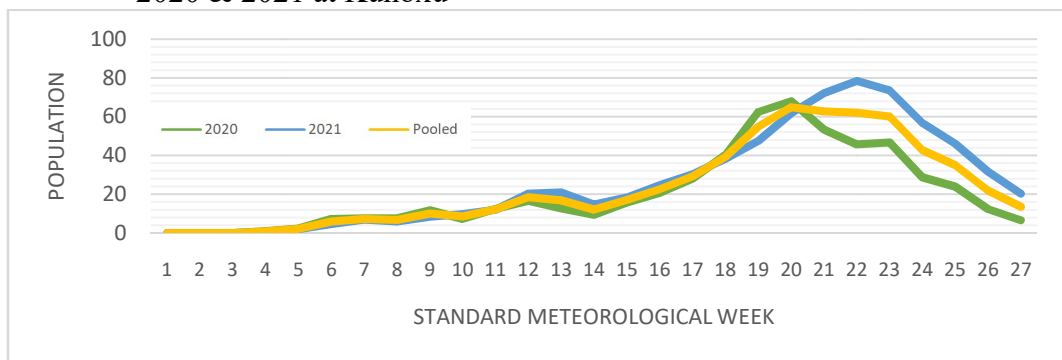


Fig.4.3f: Seasonal abundance of *Sogatella furcifera* Horvith from June to December, 2020 & 2021 at Kuhoxu

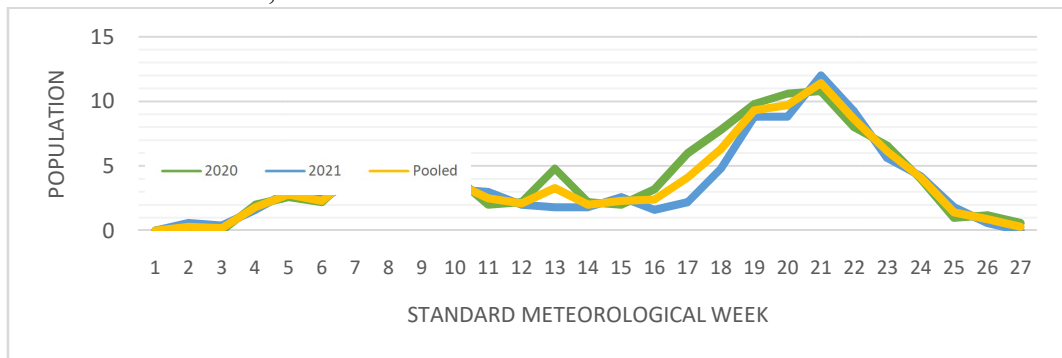


Fig.4.3g: Seasonal abundance of *Leptocoris acuta* Thunberg from June to December, 2020 & 2021 at Kuhoxu

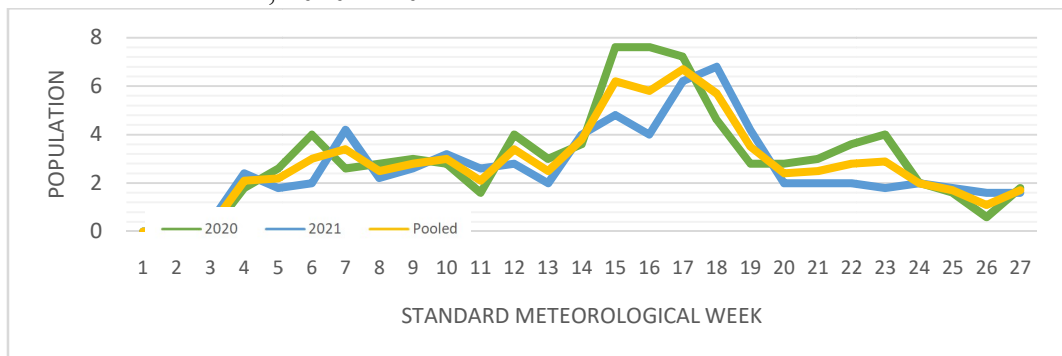


Fig.4.3h: Seasonal abundance of *Cletus punctiger* Dallas from June to December, 2020 & 2021 at Kuhoxu

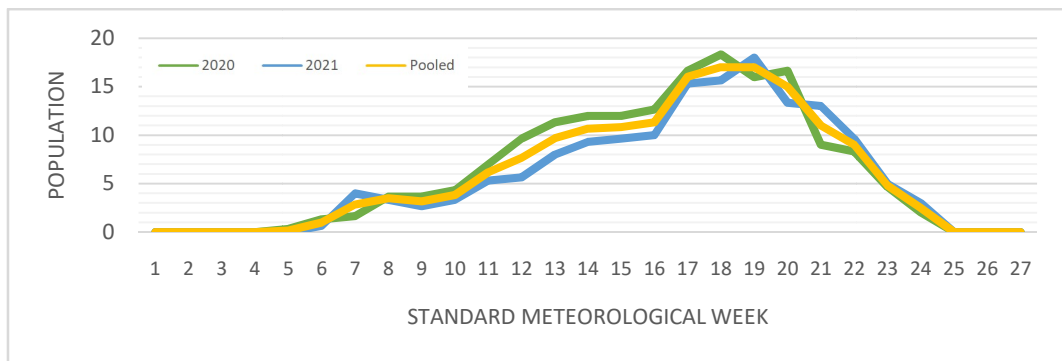


Fig.4.3i: Seasonal abundance of *Scirpophaga incertulas* Walker from June to December, 2020 & 2021 at Kuhoxu

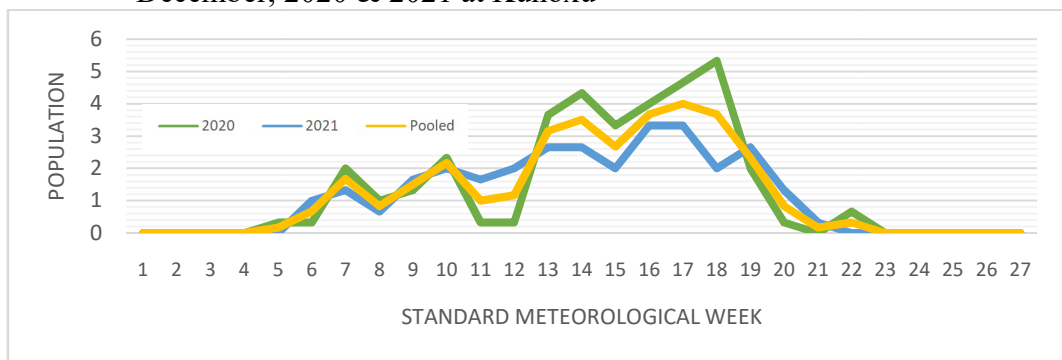


Fig.4.3j: Seasonal abundance of *Chilo suppressalis* Dudgeon from June to December, 2020 & 2021 at Kuhoxu

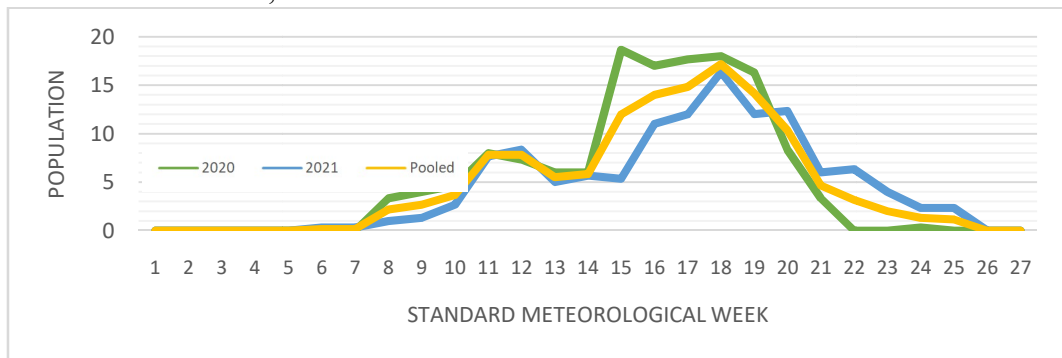


Fig.4.3k: Seasonal abundance of *Scirpophaga* spp. from June to December, 2020 & 2021 at Kuhoxu

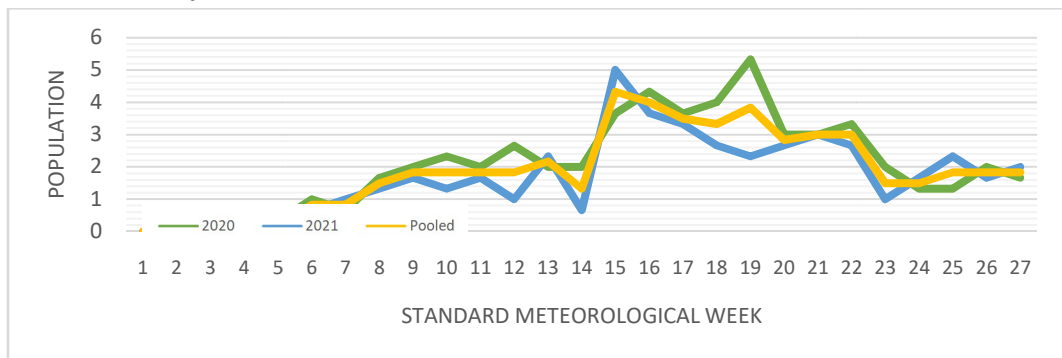


Fig.4.3l: Seasonal abundance of *Scirpophaga nivella* from June to December, 2020 & 2021 at Kuhoxu

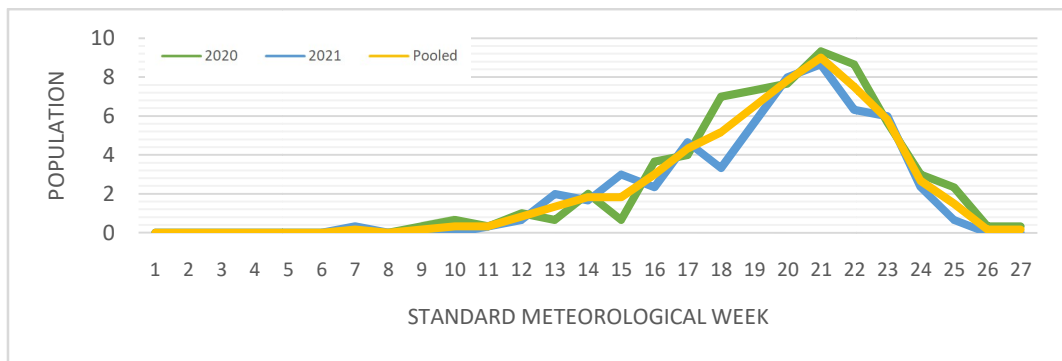


Fig.4.3m: Seasonal abundance of *Cnaphalocrocis medinalis* Guenée from June to December, 2020 & 2021 at Kuhoxu

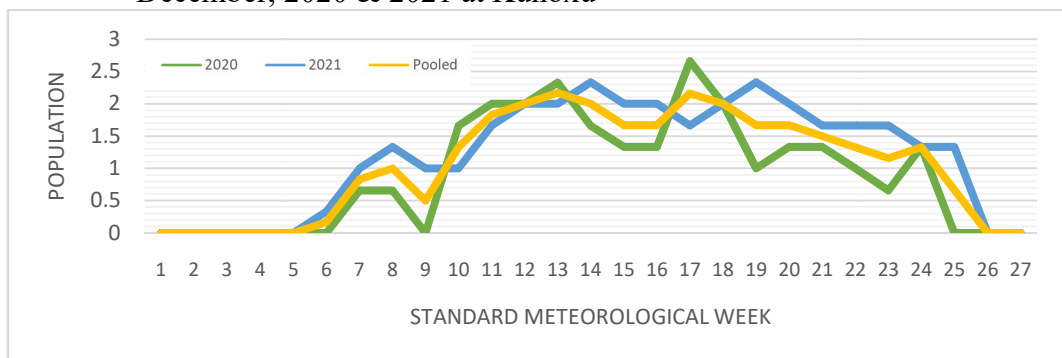


Fig.4.3n: Seasonal abundance of *Melanitis leda ismene* Linnaeus from June to December, 2020 & 2021 at Kuhoxu

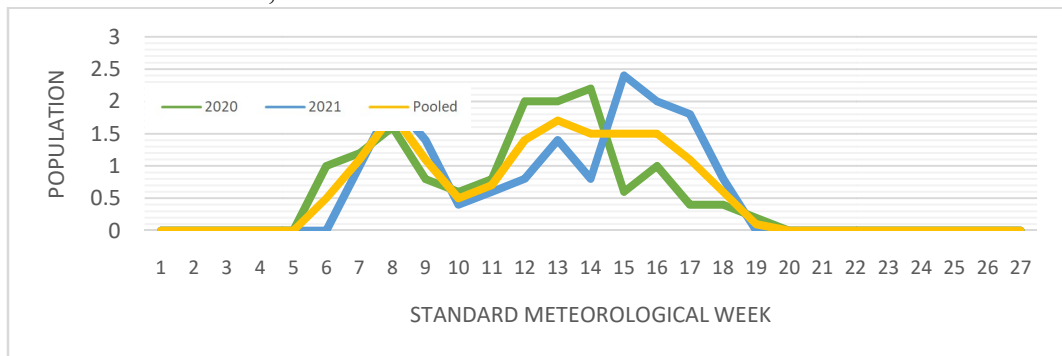


Fig.4.3o: Seasonal abundance of green horned caterpillars from June to December, 2020 & 2021 at Kuhoxu

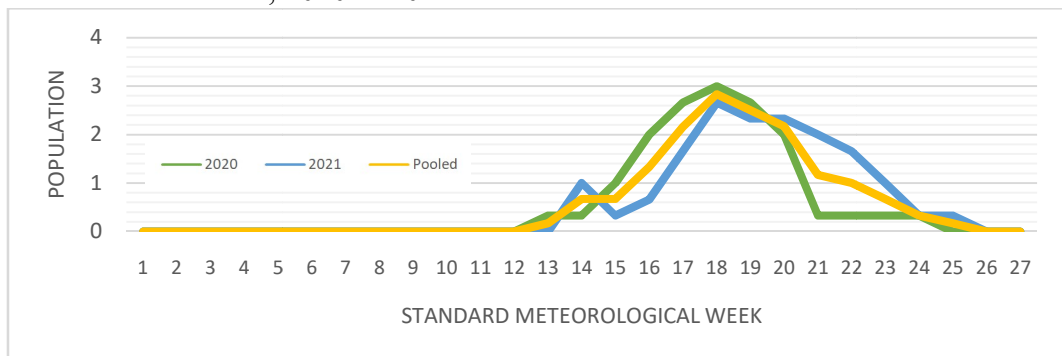


Fig.4.3p: Seasonal abundance of *Spodoptera litura* Fabricius from June to December, 2020 & 2021 at Kuhoxu

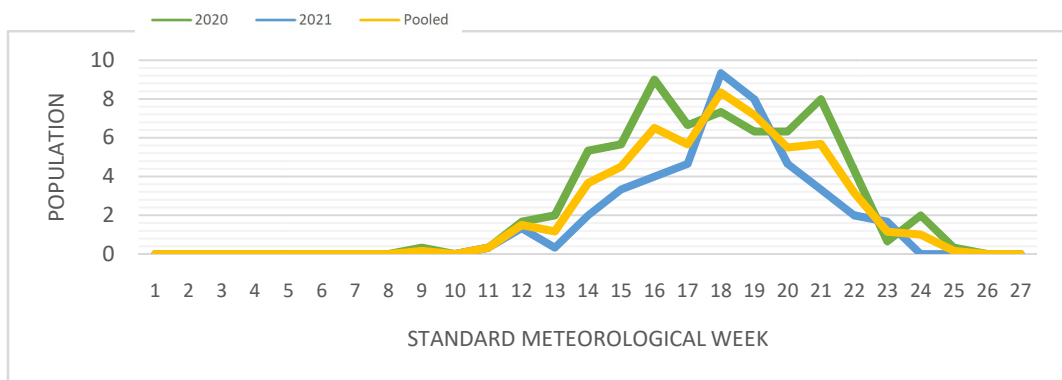


Fig.4.3q: Seasonal abundance of *Leucania loreyi* Duponchel from June to December, 2020 & 2021 at Kuhoxu

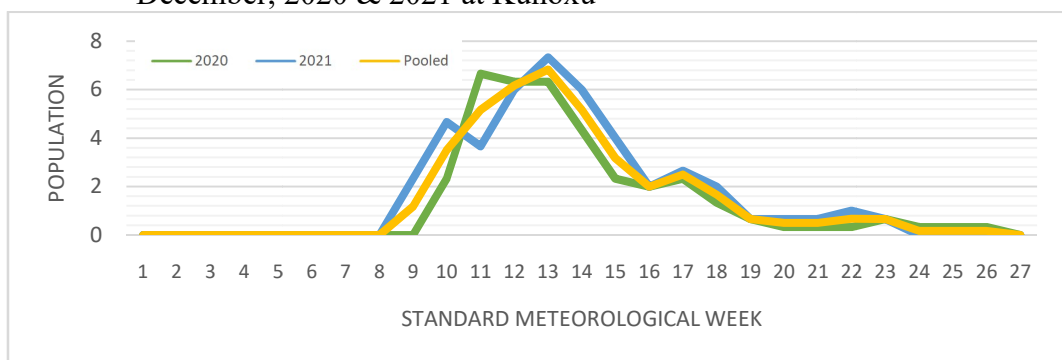


Fig.4.3r: Seasonal abundance of *Nymphula depunctalis* Guenée from June to December, 2020 & 2021 at Kuhoxu

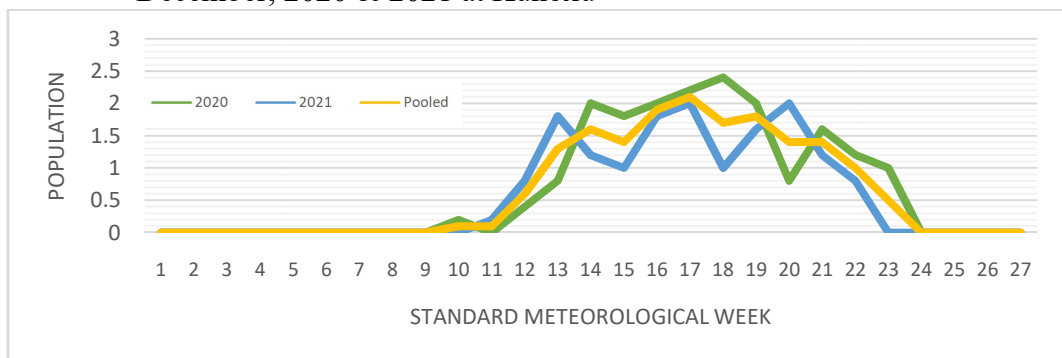


Fig.4.3s: Seasonal abundance of *Pelopidas mathias* Fabricius from June to December, 2020 & 2021 at Kuhoxu

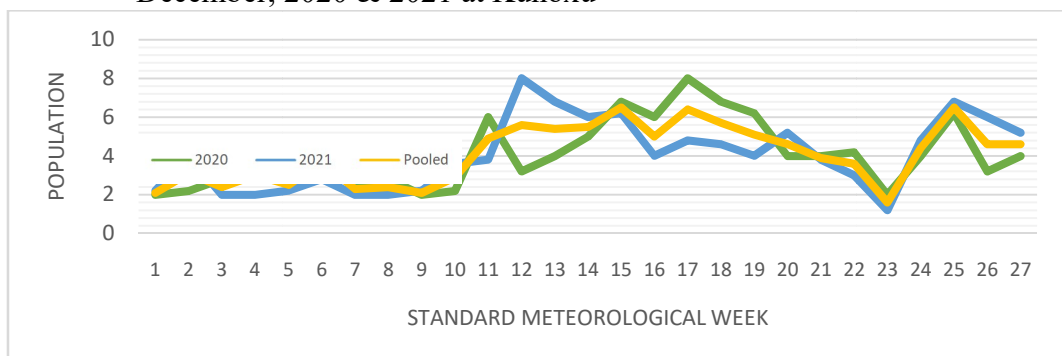


Fig.4.3t: Seasonal abundance of short horned grasshoppers from June to December, 2020 & 2021 at Kuhoxu

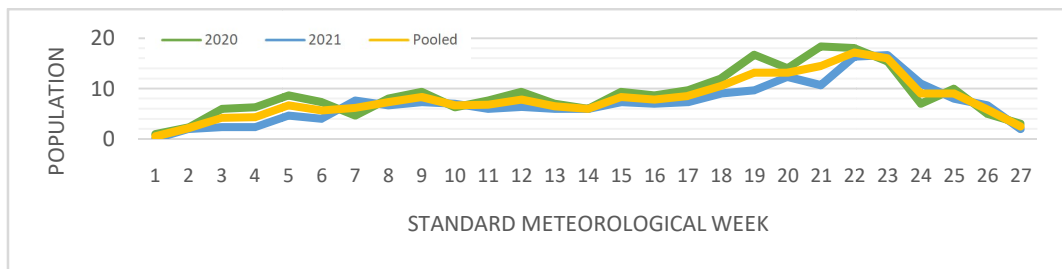


Fig.4.3u: Seasonal abundance of field crickets from June to December, 2020 & 2021 at Kuhoxu

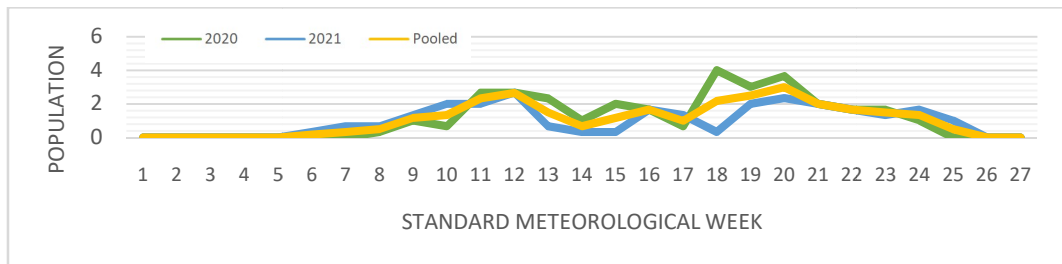


Fig.4.3v: Seasonal abundance of *Gryllotalpa orientalis* Burmeister from June to December, 2020 & 2021 at Kuhoxu

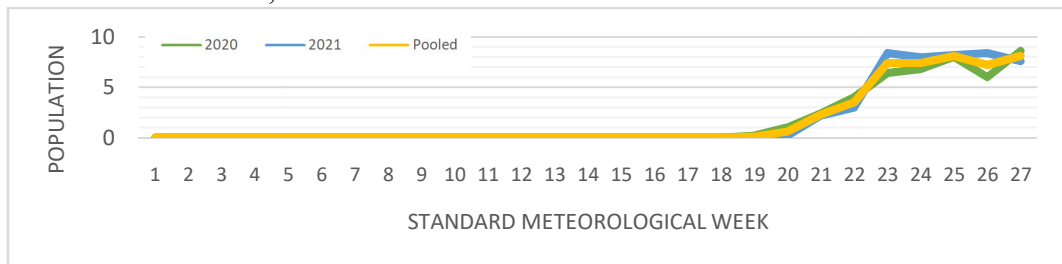


Fig.4.3w: Seasonal abundance of *Sitophilus oryzae* Linnaeus from June to December, 2020 & 2021 at Kuhoxu

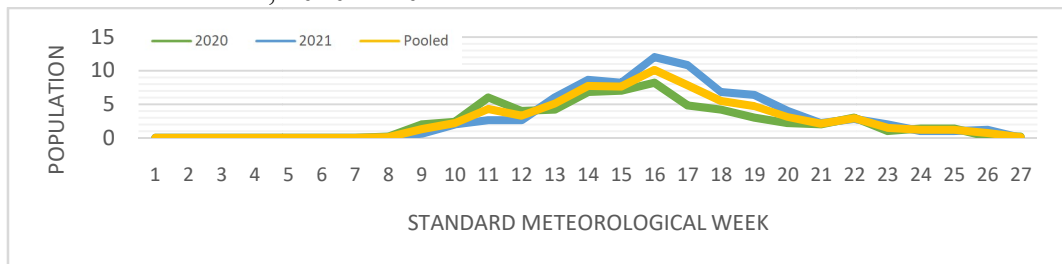


Fig.4.3x: Seasonal abundance of *Dieladisa armigera* Olivier from June to December, 2020 & 2021 at Kuhoxu

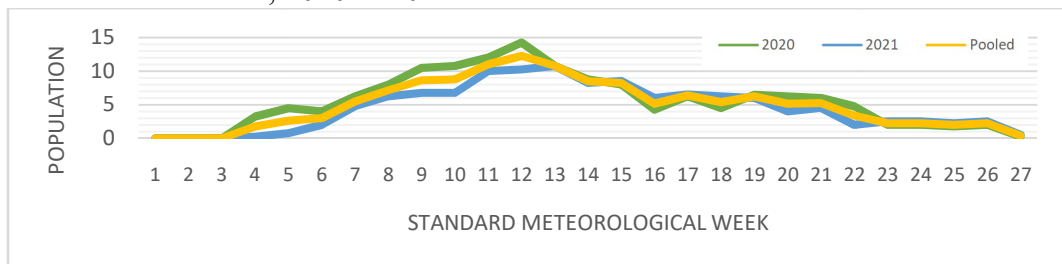


Fig.4.3y: Seasonal abundance of *Stenchaetothrips biformis* Bagnall from June to December, 2020 & 2021 at Kuhoxu

S. incertulas populations increased from week 30, with peak densities between weeks 39 and 42 (Fig. 4.3i). The total population recorded was 171.26 in 2020 and 154.94 in 2021, leading to a pooled total of 163.10.

C. suppressalis had relatively low population densities, peaking between weeks 35 and 40 (Fig. 4.3j). The total recorded population was 36.28 in 2020 and 30.61 in 2021, with a pooled total of 33.45.

A steady rise in population was observed for *Scirpophaga* spp. from week 28, with peak infestations occurring between weeks 37 and 42 (Fig. 4.3k). The total recorded population was 138.96 in 2020 and 122.27 in 2021, bringing the pooled total to 130.62.

A gradual rise in population was observed for *S. nivella* from week 30, reaching its highest densities between weeks 37 and 41 (Fig. 4.3l). The total recorded population in 2020 was 55.27, while in 2021, it was 45.58, leading to a pooled total of 50.43.

From week 31 onwards, *C. medinalis* exhibited a gradual increase in population, with peak densities between weeks 40 and 45 (Fig. 4.3m). The total recorded numbers were 64.93 in 2020 and 55.94 in 2021, leading to a pooled total of 60.44.

The population of *M. leda ismene* remained consistently low throughout the season, with a minor peak occurring between weeks 34 and 40 (Fig. 4.3n). The total recorded numbers were 24.94 in 2020 and 32.28 in 2021, leading to a pooled total of 28.61.

Green horned caterpillars were among the least abundant species recorded. Peak densities were observed between weeks 34 and 39 (Fig. 4.3o), but overall infestation levels remained minimal. The total population recorded was 14.80 in 2020 and 15.40 in 2021, with a pooled total of 15.10.

S. litura remained at a significantly low level throughout the study period, peaking between weeks 39 and 42 (Fig. 4.3p). The total recorded population was 15.30 in 2020 and 16.29 in 2021, leading to a pooled total of 15.80.

L. loreyi remained low in the early weeks but increased from week 34 onwards. The highest densities were recorded between weeks 38 and 43 (Fig. 4.3q). In 2020, the total population recorded was 66.28, while in 2021, it was 44.96, leading to a pooled total of 55.62.

Rarely observed in early weeks, *N. depunctalis* showed a gradual increase from week 31, peaking between weeks 33 and 37 (Fig. 4.3r). The total recorded population was 37.27 in 2020 and 44.28 in 2021, resulting in a pooled total of 40.78.

P. mathias had low population densities throughout the study, with peak occurrences between weeks 38 and 41 (Fig. 4.3s). The total recorded population was 18.40 in 2020 and 15.40 in 2021, leading to a pooled total of 16.90.

Short horned grasshoppers exhibited seasonal fluctuations, with peak infestations occurring between weeks 34 and 41 (Fig. 4.3t). The recorded population was 111.60 in 2020 and 109.20 in 2021, leading to a pooled total of 110.40.

Field crickets remained relatively stable throughout the season, with peak occurrences between weeks 40 and 45 (Fig. 4.3u). In 2020, the total recorded population was 236.93, while in 2021, it was 192.26, leading to a pooled total of 214.60.

G. orientalis exhibited a steady population increase from week 30 onwards, peaking between weeks 40 and 44 (Fig. 4.3v). The total population recorded was 31.94 in 2020 and 26.26 in 2021, leading to a pooled total of 29.10.

Recorded primarily in the later part of the season, *S. oryzae* showed peak abundance between weeks 45 and 49 (Fig. 4.3w). The total population recorded was 43.40 in 2020 and 46.00 in 2021, leading to a pooled total of 44.70.

D. armigera exhibited a moderate population, peaking between weeks 36 and 39 (Fig. 4.3x). The total recorded numbers were 64.20 in 2020 and 80.80 in 2021, with a pooled total of 72.50.

S. biformis had a steady rise in population from week 26, peaking between weeks 31 and 37 (Fig. 4.3y). The total recorded numbers were 147.50 in 2020 and 120.75 in 2021, with a pooled total of 134.13.

Several studies have documented the seasonal occurrence or seasonal abundance of insect pests in rice ecosystems. Zhimomi and Ao (2011) reported that insect pest activity was highest between May and November, with peak populations occurring during the tillering stage of the rice crop. These observations align with the present findings, which also indicate increased pest activity during similar periods.

Vennila *et al.* (2021) noted that the brown planthopper (*Nilaparvata lugens*) exhibited a population surge during the 38th SMW. Similarly, Saikia *et al.* (2022) observed fluctuations in the gundhi bug population, with the highest incidence recorded in the 46th SMW. These findings correspond with the present study, which recorded peak infestations of these pests during comparable crop stages.

Hemanth *et al.* (2024) found that yellow stem borer populations peaked in the 38th SMW, while white ears incidence was highest in the 44th SMW. Additionally, brown planthopper populations peaked in the 39th SMW and white-backed planthopper numbers reached their maximum in the 38th SMW. These results are consistent with the present findings. Similarly, Bisen *et al.* (2019) reported that yellow stem borer activity increased from mid to late September, while leaf folder populations began rising in mid-September. Their study also recorded an increase in green leafhopper populations from mid-August to early October, supporting the trends observed in the present study.

Varsha *et al.* (2022) recorded a similar pattern for rice leaf folder infestations, with the highest leaf damage occurring in September. Their study also noted that yellow stem borer first appeared in August, with peak infestations occurring in September.

Borath *et al.* (2011) documented variations in rice borer populations across different years, with peak infestations occurring in August, September, and October, coinciding with active tillering and reproductive stages. These findings are in agreement with the present study, which also demonstrates similar seasonal fluctuations in rice borer populations. Dumra and Srivastav (2019) reported that caseworm first appeared in July, reaching its highest population in the 32nd SMW before declining in September, a trend consistent with the present findings.

Parasappa *et al.* (2017) identified yellow stem borer, plant hoppers, gall midge, and leaf folder as the most severe insect pests in rice ecosystems, with peak infestations occurring during critical crop growth stages. These observations align with the present study, which also recorded peak infestations of these pests during key crop periods. Similarly, Patil *et al.* (2020) found that brown planthopper populations increased steadily from early September, reaching their highest levels in mid-October, a pattern that mirrors the present findings.

Singh *et al.* (2020) reported that pest activity in rice fields began in the 34th SMW and continued until the 49th SMW. Their study observed that yellow stem borer populations peaked in the 39th SMW, while leaf folder and green leafhopper infestations reached their highest levels in the 44th SMW. These results align with the present study, confirming similar seasonal trends in pest abundance.

Deshwal *et al.* (2019) noted that *Scirpophaga incertulas* populations persisted throughout the rice-growing season, with peak densities recorded from early August to late September. Additionally, *Cnaphalocrocis medinalis*, plant hoppers, and leaf hoppers was most abundant between August and September, while grasshoppers remained active throughout the season. These findings support the present study, which recorded similar pest activity patterns.

Sabir *et al.* (2006) observed that leaf folder and stem borer populations peaked in September, while white-backed planthopper (*Sogatella furcifera*) and green leafhopper (*Nephotettix cincticeps*) reached their highest densities in October. These trends are comparable to those recorded in the present findings.

Kalita *et al.* (2020) reported peak infestations of rice leaf folder in the 38th SMW, rice hispa between the 33rd and 34th SMW, and gundhi bug between the 43rd and 46th SMW. Similarly, Kumar *et al.* (2020) documented that major rice insect pests active from the 31st to the 49th SMW, with peak infestations occurring in mid to late crop growth stages. These findings align with the present study, further validating observed trends in insect pest occurrences.

Meena *et al.* (2018) recorded armyworm activity beginning in mid-August, with peak infestations in the 40th and 44th SMW. Their study also noted that rice leaf folder and rice butterfly followed a similar trend, reaching peak populations between the 38th and 45th SMW. These observations are consistent with the present findings. Sreelatha *et al.* (2022) documented that yellow stem borer activity began in July and peaked in late September, while leaf folder and gundhi bug infestations reached their highest levels in August and September. Their findings support the present study, which recorded similar seasonal trends for these pests.

Lisha *et al.* (2020b) found that pest activity commenced from the 35th SMW and continued until the 41st SMW of 2018. The highest white ears caused by *Scirpophaga incertulas* was observed in the 41st SMW, while the maximum population of *Cnaphalocrocis medinalis* was recorded in the 37th SMW. Similarly, the peak population of *Nephotettix* spp. was estimated in the 37th SMW, and the highest number of *Leptocorisa acuta* was recorded in the 41st SMW. These findings align with the present study's observations. Seni and Naik (2018) reported that yellow stem borer infestation began in the 34th SMW and peaked in the 41st SMW, while *C. medinalis* activity peaked in the 39th SMW. Planthopper populations increased from the 36th SMW, peaking in the 44th SMW. These observations align with the present study.

Sawai and Kothikar (2019) found that dead heart incidence peaked in the 44th SMW, while leaf folder infestation was highest in the 40th SMW. The population trends of planthoppers and leafhoppers between the 39th and 44th SMW were consistent with the present findings.

Nishanthini and Kandibane (2021) observed seasonal pest activity using light traps. Yellow stem borer peaked in the 43rd MSW, green leafhopper in the 4th MSW, and brown planthopper in the 1st MSW. Their study supports the seasonal variations noted in this investigation.

Sulagitti *et al.* (2017) documented that yellow stem borer and brown planthopper peaked in early October, while leaf folder infestations increased until the 38th SMW. Their findings match the seasonal patterns observed in this study.

4.2.2. SEASONAL ABUNDANCE OF NATURAL ENEMIES IN LOWLAND RICE AGROECOSYSTEM

4.2.2.1. SEASONAL ABUNDANCE OF NATURAL ENEMIES AT MEDZIPHEMA

The study meticulously recorded various natural enemies in the lowland rice agroecosystem at Medziphema, with significant variations in their seasonal abundance. The major natural enemy groups identified included Hymenoptera (81.40) recorded as the most dominant group followed by Coleoptera (78.08), Arachnida (63.40), Odonata-Zygoptera (36.70), Orthoptera (32.00), Odonata-Anisoptera (28.50), Hemiptera (15.94), and the least dominant groups were Diptera (2.48), Neuroptera (3.63), Mantodea (5.20) and Dermaptera (6.20) as evident from table 4.2d.

Anisoptera populations showed a steady increase from week 26, reaching their peak between weeks 35 and 41 (Fig.4.4a). The total recorded population was 24.80 in 2020 and 32.20 in 2021, resulting in a pooled total of 28.50.

Zygoptera exhibited a more sustained population trend, with a gradual increase from week 23 and a peak occurring between weeks 34 and 43 (Fig.4.4b). The total recorded numbers were 36.00 in 2020 and 37.40 in 2021, leading to a pooled total of 36.70.

The population of Coleoptera fluctuated throughout the season, rising from week 24 and reaching peak abundance between weeks 33 and 38 (Fig.4.4c). The total

recorded numbers were 78.92 in 2020 and 77.23 in 2021, resulting in a pooled total of 78.08.

Hymenoptera exhibited strong population growth from week 28 onwards, peaking between weeks 34 and 38 (Fig.4.4d). The total population recorded in 2020 was 89.60, while in 2021, it was 73.20, leading to a pooled total of 81.40.

Neuroptera had relatively low occurrences, with slight peaks around weeks 37 and 41 (Fig.4.4e). The total recorded population was 2.97 in 2020 and 4.29 in 2021, resulting to a pooled total of 3.63.

The population of Hemiptera showed a gradual increase from week 25, peaking between weeks 30 and 35 (Fig.4.4f). The total recorded numbers were 15.27 in 2020 and 16.61 in 2021, leading to a pooled total of 15.94.

Diptera remained at very low levels throughout the study, with a minor peak between weeks 36 and 39 (Fig.4.4g). The total population was 1.32 in 2020 and 3.63 in 2021, leading to a pooled total of 2.48.

Dermaptera populations increased gradually, reaching peak abundance between weeks 29 and 35 (Fig.4.4h). The total recorded numbers were 7.00 in 2020 and 5.20 in 2021, leading to a pooled total of 6.20.

The population of Mantodea remained relatively stable, peaking between weeks 28 and 32 (Fig.4.4i). The total recorded numbers were 5.60 in 2020 and 4.80 in 2021, resulting in a pooled total of 5.20.

A gradual increase in Orthoptera populations was observed, with peak densities occurring between weeks 30 and 35 (Fig.4.4j). The total recorded numbers were 28.20 in 2020 and 35.80 in 2021, leading to a pooled total of 32.00.

Arachnida populations followed a consistent trend, peaking between weeks 36 and 41 (Fig.4.4k). The total recorded numbers were 54.00 in 2020 and 72.80 in 2021, resulting in a pooled total of 63.40.

Table 4.2d: Seasonal abundance of natural enemies in lowland rice agro ecosystem at Medziphema

Natural enemies	SMW	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	Total
Odonata-Anisoptera	2020	0.00	0.00	0.00	0.20	0.40	0.20	0.20	0.40	0.20	0.20	1.20	1.20	2.00	2.80	3.00	2.00	3.20	2.80	2.20	1.00	0.20	0.20	0.40	0.20	0.20	0.20	0.20	24.80
	2021	0.00	0.00	0.00	0.00	0.40	0.40	0.20	0.40	0.60	0.40	1.80	2.20	2.40	1.60	2.80	2.80	2.80	2.60	2.60	2.00	2.20	1.00	1.00	1.20	0.40	0.20	0.20	32.20
	Pooled	0.00	0.00	0.00	0.10	0.40	0.30	0.20	0.40	0.40	0.30	1.50	1.70	2.20	2.20	2.90	2.40	3.00	2.70	2.40	1.50	1.20	0.60	0.70	0.70	0.30	0.20	0.20	28.50
Odonata-Zygoptera	2020	0.20	0.20	0.40	0.60	2.00	1.80	0.80	0.60	0.60	0.40	1.60	2.80	2.00	2.20	1.80	2.00	2.20	2.80	2.20	3.00	2.80	1.20	0.20	0.80	0.40	0.20	0.20	36.00
	2021	0.20	0.40	0.40	0.40	0.40	0.60	2.00	2.20	2.00	1.80	2.00	2.20	2.60	2.60	2.60	2.00	1.80	2.00	1.60	1.80	1.60	1.00	1.00	1.20	0.20	0.40	0.40	37.40
	Pooled	0.20	0.30	0.40	0.50	1.20	1.20	1.40	1.40	1.30	1.10	1.80	2.50	2.30	2.40	2.20	2.00	2.00	2.40	1.90	2.40	2.20	1.10	0.60	1.00	0.30	0.30	0.30	36.70
Coleoptera	2020	0.00	1.00	1.33	1.66	1.00	2.33	3.00	3.66	3.00	3.66	4.33	4.00	5.33	4.66	5.33	5.00	3.33	4.33	2.66	3.00	2.66	2.33	2.00	2.66	2.66	2.00	2.00	78.92
	2021	0.00	0.00	0.33	1.66	2.00	2.66	4.00	4.33	4.33	4.00	3.66	4.66	4.66	6.00	4.66	3.66	2.33	2.66	4.33	2.33	3.00	3.66	1.66	1.66	1.00	2.33	1.66	77.23
	Pooled	0.00	0.50	0.83	1.66	1.50	2.50	3.50	4.00	3.67	3.83	4.00	4.33	5.00	5.33	5.00	4.33	2.83	3.50	3.50	2.67	2.83	3.00	1.83	2.16	1.83	2.17	1.83	78.08
Hymenoptera	2020	0.00	0.20	0.20	0.40	0.20	1.60	1.80	4.60	3.60	3.80	4.20	5.20	3.60	6.00	4.80	6.20	4.80	4.60	4.60	3.80	4.80	4.20	4.20	3.00	4.00	2.00	3.20	89.60
	2021	0.20	0.20	0.40	0.40	0.40	0.60	0.80	2.60	4.20	4.80	4.80	4.80	4.20	5.60	4.80	4.60	3.80	3.20	2.80	2.80	2.60	2.00	3.20	2.60	2.00	2.80	2.00	73.20
	Pooled	0.10	0.20	0.30	0.40	0.30	1.10	1.30	3.60	3.90	4.30	4.50	5.00	3.90	5.80	4.80	5.40	4.30	3.90	3.70	3.30	3.70	3.10	3.70	2.80	3.00	2.40	2.60	81.40
Neuroptera	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.00	0.00	0.00	0.33	0.33	0.66	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.97
	2021	0.00	0.00	0.00	0.33	0.33	0.00	0.33	0.00	0.00	0.66	0.33	0.33	0.00	0.00	0.33	0.00	0.00	0.66	0.33	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	4.29
	Pooled	0.00	0.00	0.00	0.17	0.17	0.00	0.17	0.00	0.17	0.50	0.33	0.17	0.00	0.00	0.33	0.17	0.33	0.50	0.33	0.17	0.17	0.00	0.00	0.00	0.00	0.00	0.00	3.63
Hemiptera	2020	0.00	0.00	0.00	0.33	0.33	0.66	0.66	1.00	1.00	1.66	2.00	2.33	2.00	0.66	0.66	0.33	0.66	0.00	0.00	0.33	0.33	0.00	0.00	0.33	0.00	0.00	0.00	15.27
	2021	0.00	0.00	0.33	0.00	0.66	1.00	1.33	1.66	2.00	2.33	1.66	2.00	0.66	0.33	0.33	0.33	0.00	0.00	0.33	1.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	16.61
	Pooled	0.00	0.00	0.17	0.17	0.50	0.83	1.00	1.33	1.50	2.00	1.83	2.17	1.33	0.50	0.50	0.33	0.33	0.00	0.17	0.67	0.50	0.00	0.00	0.17	0.00	0.00	0.00	15.94
Diptera	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.33	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.66	0.33	0.66	0.33	0.00	0.00	0.66	0.33	0.00	0.00	0.00	0.00	0.00	0.00	3.63
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.33	0.33	0.50	0.33	0.00	0.17	0.33	0.17	0.00	0.00	0.00	0.00	0.00	0.00	2.48
Dermaptera	2020	0.00	0.00	0.00	0.00	0.40	0.40	0.60	0.40	0.80	0.80	1.00	0.40	0.60	0.20	0.20	0.20	0.40	0.20	0.40	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00
	2021	0.00	0.00	0.00	0.00	0.00	0.20	0.40	0.40	0.40	0.40	0.20	0.40	0.80	0.00	0.00	0.20	0.40	0.40	0.20	0.20	0.20	0.40	0.00	0.00	0.00	0.00	0.00	5.20
	Pooled	0.00	0.00	0.00	0.00	0.20	0.30	0.50	0.40	0.60	0.60	0.60	0.40	0.70	0.10	0.10	0.20	0.40	0.30	0.30	0.20	0.10	0.20	0.00	0.00	0.00	0.00	0.00	6.20
Mantodea	2020	0.00	0.00	0.00	0.40	0.20	0.40	0.40	0.60	0.40	0.40	0.20	0.60	0.80	0.20	0.00	0.20	0.20	0.00	0.20	0.00	0.20	0.00	0.00	0.00	0.00	0.20	0.00	5.60
	2021	0.00	0.20	0.00	0.00	0.00	0.20	0.40	0.20	0.60	0.40	0.20	0.20	0.40	0.40	0.60	0.00	0.20	0.40	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.80
	Pooled	0.00	0.10	0.00	0.20	0.10	0.30	0.40	0.40	0.50	0.40	0.20	0.40	0.60	0.30	0.30	0.10	0.20	0.20	0.20	0.10	0.10	0.00	0.00	0.00	0.00	0.10	0.00	5.20
Orthoptera	2020	0.00	0.20	0.20	0.40	0.80	1.40	1.00	1.80	2.00	1.40	1.40	1.20	1.60	1.80	1.20	2.00	2.00	1.80	1.60	0.80	1.20	0.20	0.40	1.00	0.60	0.20	0.00	28.20
	2021	0.00	0.00	0.80	0.20	0.60	0.80	2.00	2.20	1.80	1.80	2.00	2.20	2.60	1.20	1.00	1.80	1.60	1.00	1.80	2.00	1.00	1.00	0.60	1.80	1.00	2.00	1.00	35.80
	Pooled	0.00	0.10	0.50	0.30	0.70	1.10	1.50	2.00	1.90	1.60	1.70	1.70	2.10	1.50	1.10	1.90	1.80	1.40	1.70	1.40	1.10	0.60	0.50	1.40	0.80	1.10	0.50	32.00
Arachida	2020	1.00	1.20	1.00	0.80	1.00	1.20	1.00	0.80	1.20	1.80	2.40	2.80	3.20	3.80	3.80	4.00	4.40	4.00	4.80	3.00	2.00	1.20	1.00	0.40	0.60	0.60	1.00	54.00
	2021	1.20	2.00	2.00	0.80	1.20	1.60	1.60	1.20	2.00	2.20	2.80	4.00	2.80	4.20	4.40	4.60	4.80	4.80	4.60	4.20	3.80	3.00	2.00	2.20	1.00	2.00	1.80	72.80
	Pooled	1.10	1.60	1.50	0.80	1.10	1.40	1.30	1.00	1.60	2.00	2.60	3.40	3.00	4.00	4.10	4.30	4.60	4.40	4.70	3.60	2.90	2.10	1.50	1.30	0.80	1.30	1.40	63.40

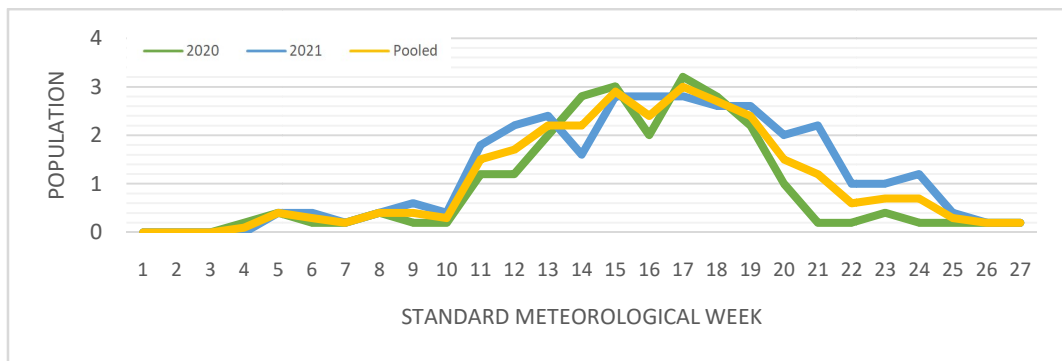


Fig. 4.4a : Seasonal abundance of Odonata-Anisoptera from June to December, 2020 & 2021 at Medziphema.

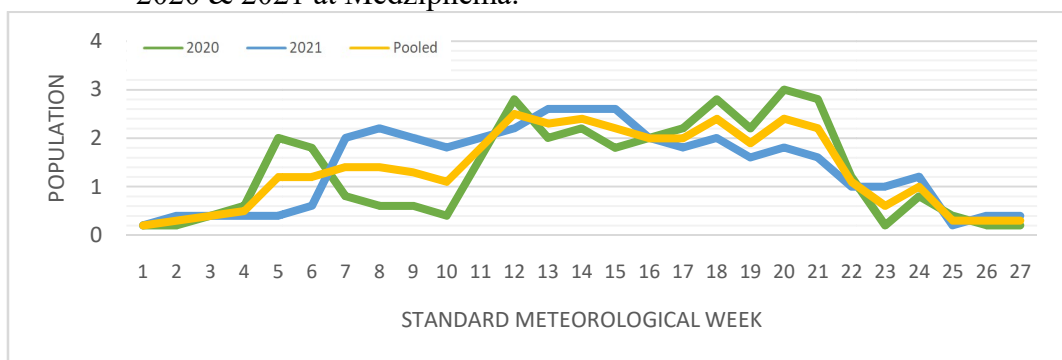


Fig. 4.4b : Seasonal abundance of Odonata-Zygoptera from June to December, 2020 & 2021 at Medziphema

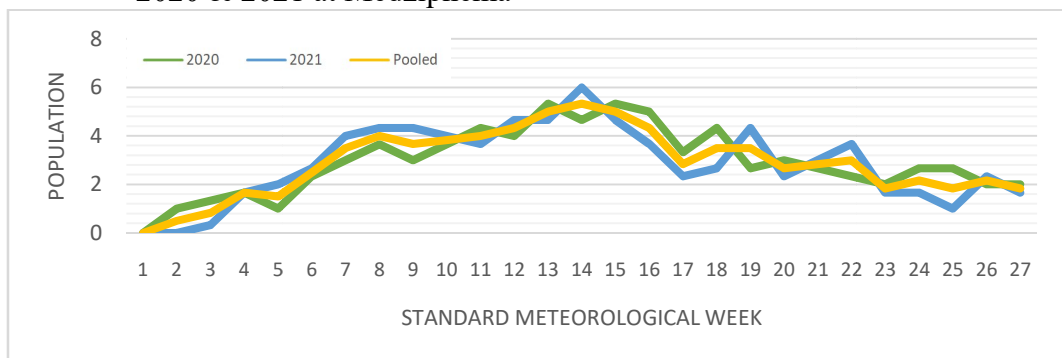


Fig. 4.4c : Seasonal abundance of Coleoptera from June to December, 2020 & 2021 at Medziphema

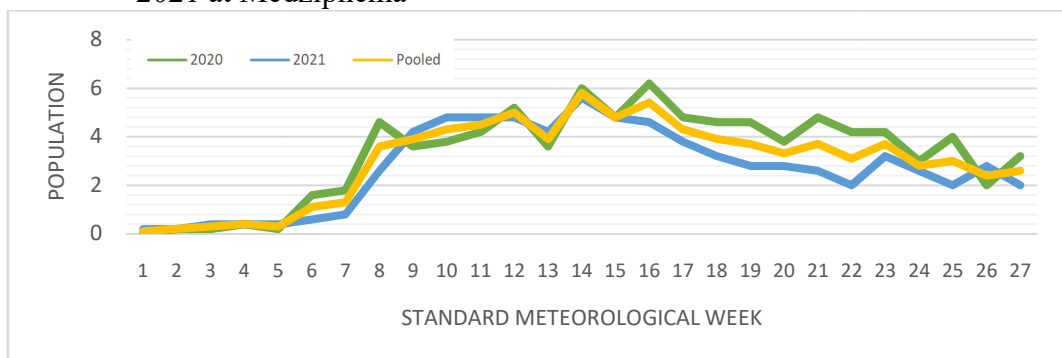


Fig. 4.4d : Seasonal abundance of Hymenoptera from June to December, 2020 & 2021 at Medziphema

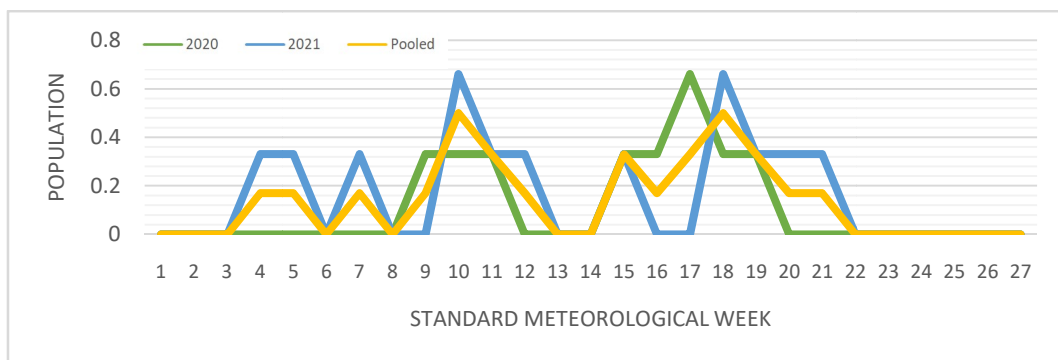


Fig. 4.4e : Seasonal abundance of Neuroptera from June to December, 2020 & 2021 at Medziphema

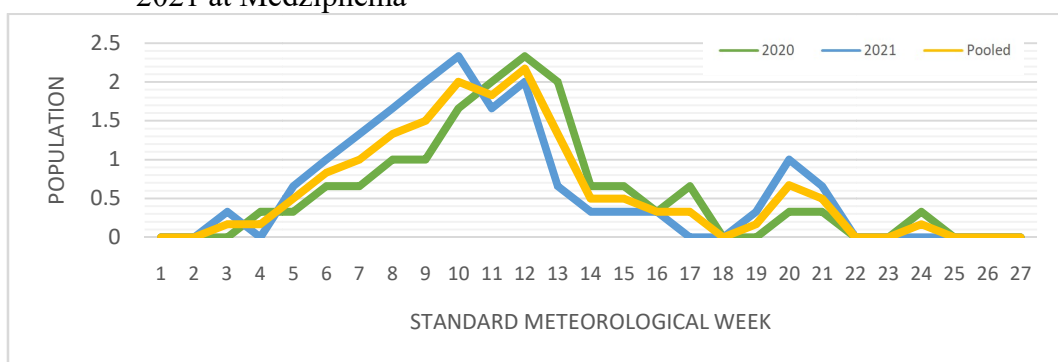


Fig. 4.4f : Seasonal abundance of Hemiptera from June to December, 2020 & 2021 at Medziphema

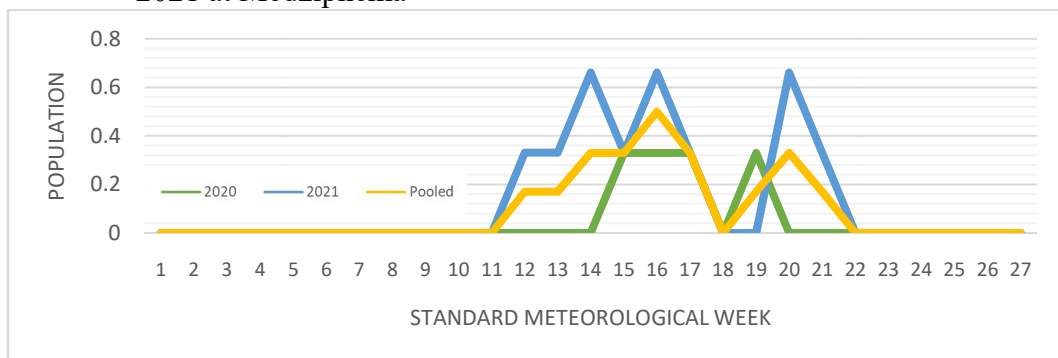


Fig. 4.4g : Seasonal abundance of Diptera from June to December, 2020 & 2021 at Medziphema

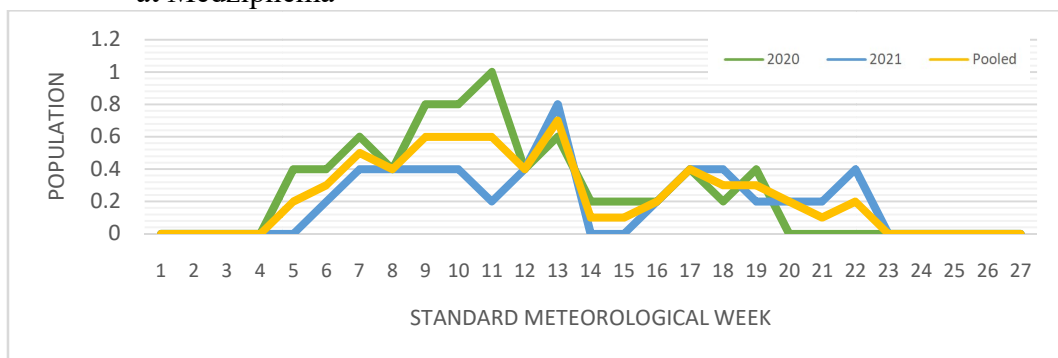


Fig. 4.4h : Seasonal abundance of Dermaptera from June to December, 2020 & 2021 at Medziphema

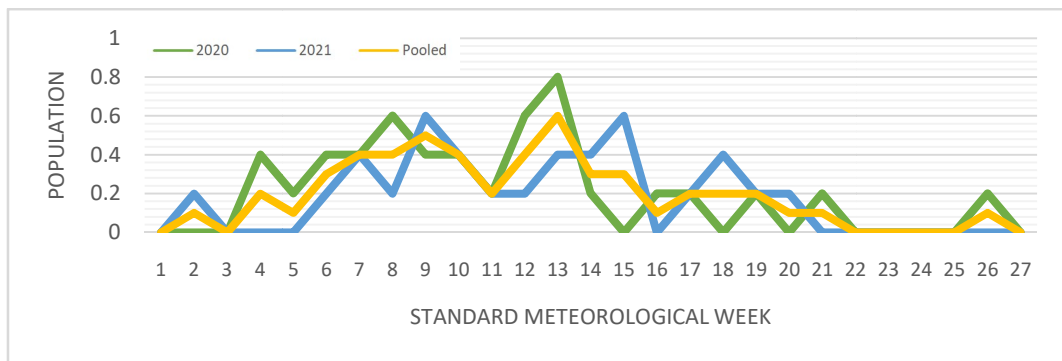


Fig. 4.4i: Seasonal abundance of Mantodea from June to December, 2020 & 2021 at Medziphema

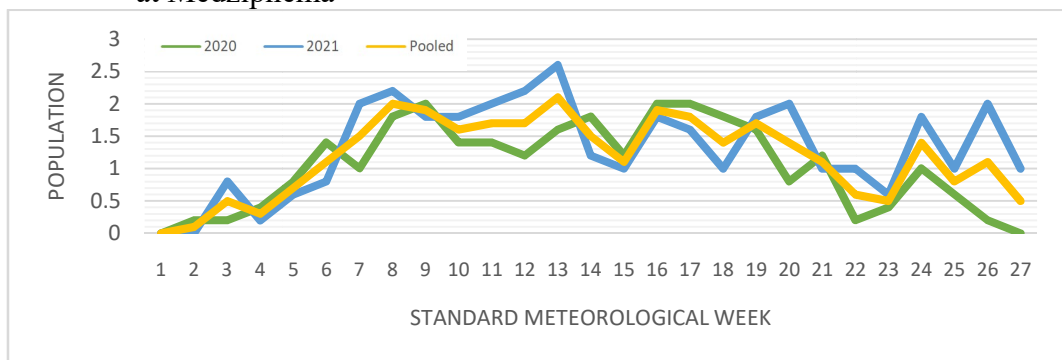


Fig. 4.4j: Seasonal abundance of Orthoptera from June to December, 2020 & 2021 at Medziphema

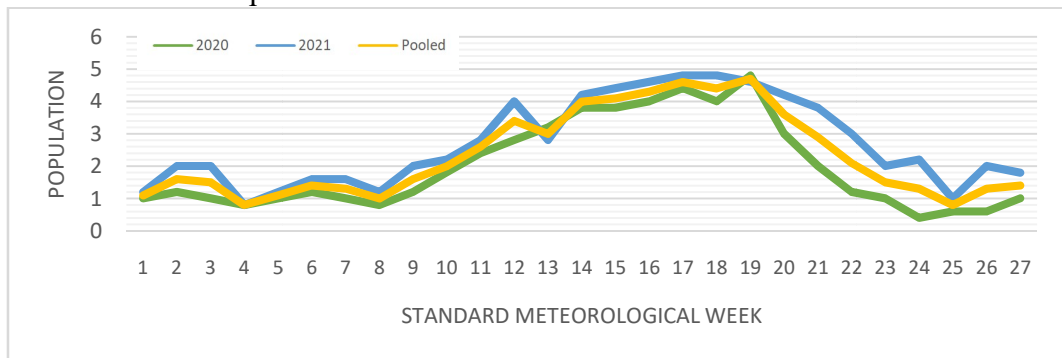


Fig. 4.4k: Seasonal abundance of Arachnida from June to December, 2020 & 2021 at Medziphema

4.2.2.2. SEASONAL ABUNDANCE OF NATURAL ENEMIES AT SINGRIJAN

As evident from table 4.2e, it is observed that Hymenoptera (92.50) and Coleoptera (67.57) were the most abundant followed by Arachnida (49), Orthoptera (46.70), Hemiptera (34.24), Odonata – Zygoptera (23.50) and Anisoptera (19.50) and Neuroptera (15.44). Lower populations were observed in Diptera (5.62), Dermaptera (4.90) and Mantodea (4.10).

In Odonata, the recorded numbers were 19.20 in 2020 and 19.80 in 2021 for Anisoptera, and 21.60 in 2020 and 25.40 in 2021 for Zygoptera. The pooled total for Anisoptera was 19.50 and for Zygoptera 23.50. Pooled data shows peak population at weeks 37-41 (Fig.4.5a) for Anisoptera and at weeks 35-39 (Fig.4.5b) for Zygoptera.

Coleopterans were first observed in week 23. Pooled data shows peak population between weeks 34-38 (Fig.4.5c). Total Coleopteran population recorded were 65.23 (2020) and 69.90 (2021), with a pooled total of 67.57.

The Hymenopterans first appeared in week 25, with continuous growth, peaking in weeks 35 to 40 (Fig.4.5d). The recorded population in 2020 was 93.20 and in 2021, it was 91.80 with a pooled data of 92.50.

The Neuropterans appeared in week 27, its population peaked between weeks 36 to 39 (Fig.4.5e). The pooled data reveals an incidence of 12.93 in 2020 and 17.94 in 2021 with a total pooled incidence of 15.44.

Hemipterans were present from week 23 which peaked between weeks 31 and 35 (Fig.4.5f). Pooled data of hemipteran insect pests shows a total of 36.56 in 2020 and 31.91 in 2021. The total pooled population was 34.24.

The Dipteran insect pests were first observed in week 31 with minor fluctuations that peaked in weeks 34-37 (Fig.4.5g). The incidence recorded in 2020 was 3.96 and in 2021, it was 7.27. Total Pooled population was 5.62.

Table 4.2e: Seasonal abundance of natural enemies in lowland rice agro ecosystem at Singrijan

Natural Enemies	SMW	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	Total
Odonata-Anisoptera	2020	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.40	1.00	0.60	2.20	2.00	2.60	2.80	2.40	2.20	1.60	0.60	0.00	0.00	0.00	0.20	0.20	0.00	0.20	19.20
	2021	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.20	0.00	2.00	1.00	0.60	0.80	1.00	0.80	2.00	2.20	2.40	2.60	2.60	0.80	0.20	0.00	0.20	0.00	0.00	19.80
	Pooled	0.00	0.00	0.00	0.00	0.10	0.20	0.00	0.00	0.10	0.20	1.50	0.80	1.40	1.40	1.80	1.80	2.20	2.20	2.00	1.60	1.30	0.40	0.10	0.10	0.20	0.00	0.10	19.50
Odonata-Zygoptera	2020	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.20	0.20	1.00	1.80	2.00	2.80	2.20	2.40	2.00	2.60	2.00	0.80	1.20	0.00	0.00	0.00	0.00	0.00	21.60
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.60	0.40	0.80	2.00	2.20	2.80	4.00	2.60	2.80	1.80	2.00	1.80	1.20	0.20	0.00	0.00	0.00	0.00	0.00	25.40
	Pooled	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.30	0.30	0.50	1.50	2.00	2.40	3.40	2.40	2.60	1.90	2.30	1.90	1.00	0.70	0.00	0.00	0.00	0.00	0.00	23.50
Coleoptera	2020	1.00	0.66	0.33	0.66	0.66	1.66	1.33	2.66	3.00	3.33	2.66	4.33	6.33	4.66	4.33	3.33	1.66	3.00	2.66	2.33	2.00	3.00	2.66	2.00	2.33	1.00	1.66	65.23
	2021	0.66	0.66	0.66	2.00	1.33	2.33	2.00	2.33	2.33	2.66	3.00	3.66	4.33	3.00	5.66	5.00	4.33	1.66	2.66	5.00	3.66	3.00	2.00	2.66	1.66	0.66	1.00	69.90
	Pooled	0.83	0.66	0.50	1.33	1.00	2.00	1.67	2.50	2.67	3.00	2.83	4.00	5.33	3.83	5.00	4.17	3.00	2.33	2.66	3.67	2.83	3.00	2.33	2.33	2.00	0.83	1.33	67.57
Hymenoptera	2020	0.00	0.00	0.20	0.60	0.20	2.00	2.60	6.20	2.80	2.40	4.80	4.20	5.20	5.80	6.80	5.20	5.80	5.40	4.20	5.00	3.20	3.60	3.40	3.20	3.00	3.60	3.80	93.20
	2021	0.00	0.00	0.00	0.80	0.20	0.80	2.00	4.60	6.40	6.00	4.20	2.80	6.00	6.20	6.40	6.20	4.80	4.20	4.20	4.60	4.80	3.00	3.00	3.20	2.60	2.40	2.40	91.80
	Pooled	0.00	0.00	0.10	0.70	0.20	1.40	2.30	5.40	4.60	4.20	4.50	3.50	5.60	6.00	6.60	5.70	5.30	4.80	4.20	4.80	4.00	3.30	3.20	3.20	2.80	3.00	3.10	92.50
Neuroptera	2020	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.33	0.66	0.33	0.33	1.00	0.66	2.00	2.33	0.66	1.33	0.66	0.66	0.33	0.33	0.66	0.33	0.00	0.00	0.00	0.00	12.93
	2021	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.33	0.66	1.00	1.33	1.66	2.66	2.00	1.66	2.33	2.00	0.66	0.66	0.33	0.00	0.00	0.00	0.00	0.00	0.00	17.94
	Pooled	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.17	0.50	0.50	0.67	1.17	1.16	2.33	2.17	1.16	1.83	1.33	0.66	0.50	0.33	0.33	0.17	0.00	0.00	0.00	0.00	15.44
Hemiptera	2020	0.66	1.00	0.66	1.00	1.33	0.66	1.00	1.66	2.00	2.66	4.66	3.66	3.33	2.00	1.33	0.66	0.66	0.33	1.33	0.66	1.00	1.66	1.33	0.33	0.66	0.00	0.33	36.56
	2021	0.00	0.00	0.33	0.66	1.00	1.66	1.00	2.00	2.33	3.33	3.66	2.33	2.66	1.66	2.00	1.33	0.33	0.33	0.33	1.00	1.33	0.33	0.66	0.66	0.33	0.33	0.33	31.91
	Pooled	0.33	0.50	0.50	0.83	1.17	1.16	1.00	1.83	2.17	3.00	4.16	3.00	3.00	1.83	1.67	1.00	0.50	0.33	0.83	0.83	1.17	1.00	1.00	0.50	0.50	0.17	0.33	34.24
Diptera	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.66	0.33	0.00	0.33	0.33	0.66	0.33	0.00	0.33	0.00	0.00	0.00	0.00	0.00	3.96
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.66	1.00	0.66	0.66	0.66	0.33	0.33	0.33	0.33	0.66	0.33	0.33	0.00	0.00	0.00	0.00	7.27
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.33	0.50	0.67	0.66	0.50	0.33	0.33	0.33	0.50	0.33	0.33	0.33	0.17	0.00	0.00	0.00	0.00	5.62
Dermaptera	2020	0.00	0.00	0.00	0.00	0.00	0.60	0.80	0.20	0.60	0.40	0.80	0.20	0.80	0.60	0.80	0.00	0.20	0.00	0.00	0.20	0.00	0.20	0.00	0.00	0.00	0.00	0.00	6.40
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.20	0.20	0.60	0.40	0.60	0.20	0.20	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.40
	Pooled	0.00	0.00	0.00	0.00	0.00	0.30	0.40	0.40	0.40	0.30	0.70	0.30	0.70	0.40	0.50	0.00	0.10	0.10	0.10	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.00	4.90
Mantodea	2020	0.00	0.00	0.20	0.20	0.40	0.00	0.00	0.20	0.00	0.20	0.40	0.00	0.60	0.40	0.20	0.00	0.00	0.20	0.40	0.40	0.00	0.00	0.00	0.20	0.20	0.00	0.00	4.20
	2021	0.20	0.00	0.00	0.00	0.20	0.20	0.20	0.20	0.40	0.20	0.00	0.00	0.20	0.40	0.20	0.20	0.20	0.20	0.00	0.00	0.20	0.20	0.40	0.20	0.00	0.00	0.00	4.00
	Pooled	0.10	0.00	0.10	0.10	0.30	0.10	0.10	0.20	0.20	0.20	0.20	0.00	0.40	0.40	0.20	0.10	0.10	0.20	0.20	0.20	0.10	0.10	0.20	0.20	0.10	0.00	0.00	4.10
Orthoptera	2020	0.20	1.60	2.20	1.80	2.60	2.40	3.00	1.20	1.20	2.60	0.80	1.40	0.20	3.00	0.20	0.60	1.40	2.60	3.20	1.00	1.20	2.20	2.20	1.00	0.60	0.20	0.00	40.60
	2021	1.00	2.00	0.80	0.40	3.20	3.20	4.20	2.60	1.20	1.20	3.40	2.20	2.00	1.60	1.60	3.40	2.00	1.60	1.60	2.20	2.20	2.00	1.40	1.80	1.00	2.00	1.00	52.80
	Pooled	0.60	1.80	1.50	1.10	2.90	2.80	3.60	1.90	1.20	1.90	2.10	1.80	1.10	2.30	0.90	2.00	1.70	2.10	2.40	1.60	1.70	2.10	1.80	1.40	0.80	1.10	0.50	46.70
Arachida	2020	0.60	1.00	0.60	0.60	1.20	0.60	0.80	1.40	1.60	2.00	2.80	2.40	2.80	3.20	4.00	3.60	4.20	4.20	3.80	2.20	1.80	0.80	0.40	0.60	0.20	0.40	0.40	48.20
	2021	0.40	0.80	0.60	0.40	1.00	1.20	1.80	2.00	0.80	1.20	1.60	2.60	2.80	3.00	4.80	6.00	5.20	2.80	3.40	2.20	1.20	1.00	1.00	1.20	0.20	0.40	0.20	49.80
	Pooled	0.50	0.90	0.60	0.50	1.10	0.90	1.30	1.70	1.20	1.60	2.20	2.50	2.80	3.10	4.40	4.80	4.70	3.50	3.60	2.20	1.50	0.90	0.70	0.90	0.20	0.40	0.30	49.00

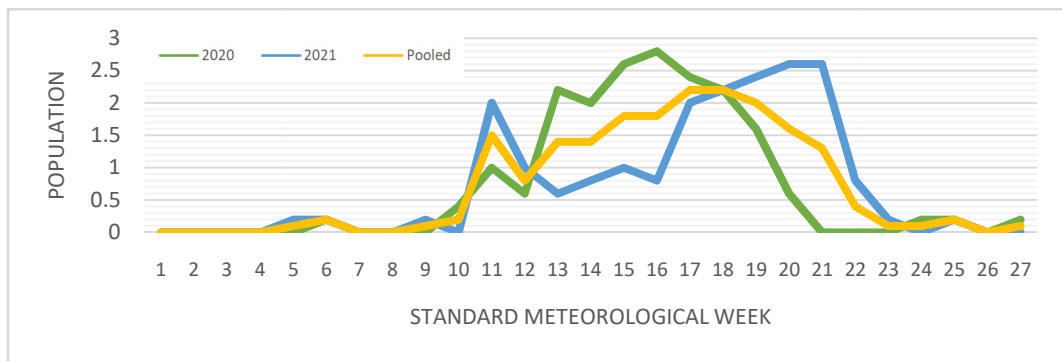


Fig. 4.5a: Seasonal abundance of Odonata-Anisoptera from June to December, 2020 & 2021 at Singrijan

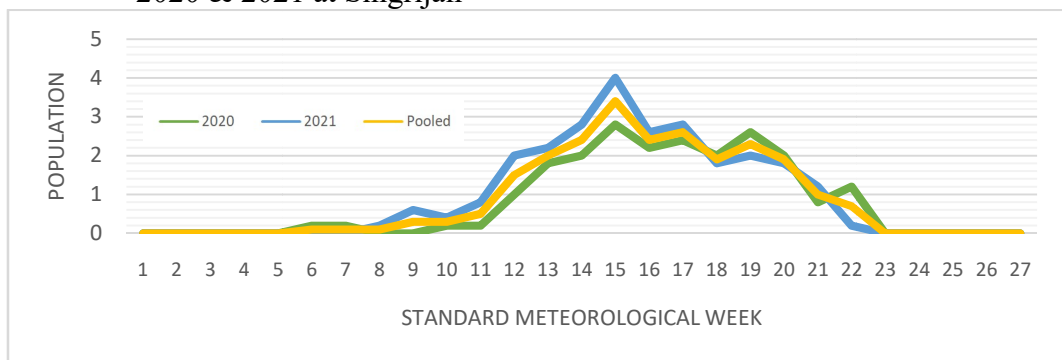


Fig. 4.5b: Seasonal abundance of Odonata-Zygoptera from June to December, 2020 & 2021 at Singrijan

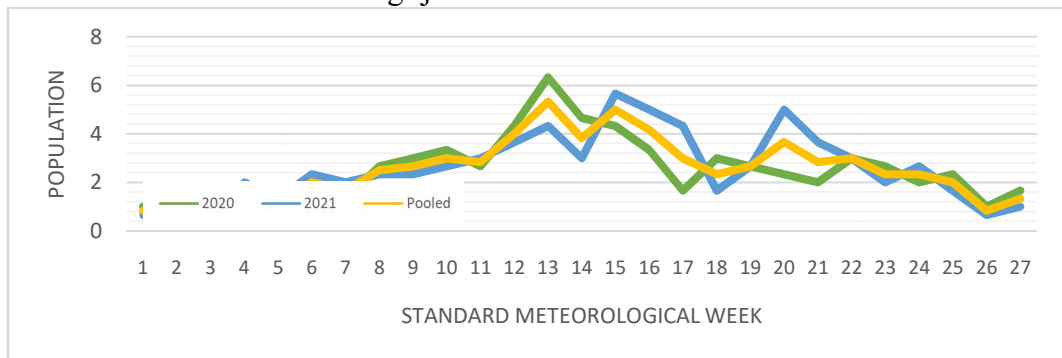


Fig. 4.5c: Seasonal abundance of Coleoptera from June to December, 2020 & 2021 at Singrijan

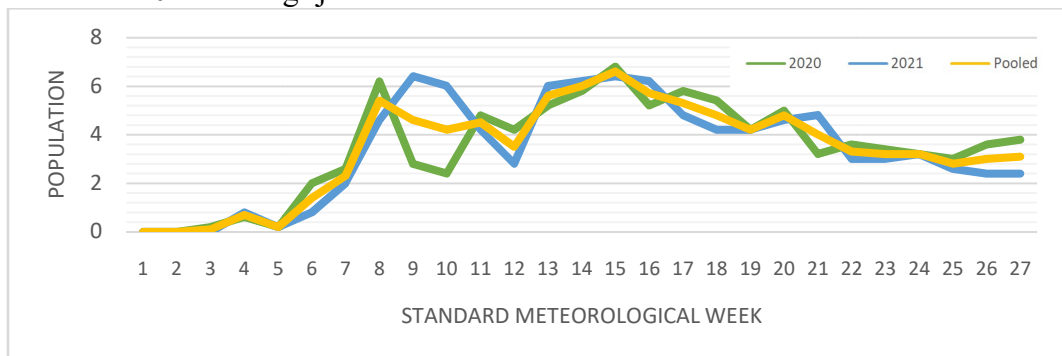


Fig. 4.5d: Seasonal abundance of Hymenoptera from June to December, 2020 & 2021 at Singrijan

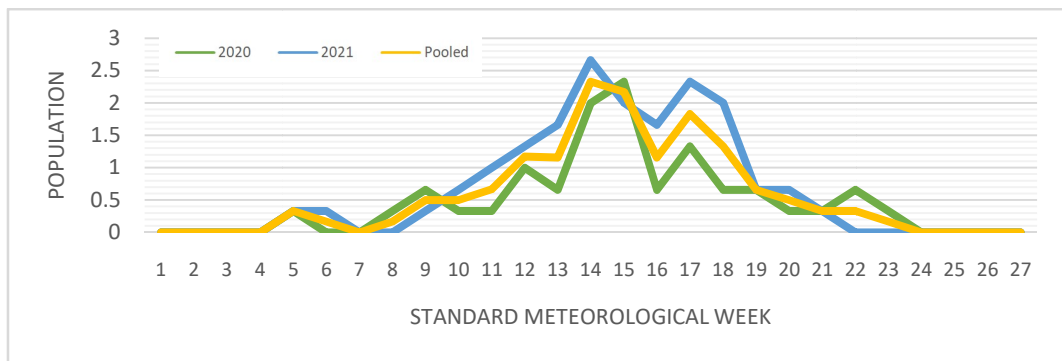


Fig. 4.5e: Seasonal abundance of Neuroptera from June to December, 2020 & 2021 at Singrijan

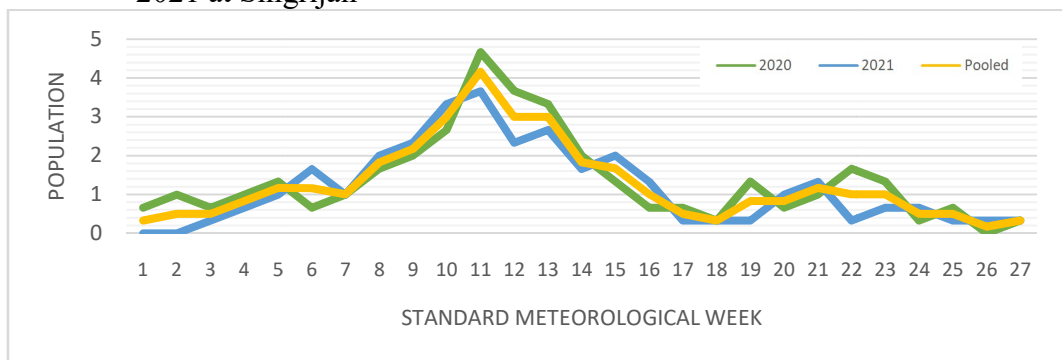


Fig. 4.5f: Seasonal abundance of Hemiptera from June to December, 2020 & 2021 at Singrijan

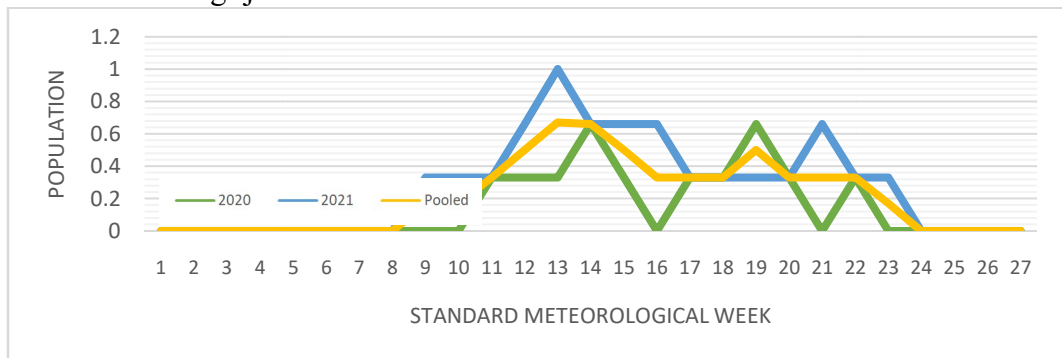


Fig. 4.5g: Seasonal abundance of Diptera from June to December, 2020 & 2021 at Singrijan

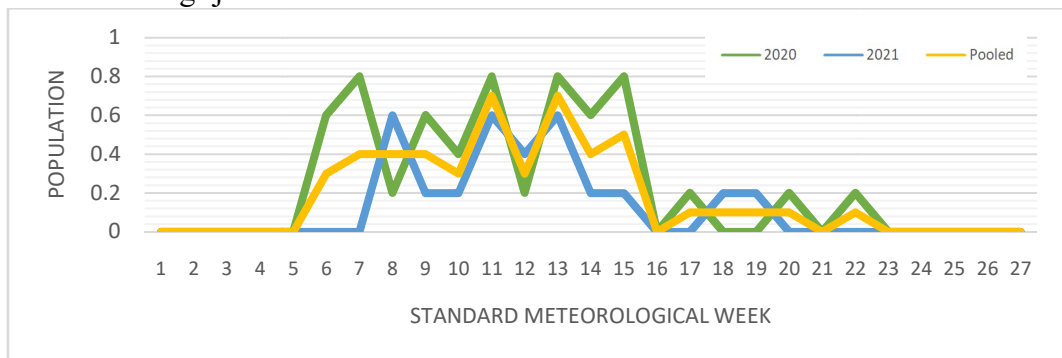


Fig. 4.5h: Seasonal abundance of Dermaptera from June to December, 2020 & 2021 at Singrijan

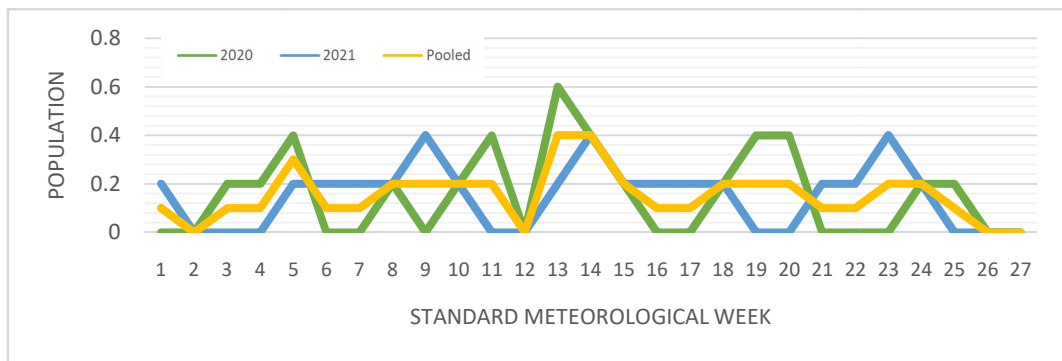


Fig. 4.5i: Seasonal abundance of Mantodea from June to December, 2020 & 2021 at Singrijan

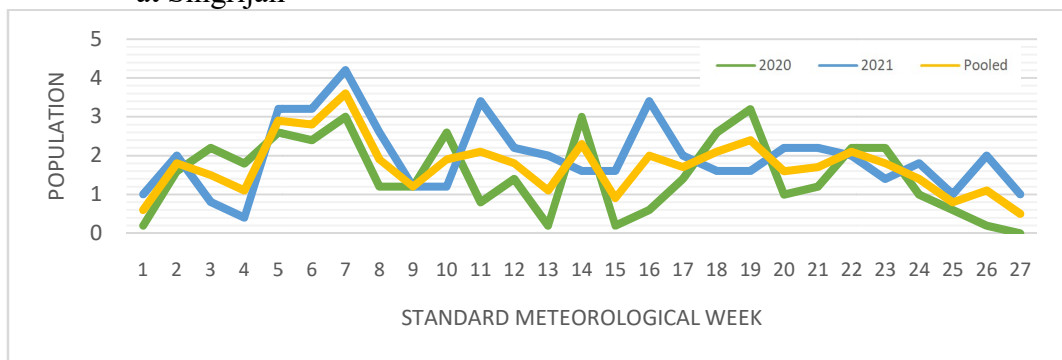


Fig. 4.5j: Seasonal abundance of Orthoptera from June to December, 2020 & 2021 at Singrijan

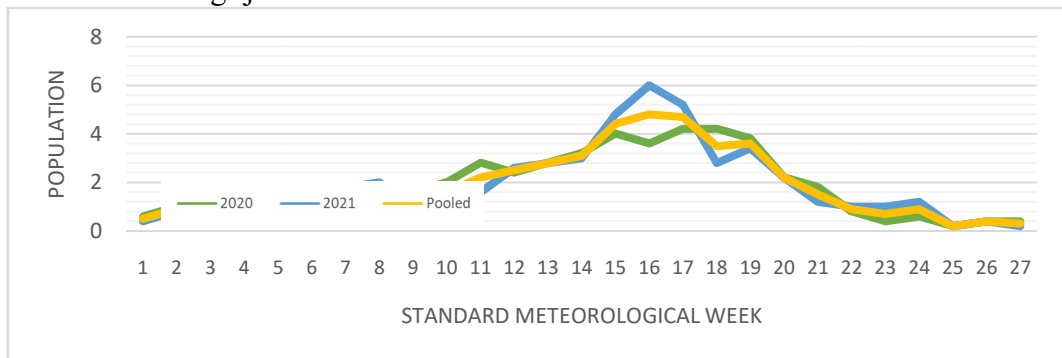


Fig. 4.5k: Seasonal abundance of Arachnida from June to December, 2020 & 2021 at Singrijan

Dermaptera were first recorded in week 28 and their population peaked between weeks 35-37 (Fig.4.5h). The observed population in 2020 was 6.40 and in 2021, it was 3.40. The pooled data shows a total population of 4.90.

The predators from the order Mantodea were first observed in week 23 which peaked between weeks 35-37 (Fig.4.5i). In 2020, the incidence was 4.20 and subsequently in 2021, it was 4.00. Pooled data shows the total population of Mantodea as 4.10.

Orthopterans were first recorded in week 23 and it was observed that their population peaked between weeks 27 and 29 (Fig.4.5j). The incidence as recorded in 2020 was 40.60 and in 2021, it was 52.80. The pooled data of both the years recorded the total population of 46.70.

The Arachnid population recorded in 2020 shows its presence from week 23 onwards which saw them peak between weeks 36 and 41 (Fig.4.5k). In 2020, the incidence was recorded as 48.20 while in 2021, it was 49.80. The pooled data recorded a total population of 49.00.

4.2.2.3. SEASONAL ABUNDANCE OF NATURAL ENEMIES AT KUHOXU.

The observations at Kuhoxu reveals that the most dominant group of natural enemies was Hymenoptera (104.70), followed by Coleoptera (66.89) and Arachnida (47.70), indicating their significant role in biological control within the rice ecosystem. Orthoptera (43.20) and Hemiptera (32.93) also contributed notably to the predator-prey balance. Among the aerial predators, Odonata - Zygoptera (22.40) were more abundant than Odonata - Anisoptera (12.30), suggesting a stronger presence of Zygoptera in the rice fields. Other groups such as Neuroptera (15.94), Diptera (9.11), and Dermaptera (6.50) were present in moderate numbers, while Mantodea (4.10) had the least abundance, the observations of which are illustrated in table 4.2f.

Anisoptera of the order Odonata exhibited a steady increase in population from week 26, reaching peak abundance between weeks 36 and 41 (Fig.4.6a). The

total recorded population was 13.20 in 2020 and 11.40 in 2021, resulting in a pooled total of 12.30.

Unlike Anisoptera, Zygoptera maintained a more sustained population level, steadily increasing from week 27 and peaking between weeks 35 and 42 (Fig.4.6b). The total recorded population was 22.80 in 2020 and 22.00 in 2021, with a pooled total of 22.40.

Coleopteran populations fluctuated throughout the season, with an increase from week 23 and peak abundance between weeks 33 and 37 (Fig.4.6c). The total recorded population was 59.57 in 2020 and 74.21 in 2021, resulting in a pooled total of 66.89.

Starting from week 25, Hymenoptera exhibited strong population growth, with peak densities occurring between weeks 35 and 41 (Fig.4.6d). The total population recorded was 113.00 in 2020 and 96.40 in 2021, leading to a pooled total of 104.70.

Neuroptera had relatively low occurrences, with slight peaks around weeks 35 and 39 (Fig.4.6e). The total recorded population was 13.28 in 2020 and 18.59 in 2021, leading to a pooled total of 15.94.

A gradual rise in population was observed for Hemiptera from week 25, reaching peak abundance between weeks 32 and 37 (Fig.4.6f). The total recorded numbers were 35.58 in 2020 and 30.27 in 2021, leading to a pooled total of 32.93.

Diptera remained at very low levels throughout the study, with a minor peak between weeks 34 and 40 (Fig.4.6g). The total population was 7.94 in 2020 and 10.27 in 2021, leading to a pooled total of 9.11.

The population of Dermaptera increased slowly and steadily, reaching peak abundance between weeks 35 and 38 (Fig.4.6h). The total recorded population was 7.20 in 2020 and 5.80 in 2021, resulting in a pooled total of 6.50.

Table 4.2f. Seasonal abundance and diversity of natural enemies in lowland rice agro ecosystem at Kuhoxu

Natural Enemies	SMW	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	Total
Odonata-Anisoptera	2020	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.00	0.00	0.20	0.40	0.40	1.20	1.40	1.60	1.80	2.00	1.80	1.40	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	13.20
	2021	0.00	0.00	0.00	0.20	0.00	0.00	0.20	0.20	0.20	0.20	0.40	0.60	0.80	1.00	1.20	1.20	1.60	1.00	1.20	0.80	0.20	0.20	0.00	0.20	0.00	0.00	0.00	11.40
	Pooled	0.00	0.00	0.00	0.10	0.10	0.10	0.20	0.10	0.10	0.20	0.40	0.50	1.00	1.20	1.40	1.50	1.80	1.40	1.30	0.50	0.20	0.10	0.00	0.10	0.00	0.00	0.00	12.30
Odonata-Zygoptera	2020	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.40	0.20	0.00	0.00	0.00	0.80	1.80	1.80	1.20	2.00	2.80	2.80	3.00	2.20	1.80	1.20	0.20	0.00	0.00	0.00	22.80
	2021	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.20	0.40	0.40	0.60	3.00	2.80	2.60	3.00	3.20	1.00	1.20	0.60	1.00	0.80	0.40	0.20	0.00	0.00	0.00	0.00	22.00
	Pooled	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.30	0.30	0.20	0.30	1.50	1.80	2.20	2.40	2.20	1.50	2.00	1.70	2.00	1.50	1.10	0.70	0.10	0.00	0.00	0.00	22.40
Coleoptera	2020	0.33	0.33	1.00	1.33	1.00	1.00	0.66	1.66	1.66	2.00	3.00	3.66	4.66	5.33	5.66	2.66	2.33	4.33	2.33	2.00	2.00	2.66	2.33	1.66	1.33	1.66	1.00	59.57
	2021	0.00	0.33	0.66	1.33	1.66	1.66	1.33	3.00	3.66	3.66	5.33	6.33	4.66	4.00	4.33	4.66	4.66	3.33	2.66	2.66	2.00	2.66	2.66	2.00	1.66	1.66	1.66	74.21
	Pooled	0.17	0.33	0.83	1.33	1.33	1.33	1.00	2.33	2.66	2.83	4.17	5.00	4.66	4.67	5.00	3.66	3.50	3.83	2.50	2.33	2.00	2.66	2.50	1.83	1.50	1.66	1.33	66.89
Hymenoptera	2020	0.00	0.00	0.00	0.40	0.40	2.20	2.80	4.60	4.80	5.60	5.80	6.40	6.80	6.20	6.00	5.80	6.20	6.00	6.80	5.80	4.80	4.60	4.20	4.00	4.20	4.60	4.00	113.00
	2021	0.00	0.00	0.60	0.60	0.60	0.80	3.20	3.60	4.00	4.80	4.60	4.80	5.80	5.20	5.60	5.60	5.80	5.00	5.20	4.80	4.00	4.20	4.00	3.80	3.60	3.00	3.20	96.40
	Pooled	0.00	0.00	0.30	0.50	0.50	1.50	3.00	4.10	4.40	5.20	5.20	5.60	6.30	5.70	5.80	5.70	6.00	5.50	6.00	5.30	4.40	4.40	4.10	3.90	3.90	3.80	3.60	104.70
Neuroptera	2020	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.33	0.33	1.33	1.00	1.66	1.66	1.00	1.66	0.00	0.00	0.66	1.00	1.00	0.33	0.33	0.33	0.00	0.00	13.28
	2021	0.00	0.00	0.00	0.33	0.00	0.66	0.66	0.66	0.33	0.33	0.00	0.33	1.33	1.33	1.66	2.00	2.00	1.66	1.00	1.00	1.33	0.66	0.33	0.33	0.33	0.33	0.00	18.59
	Pooled	0.00	0.00	0.00	0.17	0.17	0.50	0.33	0.33	0.17	0.33	0.17	0.83	1.17	1.50	1.66	1.50	1.83	0.83	0.50	0.83	1.17	0.83	0.33	0.33	0.33	0.17	0.00	15.94
Hemiptera	2020	0.00	0.00	0.33	0.66	1.00	1.33	1.33	1.00	1.66	2.00	3.33	3.00	2.66	2.66	2.33	1.33	1.33	1.66	1.66	1.00	1.33	1.00	1.00	0.66	0.66	0.33	0.33	35.58
	2021	0.00	0.00	0.00	0.00	0.66	1.33	1.66	1.66	2.00	2.33	3.00	3.33	3.33	2.33	1.66	1.00	1.00	0.33	0.00	0.00	1.33	0.33	1.00	1.00	0.33	0.33	0.33	30.27
	Pooled	0.00	0.00	0.17	0.33	0.83	1.33	1.50	1.33	1.83	2.17	3.17	3.17	3.00	2.50	2.00	1.17	1.17	1.00	0.83	0.50	1.33	0.67	1.00	0.83	0.50	0.33	0.33	32.93
Diptera	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.66	0.66	0.66	0.66	0.33	1.00	0.66	1.00	0.66	0.33	0.66	0.33	0.00	0.00	0.00	0.00	0.00	0.00	7.94
	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.66	0.66	0.66	1.00	0.66	1.00	0.66	0.66	0.66	1.00	1.00	0.66	0.33	0.33	0.00	0.00	0.00	0.00	0.00	10.27
	Pooled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.50	0.66	0.66	0.83	0.66	0.67	0.83	0.66	0.83	0.83	0.67	0.66	0.33	0.17	0.00	0.00	0.00	0.00	0.00	9.11
Dermaptera	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.80	0.80	0.60	0.40	0.40	0.40	0.80	0.80	0.20	0.20	0.20	0.00	0.20	0.40	0.00	0.20	0.20	0.00	0.00	0.00	7.20
	2021	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.40	0.40	0.40	0.00	0.20	0.80	0.60	0.60	0.60	0.40	0.20	0.20	0.20	0.20	0.20	0.00	0.00	0.00	0.00	0.00	5.80
	Pooled	0.00	0.00	0.00	0.00	0.00	0.10	0.40	0.60	0.60	0.50	0.20	0.30	0.60	0.70	0.70	0.40	0.30	0.20	0.10	0.20	0.30	0.10	0.10	0.10	0.00	0.00	0.00	6.50
Mantodea	2020	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.20	0.20	0.20	0.60	0.40	0.40	0.40	0.20	0.20	0.20	0.20	0.40	0.00	0.20	0.20	0.00	0.00	0.00	0.00	4.40
	2021	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.20	0.20	0.40	0.20	0.40	0.20	0.20	0.40	0.40	0.20	0.20	0.20	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	3.80
	Pooled	0.00	0.00	0.00	0.10	0.10	0.10	0.00	0.10	0.20	0.30	0.20	0.50	0.30	0.30	0.40	0.30	0.20	0.20	0.20	0.30	0.10	0.10	0.10	0.00	0.00	0.00	0.00	4.10
Orthoptera	2020	1.00	0.40	0.80	0.80	2.00	2.80	2.80	3.00	0.80	2.00	2.00	1.80	0.80	2.20	2.20	0.80	2.20	2.20	2.20	2.00	0.80	0.60	1.00	1.00	0.60	0.20	0.00	39.00
	2021	0.20	0.80	2.00	0.40	2.20	2.20	3.20	3.80	2.00	2.20	3.00	3.20	0.20	0.60	1.80	2.20	1.80	1.80	2.00	2.00	2.40	0.80	0.80	1.80	1.00	2.00	1.00	47.40
	Pooled	0.60	0.60	1.40	0.60	2.10	2.50	3.00	3.40	1.40	2.10	2.50	2.50	0.50	1.40	2.00	1.50	2.00	2.00	2.10	2.00	1.60	0.70	0.90	1.40	0.80	1.10	0.50	43.20
Arachida	2020	0.20	0.60	0.40	0.60	0.80	1.20	1.80	1.20	1.20	1.80	2.00	3.00	3.80	4.20	3.80	3.20	2.80	3.60	3.40	3.00	1.60	1.80	1.20	0.80	0.60	0.60	0.60	49.80
	2021	0.20	0.40	0.40	0.60	0.60	0.80	1.20	1.60	2.00	1.60	1.80	2.00	3.00	3.20	3.20	4.00	4.20	2.00	2.60	2.00	2.20	1.80	1.60	1.00	1.20	0.20	0.20	45.60
	Pooled	0.20	0.50	0.40	0.60	0.70	1.00	1.50	1.40	1.60	1.70	1.90	2.50	3.40	3.70	3.50	3.60	3.50	2.80	3.00	2.50	1.90	1.80	1.40	0.90	0.90	0.40	0.40	47.70

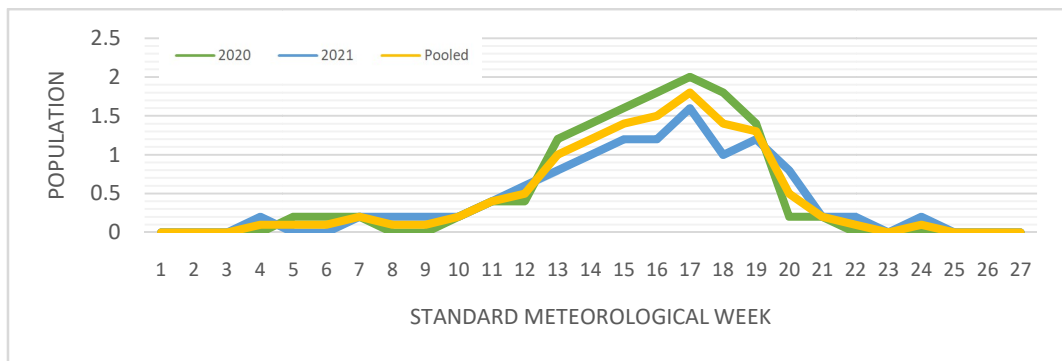


Fig. 4.6a: Seasonal abundance of Odonata-Anisoptera from June to December, 2020 & 2021 at Kuhoxu

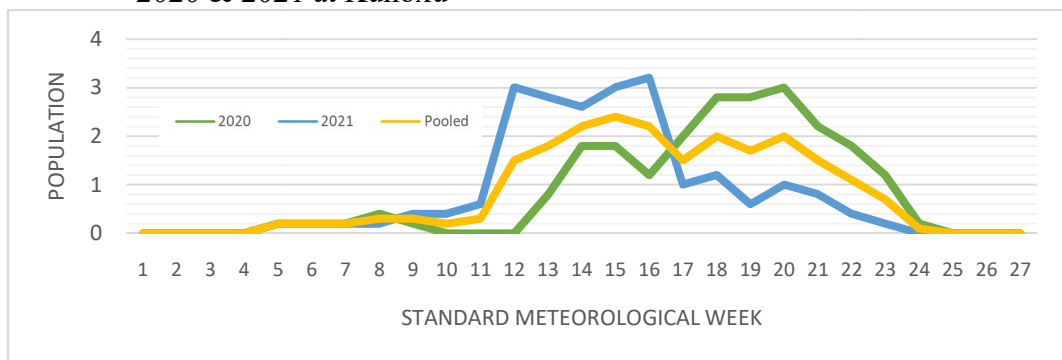


Fig. 4.6b: Seasonal abundance of Odonata-Zygoptera from June to December, 2020 & 2021 at Kuhoxu

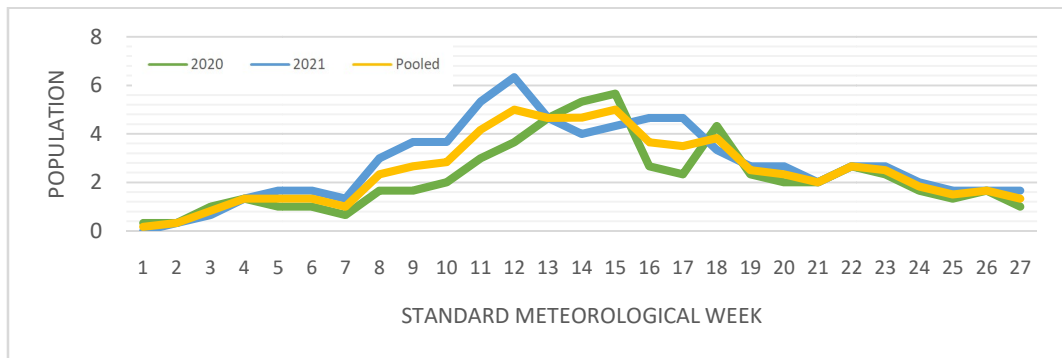


Fig. 4.6c: Seasonal abundance of Coleoptera from June to December, 2020 & 2021 at Kuhoxu

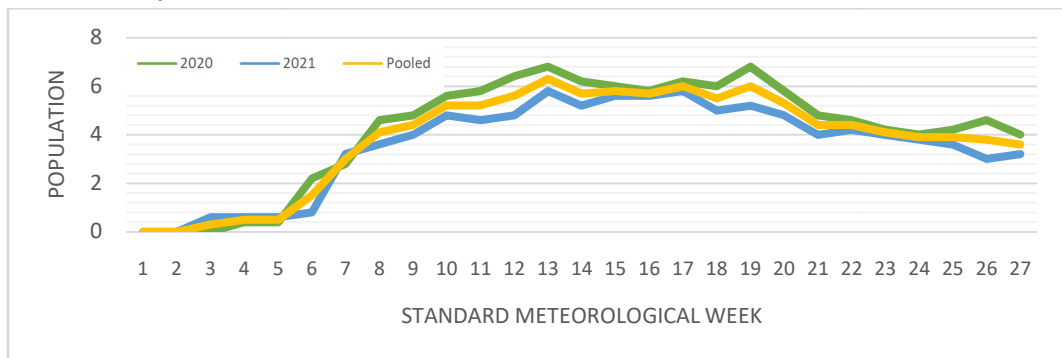


Fig. 4.6d: Seasonal abundance of Hymenoptera from June to December, 2020 & 2021 at Kuhoxu

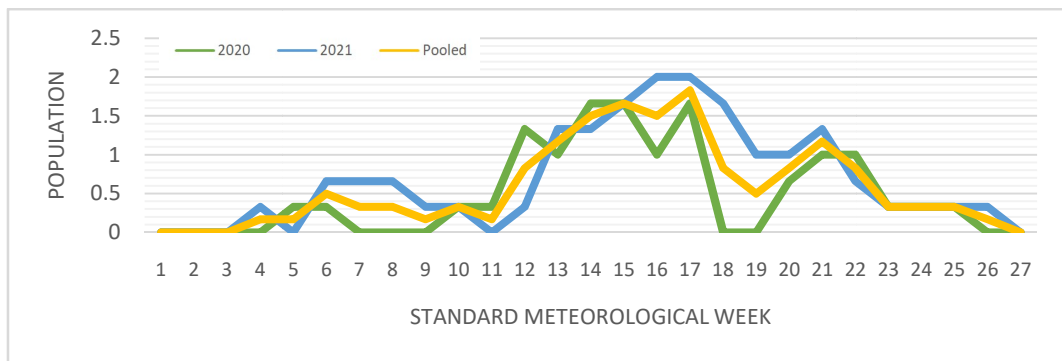


Fig. 4.6e: Seasonal abundance of Neuroptera from June to December, 2020 & 2021 at Kuhoxu

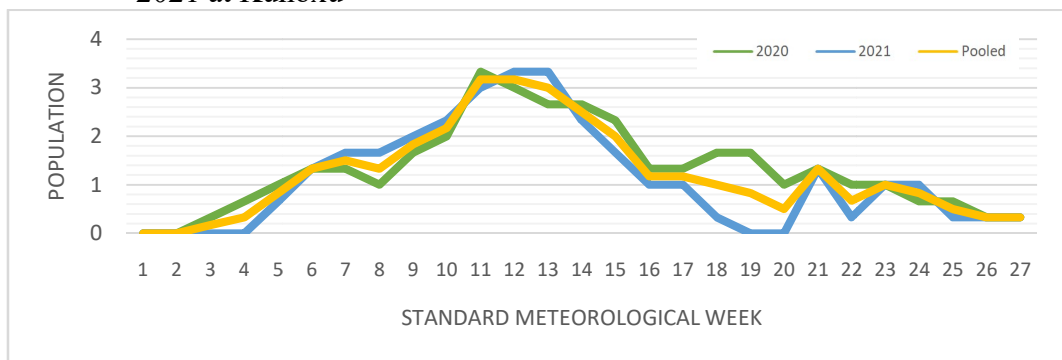


Fig. 4.6f: Seasonal abundance of Hemiptera from June to December, 2020 & 2021 at Kuhoxu

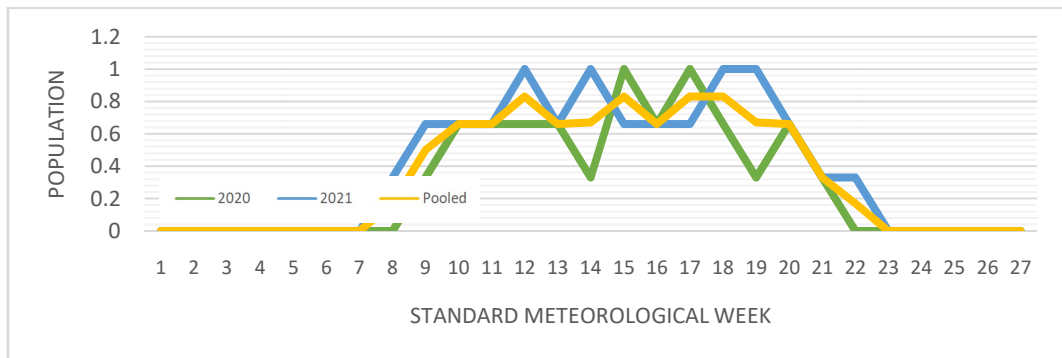


Fig. 4.6g: Seasonal abundance of Diptera from June to December, 2020 & 2021 at Kuhoxu

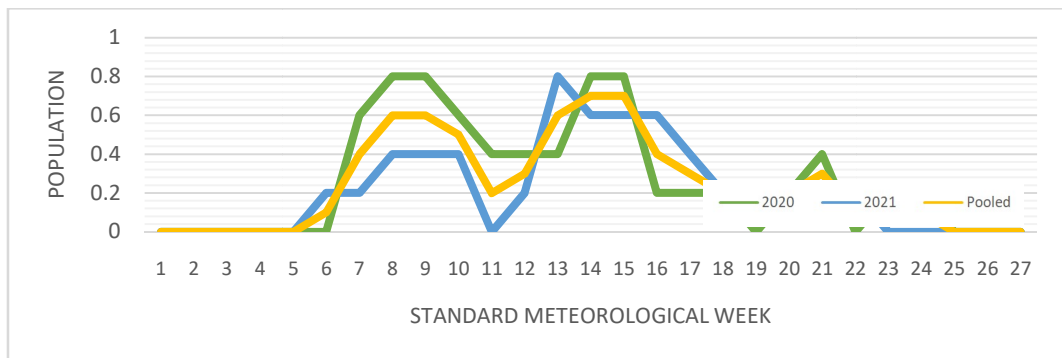


Fig. 4.6h: Seasonal abundance of Dermaptera from June to December, 2020 & 2021 at Kuhoxu

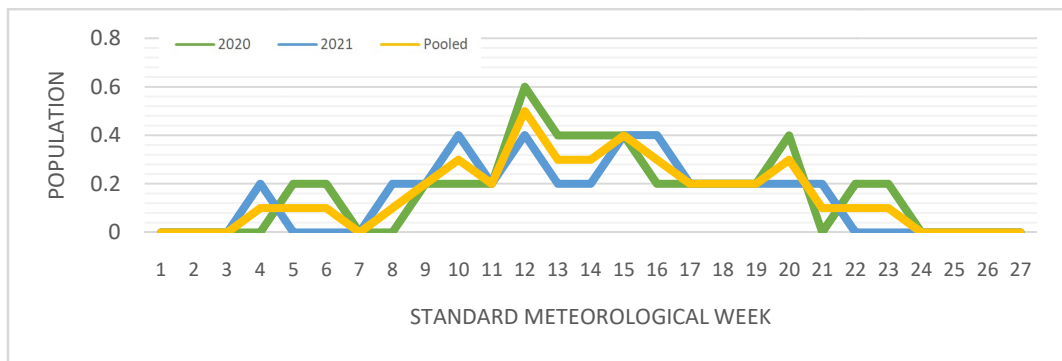


Fig. 4.6i: Seasonal abundance of Mantodea from June to December, 2020 & 2021 at Kuhoxu

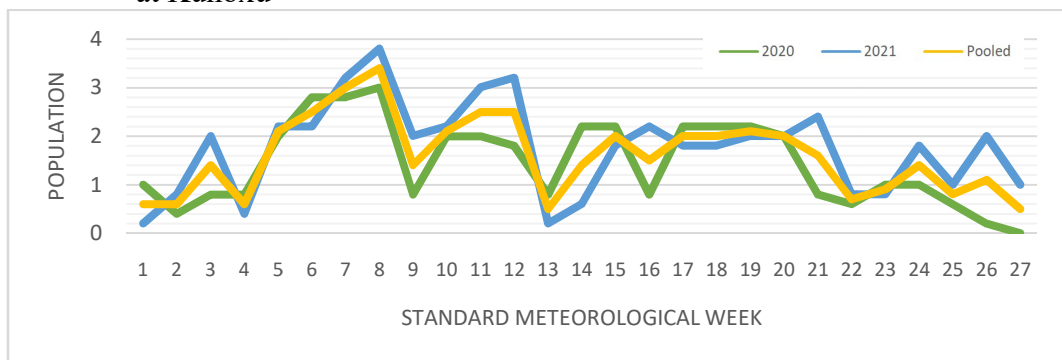


Fig. 4.6j: Seasonal abundance of Orthoptera from June to December, 2020 & 2021 at Kuhoxu

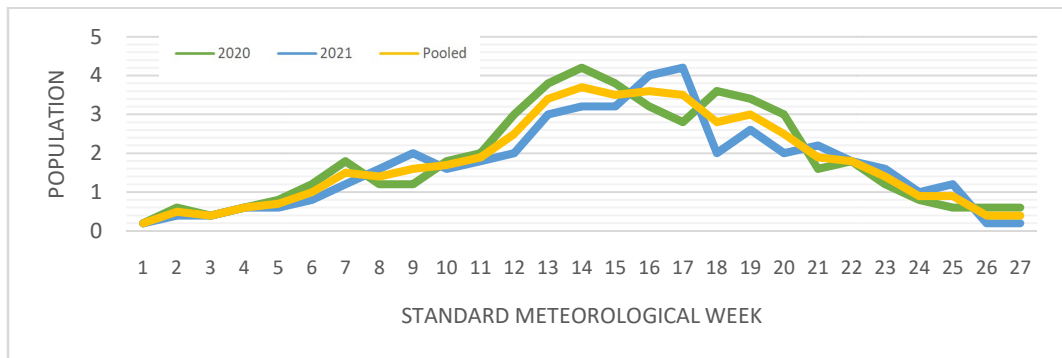


Fig. 4.6k: Seasonal abundance of Arachnida from June to December, 2020 & 2021 at Kuhoxu

Mantodea showed relatively stable population levels, peaking between weeks 34 and 38 (Fig.4.6i). The total recorded population was 4.40 in 2020 and 3.80 in 2021, leading to a pooled total of 4.10.

Gradual population growth was noted for Orthoptera, which peaked between weeks 32 and 34 (Fig.4.4j). The total recorded population was 39.00 in 2020 and 47.40 in 2021, resulting in a pooled total of 43.20.

Arachnida displayed a consistent population trend, peaking between weeks 35 and 41 (Fig.4.4k). The total population recorded was 49.80 in 2020 and 45.60 in 2021, leading to a pooled total of 47.70.

Parasappa *et al.* (2017) observed a positive correlation between planthoppers and their natural enemies (mirid bugs, spiders, and Odonata), aligning with present study's recorded predator trends. They also found a strong positive correlation between yellow stem borer and natural enemies (Hymenoptera, Odonata, and Staphylinids), supporting this study's findings.

Moses *et al.* (2019) reported that predatory spiders peaked in week 29, followed by ladybird beetles in week 33, staphylinid beetles in week 39, Anisoptera and Zygotera peaked in week 29 which is consistent with the current findings.

Kalita *et al.* (2020) found that spiders, Anisoptera, and coccinellid beetles peaked between weeks 38 and 40, confirming this study's observed trends.

Singh *et al.* (2020) recorded Anisoptera peaking in the 39th–41st SMW, Zygotera in the 42nd SMW, and ladybird beetles from the 39th to 44th SMW which is in agreement with the present investigation.

Selvam *et al.* (2022) reported peak insect catches in the 36th SMW using light traps, with natural enemy populations peaking in the 39th and 40th SMW. Their findings align with the present study's trends in pest and predator activity.

These findings collectively confirm the present findings on seasonal population trends of natural enemies in rice agroecosystem.

4.3. CORRELATION OF INSECT PESTS OF RICE WITH WEATHER PARAMETERS IN LOWLAND RICE AGROECOSYSTEM IN NAGALAND

The correlation between insect pests of rice and weather parameters - maximum and minimum temperature, maximum and minimum relative humidity and rainfall recorded during the rice cropping seasons of 2020 and 2021 are discussed in this chapter. Additionally, multiple regression models were developed to predict insect pest populations based on various weather parameters, including maximum temperature (X_1), minimum temperature (X_2), maximum relative humidity (X_3), minimum relative humidity (X_4), and rainfall (X_5).

4.3.1. CORRELATION COEFFICIENT OF INSECT PESTS OF RICE WITH WEATHER PARAMETERS AT MEDZIPHEMA

Table 4.3a presents the correlation coefficients (Pearson's r) at Medziphema between insect pests of rice and weather parameters recorded from June to December 2020. Some insect pests showed negative correlations with temperature, indicating that higher temperatures reduce their populations.

C. spectra had a highly significant negative correlation with maximum temperature (-0.621 , $p < 0.01$) and minimum temperature (-0.563 , $p < 0.01$), confirming that this species declines as temperature rises. *S. oryzae* exhibited the strongest negative correlation with maximum temperature (-0.926 , $p < 0.01$) and minimum temperature (-0.947 , $p < 0.01$), indicating that this pest is highly sensitive to warm conditions.

Some pests showed positive correlations with temperature, meaning warmer temperatures favor their population growth. Green horned caterpillars had a significant positive correlation with maximum temperature (0.415 , $p < 0.05$), indicating it thrives in warm conditions. *S. incertulas* exhibited a positive correlation with minimum temperature (0.408 , $p < 0.05$), suggesting an increase in population with rising temperatures.

Table 4.3a: Correlation coefficient (r) of insect pests of rice in relation to weather parameters recorded during June to December 2020 in Medziphema

Insect pests	Pearson's correlation coefficient				
	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
<i>Nephotettix virescens</i> Distant	-0.159	-0.078	0.542**	0.111	-0.259
<i>Nephotettix nigropictus</i> Stål	-0.158	-0.109	0.558**	-0.042	-0.229
<i>Cofana spectra</i> Distant	-0.621**	-0.563**	0.757**	-0.328	-0.303
<i>Maistas dorsalis</i> Motchulsky	0.312	0.364	0.074	0.324	0.024
<i>Nilaparvata lugens</i> Stål	-0.149	-0.051	0.517**	0.126	-0.093
<i>Sogatella furcifera</i> Horvith	-0.007	0.051	0.391*	0.192	-0.024
<i>Leptocorisa acuta</i> Thunberg	-0.364	-0.255	0.572**	-0.140	-0.313
<i>Cletus punctiger</i> Dallas	0.044	0.100	0.468*	0.213	-0.154
<i>Scirpophaga incertulas</i> Walker	0.355	0.408*	0.136	0.356	-0.023
<i>Chilo suppressalis</i> Dudgeon	0.296	0.295	0.109	0.381*	0.108
<i>Scirpophaga</i> spp.	0.288	0.323	0.068	0.323	0.116
<i>Scirpophaga nivella</i> Fabricius	0.000	0.000	0.000	0.000	0.000
<i>Cnaphalocrocis medinalis</i> Guenée	-0.156	0.018	0.400*	0.177	-0.039
<i>Melanitis leda ismene</i> Linnaeus	0.323	0.304	0.097	0.165	-0.064
Green horned caterpillars	0.415*	0.316	0.014	0.065	-0.052
<i>Spodoptera litura</i> Fabricius	-0.208	-0.342	0.361	-0.269	-0.201
<i>Leucania loreyi</i> Duponchel	0.142	0.246	0.351	0.363	0.010
<i>Nymphula depunctalis</i> Guenée	0.281	0.242	0.252	0.167	-0.039
<i>Pelopidas mathias</i> Fabricius	0.197	0.281	0.210	0.353	0.007
Short horned grasshoppers	-0.320	-0.304	0.556**	-0.161	-0.168
Field crickets	-0.362	-0.366	0.587**	-0.348	-0.389*
<i>Gryllotalpa orientalis</i> Burmeister	0.171	0.257	0.184	0.148	-0.153
<i>Sitophilus oryzae</i> Linnaeus	-0.926**	-0.947**	0.741**	-0.753**	-0.472*
<i>Dicladyspa armigera</i> Olivier	0.378	0.367	0.053	0.180	-0.122
<i>Stenchaetothrips biformis</i> Bagnall	0.377	0.290	-0.125	-0.022	-0.217

Note: df = (27-2) = 25

$r_{0.05} = 0.381$

$r_{0.01} = 0.487$

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Several pests showed weak or non-significant correlations with temperature. *N. virescens* (-0.159, max temp) and *N. nigropictus* (-0.158, max temp) had weak negative correlations. *N. lugens* (-0.149, max temp) and *C. medinalis* (-0.156, max temp) also had weak correlations.

Most of the insect pests showed positive correlations with relative humidity, indicating that higher humidity levels increase their populations. *C. spectra* had a highly significant positive correlation with maximum humidity (0.757, $p < 0.01$), confirming that humid conditions favor its population. *N. lugens* showed a significant positive correlation with minimum relative humidity (0.517, $p < 0.01$), suggesting that higher humidity levels favor its population growth. Similarly, *S. furcifera* (0.391, $p < 0.05$) and *C. Punctiger* (0.468, $p < 0.05$), exhibited a positive correlation with minimum relative humidity. *C. medinalis* was also positively associated with minimum relative humidity (0.400, $p < 0.05$). *S. oryzae* exhibited a highly significant positive correlation with maximum humidity (0.741, $p < 0.01$), suggesting that this pest thrives in humid conditions. *N. virescens* (0.542, $p < 0.01$), *N. nigropictus* (0.558, $p < 0.01$), *L. acuta* (0.572, $p < 0.01$), short-horned grasshoppers (0.556, $p < 0.01$) and Field crickets (0.587, $p < 0.01$) all showed significant positive correlations with maximum humidity whereas *C. suppressalis* demonstrated a significant positive correlation with minimum humidity ($r = 0.381$, $p < 0.05$).

Some pests had negative correlations with rainfall, indicating that higher rainfall reduces their populations. Field crickets exhibited a significant negative correlation with rainfall ($r = -0.389$, $p < 0.05$), indicating that excessive rainfall might reduce their population. *S. oryzae* also had a significant negative correlation with rainfall (-0.472, $p < 0.05$), confirming that excessive rainfall suppresses its population. Correlations of other insect pests to rainfall were found non-significant.

Upon perusal of table 4.3b, the correlation coefficients (Pearson's r) between insect pests of rice and weather parameters recorded from June to December 2021 at Medziphema.

Table 4.3b: Correlation coefficient (r) of insect pests of rice in relation to weather parameters recorded during June to December 2021 in Medziphema

Insect pests	Pearson's correlation coefficient				
	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
<i>Nephotettix virescens</i> Distant	0.136	0.016	0.183	-0.014	-0.035
<i>Nephotettix nigropictus</i> Stål	-0.224	-0.312	0.459*	-0.281	-0.346
<i>Cofana spectra</i> Distant	-0.484*	-0.558**	0.527**	-0.506**	-0.440*
<i>Recilia dorsalis</i> Motchulsky	0.346	0.321	-0.007	0.323	0.024
<i>Nilaparvata lugens</i> Stål	-0.061	-0.163	0.372	-0.158	-0.258
<i>Sogatella furcifera</i> Horvith	-0.104	-0.187	0.445*	-0.066	-0.267
<i>Leptocorisa acuta</i> Thunberg	-0.250	-0.327	0.451*	-0.215	-0.214
<i>Cletus punctiger</i> Dallas	0.179	0.055	0.189	0.012	-0.125
<i>Scirpophaga incertulas</i> Walker	0.390*	0.354	-0.043	0.288	0.065
<i>Chilo suppressalis</i> Dudgeon	0.317	0.321	-0.052	0.291	-0.018
<i>Scirpophaga</i> spp.	0.376	0.298	-0.006	0.229	0.034
<i>Scirpophaga nivella</i> Fabricius	0.000	0.000	0.000	0.000	0.000
<i>Cnaphalocrocis medinalis</i> Guenée	-0.302	-0.476*	0.445*	-0.548**	-0.265
<i>Melanitis leda ismene</i> Linnaeus	0.033	0.001	0.311	0.050	-0.130
Green horned caterpillars	0.367	0.331	-0.034	0.248	-0.004
<i>Spodoptera litura</i> Fabricius	-0.471*	-0.504**	0.292	-0.476*	-0.311
<i>Leucania loreyi</i> Duponchel	0.113	0.020	0.323	0.042	-0.210
<i>Nymphula depunctalis</i> Guenée	0.223	0.225	0.107	0.215	-0.068
<i>Pelopidas mathias</i> Fabricius	0.206	0.075	0.193	0.031	-0.099
Short horned grasshoppers	-0.374	-0.377	0.290	-0.376	-0.349
Field crickets	-0.405*	-0.484*	0.480*	-0.401*	-0.346
<i>Gryllotalpa orientalis</i> Burmeister	0.185	0.150	0.155	0.195	-0.007
<i>Sitophilus oryzae</i> Linnaeus	-0.941**	-0.952**	0.565**	-0.851**	-0.559**
<i>Dicladyspa armigera</i> Olivier	0.306	0.229	0.088	0.189	-0.079
<i>Stenchaetothrips biformis</i> Bagnall	0.093	0.106	0.114	0.102	-0.012

Note: df = (27-2) = 25

$r_{0.05} = 0.381$

$r_{0.01} = 0.487$

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Some insect pests showed negative correlations with temperature, indicating that higher temperatures reduce their populations. *C. spectra* had a significant negative correlation with maximum temperature (-0.484, $p < 0.05$) and a highly significant negative correlation with minimum temperature (-0.558, $p < 0.01$), confirming that its population declines with increasing temperature. *C. medinalis* exhibited a negative correlation with minimum temperature (-0.476, $p < 0.05$). *S. litura* also showed a significant negative correlation with maximum temperature (-0.471, $p < 0.05$) and a highly significant negative correlation with minimum temperature (-0.504, $p < 0.01$). *S. oryzae* exhibited the strongest negative correlation with maximum temperature (-0.941, $p < 0.01$) and minimum temperature (-0.952, $p < 0.01$), confirming that this pest is highly sensitive to warm conditions. Field crickets had a significant negative correlation with maximum temperature (-0.405, $p < 0.05$) and minimum temperature (-0.484, $p < 0.05$).

Some insect pests showed positive correlations with relative humidity, indicating that higher humidity levels increase their populations. *C. spectra* had a highly significant positive correlation with maximum humidity (0.527, $p < 0.01$) and minimum humidity (-0.506, $p < 0.01$), confirming that humid conditions favor its population. *S. furcifera* demonstrated a significant positive correlation with maximum relative humidity (0.445, $p < 0.05$). *S. oryzae* exhibited a highly significant positive correlation with maximum humidity (0.565, $p < 0.01$), suggesting that this pest thrives in humid conditions. *N. nigropictus* (0.459, $p < 0.05$) and *L. acuta* (0.451, $p < 0.05$) showed significant positive correlations with maximum humidity. *C. medinalis* had a significant positive correlation with maximum humidity (0.445, $p < 0.05$) and a highly significant negative correlation with minimum humidity (-0.548, $p < 0.01$). *S. litura* was significantly negatively correlated with minimum humidity (-0.476, $p < 0.05$). Field Crickets (0.480, $p < 0.05$) exhibited positive correlation with maximum humidity but was negatively correlated with minimum temperature (-0.401, $p < 0.05$) while *S. oryzae* (-0.851, $p < 0.01$) also exhibited negative correlation with minimum humidity indicating high humidity reduced their population.

Some pests had negative correlations with rainfall, indicating that higher rainfall reduces their populations. *S. oryzae* and *C. spectra* had significant negative correlation with rainfall (-0.559, $p < 0.01$) and (-0.440, $p < 0.05$) confirming that excessive rainfall suppresses its population. *C. medinalis* (-0.265) and *S. litura* (-0.311) also had negative correlations with rainfall. Certain pests exhibited positive correlations with rainfall, suggesting their population increases during rainy conditions. Several pests, including field crickets (-0.346) *N. lugens* (-0.258), *C. medinalis* (-0.265), and *P. mathias* (-0.099), showed weak or no correlation with rainfall.

From the above findings and with the data collected, a regression model was prepared between insect pest and weather parameters at Medziphema for 2020 and 2021 which is presented in table 4.3c.

Table 4.3c: Regression equations between insect pest and weather parameters at Medziphema for 2020 and 2021

Insect pest	Year	Regression Equation	R ²
<i>Nephotettix virescens</i> Distant	2020	$y = -444.868 + 1.846X_1 - 0.315X_2 + 3.952X_3 + 0.425X_4 - 0.006X_5$	0.440
	2021	$y = -268.294 + 5.264X_1 - 2.510X_2 + 1.573X_3 + 0.273X_4 - 0.042X_5$	0.228
<i>Nephotettix nigropictus</i> Stål	2020	$y = -101.927 - 0.213X_1 + 0.576X_2 + 1.111X_3 - 0.095X_4 - 0.004X_5$	0.526
	2021	$y = -61.084 + 0.746X_1 - 0.314X_2 + 0.501X_3 + 0.009X_4 - 0.022X_5$	0.320
<i>Cofana spectra</i> Distant	2020	$y = -45.249 - 0.337X_1 + 0.196X_2 + 0.583X_3 - 0.023X_4 - 0.002X_5$	0.600
	2021	$y = -24.395 + 0.276X_1 - 0.207X_2 + 0.246X_3 - 0.013X_4 - 0.010X_5$	0.402
<i>Maiestas dorsalis</i> Motchulsky	2020	$y = -62.329 - 0.009X_1 + 0.401X_2 + 0.608X_3 - 0.028X_4 - 0.004X_5$	0.377
	2021	$y = -42.124 + 0.576X_1 - 0.124X_2 + 0.266X_3 + 0.060X_4 - 0.017X_5$	0.263
<i>Nilaparvata lugens</i> Stål	2020	$y = -1040.090 - 2.962X_1 + 5.016X_2 + 11.007X_3 + 0.086X_4 - 0.067X_5$	0.488
	2021	$y = -750.896 + 10.608X_1 - 4.127X_2 + 5.543X_3 + 0.277X_4 - 0.249X_5$	0.301
<i>Sogatella furcifera</i> Horvith	2020	$y = -129.849 + 0.156X_1 + 0.284X_2 + 1.240X_3 + 0.066X_4 - 0.008X_5$	0.377
	2021	$y = -129.764 + 2.094X_1 - 1.395X_2 + 0.837X_3 + 0.305X_4 - 0.032X_5$	0.410
<i>Leptocorisa acuta</i> Thunberg	2020	$y = -141.370 - 1.940X_1 + 1.780X_2 + 1.956X_3 - 0.206X_4 - 0.027X_5$	0.497
	2021	$y = -122.580 + 2.151X_1 - 1.796X_2 + 0.834X_3 + 0.334X_4 - 0.006X_5$	0.301
<i>Cletus punctiger</i> Dallas	2020	$y = -77.796 + 0.132X_1 + 0.173X_2 + 0.725X_3 + 0.044X_4 - 0.012X_5$	0.642
	2021	$y = -57.169 + 1.026X_1 - 0.381X_2 + 0.349X_3 + 0.034X_4 - 0.019X_5$	0.319
<i>Scirpophaga incertulas</i> Walker	2020	$y = -115.773 + 0.058X_1 + 0.658X_2 + 1.111X_3 - 0.043X_4 - 0.011X_5$	0.579
	2021	$y = -61.089 + 0.652X_1 + 0.159X_2 + 0.439X_3 - 0.024X_4 - 0.025X_5$	0.267
<i>Chilo suppressalis</i> Dudgeon	2020	$y = -34.246 + 0.312X_1 - 0.113X_2 + 0.243X_3 + 0.065X_4 - 0.004X_5$	0.381
	2021	$y = -21.012 + 0.149X_1 + 0.133X_2 + 0.161X_3 - 0.006X_4 - 0.015X_5$	0.224
<i>Scirpophaga</i> spp.	2020	$y = -67.451 + 0.154X_1 + 0.273X_2 + 0.622X_3 - 0.014X_4 + 0.002X_5$	0.292
	2021	$y = -54.525 + 0.867X_1 - 0.151X_2 + 0.336X_3 + 0.015X_4 - 0.020X_5$	0.292
<i>Cnaphalocrocis medinalis</i> Guenée	2020	$y = -43.074 - 0.691X_1 + 0.643X_2 + 0.581X_3 - 0.046X_4 - 0.002X_5$	0.473
	2021	$y = -29.867 + 0.613X_1 - 0.305X_2 + 0.227X_3 - 0.044X_4 - 0.002X_5$	0.463
<i>Melanitis leda ismene</i> Linnaeus	2020	$y = -40.482 + 0.108X_1 + 0.213X_2 + 0.391X_3 - 0.053X_4 - 0.000X_5$	0.397
	2021	$y = -29.094 + 0.255X_1 - 0.069X_2 + 0.238X_3 + 0.022X_4 - 0.007X_5$	0.223
Green horned	2020	$y = -26.281 + 0.159X_1 + 0.104X_2 + 0.243X_3 - 0.055X_4 + 0.003X_5$	0.494

caterpillars	2021	$y = -10.891 + 0.102X_1 + 0.065X_2 + 0.082X_3 - 0.013X_4 - 0.007X_5$	0.251
<i>Spodoptera litura</i> Fabricius	2020	$y = -1.606 + 0.033X_1 - 0.025X_2 + 0.009X_3 + 0.003X_4 - 0.000X_5$	0.296
	2021	$y = 0.537 - 0.006X_1 - 0.004X_2 - 0.001X_3 - 0.002X_4 - 0.000X_5$	0.261
<i>Leucania loreyi</i> Duponchel	2020	$y = -50.723 - 0.044X_1 + 0.236X_2 + 0.497X_3 + 0.012X_4 - 0.004X_5$	0.631
	2021	$y = -39.798 + 0.546X_1 - 0.200X_2 + 0.274X_3 + 0.035X_4 - 0.014X_5$	0.415
<i>Nymphula depunctalis</i> Guenée	2020	$y = -157.794 + 0.698X_1 + 0.400X_2 + 1.452X_3 - 0.119X_4 + 0.005X_5$	0.548
	2021	$y = -72.598 + 0.320X_1 + 0.386X_2 + 0.638X_3 - 0.032X_4 - 0.035X_5$	0.234
<i>Pelopidas mathias</i> Fabricius	2020	$y = -25.430 - 0.006X_1 + 0.113X_2 + 0.240X_3 + 0.015X_4 - 0.004X_5$	0.437
	2021	$y = -21.296 + 0.384X_1 - 0.149X_2 + 0.128X_3 + 0.015X_4 - 0.006X_5$	0.353
Short horned grasshoppers	2020	$y = -48.381 - 0.010X_1 + 0.111X_2 + 0.540X_3 - 0.026X_4 + 0.002X_5$	0.330
	2021	$y = 3.899 - 0.374X_1 + 0.317X_2 + 0.129X_3 - 0.107X_4 - 0.013X_5$	0.206
Field crickets	2020	$y = -71.934 - 0.262X_1 + 0.477X_2 + 0.890X_3 - 0.150X_4 - 0.004X_5$	0.445
	2021	$y = -47.791 + 0.867X_1 - 0.766X_2 + 0.381X_3 + 0.089X_4 - 0.010X_5$	0.330
<i>Gryllotalpa orientalis</i> Burmeister	2020	$y = -66.941 - 0.578X_1 + 0.951X_2 + 0.820X_3 - 0.165X_4 - 0.005X_5$	0.495
	2021	$y = -42.998 + 0.572X_1 - 0.255X_2 + 0.292X_3 + 0.077X_4 - 0.009X_5$	0.204
<i>Sitophilus oryzae</i> Linnaeus	2020	$y = 13.139 - 0.811X_1 - 0.239X_2 + 0.300X_3 - 0.114X_4 - 0.003X_5$	0.930
	2021	$y = 82.907 - 1.566X_1 - 0.176X_2 - 0.152X_3 - 0.186X_4 + 0.009X_5$	0.945
<i>Dicladispa armigera</i> Olivier	2020	$y = -143.990 + 0.227X_1 + 0.971X_2 + 1.412X_3 - 0.210X_4 - 0.011X_5$	0.479
	2021	$y = -164.981 + 2.420X_1 - 0.488X_2 + 1.066X_3 + 0.077X_4 - 0.071X_5$	0.337
<i>Stenchaetothrips biformis</i> Bagnall	2020	$y = -52.984 + 0.350X_1 + 0.448X_2 + 0.507X_3 - 0.188X_4 - 0.010X_5$	0.354
	2021	$y = -34.639 - 0.052X_1 + 0.320X_2 + 0.375X_3 - 0.042X_4 - 0.010X_5$	0.079

4.3.3. CORRELATION OF INSECT PESTS OF RICE WITH WEATHER PARAMETERS AT SINGJIRAN

As evident from table 4.3d, the correlation between insect pests of rice and weather parameters (temperature, humidity, and rainfall) recorded in Singjiran from June to December 2020 are presented below.

Some insect pests showed a significant negative correlation with temperature, indicating that higher temperatures reduce their populations. *N. virescens* had a strong negative correlation with maximum temperature (-0.548, $p < 0.01$) and minimum temperature (-0.478, $p < 0.05$), suggesting that warm conditions are unfavorable for its survival. *C. spectra* exhibited an even stronger negative correlation with maximum temperature (-0.598, $p < 0.01$) and minimum temperature (-0.580, $p < 0.01$), meaning this species significantly declines as temperature increases. *N. nigropictus* also showed a negative correlation with maximum temperature (-0.403, $p < 0.05$), though its correlation with minimum temperature was weaker (-0.277, not significant). *S. oryzae* had the strongest negative correlation with maximum temperature (-0.899,

Table 4.3d: Correlation coefficient (r) of insect pests of rice in relation to weather parameters recorded during June to December 2020 in Singjiran

Insect pests	Pearson's correlation coefficient				
	Temperature (°C)		Relative humidity(%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
<i>Nephotettix virescens</i> Distant	-0.548**	-0.478*	-0.233	0.116	-0.088
<i>Nephotettix nigropictus</i> Stål	-0.403*	-0.277	-0.049	0.173	0.064
<i>Cofana spectra</i> Distant	-0.598**	-0.580**	-0.306	0.053	-0.078
<i>Recilia dorsalis</i> Motchulsky	0.448*	0.520**	0.362	0.309	0.151
<i>Nilaparvata lugens</i> Stål	-0.193	-0.101	0.032	0.233	0.065
<i>Sogatella furcifera</i> Horvith	-0.321	-0.229	-0.037	0.173	0.092
<i>Leptocorisa acuta</i> Thunberg	0.111	0.183	0.347	0.302	0.246
<i>Cletus punctiger</i> Dallas	0.047	0.135	0.146	0.373	-0.141
<i>Scirpophaga incertulas</i> Walker	0.278	0.365	0.344	0.319	0.218
<i>Chilo suppressalis</i> Dudgeon	0.338	0.356	0.347	0.200	-0.048
<i>Scirpophaga</i> spp.	0.194	0.293	0.270	0.277	0.062
<i>Scirpophaga nivella</i> Fabricius	0.000	0.000	0.000	0.000	0.000
<i>Cnaphalocrocis medinalis</i> Guenée	-0.221	-0.119	0.095	0.231	0.163
<i>Melanitis leda ismene</i> Linnaeus	0.234	0.259	0.257	0.198	-0.168
Green horned caterpillars	0.457*	0.509**	0.300	0.153	-0.030
<i>Spodoptera litura</i> Fabricius	-0.052	0.035	0.242	0.242	0.230
<i>Leucania loreyi</i> Duponchel	0.054	0.118	0.224	0.226	0.161
<i>Nymphula depunctalis</i> Guenée	0.281	0.348	0.159	0.109	0.009
<i>Pelopidas mathias</i> Fabricius	0.102	0.239	0.230	0.282	-0.025
Short horned grasshoppers	-0.038	0.051	0.113	0.220	-0.156
Field crickets	-0.070	0.051	0.161	0.360	0.088
<i>Gryllotalpa orientalis</i> Burmeister	0.233	0.314	0.271	0.274	0.111
<i>Sitophilus oryzae</i> Linnaeus	-0.899**	-0.928**	-0.750**	-0.262	-0.357
<i>Di cladispa armigera</i> Olivier	0.282	0.384*	0.194	0.243	-0.094
<i>Stenchaetothrips biformis</i> Bagnall	0.539**	0.628**	0.386*	0.406*	0.083

Note: df = (27-2) = 25

$r_{0.05} = 0.381$

$r_{0.01} = 0.487$

* = Significant at 5% level of significance

** = Significant at 1% level of significance

$p < 0.01$) and minimum temperature (-0.928 , $p < 0.01$), confirming that this pest prefers cooler conditions.

M. dorsalis had a positive correlation with maximum temperature (0.448 , $p < 0.05$) and minimum temperature (0.520 , $p < 0.01$), meaning it thrives in warmer conditions. Green horned caterpillars showed a positive correlation with maximum temperature (0.457 , $p < 0.05$) and minimum temperature (0.509 , $p < 0.01$), suggesting it is favored by higher temperatures. *S. biformis* exhibited a strong positive correlation with maximum temperature (0.539 , $p < 0.01$) and minimum temperature (0.628 , $p < 0.01$), indicating a clear preference for warm conditions.

Several pests, including *N. lugens* (-0.193 , max temp), *C. medinalis* (-0.221 , max temp), and *S. litura* (-0.052 , max temp), showed weak or non-significant correlations with temperature.

S. oryzae showed a strong negative correlation with maximum humidity (-0.750 , $p < 0.01$), meaning high humidity reduces its population. *S. biformis* had a positive correlation with maximum humidity (0.386 , $p < 0.05$) and minimum humidity (0.406 , $p < 0.05$), meaning it thrives in humid conditions.

Table 4.3e presents the correlation coefficients (Pearson's r) at Singrijan between insect pests of rice and weather parameters recorded from June to December 2021.

Some insect pests showed a significant negative correlation with temperature, indicating that higher temperatures reduced their population. *C. spectra* showed a negative correlation with maximum temperature (-0.469 , $p < 0.05$) and minimum temperature (-0.449 , $p < 0.05$), suggesting that an increase in temperature negatively impacts its population. *S. oryzae* had the strongest negative correlation with maximum temperature (-0.964 , $p < 0.01$) and minimum temperature (-0.971 , $p < 0.01$), confirming that this pest thrives in cooler conditions.

Table 4.3e: Correlation coefficient (r) of insect pests of rice in relation to weather parameters recorded during June to December 2021 in Singjiran

Insect pests	Pearson's correlation coefficient				
	Temperature (°C)		Relative humidity(%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
<i>Nephotettix virescens</i> Distant	-0.287	-0.268	-0.120	-0.335	-0.218
<i>Nephotettix nigropictus</i> Stål	0.094	0.115	0.204	0.021	-0.077
<i>Cofana spectra</i> Distant	-0.469*	-0.449*	-0.338	-0.534**	-0.227
<i>Recilia dorsalis</i> Motchulsky	0.446*	0.447*	0.460*	0.353	0.086
<i>Nilaparvata lugens</i> Stål	-0.059	-0.050	0.105	-0.159	-0.254
<i>Sogatella furcifera</i> Horvith	-0.104	-0.085	-0.031	-0.205	-0.230
<i>Leptocorisa acuta</i> Thunberg	0.010	0.036	-0.084	-0.056	-0.091
<i>Cletus punctiger</i> Dallas	0.224	0.251	0.178	0.112	0.426
<i>Scirpophaga incertulas</i> Walker	0.332	0.344	0.432*	0.232	0.017
<i>Chilo suppressalis</i> Dudgeon	0.406*	0.409*	0.508**	0.379	0.241
<i>Scirpophaga</i> spp.	0.316	0.309	0.421*	0.159	-0.047
<i>Scirpophaga nivella</i> Fabricius	0.000	0.000	0.000	0.000	0.000
<i>Cnaphalocrocis medinalis</i> Guenée	-0.157	-0.154	-0.183	-0.245	-0.261
<i>Melanitis leda ismene</i> Linnaeus	0.208	0.214	0.072	0.127	0.100
Green horned caterpillars	0.408*	0.419*	0.387*	0.324	0.358
<i>Spodoptera litura</i> Fabricius	-0.050	-0.053	-0.055	-0.170	-0.236
<i>Leucania loreyi</i> Duponchel	0.152	0.153	0.198	0.036	-0.096
<i>Nymphula depunctalis</i> Guenée	0.239	0.236	0.354	0.129	0.135
<i>Pelopidas mathias</i> Fabricius	0.275	0.279	0.440*	0.111	0.019
Short horned grasshoppers	-0.256	-0.272	-0.136	-0.209	-0.157
Field crickets	0.028	0.047	0.060	-0.134	-0.004
<i>Gryllotalpa orientalis</i> Burmeister	0.298	0.303	0.345	0.195	0.055
<i>Sitophilus oryzae</i> Linnaeus	-0.964**	-0.971**	-0.731**	-0.854**	-0.244
<i>Dicladispa armigera</i> Olivier	0.228	0.222	0.346	0.084	0.098
<i>Stenchaetothrips biformis</i> Bagnall	0.478*	0.478*	0.427*	0.481*	0.202

Note: df = (27-2) = 25

$r_{0.05} = 0.381$

$r_{0.01} = 0.487$

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Some pests showed a significant positive correlation with temperature, meaning warmer temperatures favor their population growth. *M. dorsalis* had a positive correlation with maximum temperature (0.446, $p < 0.05$) and minimum temperature (0.447, $p < 0.05$), suggesting that it thrives in warm environments. *C. suppressalis* exhibited significant positive correlations with maximum temperature (0.406, $p < 0.05$) and minimum temperature (0.409, $p < 0.05$), indicating that higher temperatures enhance its survival. Green horned caterpillars showed a positive correlation with maximum temperature (0.408, $p < 0.05$) and minimum temperature (0.419, $p < 0.05$). *S. biformis* displayed a positive correlation with maximum temperature (0.478, $p < 0.05$) and minimum temperature (0.478, $p < 0.05$), suggesting that it prefers warm conditions.

Several pests showed weak or non-significant correlations with temperature. *N. virescens* (-0.287, max temp), *N. lugens* (-0.059, max temp), and *S. litura* (-0.050, max temp) had weak negative correlations. *C. punctiger* (0.224, max temp) and *L. acuta* (0.010, max temp) had weak positive correlations.

Some insect pests showed negative correlations with relative humidity, indicating that higher humidity reduces their population. *S. oryzae* had the strongest negative correlation with maximum humidity (-0.731, $p < 0.01$) and minimum humidity (-0.854, $p < 0.01$), meaning that high humidity is unfavorable for this pest. *C. spectra* exhibited a significant negative correlation with minimum humidity (-0.534, $p < 0.01$), showing that high moisture levels negatively affect its population. *Scirpophaga* spp. (0.421, $p < 0.05$), green horned caterpillars (0.387, $p < 0.05$) and *S. biformis* (0.427, $p < 0.05$) all showed significant positive correlation with maximum relative humidity indicating that higher humidity levels favor their population.

Certain pests showed a positive correlation with relative humidity, meaning higher humidity levels increased their numbers. *M. dorsalis* (0.460, $p < 0.05$), and *P. mathias* (0.440, $p < 0.05$) showed a positive correlation with maximum humidity suggesting it benefits from humid conditions. *C. suppressalis* had a strong positive correlation with maximum humidity (0.508, $p < 0.01$). *S. incertulas* also showed a significant positive correlation with maximum humidity (0.432, $p < 0.05$). *S. biformis*

Table 4.3f: Regression equations between insect pest and weather parameters at Singrijan for 2020 and 2021

Insect Pest	year	Regression Equation	R ²
<i>Nephotettix virescens</i> Distant	2020	$y = -1312 - 12.818X_1 + 1.265X_2 + 18.661X_3 + 0.543X_4 - 0.035X_5$	0.445
	2021	$y = 394.148 - 24.188X_1 + 20.007X_2 + 0.956X_3 - 1.549X_4 - 0.096X_5$	0.243
<i>Nephotettix nigropictus</i> Stål	2020	$y = -850.886 - 11.294X_1 + 3.577X_2 + 12.351X_3 + 0.360X_4 + 0.013X_5$	0.479
	2021	$y = -21.197 - 2.887X_1 + 2.587X_2 + 0.807X_3 - 0.184X_4 - 0.010X_5$	0.146
<i>Cofana spectra</i> Distant	2020	$y = -146.327 - 0.548X_1 - 0.660X_2 + 1.883X_3 + 0.156X_4 + 0.001X_5$	0.501
	2021	$y = 195.831 - 5.189X_1 + 4.338X_2 - 1.026X_3 - 0.362X_4 - 0.019X_5$	0.425
<i>Maistas dorsalis</i> Motchulsky	2020	$y = 16.433 - 1.540X_1 + 1.804X_2 + 0.201X_3 - 0.274X_4 + 0.000X_5$	0.417
	2021	$y = -163.124 + 0.393X_1 + 0.075X_2 + 1.734X_3 - 0.077X_4 + 0.000X_5$	0.250
<i>Nilaparvata lugens</i> Stål	2020	$y = -1957 - 28.345X_1 + 10.539X_2 + 28.975X_3 + 0.978X_4 + 0.027X_5$	0.200
	2021	$y = -579.733 - 47.180X_1 + 43.754X_2 + 16.836X_3 - 4.721X_4 - 0.307X_5$	0.215
<i>Sogatella furcifera</i> Horvith	2020	$y = -929.099 - 11.190X_1 + 3.108X_2 + 13.336X_3 + 0.383X_4 + 0.044X_5$	0.296
	2021	$y = 971.775 - 32.123X_1 + 29.281X_2 - 4.429X_3 - 2.188X_4 - 0.155X_5$	0.264
<i>Leptocoris acuta</i> Thunberg	2020	$y = -267.352 - 1.667X_1 + 0.728X_2 + 3.425X_3 - 0.047X_4 + 0.012X_5$	0.246
	2021	$y = 400.843 - 6.880X_1 + 6.309X_2 - 3.216X_3 - 0.289X_4 - 0.026X_5$	0.232
<i>Cletus punctiger</i> Dallas	2020	$y = -40.040 - 0.894X_1 + 0.532X_2 + 0.641X_3 + 0.032X_4 - 0.014X_5$	0.184
	2021	$y = -18.267 - 0.791X_1 + 0.795X_2 + 0.374X_3 - 0.085X_4 + 0.008X_5$	0.249
<i>Scirpophaga incertulas</i> Walker	2020	$y = -129.151 - 3.067X_1 + 2.392X_2 + 2.058X_3 - 0.094X_4 + 0.016X_5$	0.225
	2021	$y = -315.877 - 2.534X_1 + 2.747X_2 + 4.000X_3 - 0.317X_4 - 0.009X_5$	0.230
<i>Chilo suppressalis</i> Dudgeon	2020	$y = -84.197 - 0.355X_1 + 0.413X_2 + 1.033X_3 - 0.087X_4 - 0.013X_5$	0.203
	2021	$y = -129.126 + 0.758X_1 - 0.645X_2 + 1.298X_3 + 0.020X_4 + 0.006X_5$	0.329
<i>Scirpophaga</i> spp.	2020	$y = -98.741 - 2.486X_1 + 1.837X_2 + 1.647X_3 - 0.110X_4 - 0.010X_5$	0.214
	2021	$y = -333.208 + 0.788X_1 + 0.117X_2 + 3.623X_3 - 0.324X_4 - 0.007X_5$	0.260
<i>Cnaphalocrocis medinalis</i> Guenée	2020	$y = -162.586 - 1.570X_1 + 0.289X_2 + 2.152X_3 + 0.183X_4 + 0.009X_5$	0.389
	2021	$y = 181.497 - 2.583X_1 + 2.520X_2 - 1.503X_3 - 0.209X_4 - 0.018X_5$	0.216
<i>Melanitis leda ismene</i> Linnaeus	2020	$y = -39.158 - 0.251X_1 + 0.232X_2 + 0.516X_3 - 0.055X_4 - 0.008X_5$	0.231
	2021	$y = 27.921 - 0.276X_1 + 0.343X_2 - 0.262X_3 - 0.025X_4 - 0.001X_5$	0.079
Green horned caterpillars	2020	$y = 5.471 - 0.350X_1 + 0.469X_2 + 0.030X_3 - 0.096X_4 - 0.004X_5$	0.577
	2021	$y = -44.426 + 0.191X_1 - 0.099X_2 + 0.456X_3 - 0.011X_4 + 0.004X_5$	0.279
<i>Spodoptera litura</i> Fabricius	2020	$y = -28.260 - 0.196X_1 + 0.047X_2 + 0.359X_3 + 0.015X_4 + 0.002X_5$	0.311
	2021	$y = 12.846 - 0.224X_1 + 0.247X_2 - 0.097X_3 - 0.030X_4 - 0.002X_5$	0.166
<i>Leucania loreyi</i> Duponchel	2020	$y = -135.293 - 1.116X_1 + 0.507X_2 + 1.782X_3 - 0.000X_4 + 0.006X_5$	0.129
	2021	$y = -50.495 - 1.127X_1 + 1.395X_2 + 0.797X_3 - 0.213X_4 - 0.010X_5$	0.114
<i>Nymphula depunctalis</i> Guenée	2020	$y = 71.410 - 1.497X_1 + 1.733X_2 - 0.438X_3 - 0.287X_4 - 0.008X_5$	0.330
	2021	$y = -241.282 + 1.274X_1 - 0.875X_2 + 2.501X_3 - 0.111X_4 + 0.008X_5$	0.190
<i>Pelopidas mathias</i> Fabricius	2020	$y = -17.239 - 0.644X_1 + 0.406X_2 + 0.310X_3 + 0.020X_4 - 0.005X_5$	0.327
	2021	$y = -60.030 - 0.027X_1 + 0.116X_2 + 0.687X_3 - 0.058X_4 - 0.000X_5$	0.296
Short horned grasshoppers	2020	$y = -61.252 - 0.927X_1 + 0.486X_2 + 0.921X_3 + 0.013X_4 - 0.014X_5$	0.197
	2021	$y = -42.551 + 0.827X_1 - 0.848X_2 + 0.410X_3 + 0.026X_4 + 0.000X_5$	0.103
Field crickets	2020	$y = -209.599 - 3.658X_1 + 1.569X_2 + 3.133X_3 + 0.263X_4 - 0.003X_5$	0.299
	2021	$y = 103.227 - 5.585X_1 + 5.500X_2 + 0.034X_3 - 0.573X_4 - 0.016X_5$	0.205
<i>Gryllotalpa orientalis</i> Burmeister	2020	$y = -21.092 - 0.708X_1 + 0.578X_2 + 0.388X_3 - 0.040X_4 - 0.001X_5$	0.177
	2021	$y = -36.039 - 0.076X_1 + 0.159X_2 + 0.422X_3 - 0.037X_4 - 0.000X_5$	0.152
<i>Sitophilus oryzae</i> Linnaeus	2020	$y = -5.681 - 0.202X_1 - 0.748X_2 + 0.354X_3 - 0.006X_4 - 0.010X_5$	0.871
	2021	$y = 37.753 + 0.249X_1 - 1.139X_2 - 0.194X_3 - 0.006X_4 + 0.003X_5$	0.946
<i>Di cladispa armigera</i> Olivier	2020	$y = 60.464 - 1.771X_1 + 1.746X_2 - 0.309X_3 - 0.157X_4 - 0.020X_5$	0.367
	2021	$y = -370.141 + 1.989X_1 - 1.209X_2 + 3.851X_3 - 0.248X_4 + 0.009X_5$	0.207
<i>Stenchaetothrips biformis</i> Bagnall	2020	$y = 108.973 - 1.939X_1 + 2.455X_2 - 0.838X_3 - 0.262X_4 - 0.011X_5$	0.559
	2021	$y = -191.263 + 1.955X_1 - 1.477X_2 + 1.696X_3 + 0.163X_4 + 0.011X_5$	0.282

exhibited a positive correlation with maximum humidity (0.427, $p < 0.05$) and minimum humidity (0.481, $p < 0.05$).

Several pests, including *N. virescens* (-0.120, max humidity), *N. lugens* (0.105, max humidity), and *C. medinalis* (-0.183, max humidity), showed non significant, weak or no correlation with humidity.

4.3.3: CORRELATION OF INSECT PESTS OF RICE WITH WEATHER PARAMETERS AT KUHOXU

Table 4.3g presents the correlation between insect pests of rice and weather parameters (temperature, humidity, and rainfall) recorded in Kuhoxu from June to December 2020. Some insect pests showed a significant negative correlation with temperature, indicating that higher temperatures reduce their populations. *N. virescens* exhibited a significant negative correlation with maximum temperature (-0.477, $p < 0.05$) and a highly significant negative correlation with minimum temperature (-0.718, $p < 0.01$). This suggests that as temperatures rise, the population of this pest declines. *C. spectra* also had a significant negative correlation with maximum temperature (-0.482, $p < 0.05$) and a highly significant negative correlation with minimum temperature (-0.687, $p < 0.01$), confirming that this pest is negatively affected by increasing temperatures. *N. nigropictus* exhibited a negative correlation with minimum temperature (-0.449, $p < 0.01$). *S. oryzae* exhibited the strongest negative correlation with maximum temperature (-0.920, $p < 0.01$) and minimum temperature (-0.907, $p < 0.01$), indicating that this species thrives in cooler conditions and is significantly impacted by rising temperatures.

Some pests showed a significant positive correlation with temperature, meaning warmer temperatures favor their population growth. *Scirpophaga* spp. was positively influenced by maximum temperature (0.395, $p < 0.05$). Minimum temperature (0.438, $p < 0.05$) also had a positive correlation with green horned caterpillars indicating that they thrive in higher temperatures. *M. dorsalis* had a positive

Table 4.3g: Correlation coefficient (r) of insect pests of rice in relation to weather parameters recorded during June to December 2020 in Kuhoxu

Insect pests	Pearson's correlation coefficient				
	Temperature (°C)		Relative humidity(%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
<i>Nephotettix virescens</i> Distant	-0.477*	-0.718**	-0.431*	-0.292	-0.333
<i>Nephotettix nigropictus</i> Stål	-0.153	-0.449*	-0.407*	-0.022	-0.184
<i>Cofana spectra</i> Distant	-0.482*	-0.687**	-0.415*	-0.321	-0.268
<i>Recilia dorsalis</i> Motchulsky	0.391*	0.277	-0.107	0.318	0.031
<i>Nilaparvata lugens</i> Stål	0.122	-0.162	-0.276	0.179	-0.061
<i>Sogatella furcifera</i> Horvith	-0.033	-0.308	-0.286	0.024	-0.106
<i>Leptocorisa acuta</i> Thunberg	0.237	-0.024	-0.101	0.312	0.118
<i>Cletus punctiger</i> Dallas	0.271	0.092	-0.138	0.364	-0.093
<i>Scirpophaga incertulas</i> Walker	0.402*	0.164	-0.082	0.377	0.118
<i>Chilo suppressalis</i> Dudgeon	0.409*	0.281	0.041	0.390*	0.151
<i>Scirpophaga</i> spp.	0.395*	0.223	-0.022	0.405*	0.141
<i>Scirpophaga nivella</i> Fabricus	0.094	-0.106	-0.182	0.205	-0.065
<i>Cnaphalocrocis medinalis</i> Guenée	0.031	-0.271	-0.280	0.177	-0.063
<i>Melanitis leda ismene</i> Linnaeus	0.347	0.216	-0.022	0.346	0.073
Green horned caterpillars	0.324	0.438*	-0.008	0.173	0.205
<i>Spodoptera litura</i> Fabricius	0.260	0.019	0.054	0.322	0.145
<i>Leucania loreyi</i> Duponchel	0.281	-0.045	-0.337	0.361	0.029
<i>Nymphula depunctalis</i> Guenée	0.242	0.307	0.010	0.121	-0.008
<i>Pelopidas mathias</i> Fabricius	0.279	-0.011	-0.255	0.373	0.021
Short horned grasshoppers	0.029	-0.095	-0.067	0.153	-0.056
Field crickets	0.110	-0.122	-0.226	0.245	-0.072
<i>Gryllotalpa orientalis</i> Burmeister	0.333	0.127	-0.168	0.250	0.102
<i>Sitophilus oryzae</i> Linnaeus	-0.920**	-0.907**	-0.368	-0.750**	-0.465*
<i>Diadisa armigera</i> Olivier	0.309	0.173	-0.264	0.240	-0.103
<i>Stenchaetothrips biformis</i> Bagnall	0.468*	0.522**	0.086	0.316	0.058

Note: df = (27-2) = 25

$r_{0.05} = 0.381$

$r_{0.01} = 0.487$

* = Significant at 5% level of significance

** = Significant at 1% level of significance

correlation with maximum temperature (0.391, $p < 0.05$), suggesting that it thrives in warm conditions. *S. incertulas* exhibited a significant positive correlation with maximum temperature (0.402, $p < 0.05$), indicating that its population increases with rising temperatures. *C. suppressalis* also showed a significant positive correlation with maximum temperature (0.409, $p < 0.05$), meaning that higher temperatures favor its population growth. *S. biformis* displayed a significant positive correlation with maximum temperature (0.468, $p < 0.05$) and minimum temperature (0.522, $p < 0.01$), suggesting that it prefers warm conditions.

Some insect pests showed negative correlations with relative humidity, indicating that higher humidity reduces their population. *N. virescens* had a significant negative correlation with maximum humidity (-0.431, $p < 0.05$), suggesting that humid conditions are not favorable for this species. *C. spectra* exhibited a significant negative correlation with maximum humidity (-0.415, $p < 0.05$), indicating that high humidity negatively affects its population. *N. nigropictus* had a significant negative correlation with maximum humidity (-0.407, $p < 0.05$). *S. oryzae* also exhibited a strong negative correlation with minimum humidity (-0.750, $p < 0.05$).

Certain pests showed a positive correlation with relative humidity, meaning higher humidity levels increased their numbers. *C. suppressalis* had a significant positive correlation with minimum humidity (0.390, $p < 0.05$), indicating that this species thrives in more humid environments. *Scirpophaga* spp. exhibited a significant positive correlation with minimum humidity (0.405, $p < 0.05$), meaning that its population increases in humid conditions.

Some pests had negative correlations with rainfall, indicating that higher rainfall reduces their population. *S. oryzae* had a significant negative correlation with rainfall (-0.465, $p < 0.05$), confirming that excessive rain suppresses its presence.

Table 4.3h presents the correlation coefficients (Pearson's r) at Kuhoxu between insect pests of rice and weather parameters recorded from June to December 2021.

Table 4.3h: Correlation coefficient (r) of insect pests of rice in relation to weather parameters recorded during June to December 2021in Kuhoxu

Insect pests	Pearson's correlation coefficient				
	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
<i>Nephotettix virescens</i> Distant	-0.412*	-0.399*	-0.555**	-0.546**	-0.518**
<i>Nephotettix nigropictus</i> Stål	0.005	0.073	-0.198	-0.114	-0.334
<i>Cofana spectra</i> Distant	-0.275	-0.260	-0.405*	-0.455*	-0.435*
<i>Recilia dorsalis</i> Motchulsky	0.536**	0.478*	0.147	0.249	0.116
<i>Nilaparvata lugens</i> Stål	0.137	0.157	-0.161	-0.125	-0.236
<i>Sogatella furcifera</i> Horvith	-0.280	-0.292	-0.539**	-0.495**	-0.484*
<i>Leptocorisa acuta</i> Thunberg	0.158	0.227	-0.127	0.067	-0.105
<i>Cletus punctiger</i> Dallas	0.291	0.348	0.132	0.155	0.141
<i>Scirpophaga incertulas</i> Walker	0.396*	0.441*	0.087	0.168	-0.010
<i>Chilo suppressalis</i> Dudgeon	0.602**	0.557**	0.417*	0.383*	0.306
<i>Scirpophaga</i> spp.	0.377	0.360	0.061	0.139	-0.153
<i>Scirpophaga nivella</i> Fabricius	0.052	0.068	-0.064	-0.106	-0.324
<i>Cnaphalocrocis medinalis</i> Guenée	0.087	0.150	-0.202	-0.114	-0.283
<i>Melanitis leda ismene</i> Linnaeus	0.420*	0.352	-0.008	0.079	0.056
Green horned caterpillars	0.451*	0.457*	0.337	0.340	0.222
<i>Spodoptera litura</i> Fabricius	0.133	0.212	-0.137	-0.027	-0.163
<i>Leucania loreyi</i> Duponchel	0.266	0.329	0.028	0.074	-0.097
<i>Nymphula depunctalis</i> Guenée	0.530**	0.373	0.308	0.309	0.247
<i>Pelopidas mathias</i> Fabricius	0.429*	0.433*	0.199	0.198	0.032
Short horned grasshoppers	-0.020	-0.147	-0.027	-0.199	-0.180
Field crickets	-0.068	-0.075	-0.492	-0.335	-0.295
<i>Gryllotalpa orientalis</i> Burmeister	0.303	0.213	0.047	0.037	-0.250
<i>Sitophilus oryzae</i> Linnaeus	-0.874**	-0.925**	-0.685**	-0.866**	-0.510**
<i>Dicladispa armigera</i> Olivier	0.394*	0.353	0.090	0.087	0.114
<i>Stenchaetothrips biformis</i> Bagnall	0.558**	0.446*	0.291	0.361	0.208

Note: df = (27-2) = 25

$r_{0.05} = 0.381$

$r_{0.01} = 0.487$

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Some insect pests showed a significant negative correlation with temperature, indicating that higher temperatures reduce their populations. *N. virescens* exhibited a significant negative correlation with maximum temperature (-0.412, $p < 0.05$) and minimum temperature (-0.399, $p < 0.05$), suggesting that increasing temperatures negatively impact its population. *S. oryzae* had the strongest negative correlation with maximum temperature (-0.874, $p < 0.01$) and minimum temperature (-0.925, $p < 0.01$), confirming that this pest prefers cooler conditions and is significantly reduced by temperature increases.

Some pests showed a significant positive correlation with temperature, meaning warmer temperatures favor their population growth. *M. dorsalis* had a highly significant positive correlation with maximum temperature (0.536, $p < 0.01$) and a significant correlation with minimum temperature (0.478, $p < 0.05$), suggesting that it thrives in warm environments. *C. suppressalis* exhibited a strong positive correlation with maximum temperature (0.602, $p < 0.01$) and minimum temperature (0.557, $p < 0.01$), indicating that it benefits from higher temperatures. *S. biformis* displayed a significant positive correlation with maximum temperature (0.558, $p < 0.01$) and minimum temperature (0.446, $p < 0.05$), showing that this species favors warm conditions. Similarly, *S. incertulas* exhibited significant positive correlations with maximum temperature (0.396, $p < 0.05$) and minimum temperature (0.441, $p < 0.05$), *M. leda ismene* showed a significant positive correlation with maximum temperature (0.420, $p < 0.05$), green horned caterpillars demonstrated significant positive correlations with maximum temperature (0.451, $p < 0.05$) and minimum temperature (0.457, $p < 0.05$), *N. depunctalis* exhibited a strong positive correlation with maximum temperature (0.530, $p < 0.01$) and *P. mathias* displayed significant positive correlations with maximum temperature (0.429, $p < 0.05$) and minimum temperature (0.433, $p < 0.05$), reinforcing that warmer temperatures contribute to their population growth. *D. armigera* also showed a significant positive correlation with maximum temperature (0.394, $p < 0.05$).

Several pests showed weak or non-significant correlations with temperature. *N. lugens* (0.137, max temp) and *C. medinalis* (0.087, max temp) had weak positive

correlations. *S. furcifera* (-0.280, max temp) and field crickets (-0.068, max temp) had weak negative correlations.

Some insect pests showed negative correlations with relative humidity, indicating that higher humidity reduces their population. *N. virescens* had a highly significant negative correlation with maximum humidity (-0.555, $p < 0.01$) and minimum humidity (-0.546, $p < 0.01$), *C. spectra* showed significant negative correlations with maximum relative humidity (-0.405, $p < 0.05$) and minimum relative humidity (-0.455, $p < 0.05$) and *S. oryzae* had a highly significant negative correlation with maximum humidity (-0.685, $p < 0.01$) and minimum humidity (-0.866, $p < 0.01$), confirming that increased humidity is unfavorable for these pest. *S. furcifera* also showed a significant negative correlation with maximum humidity (-0.539, $p < 0.01$) and minimum humidity (-0.495, $p < 0.01$).

Certain pests showed a positive correlation with relative humidity, meaning higher humidity levels increased their numbers. *C. suppressalis* had a significant positive correlation with maximum humidity (0.417, $p < 0.05$) and minimum humidity (0.383, $p < 0.05$), suggesting it thrives in humid conditions.

Some pests had negative correlations with rainfall, indicating that higher rainfall reduces their population. *N. virescens* had a significant negative correlation with rainfall (-0.518, $p < 0.01$), suggesting that excessive rainfall suppresses its presence. *S. oryzae* showed a significant negative correlation with rainfall (-0.510, $p < 0.01$), confirming that this pest population declines in wet conditions. *S. furcifera* (-0.484, $p < 0.05$) and *C. spectra* (-0.435, $p < 0.05$) also had negative correlations with rainfall.

Table 4.3i: Regression equations between insect pests and weather parameters at Kuhoxu for 2020 and 2021

Insect pests	Year	Regression Equation	R ²
<i>Nephotettix virescens</i> Distant	2020	$y = -45.814 + 12.641X_1 - 19.520X_2 + 0.329X_3 + 1.231X_4 - 0.173X_5$	0.717
	2021	$y = 267.605 - 5.937X_1 + 7.807X_2 - 1.928X_3 - 0.889X_4 - 0.400X_5$	0.487
<i>Nephotettix nigropictus</i> Stål	2020	$y = -86.940 + 8.213X_1 - 9.030X_2 - 0.022X_3 + 0.555X_4 - 0.043X_5$	0.593
	2021	$y = 64.160 - 3.948X_1 + 6.460X_2 - 0.704X_3 - 0.205X_4 - 0.196X_5$	0.315

<i>Cofana spectra</i> Distant	2020	$y = 4.457 + 0.976X_1 - 1.629X_2 - 0.020X_3 + 0.078X_4 - 0.003X_5$	0.593
	2021	$y = 19.900 - 0.504X_1 + 0.951X_2 - 0.114X_3 - 0.176X_4 - 0.040X_5$	0.351
<i>Maiestas dorsalis</i> Motchulsky	2020	$y = -9.024 + 0.833X_1 - 0.255X_2 - 0.126X_3 + 0.045X_4 - 0.012X_5$	0.207
	2021	$y = -23.399 + 0.938X_1 + 0.023X_2 - 0.011X_3 - 0.103X_4 - 0.010X_5$	0.349
<i>Nilaparvata</i> <i>lugens</i> Stål	2020	$y = -652.663 + 40.726X_1 - 35.234X_2 + 0.910X_3 + 1.597X_4 - 0.144X_5$	0.452
	2021	$y = 53.090 - 5.452X_1 + 26.127X_2 - 2.154X_3 - 3.741X_4 - 0.794X_5$	0.293
<i>Sogatella</i> <i>furcifera</i> Horvith	2020	$y = -213.276 + 13.299X_1 - 12.047X_2 + 0.695X_3 + 0.131X_4 - 0.019X_5$	0.451
	2021	$y = 160.473 - 1.914X_1 + 5.521X_2 - 1.693X_3 - 0.945X_4 - 0.343X_5$	0.461
<i>Leptocorisa acuta</i> Thunberg	2020	$y = -46.371 + 2.160X_1 - 1.813X_2 + 0.168X_3 + 0.081X_4 + 0.008X_5$	0.435
	2021	$y = 16.408 - 0.935X_1 + 1.515X_2 - 0.228X_3 + 0.023X_4 - 0.027X_5$	0.257
<i>Cletus punctiger</i> Dallas	2020	$y = -10.068 + 0.500X_1 - 0.479X_2 - 0.030X_3 + 0.155X_4 - 0.023X_5$	0.320
	2021	$y = 0.624 - 0.271X_1 + 0.640X_2 - 0.001X_3 - 0.066X_4 + 0.001X_5$	0.179
<i>Scirpophaga</i> <i>incertulas</i> Walker	2020	$y = -93.453 + 4.323X_1 - 2.885X_2 + 0.235X_3 + 0.037X_4 + 0.004X_5$	0.406
	2021	$y = -10.348 - 0.639X_1 + 2.595X_2 - 0.115X_3 - 0.242X_4 - 0.045X_5$	0.335
<i>Chilo suppressalis</i> Dudgeon	2020	$y = -17.881 + 0.673X_1 - 0.375X_2 + 0.042X_3 + 0.028X_4 - 0.000X_5$	0.226
	2021	$y = -13.386 + 0.407X_1 - 0.071X_2 + 0.068X_3 - 0.059X_4 + 0.004X_5$	0.436
<i>Scirpophaga</i> spp.	2020	$y = -69.903 + 2.951X_1 - 1.943X_2 + 0.113X_3 + 0.179X_4 - 0.001X_5$	0.279
	2021	$y = -24.638 + 0.647X_1 + 0.883X_2 - 0.070X_3 - 0.139X_4 - 0.064X_5$	0.308
<i>Scirpophaga</i> <i>nivella</i> Fabricius	2020	$y = -7.597 + 0.483X_1 - 0.515X_2 + 0.003X_3 + 0.078X_4 - 0.007X_5$	0.266
	2021	$y = -0.267 - 0.054X_1 + 0.310X_2 - 0.002X_3 - 0.049X_4 - 0.019X_5$	0.205
<i>Cnaphalocrocis</i> <i>medinalis</i> Guenée	2020	$y = -32.375 + 1.869X_1 - 1.918X_2 + 0.070X_3 + 0.157X_4 - 0.007X_5$	0.562
	2021	$y = 10.662 - 0.751X_1 + 1.506X_2 - 0.151X_3 - 0.099X_4 - 0.038X_5$	0.367
<i>Melanitis leda</i> <i>ismene</i> Linnaeus	2020	$y = -6.395 + 0.276X_1 - 0.166X_2 + 0.005X_3 + 0.023X_4 - 0.003X_5$	0.190
	2021	$y = -5.276 + 0.280X_1 + 0.014X_2 - 0.012X_3 - 0.045X_4 - 0.003X_5$	0.314
Green horned caterpillars	2020	$y = 9.340 - 0.234X_1 + 0.324X_2 - 0.089X_3 - 0.011X_4 + 0.005X_5$	0.346
	2021	$y = -5.028 + 0.078X_1 + 0.080X_2 + 0.026X_3 - 0.020X_4 + 0.001X_5$	0.233
<i>Spodoptera</i> <i>litura</i> Fabricius	2020	$y = -20.946 + 0.747X_1 - 0.600X_2 + 0.113X_3 + 0.009X_4 + 0.002X_5$	0.459
	2021	$y = 3.854 - 0.292X_1 + 0.517X_2 - 0.049X_3 - 0.024X_4 - 0.009X_5$	0.306
<i>Leucania loreyi</i> Duponchel	2020	$y = -27.013 + 1.976X_1 - 1.693X_2 - 0.096X_3 + 0.164X_4 - 0.002X_5$	0.636
	2021	$y = 0.015 - 0.529X_1 + 1.298X_2 - 0.051X_3 - 0.111X_4 - 0.024X_5$	0.285
<i>Nymphula</i> <i>depunctalis</i> Guenée	2020	$y = 10.747 - 0.327X_1 + 0.578X_2 - 0.119X_3 - 0.016X_4 - 0.009X_5$	0.148
	2021	$y = -33.806 + 1.707X_1 - 1.287X_2 + 0.120X_3 - 0.053X_4 + 0.007X_5$	0.504
<i>Pelopidas mathias</i> Fabricius	2020	$y = -8.120 + 0.489X_1 - 0.429X_2 - 0.012X_3 + 0.051X_4 - 0.002X_5$	0.528
	2021	$y = -4.660 + 0.069X_1 + 0.169X_2 + 0.014X_3 - 0.039X_4 - 0.004X_5$	0.277
Short horned grasshoppers	2020	$y = -5.325 + 0.304X_1 - 0.427X_2 + 0.035X_3 + 0.090X_4 - 0.009X_5$	0.140
	2021	$y = -11.988 + 0.987X_1 - 0.862X_2 + 0.105X_3 - 0.092X_4 - 0.008X_5$	0.251

Field crickets	2020	$y = -22.272 + 1.673X_1 - 1.831X_2 - 0.030X_3 + 0.301X_4 - 0.026X_5$	0.365
	2021	$y = 26.204 - 0.322X_1 + 1.246X_2 - 0.368X_3 - 0.134X_4 - 0.039X_5$	0.409
<i>Gryllotalpa orientalis</i> Burmeister	2020	$y = -11.895 + 0.763X_1 - 0.454X_2 - 0.003X_3 - 0.022X_4 + 0.004X_5$	0.294
	2021	$y = -7.807 + 0.378X_1 - 0.140X_2 + 0.014X_3 - 0.033X_4 - 0.013X_5$	0.333
<i>Sitophilus oryzae</i> Linnaeus	2020	$y = 43.564 - 0.928X_1 - 0.230X_2 - 0.092X_3 + 0.028X_4 - 0.012X_5$	0.893
	2021	$y = 32.515 - 0.024X_1 - 0.756X_2 - 0.058X_3 - 0.096X_4 - 0.009X_5$	0.911
<i>Dicladispa armigera</i> Olivier	2020	$y = 3.211 + 0.508X_1 - 0.153X_2 - 0.206X_3 + 0.062X_4 - 0.019X_5$	0.245
	2021	$y = -24.418 + 0.895X_1 + 0.278X_2 + 0.056X_3 - 0.249X_4 - 0.000X_5$	0.264
<i>Stenchaetothrips biformis</i> Bagnall	2020	$y = 8.618 - 0.348X_1 + 1.157X_2 - 0.198X_3 - 0.002X_4 - 0.023X_5$	0.319
	2021	$y = -40.487 + 1.952X_1 - 1.212X_2 + 0.094X_3 - 0.036X_4 - 0.001X_5$	0.394

Upon reviewing available literatures, Nishanthini and Kandibane (2021) reported that *Cofana spectra* had a significant negative correlation with minimum temperature (-0.71) and a non-significant positive correlation with rainfall (0.21), aligning with the current study's temperature results but differing in its rainfall response.

Singh *et al.* (2020) also reported that maximum temperature and humidity favored *Scirpophaga incertulas*. Sreelatha *et al.* (2022) observed positive but non-significant correlations with temperature and humidity, which aligns with the present study. However, Seni & Naik (2018) found a negative correlation between *Scirpophaga incertulas* and rainfall, partially matching this study's findings.

Similar results were observed for *Cnaphalocrocis medinalis* (Leaf folder) by Kumar *et al.* (2020), who reported a positive correlation with temperature and humidity.

Singh *et al.* (2020) also found that maximum humidity favored *Nephotettix virescens*. Sawai and Kothikar (2019) reported that *Nephotettix cincticeps* (a related species) was positively correlated with temperature and humidity but suppressed by rainfall, supporting the study's results.

Patil *et al.* (2020) reported a significant positive correlation with maximum temperature for *Cnaphalocrocis medinalis*, aligning with this study's humidity correlation but contradicting the temperature finding. Seni and Naik (2018) observed a significant positive correlation between *Cnaphalocrocis medinalis* and maximum temperature ($r = 0.749$) and minimum temperature ($r = 0.654$), supporting this study's

weak temperature relationship. They also reported a significant negative correlation with temperature (-0.619), relative humidity (-0.755), and rainfall (-0.583), confirming this study's negative trend. Hemanth *et al.* (2024) found that *Nilaparvata lugens* had a non-significant negative correlation with temperature and rainfall, further validating the present investigation.

Adhikari *et al.* (2021) found that *Leptocorisa acuta* exhibited a significant negative correlation with temperature and humidity, contradicting this study's findings. However, Kafle *et al.* (2018) reported a negative correlation with minimum humidity and average humidity, partially supporting the results.

Lisha *et al.* (2020b), Morshed *et al.* (2023), and Kalita *et al.* (2020) reported that yellow stem borer, leaf folder, green leafhopper, and grasshoppers were positively correlated with temperature, while pollen feeders and earhead bugs showed negative correlations. Caseworm, whorl maggot, and leaf folder were positively correlated with temperature and rainfall, while rice hispa and stem borer had a negative correlation with morning humidity. Gundhi bug displayed a negative correlation with temperature but a positive correlation with morning humidity. These findings are in agreement with the present investigation.

Sabir *et al.* (2006) and Sulagitti *et al.* (2017) found that temperature and rainfall significantly influenced pest populations. Stem borer responded positively to temperature, and green leafhopper was positively influenced by rainfall, while relative humidity generally favored pests. Environmental factors explained a large proportion of the population variations in green leafhopper, leaf folder, stem borer, whitebacked planthopper, and white leafhopper. Brown planthopper had a non-significant positive correlation with temperature, humidity, and rainfall. Leaf folder correlated positively with evening humidity, and gundhi bug showed mixed correlations. These results align with the present study's observations.

Kalita *et al.* (2015) and Selvam *et al.* (2022) observed that stem borer infestation peaked in August-September, with leaf folder populations also reaching maximum levels in late August-early September. Gundhi bug was most abundant in October. Natural enemies, including spiders, *Apanteles*, and Anisoptera, were

recorded predominantly in August-September, while ladybird beetles peaked in late September. Overall, pests and their natural enemies had positive correlations with temperature but negative correlations with humidity and rainfall. These results are consistent with the present findings.

Priyadarshini and Mahapatra (2023) found that spider abundance was strongly correlated with humidity, while rainfall and windspeed influenced colonization but not abundance. This is in partial agreement with the present study, where relative humidity played a significant role in insect population fluctuations.

4.4. CORRELATION OF INSECT PESTS OF RICE WITH THEIR NATURAL ENEMIES IN LOWLAND RICE AGROECOSYSTEM IN NAGALAND

The following discussion explains the correlation between insect pests of rice with their natural enemies at Medziphema, Singrijan and Kuhoxu under lowland rice agroecosystem recorded from June to December for the years 2020 and 2021.

4.4.1. CORRELATION COEFFICIENT OF INSECT PESTS OF RICE WITH THEIR NATURAL ENEMIES AT MEDZIPHEMA

Table 4.4a presents the correlation coefficients (Pearson's r) between insect pests of rice and their natural enemies recorded from June to December 2020 at Medziphema. Several insect pests show strong positive correlations with multiple natural enemy groups, indicating a high level of natural pest regulation.

Nephotettix virescens exhibited highly significant correlations with a broad array of predator groups. Strong positive relationships were observed with Diptera (0.816, $p < 0.01$), Odonata-Anisoptera (0.779, $p < 0.01$), Arachnida (0.752, $p < 0.01$), Hymenoptera (0.673, $p < 0.01$), Neuroptera (0.622, $p < 0.01$), and Odonata-Zygoptera (0.560, $p < 0.01$). Significant associations were also noted with Orthoptera (0.486, $p < 0.05$) and Coleoptera (0.430, $p < 0.05$). In contrast, correlations with Dermaptera (-0.055), Mantodea (-0.098), and Hemiptera (-0.082) were negative and not statistically significant.

In a similar pattern, *Nephotettix nigropictus* showed significant positive associations with Arachnida (0.716, $p < 0.01$), Hymenoptera (0.752, $p < 0.01$), Odonata-Anisoptera (0.675, $p < 0.01$), Odonata-Zygoptera (0.590, $p < 0.01$), Diptera (0.582, $p < 0.01$), Coleoptera (0.511, $p < 0.01$), and Neuroptera (0.396, $p < 0.05$). However, no significant correlations were found with Orthoptera (0.299), Dermaptera (-0.154), Mantodea (-0.270), or Hemiptera (-0.108).

Table 4.4a: Correlation coefficient (r) between insect pests of rice and natural enemies recorded during June to December 2020 at Medziphema

Insect pests	Pearson's correlation coefficient										
	Odonata-Anisoptera	Odonata-Zygoptera	Coleoptera	Hymenoptera	Neuroptera	Hemiptera	Diptera	Dermaptera	Mantodea	Orthoptera	Arachnida
<i>Nephotettix virescens</i> Distant	0.779**	0.560**	0.430*	0.673**	0.622**	-0.082	0.816**	-0.055	-0.098	0.486*	0.752**
<i>Nephotettix nigropictus</i> Stål	0.675**	0.590**	0.511**	0.752**	0.396*	-0.108	0.582**	-0.154	-0.270	0.299	0.716**
<i>Cofana spectra</i> Distant	0.005	0.152	0.094	0.423*	-0.086	-0.282	0.007	-0.367	-0.337	-0.047	-0.014
<i>Maistas dorsalis</i> Motchulsky	0.766**	0.794**	0.674**	0.667**	0.585**	0.255	0.580**	0.302	0.042	0.562**	0.901**
<i>Nilaparvata lugens</i> Stål	0.533**	0.603**	0.310	0.610**	0.367	-0.275	0.491**	-0.208	-0.345	0.281	0.629**
<i>Sogatella furcifera</i> Horvith	0.778**	0.672**	0.506**	0.670**	0.565**	-0.113	0.582**	-0.017	-0.179	0.480*	0.823**
<i>Leptocoris acuta</i> Thunberg	0.163	0.329	0.183	0.588**	0.108	-0.266	0.158	-0.165	-0.326	0.111	0.234
<i>Cletus punctiger</i> Dallas	0.712**	0.523**	0.571**	0.773**	0.673**	0.020	0.726**	0.039	-0.115	0.559**	0.722**
<i>Scirpophaga incertulas</i> Walker	0.867**	0.711**	0.762**	0.819**	0.608**	0.310	0.614**	0.259	0.150	0.720**	0.905**
<i>Chilo suppressalis</i> Dudgeon	0.727**	0.450*	0.487**	0.518**	0.659**	-0.009	0.454*	0.151	-0.037	0.660**	0.663**
<i>Scirpophaga</i> spp.	0.858**	0.776**	0.578**	0.580**	0.593**	0.117	0.526**	0.211	-0.027	0.574**	0.915**
<i>Cnaphalocrocis medinalis</i> Guenée	0.247	0.534**	0.112	0.486*	0.174	-0.286	0.235	-0.218	-0.353	0.125	0.404*

<i>Melanitis leda ismene</i> Linnaeus	0.709**	0.726**	0.655**	0.699**	0.348	0.399*	0.207	0.344	0.215	0.664**	0.752**
Green horned caterpillars	0.702**	0.416*	0.750**	0.556**	0.269	0.362	0.449*	0.176	0.167	0.486*	0.638**
<i>Spodoptera litura</i> Fabricius	-0.134	-0.110	-0.038	-0.034	-0.120	-0.068	-0.082	-0.184	-0.184	-0.013	-0.232
<i>Leucania loreyi</i> Duponchel	0.742**	0.698**	0.524**	0.741**	0.511**	-0.023	0.592**	-0.034	-0.105	0.508**	0.815**
<i>Nymphula depunctalis</i> Guenée	0.862**	0.616**	0.747**	0.727**	0.431*	0.206	0.617**	0.044	-0.003	0.542**	0.835**
<i>Pelopidas mathias</i> Fabricius	0.803**	0.691**	0.477*	0.616**	0.644**	-0.095	0.729**	0.056	-0.140	0.533**	0.896**
Short horned grasshoppers	0.569**	0.473**	0.362	0.504**	0.405*	-0.097	0.474*	-0.148	-0.272	0.282	0.511**
Field crickets	0.318	0.299	0.468*	0.640**	0.133	0.022	0.252	-0.036	-0.032	0.337	0.301
<i>Gryllotalpa orientalis</i> Burmeister	0.465*	0.681**	0.450*	0.637**	0.225	0.173	0.266	0.168	-0.010	0.333	0.625**
<i>Sitophilus oryzae</i> Linnaeus	-0.336	-0.338	-0.256	0.072	-0.339	-0.450*	-0.212	-0.525**	-0.452*	-0.507**	-0.402*
<i>Dicladispa armigera</i> Olivier	0.757**	0.598**	0.800**	0.753**	0.517**	0.601**	0.459*	0.400*	0.246	0.615**	0.768**
<i>Stenchaetothrips biformis</i> Bagnall	0.466*	0.386*	0.756**	0.604**	0.263	0.826**	0.045	0.593**	0.504**	0.544**	0.468*

Note: $df = (27-2) = 25$

$r_{0.05} = 0.381$

$r_{0.01} = 0.487$

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Cofana spectra exhibited a significant positive correlation only with Hymenoptera (0.423, $p < 0.05$). All other predator groups, including Diptera (0.007), Coleoptera (0.094), Odonata-Zygoptera (0.152), and Odonata-Anisoptera (0.005), showed non-significant associations. Several groups such as Hemiptera (-0.282), Dermaptera (-0.367), Mantodea (-0.337), Orthoptera (-0.047) and Arachnida (-0.014) had negative but non-significant correlations.

In contrast, *Maiestas dorsalis* showed highly significant positive correlations with Arachnida (0.901, $p < 0.01$), Odonata-Zygoptera (0.794, $p < 0.01$), Odonata-Anisoptera (0.766, $p < 0.01$), Coleoptera (0.674, $p < 0.01$), Hymenoptera (0.667, $p < 0.01$), Neuroptera (0.585, $p < 0.01$), Diptera (0.580, $p < 0.01$), and Orthoptera (0.562, $p < 0.01$). Although positive, relationships with Hemiptera (0.225), Dermaptera (0.302), and Mantodea (0.042) were not statistically significant.

Nilaparvata lugens also exhibited multiple strong correlations, particularly with Arachnida (0.629, $p < 0.01$), Hymenoptera (0.610, $p < 0.01$), Odonata-Zygoptera (0.603, $p < 0.01$), Odonata-Anisoptera (0.533, $p < 0.01$), and Diptera (0.491, $p < 0.01$). Other associations, including Neuroptera (0.367), Coleoptera (0.310), and Orthoptera (0.281), were positive but not significant. Hemiptera (-0.275), Dermaptera (-0.208), and Mantodea (-0.345) showed negative correlations without statistical significance.

The correlation analysis revealed that *Sogatella furcifera* exhibited highly significant associations with a broad spectrum of natural enemy groups. Strong positive correlations were observed with Arachnida (0.823, $p < 0.01$), Odonata-Anisoptera (0.778, $p < 0.01$), Odonata-Zygoptera (0.672, $p < 0.01$), Hymenoptera (0.670, $p < 0.01$), Diptera (0.582, $p < 0.01$), Neuroptera (0.565, $p < 0.01$), and Coleoptera (0.506, $p < 0.01$). A moderate but significant relationship was also detected with Orthoptera (0.480, $p < 0.05$). In contrast, negative correlations with Hemiptera (-0.113), Dermaptera (-0.017), and Mantodea (-0.179) were not statistically significant.

By contrast, *Leptocorisa acuta* demonstrated a more limited association, with a significant correlation observed only for Hymenoptera (0.588, $p < 0.01$), while no other predator groups showed significant relationships.

Cletus punctiger demonstrated significant positive correlations across a wide range of natural enemy groups. Strong associations were observed with Hymenoptera (0.773, $p < 0.01$), Diptera (0.726, $p < 0.01$), Arachnida (0.722, $p < 0.01$), Odonata-Anisoptera (0.712, $p < 0.01$), Neuroptera (0.673, $p < 0.01$), Coleoptera (0.571, $p < 0.01$), and Orthoptera (0.559, $p < 0.01$). Moderate significance was also found with Odonata-Zygoptera (0.523, $p < 0.01$), while associations with Hemiptera (0.020), Dermaptera (0.039), and Mantodea (0.115) were statistically not significant.

Similarly, *Scirpophaga incertulas* exhibited strong correlations with Arachnida (0.905, $p < 0.01$), Odonata-Anisoptera (0.867, $p < 0.01$), and Hymenoptera (0.819, $p < 0.01$). Other significant relationships included Neuroptera (0.608, $p < 0.01$), Diptera (0.614, $p < 0.01$), Coleoptera (0.762, $p < 0.01$), Odonata-Zygoptera (0.711, $p < 0.01$), and Orthoptera (0.720, $p < 0.01$). Associations with Hemiptera (0.310), Dermaptera (0.259), and Mantodea (0.150) were positive but not statistically significant.

Chilo suppressalis showed strong and significant associations with Odonata-Anisoptera (0.727, $p < 0.01$), Arachnida (0.663, $p < 0.01$), Orthoptera (0.660, $p < 0.01$), Neuroptera (0.659, $p < 0.01$), and Hymenoptera (0.518, $p < 0.01$). Weaker but significant correlations were also noted for Coleoptera (0.487, $p < 0.01$), Odonata-Zygoptera (0.450, $p < 0.05$), and Diptera (0.454, $p < 0.05$). Relationships with Hemiptera (-0.009), Dermaptera (0.151), and Mantodea (-0.037) were not significant.

Scirpophaga spp. exhibited robust and highly significant correlations with a diverse range of natural enemy groups. Notably strong associations were recorded with Arachnida (0.915, $p < 0.01$), Odonata-Anisoptera (0.858, $p < 0.01$), Odonata-Zygoptera (0.776, $p < 0.01$), Coleoptera (0.578, $p < 0.01$), Hymenoptera (0.580, $p < 0.01$), Neuroptera (0.593, $p < 0.01$), Diptera (0.526, $p < 0.01$), and Orthoptera (0.574, $p < 0.01$).

Relationships with Hemiptera (0.117), Mantodea (-0.027), and Dermaptera (0.211) were non-significant.

Cnaphalocrocis medinalis showed statistically significant associations with Odonata-Zygoptera (0.534, $p < 0.01$), Hymenoptera (0.486, $p < 0.05$), and Arachnida (0.404, $p < 0.05$). Other correlations, including those with Odonata-Anisoptera (0.247), Coleoptera (0.112), and Diptera (0.235), did not reach significance.

Melanitis leda ismene demonstrated multiple highly significant correlations, including those with Arachnida (0.752, $p < 0.01$), Odonata-Zygoptera (0.726, $p < 0.01$), Odonata-Anisoptera (0.709, $p < 0.01$), Hymenoptera (0.699, $p < 0.01$), Coleoptera (0.655, $p < 0.01$), and Orthoptera (0.664, $p < 0.01$). A moderate but significant association was also observed with Hemiptera (0.399, $p < 0.05$), while correlations with other groups such as Diptera (0.207), Dermaptera (0.344), Neuroptera (0.348) and Mantodea (0.215) were not significant.

Green horned caterpillars exhibited strong and statistically significant associations with several natural enemy groups. High correlations were noted with Coleoptera (0.750, $p < 0.01$), Odonata-Anisoptera (0.702, $p < 0.01$), Hymenoptera (0.556, $p < 0.01$) and Arachnida (0.638, $p < 0.01$). Additionally, moderate yet significant relationships were found with Orthoptera (0.486, $p < 0.05$), Diptera (0.449, $p < 0.05$), and Odonata-Zygoptera (0.416, $p < 0.05$). Other groups, including Neuroptera (0.269), Hemiptera (0.362), Dermaptera (0.176), and Mantodea (0.167) did not show significant associations.

In contrast, *Spodoptera litura* showed no statistically significant correlations with any of the natural enemy groups. Correlation values were low and negative across the board, including Arachnida (-0.232), Odonata-Zygoptera (-0.110), Odonata-Anisoptera (-0.134), and Hymenoptera (-0.034), indicating negligible predator influence under the observed conditions.

Leucania loreyi exhibited strong and highly significant correlations with a range of natural enemy groups. Positive associations were found with Odonata-Anisoptera (0.742, $p < 0.01$), Odonata-Zygoptera (0.698, $p < 0.01$), Hymenoptera (0.741, $p < 0.01$), Arachnida (0.815, $p < 0.01$), Diptera (0.592, $p < 0.01$), Coleoptera (0.524, $p < 0.01$), and Neuroptera (0.511, $p < 0.01$). A significant correlation was also observed with Orthoptera (0.508, $p < 0.01$), while remaining groups showed no significant relationships.

Nymphula depunctalis was strongly associated with multiple natural enemy groups, including Odonata-Anisoptera (0.862, $p < 0.01$), Odonata-Zygoptera (0.616, $p < 0.01$), Hymenoptera (0.727, $p < 0.01$), Coleoptera (0.747, $p < 0.01$), Diptera (0.617, $p < 0.01$) and Neuroptera (0.835, $p < 0.01$). Significant associations were also noted with Neuroptera (0.431, $p < 0.05$) and Orthoptera (0.542, $p < 0.01$), while no meaningful relationships were found for other groups.

Pelopidas mathias also demonstrated highly significant correlations with multiple predator groups. Notable associations were found with Arachnida (0.896, $p < 0.01$), Odonata-Anisoptera (0.803, $p < 0.01$), Diptera (0.729, $p < 0.01$), Odonata-Zygoptera (0.691, $p < 0.01$), Hymenoptera (0.616, $p < 0.01$), Neuroptera (0.644, $p < 0.01$) Coleoptera (0.477, $p < 0.05$) and Orthoptera (0.533, $p < 0.01$). No significant associations were observed with the remaining natural enemy groups.

Short-horned grasshoppers exhibited significant correlations with Odonata-Anisoptera (0.569, $p < 0.01$), Odonata-Zygoptera (0.473, $p < 0.01$), Hymenoptera (0.504, $p < 0.01$), Neuroptera (0.405, $p < 0.05$), Diptera (0.474, $p < 0.05$), and Arachnida (0.511, $p < 0.01$) while relationship with remaining natural enemy groups were not significant. Field crickets showed significant associations with Coleoptera (0.468, $p < 0.05$) and Hymenoptera (0.640, $p < 0.01$) and no other significant relationships were observed. The mole cricket, *Gryllotalpa orientalis*, was significantly correlated with Odonata-Anisoptera (0.465, $p < 0.05$), Odonata-Zygoptera (0.681, $p < 0.01$), Coleoptera (0.450, p

< 0.05), Hymenoptera (0.637, $p < 0.01$), and Arachnida (0.625, $p < 0.01$) and no significant associations with remaining natural enemy groups were observed.

Sitophilus oryzae differed from other pests, it exhibited significant negative relationships with Dermaptera (-0.525, $p < 0.01$) and Orthoptera (-0.507, $p < 0.01$) and Arachnida (-0.402, $p < 0.05$). *Dicladispa armigera*, on the other hand, displayed strong positive associations with all natural enemies except mantodae (0.246). Odonata-Anisoptera (0.757, $p < 0.01$), Odonata-Zygoptera (0.598, $p < 0.01$), Coleoptera (0.800, $p < 0.01$), Hymenoptera (0.753, $p < 0.01$), Neuroptera (0.517, $p < 0.01$), Hemiptera (0.601, $p < 0.01$), Orthoptera (0.615, $p < 0.01$) and Arachnida (0.768, $p < 0.01$) exhibited highly significant associations. Diptera (0.459, $p < 0.05$) and Dermaptera (0.400, $p < 0.05$) also showed significant associations with *D. armigera*. Likewise, *Stenchaetothrips biformis* exhibited highly significant correlations with Coleoptera (0.756, $p < 0.01$), Hymenoptera (0.604, $p < 0.01$), Hemiptera (0.826, $p < 0.01$), Dermaptera (0.593, $p < 0.01$), and Arachnida (0.468, $p < 0.05$), while Odonata-Anisoptera (0.466, $p < 0.05$) and Odonata-Zygoptera (0.386, $p < 0.05$), Mantodea (0.504, $p < 0.01$) and Orthoptera (0.544, $p < 0.01$) also showed significant positive correlations, while correlations with Neuroptera (0.263) and Diptera (0.045) were not found to be statistically significant.

Table 4.4b presents the correlation coefficients (Pearson's r) between insect pests of rice and their natural enemies, recorded from June to December of 2021. Several insect pests exhibit strong positive correlations with multiple natural enemy groups, suggesting effective natural pest regulation.

Nephotettix virescens showed highly significant positive correlations with Odonata-Anisoptera (0.737, $p < 0.01$) and Arachnida (0.786, $p < 0.01$), indicating strong associations with these predator groups, although correlation with other groups were not statistically significant. In the case of *Nephotettix nigropictus*, strong and significant correlations were evident with Odonata-Anisoptera (0.770, $p < 0.01$), Hymenoptera (0.549, $p < 0.01$), and Arachnida (0.778, $p < 0.01$), while Diptera (0.437, $p < 0.05$) also exhibited a significant association.

Cofana spectra displayed significant correlations with Odonata-Anisoptera (0.477, $p < 0.05$) and Arachnida (0.394, $p < 0.05$), suggesting potential regulatory roles of these predator groups. In contrast, *Maiestas dorsalis* exhibited highly significant associations across multiple taxa, including Odonata (0.899, $p < 0.01$ for Odonata-Anisoptera; 0.817, $p < 0.01$ for Zygoptera), Hymenoptera (0.752, $p < 0.01$), Coleoptera (0.681, $p < 0.01$), Diptera (0.615, $p < 0.01$), Orthoptera (0.550, $p < 0.01$), Dermaptera (0.508, $p < 0.01$), Neuroptera (0.474, $p < 0.05$), and Arachnida (0.862, $p < 0.01$). A correlation with Neuroptera (0.312) and Hemiptera (0.128) were also observed, though not statistically significant.

Nilaparvata lugens showed strong positive correlations with Odonata-Anisoptera (0.845, $p < 0.01$), Odonata-Zygoptera (0.476, $p < 0.05$), Hymenoptera (0.548, $p < 0.01$), Arachnida (0.860, $p < 0.01$), and Diptera (0.535, $p < 0.01$). Similarly, *Sogatella furcifera* displayed significant associations with Odonata-Anisoptera (0.723, $p < 0.01$), Odonata-Zygoptera (0.427, $p < 0.05$), Hymenoptera (0.431, $p < 0.05$), Diptera (0.494, $p < 0.01$), and Arachnida (0.765, $p < 0.01$), while the remaining natural enemy groups exhibited statistically insignificant correlations.

No significant correlations were found between *Leptocorisa acuta* and any predator group, indicating weak ecological interactions. In contrast, *Cletus punctiger* exhibited highly significant positive associations with Odonata-Anisoptera (0.805, $p < 0.01$) and Arachnida (0.819, $p < 0.01$). Additionally, significant correlations were found with Odonata-Zygoptera (0.462, $p < 0.05$) and Hymenoptera (0.444, $p < 0.05$).

Scirpophaga incertulas demonstrated strong positive correlations with a wide range of predator groups, including Odonata-Anisoptera (0.856, $p < 0.01$), Odonata-Zygoptera (0.750, $p < 0.01$), Coleoptera (0.581, $p < 0.01$), Hymenoptera (0.683, $p < 0.01$), Diptera (0.659, $p < 0.01$), Mantodea (0.501, $p < 0.01$), Orthoptera (0.384, $p < 0.05$), and Arachnida (0.818, $p < 0.01$). Similarly, *Chilo suppressalis* showed highly significant associations with Odonata-Anisoptera (0.777, $p < 0.01$), Odonata-Zygoptera (0.700, $p < 0.01$), Coleoptera (0.512, $p < 0.01$), Hymenoptera (0.646, $p < 0.01$), Diptera

(0.637, $p < 0.01$), Neuroptera (0.386, $p < 0.05$), Mantodea (0.457, $p < 0.05$), and Arachnida (0.710, $p < 0.01$).

Scirpophaga spp. demonstrated strong positive associations with a range of natural enemy groups, including Odonata-Anisoptera (0.827, $p < 0.01$), Odonata-Zygoptera (0.571, $p < 0.01$), Coleoptera (0.407, $p < 0.05$), Hymenoptera (0.487, $p < 0.01$), and Diptera (0.484, $p < 0.05$). A strong correlation was also observed with Arachnida (0.875, $p < 0.01$), indicating consistent regulatory interactions with these natural enemy groups. The correlations with other groups were limited and not significant. In the case of *Cnaphalocrocis medinalis*, significant relationships were found only with Odonata-Anisoptera (0.440, $p < 0.05$), Hemiptera (-0.405 , $p < 0.05$), and Arachnida (0.446, $p < 0.05$) while with other natural enemy groups were not significant to be considered.

Melanitis leda ismene was strongly correlated with Odonata-Anisoptera (0.844, $p < 0.01$), Hymenoptera (0.661, $p < 0.01$), Arachnida (0.738, $p < 0.01$), and Diptera (0.573, $p < 0.01$). Additional significant relationships were noted with Odonata-Zygoptera (0.639, $p < 0.01$), Coleoptera (0.508, $p < 0.01$), Neuroptera (0.393, $p < 0.05$), and Orthoptera (0.462, $p < 0.05$), suggesting broad natural enemy groups involvement in population regulation. Similarly, green horned caterpillars exhibited highly significant associations with Odonata-Anisoptera (0.758, $p < 0.01$), Hymenoptera (0.624, $p < 0.01$), Arachnida (0.734, $p < 0.01$), and Diptera (0.531, $p < 0.01$). Significant correlations were also observed with Odonata-Zygoptera (0.652, $p < 0.01$), Coleoptera (0.491, $p < 0.01$), and Mantodea (0.428, $p < 0.05$), reflecting a diverse assemblage of natural enemies potentially impacting this pest.

Table 4.4b: Correlation coefficient (r) between insect pests of rice and natural enemies recorded during June to December 2021 in Medziphema

Insect pests	Pearson's correlation coefficient										
	Odonata-Anisoptera	Odonata-Zygoptera	Coleoptera	Hymenoptera	Neuroptera	Hemiptera	Diptera	Dermaptera	Mantodea	Orthoptera	Arachnida
<i>Nephotettix virescens</i> Distant	0.737**	0.312	0.204	0.259	0.297	-0.271	0.366	0.158	0.074	0.168	0.786**
<i>Nephotettix nigropictus</i> Stål	0.770**	0.383*	0.228	0.549**	0.190	-0.320	0.437*	0.178	0.091	0.278	0.778**
<i>Cofana spectra</i> Distant	0.477*	0.122	0.048	0.298	-0.045	-0.353	0.191	0.025	-0.170	0.163	0.394*
<i>Maiestas dorsalis</i> Motchulsky	0.899**	0.817**	0.681**	0.752**	0.312	0.128	0.615**	0.550**	0.508**	0.474*	0.862**
<i>Nilaparvata lugens</i> Stål	0.845**	0.476*	0.309	0.548**	0.201	-0.302	0.535**	0.159	0.113	0.287	0.860**
<i>Sogatella furcifera</i> Horvith	0.723**	0.427*	0.326	0.431*	0.234	-0.184	0.494**	0.166	0.054	0.185	0.765**
<i>Leptocorisa acuta</i> Thunberg	0.318	0.192	0.202	0.171	0.259	0.031	0.017	0.272	-0.047	0.271	0.346
<i>Cletus punctiger</i> Dallas	0.805**	0.462*	0.257	0.444*	0.336	-0.198	0.372	0.303	0.276	0.210	0.819**
<i>Scirpophaga incertulas</i> Walker	0.856**	0.750**	0.581**	0.683**	0.201	-0.002	0.659**	0.339	0.501**	0.384*	0.818**
<i>Chilo suppressalis</i> Dudgeon	0.777**	0.700**	0.512**	0.646**	0.075	-0.038	0.637**	0.386*	0.457*	0.320	0.710**
<i>Scirpophaga</i> spp.	0.827**	0.571**	0.407*	0.487**	0.326	0.001	0.484*	0.319	0.323	0.335	0.875**
<i>Cnaphalocrocis medinalis</i> Guenée	0.440*	0.066	0.019	0.223	-0.004	-0.405*	0.179	-0.089	-0.157	0.153	0.446*

<i>Melanitis leda ismene</i> Linnaeus	0.844**	0.639**	0.508**	0.661**	0.168	0.061	0.573**	0.393*	0.182	0.462*	0.738**
Green horned caterpillars	0.758**	0.652**	0.491**	0.624**	0.160	-0.054	0.531**	0.339	0.428*	0.326	0.734**
<i>Spodoptera litura</i> Fabricius	-0.108	-0.238	-0.281	-0.070	-0.216	-0.239	-0.169	-0.263	-0.263	0.030	-0.238
<i>Leucania loreyi</i> Duponchel	0.739**	0.427*	0.191	0.396*	0.334	-0.159	0.505**	0.303	0.118	0.189	0.794**
<i>Nymphula depunctalis</i> Guenée	0.865**	0.780**	0.649**	0.803**	0.161	0.040	0.757**	0.384*	0.454*	0.405*	0.819**
<i>Pelopidas mathias</i> Fabricius	0.776**	0.467*	0.342	0.402*	0.213	-0.257	0.425*	0.260	0.154	0.127	0.827**
Short horned grasshoppers	0.393*	0.237	0.271	0.566**	0.256	0.044	0.148	0.135	0.074	0.509**	0.370
Field crickets	0.462*	0.241	0.177	0.414*	0.053	-0.048	0.125	0.210	-0.053	0.540**	0.372
<i>Gryllotalpa orientalis</i> Burmeister	0.866**	0.729**	0.547**	0.660**	0.137	0.126	0.715**	0.562**	0.270	0.527**	0.765**
<i>Sitophilus oryzae</i> Linnaeus	-0.274	-0.465*	-0.312	-0.091	-	-	-0.289	-0.356	-	-0.072	-0.274
				0.381*	0.381*	0.443*			0.510**		
<i>Dicladispa armigera</i> Olivier	0.888**	0.592**	0.362	0.560**	0.400*	-0.089	0.451*	0.312	0.354	0.283	0.895**
<i>Stenchaetothrips biformis</i> Bagnall	0.655**	0.785**	0.751**	0.857**	0.086	0.262	0.576**	0.476*	0.537**	0.560**	0.558**

Note: df = (27-2) = 25

$r_{0.05} = 0.381$

$r_{0.01} = 0.487$

* = Significant at 5% level of significance

** = Significant at 1% level of significance

No significant correlations were observed for *Spodoptera litura*, indicating limited interactions with natural enemies under the conditions studied. *Leucania loreyi* showed significant correlations with Odonata-Anisoptera (0.739, $p < 0.01$), Odonata-Zygoptera (0.427, $p < 0.05$), Arachnida (0.794, $p < 0.01$), Diptera (0.505, $p < 0.01$), and Hymenoptera (0.396, $p < 0.05$). *Nymphula depunctalis* exhibited highly significant associations across multiple natural enemy groups, including Odonata-Anisoptera (0.865, $p < 0.01$), Odonata-Zygoptera (0.780, $p < 0.01$), Coleoptera (0.649, $p < 0.01$), Hymenoptera (0.803, $p < 0.01$), Diptera (0.757, $p < 0.01$), and Arachnida (0.819, $p < 0.01$), as well as significant correlations with Orthoptera (0.405, $p < 0.05$), Dermaptera (0.384, $p < 0.05$) and Mantodea (0.454, $p < 0.05$). Similarly, *Pelopidas mathias* demonstrated strong interactions with Odonata-Anisoptera (0.776, $p < 0.01$), Arachnida (0.827, $p < 0.01$), Odonata-Zygoptera (0.467, $p < 0.05$) and also with Hymenoptera (0.402, $p < 0.05$) and Diptera (0.425, $p < 0.05$). their interactions with remaining natural enemy groups were limited and insignificant.

Short-horned grasshoppers showed significant correlations with only Hymenoptera (0.566, $p < 0.01$), Orthoptera (0.509, $p < 0.01$), and Odonata-Anisoptera (0.393, $p < 0.05$), highlighting its limited influence by natural enemy groups. Field crickets were also significantly associated with Odonata (0.462, $p < 0.05$), Hymenoptera (0.414, $p < 0.05$), and Orthoptera (0.540, $p < 0.01$) and their associations with the remaining natural enemy groups were not significant for consideration in this study.

Gryllotalpa orientalis demonstrated strong and highly significant correlations with multiple natural enemy groups, including Odonata-Anisoptera (0.866, $p < 0.01$), Odonata-Zygoptera (0.729, $p < 0.01$), Coleoptera (0.547, $p < 0.01$), Hymenoptera (0.660, $p < 0.01$), Diptera (0.715, $p < 0.01$), Dermaptera (0.562, $p < 0.01$), Orthoptera (0.527, $p < 0.01$), and Arachnida (0.765, $p < 0.01$), reflecting broad ecological interactions with these natural enemy groups. In contrast, *Sitophilus oryzae* exhibited multiple negative relationships, including significant correlations with Odonata-Zygoptera (-0.465, $p < 0.05$), Neuroptera (-0.381, $p < 0.05$), Hemiptera (-0.443, $p < 0.05$), and Mantodea (-

0.510, $p < 0.01$), while additional negative associations with Diptera (-0.289), Hymenoptera (-0.091), and Arachnida (-0.274) were observed but not statistically significant.

Dicladispa armigera displayed highly significant associations with Odonata-Anisoptera (0.888, $p < 0.01$), Hymenoptera (0.560, $p < 0.01$), Arachnida (0.895, $p < 0.01$), and Diptera (0.451, $p < 0.05$). Correlations with Odonata-Zygoptera (0.592, $p < 0.01$) and Neuroptera (0.400, $p < 0.05$) were also found to significantly suppress the pest species. Lastly, *Stenchaetothrips biformis* was strongly associated with multiple natural enemy groups, including Odonata-Anisoptera (0.655, $p < 0.01$), Odonata-Zygoptera (0.785, $p < 0.01$), Hymenoptera (0.857, $p < 0.01$), Diptera (0.576, $p < 0.01$), and Arachnida (0.558, $p < 0.01$). Significant correlations with natural enemy groups that influenced its suppression were also found with Coleoptera (0.751, $p < 0.01$), Dermaptera (0.476, $p < 0.05$), Mantodea (0.537, $p < 0.01$) and Orthoptera (0.560, $p < 0.01$).

4.4.2. CORRELATION COEFFICIENT OF INSECT PESTS OF RICE WITH THEIR NATURAL ENEMIES AT SINGRIJAN

Upon analysis of the table 4.4c on the correlation between insect pests of rice and natural enemies observed in Singjiran from June to December 2020, the Pearson's correlation coefficient (r) was computed to determine their relationship.

Nephotettix virescens showed a significant positive correlation with Odonata-Zygoptera (0.471, $p < 0.05$) and Hymenoptera (0.457, $p < 0.05$), whereas the correlations with other natural enemy groups were found non-significant. Likewise, *Nephotettix nigropictus* was also significantly correlated with Odonata-Zygoptera (0.471, $p < 0.05$), and no significant correlations were reported from other natural enemy groups.

In contrast, *Cofana spectra* did not exhibit any statistically significant positive correlations, though a negative relationship was observed with Dermaptera (-0.389, $p <$

0.05). Among the delphacid planthoppers, *Maiestas dorsalis* exhibited highly significant correlations with Coleoptera (0.650, $p < 0.01$), Hymenoptera (0.574, $p < 0.01$), Hemiptera (0.711, $p < 0.01$), and Arachnida (0.646, $p < 0.01$). It was also significantly associated with Odonata-Anisoptera (0.488, $p < 0.01$), Odonata-Zygoptera (0.449, $p < 0.05$), Neuroptera (0.410, $p < 0.05$), Diptera (0.456, $p < 0.05$), and Dermaptera (0.516, $p < 0.01$). *Nilaparvata lugens* showed strong interactions with Odonata-Zygoptera (0.684, $p < 0.01$), Hymenoptera (0.575, $p < 0.01$), Diptera (0.571, $p < 0.01$), and Arachnida (0.566, $p < 0.01$), along with moderate associations with Odonata-Anisoptera (0.462, $p < 0.05$) and Coleoptera (0.385, $p < 0.05$). In contrast, *Sogatella furcifera* was significantly associated with Odonata-Zygoptera (0.469, $p < 0.05$) and Hymenoptera (0.387, $p < 0.05$), while correlations to other natural enemy groups were not statistically significant.

The predatory activity of natural enemies against Hemipteran bugs was evident for *Leptocorisa acuta*, which showed significant correlation with Odonata-Zygoptera (0.496, $p < 0.01$), Diptera (0.402, $p < 0.05$), Orthoptera (0.408, $p < 0.05$), and Arachnida (0.383, $p < 0.05$). In contrast, *Cletus punctiger* was strongly correlated with multiple natural enemy groups, including Odonata-Anisoptera (0.714, $p < 0.01$), Odonata-Zygoptera (0.705, $p < 0.01$), Hymenoptera (0.612, $p < 0.01$), Arachnida (0.700, $p < 0.01$), and Neuroptera (0.555, $p < 0.01$). Non-significant correlations with natural enemy groups were observed.

Scirpophaga incertulas exhibited strong and highly significant correlation with Odonata-Anisoptera (0.884, $p < 0.01$), Odonata-Zygoptera (0.946, $p < 0.01$), Coleoptera (0.619, $p < 0.01$), Hymenoptera (0.732, $p < 0.01$), Neuroptera (0.710, $p < 0.01$), Diptera (0.789, $p < 0.01$), and Arachnida (0.944, $p < 0.01$). *Chilo suppressalis* showed significant correlations with Odonata-Anisoptera (0.709, $p < 0.01$), Odonata-

Table 4.4c: Correlation coefficient (r) between insect pests of rice and natural enemies recorded during June to December 2020 in Singjiran

Insect pests	Pearson's correlation coefficient										
	Odonata-Anisoptera	Odonata-Zygoptera	Coleoptera	Hymenoptera	Neuroptera	Hemiptera	Diptera	Dermaptera	Mantodea	Orthoptera	Arachnida
<i>Nephotettix virescens</i> Distant	0.251	0.471*	0.222	0.457*	0.194	-0.270	0.333	-0.292	0.025	-0.031	0.235
<i>Nephotettix nigropictus</i> Stål	0.181	0.471*	0.161	0.372	0.140	-0.192	0.307	-0.279	-0.001	0.025	0.273
<i>Cofana spectra</i> Distant	0.007	0.199	0.036	0.314	-0.006	-0.335	0.111	-0.389*	-0.139	0.020	-0.008
<i>Maiestas dorsalis</i> Motchulsky	0.488**	0.449*	0.650**	0.574**	0.410*	0.711**	0.456*	0.516**	0.325	0.053	0.646**
<i>Nilaparvata lugens</i> Stål	0.462*	0.684**	0.385*	0.575**	0.334	-0.034	0.571**	-0.165	0.144	0.080	0.566**
<i>Sogatella furcifera</i> Horvith	0.153	0.469*	0.169	0.387*	0.137	-0.149	0.369	-0.259	0.022	0.139	0.284
<i>Leptocorisa acuta</i> Thunberg	0.174	0.496**	0.077	0.250	0.107	-0.081	0.402*	-0.028	0.181	0.408*	0.383*
<i>Cletus punctiger</i> Dallas	0.714**	0.705**	0.324	0.612**	0.555**	-0.176	0.286	0.013	-0.038	0.103	0.700**
<i>Scirpophaga incertulas</i> Walker	0.884**	0.946**	0.619**	0.732**	0.710**	0.202	0.789**	0.184	0.326	0.124	0.944**
<i>Chilo suppressalis</i> Dudgeon	0.709**	0.601**	0.385*	0.473*	0.543**	0.109	0.368	0.323	0.139	0.047	0.618**
<i>Scirpophaga</i> spp.	0.803**	0.862**	0.519**	0.735**	0.700**	0.113	0.665**	0.189	0.279	0.028	0.910**
<i>Cnaphalocrocis medinalis</i> Guenée	0.196	0.522**	0.123	0.303	0.178	-0.209	0.410*	-0.275	-0.009	0.193	0.313
<i>Melanitis leda ismene</i> Linnaeus	0.539**	0.600**	0.380	0.571**	0.408*	0.134	0.410*	0.272	0.162	0.112	0.603**

Green horned caterpillars	0.436*	0.232	0.550**	0.412*	0.465*	0.625**	0.331	0.818**	0.331	0.085	0.406*
<i>Spodoptera litura</i> Fabricius	0.453*	0.700**	0.074	0.399*	0.325	-0.239	0.386*	-0.197	-0.020	0.008	0.556**
<i>Leucania loreyi</i> Duponchel	0.746**	0.898**	0.372	0.616**	0.586**	-0.154	0.685**	-0.080	0.222	0.161	0.785**
<i>Nymphula depunctalis</i> Guenée	0.549**	0.477*	0.770**	0.502**	0.685**	0.687**	0.633**	0.523**	0.384*	-0.123	0.530**
<i>Pelopidas mathias</i> Fabricius	0.809**	0.748**	0.433*	0.547**	0.564**	-0.104	0.350	0.046	0.079	-0.063	0.751**
Short horned grasshoppers	0.246	0.159	0.060	0.142	0.142	-0.091	0.243	0.094	0.029	0.387*	0.267
Field crickets	0.263	0.526**	0.252	0.320	0.231	-0.089	0.379	-0.216	0.111	0.287	0.389*
<i>Gryllotalpa orientalis</i> Burmeister	0.413*	0.503**	0.397*	0.442*	0.191	0.311	0.544**	0.236	0.292	0.316	0.603**
<i>Sitophilus oryzae</i> Linnaeus	-0.337	-0.330	-0.123	-0.017	-0.318	-0.336	-0.286	-0.388*	-0.206	-0.313	- 0.519**
<i>Dicladispa armigera</i> Olivier	0.778**	0.670**	0.788**	0.667**	0.792**	0.395*	0.528**	0.380	0.211	-0.018	0.762**
<i>Stenchaetothrips biformis</i> Bagnall	0.384*	0.332	0.642**	0.523**	0.523**	0.723**	0.364	0.710**	0.378	0.105	0.568**

Note: df = (27-2) = 25

$r_{0.05} = 0.381$

$r_{0.01} = 0.487$

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Zygoptera (0.601, $p < 0.01$), Coleoptera (0.385, $p < 0.05$), Hymenoptera (0.473, $p < 0.05$), and Neuroptera (0.543, $p < 0.01$), along with a strong association with Arachnida (0.618, $p < 0.01$). The broader group *Scirpophaga* spp. was significantly associated with multiple natural enemy groups, including Odonata-Anisoptera (0.803, $p < 0.01$), Odonata-Zygoptera (0.862, $p < 0.01$), Coleoptera (0.519, $p < 0.01$), Hymenoptera (0.735, $p < 0.01$), Neuroptera (0.700, $p < 0.01$), Diptera (0.665, $p < 0.01$), and Arachnida (0.910, $p < 0.01$), suggesting a broad spectrum of predatory interactions.

Cnaphalocrocis medinalis showed significant associations with only Odonata-Zygoptera (0.522, $p < 0.01$) and Diptera (0.410, $p < 0.05$), while a weak negative correlation was observed with Hemiptera (-0.209). In contrast, *Melanitis leda ismene* was significantly correlated with multiple natural enemy groups, including Odonata-Anisoptera (0.539, $p < 0.01$), Odonata-Zygoptera (0.600, $p < 0.01$), Hymenoptera (0.571, $p < 0.01$), Neuroptera (0.408, $p < 0.05$), Diptera (0.410, $p < 0.05$), and Arachnida (0.603, $p < 0.01$). Green horned caterpillars displayed significant correlations with Odonata-Anisoptera (0.436, $p < 0.05$), Coleoptera (0.550, $p < 0.01$), Hymenoptera (0.412, $p < 0.05$), Neuroptera (0.465, $p < 0.05$), Hemiptera (0.625, $p < 0.01$), Dermaptera (0.818, $p < 0.01$), and Arachnida (0.406, $p < 0.05$), indicating widespread interactions with various natural enemies.

Spodoptera litura showed significant correlations with Odonata-Anisoptera (0.453, $p < 0.05$), Odonata-Zygoptera (0.700, $p < 0.01$), Hymenoptera (0.399, $p < 0.05$), Diptera (0.386, $p < 0.05$), and Arachnida (0.556, $p < 0.01$), suggesting multiple natural enemy interactions. For *Leucania loreyi*, strong associations were observed with Odonata-Anisoptera (0.746, $p < 0.01$), Odonata-Zygoptera (0.898, $p < 0.01$), Hymenoptera (0.616, $p < 0.01$), Neuroptera (0.586, $p < 0.01$), and Diptera (0.685, $p < 0.01$), along with a significant link to Arachnida (0.785, $p < 0.01$). *Nymphula depunctalis* exhibited highly significant correlations with Coleoptera (0.770, $p < 0.01$), Hymenoptera (0.502, $p < 0.01$), Neuroptera (0.685, $p < 0.01$), Hemiptera (0.687, $p < 0.01$), Diptera (0.633, $p < 0.01$), Dermaptera (0.523, $p < 0.01$), Mantodea (0.384, $p < 0.05$), Odonata-

Anisoptera (0.549, $p < 0.01$), Odonata-Zygoptera (0.477, $p < 0.05$), and Arachnida (0.530, $p < 0.01$), indicating extensive interactions across natural enemy groups.

Pelopidas mathias exhibited highly significant correlations with Odonata-Anisoptera (0.809, $p < 0.01$), Odonata-Zygoptera (0.748, $p < 0.01$), Hymenoptera (0.547, $p < 0.01$), and Arachnida (0.751, $p < 0.01$), along with a significant relationship with Coleoptera (0.433, $p < 0.05$) and Neuroptera (0.564, $p < 0.01$). Short horned grasshoppers showed a significant association with only Orthoptera (0.387, $p < 0.05$) and no correlation with other natural enemy groups. Field crickets were significantly associated with Odonata-Zygoptera (0.526, $p < 0.01$) and Arachnida (0.389, $p < 0.05$), while its correlations with other natural enemy groups were limited and found insignificant.

Gryllotalpa orientalis exhibited significant associations with Odonata-Anisoptera (0.413, $p < 0.05$), Odonata-Zygoptera (0.503, $p < 0.01$), Coleoptera (0.397, $p < 0.05$), Hymenoptera (0.442, $p < 0.05$), Diptera (0.544, $p < 0.01$), and Arachnida (0.603, $p < 0.01$), suggesting a broad spectrum of influence by natural enemy groups. In contrast, *Sitophilus oryzae* revealed consistently negative correlations across all predator groups, with significant negative associations recorded for Dermaptera (-0.388, $p < 0.05$) and Arachnida (-0.519, $p < 0.01$), indicating possible predator avoidance or reduced predation susceptibility.

Dicladispa armigera showed strong and highly significant correlations with Odonata-Anisoptera (0.778, $p < 0.01$), Odonata-Zygoptera (0.670, $p < 0.01$), Coleoptera (0.788, $p < 0.01$), Hymenoptera (0.667, $p < 0.01$), Neuroptera (0.792, $p < 0.01$), Hemiptera (0.395, $p < 0.05$), Diptera (0.528, $p < 0.01$), and Arachnida (0.762, $p < 0.01$), indicating extensive natural enemy influence on its population.

Stenchaetothrips biformis was significantly associated with Odonata-Anisoptera (0.384, $p < 0.05$), Coleoptera (0.642, $p < 0.01$), Hymenoptera (0.523, $p < 0.01$), Neuroptera (0.523, $p < 0.01$), Hemiptera (0.723, $p < 0.01$), Dermaptera (0.710, $p < 0.01$),

and Arachnida (0.568, $p < 0.01$), reflecting broad-spectrum natural enemy involvement in its suppression.

Table 4.4d shows the findings on correlation between rice insect pests and their natural enemies from June to December 2021 at Singjiran.

Nephotettix virescens exhibited significant associations with Odonata-Anisoptera (0.664, $p < 0.01$), Odonata-Zygoptera (0.430, $p < 0.05$), Coleoptera (0.516, $p < 0.01$), Hymenoptera (0.458, $p < 0.05$), Diptera (0.433, $p < 0.05$), and Arachnida (0.418, $p < 0.05$). Similarly, in the case of *Nephotettix nigropictus*, highly significant relationships were observed with Odonata-Anisoptera (0.716, $p < 0.01$), Odonata-Zygoptera (0.563, $p < 0.01$), Coleoptera (0.589, $p < 0.01$), Hymenoptera (0.550, $p < 0.01$), Diptera (0.601, $p < 0.01$), Arachnida (0.517, $p < 0.01$) and their correlations with other natural enemy groups were insignificant

For *Cofana spectra*, no strong associations were detected with most natural enemy groups, except Odonata-Anisoptera showed a significant positive correlation (0.551, $p < 0.01$). Other correlations remained insignificant, including Hemiptera (-0.373), indicating limited predation effects. *Maiestas dorsalis* demonstrated robust associations with multiple natural enemy groups, including Odonata-Anisoptera (0.510, $p < 0.01$), Odonata-Zygoptera (0.788, $p < 0.01$), Coleoptera (0.790, $p < 0.01$), Hymenoptera (0.830, $p < 0.01$), Neuroptera (0.765, $p < 0.01$), Hemiptera (0.584, $p < 0.01$), Diptera (0.757, $p < 0.01$), Dermaptera (0.443, $p < 0.05$), and Arachnida (0.785, $p < 0.01$), suggesting a wide range of natural enemies interactions shaping its dynamics.

Nilaparvata lugens exhibited strong correlations with Odonata-Anisoptera (0.785, $p < 0.01$), Odonata-Zygoptera (0.492, $p < 0.01$), Coleoptera (0.504, $p < 0.01$), and Hymenoptera (0.507, $p < 0.01$), while Diptera (0.484, $p < 0.05$) and Arachnida (0.441, $p < 0.05$) also played a potential role in its suppression. In the case of *Sogatella furcifera*, significant associations were recorded with Odonata-Anisoptera (0.708, $p < 0.01$), Coleoptera (0.459, $p < 0.05$), Hymenoptera (0.385, $p < 0.05$), and Diptera (0.432, $p < 0.05$).

0.05) and weak or insignificant correlation was recorded with the remaining natural enemy groups.

A strong correlation with Odonata-Anisoptera (0.570, $p < 0.01$) was observed for *Leptocorisa acuta*, but other natural enemy groups showed insignificant interactions, particularly Neuroptera (-0.123) and Hemiptera (-0.169). *Cletus punctiger* was significantly associated with Odonata-Zygoptera (0.577, $p < 0.01$), Hymenoptera (0.531, $p < 0.01$), and Neuroptera (0.693, $p < 0.01$), with additional positive correlations noted for Coleoptera (0.424, $p < 0.05$), Mantodea (0.429, $p < 0.05$), and Arachnida (0.680, $p < 0.01$).

Scirpophaga incertulas exhibited strong correlations with a wide range of natural enemy groups, including Odonata-Anisoptera (0.830, $p < 0.01$), Odonata-Zygoptera (0.870, $p < 0.01$), Coleoptera (0.759, $p < 0.01$), Hymenoptera (0.665, $p < 0.01$), Neuroptera (0.789, $p < 0.01$), Diptera (0.693, $p < 0.01$), and Arachnida (0.832, $p < 0.01$), indicating broad and effective natural enemy interactions. Similarly, *Chilo suppressalis* demonstrated significant correlations with Odonata-Zygoptera (0.727, $p < 0.01$), Coleoptera (0.565, $p < 0.01$), Hymenoptera (0.639, $p < 0.01$), Neuroptera (0.872, $p < 0.01$), Hemiptera (0.529, $p < 0.01$), Diptera (0.701, $p < 0.01$), Dermaptera (0.536, $p < 0.01$), and Arachnida (0.667, $p < 0.01$), suggesting strong biological control pressure of this pest.

For *Scirpophaga* spp., notable correlations were found with Odonata-Anisoptera (0.683, $p < 0.01$), Odonata-Zygoptera (0.724, $p < 0.01$), Coleoptera (0.568, $p < 0.01$), Hymenoptera (0.545, $p < 0.01$), Neuroptera (0.699, $p < 0.01$), Diptera (0.488, $p < 0.01$), and Arachnida (0.789, $p < 0.01$), reinforcing the pattern of widespread natural enemies involvement. In the case of *Cnaphalocrocis medinalis*, significant associations were observed with Odonata-Anisoptera (0.611, $p < 0.01$) and Coleoptera (0.396, $p < 0.05$) and several natural enemy groups showed non-significant correlations.

Table 4.4d: Correlation coefficient (r) between insect pests of rice and natural enemies recorded during June to December 2021 in Singjiran

Insect pests	Pearson's correlation coefficient										
	Odonata-Anisoptera	Odonata-Zygoptera	Coleoptera	Hymenoptera	Neuroptera	Hemiptera	Diptera	Dermaptera	Mantodea	Orthoptera	Arachnida
<i>Nephotettix virescens</i> Distant	0.664**	0.430*	0.516**	0.458*	0.272	-0.233	0.433*	-0.185	0.117	0.051	0.418*
<i>Nephotettix nigropictus</i> Stål	0.716**	0.563**	0.589**	0.550**	0.363	0.000	0.601**	0.022	0.122	0.193	0.517**
<i>Cofana spectra</i> Distant	0.551**	0.219	0.287	0.261	0.074	-0.373	0.154	-0.302	-0.024	-0.043	0.194
<i>Maiestas dorsalis</i> Motchulsky	0.510**	0.788**	0.790**	0.830**	0.765**	0.584**	0.757**	0.443*	0.304	0.230	0.785**
<i>Nilaparvata lugens</i> Stål	0.785**	0.492**	0.504**	0.507**	0.363	-0.074	0.484*	0.036	0.025	-0.030	0.441*
<i>Sogatella furcifera</i> Horvith	0.708**	0.335	0.459*	0.385*	0.134	-0.169	0.432*	-0.131	0.097	-0.011	0.274
<i>Leptocorisa acuta</i> Thunberg	0.570**	0.045	0.231	0.192	-0.123	-0.169	0.204	-0.120	0.165	0.084	0.019
<i>Cletus punctiger</i> Dallas	0.300	0.577**	0.424*	0.531**	0.693**	0.101	0.335	0.041	0.429*	0.237	0.680**
<i>Scirpophaga incertulas</i> Walker	0.830**	0.870**	0.759**	0.665**	0.789**	0.095	0.693**	0.165	0.172	0.156	0.832**
<i>Chilo suppressalis</i> Dudgeon	0.279	0.727**	0.565**	0.639**	0.872**	0.529**	0.701**	0.536**	0.329	0.150	0.667**
<i>Scirpophaga</i> spp.	0.683**	0.724**	0.568**	0.545**	0.699**	0.043	0.488**	0.158	0.064	0.100	0.789**
<i>Cnaphalocrocis medinalis</i> Guenée	0.611**	0.216	0.396*	0.275	0.031	-0.213	0.301	-0.213	0.163	-0.045	0.173
<i>Melanitis leda ismene</i> Linnaeus	0.107	0.337	0.337	0.517**	0.473*	0.536**	0.404*	0.558**	0.489**	0.248	0.408*

Green horned caterpillars	0.174	0.708**	0.595**	0.554**	0.702**	0.448*	0.518**	0.504**	0.276	0.295	0.739**
<i>Spodoptera litura</i> Fabricius	0.663**	0.201	0.104	0.160	0.063	-0.344	0.119	-0.104	-0.065	-0.140	0.177
<i>Leucania loreyi</i> Duponchel	0.807**	0.599**	0.458*	0.418*	0.520**	-0.262	0.388*	-0.127	0.087	0.006	0.605**
<i>Nymphula depunctalis</i> Guenée	0.423*	0.803**	0.575**	0.590**	0.868**	0.031	0.651**	0.123	0.323	0.106	0.839**
<i>Pelopidas mathias</i> Fabricius	0.665**	0.836**	0.698**	0.546**	0.778**	-0.043	0.661**	0.088	0.110	0.115	0.863**
Short horned grasshoppers	0.550**	0.409*	0.135	0.283	0.502**	-0.047	0.183	0.071	-0.128	-0.079	0.295
Field crickets	0.596**	0.449*	0.431*	0.451*	0.412*	-0.155	0.423*	-0.087	0.298	-0.001	0.400*
<i>Gryllotalpa orientalis</i> Burmeister	0.532**	0.564**	0.553**	0.650**	0.516**	0.391*	0.427*	0.378	0.106	0.078	0.538**
<i>Sitophilus oryzae</i> Linnaeus	-0.334	-0.374	-0.375	-0.162	-0.372	-0.348	-0.353	-0.297	-0.200	-0.257	-0.399*
<i>Dicladispa armigera</i> Olivier	0.318	0.900**	0.740**	0.662**	0.841**	0.224	0.756**	0.185	0.263	0.107	0.881**
<i>Stenchaetothrips biformis</i> Bagnall	0.234	0.540**	0.463*	0.701**	0.630**	0.728**	0.477*	0.795**	0.287	0.252	0.545**

Note: df = (27-2) = 25

$r_{0.05} = 0.381$

$r_{0.01} = 0.487$

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Melanitis leda ismene exhibits significant correlations with Hymenoptera (0.517, $p < 0.01$), Hemiptera (0.536, $p < 0.01$), and Dermaptera (0.558, $p < 0.01$), alongside moderate associations with Diptera (0.404, $p < 0.05$), Neuroptera (0.473, $p < 0.05$), Mantodea (0.489, $p < 0.05$) and Arachnida (0.408, $p < 0.05$). These findings suggest a diverse range of predatory and parasitic interactions. In contrast, Green horned caterpillars demonstrated extensive and statistically significant associations with a broad range of predator groups. Strong positive correlations were observed with Odonata-Zygoptera (0.708, $p < 0.01$), Coleoptera (0.595, $p < 0.01$), Hymenoptera (0.554, $p < 0.01$), Neuroptera (0.702, $p < 0.01$), Diptera (0.518, $p < 0.01$), Dermaptera (0.504, $p < 0.01$), Hemiptera (0.448, $p < 0.05$), and Arachnida (0.739, $p < 0.01$). These values reflect a complex web of natural enemies actively contributing to the regulation of this species.

Spodoptera litura shows a significant positive correlation with Odonata-Anisoptera (0.663, $p < 0.01$), while other predator groups exhibited insignificant relationships, indicating restricted natural regulation. In the case of *Leucania loreyi*, strong positive associations are observed with Odonata-Anisoptera (0.807, $p < 0.01$), Odonata-Zygoptera (0.599, $p < 0.01$), and Neuroptera (0.520, $p < 0.01$), Coleoptera (0.458, $p < 0.05$), Hymenoptera (0.418, $p < 0.05$), Diptera (0.388, $p < 0.05$), and Arachnida (0.605, $p < 0.01$). A weak negative correlation with Hemiptera (-0.262) suggests minimal contribution from this group.

Nymphula depunctalis demonstrated highly significant associations with Odonata-Zygoptera (0.803, $p < 0.01$), Neuroptera (0.868, $p < 0.01$), Arachnida (0.839, $p < 0.01$), Hymenoptera (0.590, $p < 0.01$), and Diptera (0.651, $p < 0.01$), reflecting a well-supported and diverse predator complex. Additionally, positive relationships with Coleoptera (0.575, $p < 0.01$) and Odonata-Anisoptera (0.423, $p < 0.05$) further emphasize its suppression by multiple natural enemy groups.

Similarly, *Pelopidas mathias* showed strong positive correlations with Odonata-Zygoptera (0.836, $p < 0.01$), Arachnida (0.863, $p < 0.01$), Neuroptera (0.778, $p < 0.01$), Diptera (0.661, $p < 0.01$), and Coleoptera (0.698, $p < 0.01$). Odonata-Anisoptera (0.665,

$p < 0.01$) and Hymenoptera (0.546, $p < 0.01$) also appear to contribute substantially to natural regulation.

Short-horned grasshoppers were significantly correlated with Odonata-Anisoptera (0.550, $p < 0.01$), Odonata-Zygoptera (0.409, $p < 0.05$) and Neuroptera (0.502, $p < 0.01$) suggest some degree of predatory interaction, although relationships with other groups remained insignificant. Field Crickets exhibit notable associations with Odonata-Anisoptera (0.596, $p < 0.01$), Odonata-Zygoptera (0.449, $p < 0.05$), Coleoptera (0.431, $p < 0.05$), Hymenoptera (0.451, $p < 0.05$), Neuroptera (0.412, $p < 0.05$), Diptera (0.423, $p < 0.05$), and Arachnida (0.400, $p < 0.05$), indicating multi-trophic regulation by a wide range of natural enemy groups.

Gryllotalpa orientalis is significantly associated with Odonata-Anisoptera (0.532, $p < 0.01$), Odonata-Zygoptera (0.564, $p < 0.01$), Coleoptera (0.553, $p < 0.01$), Hymenoptera (0.650, $p < 0.01$), Neuroptera (0.516, $p < 0.01$), Hemiptera (0.391, $p < 0.05$), Diptera (0.427, $p < 0.05$), and Arachnida (0.538, $p < 0.01$), indicating broad group natural enemies supporting for natural pest regulation.

In contrast, *Sitophilus oryzae* displays consistent negative correlations across all predator groups, with Arachnida (-0.399, $p < 0.05$) being significant, suggesting minimal predatory and parasitic impact on this pest. For *Dicladispa armigera*, strong associations are evident with Odonata-Zygoptera (0.900, $p < 0.01$), Neuroptera (0.841, $p < 0.01$), Arachnida (0.881, $p < 0.01$), Diptera (0.756, $p < 0.01$), Coleoptera (0.740, $p < 0.01$), and Hymenoptera (0.662, $p < 0.01$), highlighting an effective and diverse natural enemies complex contributing to natural control. Similarly, *Stenchaetothrips biformis* is significantly correlated with Hymenoptera (0.701, $p < 0.01$), Neuroptera (0.630, $p < 0.01$), Hemiptera (0.728, $p < 0.01$), Dermaptera (0.795, $p < 0.01$), Arachnida (0.545, $p < 0.01$), Odonata-Zygoptera (0.540, $p < 0.01$), Diptera (0.477, $p < 0.05$), and Coleoptera (0.463, $p < 0.05$), suggesting a comprehensive network of natural enemies involved in its suppression.

4.4.3. CORRELATION COEFFICIENT OF INSECT PESTS OF RICE WITH THEIR NATURAL ENEMIES AT KUHOXU

Table 4.4e assessed the correlation between insect pests of rice and their natural enemies recorded in Kuhoxu from June to December 2020.

Significant predator-prey relationships were observed for several pests. *Nephotettix virescens* was positively associated with Odonata-Zygoptera (0.573, $p < 0.01$) and Hymenoptera (0.392, $p < 0.05$), while *Nephotettix nigropictus* showed strong associations with Odonata-Zygoptera (0.761, $p < 0.01$) and Hymenoptera (0.463, $p < 0.05$). In both cases, insignificant correlations were found for other natural enemy groups. *Cofana spectra* followed a similar pattern, showing significant correlation with Odonata-Zygoptera (0.409, $p < 0.05$) and moderate association with Hymenoptera (0.349) which suggest a limited natural suppression by the other natural enemy groups.

Similarly, *Sogatella furcifera* was strongly linked with Odonata-Zygoptera (0.815, $p < 0.01$) and Hymenoptera (0.524, $p < 0.01$), while a weaker but significant association was noted with Arachnida (0.388, $p < 0.05$). Although correlations with most other groups were positive, they were generally not significant, indicating limited influence from natural enemy groups. *Maiesta dorsalis* demonstrated exceptionally strong associations with a broad natural enemy groups. Highly significant correlations were observed with Hymenoptera (0.851, $p < 0.01$), Arachnida (0.855, $p < 0.01$), Diptera (0.812, $p < 0.01$), Hemiptera (0.788, $p < 0.01$), Coleoptera (0.734, $p < 0.01$), Odonata-Zygoptera (0.593, $p < 0.01$), Odonata-Anisoptera (0.617, $p < 0.01$), Neuroptera (0.604, $p < 0.01$), Dermaptera (0.503, $p < 0.01$), Mantodea (0.765, $p < 0.01$), and Orthoptera (0.440, $p < 0.05$).

Likewise, *Nilaparvata lugens* showed a strong correlation with Odonata-Zygoptera (0.898, $p < 0.01$), and was also significantly associated with Hymenoptera (0.713, $p < 0.01$), Coleoptera (0.520, $p < 0.01$), Diptera (0.518, $p < 0.01$), Arachnida (0.651, $p < 0.01$), Neuroptera (0.446, $p < 0.05$), Odonata-Anisoptera (0.499, $p < 0.01$),

Table 4.4e: Correlation coefficient (r) between insect pests of rice and natural enemies recorded during June to December 2020 in Kuhoxu.

Insect pests	Pearson's correlation coefficient										
	Odonata-Anisoptera	Odonata-Zygoptera	Coleoptera	Hymenoptera	Neuroptera	Hemiptera	Diptera	Dermoptera	Mantodea	Orthoptera	Arachnida
<i>Nephotettix virescens</i> Distant	0.034	0.573**	0.096	0.392*	0.188	-0.185	0.003	-0.267	-0.053	-0.291	0.092
<i>Nephotettix nigropictus</i> Stål	0.172	0.761**	0.235	0.463*	0.266	-0.004	0.169	-0.155	0.144	-0.121	0.306
<i>Cofana spectra</i> Distant	-0.024	0.409*	0.055	0.349	0.050	-0.191	-0.070	-0.183	-0.148	-0.207	-0.008
<i>Maiestas dorsalis</i> Motchulsky	0.617**	0.593**	0.734**	0.851**	0.604**	0.788**	0.812**	0.503**	0.765**	0.440*	0.855**
<i>Nilaparvata lugens</i> Stål	0.499**	0.898**	0.520**	0.713**	0.446*	0.317	0.518**	0.068	0.420*	0.086	0.651**
<i>Sogatella furcifera</i> Horvith	0.221	0.815**	0.227	0.524**	0.202	0.078	0.251	-0.114	0.231	0.055	0.388*
<i>Leptocorisa acuta</i> Thunberg	0.232	0.796**	0.210	0.508**	0.166	0.179	0.286	0.126	0.216	0.250	0.427*
<i>Cletus punctiger</i> Dallas	0.745**	0.524**	0.594**	0.581**	0.694**	0.454*	0.680**	0.356	0.540**	0.380	0.680**
<i>Scirpophaga incertulas</i> Walker	0.809**	0.871**	0.705**	0.761**	0.587**	0.545**	0.790**	0.252	0.643**	0.371	0.899**
<i>Chilo suppressalis</i> Dudgeon	0.907**	0.518**	0.671**	0.564**	0.487**	0.482*	0.678**	0.417*	0.427*	0.389*	0.796**
<i>Scirpophaga</i> spp.	0.904**	0.662**	0.637**	0.658**	0.479*	0.498**	0.850**	0.266	0.504**	0.386*	0.801**
<i>Scirpophaga nivella</i> Fabricus	0.689**	0.767**	0.587**	0.839**	0.460*	0.441*	0.661**	0.187	0.471*	0.203	0.734
<i>Cnaphalocrocis medinalis</i> Guenée	0.258	0.833**	0.228	0.430*	0.252	0.016	0.202	-0.161	0.144	-0.029	0.362

<i>Melanitis leda ismene</i> Linnaeus	0.670**	0.506**	0.713**	0.760**	0.659**	0.721**	0.814**	0.395*	0.607**	0.362	0.787**
Green horned caterpillars	0.351	-0.049	0.539**	0.446*	0.420*	0.710**	0.341	0.660**	0.568**	0.462*	0.572**
<i>Spodoptera litura</i> Fabricius	0.776**	0.813**	0.355	0.494**	0.250	0.127	0.584**	-0.094	0.279	0.282	0.629**
<i>Leucania loreyi</i> Duponchel	0.745**	0.878**	0.540**	0.578**	0.588**	0.264	0.605**	0.108	0.365	0.148	0.721**
<i>Nymphula depunctalis</i> Guenée	0.435*	0.024	0.696**	0.573**	0.556**	0.860**	0.638**	0.376	0.691**	0.184	0.619**
<i>Pelopidas mathias</i> Fabricius	0.855**	0.866**	0.666**	0.600**	0.607**	0.348	0.607**	0.158	0.423*	0.217	0.784**
Short horned grasshoppers	0.763**	0.539**	0.513**	0.523**	0.475*	0.343	0.575**	-0.043	0.244	0.240	0.574**
Field crickets	0.177	0.717**	0.290	0.465*	0.283	0.212	0.216	-0.006	0.279	0.099	0.347
<i>Gryllotalpa orientalis</i> Burmeister	0.484*	0.718**	0.641**	0.691**	0.317	0.576**	0.639**	0.182	0.625**	0.224	0.729**
<i>Sitophilus oryzae</i> Linnaeus	-0.391*	-0.150	-0.210	0.031	-0.169	-0.417*	-0.433*	-0.355	-0.366	-0.568**	-0.415*
<i>Dicladispa armigera</i> Olivier	0.796**	0.476*	0.822**	0.719**	0.733**	0.718**	0.800**	0.418*	0.641**	0.200	0.830**
<i>Stenchaetothrips biformis</i> Bagnall	0.298	0.133	0.580**	0.654**	0.449*	0.904**	0.637**	0.707**	0.702**	0.485*	0.612**

Note: df = (27-2) = 25

$r_{0.05} = 0.381$

$r_{0.01} = 0.487$

* = Significant at 5% level of significance

** = Significant at 1% level of significance

and Mantodea (0.420, $p < 0.05$). These associations further emphasize the important role of aerial predators, particularly Zygoptera and hymenopterans, in suppressing this major pest.

Leptocorisa acuta exhibited a strong positive correlation with Odonata-Zygoptera (0.796, $p < 0.01$), along with a significant association with Hymenoptera (0.508, $p < 0.01$). Statistically significant relationship was also observed with Arachnida (0.427, $p < 0.05$). In contrast, *Cletus punctiger* showed a wide range of significant correlations across natural enemy groups. Strong associations were detected with Odonata-Anisoptera (0.745, $p < 0.01$), Coleoptera (0.594, $p < 0.01$), Hymenoptera (0.581, $p < 0.01$), Neuroptera (0.694, $p < 0.01$), Diptera (0.680, $p < 0.01$), and Arachnida (0.680, $p < 0.01$). Significant correlations were also found with Odonata-Zygoptera (0.524, $p < 0.01$), Hemiptera (0.454, $p < 0.05$), and Mantodea (0.540, $p < 0.01$), reflecting a diverse and effective assemblage of natural enemies.

Scirpophaga incertulas demonstrates strong associations with Odonata-Anisoptera (0.809, $p < 0.01$), Hymenoptera (0.761, $p < 0.01$), Diptera (0.790, $p < 0.01$), and Arachnida (0.899, $p < 0.01$), indicating high levels of aerial and web-based predation and parasitization. Additionally, significant relationships with Coleoptera (0.705, $p < 0.01$), Neuroptera (0.587, $p < 0.01$), Hemiptera (0.545, $p < 0.01$), Mantodea (0.643, $p < 0.01$), and Odonata-Zygoptera (0.871, $p < 0.01$) further support a broad predator complex. *Chilo suppressalis* is subject to widespread and highly significant predation pressure across all examined predator groups. Strong associations were observed with Odonata-Anisoptera (0.904, $p < 0.01$), Odonata-Zygoptera (0.518, $p < 0.01$), Coleoptera (0.671, $p < 0.01$), Hymenoptera (0.564, $p < 0.01$), Neuroptera (0.487, $p < 0.01$), Diptera (0.678, $p < 0.01$) and Arachnida (0.796, $p < 0.01$). Further significant relationships include, Hemiptera (0.482, $p < 0.01$), Dermaptera (0.417, $p < 0.01$), Mantodea (0.427, $p < 0.01$), and Orthoptera (0.389, $p < 0.01$), reflecting a comprehensive natural enemy complex in the suppression of this pest by their natural enemies.

Likewise, *Scirpophaga* spp. exhibited strong and significant association with Odonata-Anisoptera (0.904, $p < 0.01$), Odonata-Zygoptera (0.662, $p < 0.01$), Coleoptera (0.637, $p < 0.01$), Hymenoptera (0.658, $p < 0.01$), Hemiptera (0.498, $p < 0.01$), Diptera (0.850, $p < 0.01$), Mantodea (0.504, $p < 0.01$) and Arachnida (0.801, $p < 0.01$). Positive correlations were also seen with Neuroptera (0.479, $p < 0.05$) and Orthoptera (0.469, $p < 0.05$) reflecting pressure from multiple natural enemy groups. *Scirpophaga nivella* exhibited highly significant correlations with Odonata-Anisoptera (0.689, $p < 0.01$), Odonata-Zygoptera (0.767, $p < 0.01$), Coleoptera (0.587, $p < 0.01$), Hymenoptera (0.839, $p < 0.01$) and Diptera (0.661, $p < 0.01$). Notable additional associations include Neuroptera (0.460, $p < 0.05$), Hemiptera (0.441, $p < 0.05$), and Mantodae (0.471, $p < 0.05$), indicating extensive natural pest suppression. *Cnaphalocrocis medinalis* exhibited a strong positive correlation with Odonata-Zygoptera (0.833, $p < 0.01$) and with Hymenoptera (0.430, $p < 0.05$). Their relationships with other natural enemy groups were insignificant.

Melanitis leda ismene demonstrated extensive and highly significant associations with a broad array of natural enemy groups. These include Diptera (0.814, $p < 0.01$), Hemiptera (0.721, $p < 0.01$), Hymenoptera (0.760, $p < 0.01$), Coleoptera (0.713, $p < 0.01$), Neuroptera (0.659, $p < 0.01$), Arachnida (0.787, $p < 0.01$), Mantodea (0.607, $p < 0.01$), and Odonata-Anisoptera (0.670, $p < 0.01$). Additional significant associations with Odonata-Zygoptera (0.506, $p < 0.01$) and Dermaptera (0.395, $p < 0.05$) reflect strong regulation by natural enemy groups. Green horned caterpillars were significantly associated with Hemiptera (0.710, $p < 0.01$), Coleoptera (0.539, $p < 0.01$), Diptera (0.660, $p < 0.01$), and Arachnida (0.572, $p < 0.01$), indicating strong regulation by these natural enemy groups. Positive correlations also existed with Hymenoptera (0.446, $p < 0.05$), Neuroptera (0.420, $p < 0.05$), Mantodea (0.568, $p < 0.01$), and Orthoptera (0.462, $p < 0.05$), further supporting the role of diverse natural enemies.

Spodoptera litura demonstrated strong associations with Odonata-Zygoptera (0.813, $p < 0.01$), Odonata-Anisoptera (0.776, $p < 0.01$), Diptera (0.584, $p < 0.01$),

Arachnida (0.629, $p < 0.01$), and Hymenoptera (0.494, $p < 0.01$), highlighting both aerial and terrestrial biocontrol pressure. *Leucania loreyi* exhibited strong associations with key aerial predators, including Odonata-Zygoptera (0.878, $p < 0.01$), Odonata-Anisoptera (0.745, $p < 0.01$), Diptera (0.605, $p < 0.01$), and Arachnida (0.721, $p < 0.01$). Additional significant correlations with Hymenoptera (0.578, $p < 0.01$), Neuroptera (0.588, $p < 0.01$), and Coleoptera (0.540, $p < 0.01$) suggest a broad and integrated natural enemies complex.

Similarly, *Nymphula depunctalis* demonstrated highly significant associations with Hemiptera (0.860, $p < 0.01$), Orthoptera (0.691, $p < 0.01$), Coleoptera (0.696, $p < 0.01$), Diptera (0.638, $p < 0.01$), Hymenoptera (0.573, $p < 0.01$), Neuroptera (0.556, $p < 0.01$), and Arachnida (0.619, $p < 0.01$). A significant correlation with Odonata-Anisoptera (0.435, $p < 0.05$) further underscores the diverse groups of natural enemies acting on this pest.

Pelopidas mathias exhibited robust associations with multiple aerial and ground-dwelling predators, reflecting a complex network of natural regulation. Notably, strong correlations were observed with Odonata-Zygoptera (0.866, $p < 0.01$), Odonata-Anisoptera (0.855, $p < 0.01$), Arachnida (0.784, $p < 0.01$), Coleoptera (0.666, $p < 0.01$), Diptera (0.607, $p < 0.01$), Neuroptera (0.607, $p < 0.01$), and Hymenoptera (0.600, $p < 0.01$). A significant association with Mantodea (0.423, $p < 0.05$) further suggests that this pest is subject to predation from a wide array of natural enemies spanning both aerial and terrestrial natural enemy groups.

Short-horned grasshoppers were significantly associated with a wide range of predators, with strong correlations observed for Odonata-Anisoptera (0.763, $p < 0.01$), Odonata-Zygoptera (0.539, $p < 0.01$), Diptera (0.575, $p < 0.01$), Coleoptera (0.513, $p < 0.01$), Hymenoptera (0.523, $p < 0.01$), and Arachnida (0.574, $p < 0.01$). Significant associations with Neuroptera (0.475, $p < 0.05$) suggest additional support. Field crickets demonstrated a distinct predator profile, with a significant correlation with Odonata-

Zygoptera (0.717, $p < 0.01$) and Hymenoptera (0.465, $p < 0.05$), while their interactions with other natural enemy groups were found to be insignificant.

Gryllotalpa orientalis exhibited extensive predation pressure across multiple predator groups, including Odonata-Anisoptera (0.484, $p < 0.01$), Odonata-Zygoptera (0.718, $p < 0.01$), Diptera (0.639, $p < 0.01$), Arachnida (0.729, $p < 0.01$), Coleoptera (0.641, $p < 0.01$), Hymenoptera (0.691, $p < 0.01$), and Hemiptera (0.576, $p < 0.01$). Additionally, strong correlations with Mantodea (0.625, $p < 0.01$) indicate notable involvement of larger predatory insects in suppressing this pest.

Sitophilus oryzae showed significant inverse correlations with Orthoptera (-0.568, $p < 0.01$), Diptera (-0.433, $p < 0.05$), Hemiptera (-0.417, $p < 0.05$), Odonata-Anisoptera (-0.391, $p < 0.05$), and Arachnida (-0.415, $p < 0.05$), suggesting limited predation or possible avoidance interactions. In contrast, *Dicladispa armigera* was regulated by a broad and highly effective natural enemy complex, with strong correlations observed for Coleoptera (0.822, $p < 0.01$), Diptera (0.800, $p < 0.01$), Arachnida (0.830, $p < 0.01$), Hymenoptera (0.719, $p < 0.01$), Neuroptera (0.733, $p < 0.01$), and Hemiptera (0.718, $p < 0.01$). Additional support was evident from Odonata-Anisoptera (0.796, $p < 0.01$), Odonata-Zygoptera (0.476, $p < 0.05$), Dermaptera (0.418, $p < 0.05$), and Mantodea (0.641, $p < 0.01$). Similarly, *Stenchaetothrips biformis* was regulated by a diverse and highly effective predator assemblage, with strong associations observed for Hemiptera (0.904, $p < 0.01$), Dermaptera (0.707, $p < 0.01$), Mantodea (0.702, $p < 0.01$), Diptera (0.637, $p < 0.01$), Hymenoptera (0.654, $p < 0.01$), Coleoptera (0.580, $p < 0.01$), Arachnida (0.612, $p < 0.01$), Orthoptera (0.485, $p < 0.05$) and Neuroptera (0.449, $p < 0.05$).

Table 4.4f presents the correlation coefficients (Pearson's r) between insect pests of rice and their natural enemies, recorded from June to December 2021 in Kuhoxu.

Unlike other locations, *Nephotettix virescens* did not exhibit significant correlations with any natural enemy groups. In contrast, *Nephotettix nigropictus* showed

significant positive correlations with Hymenoptera (0.430, $p < 0.05$) and Neuroptera (0.433, $p < 0.05$), indicating possible parasitization and predation from these groups. Similarly, *Cofana spectra* was significantly associated with Hymenoptera (0.588, $p < 0.01$) and Neuroptera (0.469, $p < 0.05$) and Arachnida (0.396, $p < 0.05$) suggesting the influence of pest suppression by these natural enemy groups.

Strong natural enemies-prey dynamics were evident in *Maiestas dorsalis*, which showed highly significant associations with multiple predator groups: Odonata-Anisoptera (0.851, $p < 0.01$), Odonata-Zygoptera (0.742, $p < 0.01$), Coleoptera (0.795, $p < 0.01$), Hymenoptera (0.816, $p < 0.01$), Neuroptera (0.788, $p < 0.01$), Hemiptera (0.411, $p < 0.05$), Diptera (0.852, $p < 0.01$), Dermaptera (0.671, $p < 0.01$), Mantodea (0.759, $p < 0.01$) and Arachnida (0.879, $p < 0.01$). Likewise, *Nilaparvata lugens* displayed highly significant associations with Hymenoptera (0.709, $p < 0.01$), Neuroptera (0.709, $p < 0.01$), Diptera (0.588, $p < 0.01$), and Odonata-Anisoptera (0.682, $p < 0.01$), suggesting susceptibility to both aerial predators and parasitoids. Additional correlations with Arachnida (0.656, $p < 0.01$) and Coleoptera (0.384, $p < 0.05$) further establishes the breadth of its predator interactions. In contrast, *Sogatella furcifera* showed minimal significant associations, with only Hymenoptera (0.465, $p < 0.05$) suggesting limited regulation by natural enemies. No other predator groups were significantly associated with this pest.

Leptocorisa acuta exhibited no statistically significant correlations across the examined natural enemy groups, indicating either low exposure to predation or a lack of effective natural enemy pressure. However, *Cletus punctiger* was characterized by strong multi-enemy regulation, showing significant positive correlations with Odonata-Anisoptera (0.790, $p < 0.01$), Neuroptera (0.753, $p < 0.01$), Hymenoptera (0.675, $p < 0.01$), Diptera (0.663, $p < 0.01$), Arachnida (0.703, $p < 0.01$), and Coleoptera (0.575, $p < 0.01$). Additionally, Dermaptera (0.492, $p < 0.01$), Mantodea (0.541, $p < 0.01$), and Odonata-Zygoptera (0.464, $p < 0.05$) were also significantly associated, reflecting a broad spectrum of natural enemy pressure.

Scirpophaga incertulas displayed strong associations with multiple predator groups, including Odonata-Anisoptera (0.828, $p < 0.01$), Odonata-Zygoptera (0.495, $p < 0.01$), Coleoptera (0.502, $p < 0.01$), Hymenoptera (0.733, $p < 0.01$), Neuroptera (0.802, $p < 0.01$), Diptera (0.750, $p < 0.01$), Dermaptera (0.472, $p < 0.05$), Mantodea (0.488, $p < 0.01$), and Arachnida (0.783, $p < 0.01$). Similarly, *Chilo suppressalis* was significantly correlated with Odonata-Anisoptera (0.873, $p < 0.01$), Odonata-Zygoptera (0.734, $p < 0.01$), Coleoptera (0.767, $p < 0.01$), Hymenoptera (0.728, $p < 0.01$), Neuroptera (0.735, $p < 0.01$), Hemiptera (0.503, $p < 0.01$), Diptera (0.840, $p < 0.01$), Dermaptera (0.778, $p < 0.01$), Mantodea (0.733, $p < 0.01$) and Arachnida (0.865, $p < 0.01$), indicating extensive interactions with natural enemy groups.

Scirpophaga spp. also showed strong interactions with Odonata-Anisoptera (0.812, $p < 0.01$), Odonata-Zygoptera (0.526, $p < 0.01$), Coleoptera (0.602, $p < 0.01$), Hymenoptera (0.714, $p < 0.01$), Neuroptera (0.706, $p < 0.01$), Diptera (0.785, $p < 0.01$), Mantodea (0.530, $p < 0.01$), and Arachnida (0.721, $p < 0.01$). For *Scirpophaga nivella*, significant positive correlations were observed with Odonata-Anisoptera (0.648, $p < 0.01$), Odonata-Zygoptera (0.503, $p < 0.01$), Coleoptera (0.501, $p < 0.01$), Hymenoptera (0.766, $p < 0.01$), Neuroptera (0.739, $p < 0.01$), Diptera (0.463, $p < 0.05$), Dermaptera (0.508, $p < 0.01$), Mantodea (0.485, $p < 0.05$), and Arachnida (0.695, $p < 0.01$). *Cnaphalocrocis medinalis* exhibited notable associations with natural enemy groups, particularly with Hymenoptera (0.481, $p < 0.05$) and Neuroptera (0.523, $p < 0.01$), while Arachnida also showed a significant correlation (0.476, $p < 0.05$). Although correlations with Odonata-Anisoptera (0.409, $p < 0.05$) and Diptera (0.307) were weaker, they suggest potential interactions with these natural enemy groups.

Strong correlations with multiple natural enemy groups were observed for *Melanitis leda ismene*, including Odonata-Anisoptera (0.731, $p < 0.01$), Odonata-Zygoptera (0.670, $p < 0.01$), Coleoptera (0.734, $p < 0.01$), Hymenoptera (0.886, $p < 0.01$), Neuroptera (0.687, $p < 0.01$), Hemiptera (0.433, $p < 0.05$), Diptera (0.790, $p < 0.01$), Dermaptera (0.594, $p < 0.01$), Mantodea (0.583, $p < 0.01$), and Arachnida (0.835, $p < 0.01$).

Table 4.4f: Correlation coefficient (r) between insect pests of rice and natural enemies recorded during June to December 2021 in Kuhoxu

Insect pests	Pearson's correlation coefficient										
	Odonata-Anisoptera	Odonata-Zygoptera	Coleoptera	Hymenoptera	Neuroptera	Hemiptera	Diptera	Dermaptera	Mantodea	Orthoptera	Arachnida
<i>Nephotettix virescens</i> Distant	0.022	-0.125	-0.054	0.338	0.188	-0.324	-0.039	-0.198	-0.193	-0.142	0.116
<i>Nephotettix nigropictus</i> Stål	0.316	0.070	0.064	0.430*	0.433*	-0.283	0.280	0.023	0.106	0.010	0.337
<i>Cofana spectra</i> Distant	0.350	0.124	0.172	0.588**	0.469*	-0.233	0.247	0.070	0.034	-0.105	0.396*
<i>Maiestas dorsalis</i> Motchulsky	0.851**	0.742**	0.795**	0.816**	0.788**	0.411*	0.852**	0.671**	0.759**	0.155	0.879**
<i>Nilaparvata lugens</i> Stål	0.682**	0.372	0.384*	0.709**	0.709**	-0.090	0.588**	0.285	0.329	-0.003	0.656**
<i>Sogatella furcifera</i> Horvith	0.137	0.008	0.091	0.465*	0.281	-0.196	0.107	-0.083	-0.082	-0.117	0.251
<i>Leptocorisa acuta</i> Thunberg	0.135	-0.053	0.069	0.351	0.277	-0.073	0.254	0.038	0.098	0.232	0.260
<i>Cletus punctiger</i> Dallas	0.790**	0.464*	0.575**	0.675**	0.753**	0.219	0.663**	0.492**	0.541**	0.257	0.703**
<i>Scirpophaga incertulas</i> Walker	0.828**	0.495**	0.502**	0.733**	0.802**	0.068	0.750**	0.472*	0.488**	0.107	0.783**
<i>Chilo suppressalis</i> Dudgeon	0.873**	0.734**	0.767**	0.728**	0.735**	0.503**	0.840**	0.778**	0.733**	0.200	0.865**
<i>Scirpophaga</i> spp.	0.812**	0.526**	0.602**	0.714**	0.706**	0.071	0.785**	0.345	0.530**	0.136	0.721**
<i>Scirpophaga nivella</i> Fabricus	0.648**	0.503**	0.501**	0.766**	0.739**	0.097	0.463*	0.508**	0.485*	0.114	0.695**

<i>Cnaphalocrocis medinalis</i> Guenée	0.409*	0.180	0.156	0.481*	0.523**	-0.178	0.307	0.135	0.135	-0.074	0.476*
<i>Melanitis leda ismene</i> Linnaeus	0.731**	0.670**	0.734**	0.886**	0.687**	0.433*	0.790**	0.594**	0.583**	0.159	0.835**
Green horned caterpillars	0.617**	0.638**	0.637**	0.551**	0.627**	0.494**	0.488**	0.781**	0.629**	0.313	0.705**
<i>Spodoptera litura</i> Fabricius	0.542**	0.140	0.137	0.466*	0.590**	-0.311	0.481*	0.103	0.150	-0.046	0.463*
<i>Leucania loreyi</i> Duponchel	0.745**	0.355	0.303	0.532**	0.702**	-0.217	0.649**	0.243	0.380	0.060	0.572**
<i>Nymphula depunctalis</i> Guenée	0.525**	0.781**	0.815**	0.627**	0.377	0.808**	0.734**	0.711**	0.675**	-0.037	0.618**
<i>Pelopidas mathias</i> Fabricius	0.865**	0.684**	0.535**	0.679**	0.830**	0.119	0.693**	0.618**	0.525**	-0.050	0.828**
Short horned grasshoppers	0.427*	0.587**	0.480*	0.518**	0.316	0.311	0.445*	0.310	0.351	-0.080	0.341
Field crickets	0.178	0.069	0.266	0.563**	0.302	0.026	0.219	0.091	0.044	0.089	0.363
<i>Gryllotalpa orientalis</i> Burmeister	0.299	0.258	0.569**	0.609**	0.194	0.361	0.512**	0.152	0.481*	0.388*	0.462*
<i>Sitophilus oryzae</i> Linnaeus	-0.410*	-0.363	-0.265	0.007	-0.295	-0.266	-0.486*	-0.451*	-0.498**	-0.241	-0.345
<i>Dicladispa armigera</i> Olivier	0.937**	0.759**	0.639**	0.732**	0.883**	0.182	0.711**	0.684**	0.601**	-0.066	0.909**
<i>Stenchaetothrips biformis</i> Bagnall	0.636**	0.730**	0.905**	0.800**	0.511**	0.827**	0.828**	0.717**	0.748**	0.355	0.736**

Note: df = (27-2) = 25

$r_{0.05} = 0.381$

$r_{0.01} = 0.487$

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Likewise, green horned caterpillars were significantly correlated with Odonata-Anisoptera (0.617, $p<0.01$), Odonata-Zygoptera (0.638, $p<0.01$), Coleoptera (0.637, $p<0.01$), Hymenoptera (0.551, $p<0.01$), Neuroptera (0.627, $p<0.01$), Hemiptera (0.494, $p<0.01$), Diptera (0.488, $p<0.01$), Dermaptera (0.781, $p<0.01$), Mantodea (0.629, $p<0.01$), and Arachnida (0.705, $p<0.01$).

Spodoptera litura showed associations through positive and significant correlations with Odonata-Anisoptera (0.542, $p<0.01$), Hymenoptera (0.466, $p<0.05$), Neuroptera (0.590, $p<0.01$), Diptera (0.481, $p<0.05$), and Arachnida (0.463, $p<0.05$). *Leucania loreyi* exhibited strong correlations with Odonata-Anisoptera (0.745, $p<0.01$), Hymenoptera (0.532, $p<0.01$), Neuroptera (0.702, $p<0.01$), Diptera (0.649, $p<0.01$), and Arachnida (0.572, $p<0.01$). The moth *Nymphula depunctalis* displayed significant correlations with several natural enemy groups, including Odonata-Anisoptera (0.525, $p<0.01$), Odonata-Zygoptera (0.781, $p<0.01$), Coleoptera (0.815, $p<0.01$), Hymenoptera (0.627, $p<0.01$), Hemiptera (0.808, $p<0.01$), Diptera (0.734, $p<0.01$), Dermaptera (0.711, $p<0.01$), Mantodea (0.675, $p<0.01$), and Arachnida (0.618, $p<0.01$). For *Pelopidas mathias*, the analysis showed strong associations with Odonata-Anisoptera (0.865, $p<0.01$), Odonata-Zygoptera (0.684, $p<0.01$), Coleoptera (0.535, $p<0.01$), Hymenoptera (0.679, $p<0.01$), Neuroptera (0.830, $p<0.01$), Diptera (0.693, $p<0.01$), Dermaptera (0.618, $p<0.01$), Mantodea (0.525, $p<0.01$), and Arachnida (0.828, $p<0.01$).

Short-horned grasshoppers showed significant correlations with Odonata-Anisoptera (0.427, $p<0.05$), Odonata-Zygoptera (0.587, $p<0.01$), Coleoptera (0.480, $p<0.05$), Hymenoptera (0.518, $p<0.01$), and Diptera (0.445, $p<0.05$), while field crickets were significantly associated only with Hymenoptera (0.563, $p<0.01$). *Gryllotalpa orientalis* exhibited correlations with Coleoptera (0.569, $p<0.01$), Hymenoptera (0.609, $p<0.01$), Diptera (0.512, $p<0.01$), Mantodea (0.481, $p<0.05$), Orthoptera (0.388, $p<0.05$), and Arachnida (0.462, $p<0.05$).

Interestingly, *Sitophilus oryzae* showed negative correlations with Odonata-Anisoptera (-0.410, $p<0.05$), Diptera (-0.486, $p<0.05$), Dermaptera (-0.451, $p<0.05$), and Mantodea (-0.498, $p<0.01$), suggesting limited natural enemy impact. In contrast,

Dicladispa armigera demonstrated strong associations with a wide range of predators, including Odonata-Anisoptera (0.937, $p < 0.01$), Odonata-Zygoptera (0.759, $p < 0.01$), Coleoptera (0.639, $p < 0.01$), Hymenoptera (0.732, $p < 0.01$), Neuroptera (0.883, $p < 0.01$), Diptera (0.711, $p < 0.01$), Dermaptera (0.684, $p < 0.01$), Mantodea (0.601, $p < 0.01$), and Arachnida (0.909, $p < 0.01$). Lastly, *Stenchaetothrips biformis* showed highly significant correlations with Odonata-Anisoptera (0.636, $p < 0.01$), Odonata-Zygoptera (0.730, $p < 0.01$), Coleoptera (0.905, $p < 0.01$), Hymenoptera (0.800, $p < 0.01$), Neuroptera (0.511, $p < 0.01$), Hemiptera (0.827, $p < 0.01$), Diptera (0.828, $p < 0.01$), Dermaptera (0.717, $p < 0.01$), Mantodea (0.748, $p < 0.01$), and Arachnida (0.736, $p < 0.01$).

Upon perusal of available literatures of correlation of insect pests of rice and their natural enemies, it is reviewed that Parasappa *et al.* (2017) reported *Scirpophaga incertulas* had a significant positive correlation with Odonata and Hymenoptera. They also reported positive correlations between leafhoppers and natural predators (spiders & mirid bugs) and also positive correlation ($r = 0.770$) between *Nilaparvata lugens* and mirid bugs supporting the present findings. Kalita *et al.* (2020) noted that *Scirpophaga incertulas* populations peaked between August and September, aligning with the peak activity of natural predators. They also found that spiders and Anisoptera were abundant when planthopper populations peaked, similar to this study.

Dumra and Srivastav (2019) observed that *Nymphula depunctalis* peaked in July-August, aligning with peak predator presence. Parasappa *et al.*, (2017) reported a positive correlation ($r = 0.770$) between *Nilaparvata lugens* and mirid bugs, supporting this study.

Adhikari *et al.* (2021) reported weak interactions between *Leptocorisa acuta* and natural enemies, confirming limited biological control. Khan and Misra (2003) reported that as hopper density increased, spider populations also grew, showing a direct relationship between pest population and predator abundance. This finding is in agreement with the present study, as spiders have been shown to correlate positively with several insect pests. Zhimomi and Ao (2011) reported that ground beetles had no

significant effect on pest populations, except for Hemiptera. However, odonates played a crucial role as predators, showing significant correlation with Orthoptera, Hemiptera, and Lepidoptera. These findings partially agree with the present study, as odonates are found to be significant predators, though the effect of ground beetles remains inconsistent.

Heong *et al.* (1991) found positive correlations between veliid densities and hopper densities, suggesting that veliids and mesoveliids are closely linked to planthopper and leafhopper abundance. However, the mirid egg predator *C. lividipennis* did not exhibit a strong positive response to planthopper and leafhopper densities, which is partially in agreement with the present study, as mirid bugs have shown varying correlations with planthoppers. Rani *et al.* (2022) recorded that YSB exhibited a significant positive correlation with the spider guild in both wet and dry seasons. This finding is in agreement with the present investigation, as YSB showed strong associations with arachnids.

Rani *et al.* (2022) also found that pink stem borer (PSB) exhibited overall negative correlations with most predatory species in the rice ecosystem, except for Zygoptera and long-jawed spiders. White stem borer (WSB) showed negative correlations with long-jawed spiders, lynx spiders, and preying mantids in the wet season but had positive correlations with other predatory groups in the dry season. These findings indicate seasonal shifts in predator-prey dynamics, which are partially in agreement with the present study, as some pests showed seasonal variation in predator interactions.

Rahaman *et al.* (2014) found that correlation analysis revealed strong positive associations between stem borers (PSB, DHSB, YSB, WSB, and SSB) and key predators like Zygoptera, ladybird beetles, long-jawed spiders, and wolf spiders. This is in agreement with the present findings, where strong predator-prey correlations were recorded. However, Rahaman *et al.* (2014) also reported consistently negative correlations between carabid beetles and stem borers, which does not fully align with the present study, as carabid beetles showed variable effects.

Mondal and Chakravorthy (2017) reported a positive correlation between YSB infestations and natural enemy abundance, reinforcing the idea that predator populations fluctuate in response to pest incidence. This finding is in full agreement with the present investigation, where predator abundance was closely associated with peak pest populations.

4.5. MORPHOMETRIC CHARACTERISTICS OF INSECT PESTS OF RICE WITH THEIR NATURAL ENEMIES IN LOWLAND RICE AGROECOSYSTEM IN NAGALAND

The Morphometric characteristics of insect pests and their natural enemies in lowland rice agroecosystem as recorded during the present investigation are discussed below:

4.5.1. MORPHOMETRIC CHARACTERISTICS OF INSECT PESTS OF RICE

4.5.1.1. *Nephotettix virescens*: The mean body length of *N. virescens* was recorded as 4.48 ± 0.046 mm and a body width of 1.52 ± 0.015 mm. The head length was 0.37 ± 0.001 mm, while the head width was 1.18 ± 0.020 mm. The thorax and abdomen lengths measured 1.46 ± 0.031 mm and 1.94 ± 0.046 mm, respectively. The forewing length was 3.60 ± 0.038 mm, with a width of 0.90 ± 0.012 mm. The hind leg length measured 4.26 ± 0.062 mm, while the hind wing width was 1.40 ± 0.021 mm. The stylet length recorded for this species was 0.50 ± 0.000 mm, antenna length was 1.05 ± 0.017 mm while interocular distance was recorded as 0.68 ± 0.001 mm (Table no. 4.5a, Plate 2.A).

Das and Devee (2017) reported that *N. virescens* males measure approximately 4.57 mm in body length, head length of 0.42 mm, Inter ocular distance of 0.75 mm and wing length as 3.77 mm. These findings suggest that the observed parameters are in agreement with the present investigation.

4.5.1.2. *Nephotettix nigropictus*: The mean body length was 3.68 ± 0.017 mm and body width was 1.31 ± 0.019 mm. The head length was 0.37 ± 0.014 mm, and the head width measured 1.29 ± 0.005 mm. The thorax length was 1.48 ± 0.002 mm, while the abdomen measured 1.56 ± 0.041 mm. The forewing length was 3.35 ± 0.021 mm, with a width of 0.95 ± 0.015 mm. The hind leg length measured 4.21 ± 0.051 mm, while the hind wing width was 1.53 ± 0.041 mm. The stylet length recorded for this species was 0.38 ± 0.00

Table 4.5a: Morphometric measurement (♂) of *Nephotettix virescens*, *Nephotettix nigropictus*, *Cofana spectra*, *Maiestas dorsalis*, *Nilaparvata lugens* and *Sogatella furcifera*.

Parameters	Insect pests (Measurements in mm $\pm$ SEM)					
	<i>Nephotettix virescens</i>	<i>Nephotettix nigropictus</i>	<i>Cofana spectra</i>	<i>Maiestas dorsalis</i>	<i>Nilaparvata lugens</i>	<i>Sogatella furcifera</i>
Body length (BL)	4.48 $\pm$ 0.046	3.68 $\pm$ 0.017	9.86 $\pm$ 0.041	3.33 $\pm$ 0.06	4.41 $\pm$ 0.03	4.29 $\pm$ 0.06
Body width (BW)	1.52 $\pm$ 0.015	1.31 $\pm$ 0.019	2.44 $\pm$ 0.000	1.18 $\pm$ 0.01	1.07 $\pm$ 0.02	1.20 $\pm$ 0.02
Head length (HL)	0.37 $\pm$ 0.001	0.37 $\pm$ 0.014	0.80 $\pm$ 0.021	0.30 $\pm$ 0.03	0.26 $\pm$ 0.00	0.33 $\pm$ 0.01
Head width (HW)	1.18 $\pm$ 0.020	1.29 $\pm$ 0.005	2.22 $\pm$ 0.015	0.85 $\pm$ 0.02	0.78 $\pm$ 0.01	0.69 $\pm$ 0.01
Thorax length (TL)	1.46 $\pm$ 0.031	1.48 $\pm$ 0.002	2.47 $\pm$ 0.051	1.08 $\pm$ 0.24	1.16 $\pm$ 0.01	1.23 $\pm$ 0.00
Abdomen length (AL)	1.94 $\pm$ 0.046	1.56 $\pm$ 0.041	5.16 $\pm$ 0.102	1.19 $\pm$ 0.02	1.20 $\pm$ 0.02	1.38 $\pm$ 0.04
Stylet length (SL)	0.50 $\pm$ 0.000	0.38 $\pm$ 0.000	0.80 $\pm$ 0.005	0.17 $\pm$ 0.13	0.45 $\pm$ 0.00	0.64 $\pm$ 0.01
Fore wing length (WL)	3.60 $\pm$ 0.038	3.35 $\pm$ 0.021	7.60 $\pm$ 0.012	2.45 $\pm$ 0.00	3.26 $\pm$ 0.09	3.66 $\pm$ 0.06
Fore wing width (WW)	0.90 $\pm$ 0.012	0.95 $\pm$ 0.015	2.09 $\pm$ 0.009	0.75 $\pm$ 0.01	0.82 $\pm$ 0.02	0.93 $\pm$ 0.10
Hind leg length (LL)	4.26 $\pm$ 0.062	4.21 $\pm$ 0.051	6.38 $\pm$ 0.080	2.43 $\pm$ 0.06	2.25 $\pm$ 0.06	3.21 $\pm$ 0.02
Hind wing width (HWW)	1.40 $\pm$ 0.021	1.53 $\pm$ 0.041	3.28 $\pm$ 0.046	1.11 $\pm$ 0.02	3.05 $\pm$ 0.01	2.37 $\pm$ 0.02
Antennae Length (AL)	1.05 $\pm$ 0.017	1.14 $\pm$ 0.012	1.68 $\pm$ 0.031	0.74 $\pm$ 0.02	0.88 $\pm$ 0.01	0.33 $\pm$ 0.01
Inter ocular distance (IOD)	0.68 $\pm$ 0.001	0.57 $\pm$ 0.062	1.65 $\pm$ 0.013	0.39 $\pm$ 0.01	0.29 $\pm$ 0.01	0.38 $\pm$ 0.00

mm and antennae length was 1.14 ± 0.012 mm while Interocular distance was measured at 0.57 ± 0.062 mm (Table no. 4.5a and Plate 2.B).

The recorded body length closely aligns with the range reported by Das & Deveci (2017), who noted that *N. nigropictus* exhibits a body length of approximately 3.64 mm. Their recorded head width of 0.36mm, Inter ocular distance of 0.53mm and forewing length of 3.08mm is also in agreement with the present findings.

4.5.1.3. *Nilaparvata lugens*: The body length measured 2.66 ± 0.03 mm, while body width was 1.07 ± 0.02 mm. The head length was 0.26 ± 0.00 mm, while the head width measured 0.78 ± 0.01 mm. The thorax and abdomen lengths were 1.16 ± 0.01 mm and 1.20 ± 0.02 mm, respectively. The forewing length was 3.26 ± 0.09 mm, with a width of 0.82 ± 0.02 mm. The hind leg length measured 2.25 ± 0.06 mm, while the hind wing width was 3.05 ± 0.01 mm. The stylet length recorded for this species was 0.45 ± 0.00 mm, antennae length was 0.88 ± 0.01 mm and an Interocular distance of 0.29 ± 0.01 mm (Table no. 4.5a, Plate 3.B).

The recorded body length of *N. lugens* in the present study closely aligns with the findings of Priyadarshini *et al.* (2021), who reported that macropterous male exhibited a body length of 2.316 mm in length and 1.023 mm in width. Their reported measurements of antennal length of 0.940mm, inter-ocular of 0.255 mm, wing length of 3.060 mm and wing width of 0.602 mm is also in confirmation with the present findings. Rashid *et al.* (2017) suggested that body size can be influenced by ecological factors, which may account for small discrepancies across different studies.

4.5.1.4. *Sogatella furcifera*: The mean body length recorded was 4.29 ± 0.06 mm and body width was 1.20 ± 0.02 mm. The head length was 0.33 ± 0.01 mm, while the head width was 0.69 ± 0.01 mm. The thorax length measured 1.23 ± 0.00 mm, and the abdomen length was 1.38 ± 0.04 mm. The forewing length was 3.66 ± 0.06 mm, with a width of 0.93 ± 0.10 mm. The hind leg length measured 3.21 ± 0.02 mm, antenna length was 0.33 ± 0.01 mm while the hind wing width was 2.37 ± 0.02 mm. The stylet length



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A. *Nephotettix virescens* Distant (i. Adult, ii. Forewing, iii. Hindwing, iv. Foreleg, v. Midleg, vi. Hindleg)



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viii



ix



x



xi



xii

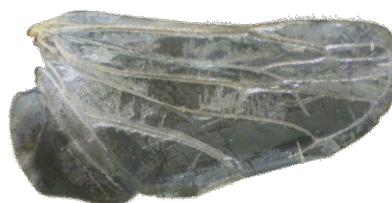
B. *Nephotettix nigropictus* Stål (vii. Adult , viii. Forewing, ix. Hindwing, x. Foreleg, xi. Midleg, xii. Hindleg)



xiii



xiv



xv



xvi



xvii



xviii

C. *Cofana spectra* Distant (xiii. Adult , xiv. Forewing, xv. Hindwing, xvi. Foreleg, xvii. Midleg, xviii. Hindleg)

Plate 2. Morphometric parameters of *N. virescens*, *N. nigropictus* and *C. spectra*

was 0.64 ± 0.01 mm, antennae length was 0.33 ± 0.01 mm and an interocular distance of 0.38 ± 0.00 mm (Table no. 4.5a, Plate 3.C).

4.5.1.5. *Cofana spectra*: The mean body length recorded was 9.86 ± 0.041 mm and body width was 2.44 ± 0.000 mm. The head length was 0.80 ± 0.021 mm, while the head width measured 2.22 ± 0.015 mm. The thorax length was 2.47 ± 0.051 mm, and the abdomen length measured 5.16 ± 0.102 mm. The forewing length was 7.60 ± 0.012 mm, with a width of 2.09 ± 0.009 mm. The hind leg length measured 6.38 ± 0.080 mm, while the hind wing width was 3.28 ± 0.046 mm. The stylet length was recorded as 0.80 ± 0.005 mm, antenna length was 1.68 ± 0.031 mm and Interocular distance was measured at 1.65 ± 0.013 mm (Table no. 4.5a, Plate 2.C).

The recorded body length of *C. spectra* aligns with the findings of Manurung *et al.* (2019), who reported body length from 7.35 to 9.07 mm, body width of 1.92 to 2.08 mm, head length of 0.45 to 0.69 mm, head width of 1.74 to 2.08 mm. The thorax length reported was 2.06-2.36 mm, abdomen length measured 2.22 to 3.77 mm. The forewing length was 5.97 to 7.81 mm, with a width of 1.28 to 1.42 mm. The hind leg length measured 6.52 to 7.51 mm. The stylet length was recorded as 0.54 to 0.67 mm. these reports are consistent and align with the current findings. The present readings are further validated by the findings of Das & Devee (2017) who reported Body length of 9.74 mm, Length of head of 0.79 mm, Inter ocular distance of 1.73 mm and Length of wing as 7.74 mm.

4.5.1.6. *Maiestas dorsalis*: *M. dorsalis* was recorded with a mean body length of 3.33 ± 0.06 mm and a body width of 1.18 ± 0.01 mm. The head length was 0.30 ± 0.03 mm, while the head width measured 0.85 ± 0.02 mm. The thorax length was 1.08 ± 0.24 mm, and the abdomen length was 1.19 ± 0.02 mm. The forewing length was 2.75 ± 0.00 mm, with a width of 0.75 ± 0.01 mm. The hind leg length measured 2.43 ± 0.06 mm, while the hind wing width was 1.11 ± 0.02 mm. The stylet length was recorded as 0.17 ± 0.13 mm, antennae length was 0.74 ± 0.02 mm and interocular distance was measured at 0.39 ± 0.01 mm (Table no. 4.5a, Plate 3.A).



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A. *Maiestas dorsalis* Motchulsky (i. Adult, ii. Forewing, iii. Hindwing, iv. Foreleg, v. Midleg, vi. Hindleg)



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xii

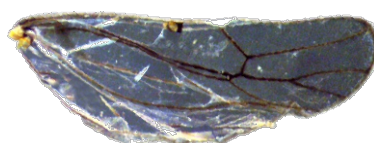
B. *Nilaparvata lugens* Stål (vii. Adult, viii. Forewing, ix. Hindwing, x. Foreleg, xi. Midleg, xii. Hindleg)



xiii



xiv



xv



xvi



xvii



xviii

C. *Sogatella furcifera* Horvith (xiii. Adult, xiv. Forewing, xv. Hindwing, xvi. Foreleg, xvii. Midleg, xviii. Hindleg)

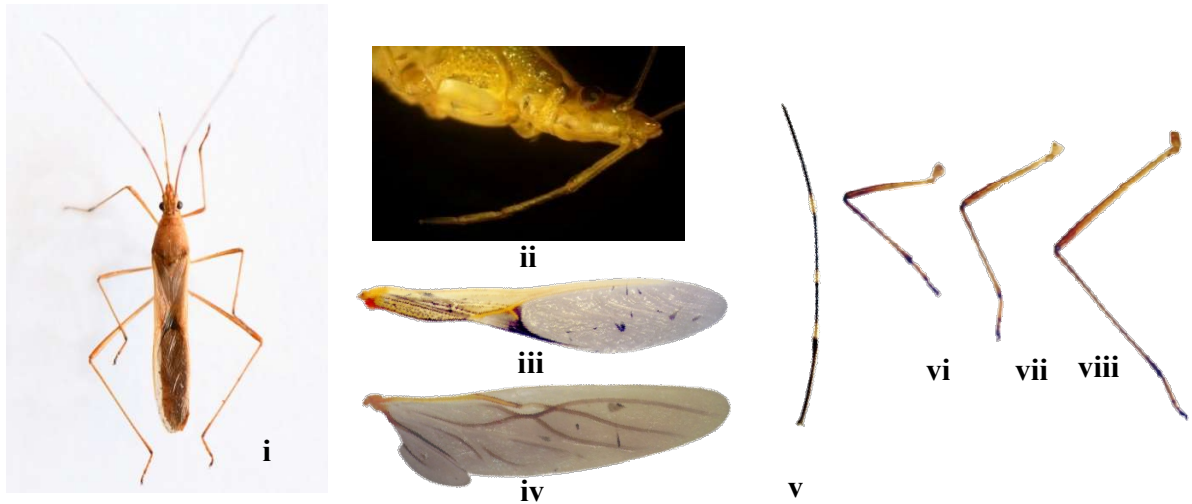
Plate 3. Morphometric parameters of *M. dorsalis*, *N. lugens* and *S. furcifera*

The recorded body length closely aligns with the findings of Das and Devee (2017), who reported a body length of 3.24 mm for this species. The head length is consistent with their findings, which noted head length of 0.24-0.30 mm. Similarly, the forewing length recorded in this study is also within the range documented by them who observed forewing lengths at 3.24 mm as well as the consistency in the reading of interocular distance measured at 0.43 mm which closely aligns with the present findings.

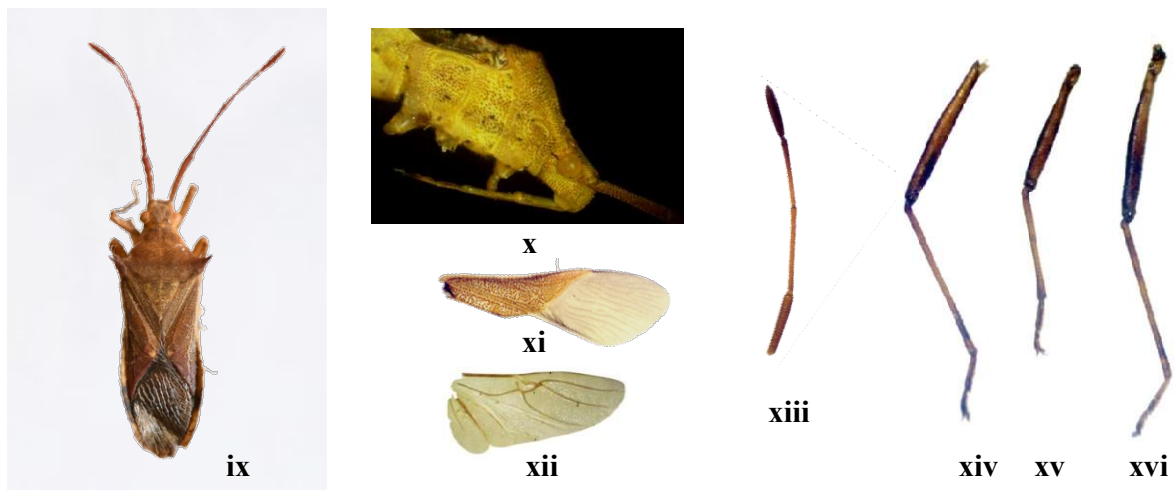
4.5.1.7. *Scirpophaga incertulas*: The mean forewing length was recorded as 11.95 ± 0.17 mm and hindwing length as 9.80 ± 0.15 mm. The distance between the first and seventh black spots along the forewing margin was 4.06 ± 0.03 mm. The fore femur measured 1.50 ± 0.02 mm, while the fore tibia was slightly longer at 2.00 ± 0.03 mm. The midfemur had a length of 2.56 ± 0.06 mm, and the midtibia measured 2.53 ± 0.04 mm. The hind femur was 2.06 ± 0.04 mm, and the hind tibia was 3.96 ± 0.10 mm. head width measured was 1.41 ± 0.02 mm, total body length was 11.97 ± 0.08 mm, labial length was 2.86 ± 0.02 mm with and antennal length of 4.40 ± 0.07 mm and total body length recorded was 11.97 ± 0.08 mm (Table no. 4.5b, Plate 4.C).

The current measurements of forewing length and breadth, head length and width are consistent and agree with the morphometric data presented by Amir *et al.* (2004), who observed head length from 0.7 to 1.3 mm, head width from 1.25-1.8 mm, and the forewing length and width between 10 to 13.25 mm and between 3-4 mm respectively.

4.5.1.8. *Chilo suppressalis*: The measurement for mean forewing length was 10.95 ± 0.15 mm and a hindwing length of 8.60 ± 0.08 mm. The distance between the first and seventh black spots along the forewing was 4.26 ± 0.07 mm. The fore femur measured 1.80 ± 0.04 mm, whereas the fore tibia was shorter at 1.25 ± 0.02 mm. The midfemur length was recorded at 2.64 ± 0.01 mm, with a midtibia length of 2.76 ± 0.02 mm. The hind femur measured 2.22 ± 0.05 mm, while the hind tibia was 3.41 ± 0.05 mm. The head width was 1.42 ± 0.04 mm, the antennae length was 4.14 ± 0.012 mm, and the labial length recorded as 2.35 ± 0.05 mm. Total body length recorded was 10.32 ± 0.22 mm (Table no. 4.5b, Plate 5.A).



A. *Leptocorisa acuta* Thunberg (i. Adult, ii. Mouthpart, iii. Forewing iv. Hindwing, v. Antenna, vi. Foreleg, vii. Midleg, viii. Hindleg)



B. *Cletus punctiger* Dallas (ix. Adult, x. Mouthpart xi. Forewing, xii. Hindwing, xiii. Antenna, xiv. Foreleg, xv. Midleg, xvi. Hindleg)



C. *Scirpophaga incertulas* Walker (xvii. Adult, xviii. Head with labial palpi, xix. Antenna, xx. Foreleg, xxi. Midleg, xxii. Hindleg)

Table 4.5b: Morphometric measurement (♂) of *Scirpophaga incertulas*, *Chilo suppressalis*, *Scirpophaga* spp., *Scirpophaga nivella*, *Leucania loreyi* and *Nymphula depunctalis*.

Parameters	Insect pests (Measurements in mm $\pm$ SEM)						
	<i>Scirpophaga incertulas</i>	<i>Chilo suppressalis</i>	<i>Scirpophaga</i> spp.	<i>Scirpophaga nivella</i>	<i>Cnaphalocrocis medinalis</i>	<i>Leucania loreyi</i>	<i>Nymphula depunctalis</i>
Length of the forewing (FWL)	11.95 $\pm$ 0.17	10.95 $\pm$ 0.15	9.75 $\pm$ 0.18	15.52 $\pm$ 0.06	8.42 $\pm$ 0.13	16.23 $\pm$ 0.05	6.03 $\pm$ 0.09
Distance between the first and last black spots(DBS)	4.06 $\pm$ 0.03	4.26 $\pm$ 0.07	3.31 $\pm$ 0.05	6.29 $\pm$ 0.14	4.09 $\pm$ 0.07	6.17 $\pm$ 0.14	2.67 $\pm$ 0.05
Length of the hindwing (HWL)	9.80 $\pm$ 0.15	8.60 $\pm$ 0.08	8.10 $\pm$ 0.03	12.31 $\pm$ 0.31	6.70 $\pm$ 0.09	11.35 $\pm$ 0.01	5.06 $\pm$ 0.04
Fore femur length (FFL)	1.50 $\pm$ 0.02	1.80 $\pm$ 0.04	1.91 $\pm$ 0.04	2.20 $\pm$ 0.01	1.51 $\pm$ 0.04	3.06 $\pm$ 0.07	1.14 $\pm$ 0.01
Fore tibia length (FTL)	2.00 $\pm$ 0.03	1.25 $\pm$ 0.02	1.10 $\pm$ 0.03	2.90 $\pm$ 0.07	2.12 $\pm$ 0.04	2.72 $\pm$ 0.06	2.01 $\pm$ 0.01
Midfemur length (MFL)	2.56 $\pm$ 0.06	2.64 $\pm$ 0.01	2.12 $\pm$ 0.02	3.31 $\pm$ 0.08	2.47 $\pm$ 0.02	3.12 $\pm$ 0.04	2.34 $\pm$ 0.05
Mid tibia length (MTL)	2.53 $\pm$ 0.04	2.76 $\pm$ 0.02	2.23 $\pm$ 0.03	3.36 $\pm$ 0.04	2.37 $\pm$ 0.06	2.73 $\pm$ 0.02	2.35 $\pm$ 0.02
Hind femur length (HFL)	2.06 $\pm$ 0.04	2.22 $\pm$ 0.05	2.16 $\pm$ 0.05	2.78 $\pm$ 0.06	1.90 $\pm$ 0.01	3.55 $\pm$ 0.04	1.68 $\pm$ 0.01
Hind tibia length (HTL)	3.96 $\pm$ 0.10	3.41 $\pm$ 0.05	3.84 $\pm$ 0.01	4.43 $\pm$ 0.05	2.67 $\pm$ 0.05	3.16 $\pm$ 0.01	2.61 $\pm$ 0.02
Head width (HW)	1.41 $\pm$ 0.02	1.42 $\pm$ 0.04	1.25 $\pm$ 0.01	1.57 $\pm$ 0.03	1.40 $\pm$ 0.02	2.78 $\pm$ 0.01	0.91 $\pm$ 0.01
Total Body Length (TBL)	11.97 $\pm$ 0.08	10.32 $\pm$ 0.22	9.32 $\pm$ 0.11	13.01 $\pm$ 0.14	7.11 $\pm$ 0.11	15.94 $\pm$ 0.25	5.43 $\pm$ 0.12
Labial Length (LL)	2.86 $\pm$ 0.02	2.35 $\pm$ 0.05	0.95 $\pm$ 0.02	1.41 $\pm$ 0.00	---	1.81 $\pm$ 0.02	---
Proboscis Length (PbL)	---	---	---	---	---	5.60 $\pm$ 0.14	---
Antennal Length (AL)	4.40 $\pm$ 0.07	4.14 $\pm$ 0.08	2.78 $\pm$ 0.01	---	4.49 $\pm$ 0.12	8.36 $\pm$ 0.08	6.03 $\pm$ 0.09
Abdomen Length (AbL)	---	---	---	---	5.40 $\pm$ 0.02	---	4.44 $\pm$ 0.03
Thorax Length (TL)	---	---	---	---	1.41 $\pm$ 0.02	---	1.88 $\pm$ 0.02

4.5.1.9. *Scirpophaga* spp.: The mean forewing length was measured at 9.75 ± 0.18 mm and the hindwing length at 8.10 ± 0.03 mm. The distance between the first and seventh black spots was 3.31 ± 0.05 mm. The fore femur measured 1.91 ± 0.04 mm, while the fore tibia length was 1.10 ± 0.03 mm. The midfemur was 2.12 ± 0.02 mm, and the midtibia length was 2.23 ± 0.03 mm. The hind femur was recorded at 2.16 ± 0.05 mm, while the hind tibia measured 3.84 ± 0.01 mm. Head width was 1.25 ± 0.01 mm, the antennae length was 2.78 ± 0.01 mm, and the labial was 0.95 ± 0.02 mm. Total body length recorded was 9.32 ± 0.11 mm (Table no. 4.5b, Plate 5.B).

4.5.1.10. *Scirpophaga nivella*: *S. nivella* had a mean forewing length measurement of 15.52 ± 0.06 mm, while its hindwing length was 12.31 ± 0.31 mm. The distance between the first and seventh black spots was measured at 6.29 ± 0.14 mm. The fore femur was 2.20 ± 0.01 mm long, while the fore tibia length was 2.90 ± 0.07 mm. The midfemur had a length of 3.31 ± 0.08 mm, and the midtibia was 3.36 ± 0.04 mm. The hind femur was 2.78 ± 0.06 mm, while the hind tibia was 4.43 ± 0.05 mm. Head width was 1.57 ± 0.03 mm and the labial was 1.41 ± 0.00 mm. Total body length recorded was 13.01 ± 0.14 mm (Table no. 4.5b, Plate 5.C).

4.5.1.11. *Cnaphalocrocis medinalis*: The mean forewing length was 8.42 ± 0.13 mm and hindwing length was 6.70 ± 0.09 mm. The distance between the first and seventh black spots was 4.09 ± 0.07 mm. The fore femur measured 1.51 ± 0.04 mm, while the fore tibia length was 2.12 ± 0.04 mm. The midfemur length was recorded as 2.47 ± 0.02 mm, and the midtibia measured 2.37 ± 0.06 mm. The hind femur length was 1.90 ± 0.01 mm, while the hind tibia was 2.67 ± 0.05 mm. The recorded head width was 1.40 ± 0.02 mm, the antennae length was 4.49 ± 0.12 mm, and the abdomen was 5.40 ± 0.02 mm long whereas the thorax length was 1.41 ± 0.02 mm. The total length of the body recorded was 7.11 ± 0.11 mm (Table no. 4.5b, Plate 5.D).

4.5.1.12. *Leucania loreyi*: The measurements for mean forewing length was 16.23 ± 0.05 mm, while the hindwing measured 11.35 ± 0.01 mm. The distance between the first and seventh black spots was 6.17 ± 0.14 mm. The fore femur was recorded at 3.06 ± 0.07



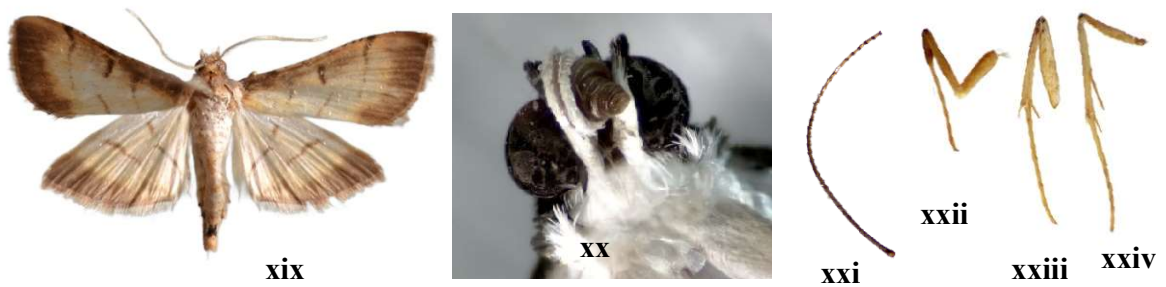
A. *Chilo suppressalis* Dudgeon (i. Adult , ii. Head with labial palpi, iii. Antenna, iv. Foreleg, v. Midleg, vi. Hindleg)



B. *Scirpophaga* spp. (vii. Adult, viii. Head with labial palpi, ix. Antenna, x. Foreleg, xi. Midleg, xii. Hindleg)



C. *Scirpophaga nivella* Fabricus (xiii. Adult , xiv. Head with labial palpi, xv. Antenna, xvi. Foreleg, xvii. Midleg, xviii. Hindleg)



D. *Cnaphalocrocis medinalis* Guenée (xix. Adult , xx. Head with labial palpi, xxi. Antenna, xxii. Foreleg, xxiii. Midleg, xxiv. Hindleg)

Plate 5. Morphometric parameters of *Scirpophaga* spp., *S. nivella* and *C. medinalis*

mm, and the fore tibia length was 2.72 ± 0.06 mm. The midfemur measured 3.12 ± 0.04 mm, while the midtibia length was 2.73 ± 0.02 mm. The hind femur length was 3.55 ± 0.04 mm, while the hind tibia was 3.16 ± 0.01 mm. Head width was 2.78 ± 0.01 mm, the antennae length was 8.36 ± 0.08 mm, and the labial was 1.81 ± 0.02 mm while proboscis length was 5.60 ± 0.14 mm. Total body length recorded was 15.94 ± 0.25 mm (Table no. 4.5b, Plate 7.A).

4.5.1.13. *Nymphula depunctalis*: The recorded mean forewing length was 6.03 ± 0.09 mm and hindwing length was 5.06 ± 0.04 mm. The distance between the first and seventh black spots was 2.67 ± 0.05 mm. The fore femur length was 1.14 ± 0.01 mm, while the fore tibia was 2.01 ± 0.01 mm. The midfemur measured 2.34 ± 0.05 mm, while the midtibia was 2.35 ± 0.02 mm. The hind femur was 1.68 ± 0.01 mm, while the hind tibia was 2.61 ± 0.02 mm. The Head width was 0.91 ± 0.01 mm, antennae length was 6.03 ± 0.09 mm, and the abdomen was 4.44 ± 0.03 mm long whereas the thorax length was 1.88 ± 0.02 mm. The length of the Total body recorded was 5.43 ± 0.12 mm (Table no. 4.5b, Plate 7.B).

4.5.1.14. *Leptocorisa acuta*: *L. acuta* recorded a body length of 15.01 ± 0.12 mm and a body width of 2.46 ± 0.01 mm. The body height measured 2.19 ± 0.02 mm. The antennae length was recorded at 14.04 ± 0.04 mm, while the mouthpart length was 4.82 ± 0.06 mm. The left forewing length was 10.81 ± 0.02 mm, while the right forewing length measured 10.80 ± 0.25 mm. The left hindwing length was 7.63 ± 0.08 mm, and the right hindwing length was 7.65 ± 0.14 mm. The left forewing width was 2.30 ± 0.03 mm, while the right forewing width was slightly larger at 2.39 ± 0.02 mm. The left hindwing width was recorded as 1.86 ± 0.03 mm, while the right hindwing width was 1.85 ± 0.05 mm. The femur length was 6.21 ± 0.04 mm, the tibia length was 6.72 ± 0.11 mm, and the tarsus length was 1.97 ± 0.03 mm. The Prothorax leg length was 10.46 ± 0.07 mm, the Mesothorax leg length was 11.04 ± 0.12 mm, and the Metathorax leg length measured 16.53 ± 0.34 mm. Head length measured 1.82 ± 0.03 mm, abdomen and thorax length

measured 8.06 ± 0.15 mm and 4.42 ± 0.02 mm respectively (Table no. 4.5c and Plate 4.H).

Table 4.5c: Morphometric measurement (♂) of *Leptocorisa acuta* and *Cletus punctiger*.

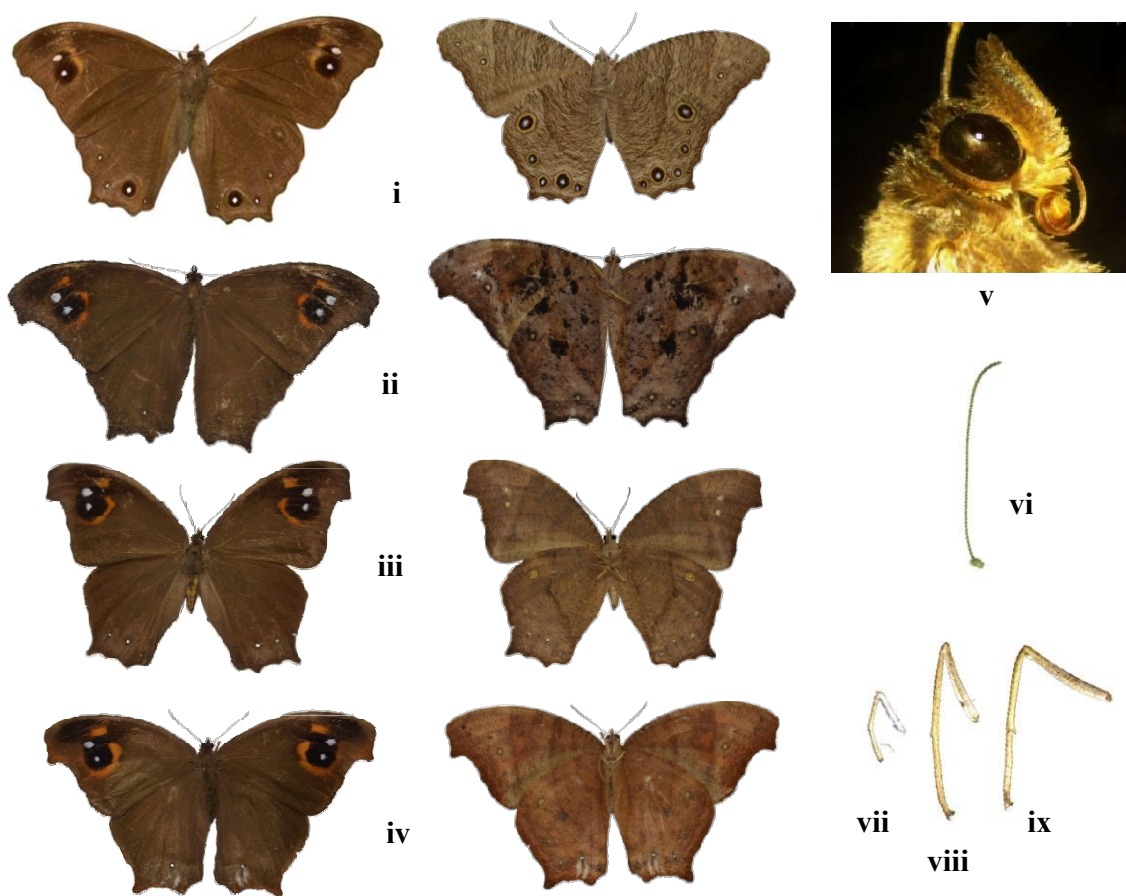
Parameters	Insect pests (Measurements in mm $\pm$ SEM)	
	<i>Leptocorisa acuta</i>	<i>Cletus punctiger</i>
Body Length (B.L)	15.01 ± 0.12	9.09 ± 0.02
Body Width (B.W)	2.46 ± 0.01	3.34 ± 0.08
Body Height (B.H)	2.19 ± 0.02	2.51 ± 0.06
Antennae Length (An.L)	14.04 ± 0.04	7.46 ± 0.18
Mouthpart Length (M.L)	4.82 ± 0.06	3.31 ± 0.01
Left Forewing Length (Lf.L)	10.81 ± 0.02	5.91 ± 0.04
Right Forewing Length (Rf.L)	10.80 ± 0.25	6.18 ± 0.11
Left Hindwing Length (Lh.L)	7.63 ± 0.08	5.03 ± 0.07
Right Hindwing Length (Rh.L)	7.65 ± 0.14	5.04 ± 0.12
Left Forewing Width (Lf.W)	2.30 ± 0.03	2.01 ± 0.02
Right Forewing Width (Rf.W)	2.39 ± 0.02	2.00 ± 0.02
Left Hindwing Width (Lh.W)	1.86 ± 0.03	2.15 ± 0.03
Right Hindwing Width (Rh.W)	1.85 ± 0.05	1.98 ± 0.03
Femur Length (F.L)	6.21 ± 0.04	3.38 ± 0.02
Tibia Length (Ti.L)	6.72 ± 0.11	3.16 ± 0.03
Tarsus Length (Tar.L)	1.97 ± 0.03	1.38 ± 0.03
Prothorax Leg Length (Pro. Leg L)	10.46 ± 0.07	8.09 ± 0.19
Mesothorax Leg Length (Mes. Leg L)	11.04 ± 0.12	6.35 ± 0.01
Metathorax Leg Length (Met. Leg L)	16.53 ± 0.34	8.24 ± 0.05
Head Length (h.L)	1.82 ± 0.03	1.55 ± 0.04
Abdomen Length (Ab.L)	8.06 ± 0.15	4.07 ± 0.07
Thorax Length (Th. L)	4.42 ± 0.02	3.75 ± 0.08

These measurements are in agreement with Lahari *et al.* (2024) who also recorded similar measurements while studying the diversity of *Leptocorisa* spp. comparable results were observed by them where Insect length (15.7 ± 0.50), Head length (4.8 ± 0.02), rostrum/mouthpart (4.7 ± 0.02), antenna (14.0 ± 0.50), forewing (11.8 ± 0.02) and Hindleg (13.1 ± 0.02) on male specimens all agree with the current results.

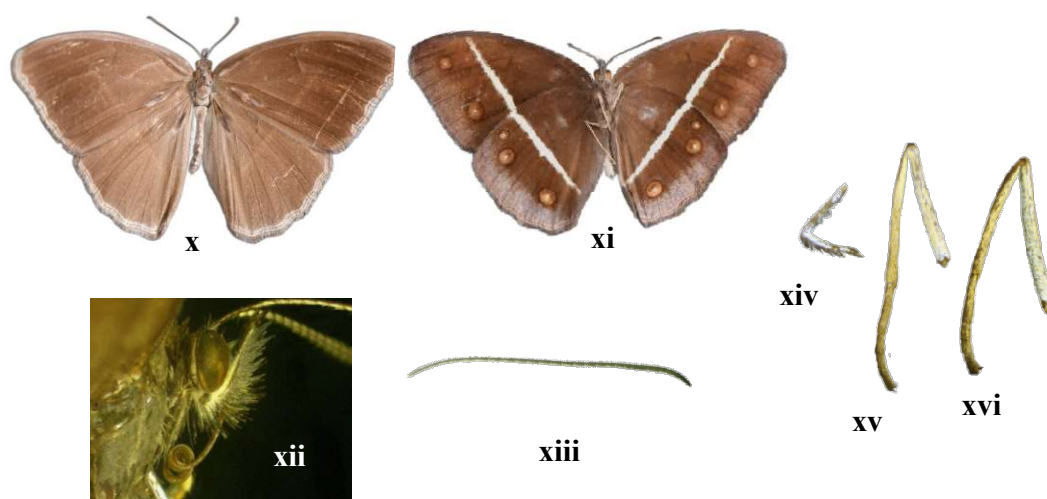
4.5.1.15. *Cletus punctiger*: The mean body length was 9.09 ± 0.02 mm and body width was 3.34 ± 0.08 mm. The body height was slightly higher at 2.51 ± 0.06 mm. The

antennae length measured 7.46 ± 0.18 mm, while the mouthpart length was recorded at 3.31 ± 0.01 mm. The left forewing length was 5.91 ± 0.04 mm, while the right forewing length was slightly longer at 6.18 ± 0.11 mm. The left hindwing length was 5.03 ± 0.07 mm, and the right hindwing length was nearly identical at 5.04 ± 0.12 mm. The left forewing width measured 2.01 ± 0.02 mm, while the right forewing width was 2.00 ± 0.02 mm. The left hindwing width was 2.15 ± 0.03 mm, while the right hindwing width was 1.98 ± 0.03 mm. The femur length measured 3.38 ± 0.02 mm, and the tibia length was 3.16 ± 0.03 mm. The tarsus length was recorded at 1.38 ± 0.03 mm. The prothorax leg length was 8.09 ± 0.19 mm, while the mesothorax leg length measured 6.35 ± 0.01 mm, and the metathorax leg length was 8.24 ± 0.05 mm. Head length measured 1.55 ± 0.04 mm, abdomen and thorax length measured 4.07 ± 0.07 mm and 3.75 ± 0.08 mm, respectively (Table no. 4.5c, Plate 4.B).

4.5.1.16. *Melanitis leda ismene*: Mean total length of *M. leda ismene* was 21.94 ± 0.36 mm and antenna length was 15.45 ± 0.21 mm. The forewing base-apex length was 39.09 ± 0.90 mm, while the forewing base-tornus and apex-tornus lengths measured 28.75 ± 0.24 mm and 26.41 ± 0.37 mm, respectively. The hindwing base-apex length was recorded at 27.61 ± 0.00 mm, and the hindwing base-tornus and apex-tornus were 29.97 ± 0.30 mm and 25.78 ± 0.17 mm, respectively. The total foreleg, midleg, and hindleg lengths were 6.22 ± 0.02 mm, 13.66 ± 0.24 mm, and 14.78 ± 0.29 mm, respectively. The vein forewing cubitus2 length was 20.49 ± 0.52 mm, the vein forewing anal length was 28.19 ± 0.35 mm, Vein Hindwing Radius2 was 19.40 ± 0.50 and the vein hindwing cubitus2 measured 22.86 ± 0.52 mm. The proboscis length was recorded as 9.58 ± 0.03 mm, the abdomen length was 13.09 ± 0.09 mm, and the thorax length was 6.89 ± 0.07 mm (Table no. 4.5d, Plate 6.A).



A. *Melanitis leda ismene* Linnaeus (i-iv. Polymorph Adults , v. Head with labial palpi and proboscis, vi. Antenna, vii. Foreleg, viii. Midleg, ix. Hindleg)



B. *Mycalesis mineus* Linnaeus (x-xi. Adult , xii. Head with labial palpi & proboscis, xiii. Antenna, xiv. Foreleg, xv. Midleg, xvi. Hindleg)

Table 4.5d: Morphometric measurement (♂) of *Melanitis leda ismene*, *Mycalesis mineus* and *Pelopidas mathias*.

Parameters	Insect pests (Measurements in mm $\pm$ SEM)		
	<i>Melanitis leda ismene</i>	<i>Mycalesis mineus</i>	<i>Pelopidas mathias</i>
Total Length (TL)	21.94 $\pm$ 0.36	17.71 $\pm$ 0.19	17.47 $\pm$ 0.38
Antenna Length (AL)	15.45 $\pm$ 0.21	11.71 $\pm$ 0.11	8.27 $\pm$ 0.18
Forewing Base-Apex (FWBA)	39.09 $\pm$ 0.90	26.59 $\pm$ 0.24	19.28 $\pm$ 0.05
Forewing Base-Tornus (FWBT)	28.75 $\pm$ 0.24	20.84 $\pm$ 0.33	12.34 $\pm$ 0.15
Forewing Apex-Tornus (FWAT)	26.41 $\pm$ 0.37	17.61 $\pm$ 0.19	11.59 $\pm$ 0.12
Hindwing Base-Apex (HWBA)	27.61 $\pm$ 0.00	20.36 $\pm$ 0.28	11.73 $\pm$ 0.28
Hindwing Base-Tornus (HWBT)	29.97 $\pm$ 0.30	21.31 $\pm$ 0.23	11.17 $\pm$ 0.24
Hindwing Apex-Tornus (HWAT)	25.78 $\pm$ 0.17	17.49 $\pm$ 0.40	9.80 $\pm$ 0.19
Total Foreleg (TFL)	6.22 $\pm$ 0.02	3.58 $\pm$ 0.09	8.37 $\pm$ 0.21
Total Midleg (TML)	13.66 $\pm$ 0.24	10.85 $\pm$ 0.05	9.26 $\pm$ 0.22
Total Hindleg (THL)	14.78 $\pm$ 0.29	11.21 $\pm$ 0.12	12.81 $\pm$ 0.24
Vein Forewing Cubitus2 (VFCU2)	20.49 $\pm$ 0.52	---	---
Vein Forewing Anal (VFA)	28.19 $\pm$ 0.35	---	---
Vein Hindwing Radius2 (VHR2)	19.40 $\pm$ 0.50	---	---
Vein Hindwing Cubitus2 (VHCU2)	22.86 $\pm$ 0.52	---	---
Proboscis Length (PbL)	9.58 $\pm$ 0.03	7.43 $\pm$ 0.05	13.37 $\pm$ 0.18
Abdomen Length (Ab.L)	13.09 $\pm$ 0.09	9.45 $\pm$ 0.13	7.21 $\pm$ 0.15
Thorax Length (Th. L)	6.89 $\pm$ 0.07	5.53 $\pm$ 0.03	5.95 $\pm$ 0.01

4.5.1.17. *Mycalesis mineus*: The mean total length of *M. mineus* recorded was 17.71 $\pm$ 0.19 mm and antenna length was 11.71 $\pm$ 0.11 mm. The forewing base-apex length was 26.59 $\pm$ 0.24 mm, while the forewing base-tornus and apex-tornus were 20.84 $\pm$ 0.33 mm and 17.61 $\pm$ 0.19 mm, respectively. The hindwing base-apex length measured 20.36 $\pm$ 0.28 mm, while the hindwing base-tornus and apex-tornus were 21.31 $\pm$ 0.23 mm and 17.49 $\pm$ 0.40 mm, respectively. The total foreleg, midleg, and hindleg lengths were 3.58 $\pm$ 0.09 mm, 10.85 $\pm$ 0.05 mm, and 11.21 $\pm$ 0.12 mm, respectively. The proboscis length was 7.43 $\pm$ 0.05 mm. The abdomen length was recorded as 9.45 $\pm$ 0.13 mm and thorax length was 5.53 $\pm$ 0.03 (Table no. 4.5d and Plate 6.O).

4.5.1.18. *Pelopidas mathias*: *P. mathias* had a total length of 17.47 ± 0.38 mm and an antenna length of 8.27 ± 0.18 mm. The forewing base-apex length was recorded at 19.28 ± 0.05 mm, while the forewing base-tornus and apex-tornus were 12.34 ± 0.15 mm and 11.59 ± 0.12 mm, respectively. The hindwing base-apex measured 11.73 ± 0.28 mm, while the hindwing base-tornus and apex-tornus were 11.17 ± 0.24 mm and 9.80 ± 0.19 mm, respectively. The total foreleg, midleg, and hindleg lengths were 8.37 ± 0.21 mm, 9.26 ± 0.22 mm, and 12.81 ± 0.24 mm, respectively. The proboscis length measured 13.37 ± 0.18 mm while the abdomen length was 7.21 ± 0.15 mm and thorax length was 5.95 ± 0.01 (Table no. 4.5d and Plate 7.C).

4.5.1.19. *Oxya* spp.: The mean body length was 27.91 ± 0.70 mm (Table no. 4.5e). The pronotum measured 6.06 ± 0.14 mm in length and 4.35 ± 0.06 mm in width. Head width averaged 4.51 ± 0.10 mm, with an interocular distance of 0.96 ± 0.02 mm. The antennae were 8.70 ± 0.21 mm long, and thorax height was recorded at 5.48 ± 0.11 mm. Tegmen length reached 14.77 ± 0.15 mm. The forewings measured 23.57 ± 0.45 mm in length and 3.64 ± 0.03 mm in width, while hindwings were 21.33 ± 0.18 mm long and 8.69 ± 0.21 mm wide. Foreleg and midleg lengths were 11.94 ± 0.23 mm and 13.83 ± 0.09 mm, respectively. The hindleg extended to 33.44 ± 0.84 mm, with the third femur and third tibia measuring 15.31 ± 0.28 mm and 12.77 ± 0.29 mm, respectively. Additionally, the metanotal gland exhibited a length of 1.81 ± 0.78 mm and a width of 2.51 ± 0.03 mm.



A. *Leucania loreyi* Duponchel (i. Adult , ii. Head with labial palpi and proboscis, iii. Antenna. iv. Foreleg. v. Midleg. vi. Hindleg)



B. *Nymphula depunctalis* Guenée (vii. Adult , viii. Forewing, ix. Hindwing, x. Head with labial palpi and proboscis, xi. Antenna, xii. Foreleg, xiii. Midleg, xiv. Hindleg)



C. *Pelopidas mathias* Fabricius (xv-xvi. Adult , xvii. Forewing, xviii. Hindwing, xix. Antenna, xx. Foreleg, xxi. Midleg, xxii. Hindleg)

Table 4.5e: Morphometrics measurement (♂) of *Oxya* spp., *Melanoplus bivittatus*, *Dociostaurus* Spp., *Atractomorpha* Spp, *Gryllus* spp. and *Gryllus bimaculatus*.

Parameters	Insect pests (Measurements in mm $\pm$ SEM)					
	<i>Oxya</i> spp.	<i>Melanoplus bivittatus</i>	<i>Dociostaurus</i> spp.	<i>Atractomorpha</i> spp	<i>Gryllus</i> spp.	<i>Gryllus bimaculatus</i>
Body length (BL)	27.91 $\pm$ 0.70	37.19 $\pm$ 0.24	24.30 $\pm$ 0.41	52.46 $\pm$ 0.17	28.60 $\pm$ 0.45	26.82 $\pm$ 0.50
Pronotum length (PL)	6.06 $\pm$ 0.14	6.77 $\pm$ 0.02	4.41 $\pm$ 0.05	9.17 $\pm$ 0.01	5.02 $\pm$ 0.02	5.21 $\pm$ 0.11
Pronotum width (PW)	4.35 $\pm$ 0.06	6.10 $\pm$ 0.15	4.57 $\pm$ 0.08	5.39 $\pm$ 0.13	8.17 $\pm$ 0.05	9.35 $\pm$ 0.15
Head width (HW)	4.51 $\pm$ 0.10	6.08 $\pm$ 0.10	3.92 $\pm$ 0.02	2.82 $\pm$ 0.05	7.77 $\pm$ 0.07	8.49 $\pm$ 0.20
Interocular distance (IOD)	0.96 $\pm$ 0.02	2.43 $\pm$ 0.05	1.38 $\pm$ 0.03	1.47 $\pm$ 0.00	4.15 $\pm$ 0.08	5.05 $\pm$ 0.11
Antenna length (AL)	8.70 $\pm$ 0.21	16.27 $\pm$ 0.20	7.56 $\pm$ 0.06	13.33 $\pm$ 0.11	32.92 $\pm$ 0.33	37.29 $\pm$ 0.52
Thorax height (TxH)	5.48 $\pm$ 0.11	8.39 $\pm$ 0.18	6.60 $\pm$ 0.09	7.48 $\pm$ 0.16	8.41 $\pm$ 0.13	8.65 $\pm$ 0.05
Tegmen length (TegL)	14.77 $\pm$ 0.15	17.64 $\pm$ 0.30	17.30 $\pm$ 0.21	26.01 $\pm$ 0.34	11.77 $\pm$ 0.28	10.80 $\pm$ 0.08
Forewing length (FWL)	23.57 $\pm$ 0.45	34.23 $\pm$ 0.68	28.51 $\pm$ 0.18	46.04 $\pm$ 0.96	20.27 $\pm$ 0.46	20.44 $\pm$ 0.02
Forewing width (FWW)	3.64 $\pm$ 0.03	5.66 $\pm$ 0.07	4.31 $\pm$ 0.05	4.97 $\pm$ 0.11	11.47 $\pm$ 0.25	11.05 $\pm$ 0.10
Hindwing length(HWL)	21.33 $\pm$ 0.18	31.79 $\pm$ 0.13	26.69 $\pm$ 0.38	41.64 $\pm$ 0.22	27.82 $\pm$ 0.16	29.27 $\pm$ 0.23
Hindwing width (HWW)	8.69 $\pm$ 0.21	13.23 $\pm$ 0.33	11.49 $\pm$ 0.19	14.62 $\pm$ 0.34	16.23 $\pm$ 0.34	14.46 $\pm$ 0.07
Foreleg length (FLL)	11.94 $\pm$ 0.23	17.50 $\pm$ 0.28	10.81 $\pm$ 0.09	18.90 $\pm$ 0.46	17.65 $\pm$ 0.11	17.27 $\pm$ 0.18
Midleg length (MLL)	13.83 $\pm$ 0.09	18.70 $\pm$ 0.44	12.84 $\pm$ 0.28	24.85 $\pm$ 0.45	20.41 $\pm$ 0.16	17.70 $\pm$ 0.27
Hindleg length (HLL)	33.44 $\pm$ 0.84	49.02 $\pm$ 0.03	33.03 $\pm$ 0.81	66.71 $\pm$ 0.76	40.14 $\pm$ 0.73	35.71 $\pm$ 0.91
Third femur length (FL)	15.31 $\pm$ 0.28	21.75 $\pm$ 0.51	15.37 $\pm$ 0.19	30.57 $\pm$ 0.06	16.60 $\pm$ 0.40	16.57 $\pm$ 0.41
Third tibia length (TiL)	12.77 $\pm$ 0.29	17.73 $\pm$ 0.30	13.35 $\pm$ 0.33	29.03 $\pm$ 0.33	12.73 $\pm$ 0.24	10.89 $\pm$ 0.20
Metanotal gland length MGL	1.81 $\pm$ 0.78	2.80 $\pm$ 0.08	1.77 $\pm$ 0.11	2.61 $\pm$ 0.86	---	---
Metanotal gland width MGW	2.51 $\pm$ 0.05	3.21 $\pm$ 0.30	2.01 $\pm$ 0.23	2.73 $\pm$ 0.41	---	---



Spodoptera litura Fabricius



Orsotriaena medus Fabricius



Phlaeoba infumata Brunner von Wattenwyl



Oxya spp.



Melanoplus bivittatus Say



Dociostaurus spp.



Atractomorpha spp.



Euscyrtus oncinus
de Haan



Gryllus bimaculatus
De Geer



Gryllus spp.



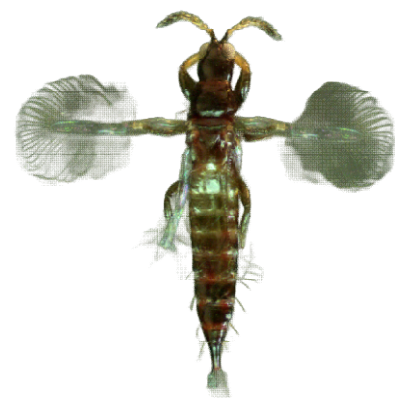
Gryllotalpa orientalis
Burmeister



Sitophilus oryzae
Linnaeus



Dicladispa armigera
Olivier



Stenchaetothrips biformis
Bagnall

Plate 8. Insect pests belonging to order Lepidoptera, Orthoptera, Coleoptera and Thysanoptera.

4.5.1.20. *Melanoplus bivittatus*: Morphometric measurements of *Melanoplus bivittatus* showed a mean body length of 37.19 ± 0.24 mm. The pronotum measured 6.77 ± 0.02 mm in length and 6.10 ± 0.15 mm in width. Head width was 6.08 ± 0.10 mm, with an interocular distance of 2.43 ± 0.05 mm. Antennae were notably long at 16.27 ± 0.20 mm. The thorax height averaged 8.39 ± 0.18 mm. Tegmen length was recorded at 17.64 ± 0.30 mm. The forewings measured 34.23 ± 0.68 mm in length and 5.66 ± 0.07 mm in width, while hindwings were 31.79 ± 0.13 mm long and 13.23 ± 0.33 mm wide. Foreleg and midleg lengths were 17.50 ± 0.28 mm and 18.70 ± 0.44 mm, respectively. The hindleg reached 49.02 ± 0.03 mm in length, with the third femur measuring 21.75 ± 0.51 mm and the third tibia 17.73 ± 0.30 mm. The metanotal gland measured 2.80 ± 0.08 mm in length and 3.21 ± 0.30 mm in width (Table no. 4.5e).

4.5.1.21. *Dociostaurus* spp.: Morphometric observations of *Dociostaurus* spp. revealed a mean body length of 24.30 ± 0.41 mm. The pronotum measured 4.41 ± 0.05 mm in length and 4.57 ± 0.08 mm in width. Head width was 3.92 ± 0.02 mm, with an interocular distance of 1.38 ± 0.03 mm. The antennae reached 7.56 ± 0.06 mm in length. Thorax height was recorded at 6.60 ± 0.09 mm. The tegmen measured 17.30 ± 0.21 mm, while the forewings were 28.51 ± 0.18 mm long and 4.31 ± 0.05 mm wide. Hindwings reached 26.69 ± 0.38 mm in length and 11.49 ± 0.19 mm in width. Foreleg and midleg lengths were 10.81 ± 0.09 mm and 12.84 ± 0.28 mm, respectively. The hindleg extended 33.03 ± 0.81 mm, with the third femur and third tibia measuring 15.37 ± 0.19 mm and 13.35 ± 0.33 mm, respectively. The metanotal gland was 1.77 ± 0.11 mm in length and 2.01 ± 0.23 mm in width (Table no. 4.5e).

4.5.1.22. *Atractomorpha* spp.: *Atractomorpha* spp. exhibited a mean body length of 52.46 ± 0.17 mm, with a pronotum length of 9.17 ± 0.01 mm and a pronotum width of 5.39 ± 0.13 mm. The head width was 2.82 ± 0.05 mm, and the interocular distance measured 1.47 ± 0.00 mm. Antenna length reached 13.33 ± 0.11 mm. The thorax height was 7.48 ± 0.16 mm, while the tegmen measured 26.01 ± 0.34 mm in length. The forewing length and width were 46.04 ± 0.96 mm and 4.97 ± 0.11 mm, respectively, and

the hindwing extended 41.64 ± 0.22 mm in length with a width of 24.85 ± 0.45 mm. The foreleg, midleg, and hindleg lengths were 14.62 ± 0.34 mm, 18.90 ± 0.46 mm, and 66.71 ± 0.76 mm, respectively. The third femur measured 30.57 ± 0.06 mm, while the third tibia was 29.03 ± 0.33 mm long. Lastly, the metanotal gland length and width were recorded at 2.61 ± 0.86 mm and 2.73 ± 0.41 mm, respectively (Table no. 4.5e).

4.5.1.23. *Gryllus* Spp.: The brown field cricket, exhibited a body length of 28.60 ± 0.45 mm, with a pronotum length of 5.02 ± 0.02 mm and a pronotum width of 8.17 ± 0.05 mm. The head width was measured at 7.77 ± 0.07 mm, and the interocular distance was 4.15 ± 0.08 mm. The antenna length reached 32.92 ± 0.33 mm. Thorax height was recorded at 8.41 ± 0.13 mm, and the tegmen length measured 11.77 ± 0.28 mm. The forewing length and width were 20.27 ± 0.46 mm and 11.47 ± 0.25 mm, respectively, while the hindwing measured 27.82 ± 0.16 mm in length with a width of 20.41 ± 0.16 mm. The foreleg and midleg lengths were 16.23 ± 0.34 mm and 17.65 ± 0.11 mm, respectively. The hindleg extended to 40.14 ± 0.73 mm, with the third femur and third tibia measuring 16.60 ± 0.40 mm and 12.73 ± 0.24 mm, respectively (Table no. 4.5e).

4.5.1.24. *Gryllus bimaculatus*: The mean body length of *G. bimaculatus* was 26.82 ± 0.50 mm. Pronotum length and width were 5.21 ± 0.11 mm and 9.35 ± 0.15 mm, respectively. The head width measured 8.49 ± 0.20 mm, while the interocular distance was 5.05 ± 0.11 mm. The antenna length was the longest among the species studied, at 37.29 ± 0.52 mm. Thorax height was 8.65 ± 0.05 mm, and the tegmen length reached 10.80 ± 0.08 mm. The forewing dimensions were 20.44 ± 0.02 mm in length and 11.05 ± 0.10 mm in width. Hindwing length and width were 29.27 ± 0.23 mm and 14.46 ± 0.07 mm, respectively. The foreleg and midleg measured 17.27 ± 0.18 mm and 17.70 ± 0.27 mm, while the hindleg was 35.71 ± 0.91 mm long. The third femur and tibia lengths were 16.57 ± 0.41 mm and 10.89 ± 0.20 mm, respectively (Table no. 4.5e).

Table 4.5f: Morphometric measurement (♂) of *Sitophilus oryzae*

Parameters	Measurements in mm $\pm$ SEM
Snout length (sl)	1.09 $\pm$ 0.01
Snout width (sw)	0.18 $\pm$ 0.00
Scape of antenna length (sal)	0.31 $\pm$ 0.01
Antenna length (al)	0.12 $\pm$ 0.00
Antenna width (aw)	0.10 $\pm$ 0.00
Distance between eyes (ed)	0.11 $\pm$ 0.00
Pronotum length (pl)	0.91 $\pm$ 0.01
Pronotum width (pw)	0.95 $\pm$ 0.02
Elythra length (el)	1.44 $\pm$ 0.03
Elythra width (ew)	0.99 $\pm$ 0.01
Total length (without snout) (tl)	2.86 $\pm$ 0.05
Profemur length (f1l)	0.75 $\pm$ 0.00
Protibia length (f1tb)	0.31 $\pm$ 0.01
Protarsus length (f1ta)	0.18 $\pm$ 0.00
Mesofemur length (f2l)	0.66 $\pm$ 0.01
Mesotibia length (f2tb)	0.28 $\pm$ 0.00
Mesotarsus length (f2ta)	0.18 $\pm$ 0.00
Metafemur length (f3l)	0.73 $\pm$ 0.01
Metatibia length (f3tb),	0.52 $\pm$ 0.01
Metatarsus length (f3ta)	0.21 $\pm$ 0.00
Mesocoxal distance (msd)	0.18 $\pm$ 0.00
Metacoxal distance (mtd)	0.28 $\pm$ 0.00
Meso-metacoxal distance (mmd)	0.46 $\pm$ 0.01

4.5.1.25. *Sitophilus oryzae*: The mean snout length recorded was 1.09 $\pm$ 0.01 mm and snout width was 0.18 $\pm$ 0.00 mm (Table no. 4.5f). The scape of the antenna measured 0.31 $\pm$ 0.01 mm, while the total antenna length was 0.12 $\pm$ 0.00 mm, with an antenna width of 0.10 $\pm$ 0.00 mm. The distance between the eyes was recorded at 0.11 $\pm$ 0.00 mm. The pronotum length was 0.91 $\pm$ 0.01 mm, while the pronotum width was 0.95 $\pm$ 0.02 mm. The elytra length was 1.44 $\pm$ 0.03 mm, and the elytra width measured 0.99 $\pm$ 0.01 mm. The total body length, excluding the snout, was 2.86 $\pm$ 0.05 mm. The profemur measured 0.75 $\pm$ 0.00 mm, the protibia length was 0.31 $\pm$ 0.01 mm, and the protarsus length was 0.18 $\pm$ 0.00 mm. The mesofemur length was recorded at 0.66 $\pm$ 0.01 mm, with the mesotibia measuring 0.28 $\pm$ 0.00 mm and the mesotarsus at 0.18 $\pm$ 0.00 mm. The metafemur was 0.73 $\pm$ 0.01 mm long, while the metatibia measured 0.52 $\pm$ 0.01 mm, and the metatarsus length was 0.21 $\pm$ 0.00 mm. The mesocoxal distance was 0.18 $\pm$ 0.00 mm,

the metacoxal distance was 0.28 ± 0.00 mm, and the meso-metacoxal distance was 0.46 ± 0.01 mm.

The present measurements are in confirmation to the findings of Suhriani *et al.* (2023) who observed similar results of total body length as 3.190 mm abdomen length as 1.120 mm, abdomen width as 0.700 mm, pronotum length as 1.055 mm with pronotum width of 0.630 mm. The average head size recorded was 1.105mm while the length of the rostrum to insertion of the antennae was 0.580mm which is similar to the present investigation.

Table 4.5g: Morphometric measurement (♂) of *Dicladispa armigera*

Parameters	Measurements in mm $\pm$ SEM
Antennal length (AL)	1.40 ± 0.00
Length of Head (HL)	0.33 ± 0.00
Width of Head (HW)	0.75 ± 0.02
Length of Pronotum (PL)	0.88 ± 0.02
Width of Pronotum (PW)	1.15 ± 0.03
Elytral length (EL)	2.75 ± 0.02
Elytral width (EW)	1.79 ± 0.01
Total body length (BL)	4.15 ± 0.08
Inter ocular distance (IoD)	0.36 ± 0.01
Fore femur length (FFL)	0.97 ± 0.03
Fore tibia length (FTL)	0.36 ± 0.01
Midfemur length (MFL)	0.83 ± 0.01
Mid tibia length (MTL)	0.75 ± 0.00
Hind femur length (HFL)	0.58 ± 0.01
Hind tibia length (HTL)	0.63 ± 0.01

4.5.1.26. *Dicladispa armigera*: The mean antennal length was 1.40 ± 0.00 mm, head length was 0.33 ± 0.00 mm, and a head width of 0.75 ± 0.02 mm. The pronotum length was 0.88 ± 0.02 mm, while the pronotum width measured 1.15 ± 0.03 mm. The elytral length was recorded at 2.75 ± 0.02 mm, and the elytral width was 1.79 ± 0.01 mm. The total body length measured 4.15 ± 0.08 mm. The interocular distance was 0.36 ± 0.01 mm. The fore femur length was 0.97 ± 0.03 mm, while the fore tibia length was 0.36 ± 0.01 mm. The midfemur length was recorded at 0.83 ± 0.01 mm, and the mid tibia

measured 0.75 ± 0.00 mm. The hind femur length was 0.58 ± 0.01 mm, while the hind tibia length was 0.63 ± 0.01 mm (Table no. 4.5g).

Similar morphometric measurements of *D. armigera* have been documented by Sharma and Srivastava (2017). The adult body length of males was 4.03 ± 0.047 mm while in females it was 4.45 ± 0.056 mm. The head width recorded in males was 0.60 ± 0.006 mm and 0.70 ± 0.011 mm in females. These results are in agreement with the present measurements of the insect pest.

Table 4.5h: Morphometric measurement (♂) of *Stenchaetothrips biformis*

Parameters	Measurements in mm $\pm$ SEM
Head width(HW)	0.13 ± 0.000
Head length (dorsal side) (HL)	0.14 ± 0.003
Head length (ventral side, including mouthcone) (HLiMC)	0.20 ± 0.004
Clavus length (CL)	0.14 ± 0.003
Clavus width (CW)	0.03 ± 0.000
Forewing length (FL)	0.54 ± 0.007
Forewing basal width (FbW)	0.07 ± 0.001
Total body length (excluding antenna and penis) (TL)	1.16 ± 0.004
Pronotum width (PW)	0.16 ± 0.000
Pronotum length (PL)	0.17 ± 0.003
Eye length (EL)	0.06 ± 0.000
Ovipositor length (OL)	0.11 ± 0.001
Ovipositor width (OW)	0.04 ± 0.001
Antennal segment V length (ALV)	0.04 ± 0.001
Antennal segment VI length (ALVI)	0.05 ± 0.001
Antenn lgt	0.27 ± 0.004
Distance between the posterior pair of ocelli	---
Distance between an anterior and posterior pair of ocelli	---
Hind wing width (HWW)	0.04 ± 0.000
Hind wing Length (HWL)	0.50 ± 0.002
Inter ocular distance (IoD)	0.05 ± 0.001

4.5.1.27. *Stenchaetothrips biformis*: The mean head width of *S. biformis* was recorded as 0.13 ± 0.000 mm and dorsal head length was 0.14 ± 0.003 mm. The ventral head length, including the mouthcone, measured 0.20 ± 0.004 mm. The clavus length was recorded at 0.14 ± 0.003 mm, while the clavus width measured 0.03 ± 0.000 mm. The forewing length was 0.54 ± 0.007 mm, with a basal width of 0.07 ± 0.001 mm. The total body

length, excluding the antenna and penis, was 1.16 ± 0.004 mm. The pronotum width measured 0.16 ± 0.000 mm, while the pronotum length was 0.17 ± 0.003 mm. The eye length was 0.06 ± 0.000 mm. The ovipositor length was 0.11 ± 0.001 mm, while the ovipositor width was 0.04 ± 0.001 mm. The antennal segment V length was 0.04 ± 0.001 mm, while antennal segment VI measured 0.05 ± 0.001 mm. The total antenna length was 0.27 ± 0.004 mm. The hindwing length was recorded at 0.50 ± 0.002 mm, with a hindwing width of 0.04 ± 0.000 mm. The interocular distance measured 0.05 ± 0.001 mm (Table no. 4.5h).

4.5.2. MORPHOMETRIC CHARACTERISTICS OF NATURAL ENEMIES OF INSECT PESTS OF RICE

4.5.2.1. *Brachythemis contaminata*: The body length of *Brachythemis contaminata* was recorded at 37.96 ± 0.96 mm (Table 4.5i). The abdomen measured 22.98 ± 0.09 mm, while the thorax length was 8.28 ± 0.09 mm. The head width and head length were 6.24 ± 0.08 mm and 3.51 ± 0.02 mm, respectively. The forewing length was 26.08 ± 0.62 mm, with a height of 7.11 ± 0.07 mm. The hindwing measured 25.28 ± 0.71 mm in length and 8.72 ± 0.11 mm in height. The pterostigma length was 3.36 ± 0.01 mm.

The measurements of the present species are in agreement with those of Prasad and Ghosh (1983). They observed the abdomen length including the anal appendages to be between 18 to 21.5 mm long, forewing lengths between 22 to 22.5 mm, hindwing lengths between 21.5 to 24.5 mm, hindwing width between 8 to 9.5 mm and pterostigma length was observed to be 3 mm.

4.5.2.2. *Crocothemis servilia*: The total body length of *Crocothemis servilia* was 38.75 ± 0.58 mm. The abdomen length was 25.07 ± 0.40 mm, with a thorax length of 9.13 ± 0.05 mm. The head width measured 6.27 ± 0.09 mm, while the head length was 4.92 ± 0.12 mm. The forewing and hindwing lengths were 32.26 ± 0.60 mm and 31.15 ± 0.26 mm, respectively. The forewing height was 7.60 ± 0.14 mm, and the hindwing height was 9.45 ± 0.05 mm. The pterostigma length was 3.36 ± 0.08 mm. The measurements of

Crocothemis servilia recorded are in alignment with those reported by Ahmed and Kareem (2019) as they recorded almost similar results with total length of 36-40 mm, hind wing at 30-32 mm, an abdomen length of about 26 mm, Thorax, length of 9 mm, Head width of 5 mm, Head Length of 4.5 mm and the pterostigma length was measured about 3 mm (Table 4.5i).

4.5.2.3. *Orthetrum sabina*: *O. sabina* exhibited a body length of 48.72 ± 0.87 mm. The abdomen measured 35.11 ± 0.29 mm, and the thorax length was 9.92 ± 0.04 mm. The head width was 6.20 ± 0.01 mm, with a head length of 3.94 ± 0.03 mm. The forewing length was 33.09 ± 0.03 mm, with a forewing height of 7.50 ± 0.07 mm. The hindwing length was recorded at 32.27 ± 0.71 mm, and the hindwing height was 9.60 ± 0.24 mm. The pterostigma length was 3.48 ± 0.01 mm (Table 4.5i).

The measurements of *Orthetrum sabina* are also in line with the findings of Ahmed and Kareem (2019) as they also observed similar results of total length between 45-49mm in male, hindwing between 32-34mm. The Abdomen length was similar with 35 mm, Thorax length was about 10 mm, similar Head width with 6 mm, Head Length was 4.5mm and the Pterostigma length was same at 3mm. However, Shaikh *et al.* (2018) recorded the same species with slightly smaller measurements indicating a possible variation due to geographic factors.

4.5.2.4. *Crocothemis nigrifrons*: The body length of *Crocothemis nigrifrons* was 43.79 ± 0.46 mm (Table 4.5i). The abdomen length measured 28.36 ± 0.52 mm, and the thorax length was 10.44 ± 0.02 mm. The head width was 6.57 ± 0.13 mm, while the head length was 4.26 ± 0.08 mm. The forewing length was 34.41 ± 0.18 mm, forewing height was 7.36 ± 0.03 mm, hindwing length was 31.93 ± 0.08 mm and the hindwing height was 9.38 ± 0.16 mm The pterostigma length was 3.62 ± 0.05 mm.

Table 4.5i: Morphometric measurement (♂) of Odonata-Anisoptera

Parameters	Natural Enemies (Measurements in mm $\pm$ SEM)							
	<i>Brachythemis contaminata</i>	<i>Crocothemis servilia</i>	<i>Orthetrum sabina</i>	<i>Crocothemis nigrifrons</i>	<i>Neurothemis intermedia</i>	<i>Neurothemis tullia</i>	<i>Orthetrum pruinatum</i>	<i>Palpopleura sexmaculata</i>
Body length (BD)	37.96 $\pm$ 0.96	38.75 $\pm$ 0.58	48.72 $\pm$ 0.87	43.79 $\pm$ 0.46	29.46 $\pm$ 0.52	25.09 $\pm$ 0.42	44.42 $\pm$ 0.89	24.67 $\pm$ 0.42
Abdomen length (AL)	22.98 $\pm$ 0.09	25.07 $\pm$ 0.40	35.11 $\pm$ 0.29	28.36 $\pm$ 0.52	19.26 $\pm$ 0.03	16.73 $\pm$ 0.36	29.71 $\pm$ 0.67	14.73 $\pm$ 0.38
Thorax length (TL)	8.28 $\pm$ 0.09	9.13 $\pm$ 0.05	9.92 $\pm$ 0.04	10.44 $\pm$ 0.02	5.84 $\pm$ 0.01	5.60 $\pm$ 0.05	9.96 $\pm$ 0.25	6.56 $\pm$ 0.06
Head width (HW)	6.24 $\pm$ 0.08	6.27 $\pm$ 0.09	6.20 $\pm$ 0.01	6.57 $\pm$ 0.13	4.43 $\pm$ 0.05	3.91 $\pm$ 0.10	6.97 $\pm$ 0.05	4.77 $\pm$ 0.00
Head Length (HL)	3.51 $\pm$ 0.02	4.92 $\pm$ 0.12	3.94 $\pm$ 0.03	4.26 $\pm$ 0.08	2.88 $\pm$ 0.02	3.02 $\pm$ 0.07	4.62 $\pm$ 0.10	3.38 $\pm$ 0.07
Forewing length (FWL)	26.08 $\pm$ 0.62	32.26 $\pm$ 0.60	33.09 $\pm$ 0.03	34.41 $\pm$ 0.18	23.93 $\pm$ 0.13	21.38 $\pm$ 0.31	34.33 $\pm$ 0.79	19.50 $\pm$ 0.38
Forewing height (FWH)	7.11 $\pm$ 0.07	7.60 $\pm$ 0.14	7.50 $\pm$ 0.07	7.36 $\pm$ 0.03	5.70 $\pm$ 0.05	5.04 $\pm$ 0.03	7.41 $\pm$ 0.12	4.97 $\pm$ 0.04
Hindwing length (HWL)	25.28 $\pm$ 0.71	31.15 $\pm$ 0.26	32.27 $\pm$ 0.71	31.93 $\pm$ 0.08	22.44 $\pm$ 0.55	19.38 $\pm$ 0.37	33.57 $\pm$ 0.23	17.69 $\pm$ 0.30
Hindwing height (HWH)	8.72 $\pm$ 0.11	9.45 $\pm$ 0.05	9.60 $\pm$ 0.24	9.38 $\pm$ 0.16	7.40 $\pm$ 0.10	6.95 $\pm$ 0.11	9.51 $\pm$ 0.01	5.89 $\pm$ 0.07
Pterostigma length (PtL)	3.36 $\pm$ 0.01	3.36 $\pm$ 0.08	3.48 $\pm$ 0.01	3.62 $\pm$ 0.05	2.81 $\pm$ 0.01	2.38 $\pm$ 0.02	3.86 $\pm$ 0.02	2.41 $\pm$ 0.04



Brachythemis contaminata
Fabricius



Crocothemis servilia
Drury



Orthetrum sabina
Drury



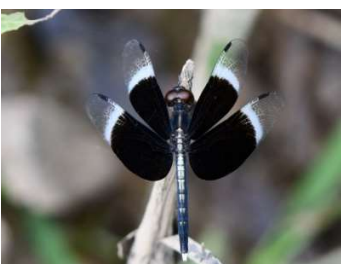
Crocothemis nigrifrons
Kirby



Neurothemis intermedia
Rambur



Diplacodes trivialis
Rambur



Neurothemis tullia
Drury



Orthetrum pruinatum
Burmeister



Palpopleura sexmaculata
Fabricius



Agriocnemis pieris
Laidlaw



Agriocnemis pygmaea
Rambur



Agriocnemis argentea
Tillyard



Ischnura rubilio
Selys



Ceriagrion cerinorubellum
Brauer



Ceriagrion coromandelianum
Fabricius

4.5.2.5. *Neurothemis intermedia*: The body length of *Neurothemis intermedia* was recorded at 29.46 ± 0.52 mm. The abdomen length measured 19.26 ± 0.03 mm, while the thorax length was 5.84 ± 0.01 mm. The head width and head length were 4.43 ± 0.05 mm and 2.88 ± 0.02 mm, respectively. The forewing length was 23.93 ± 0.13 mm, with a height of 5.70 ± 0.05 mm. The hindwing measured 22.44 ± 0.55 mm in length and 7.40 ± 0.10 mm in height. The pterostigma length was 2.81 ± 0.01 mm (Table 4.5i). The Indian biodiversity portal maintains similar measurements of this insect.

4.5.2.6. *Neurothemis tullia*: The body length of *N. tullia* was 25.09 ± 0.42 mm, with an abdomen length of 16.73 ± 0.36 mm (Table 4.5i). The thorax measured 5.60 ± 0.05 mm in length. The head width was 3.91 ± 0.10 mm, while the head length was 3.02 ± 0.07 mm. The forewing length was 21.38 ± 0.31 mm, and the hindwing length was 19.38 ± 0.37 mm. The forewing height measured 5.04 ± 0.03 mm, while the hindwing height was 6.95 ± 0.11 mm. The pterostigma length was 2.38 ± 0.02 mm. the measurements of Abdomen ranging between 16-20 mm and hind wings between 19-23mm as recorded in Indian Biodiversity portal is in agreement with those found in the present research.

4.5.2.7. *Orthetrum pruinsum*: *O. pruinsum* exhibited a body length of 44.42 ± 0.89 mm (Table 4.5i). The abdomen measured 29.71 ± 0.67 mm, while the thorax length was 9.96 ± 0.25 mm. The head width was 6.97 ± 0.05 mm, with a head length of 4.62 ± 0.10 mm. The forewing length was 34.33 ± 0.79 mm, with a forewing height of 7.41 ± 0.12 mm. The hindwing length was recorded at 33.57 ± 0.23 mm, and the hindwing height was 9.51 ± 0.01 mm. The pterostigma length was 3.86 ± 0.02 mm. The recorded body, abdomen, forewing length and width closely aligns with the findings of Setyawati *et al.* (2017). Indian Biodiversity portal also reported similar abdominal and wing size.

4.5.2.8. *Palpopleura sexmaculata*: The body length of *P. sexmaculata* was 24.67 ± 0.42 mm. The abdomen length measured 14.73 ± 0.38 mm, while the thorax length was 6.56 ± 0.06 mm. The head width was recorded at 4.77 ± 0.00 mm, and the head length was 3.38 ± 0.07 mm. The forewing length was 19.50 ± 0.38 mm, with a height of 4.97 ± 0.04 mm.

The hindwing length was recorded at 17.69 ± 0.30 mm, and the hindwing height was 5.89 ± 0.07 mm. The pterostigma length measured 2.41 ± 0.04 mm (Table 4.5i).

The findings are closely similar to the data recorded at the India Biodiversity Portal, where abdomen is described with 14-16 mm and with a hind wing of 15-21 mm length. Similar recording is also mentioned in the webportal “Odonata of Bangladesh” where male Abdomen size is 15 mm with a wing size of 18 mm.

4.5.2.9. *Agriocnemis pieris*: The body length of *A. pieris* was recorded at 20.29 ± 0.04 mm (Table 4.5j). The abdomen length measured 16.25 ± 0.33 mm, while the thorax length was 3.31 ± 0.05 mm. The head width and head length were 2.60 ± 0.00 mm and 1.42 ± 0.03 mm, respectively. The forewing length was 11.28 ± 0.18 mm, with a height of 2.59 ± 0.03 mm. The hindwing measured 12.11 ± 0.19 mm in length and 2.54 ± 0.01 mm in height. The pterostigma length was 0.30 ± 0.01 mm. The abdominal length and wing length are in close alignment with those recordings from the Indian Biodiversity portal as well as those of Odonata of Bangladesh web portal.

4.5.2.10. *Agriocnemis pygmaea*: The body length of *A. pygmaea* was 24.04 ± 0.09 mm, with an abdomen length of 18.13 ± 0.03 mm. The thorax measured 3.43 ± 0.02 mm in length. The head width was 2.80 ± 0.06 mm, while the head length was 1.51 ± 0.04 mm. The forewing length was 11.67 ± 0.26 mm, and the hindwing length was 11.19 ± 0.20 mm. The forewing height measured 2.34 ± 0.03 mm, while the hindwing height was 2.19 ± 0.03 mm. The pterostigma length was 0.34 ± 0.00 mm (Table 4.5j). These are in agreement with the observations of Paul *et al.* (2022) who observed the body size to be between 19.84-22.68 mm with an abdomen length between 15.03-17.62 mm, thorax length in between 1.92-2.45 mm while abdomen width and thorax width were between 0.17-0.36 mm and 1.20-1.54 mm respectively are in close alignment with the present findings.

Table 4.5j: Morphometric measurement (♂) of Odonata-Zygoptera

Parameters	Natural Enemies (Measurements in mm $\pm$ SEM)					
	<i>Agriocnemis pieris</i>	<i>Agriocnemis pygmaea</i>	<i>Agriocnemis argentea</i>	<i>Ischnura rubilio</i>	<i>Ceriagrion cerinorubellum</i>	<i>Ceriagrion coromandelianum</i>
Body length (BD)	20.29 $\pm$ 0.04	24.04 $\pm$ 0.09	20.41 $\pm$ 0.05	24.25 $\pm$ 0.20	42.99 $\pm$ 0.72	37.20 $\pm$ 0.80
Abdomen length (AL)	16.25 $\pm$ 0.33	18.13 $\pm$ 0.03	16.80 $\pm$ 0.18	18.68 $\pm$ 0.42	34.00 $\pm$ 0.66	28.58 $\pm$ 0.40
Thorax length (TL)	3.31 $\pm$ 0.05	3.43 $\pm$ 0.02	3.21 $\pm$ 0.03	3.50 $\pm$ 0.06	5.99 $\pm$ 0.03	5.51 $\pm$ 0.07
Head width (HW)	2.60 $\pm$ 0.00	2.80 $\pm$ 0.06	2.65 $\pm$ 0.00	2.88 $\pm$ 0.06	4.06 $\pm$ 0.01	4.24 $\pm$ 0.07
Head length (HL)	1.42 $\pm$ 0.03	1.51 $\pm$ 0.04	1.30 $\pm$ 0.00	1.54 $\pm$ 0.01	2.40 $\pm$ 0.01	2.68 $\pm$ 0.06
Forewing length (FWL)	11.28 $\pm$ 0.18	11.67 $\pm$ 0.26	10.30 $\pm$ 0.01	11.66 $\pm$ 0.10	21.04 $\pm$ 0.49	20.64 $\pm$ 0.06
Forewing height (FWH)	2.59 $\pm$ 0.03	2.34 $\pm$ 0.03	2.21 $\pm$ 0.01	2.32 $\pm$ 0.05	4.05 $\pm$ 0.08	3.99 $\pm$ 0.03
Hindwing length (HWL)	12.11 $\pm$ 0.19	11.19 $\pm$ 0.20	9.04 $\pm$ 0.04	11.30 $\pm$ 0.25	20.69 $\pm$ 0.41	19.13 $\pm$ 0.06
Hindwing height (HWH)	2.54 $\pm$ 0.01	2.19 $\pm$ 0.03	1.98 $\pm$ 0.01	2.21 $\pm$ 0.05	4.07 $\pm$ 0.00	3.93 $\pm$ 0.01
Pterostigma length (PtL)	0.30 $\pm$ 0.01	0.34 $\pm$ 0.00	0.22 $\pm$ 0.01	0.33 $\pm$ 0.01	0.68 $\pm$ 0.02	0.74 $\pm$ 0.00

4.5.2.11. *Agriocnemis argentea*: *A. argentea* exhibited a body length of 20.41 ± 0.05 mm. The abdomen measured 16.80 ± 0.18 mm, while the thorax length was 3.21 ± 0.03 mm. The head width was 2.65 ± 0.00 mm, with a head length of 1.30 ± 0.00 mm. The forewing length was 10.30 ± 0.01 mm which is similar to the measurement recorded at “inaturalist” web portal. The forewing height recorded in the present study was 2.21 ± 0.01 mm while the hindwing length was recorded at 9.04 ± 0.04 mm, and the hindwing height was 1.98 ± 0.01 mm. The pterostigma length was 0.22 ± 0.01 mm (Table 4.5j).

4.5.2.12. *Ischnura rubilio*: The body length of *I. rubilio* was 24.25 ± 0.20 mm (Table 4.5j). The abdomen length measured 18.68 ± 0.42 mm, while the thorax length was 3.50 ± 0.06 mm. The head width was recorded at 2.88 ± 0.06 mm, and the head length was 1.54 ± 0.01 mm. The forewing length was 11.66 ± 0.10 mm, with a height of 2.32 ± 0.05 mm. The hindwing length was recorded at 11.30 ± 0.25 mm, and the hindwing height was 2.21 ± 0.05 mm. The pterostigma length measured 0.33 ± 0.01 mm. These Morphometric parameters are in agreement as they closely match the observations of Hu and Futahashi (2023).

4.5.2.13. *Ceriagrion cerinorubellum*: *C. cerinorubellum* had a body length of 42.99 ± 0.72 mm, with an abdomen length of 34.00 ± 0.66 mm (Table 4.5j). The thorax measured 5.99 ± 0.03 mm in length. The head width was 4.06 ± 0.01 mm, while the head length was 2.40 ± 0.01 mm. The forewing length was 21.04 ± 0.49 mm, and the hindwing length was 20.69 ± 0.41 mm. The forewing height measured 4.05 ± 0.08 mm, while the hindwing height was 4.07 ± 0.00 mm. The pterostigma length was 0.68 ± 0.02 mm.

4.5.2.14. *Ceriagrion coromandelianum*: The body length of *C. coromandelianum* was 37.20 ± 0.80 mm. The abdomen length measured 28.58 ± 0.40 mm, while the thorax length was 5.51 ± 0.07 mm. The head width was recorded at 4.24 ± 0.07 mm, and the head length was 2.68 ± 0.06 mm. The forewing length was 20.64 ± 0.06 mm, with a height of 3.99 ± 0.03 mm. The hindwing length was recorded at 19.13 ± 0.06 mm, and the hindwing height was 3.93 ± 0.01 mm. The pterostigma length measured 0.74 ± 0.00 mm (Table 4.5j).

4.5.2.15. *Telenomus* spp.: *Telenomus* spp. as observed in Table 4.5k was recorded with a body length (BL) of 1.97 ± 0.03 mm. The head width (HW) is 0.54 ± 0.01 mm, with an interocular distance (OD) of 0.16 ± 0.00 mm and a head length (HL) of 0.18 ± 0.00 mm. The antenna is short, measuring 0.55 ± 0.01 mm, with a flagellum length (FL) of 0.54 ± 0.01 mm and a flagellum width (FW) of 0.05 ± 0.00 mm. The eye width (EW) is 0.22 ± 0.00 mm. The thorax length (TL) is 0.76 ± 0.02 mm, and the thorax width (TW) is 0.53 ± 0.01 mm. The forewing length (FWL) is 1.70 ± 0.04 mm, with a forewing width (FWW) of 0.50 ± 0.01 mm. The hindwing length (HWL) is 1.32 ± 0.01 mm, with a hindwing width (HWW) of 0.27 ± 0.00 mm. Leg measurements show a foreleg length (FLL) of 1.30 ± 0.01 mm, a midleg length (MLL) of 1.37 ± 0.03 mm, and a hindleg length (HLL) of 1.87 ± 0.03 mm. The hind tibia length (HTL) is 0.51 ± 0.01 mm, while the hind tibia width (HTW) is 0.13 ± 0.00 mm. The petiole length (PL) is 0.19 ± 0.00 mm, with a petiole width (PW) of 0.10 ± 0.00 mm. The gaster length (GL) is 0.82 ± 0.00 mm, and the gaster width (GW) is 0.60 ± 0.00 mm. The ovipositor length (OL) is 0.11 ± 0.00 mm, indicating limited host penetration ability.

4.5.2.16. *Agrypon* spp.: *Agrypon* spp. was measured with a body length (BL) of 22.06 ± 0.12 mm (Table 4.5k). The head width (HW) is 2.27 ± 0.01 mm, with an interocular distance (OD) of 0.97 ± 0.02 mm and a head length (HL) of 1.28 ± 0.02 mm. The antennae are extremely elongated, with an antennal length (AL) of 17.96 ± 0.41 mm, a flagellum length (FL) of 17.48 ± 0.35 mm, and a flagellum width (FW) of 0.29 ± 0.01 mm. The eye width (EW) is 1.70 ± 0.03 mm. The thorax length (TL) is 5.05 ± 0.13 mm, and the thorax width (TW) is 2.11 ± 0.03 mm. The forewing length (FWL) is 12.84 ± 0.18 mm, with a forewing width (FWW) of 4.78 ± 0.11 mm. The hindwing length (HWL) is 8.71 ± 0.00 mm, and the hindwing width (HWW) is 2.66 ± 0.05 mm. Leg measurements reveal an exceptionally long foreleg length (FLL) of 13.36 ± 0.06 mm, a midleg length (MLL) of 16.72 ± 0.43 mm, and a hindleg length (HLL) of 3.07 ± 0.01 mm. The hind tibia length (HTL) is 4.89 ± 0.06 mm, and the hind tibia width (HTW) is 4.96 ± 0.12 mm. The petiole length (PL) is 10.71 ± 0.20 mm, with a petiole width (PW) of 0.53 ± 0.01 mm. The gaster length (GL) is 15.26 ± 0.35 mm, and the gaster width

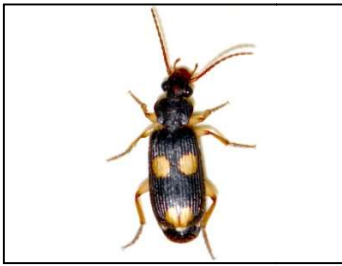
(GW) is 1.44 ± 0.03 mm. The ovipositor length (OL) is 1.93 ± 0.00 mm, indicating moderate host penetration.

4.5.2.17. *Xanthopimpla* spp.: *Xanthopimpla* spp. has a body length (BL) of 12.53 ± 0.25 mm (Table 4.5k). The head width (HW) is 2.34 ± 0.06 mm, with an interocular distance (OD) of 0.79 ± 0.01 mm and a head length (HL) of 1.38 ± 0.02 mm. The antennae measure 11.47 ± 0.22 mm in length, with a flagellum length (FL) of 10.79 ± 0.24 mm and a flagellum width (FW) of 0.25 ± 0.01 mm. The eye width (EW) is 0.60 ± 0.01 mm. The thorax length (TL) is 3.99 ± 0.03 mm, and the thorax width (TW) is 2.65 ± 0.03 mm. The forewing length (FWL) is 10.48 ± 0.10 mm, with a forewing width (FWW) of 3.69 ± 0.07 mm. The hindwing length (HWL) is 7.70 ± 0.04 mm, with a hindwing width (HWW) of 1.92 ± 0.03 mm. Leg measurements show a foreleg length (FLL) of 8.12 ± 0.03 mm, a midleg length (MLL) of 10.75 ± 0.11 mm, and a hindleg length (HLL) of 0.79 ± 0.01 mm. The hind tibia length (HTL) is 2.60 ± 0.00 mm, while the hind tibia width (HTW) is 1.14 ± 0.02 mm. The petiole length (PL) is 5.95 ± 0.02 mm, with a petiole width (PW) of 1.03 ± 0.00 mm. The gaster length (GL) is 7.58 ± 0.18 mm, and the gaster width (GW) is 2.37 ± 0.02 mm. The ovipositor length (OL) is 2.23 ± 0.02 mm, indicating significant host penetration capability.

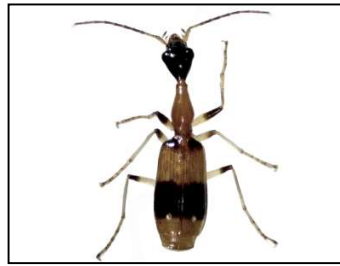
4.5.2.18. *Xanthopimpla punctata*: *Xanthopimpla punctata* has a body length (BL) of 11.53 ± 0.10 mm (Table 4.5k). The head width (HW) is 2.11 ± 0.04 mm, with an interocular distance (OD) of 0.80 ± 0.00 mm and a head length (HL) of 0.98 ± 0.01 mm. The antennae measure 9.78 ± 0.22 mm in length, with a flagellum length (FL) of 9.47 ± 0.10 mm and a flagellum width (FW) of 0.13 ± 0.00 mm. The eye width (EW) is 0.65 ± 0.01 mm. The thorax length (TL) is 3.40 ± 0.00 mm, and the thorax width (TW) is 2.33 ± 0.06 mm. The forewing length (FWL) is 9.81 ± 0.20 mm, with a forewing width (FWW) of 3.17 ± 0.04 mm. The hindwing length (HWL) is 6.54 ± 0.01 mm, with a hindwing width (HWW) of 1.67 ± 0.00 mm. Leg measurements show a foreleg length (FLL) of 6.53 ± 0.04 mm, a midleg length (MLL) of 8.79 ± 0.07 mm, and a hindleg length (HLL)

Table 4.5k: Morphometric measurement (♂) Hymenoptera

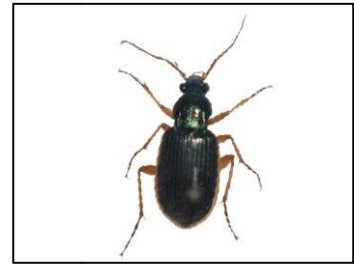
Parameters	Natural Enemies (Measurements in mm ± SEM)								
	<i>Telenomus</i> spp.	<i>Agrypon</i> spp.	<i>Xanthopimpla</i> spp.	<i>Xanthopimpla punctata</i>	<i>Agonocryptys discoidaloides</i>	<i>Aleiodes</i> spp.	<i>Brachymeria scutellocarinata</i>	<i>Ischnojoppa luteator</i>	<i>Cardiochilinae</i> spp.
Antennal length (AL)	0.55 ± 0.01	17.96 ± 0.41	11.47 ± 0.22	9.78 ± 0.22	9.85 ± 0.21	6.25 ± 0.01	1.47 ± 0.03	9.75 ± 0.15	4.72 ± 0.10
Inter ocular distance (OD)	0.16 ± 0.00	0.97 ± 0.02	0.79 ± 0.01	0.80 ± 0.00	1.15 ± 0.03	0.70 ± 0.01	0.83 ± 0.02	1.28 ± 0.02	0.44 ± 0.00
Flagellum length (FL)	0.54 ± 0.01	17.48 ± 0.35	10.79 ± 0.24	9.47 ± 0.10	9.61 ± 0.14	5.62 ± 0.09	1.35 ± 0.02	9.26 ± 0.18	4.51 ± 0.11
Flagellum width (FW)	0.05 ± 0.00	0.29 ± 0.01	0.25 ± 0.01	0.13 ± 0.00	0.19 ± 0.00	0.19 ± 0.00	0.16 ± 0.00	0.20 ± 0.00	0.11 ± 0.00
Head length (HL)	0.18 ± 0.00	1.28 ± 0.02	1.38 ± 0.02	0.98 ± 0.01	1.21 ± 0.01	0.74 ± 0.00	0.64 ± 0.01	1.14 ± 0.03	0.72 ± 0.02
Head width (HW)	0.54 ± 0.01	2.27 ± 0.01	2.34 ± 0.06	2.11 ± 0.04	2.34 ± 0.05	1.44 ± 0.04	1.67 ± 0.01	2.34 ± 0.03	1.13 ± 0.03
Eye width (EW)	0.22 ± 0.00	1.70 ± 0.03	0.60 ± 0.01	0.65 ± 0.01	0.75 ± 0.02	0.41 ± 0.01	0.76 ± 0.01	0.58 ± 0.01	0.27 ± 0.01
Fore wings length (FWL)	1.70 ± 0.04	12.84 ± 0.18	10.48 ± 0.10	9.81 ± 0.20	8.36 ± 0.17	5.46 ± 0.07	3.57 ± 0.05	8.85 ± 0.08	4.83 ± 0.08
Fore wings width (FWW)	0.50 ± 0.01	4.78 ± 0.11	3.69 ± 0.07	3.17 ± 0.04	2.81 ± 0.05	1.90 ± 0.03	1.41 ± 0.00	2.63 ± 0.05	1.49 ± 0.02
Length of hind tibia (HTL)	0.51 ± 0.01	4.89 ± 0.06	2.60 ± 0.00	2.37 ± 0.05	4.78 ± 0.05	1.59 ± 0.04	1.74 ± 0.02	2.27 ± 0.01	1.59 ± 0.01
Width of hind tibia (HTW)	0.13 ± 0.00	4.96 ± 0.12	1.14 ± 0.02	1.10 ± 0.01	0.57 ± 0.02	0.34 ± 0.00	1.32 ± 0.02	0.26 ± 0.00	0.33 ± 0.00
Ovipositor length (OL)	0.11 ± 0.00	1.93 ± 0.00	2.23 ± 0.02	4.65 ± 0.09	6.22 ± 0.08	0.59 ± 0.01	0.24 ± 0.00	0.80 ± 0.00	0.15 ± 0.00
Thorax length (TL)	0.76 ± 0.02	5.05 ± 0.13	3.99 ± 0.03	3.40 ± 0.00	4.10 ± 0.09	2.61 ± 0.05	1.96 ± 0.01	3.29 ± 0.04	1.81 ± 0.03
Thorax width (TW)	0.53 ± 0.01	2.11 ± 0.03	2.65 ± 0.03	2.33 ± 0.06	2.55 ± 0.05	1.44 ± 0.02	1.62 ± 0.01	2.02 ± 0.03	1.40 ± 0.03
Petiole length (PL)	0.19 ± 0.00	10.71 ± 0.20	5.95 ± 0.02	5.41 ± 0.06	6.75 ± 0.14	6.15 ± 0.04	2.77 ± 0.07	5.64 ± 0.03	3.11 ± 0.04
Foreleg length (FLL)	1.30 ± 0.01	13.36 ± 0.06	8.12 ± 0.03	6.53 ± 0.04	8.39 ± 0.17	6.86 ± 0.14	3.61 ± 0.08	6.77 ± 0.12	3.62 ± 0.06
Midleg length (MLL)	1.37 ± 0.03	16.72 ± 0.43	10.75 ± 0.11	8.79 ± 0.07	14.80 ± 0.05	8.65 ± 0.19	5.73 ± 0.14	10.27 ± 0.22	5.29 ± 0.09
Hindleg length (HLL)	1.87 ± 0.03	3.07 ± 0.01	0.79 ± 0.01	0.82 ± 0.02	2.12 ± 0.05	0.63 ± 0.00	0.49 ± 0.00	1.71 ± 0.04	0.11 ± 0.00
Petiole width (PW)	0.10 ± 0.00	0.53 ± 0.01	1.03 ± 0.00	0.69 ± 0.02	0.51 ± 0.01	0.26 ± 0.00	0.42 ± 0.01	0.33 ± 0.01	0.30 ± 0.00
Gaster length (GL)	0.82 ± 0.00	15.26 ± 0.35	7.58 ± 0.18	7.24 ± 0.03	4.67 ± 0.02	3.16 ± 0.04	2.12 ± 0.01	8.11 ± 0.10	1.84 ± 0.01
Gaster width (GW)	0.60 ± 0.00	1.44 ± 0.03	2.37 ± 0.02	2.37 ± 0.02	2.03 ± 0.04	1.19 ± 0.02	1.13 ± 0.03	1.59 ± 0.01	1.16 ± 0.01
Hind wings length (HWL)	1.32 ± 0.01	8.71 ± 0.00	7.70 ± 0.04	6.54 ± 0.01	6.06 ± 0.06	4.07 ± 0.10	2.58 ± 0.03	7.12 ± 0.10	3.61 ± 0.02
Hind wings width (HWW)	0.27 ± 0.00	2.66 ± 0.05	1.92 ± 0.03	1.67 ± 0.00	1.99 ± 0.04	1.31 ± 0.00	0.73 ± 0.01	1.89 ± 0.04	0.94 ± 0.01
Body Length (BL)	1.97 ± 0.03	22.06 ± 0.12	12.53 ± 0.25	11.53 ± 0.10	10.40 ± 0.09	7.50 ± 0.16	5.68 ± 0.05	14.14 ± 0.16	5.10 ± 0.06



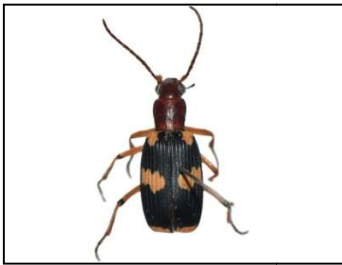
Macrocheilus bensoni
Hope



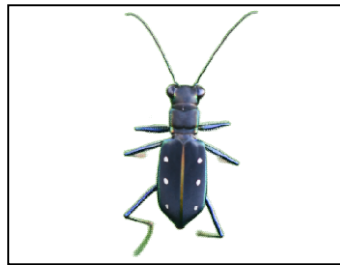
Ophionea nigrofasciata
Schmidt-Goebel



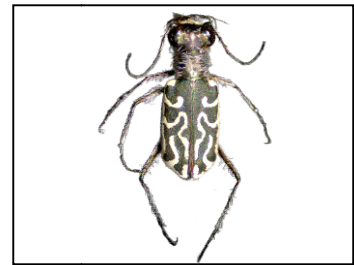
Chlaenius spp.



Pheropsophus spp.



Cicindela sexpunctata
Fabricius



Cylindera venosa
Kollar



Micraspis discolor
Fabricius



Micraspis univittata
Hope



Coccinella septempunctata
Linnaeus



Harmonia spp.



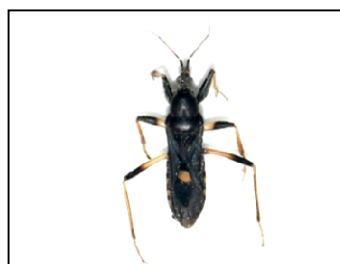
Peirates atromaculatus
Stål



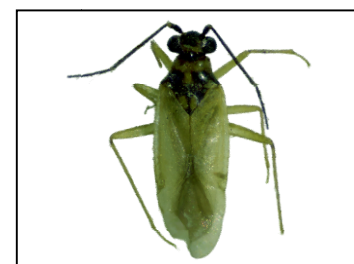
Oncocephalus spp.



Rhynocoris fuscipes
Fabricius



Ectomocoris atrox
Stål



Cyrtorhinus lividipennis
Reuter

Plate 10. Natural enemies belonging to order Coleoptera and Hemiptera.

of 0.82 ± 0.02 mm. The hind tibia length (HTL) is 2.37 ± 0.05 mm, while the hind tibia width (HTW) is 1.10 ± 0.01 mm. The petiole length (PL) is 5.41 ± 0.06 mm, with a petiole width (PW) of 0.69 ± 0.02 mm. The gaster length (GL) is 7.24 ± 0.03 mm, and the gaster width (GW) is 2.37 ± 0.02 mm. The ovipositor length (OL) is 4.65 ± 0.09 mm, suggesting high host penetration ability.

4.5.2.19. *Agonocryptus discoidaloides*: *Agonocryptus discoidaloides* has a body length (BL) of 10.40 ± 0.09 mm (Table 4.5k). The head width (HW) is 2.34 ± 0.05 mm, with an interocular distance (OD) of 1.15 ± 0.03 mm and a head length (HL) of 1.21 ± 0.01 mm. The antennae measure 9.85 ± 0.21 mm in length, with a flagellum length (FL) of 9.61 ± 0.14 mm and a flagellum width (FW) of 0.19 ± 0.00 mm. The eye width (EW) is 0.75 ± 0.02 mm. The thorax length (TL) is 4.10 ± 0.09 mm, and the thorax width (TW) is 2.55 ± 0.05 mm. The forewing length (FWL) is 8.36 ± 0.17 mm, with a forewing width (FWW) of 2.81 ± 0.05 mm. The hindwing length (HWL) is 6.06 ± 0.06 mm, with a hindwing width (HWW) of 1.99 ± 0.04 mm. Leg measurements show a foreleg length (FLL) of 8.39 ± 0.17 mm, a midleg length (MLL) of 14.80 ± 0.05 mm, and a hindleg length (HLL) of 2.12 ± 0.05 mm. The hind tibia length (HTL) is 4.78 ± 0.05 mm, while the hind tibia width (HTW) is 0.57 ± 0.02 mm. The petiole length (PL) is 6.75 ± 0.14 mm, with a petiole width (PW) of 0.51 ± 0.01 mm. The gaster length (GL) is 4.67 ± 0.02 mm, and the gaster width (GW) is 2.03 ± 0.04 mm. The ovipositor length (OL) is 6.22 ± 0.08 mm, indicating significant host penetration capability.

4.5.2.20. *Aleiodes* spp.: *Aleiodes* spp. has a body length (BL) of 7.50 ± 0.16 mm (Table 4.5k). The head width (HW) is 1.44 ± 0.04 mm, with an interocular distance (OD) of 0.70 ± 0.01 mm and a head length (HL) of 0.74 ± 0.00 mm. The antennae measure 6.25 ± 0.01 mm in length, with a flagellum length (FL) of 5.62 ± 0.09 mm and a flagellum width (FW) of 0.19 ± 0.00 mm. The eye width (EW) is 0.41 ± 0.01 mm. The thorax length (TL) is 2.61 ± 0.05 mm, and the thorax width (TW) is 1.44 ± 0.02 mm. The forewing length (FWL) is 5.46 ± 0.07 mm, with a forewing width (FWW) of 1.90 ± 0.03 mm. The hindwing length (HWL) is 4.07 ± 0.10 mm, with a hindwing width (HWW) of

1.31 $\pm$ 0.00 mm. Leg measurements show a foreleg length (FLL) of 6.86 $\pm$ 0.14 mm, a midleg length (MLL) of 8.65 $\pm$ 0.19 mm, and a hindleg length (HLL) of 0.63 $\pm$ 0.00 mm. The hind tibia length (HTL) is 1.59 $\pm$ 0.04 mm, while the hind tibia width (HTW) is 0.34 $\pm$ 0.00 mm. The petiole length (PL) is 6.15 $\pm$ 0.04 mm, with a petiole width (PW) of 0.26 $\pm$ 0.00 mm. The gaster length (GL) is 3.16 $\pm$ 0.04 mm, and the gaster width (GW) is 1.19 $\pm$ 0.02 mm. The ovipositor length (OL) is 0.59 $\pm$ 0.01 mm, indicating a relatively short penetration capability.

4.5.2.21. *Brachymeria scutellocarinata*: *Brachymeria scutellocarinata* has a body length (BL) of 5.68 $\pm$ 0.05 mm (Table 4.5k). The head width (HW) is 1.67 $\pm$ 0.01 mm, with an interocular distance (OD) of 0.83 $\pm$ 0.02 mm and a head length (HL) of 0.64 $\pm$ 0.01 mm. The antennae measure 1.47 $\pm$ 0.03 mm in length, with a flagellum length (FL) of 1.35 $\pm$ 0.02 mm and a flagellum width (FW) of 0.16 $\pm$ 0.00 mm. The eye width (EW) is 0.76 $\pm$ 0.01 mm. The thorax length (TL) is 1.96 $\pm$ 0.01 mm, and the thorax width (TW) is 1.62 $\pm$ 0.01 mm. The forewing length (FWL) is 3.57 $\pm$ 0.05 mm, with a forewing width (FWW) of 1.41 $\pm$ 0.00 mm. The hindwing length (HWL) is 2.58 $\pm$ 0.03 mm, with a hindwing width (HWW) of 0.73 $\pm$ 0.01 mm. Leg measurements show a foreleg length (FLL) of 3.61 $\pm$ 0.08 mm, a midleg length (MLL) of 5.73 $\pm$ 0.14 mm, and a hindleg length (HLL) of 0.49 $\pm$ 0.00 mm. The hind tibia length (HTL) is 1.74 $\pm$ 0.02 mm, while the hind tibia width (HTW) is 1.32 $\pm$ 0.02 mm. The petiole length (PL) is 2.77 $\pm$ 0.07 mm, with a petiole width (PW) of 0.42 $\pm$ 0.01 mm. The gaster length (GL) is 2.12 $\pm$ 0.01 mm, and the gaster width (GW) is 1.13 $\pm$ 0.03 mm. The ovipositor length (OL) is 0.24 $\pm$ 0.00 mm, suggesting very limited penetration capability.

4.5.2.22. *Ischnojoppa luteator*: From Table 4.5k, it is seen that *Ischnojoppa luteator* has a body length (BL) of 14.14 $\pm$ 0.16 mm. The head width (HW) is 2.34 $\pm$ 0.03 mm, with an interocular distance (OD) of 1.28 $\pm$ 0.02 mm and a head length (HL) of 1.14 $\pm$ 0.03 mm. The antennae measure 9.75 $\pm$ 0.15 mm in length, with a flagellum length (FL) of 9.26 $\pm$ 0.18 mm and a flagellum width (FW) of 0.20 $\pm$ 0.00 mm. The eye width (EW) is 0.58 $\pm$ 0.01 mm. The thorax length (TL) is 3.29 $\pm$ 0.04 mm, and the thorax width (TW) is

2.02 ± 0.03 mm. The forewing length (FWL) is 8.85 ± 0.08 mm, with a forewing width (FWW) of 2.63 ± 0.05 mm. The hindwing length (HWL) is 7.12 ± 0.10 mm, with a hindwing width (HWW) of 1.89 ± 0.04 mm. Leg measurements show a foreleg length (FLL) of 6.77 ± 0.12 mm, a midleg length (MLL) of 10.27 ± 0.22 mm, and a hindleg length (HLL) of 1.71 ± 0.04 mm. The hind tibia length (HTL) is 2.27 ± 0.01 mm, while the hind tibia width (HTW) is 0.26 ± 0.00 mm. The petiole length (PL) is 5.64 ± 0.03 mm, with a petiole width (PW) of 0.33 ± 0.01 mm. The gaster length (GL) is 8.11 ± 0.10 mm, and the gaster width (GW) is 1.59 ± 0.01 mm. The ovipositor length (OL) is 0.80 ± 0.00 mm, indicating moderate host penetration capability.

4.5.2.23. *Cardiochilinae* spp.: *Cardiochilinae* has a body length (BL) of 5.10 ± 0.06 mm (Table 4.5k). The head width (HW) is 1.13 ± 0.03 mm, with an interocular distance (OD) of 0.44 ± 0.00 mm and a head length (HL) of 0.72 ± 0.02 mm. The antennae measure 4.72 ± 0.10 mm in length, with a flagellum length (FL) of 4.51 ± 0.11 mm and a flagellum width (FW) of 0.11 ± 0.00 mm. The eye width (EW) is 0.27 ± 0.01 mm. The thorax length (TL) is 1.81 ± 0.03 mm, and the thorax width (TW) is 1.40 ± 0.03 mm. The forewing length (FWL) is 4.83 ± 0.08 mm, with a forewing width (FWW) of 1.49 ± 0.02 mm. The hindwing length (HWL) is 3.61 ± 0.02 mm, with a hindwing width (HWW) of 0.94 ± 0.01 mm. Leg measurements show a foreleg length (FLL) of 3.62 ± 0.06 mm, a midleg length (MLL) of 5.29 ± 0.09 mm, and a hindleg length (HLL) of 0.11 ± 0.00 mm. The hind tibia length (HTL) is 1.59 ± 0.01 mm, while the hind tibia width (HTW) is 0.33 ± 0.00 mm. The petiole length (PL) is 3.11 ± 0.04 mm, with a petiole width (PW) of 0.30 ± 0.00 mm. The gaster length (GL) is 1.84 ± 0.01 mm, and the gaster width (GW) is 1.16 ± 0.01 mm. The ovipositor length (OL) is 0.15 ± 0.00 mm, suggesting a very limited penetration capability.

4.5.2.24. *Macrocheilus bensoni*: *Macrocheilus bensoni* has a head width of 2.80 ± 0.06 mm, an eye diameter of 0.78 ± 0.00 mm, and an antenna length of 5.85 ± 0.08 mm. The pronotum measures 2.36 ± 0.05 mm in length, with a maximum width of 3.07 ± 0.02 mm and a height of 2.26 ± 0.03 mm. The elytra extend 9.19 ± 0.17 mm in length and 4.65 ±

0.04 mm in width. The metafemur length is 2.95 ± 0.01 mm, the metatibia length is 3.03 ± 0.07 mm, and the metatarsi length is 2.73 ± 0.01 mm. The maximum width of the metafemur is 0.94 ± 0.02 mm. The total body length is recorded at 13.79 ± 0.13 mm (Table 4.5l).

4.5.2.25. *Ophionea nigrofasciata*: *Ophionea nigrofasciata* is comparatively smaller, with a head width of 1.27 ± 0.03 mm and an eye diameter of 0.24 ± 0.00 mm. The antennae measure 3.71 ± 0.09 mm, while the pronotum is 2.08 ± 0.02 mm in length, 0.91 ± 0.02 mm in width, and 0.78 ± 0.02 mm in height. The elytra are 3.58 ± 0.08 mm long and 1.81 ± 0.01 mm wide. The metafemur measures 1.59 ± 0.04 mm in length, the metatibia 1.37 ± 0.01 mm, and the metatarsi 1.03 ± 0.02 mm. The metafemur width is 0.27 ± 0.00 mm. The total body length is 7.62 ± 0.06 mm (Table 4.5l).

4.5.2.26. *Chlaenius* spp.: *Chlaenius* spp. has a head width of 2.27 ± 0.04 mm and an eye diameter of 0.64 ± 0.00 mm. The antenna length is recorded at 8.81 ± 0.17 mm. The pronotum is 3.22 ± 0.02 mm long, 3.45 ± 0.08 mm wide, and 3.57 ± 0.05 mm high. The elytra are 9.50 ± 0.07 mm long and 5.82 ± 0.05 mm wide. The metafemur measures 4.17 ± 0.02 mm in length, the metatibia 4.45 ± 0.00 mm, and the metatarsi 4.19 ± 0.00 mm. The maximum width of the metafemur is 1.12 ± 0.00 mm. The total body length is 14.24 ± 0.00 mm (Table 4.5l).

4.5.2.27. *Chlaenius bimaculatus*: *Chlaenius bimaculatus* has a head width of 2.46 ± 0.06 mm, an eye diameter of 1.08 ± 0.00 mm, and an antenna length of 6.49 ± 0.01 mm. The pronotum measures 2.85 ± 0.04 mm in length, with a maximum width of 3.61 ± 0.01 mm and a height of 2.93 ± 0.02 mm. The elytra extend 8.25 ± 0.19 mm in length and 5.14 ± 0.05 mm in width. The metafemur length is 3.88 ± 0.01 mm, the metatibia length is 3.68 ± 0.08 mm, and the metatarsi length is 3.87 ± 0.02 mm. The maximum width of the metafemur is 0.88 ± 0.02 mm. The total body length is recorded at 13.57 ± 0.06 mm (Table 4.5l).

Table 4.5I: Morphometric measurement (♂) of Coleoptera-Carabidae

Parameters	Natural Enemies (Measurements in mm $\pm$ SEM)				
	<i>Macrocheilus bensoni</i>	<i>Ophionea nigrofasciata</i>	<i>Chlaenius</i> spp.	<i>Chlaenius bimaculatus</i>	<i>Pheropsophus</i> spp.
Width of the head (HW)	2.80 $\pm$ 0.06	1.27 $\pm$ 0.03	2.27 $\pm$ 0.04	2.46 $\pm$ 0.06	3.27 $\pm$ 0.01
Diameter of the eye (YW)	0.78 $\pm$ 0.00	0.24 $\pm$ 0.00	0.64 $\pm$ 0.00	1.08 $\pm$ 0.00	1.37 $\pm$ 0.03
Length of the antenna (AL)	5.85 $\pm$ 0.08	3.71 $\pm$ 0.09	8.81 $\pm$ 0.17	6.49 $\pm$ 0.01	10.44 $\pm$ 0.22
Length of the pronotum (PL)	2.36 $\pm$ 0.05	2.08 $\pm$ 0.02	3.22 $\pm$ 0.02	2.85 $\pm$ 0.04	3.49 $\pm$ 0.04
Maximum width of the pronotum (PW)	3.07 $\pm$ 0.02	0.91 $\pm$ 0.02	3.45 $\pm$ 0.08	3.61 $\pm$ 0.01	3.51 $\pm$ 0.08
Maximum height of the pronotum (PH)	2.26 $\pm$ 0.03	0.78 $\pm$ 0.02	3.57 $\pm$ 0.05	2.93 $\pm$ 0.02	4.02 $\pm$ 0.02
Length of the elytra (EL)	9.19 $\pm$ 0.17	3.58 $\pm$ 0.08	9.50 $\pm$ 0.07	8.25 $\pm$ 0.19	10.58 $\pm$ 0.26
Maximum width of the elytra (EW)	4.65 $\pm$ 0.04	1.81 $\pm$ 0.01	5.82 $\pm$ 0.05	5.14 $\pm$ 0.05	6.68 $\pm$ 0.13
Length of the metafemur (FL)	2.95 $\pm$ 0.01	1.59 $\pm$ 0.04	4.17 $\pm$ 0.02	3.88 $\pm$ 0.01	4.97 $\pm$ 0.02
Length of the metatrochanter (TR)	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
Length of the metatibia (BL)	3.03 $\pm$ 0.07	1.37 $\pm$ 0.01	4.45 $\pm$ 0.00	3.68 $\pm$ 0.08	5.68 $\pm$ 0.04
Length of the metatarsi (RL)	2.73 $\pm$ 0.01	1.03 $\pm$ 0.02	4.19 $\pm$ 0.00	3.87 $\pm$ 0.02	5.22 $\pm$ 0.10
Maximum width of the metafemur (FW)	0.94 $\pm$ 0.02	0.27 $\pm$ 0.00	1.12 $\pm$ 0.00	0.88 $\pm$ 0.02	1.13 $\pm$ 0.02
Total length (TL)	13.79 $\pm$ 0.13	7.62 $\pm$ 0.06	14.24 $\pm$ 0.00	13.57 $\pm$ 0.06	16.53 $\pm$ 0.36



Telenomus spp.



Ophion spp.



Xanthopimpla spp.



Xanthopimpla punctata
Fabricius



Agonocryptys discoidaloides
Viereck



Ischnojoppa luteator
Fabricius



Aleiodes spp.



Brachymeria scutellocarinata
Joseph



Cardiochilinae Spp.



Agrypon flaveolatum
Gravenhorst



Apochrysa spp.



Ankylopteryx spp.



Unidentified lacewing



Ascalaphus prothoracicus
Kimmins



Unidentified mantisfly

4.5.2.28. *Pheropsophus* spp.: *Pheropsophus* spp. is the largest among the compared species, with a head width of 3.27 ± 0.01 mm and an eye diameter of 1.37 ± 0.03 mm. The antennae measure 10.44 ± 0.22 mm in length. The pronotum is 3.49 ± 0.04 mm long, 3.51 ± 0.08 mm wide, and 4.02 ± 0.02 mm high. The elytra are 10.58 ± 0.26 mm long and 6.68 ± 0.13 mm wide. The metafemur measures 4.97 ± 0.02 mm in length, the metatibia 5.68 ± 0.04 mm, and the metatarsi 5.22 ± 0.10 mm. The maximum width of the metafemur is 1.13 ± 0.02 mm. The total body length is 16.53 ± 0.36 mm (Table 4.5l).

Table 4.5m: Morphometric measurement (♂) of Coleoptera-Cicindelidae

Parameters	Natural Enemies (Measurements in mm $\pm$ SEM)	
	<i>Cicindela sexpunctata</i>	<i>Cylindera venosa</i>
Right mandible length (RML)	2.09 ± 0.03	1.48 ± 0.22
Labrum length (LL)	1.69 ± 0.01	0.52 ± 0.02
Length of head (LH)	3.40 ± 0.05	1.54 ± 0.03
Width of head (WH)	4.29 ± 0.05	2.38 ± 0.17
Length of pronotum (LP)	2.88 ± 0.03	1.77 ± 0.00
Width of pronotum (WP)	3.28 ± 0.04	1.65 ± 0.02
Length of elytra (EL)	9.40 ± 0.03	5.09 ± 0.05
Width of elytra (WE)	5.01 ± 0.00	3.09 ± 0.13
Length of foreleg (FLL)	13.19 ± 0.01	5.40 ± 0.06
Length of middle leg (MLL)	15.48 ± 0.06	7.61 ± 0.01
Length of hind leg (HLL)	20.61 ± 0.02	9.88 ± 0.06
Total body length (TBL)	15.47 ± 0.30	7.62 ± 0.26
Antenna length	10.90 ± 0.34	4.85 ± 0.06

4.5.2.29. *Cicindela sexpunctata*: The morphometric characteristics of *Cicindela sexpunctata* (Table 4.5m).provide a detailed insight into its structural proportions. The right mandible measures 2.09 ± 0.03 mm in length, while the labrum length is recorded at 1.69 ± 0.01 mm. The head exhibits a length of 3.40 ± 0.05 mm and a width of 4.29 ± 0.05 mm, indicating a broad head structure in relation to its length. The pronotum measures 2.88 ± 0.03 mm in length and 3.28 ± 0.04 mm in width, contributing to the overall thoracic morphology. The elytra extend 9.40 ± 0.03 mm in length, with a width of 5.01 ± 0.00 mm, reflecting the elongated and somewhat widened elytral structure characteristic of *Cicindela* species. The legs were considerable long with foreleg length recorded as 13.19 ± 0.01 mm, middle leg as 15.48 ± 0.06 mm and hind leg was $20.61 \pm$

0.02 mm long. Antenna measurement was recorded at 10.90 ± 0.34 mm. The total body length is measured at 15.47 ± 0.30 mm, positioning *Cicindela sexpunctata* among the relatively larger *Cicindelinae* species. This morphometric profile highlights its adapted predatory form, with well-developed mandibles, a robust head, and an elongated elytral structure.

4.5.2.30. *Cylindera venosa*: Morphometric characteristics of *Cylindera venosa* (Table 4.5m) reveals the right mandible to measure 1.48 ± 0.22 mm in length, while the labrum length is recorded at 0.52 ± 0.02 mm. The head exhibits a length of 1.54 ± 0.03 mm and 2.38 ± 0.17 mm wide. The pronotum measures 1.77 ± 0.00 mm in length and 1.65 ± 0.02 mm in width. The elytral length measured was 5.09 ± 0.05 mm and 3.09 ± 0.13 mm wide. Foreleg length was recorded at 5.40 ± 0.06 mm, middle leg length was 7.61 ± 0.01 mm and hind leg was measured to be 9.88 ± 0.06 mm. The antenna was measured at 4.85 ± 0.06 mm. This species of tiger beetles are relatively small with a total body length of 7.62 ± 0.26 mm.

4.5.2.31. *Micraspis discolor*: The morphometric characteristics of *Micraspis discolor* (Table 4.5n) indicate a compact body structure with a total length of 4.11 ± 0.04 mm and a body breadth of 3.38 ± 0.08 mm. The head is relatively small, measuring 0.46 ± 0.01 mm in length and 1.23 ± 0.00 mm in breadth, with an interocular distance of 0.42 ± 0.00 mm. The compound eyes have a breadth of 0.16 ± 0.00 mm. The antenna is relatively short at 0.58 ± 0.00 mm. The pronotum measures 0.88 ± 0.01 mm in length and 2.12 ± 0.04 mm in breadth. The elytra are 3.49 ± 0.09 mm long and 3.45 ± 0.03 mm wide. The foreleg measures 1.87 ± 0.02 mm, while the middle and hind legs are 2.78 ± 0.05 mm and 2.76 ± 0.02 mm, respectively. The abdomen measures 1.26 ± 0.01 mm in length and 1.46 ± 0.00 mm in breadth.

4.5.2.32. *Micraspis univittata*: *Micraspis univittata* exhibits a slightly larger body than *Micraspis discolor*, with a total length of 4.21 ± 0.09 mm and a body breadth of 3.54 ± 0.01 mm. The head measures 0.38 ± 0.01 mm in length and 1.21 ± 0.03 mm in breadth, with a smaller interocular distance of 0.31 ± 0.00 mm. The compound eyes are slightly

broader than in *Micraspis discolor*, measuring 0.17 ± 0.00 mm. The antenna length is greater at 0.68 ± 0.02 mm. The pronotum is 0.83 ± 0.00 mm long and 2.20 ± 0.03 mm wide. The elytral measurements are 3.79 ± 0.10 mm in length and 3.53 ± 0.08 mm in width. The foreleg, middle leg, and hind leg measure 2.02 ± 0.00 mm, 2.78 ± 0.05 mm, and 2.82 ± 0.07 mm, respectively. The abdomen has a length of 1.25 ± 0.03 mm and a breadth of 1.79 ± 0.01 mm (Table 4.5n).

Table 4.5n: Morphometric measurement (♂) of Coleoptera-Coccinellidae

Parameters	Natural Enemies (Measurements in mm $\pm$ SEM)			
	<i>Micraspis discolor</i>	<i>Micraspis univittata</i>	<i>Coccinella septempunctata</i>	<i>Harmonia</i> spp.
Length of whole body (TBL)	4.11 ± 0.04	4.21 ± 0.09	7.18 ± 0.16	6.97 ± 0.05
Breadth of body (BB)	3.38 ± 0.08	3.54 ± 0.01	5.61 ± 0.13	4.96 ± 0.10
Length of head (HL)	0.46 ± 0.01	0.38 ± 0.01	0.93 ± 0.00	1.09 ± 0.02
Breadth of head (HB)	1.23 ± 0.00	1.21 ± 0.03	1.76 ± 0.04	1.77 ± 0.00
Distance between compound eyes (DBE)	0.42 ± 0.00	0.31 ± 0.00	0.67 ± 0.01	0.98 ± 0.01
Breadth of compound eye (EB)	0.16 ± 0.00	0.17 ± 0.00	0.30 ± 0.00	0.35 ± 0.00
Length of Antenna (AL)	0.58 ± 0.00	0.68 ± 0.02	0.67 ± 0.00	0.66 ± 0.01
Length of Pronotum (PL)	0.88 ± 0.01	0.83 ± 0.00	1.89 ± 0.05	1.78 ± 0.02
Breadth of Pronotum (PB)	2.12 ± 0.04	2.20 ± 0.03	3.72 ± 0.01	3.23 ± 0.03
Length of scutellum (SL)				
Breadth of scutellum (SB)				
Breadth of elytra (EB)	3.45 ± 0.03	3.53 ± 0.08	5.60 ± 0.14	4.98 ± 0.05
Length of elytra (EL)	3.49 ± 0.09	3.79 ± 0.10	5.90 ± 0.01	5.80 ± 0.14
Length of foreleg (FLL)	1.87 ± 0.02	2.02 ± 0.00	3.92 ± 0.01	3.51 ± 0.00
Length of middle leg (MLL)	2.78 ± 0.05	2.78 ± 0.05	4.49 ± 0.08	4.23 ± 0.06
Length of hind leg (HLL)	2.76 ± 0.02	2.82 ± 0.07	4.52 ± 0.06	5.68 ± 0.01
Length of Abdomen (AbL)	1.26 ± 0.01	1.25 ± 0.03	2.11 ± 0.03	2.78 ± 0.07
Breadth of Abdomen (AB)	1.46 ± 0.00	1.79 ± 0.01	2.97 ± 0.05	3.29 ± 0.03

4.5.2.33. *Coccinella septempunctata*: *Coccinella septempunctata* is significantly larger than the *Micraspis* species, with a total body length of 7.18 ± 0.16 mm and a breadth of 5.61 ± 0.13 mm. The head is more prominent, measuring 0.93 ± 0.00 mm in length and 1.76 ± 0.04 mm in breadth, with an interocular distance of 0.67 ± 0.01 mm. The compound eyes are broader, at 0.30 ± 0.00 mm. The antenna measures 0.67 ± 0.00 mm. The pronotum is considerably larger, with a length of 1.89 ± 0.05 mm and a breadth of 3.72 ± 0.01 mm. The elytra are elongated, measuring 5.90 ± 0.01 mm in length and 5.60

± 0.14 mm in width. The foreleg length is 3.92 ± 0.01 mm, while the middle and hind legs measure 4.49 ± 0.08 mm and 4.52 ± 0.06 mm, respectively. The abdomen is also more developed, with a length of 2.11 ± 0.03 mm and a breadth of 2.97 ± 0.05 mm (Table 4.5n).

4.5.2.34. *Harmonia* spp.: *Harmonia* spp. (Table 4.5n) also displays a relatively large body, measuring 6.97 ± 0.05 mm in total length and 4.96 ± 0.10 mm in breadth. The head is the longest among the species studied, measuring 1.09 ± 0.02 mm in length and 1.77 ± 0.00 mm in breadth. The interocular distance is the largest, at 0.98 ± 0.01 mm, and the compound eye breadth measures 0.35 ± 0.00 mm. The antenna length is 0.66 ± 0.01 mm. The pronotum measures 1.78 ± 0.02 mm in length and 3.23 ± 0.03 mm in breadth. The elytra are 5.80 ± 0.14 mm in length and 4.98 ± 0.05 mm in width. The foreleg, middle leg, and hind leg lengths are 3.51 ± 0.00 mm, 4.23 ± 0.06 mm, and 5.68 ± 0.01 mm, respectively, indicating strong locomotory adaptations. The abdomen is the most developed among the studied species, measuring 2.78 ± 0.07 mm in length and 3.29 ± 0.03 mm in breadth.

4.5.2.35. Long-horned grasshopper: The morphometric analysis of the long-horned grasshopper (Table 4.5o) reveals total body length measures 21.11 ± 0.29 mm. The pronotum, has a length of 4.02 ± 0.07 mm and a width of 2.97 ± 0.06 mm. The head width is measured at 2.90 ± 0.07 mm, with an interocular distance of 1.52 ± 0.03 mm, indicating moderate eye separation. The antennae are extremely elongated, measuring 44.99 ± 1.15 mm, which is more than twice the body length. The thorax height is 5.52 ± 0.01 mm. The tegmen, or leathery forewing, extends to 21.12 ± 0.02 mm, while the membranous hindwings are considerably longer, with a length of 30.53 ± 0.65 mm and a width of 9.47 ± 0.13 mm. The forewings, responsible for protective functions and limited flight, measure 26.67 ± 0.26 mm in length and 5.40 ± 0.12 mm in width while the hindwing width was measured at 9.47 ± 0.13 mm. The legs exhibit significant elongation, particularly the hind legs, which play a primary role in jumping. The foreleg measures 17.43 ± 0.44 mm, the middle leg is slightly longer at 21.70 ± 0.23 mm, and the

hind leg extends to 28.55 ± 0.24 mm. The third femur, which is crucial for jump propulsion, has a length of 20.24 ± 0.44 mm, while the third tibia, contributing to extension force during leaps, measures 21.18 ± 0.18 mm. Metanotal gland length was recorded as 1.94 ± 0.02 mm and width was 1.78 ± 0.03 mm.

Table 4.5o: Morphometric measurement (♂) of Long-horned grasshopper

Parameters	Measurements in mm $\pm$ SEM
Body length (BL)	21.11 ± 0.29
Pronotum length (PL)	4.02 ± 0.07
Pronotum width (PW)	2.97 ± 0.06
Head width (HW)	2.90 ± 0.07
Interocular distance (IOD)	1.52 ± 0.03
Antenna length (AL)	44.99 ± 1.15
Thorax height (TxH)	5.52 ± 0.01
Tegmen length (TegL)	21.12 ± 0.02
Forewing length (FWL)	26.67 ± 0.26
Forewing width (FWW)	5.40 ± 0.12
Hindwing length(HWL)	30.53 ± 0.65
Hindwing width (HWW)	9.47 ± 0.13
Foreleg length (FLL)	17.43 ± 0.44
Midleg length (MLL)	21.70 ± 0.23
Hindleg length (HLL)	28.55 ± 0.24
Third femur length (FL)	20.24 ± 0.44
Third tibia length (TiL)	21.18 ± 0.18
Metanotal gland length (MGL)	1.94 ± 0.02
Metanotal gland width (MGW)	1.78 ± 0.03

4.5.2.36. *Apochrysa salomonis*: *Apochrysa salomonis* (Table 4.5p) exhibits the largest overall body dimensions among the three species examined. The head length measures 0.97 ± 0.02 mm, while the head width is 1.89 ± 0.04 mm. The body length extends to 16.09 ± 0.36 mm, significantly longer than the other species. The antenna length is remarkably long, reaching 34.21 ± 0.78 mm. The pronotum length is 1.20 ± 0.01 mm, with a width of 0.97 ± 0.02 mm. The forewing length and width measure 25.17 ± 0.20 mm and 11.37 ± 0.27 mm, respectively, while the hindwing length is 24.70 ± 0.45 mm with a width of 8.56 ± 0.00 mm, indicating large and broad wings characteristic of this species.

Table 4.5p: Morphometric measurement (♂) of Neuroptera

Parameters	Natural Enemies (Measurements in mm $\pm$ SEM)		
	<i>Apochrysa salomonis</i>	<i>Lacewing</i>	<i>Ankylopteryx</i> spp.
Head length (HL)	0.97 $\pm$ 0.02	0.70 $\pm$ 0.01	0.54 $\pm$ 0.01
Head width (HW)	1.89 $\pm$ 0.04	1.07 $\pm$ 0.00	1.10 $\pm$ 0.01
Body length (BL)	16.09 $\pm$ 0.36	7.89 $\pm$ 0.14	7.81 $\pm$ 0.20
Dist.between tentoria (DBT)	---	---	---
Frons length (FL)	---	---	---
Clypeus length (CL)	---	---	---
Antenna length (AL)	34.21 $\pm$ 0.78	13.07 $\pm$ 0.08	11.26 $\pm$ 0.16
Pronotum length (PL)	1.20 $\pm$ 0.01	0.97 $\pm$ 0.01	0.73 $\pm$ 0.02
Pronotum width (PW)	0.97 $\pm$ 0.02	0.79 $\pm$ 0.02	0.76 $\pm$ 0.02
Forewing length (FWL)	25.17 $\pm$ 0.20	9.61 $\pm$ 0.00	14.03 $\pm$ 0.07
Forwing width (FWW)	11.37 $\pm$ 0.27	3.76 $\pm$ 0.01	5.94 $\pm$ 0.02
Hindwing length (HLW)	24.70 $\pm$ 0.45	8.65 $\pm$ 0.19	13.38 $\pm$ 0.11
Hindwing width (HWW)	8.56 $\pm$ 0.00	3.21 $\pm$ 0.07	4.23 $\pm$ 0.10

4.5.2.37. The lacewing species examined has a head length of 0.70 $\pm$ 0.01 mm and a head width of 1.07 $\pm$ 0.00 mm (Table 4.5p). The body length is considerably smaller than *Apochrysa salomonis*, measuring 7.89 $\pm$ 0.14 mm. The antenna length is 13.07 $\pm$ 0.08 mm. The pronotum measures 0.97 $\pm$ 0.01 mm in length and 0.79 $\pm$ 0.02 mm in width. The forewing length is 9.61 $\pm$ 0.00 mm, with a width of 3.76 $\pm$ 0.01 mm, while the hindwing length and width are 8.65 $\pm$ 0.19 mm and 3.21 $\pm$ 0.07 mm, respectively. The relatively smaller size and wing proportions distinguish this lacewing species from *Apochrysa salomonis*.

4.5.2.38. *Ankylopteryx* spp.: *Ankylopteryx* spp. has a head length of 0.54 $\pm$ 0.01 mm and a head width of 1.10 $\pm$ 0.01 mm (Table 4.5p). The body length is 7.81 $\pm$ 0.20 mm, similar to the lacewing species but shorter than *Apochrysa salomonis*. The antenna length is 11.26 $\pm$ 0.16 mm. The pronotum is 0.73 $\pm$ 0.02 mm in length and 0.76 $\pm$ 0.02 mm in width. The forewing length measures 14.03 $\pm$ 0.07 mm, with a width of 5.94 $\pm$ 0.02 mm, while the hindwing length is 13.38 $\pm$ 0.11 mm, and the width is 4.23 $\pm$ 0.10 mm. These dimensions suggest that *Ankylopteryx* spp. has relatively longer wings compared to its body size, contributing to its flight capabilities.

Table 4.5q: Morphometric measurement (♂) of *Ascalaphus prothoracicus*

Parameters	Measurements in mm $\pm$ SEM
Body length (BD)	22.25 $\pm$ 0.30
Abdomen length (AbL)	13.80 $\pm$ 0.19
Thorax length (TL)	6.06 $\pm$ 0.10
Head width (HW)	5.58 $\pm$ 0.01
Forewing length (FWL)	29.60 $\pm$ 0.08
Forewing width (FWW)	8.02 $\pm$ 0.19
Hindwing length (HWL)	24.39 $\pm$ 0.24
Hindwing height (HWH)	6.89 $\pm$ 0.00
Fore wing Pterostigma length (FWPtL)	2.91 $\pm$ 0.04
Hind wing Pterostigma length (HWPtL)	2.78 $\pm$ 0.06
Antenna length (AL)	18.49 $\pm$ 0.24
Interocular distance (IOD)	1.18 $\pm$ 0.02
Eye width (EW)	2.64 $\pm$ 0.07

4.5.2.39. *Ascalaphus prothoracicus*: *Ascalaphus prothoracicus* exhibits a body length of 22.25 $\pm$ 0.30 mm, with an abdomen of 13.80 $\pm$ 0.19 mm and a thorax of 6.06 $\pm$ 0.10 mm (Table 4.5q). The head width is 5.58 $\pm$ 0.01 mm, while the antenna extends to 18.49 $\pm$ 0.24 mm. The forewings measure 29.60 $\pm$ 0.08 mm in length and 8.02 $\pm$ 0.19 mm in width, while the hindwings are 24.39 $\pm$ 0.24 mm long and 6.89 $\pm$ 0.00 mm high. The pterostigma measures 2.91 $\pm$ 0.04 mm in the forewing and 2.78 $\pm$ 0.06 mm in the hindwing. The interocular distance is 1.18 $\pm$ 0.02 mm, and the eye width is 2.64 $\pm$ 0.07 mm, reflecting its highly developed vision.

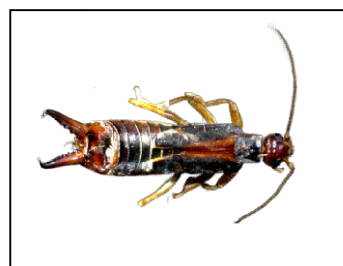
4.5.2.40. The Tachinidae species exhibits a body length of 7.19 $\pm$ 0.13 mm, with a head width of 2.26 $\pm$ 0.01 mm and an interocular distance of 0.57 $\pm$ 0.00 mm. The antenna measures 0.76 $\pm$ 0.01 mm, while the arista extends to 1.04 $\pm$ 0.01 mm. The thorax length is 2.83 $\pm$ 0.07 mm, with a proscutellum/scutellum measuring 1.01 $\pm$ 0.02 mm. The abdomen spans 3.14 $\pm$ 0.06 mm. The wing length reaches 5.10 $\pm$ 0.07 mm. Regarding leg measurements, the fore femur, tibia, and tarsus measure 1.64 $\pm$ 0.03 mm, 1.69 $\pm$ 0.00 mm, and 1.89 $\pm$ 0.01 mm, respectively. The middle femur, tibia, and tarsus are 1.72 $\pm$ 0.04 mm, 1.67 $\pm$ 0.03 mm, and 1.86 $\pm$ 0.01 mm, respectively, while the hind femur, tibia, and tarsus measure 1.71 $\pm$ 0.00 mm, 1.55 $\pm$ 0.00 mm, and 1.90 $\pm$ 0.01 mm, respectively (Table 4.5r).



Unidentified robber fly



Unidentified tachinid fly



Unidentified Earwig



Unidentified Preying mantid



Unidentified Preying mantid



Unidentified Long horned grasshopper

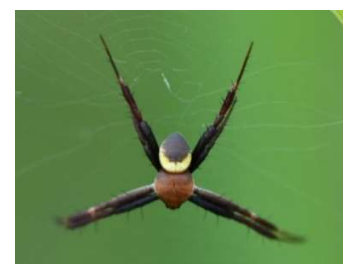
Plate 12A. Unidentified natural enemies belonging to order Diptera, Dermaptera, Mantodea and Orthoptera.



Oxyopes birmanicus
Thorell



Peucetia viridana
Stoliczka



Argiope aemula
Walckenaer



Larinia directa
Scopoli



Tetragnatha straminea
Emerton



Neoscona theisi
Walckenaer

Plate 12B. Natural enemies belonging to Class Arachnida, order Araneae.

Table 4.5r: Morphometric measurement (♂) of Tachinidae, Diptera

Parameters	Measurements in mm $\pm$ SEM
Head / Eyes (HE)	2.26 $\pm$ 0.01
Interocular distance (IOD)	0.57 $\pm$ 0.00
Body Length (BL)	7.19 $\pm$ 0.13
Antenna (AN)	0.76 $\pm$ 0.01
Arista Length (ArL)	1.04 $\pm$ 0.01
Fore leg Length of Femur (FFL)	1.64 $\pm$ 0.03
Fore leg Tibia length (FTiL)	1.69 $\pm$ 0.00
Fore leg Tarsal (FTaL)	1.89 $\pm$ 0.01
Meta Length of Femur (MFL)	1.72 $\pm$ 0.04
Meta Tibia length (MTiL)	1.67 $\pm$ 0.03
Meta Tarsal (MTaL)	1.86 $\pm$ 0.01
Hind Length of Femur (HFL)	1.71 $\pm$ 0.00
Hind Tibia length (HTiL)	1.55 $\pm$ 0.00
Hind Tarsal (HTaL)	1.90 $\pm$ 0.01
Abdomen (AB)	3.14 $\pm$ 0.06
Wing Length (WL)	5.10 $\pm$ 0.07
Thorax (TH)	2.83 $\pm$ 0.07
Proscutulum/scutellum	1.01 $\pm$ 0.02

4.5.2.41. *Peirates atromaculatus*: *Peirates atromaculatus* has a body length of 11.58 $\pm$ 0.30 mm, a width of 3.53 $\pm$ 0.05 mm, and a height of 2.42 $\pm$ 0.02 mm (Table 4.5s). Its antennae measure 5.21 $\pm$ 0.01 mm, and its mouthpart length is 2.43 $\pm$ 0.04 mm. The left forewings and hindwings measured from 8.83 $\pm$ 0.15 mm and 7.39 $\pm$ 0.10 mm in length, respectively while widths were 2.92 $\pm$ 0.01 mm and 2.06 $\pm$ 0.00 mm. The right forewings and hindwings were measured at 8.44 $\pm$ 0.02 mm and 7.03 $\pm$ 0.11 mm in length respectively, while widths were 2.88 $\pm$ 0.03 mm and 1.89 $\pm$ 0.03 mm. Its femur, tibia, and tarsus measured 4.30 $\pm$ 0.04 mm, 4.35 $\pm$ 0.07 mm, and 2.24 $\pm$ 0.05 mm, respectively. The prothoracic, mesothoracic, and metathoracic leg lengths are 8.36 $\pm$ 0.18 mm, 6.79 $\pm$ 0.05 mm, and 11.95 $\pm$ 0.12 mm, respectively. The head length is 1.24 $\pm$ 0.01 mm, the thorax is 4.48 $\pm$ 0.10 mm, and the abdomen measures 6.21 $\pm$ 0.09 mm.

Table 4.5s: Morphometric measurement (♂) of Hemiptera-Reduviidae

Parameters	Natural Enemies (Measurements in mm $\pm$ SEM)		
	<i>Peirates atromaculatus</i>	<i>Oncocephalus</i> spp.	<i>Rhynocoris fuscipes</i>
Body Length (B.L)	11.58 $\pm$ 0.30	15.53 $\pm$ 0.03	12.24 $\pm$ 0.26
Body Width (B.W)	3.53 $\pm$ 0.05	3.09 $\pm$ 0.03	3.68 $\pm$ 0.02
Body Height (B.H)	2.42 $\pm$ 0.02	2.26 $\pm$ 0.03	2.76 $\pm$ 0.07
Antennae Length (An.L)	5.21 $\pm$ 0.01	5.97 $\pm$ 0.04	5.42 $\pm$ 0.11
Mouthpart Length (M.L)	2.43 $\pm$ 0.04	2.21 $\pm$ 0.00	3.28 $\pm$ 0.07
Left Forewing Length (Lf.L)	8.83 $\pm$ 0.15	8.93 $\pm$ 0.01	9.07 $\pm$ 0.07
Right Forewing Length (Rf.L)	8.44 $\pm$ 0.02	8.79 $\pm$ 0.00	8.96 $\pm$ 0.16
Left Hindwing Length (Lh.L)	7.39 $\pm$ 0.10	6.54 $\pm$ 0.16	7.21 $\pm$ 0.13
Right Hindwing Length (Rh.L)	7.03 $\pm$ 0.11	6.42 $\pm$ 0.05	7.19 $\pm$ 0.09
Left Forewing Width (Lf.W)	2.92 $\pm$ 0.01	2.81 $\pm$ 0.03	2.36 $\pm$ 0.01
Right Forewing Width (Rf.W)	2.88 $\pm$ 0.03	2.94 $\pm$ 0.06	2.38 $\pm$ 0.02
Left Hindwing Width (Lh.W)	2.06 $\pm$ 0.00	1.78 $\pm$ 0.02	1.42 $\pm$ 0.02
Right Hindwing Width (Rh.W)	1.89 $\pm$ 0.03	1.87 $\pm$ 0.00	1.46 $\pm$ 0.02
Femur Length (F.L)	4.30 $\pm$ 0.04	6.34 $\pm$ 0.02	4.57 $\pm$ 0.04
Tibia Length (Ti.L)	4.35 $\pm$ 0.07	6.69 $\pm$ 0.05	5.47 $\pm$ 0.02
Tarsus Length (Tar.L)	2.24 $\pm$ 0.05	1.26 $\pm$ 0.03	1.18 $\pm$ 0.01
Prothorax Leg Length (Pro. Leg L)	8.36 $\pm$ 0.18	9.07 $\pm$ 0.19	10.95 $\pm$ 0.19
Mesothorax Leg Length (Mes. Leg L)	6.79 $\pm$ 0.05	9.14 $\pm$ 0.06	9.33 $\pm$ 0.05
Metathorax Leg Length (Met. Leg L)	11.95 $\pm$ 0.12	14.81 $\pm$ 0.00	12.29 $\pm$ 0.06
Head Length (h.L)	1.24 $\pm$ 0.01	1.56 $\pm$ 0.03	2.05 $\pm$ 0.01
Abdomen Length (Ab.L)	6.21 $\pm$ 0.09	7.42 $\pm$ 0.13	6.09 $\pm$ 0.02
Thorax Length (Th. L)	4.48 $\pm$ 0.10	3.95 $\pm$ 0.05	3.67 $\pm$ 0.08

4.5.2.42. *Oncocephalus* spp.: *Oncocephalus* spp measures 15.53 $\pm$ 0.03 mm in body length, 3.09 $\pm$ 0.03 mm in width, and 2.26 $\pm$ 0.03 mm in height (Table 4.5s). Its antennae are 5.97 $\pm$ 0.04 mm long, and the mouthparts measure 2.21 $\pm$ 0.00 mm. Forewing lengths vary from 8.93 $\pm$ 0.01 mm (left) to 8.79 $\pm$ 0.00 mm (right), while hindwings range from 6.54 $\pm$ 0.16 mm to 6.42 $\pm$ 0.05 mm. The leg segments include femur (6.34 $\pm$ 0.02 mm), tibia (6.69 $\pm$ 0.05 mm), and tarsus (1.26 $\pm$ 0.03 mm). The prothoracic, mesothoracic, and metathoracic legs measure 9.07 $\pm$ 0.19 mm, 9.14 $\pm$ 0.06 mm, and 14.81 $\pm$ 0.00 mm, respectively. Head length is 1.56 $\pm$ 0.03 mm, thorax length is 3.95 $\pm$ 0.05 mm, and abdomen length is 7.42 $\pm$ 0.13 mm.

4.5.2.43. *Rhynocoris fuscipes*: *Rhynocoris fuscipes* has a body length of 12.24 ± 0.26 mm, a width of 3.68 ± 0.02 mm, and a height of 2.76 ± 0.07 mm. The antennae measure 5.42 ± 0.11 mm, and the mouthparts extend to 3.28 ± 0.07 mm. Forewing lengths are 9.07 ± 0.07 mm (left) and 8.96 ± 0.16 mm (right), while hindwings are 7.21 ± 0.13 mm and 7.19 ± 0.09 mm. The femur, tibia, and tarsus measure 4.57 ± 0.04 mm, 5.47 ± 0.02 mm, and 1.18 ± 0.01 mm, respectively. The prothoracic, mesothoracic, and metathoracic leg lengths are 10.95 ± 0.19 mm, 9.33 ± 0.05 mm, and 12.29 ± 0.06 mm, respectively. Head length is 2.05 ± 0.01 mm, thorax length is 3.67 ± 0.08 mm, and abdomen length is 6.09 ± 0.02 mm (Table 4.5s).

4.5.2.44. *Oxyopes birmanicus*: *Oxyopes birmanicus* (Table 4.5t) has a head length of 2.96 ± 0.01 mm and width of 2.04 ± 0.05 mm. The abdomen measures 5.28 ± 0.07 mm in length and 3.13 ± 0.03 mm in width. Its total body length is 9.30 ± 0.07 mm. The first pair of legs is 15.33 ± 0.07 mm, followed by the second (13.94 ± 0.34 mm), third (11.64 ± 0.30 mm), and fourth (13.44 ± 0.27 mm) pairs.

4.5.2.45. *Argiope aemula*: *Argiope aemula* has a head length of 2.46 ± 0.02 mm and width of 2.65 ± 0.05 mm (Table 4.5t). The abdomen measures 7.41 ± 0.03 mm in length and 5.84 ± 0.06 mm in width. Its total length is 12.60 ± 0.10 mm. The first pair of legs is 28.90 ± 0.57 mm, while the second, third, and fourth pairs measure 28.91 ± 0.32 mm, 18.03 ± 0.06 mm, and 28.19 ± 0.35 mm, respectively.

4.5.2.46. *Argiope bruennichi*: *Argiope bruennichi* has a head length of 2.82 ± 0.04 mm and width of 2.75 ± 0.03 mm (Table 4.5t). The abdomen measures 7.64 ± 0.16 mm in length and 6.03 ± 0.04 mm in width. The total body length is 13.85 ± 0.06 mm. Its first pair of legs is 30.95 ± 0.58 mm, followed by the second (30.89 ± 0.60 mm), third (19.24 ± 0.43 mm), and fourth (30.46 ± 0.57 mm) pairs.

Table 4.5t: Morphometric measurement (♂) of Arachnida/ Araneae

Parameters	Natural Enemies (Measurements in mm $\pm$ SEM)				
	<i>Oxyopes birmanicus</i>	<i>Argiope aemula</i>	<i>Argiope bruennichi</i>	<i>Tetragnatha straminea</i>	<i>Neoscona theisi</i>
Length of head (HL)	2.96 $\pm$ 0.01	2.46 $\pm$ 0.02	2.82 $\pm$ 0.04	1.65 $\pm$ 0.02	2.32 $\pm$ 0.01
Width of head (HW)	2.04 $\pm$ 0.05	2.65 $\pm$ 0.05	2.75 $\pm$ 0.03	1.43 $\pm$ 0.04	1.89 $\pm$ 0.00
Length of abdomen (AL)	5.28 $\pm$ 0.07	7.41 $\pm$ 0.03	7.64 $\pm$ 0.16	10.44 $\pm$ 0.05	7.55 $\pm$ 0.08
Width of abdomen (AW)	3.13 $\pm$ 0.03	5.84 $\pm$ 0.06	6.03 $\pm$ 0.04	1.03 $\pm$ 0.02	5.54 $\pm$ 0.01
T o t a l l e n g t h (TL)	9.30 $\pm$ 0.07	12.60 $\pm$ 0.10	13.85 $\pm$ 0.06	14.61 $\pm$ 0.08	11.98 $\pm$ 0.30
1 st pair of legs (1 st LL)	15.33 $\pm$ 0.07	28.90 $\pm$ 0.57	30.95 $\pm$ 0.58	23.75 $\pm$ 0.46	16.85 $\pm$ 0.20
2 nd pair of legs (2 nd LL)	13.94 $\pm$ 0.34	28.91 $\pm$ 0.32	30.89 $\pm$ 0.60	14.27 $\pm$ 0.30	14.47 $\pm$ 0.05
3 rd pair of legs (3 rd LL)	11.64 $\pm$ 0.30	18.03 $\pm$ 0.06	19.24 $\pm$ 0.43	14.13 $\pm$ 0.22	10.03 $\pm$ 0.09
4 th pair of legs (5 th LL)	13.44 $\pm$ 0.27	28.19 $\pm$ 0.35	30.46 $\pm$ 0.57	6.70 $\pm$ 0.09	17.40 $\pm$ 0.24

4.5.2.47. *Tetragnatha straminea*: *Tetragnatha straminea* (Table 4.5t) has a head length of 1.65 ± 0.02 mm and width of 1.43 ± 0.04 mm. Its abdomen is 10.44 ± 0.05 mm long and 1.03 ± 0.02 mm wide. The total length is 14.61 ± 0.08 mm. The first pair of legs measures 23.75 ± 0.46 mm, while the second, third, and fourth pairs are 14.27 ± 0.30 mm, 14.13 ± 0.22 mm, and 6.70 ± 0.09 mm, respectively.

4.5.2.48. *Neoscona theisi*: *Neoscona theisi* (Table 4.5t) has a head length of 2.32 ± 0.01 mm and width of 1.89 ± 0.00 mm. The abdomen measures 7.55 ± 0.08 mm in length and 5.54 ± 0.01 mm in width. The total length is 11.98 ± 0.30 mm. The first pair of legs is 16.85 ± 0.20 mm, followed by the second (14.47 ± 0.05 mm), third (10.03 ± 0.09 mm), and fourth (17.40 ± 0.24 mm) pairs.

CHAPTER V
SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

The present investigation entitled “**Seasonal abundance and diversity of insect pests and their natural enemies in lowland rice agroecosystem under Dimapur district of Nagaland**” was carried out at three locations: Singrijan, Medziphema and Kuhoxu representing the lowland rice agroecosystem of Nagaland. It was carried out from June to December i.e., during the rice-growing seasons of 2020 and 2021. The salient findings are summarized below:

- In rice crop, 32 insect pests were observed, belonging to 28 genera, 16 families and 5 insect orders viz., Hemiptera (8 species), Lepidoptera (12 species), Orthoptera (8 species), Coleoptera (2 species) and Thysanoptera (1 species). 57 natural enemies of insect pests were also observed from the rice agroecosystem belonging to 42 genera, 19 families from 10 orders and 2 classes viz., Hymenoptera (10 species), Odonata (15 species), Coleoptera (10 species), Neuroptera (5 species), Diptera (2 species), Hemiptera (5 species), Mantodea (2 species), Orthoptera (1 species), Arachnida (Araneae: 6 species) whereas 8 specimens remained unidentified.
- Shannon-Weiner Diversity Index (H') revealed that Medziphema had the highest insect pest diversity ($H'=2.60$) while diversity of natural enemies remained consistent across all three locations, with Singrijan recording the highest value ($H'=2.06$). The highest diversity according to Simpson's Diversity Index (D) was observed in Medziphema ($D=0.87$), whereas in natural enemies, it remained relatively stable across all locations, with values ranging between 0.84 and 0.85 suggesting a consistent and well-distributed population across all three locations. Natural enemies exhibited higher species richness than insect pests. Kuhoxu (31) recorded the highest insect pest species richness followed by Singrijan (30) and Medziphema (29). The species richness of natural enemies remained relatively stable, indicating a consistent presence in all three locations. Species evenness was highest among natural enemies across all locations,

particularly in Singrijan ($E_h=0.86$) and Kuhoxu ($E_h=0.85$), suggesting a well-balanced distribution.

- Studies on Alpha (α), Beta (β) and Gamma (γ) diversity of insect pests revealed Alpha diversity as 2.6, 2.32 and 2.25 for Medziphema, Singrijan and Kuhoxu respectively. Gamma diversity *i.e.*, diversity across all locations was 2.308. Beta diversity measured 0.028 confirming that most species were shared among the three locations. The Alpha diversity of natural enemies of rice insect pests was recorded as 1.99, 2.32 and 2.25 for Medziphema, Singrijan and Kuhoxu, respectively. Gamma diversity of natural enemies was recorded as 2.05 and beta diversity was 0.00 which indicates very low species turnover across all three locations suggesting that the natural enemy communities in Medziphema, Singrijan, and Kuhoxu are highly similar.
- The relative abundance of insect pests in the lowland rice fields of Medziphema, Singrijan, and Kuhoxu revealed a consistent dominance of *Nilaparvata lugens*, which accounted for 30.72 to 37.32 percent of the total pest populations across the three sites. *Nephotettix virescens* was the second most abundant species at all locations, followed by *Sogatella furcifera*, which was notably present in Singrijan and Kuhoxu. Other moderately abundant pests included *Nephotettix nigropictus*, field crickets, *Scirpophaga incertulas*, and *Stenchaetothrips biformis*. Several species exhibited low relative abundance across sites, including *Spodoptera litura*, *Pelopidas mathias*, green horned caterpillars, *Melanitis leda ismene*, *Chilo suppressalis*, and *Gryllotalpa orientalis*. Notably, *Scirpophaga nivella* was absent from Medziphema and Singrijan but was recorded at Kuhoxu (0.91%), possibly linked to the area's history of sugarcane cultivation.
- Across all three study sites-Medziphema, Singrijan, and Kuhoxu, Hymenoptera consistently emerged as the most dominant natural enemy group, contributing between 23.02 and 28.62 percent of the total beneficial population. Coleoptera and Arachnida also showed high abundance across sites, reflecting their significant roles in biological control. Orthoptera and Odonata (both Zygoptera and Anisoptera) were moderately abundant, though their proportions varied slightly between locations. Hemiptera

maintained a moderate presence, while Neuroptera, Diptera, Dermaptera, and Mantodea were consistently recorded in lower numbers. Despite variations in proportions, the overall community structure of natural enemies remained fairly consistent, indicating stable natural enemies diversity in the lowland rice ecosystem.

- The pooled seasonal data from Medziphema revealed *Nilaparvata lugens* as the most abundant pest species, with a significantly high population of 663.25 individuals, peaking between meteorological weeks 38 and 46. Other major pests included *Nephotettix virescens* (235.75), *Leptocorisa acuta* (177.40), field crickets (110.35) and *Diadisa armigera* (100.80), all exhibiting mid-to late-season peaks. Least abundant pests included *Cnaphalocrocis medinalis* (30.60), *Melanitis leda ismene* (27.44), *Leucania loreyi* (22.77), *Chilo suppressalis* (19.27), *Pelopidas mathias* (12.70), green horned caterpillar (9.10), and *Spodoptera litura* (0.50), most of which maintained low densities throughout the season with narrow peak windows.
- The most dominant pest at Singrijan was *Nilaparvata lugens* with a pooled population of 1961.41, exhibiting peak densities between meteorological weeks 38-45. *Nephotettix virescens* (943.40) and *Sogatella furcifera* (634.24) were also major pests, with *N. virescens* peaking during weeks 39-45 and *S. furcifera* during weeks 39-45 as well. Other notable species included *Nephotettix nigropictus* (254.76) and field crickets (276.28), which showed significant population spikes in mid to late season. Moderate populations were recorded for *Scirpophaga incertulas*, *Stenchaetothrips biformis*, *Maiestas dorsalis*, and *Scirpophaga* spp., with densities typically increasing after week 30. Several species such as *Cofana spectra*, short-horned grasshoppers, *Leptocorisa acuta* and *Cletus punctiger* demonstrated mid-season activity. Lesser abundant pests included *Spodoptera litura*, green horned caterpillars, *Melanitis leda ismene*, *Chilo suppressalis* and *Gryllotalpa orientalis* with low densities throughout both seasons.
- In the Kuhoxu rice fields, *Nilaparvata lugens* was the most dominant insect pest (2058.07), followed by *Nephotettix virescens* (910.40), *Sogatella furcifera* (626.74), and *Nephotettix nigropictus* (323.91). Other pests with moderate abundance included *Stenchaetothrips biformis* (134.13), *Scirpophaga incertulas* (163.10), *Scirpophaga* spp.

(130.62), *Maiestas dorsalis* (101.59), *Leptocorisa acuta* (101.30), and short-horned grasshoppers (110.40). The least abundant pests were *Pelopidas mathias*, green horned caterpillar, *Spodoptera litura*, *Sitophilus oryzae*, *Melanitis leda ismene*, *Chilo suppressalis* and *Nymphula depunctalis*. Most pests showed seasonal population peaks coinciding with the mid-to-late crop stages. Notably, *N. virescens* and *S. furcifera* peaked during weeks 40-47, while *N. lugens* rapidly increased from week 30, peaking between weeks 37-45. *N. nigropictus* and *Cofana spectra* followed similar trends but at lower densities. Other pests such as *M. dorsalis*, *Scirpophaga* spp., *C. medinalis*, and *S. incertulas* and Ground-dwelling pests like field crickets and short-horned grasshoppers exhibited consistent mid-season activity. Populations of pests like *M. leda ismene*, green horned caterpillar, *S. litura*, and *P. mathias* remained low throughout the study.

- The seasonal abundance of natural enemies in lowland rice ecosystem at Medziphema revealed clear population trends among major natural enemies groups. Hymenoptera (81.40) was the most dominant group followed by Coleoptera (78.08), Arachnida (63.40), Odonata-Zygoptera (36.70), Orthoptera (32.00), Odonata-Anisoptera (28.50), Hemiptera (15.94), and the least dominant groups were Diptera (2.48), Neuroptera (3.63) and Mantodea. Anisoptera steadily increased from week 26 and peaked between weeks 35 and 41, while Zygoptera followed a more prolonged rise beginning in week 23, peaking between weeks 34 and 43. Coleoptera populations fluctuated but peaked between weeks 33 and 38. Hymenoptera numbers grew rapidly from week 28, with peak levels between weeks 34 and 38. Neuroptera remained low in abundance but showed slight peaks around weeks 37 and 41. Hemiptera increased from week 25, reaching peak populations between weeks 30 and 35. Diptera were consistently low but recorded a minor peak between weeks 36 and 39. Dermaptera populations peaked between weeks 29 and 35, while Mantodea showed stable trends with a peak from weeks 28 to 32. Orthoptera gradually increased, peaking between weeks 30 and 35, and Arachnida showed a consistent rise, reaching maximum abundance between weeks 36 and 41.

- Seasonal observations from Singrijan's lowland rice ecosystem indicated that Hymenoptera (92.50) and Coleoptera (67.57) were the most dominant natural enemies groups. These were followed by Arachnida (49.00), Orthoptera (46.70), Hemiptera (34.24), Odonata–Zygoptera (23.50), Anisoptera (19.50), and Neuroptera (15.44). Lower abundances were noted for Diptera (5.62), Dermaptera (4.90), and Mantodea (4.10). Anisoptera peaked between weeks 37 and 41, whereas Zygoptera peaked slightly earlier, from weeks 35 to 39. Coleoptera appeared in week 23 and peaked between weeks 34 and 38. Hymenoptera emerged by week 25 and peaked between weeks 35 and 40. Neuroptera appeared around week 27, with peak numbers between weeks 36 and 39. Hemiptera were active from week 23 and peaked between weeks 31 and 35. Diptera were first noted in week 31 and showed a small peak from weeks 34 to 37. Dermaptera appeared in week 28, peaking between weeks 35 and 37. Mantodea were observed from week 23 with a similar peak period. Orthoptera began appearing from week 23, peaking earlier between weeks 28 and 30. Arachnida showed a gradual rise, peaking between weeks 36 and 41.
- Field observations at Kuhoxu revealed Hymenoptera (104.70) as the most dominant natural enemies group, followed by Coleoptera (66.89) and Arachnida (47.70), emphasizing their major role in natural pest control. Orthoptera (43.20) and Hemiptera (32.93) were also notably present. Among aerial predators, Odonata–Zygoptera (22.40) were more abundant than Anisoptera (12.30). Moderate populations were recorded for Neuroptera (15.94), Diptera (9.11), and Dermaptera (6.50), while Mantodea (4.10) had the lowest incidence. Anisoptera increased from week 26, peaking between weeks 36 and 41, while Zygoptera rose steadily from week 27, peaking between weeks 35 and 42. Coleoptera appeared from week 23, with peak activity between weeks 33 and 37. Hymenoptera emerged in week 25 and peaked from weeks 35 to 41. Neuroptera showed low numbers, peaking around weeks 35 to 39. Hemiptera appeared from week 25 and peaked between weeks 32 and 37. Diptera were first seen in week 31, with slight peaks between weeks 34 and 40. Dermaptera emerged in week 28 and peaked between weeks 35 and 38, while Mantodea peaked from weeks 34 to 38. *Orthoptera* appeared from week

23 and peaked between weeks 32 and 34. Arachnida maintained steady numbers, peaking from weeks 35 to 41.

- At Medziphema, combined analysis from 2020 and 2021 highlighted distinct pest responses to weather parameters, with temperature showing mixed influences. *Cofana spectra* and *Sitophilus oryzae* consistently exhibited strong negative correlations with both maximum and minimum temperatures, indicating reduced populations under warmer conditions, while green horned caterpillar and *Scirpophaga incertulas* responded positively, suggesting that elevated temperatures favored their activity. Other pests, including *Nephotettix virescens*, *Nephotettix nigropictus*, *Nilaparvata lugens*, and *Cnaphalocrocis medinalis*, showed weak or inconsistent temperature relationships across years. Relative humidity generally promoted pest populations, with consistently positive correlations observed in *C. spectra*, *S. oryzae*, *N. virescens*, *N. nigropictus*, *Sogatella furcifera*, *C. medinalis*, *C. punctiger*, *L. acuta*, short-horned grasshoppers, and field crickets, especially under higher maximum humidity; *Chilo suppressalis* also showed a significant positive correlation with minimum humidity. However, exceptions included *C. medinalis* and *Spodoptera litura*, which showed negative associations with minimum humidity in 2021. Rainfall effects were variable: *S. oryzae* and *C. spectra* consistently exhibited negative correlations, implying sensitivity to excessive rainfall, whereas field crickets showed a shift from a negative correlation in 2020 to a positive one in 2021, suggesting a possible rainfall-driven boost in their population under specific conditions.
- At Singrijan, combined analysis across 2020 and 2021 revealed that temperature played a critical role in shaping insect pest populations, with several species showing consistent patterns. *Sitophilus oryzae* and *Cofana spectra* exhibited strong negative correlations with both maximum and minimum temperatures, indicating reduced abundance under warmer conditions. In contrast, pests such as *Maistas dorsalis*, green horned caterpillar, *Chilo suppressalis*, and *Stenchaetothrips biformis* displayed positive associations with temperature, suggesting that heat favored their development. Other pests, including *Nilaparvata lugens*, *Nephotettix virescens*, *Nephotettix nigropictus*, *Cnaphalocrocis medinalis*, and *Spodoptera litura*, showed weak or non-significant

temperature responses. Relative humidity had varied effects: *S. oryzae* and *C. spectra* again responded negatively, especially to minimum humidity, whereas positive correlations were found in *Scirpophaga* spp., *S. biformis*, *S. incertulas*, green horned caterpillar, *C. suppressalis*, and *Pelopidas mathias*, with most responses more pronounced at maximum humidity. Rainfall generally produced mixed results, with *S. oryzae*, *C. medinalis*, and *N. lugens* showing negative associations, while *C. punctiger* showed a strong positive response and several species, including *S. incertulas*, *C. suppressalis*, green horned caterpillar, and *P. mathias*, exhibited weak or variable positive trends, reflecting species-specific sensitivity to precipitation.

- At Kuhoxu, combined analysis from 2020 and 2021 revealed notable weather-related patterns in insect pest populations. Temperature consistently affected pest dynamics, with *Nephotettix virescens*, *Cofana spectra*, *Nephotettix nigropictus*, and *Sitophilus oryzae* showing strong negative correlations, indicating that higher temperatures reduced their populations. In contrast, green horned caterpillar, *Maistas dorsalis*, *Scirpophaga incertulas*, *Chilo suppressalis*, and *Stenchaetothrips biformis* exhibited positive correlations, thriving under warmer conditions. Other pests, such as *Nilaparvata lugens*, *Cnaphalocrocis medinalis*, and *Spodoptera litura*, showed weak or non-significant temperature relationships. Relative humidity had a generally negative effect on *N. virescens*, *C. spectra*, *N. nigropictus*, and *S. oryzae*, while pests like *C. suppressalis* and *Scirpophaga* spp. showed positive responses. Rainfall reduced populations of *S. oryzae* but supported *Scirpophaga* spp., *S. incertulas*, and *Cnaphalocrocis punctiger*, while other species displayed minimal or inconsistent rainfall effects. In 2021, similar trends persisted, with *N. virescens*, *S. oryzae*, *C. spectra*, and *Sogatella furcifera* remaining negatively associated with temperature, while *M. dorsalis*, *C. suppressalis*, *S. biformis*, *S. incertulas*, green horned caterpillar, *M. leda ismene*, *N. depunctalis*, *P. mathias*, and *D. armigera* showed positive correlations, thriving in warmer conditions. Relative humidity again negatively impacted *N. virescens*, *C. spectra*, *S. oryzae*, and *S. furcifera*, whereas *C. suppressalis* and green horned caterpillar responded positively. Rainfall exhibited negative effects on *N. virescens*, *S. oryzae*, *S.*

furcifera, and *C. spectra*, but slightly benefited *N. depunctalis*, *C. suppressalis*, and *P. mathias*.

- At Medziphema, from June to December across the 2020 and 2021 rice seasons, several insect pests demonstrated significant positive correlations with a broad range of natural enemies, highlighting extensive predator-prey interactions. *Nephotettix virescens* and *Nephotettix nigropictus* were frequently associated with Odonata (both Anisoptera and Zygoptera), Hymenoptera, Arachnida, Diptera, and Coleoptera. *Maistas dorsalis* showed strong and consistent associations with nearly all major predator groups, including Neuroptera, Orthoptera, Dermaptera, and Mantodea. *Nilaparvata lugens* and *Sogatella furcifera* were similarly correlated with Odonata, Hymenoptera, Diptera, and Arachnida, while *Cofana spectra* showed fewer but notable associations with Odonata-Anisoptera, Hymenoptera and Arachnida. *Cletus punctiger*, *Scirpophaga incertulas*, *Chilo suppressalis*, and *Scirpophaga* spp. consistently exhibited significant correlations with a wide spectrum of natural enemies, especially Coleoptera, Mantodea, and Neuroptera. *Cnaphalocrocis medinalis* showed variable interactions, including a negative correlation with Hemiptera. *Melanitis leda ismene* and green horned caterpillar both displayed broad associations with Odonata, Hymenoptera, Diptera, Arachnida, and Coleoptera. *Leucania loreyi*, *Nymphula depunctalis*, and *Pelopidas mathias* also correlated with numerous natural enemies groups, particularly Odonata and Hymenoptera. Among Orthopterans, short-horned grasshoppers and field crickets were mainly associated with Hymenoptera, Odonata, and Arachnida, while *Gryllotalpa orientalis* exhibited widespread correlations with nearly all predator groups. *Sitophilus oryzae* showed consistent negative correlations with Dermaptera, Mantodea, and Neuroptera, suggesting potential predator avoidance. In contrast, *Dicladispa armigera* and *Stenchaetothrips biformis* were significantly associated with a wide range of natural enemies, including Odonata, Hymenoptera, Diptera, Arachnida, Coleoptera, and Mantodea. Notably, *Spodoptera litura* showed no significant associations across either season, indicating minimal natural enemy interactions.

- At Singrijan across 2020 and 2021, *Nephotettix virescens* and *Nephotettix nigropictus* consistently exhibited significant positive correlations with Odonata-Anisoptera, Odonata-Zygoptera, Coleoptera, Hymenoptera, and Diptera, indicating strong interactions with aerial predators. *Cofana spectra* was notably associated with Odonata-Anisoptera in 2021, while in 2020 it showed a significant negative correlation with Dermaptera, suggesting differing predator dynamics across years. *Maiestas dorsalis* maintained broad and highly significant correlations with Odonata, Coleoptera, Hymenoptera, Neuroptera, Hemiptera, Diptera, Dermaptera, and Arachnida over both years. Similarly, *Nilaparvata lugens* and *Sogatella furcifera* showed consistent associations with multiple natural enemies groups, particularly Odonata, Coleoptera, Hymenoptera, Diptera, and Arachnida. *Leptocoris acuta* was significantly correlated with Odonata and Diptera in both years, with additional associations with Orthoptera and Arachnida in 2020. *Cletus punctiger* showed extensive interactions, significantly correlating with Odonata-Zygoptera, Hymenoptera, Neuroptera, Coleoptera, Mantodea, and Arachnida across the period. *Scirpophaga incertulas*, *Chilo suppressalis*, and *Scirpophaga* spp. exhibited strong and consistent correlations with a wide range of natural enemies, particularly Odonata, Coleoptera, Hymenoptera, Neuroptera, Diptera, and Arachnida. *Cnaphalocrocis medinalis* was mainly associated with Odonata-Zygoptera, Diptera, and Coleoptera. *Melanitis leda ismene* and green horned caterpillar each displayed significant interactions with multiple natural enemies groups including Odonata, Hymenoptera, Neuroptera, Diptera, and Arachnida. Likewise, *Spodoptera litura* and *Leucania loreyi* were significantly correlated with Odonata, Hymenoptera, Diptera, and Arachnida across both years. *Nymphula depunctalis* showed extensive and highly significant associations with nearly all predator groups, including Mantodea. *Pelopidas mathias* was significantly correlated with Odonata, Hymenoptera, Coleoptera, Neuroptera, and Arachnida. Short-horned grasshoppers, field crickets, and *Gryllotalpa orientalis* displayed associations with predatory Orthoptera, Odonata-Zygoptera, and Arachnida, with *G. orientalis* showing broader links to Coleoptera and Diptera as well. *Sitophilus oryzae* exhibited significant negative correlations with Dermaptera and

Arachnida. *Dicladispa armigera* and *Stenchaetothrips biformis* were both strongly associated with a wide range of natural enemies, including Odonata, Coleoptera, Hymenoptera, Neuroptera, Hemiptera, Diptera, Dermaptera, and Arachnida, reflecting wide influence by natural enemies on their populations.

- From June to December across 2020 and 2021 in Kuhoxu, numerous rice insect pests exhibited significant positive correlations with diverse natural enemies, indicating robust biological control potential. *Nephotettix virescens*, *Nephotettix nigropictus*, and *Cofana spectra* were consistently associated with Hymenoptera and Odonata-Zygoptera, with additional links to Neuroptera and Arachnida. *Maiestas dorsalis* showed exceptionally strong correlations with nearly all natural enemies groups in both years. *Nilaparvata lugens* and *Sogatella furcifera* were significantly associated with Hymenoptera, Diptera, Arachnida, Coleoptera, Neuroptera, and Odonata. *Leptocorisa acuta* and *Cletus punctiger* also exhibited broad associations, particularly with Odonata, Hymenoptera, Coleoptera, and Arachnida. *Scirpophaga incertulas*, *Chilo suppressalis*, *Scirpophaga spp.*, and *Scirpophaga nivella* were consistently linked to a wide range of natural enemies including Diptera, Hymenoptera, Neuroptera, Arachnida, and Odonata. *Cnaphalocrocis medinalis*, *Melanitis leda ismene*, and green horned caterpillar maintained associations with Diptera, Hymenoptera, Neuroptera, Coleoptera, and Arachnida. Similarly, *Spodoptera litura* and *Leucania loreyi* were correlated with Diptera, Hymenoptera, Neuroptera, and Odonata-Anisoptera. *Nymphula depunctalis* and *Pelopidas mathias* also showed widespread associations with major predator groups. Orthopterans, including short-horned grasshoppers and *Gryllotalpa orientalis*, were linked to Coleoptera, Hymenoptera, Diptera, and Arachnida. *Sitophilus oryzae* showed consistent negative correlations with Diptera, Odonata-Anisoptera, Arachnida, and Hemiptera. *Dicladispa armigera* and *Stenchaetothrips biformis* were regulated by a broad complex of natural enemies, with significant correlations across nearly all predator groups. These results highlight stable and widespread natural enemy activity across years, reinforcing their role in rice pest suppression and their value in integrated pest management at Kuhoxu.

- The present study presents detailed morphometric measurements of major insect pests and their natural enemies associated with rice cultivation in the lowland ecosystems of Nagaland. A total of 26 insect pest species and 46 natural enemies were examined for key morphological traits. These morphometrics offer valuable insight into the various external morphological parts of the insects by their size variation. The results were largely consistent with previously published data, confirming the reliability of the measurements. These data will serve as the baseline Morphometric data for insect pests and their natural enemies in lowland rice agroecosystem in Nagaland. Apart from aiding in species identification and taxonomic importance, these data are also valuable to understand the function of the various insect parts such as wing length, leg size, or mouthpart structure in relation to the behavior and ecological role of an organism like mobility in predators or feeding mechanisms in pests which helps in understanding the efficiency of these pests and their natural enemies. It's known that body size and shape often vary across environments and geographic locations and with the ever changing effect of climate change, the present morphometric studies will help to track how climate change influences insect morphology in the years to come.

CONCLUSION

The following conclusions are drawn based on the above findings:

1. Lowland rice agroecosystem in Nagaland supports a diverse group of insect pests and their natural enemies, highlighting its complex and rich biodiversity with at least 32 insect pests feeding on rice and 57 natural enemies performing the role of biological control.
2. Diversity analyses revealed that while insect pest diversity varied across locations, natural enemies maintained consistently high richness and evenness, indicating a stable and balanced ecological presence in the rice agroecosystem

with Medziphema recording the highest diversity for insect pests and Singrijan recorded the highest diversity for natural enemies.

3. The Alpha (α), Beta (β) and Gamma (γ) diversity of both insect pests and their natural enemies indicates very low species turnover across Medziphema, Singrijan, and Kuhoxu suggesting that they are highly similar.
4. The relative abundance analysis highlighted the consistent dominance of *Nilaparvata lugens* across all sites, with varying presence of other key pests influenced by local agroecological conditions.
5. The natural enemy community in the rice fields remained stable across locations, with Hymenoptera, Coleoptera, and Arachnida having consistently high abundance.
6. Across Medziphema, Singrijan, and Kuhoxu, though present throughout the cropping season, most insect pest species exhibited peak densities during mid to late crop stages.
7. Field observations at Medziphema, Singrijan, and Kuhoxu highlighted the presence of natural enemy groups throughout the cropping season with peak populations observed during mid to late crop stages.
8. Across Medziphema, Singrijan, and Kuhoxu, insect pest populations exhibited species-specific responses to temperature, humidity, and rainfall, with some pests thriving under warmer and more humid conditions, while others declined, highlighting the complex interplay between climatic factors and pest dynamics in lowland rice ecosystems.
9. Insect pests exhibited significant correlation with a diverse range of natural enemies in all three sites, highlighting the widespread and stable presence of biological control agents in these ecosystems.

FUTURE LINE OF WORK

Based on the comprehensive studies on insect pest dynamics and natural enemies in Nagaland's lowland rice agroecosystem, several promising avenues for future research emerge:

1. **Impact of Climate Change on Pest-Natural Enemy Interactions:** Investigate the effect of rising temperatures and altered rainfall patterns on the abundance and efficacy of natural enemies, potentially disrupting biological control mechanisms.
2. **Integration of Traditional Knowledge with Modern Pest Management:** Explore the role of indigenous practices in insect pest management and their potential integration with contemporary biological control methods to enhance sustainability.
3. **Morphometric and Molecular Characterization of Insect Species:** Conduct detailed studies to understand the morphological and genetic diversity of insect pests and their natural enemies, aiding in accurate species identification and understanding ecological roles.
4. **Evaluation of Climate-Resilient Rice Varieties:** Assess the performance of indigenous rice landraces under changing climatic conditions to identify varieties with enhanced resistance to pests and diseases.
5. **Development of Biocontrol Agents:** Focus on the mass production and field application of biocontrol agents, such as parasitoids and predators, to reduce reliance on chemical pesticides and promote eco-friendly pest management practices.

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APPENDICES

APPENDIX-A

Meteorological observation during the period of investigation at Medziphema in 2020

SMW	Temperature		Relative humidity		Rainfall (mm)
	Max	Min	Max	Min	
23	31.89	22.69	93.57	68.29	16.50
24	33.24	24.70	92.29	80.00	67.10
25	33.06	24.26	92.43	70.57	111.90
26	31.83	23.89	91.71	73.14	53.60
27	32.87	24.56	94.43	77.71	79.50
28	32.87	24.84	93.14	71.14	29.70
29	32.34	24.57	92.57	72.29	18.50
30	32.01	23.94	93.43	75.71	71.40
31	33.6	25.33	93.71	70.14	03.50
32	34.74	25.26	92.00	71.14	10.80
33	33.57	25.24	92.00	67.14	31.40
34	32.43	24.41	95.71	73.71	32.30
35	33.11	24.69	92.57	70.57	42.90
36	33.76	24.31	94.43	64.14	10.70
37	33.27	24.27	95.14	71.71	58.50
38	33.20	24.54	96.29	75.71	17.30
39	31.31	24.11	95.00	79.57	31.30
40	32.54	23.49	95.43	80.29	103.9
41	32.16	23.44	95.29	70.57	02.50
42	32.41	23.57	93.86	64.29	01.10
43	28.57	22.01	96.57	79.71	68.20
44	30.09	22.46	96.00	74.29	34.80
45	29.33	17.71	97.14	61.00	00.40
46	29.03	15.16	98.00	59.57	00.00
47	26.21	13.96	97.43	56.14	00.00
48	26.30	12.10	96.57	54.57	00.00
49	26.07	11.69	97.00	54.00	00.00

APPENDIX-B

Meteorological observation during the period of investigation at Medziphema in 2021

SMW	Temperature		Relative humidity		Rainfall (mm)
	Max	Min	Max	Min	
23	33.56	23.63	91.71	63.14	39.10
24	33.00	24.79	93.29	75.29	19.50
25	33.01	24.51	93.29	67.43	43.40
26	33.00	25.00	92.57	69.14	37.60
27	33.17	24.73	88.86	73.43	19.20
28	32.41	24.69	92.71	70.43	105.7
29	33.69	24.66	94.57	69.57	53.30
30	34.49	24.89	89.57	70.43	74.90
31	32.27	25.10	91.57	78.43	34.00
32	33.2	24.53	92.86	67.86	25.20
33	32.47	24.93	95.57	77.00	41.80
34	32.37	24.29	91.86	67.71	07.00
35	32.31	24.29	92.86	72.86	52.90
36	33.19	24.01	94.57	68.43	49.10
37	33.79	23.94	93.57	67.71	42.20
38	32.11	23.31	94.00	67.71	13.10
39	33.70	23.77	93.14	66.00	08.10
40	32.29	23.06	94.29	71.14	05.00
41	33.89	23.57	91.86	62.86	53.80
42	33.30	23.60	95.43	70.14	69.10
43	29.99	18.97	96.86	71.86	02.10
44	30.03	19.07	95.14	57.86	00.00
45	29.46	15.24	96.00	49.14	00.00
46	28.64	16.39	94.86	54.71	00.00
47	27.76	13.33	96.43	49.29	00.00
48	26.90	11.40	95.86	45.71	00.00
49	26.43	15.24	95.14	57.71	08.50

APPENDIX-C

Meteorological observation during the period of investigation at Singrijan in 2020

SMW	Temperature		Relative humidity		Rainfall (mm)
	Max	Min	Max	Min	
23	33.59	23.96	91.71	68.60	89.00
24	34.30	25.60	91.71	81.00	27.60
25	34.86	25.60	91.86	80.71	33.80
26	34.89	25.00	91.71	71.43	17.60
27	35.44	25.99	91.57	71.43	30.60
28	33.91	24.53	91.71	69.57	20.50
29	34.34	25.36	91.86	70.90	09.50
30	33.77	25.10	91.43	76.71	131.70
31	34.90	26.37	91.71	69.00	16.80
32	35.07	26.41	90.86	70.53	00.40
33	34.16	25.89	91.71	68.00	29.80
34	34.74	26.19	91.43	72.80	07.10
35	34.60	26.17	91.43	71.70	68.80
36	34.24	26.26	91.86	66.00	38.60
37	33.31	25.34	91.14	70.00	00.30
38	34.21	25.23	91.71	73.90	07.00
39	33.66	24.40	92.14	79.00	25.40
40	33.04	24.51	91.43	80.79	02.70
41	33.01	23.53	91.71	70.91	146.80
42	33.04	23.00	91.71	62.30	39.40
43	29.69	22.41	91.57	79.10	44.60
44	31.37	21.21	91.14	76.00	20.20
45	28.76	17.41	90.00	62.90	00.00
46	29.84	15.77	90.14	58.98	00.00
47	27.29	14.61	90.43	57.00	00.00
48	27.26	14.03	90.57	57.90	00.00
49	25.70	13.41	88.29	53.60	00.00

APPENDIX-D

Meteorological observation during the period of investigation at Singrijan in 2021

SMW	Temperature		Relative humidity		Rainfall (mm)
	Max	Min	Max	Min	
23	34.67	24.29	91.57	62.50	05.00
24	35.06	25.13	91.00	76.00	40.70
25	35.39	25.23	91.14	69.00	71.40
26	34.87	24.97	91.29	69.12	01.60
27	34.71	25.36	91.29	72.90	02.20
28	34.74	25.59	91.57	69.95	27.80
29	34.56	25.64	91.00	68.80	355.60
30	35.39	25.87	90.71	69.30	62.00
31	35.00	25.56	91.86	79.00	20.80
32	35.34	25.24	91.29	69.00	53.40
33	34.74	24.90	91.29	78.05	02.20
34	34.61	24.89	92.00	68.20	31.80
35	34.77	24.79	92.00	70.90	10.20
36	34.37	24.97	91.29	69.00	132.10
37	35.03	25.30	91.43	66.50	04.20
38	34.33	24.34	91.71	67.25	74.10
39	35.19	25.37	91.29	65.85	101.40
40	34.37	24.49	91.71	70.78	02.30
41	34.73	24.83	91.57	62.89	00.00
42	34.24	24.96	91.57	70.00	13.20
43	33.56	23.41	90.86	72.10	00.00
44	32.24	22.01	91.00	58.00	00.00
45	30.41	19.23	90.00	50.60	00.00
46	29.13	17.16	90.57	53.72	00.00
47	27.73	15.06	89.14	49.47	00.00
48	26.90	14.41	90.57	45.00	00.00
49	26.67	14.87	90.71	55.00	00.00

APPENDIX-E

Meteorological observation during the period of investigation at Kuhoxu in 2020

SMW	Temperature		Relative humidity		Rainfall (mm)
	Max	Min	Max	Min	
23	32.79	23.20	90.11	64.70	58.60
24	34.01	24.80	87.45	77.00	30.09
25	33.96	24.70	88.94	68.8	30.36
26	34.00	24.10	87.09	72.9	15.90
27	34.93	25.00	90.2	75.87	31.10
28	33.00	23.60	90.78	68.79	18.25
29	33.79	24.40	87.57	70.69	08.10
30	33.00	24.21	88.47	74.00	100.7
31	34.00	25.47	90.08	69.10	17.03
32	34.68	25.62	88.71	70.00	00.10
33	33.66	24.99	90.00	70.20	26.94
34	33.57	25.21	87.32	71.15	06.50
35	33.59	24.30	88.78	69.88	56.40
36	33.86	23.00	81.00	63.21	00.00
37	34.14	22.86	81.14	70.17	04.00
38	33.71	22.43	83.43	74.30	22.20
39	33.14	22.71	94.43	77.78	24.60
40	35.00	23.71	89.57	79.40	57.20
41	33.43	23.00	86.57	70.20	25.20
42	34.14	22.00	86.00	63.00	18.60
43	33.29	20.57	81.14	77.90	34.30
44	32.00	21.29	88.29	73.20	00.00
45	30.43	18.29	83.71	61.00	00.00
46	30.29	18.57	81.86	59.00	00.00
47	28.43	18.57	84.43	54.67	00.00
48	27.14	15.14	87.43	53.80	00.00
49	27.00	16.57	86.43	53.865	00.00

APPENDIX-F

Meteorological observation during the period of investigation at Kuhoxu in 2021

SMW	Temperature		Relative humidity		Rainfall (mm)
	Max	Min	Max	Min	
23	36.71	26.00	78.71	73.8	35.60
24	36.43	26.14	81.29	66.34	31.47
25	35.86	25.19	75.43	67.9	48.80
26	36.57	25.86	85.86	72	42.20
27	37.00	26.14	81.86	68.96	47.80
28	34.56	25.64	80.57	68.1	56.60
29	37.29	27.00	81.29	69.75	73.20
30	37.86	26.57	85.86	77	7.40
31	37.86	26.57	83.00	66.49	57.60
32	37.43	25.29	78.43	76	15.20
33	38.71	26.43	86.43	65.19	2.20
34	37.57	25.86	82.29	71.77	47.80
35	38.29	26.57	79.43	67.9	107.80
36	38.00	27.71	80.14	65	13.00
37	37.71	25.86	80.57	65.9	39.80
38	37.00	27.14	83.14	64.95	5.00
39	36.43	26.00	76.86	69.71	14.40
40	37.29	26.71	80.43	61.88	42.00
41	37.29	27.43	80.71	69.47	2.80
42	36.57	26.00	80.86	70.9	19.00
43	35.00	23.86	68.14	56.3	0.00
44	33.00	21.71	67.29	47.9	0.00
45	33.29	21.86	70.57	53.76	0.00
46	32.43	20.43	69.57	48	0.00
47	31.00	19.00	62.71	44.2	0.00
48	28.43	18.14	85.86	56	0.00
49	36.71	26.00	78.71	73.8	35.60