**Diversity of insect pests and their natural enemies in lowland rice agroecosystem of Nagaland.**

ABSTRACT

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| --- |
| A field study was conducted during the 2020 and 2021 rice-growing seasons across three lowland rice cultivation sites—Singrijan, Medziphema, and Kuhoxu in Nagaland—to assess the diversity and abundance of insect pests and their natural enemies. A total of 32 insect pest species were documented representing 28 genera, 16 families, and five insect orders (Hemiptera, Lepidoptera, Orthoptera, Coleoptera, and Thysanoptera). Additionally, 57 species of natural enemies were recorded, spanning 42 genera, 19 families, and 10 insect orders, along with 6 species from the class Arachnida (Araneae). Eight insect specimens remained unidentified. Diversity analysis revealed site-specific variations, with Medziphema exhibiting the highest insect pest diversity, while Singrijan showed the highest diversity of natural enemies. Despite these differences, overall alpha, beta, and gamma diversity metrics indicated low species turnover among the study sites, suggesting high similarity and a stable ecological balance within the rice agroecosystem. |

*Keywords: Insect pest diversity, natural enemies, species richness, lowland rice cultivation, biodiversity.*

1. INTRODUCTION

In India, 46.38 million hectares are occupied for rice cultivation producing 130.29 million tonnes with a productivity of about 2809 kg/ha (Agricultural Statistics at a glance, 2022). Rice is grown under diverse soil and climatic conditions in our country. The majority is produced during the *Kharif* season and occupies an important position as one of the 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 a 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 both as upland/*Jhum* under rainfed conditions and as a 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 Southeast Asian countries. There are about 120,000 rice varieties cultivated 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: (1) vegetative (germination to panicle initiation), (2) reproductive (panicle development to flowering) and (3) ripening (milk grain to mature grain) supporting a great biodiversity of flora and fauna, insect pests and their natural enemies being among them.

Rice is the staple food crop for the people of NEH (North East Hill) region and is grown extensively in valleys, terraces, uplands, hills and *jhum* fields. 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 % yield losses to complete failure of the crop during epidemics (Azad Thakur *et al*., 2012). There is also a rich biodiversity of Natural enemies in rice agroecosystems which play a crucial role as guardians of crop ecosystems, particularly in rice farming, by maintaining ecological balance and providing effective pest control (Chaitanya *et al*., 2024).

Considering the importance of rice for the people of the region and the rich faunal diversity associated with it, the present investigation was carried out to study the diversity and abundance of insect pests of rice and their associated natural enemies under lowland rice cultivation in Nagaland.

2. materialS and methods

A study was carried out at farmers’ fields at three prominent lowland rice growing locations of Nagaland *viz*., Singrijan (25.835184, 93.716652), Medziphema (25.744576, 93.860705) and Kuhoxu (25.905405, 93.990827) during the rice-growing seasons from June to December of 2020 and 2021 to assess the diversity and abundance of insect pests of rice and their associated natural enemies under lowland rice cultivation under Nagaland’s climatic and edaphic conditions.

A standard sweep net (30 cm diameter) was used at five random locations per field, with five sweeps per square meter at each site. The collected specimens were killed by carbon tetrachloride in a killing bottle and stored in 70% ethanol for later sorting and identification. The moths were, however, pinned and stored in wooden insect collection boxes. For nocturnal flying insects, light traps having a potassium cyanide bottle or carbon tetrachloride at the bottom as a killing agent, equipped with 60-watt electric bulb were operated in proper location from dusk to dawn.

Pitfall traps were used for terrestrial insects. Wide-mouth plastic jars (11 cm deep and 7.5 cm in diameter) were permanently buried in the field bunds (at the end of the cropping season, when water dried from the fields, the traps were shifted into the rice field). Twenty traps were installed at 10-foot intervals in an alternating pattern along the length of the field bunds. The traps were filled (2-3 cm) at the bottom with 95% ethylene glycol with a few drops of detergent or 5% formaldehyde solution to kill and preserve the insects.

For the study of rice thrips, it was difficult to record their presence with other sampling methods. Hence, a quadrat sampling method comprising 5 quadrats (1×1 m) was deployed for accurate observation of the pestIn each location.

All sampling was done at weekly intervals after which the collected specimens were sorted in the laboratory under a sterezoom binocular microscope and then transferred into 70% alcohol until further identification.

**Statistical analysis:**

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

$$H=-\sum\_{i=1}^{s}Pi Log Pi$$

Where:

*H* = Measure of Shannon and Wiener Diversity

*S* = Total no. of species in a sample.

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

* Simpsons diversity was also calculated as per the formula below:

$$D=1-\sum\_{i=1}^{s}P^{2}i$$

Where:

*D* = Simpson’s Index of Diversity.

*P* = Proportion of individuals in the *ith* species.

*ni​* = 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. results and discussion

**During the study, 32 insect pests associated with rice crops were observed, belonging to** 28 genera, **16 families and 5 insect orders: Hemiptera (**8 species)**, Lepidoptera (**12 species), **Orthoptera (**9 species), **Coleoptera (**2 species) and **Thysanoptera (**1 species) **were recorded as described in table 1. T**hese 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 Guenee 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 species in the present investigation also align with **Lisha *et al*. (2020),** who documented Scirpophaga ceratellus, 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, Melanitisleda 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.

**Table 1: Diversity of insect pests in lowland rice agroecosystem of Nagaland.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sl/no | **Insect pest Species**  | **Common name** | **Order** | **Family** |
|  | *Nephotettix virescens* Distant | Rice green leafhopper  | Hemiptera |  Cicadellidae  |
|  | *Nephotettix nigropictus* Stål  | Rice green leafhopper  |  Cicadellidae  |
|  | *Cofana spectra* Distant  | White Leafhopper |  Cicadellidae  |
|  | *Maiestas dorsalis* Motchulsky | Rice zigzag leafhopper  |  Cicadellidae  |
|  | *Nilaparvata lugens* Stål  | Brown planthopper  | Delphacidae |
|  | *Sogatella furcifera* Horvith | White-backed planthopper  | Delphacidae |
|  | *Leptocorisa acuta* Thunberg  | Paddy earhead bug  | Alydidae |
|  | *Cletus punctiger* Dallas  | Rice stinkbug  |  Coreidae  |
|  | *Scirpophaga incertulas* Walker  | Yellow stem borer/Rice yellow stem borer  | Lepidoptera | Crambidae |
|  | *Chilo suppressalis* Dudgeon | Asiatic rice borer/Striped rice stemborer  | Crambidae |
|  | *Scirpophaga* spp.  | Stem borer | Crambidae |
|  | *Scirpophaga nivella* Fabricus | White rice borer  | Crambidae |
|  | *Cnaphalocrocis medinalis* Guenée | Rice leafroller  | Crambidae |
|  | *Melanitisleda ismene* Linnaeus  | Rice Butterfly/ Rice horned caterpillar | Nymphalidae |
|  | *Mycalesis mineus* Linnaeus | Dark-branded bushbrown | Nymphalidae |
|  | *Orsotriaena medus* Fabricus | Medus brown | Nymphalidae |
|  | *Spodoptera litura* Fabricius  | Tobacco cutworm/Cotton leafworm  | Noctuidae |
|  | *Leucania loreyi* Duponchel | False army worm | Noctuidae |
|  | *Nymphula depunctalis* Guenée | Rice caseworm  | Pyralidae |
|  | *Pelopidas mathias*  Fabricius | Rice skipper  | Hesperiidae |
|  | *Oxya* spp.  | Rice grasshopper  | Orthoptera |  Acrididae  |
|  | *Melanoplus bivittatus* Say | Two striped grasshopper.  |  Acrididae  |
|  | *Dociostaurus* spp. | Grasshopper |  Acrididae  |
|  | *Phlaeoba infumata* Brunner von Wattenwyl | Silent Slant-Faced Grasshopper | Acrididae |
|  | *Atractomorpha* spp.  | Grasshopper | Pyrgomorphidae |
|  | *Euscyrtus concinnus* de Haan  | Field cricket |  Gryllidae  |
|  | *Gryllus bimaculatus* De Geer  | Field cricket |  Gryllidae  |
|  | *Gryllus* spp. | Field cricket |  Gryllidae  |
|  | *Gryllotalpa orientalis* Burmeister  | Oriental mole cricket | Gryllotalpidae |
|  | *Sitophilus oryzae* Linnaeus  | Rice weevil  | Coleoptera |  Curculionidae  |
|  | *Dicladispa armigera* Olivier | Rice hispa | Chrysomelidae.  |
|  | *Stenchaetothrips biformis* Bagnall  | Rice thrips  | Thysanoptera | Thripidae |

Table 2, shows the diversity of natural enemies recorded. Altogether, **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), Dermaptera (1 species), **Hemiptera** (5 species), Mantodea (2) species, **Orthoptera** (1 species), **Arachnida (Araneae:** 5 species) were identified. **8 insect specimens remained unidentified.**

 **Table 2: Diversity of natural enemies of insect pests in lowland rice agroecosystem of Nagaland.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sl.No.** | **Natural Enemy Species** | **Common name** | **Class/Order** | **Family /Class** |
| 1. | *Brachythemis contaminate* Fabricius  | Asian Groundling/Ditch Jewel  | Odonata | Libellulidae.  |
| 2. | *Crocothemis servilia* Drury  | Scarlet skimmer or ruddy marsh skimmer  | Libellulidae.  |
| 3. | *Orthetrum Sabina* Drury  | Slender skimmer or green marsh hawk  | Libellulidae.  |
| 4. | *Crocothemis nigrifrons* Kirby  | Black-headed skimmer and blue-scarlet dragonfly  | Libellulidae.  |
| 5. | *Neurothemis intermedia* Rambur  | Paddy field parasol  | Libellulidae.  |
| 6. | *Diplacodes trivialis* Rambur  | Blue Ground Skimmer  | Libellulidae.  |
| 7. | *Neurothemis tullia* Drury  | Pied Paddy Skimmer  | Libellulidae.  |
| 8. | *Orthetrum pruinosum* Burmeister | Crimson-tailed marsh hawk  | Libellulidae.  |
| 9. | *Palpopleura sexmaculata* Fabricius  | Blue-tailed Yellow Skimmer  | Libellulidae.  |
| 10. | *Agriocnemis pieris* Laidlaw  | Indian white dartlet | Coenagrionidae |
| 11. | *Agriocnemis pygmaea* Rambur  | Pygmy Dartlet  | Coenagrionidae |
| 12. | *Agriocnemis argentea* Tillyard | Silver wisp  | Coenagrionidae |
| 13. | *Ischnura rubilio* Selys  | Western Golden Dartlet  | Coenagrionidae |
| 14. | *Ceriagrion cerinorubellum* Brauer  |  Orange-tailed Marsh Dart  | Coenagrionidae |
| 15. | *Ceriagrion coromandelianum* Fabricius | Coromandel marsh dart/ Yellow wax tail  | Coenagrionidae |
| 16. | *Macrocheilus bensoni* Hope | Ground beetle  | Coleoptera | Caribidae |
| 17. | *Ophionea nigrofasciata* Schmidt-Goebel | Long-neck ground beetle  | Caribidae |
| 18. | *Chlaenius* spp*.* | Vivid metallic ground beetle  | Caribidae |
| 19. | *Pheropsophus* spp*.* | Asian bombardier beetle  | Caribidae |
| 20. | *Cicindela sexpunctata* Fabricius | Tiger beetle  | Cicindelidae  |
| 21. | *Cylindera venosa* Kollar | Tiger beetle | Cicindelidae |
| 22. | *Micraspis discolor* Fabricius | Discolored Ladybird Beetle  | Coccinellidae  |
| 23. | *Micraspis univittata* Hope | Ladybird Beetle  | Coccinellidae  |
| 24. | *Coccinella septempunctata* Linnaeus | Seven-spot ladybird beetle  | Coccinellidae  |
| 25. | *Harmonia spp.*  | Asian ladybird beetle  | Coccinellidae  |
| 26. | *Peirates atromaculatus* Stål | Assassin bug  | Hemiptera | Reduviidae  |
| 27. | *Oncocephalus* spp*.* | Assassin bug  | Reduviidae  |
| 28. | *Rhynocoris fuscipes* Fabricius | Assassin bug  | Reduviidae  |
| 29. | *Ectomocoris atrox* Stål | Assassin bug | Reduviidae |
| 30. | *Cyrtorhinus lividipennis* Reuter | Mirid bug | Miridae |
| 31. | *Telenomus spp* | Parasitic wasp  | Hymenoptera | Scelionidae |
| 32. | *Ophion* spp | Ichneumonid wasp  | Ichneumonidae  |
| 33. | *Xanthopimpla* spp | Ichneumonid wasp  | Ichneumonidae  |
| 34. | *Xanthopimpla punctata* Fabricius  | Yellow ichneumon wasp  | Ichneumonidae  |
| 35. | *Agonocryptys discoidaloides* Viereck  | Ichneumonid wasp  | Ichneumonidae  |
| 36. | *Ischnojoppa luteator* Fabricius | Ichneumonid wasp | Ichneumonidae |
| 37. | *Aleiodes* spp | Braconid wasp  | Braconidae   |
| 38. | *Brachymeria scutellocarinata* Joseph  | Chalcid wasp  | Chalcidoidea  |
| 39. | *Cardiochilinae* spp | Braconid wasp  | Braconidae   |
| 40. | *Agrypon flaveolatum* Gravenhorst  | Ichneumonid wasp  | Ichneumonidae  |
| 41. | *Apochrysa* spp*.*  | Delicate Lacewing  | Neuroptera | Chrysopidae  |
| 42. | *Ankylopteryx* spp. | Green Lacewing  | Chrysopidae  |
| 43. | Unidentified  | Green Lacewing  | Chrysopidae  |
| 44. | *Ascalaphus prothoracicus* Kimmins | Owlfly | Ascalaphidae |
| 45. | Unidentified  | Mantisfly,/ mantid lacewings  | 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. | *Oxyopes birmanicus* Thorell | Burmese Lynx Spider  | Arachnida/ Araneae | Oxyopidae |
| 53. | *Peucetia viridana* Stoliczka | Green Lynx Spider | Oxyopidae |
| 54. | *Argiope aemula* Walckenaer | Signature spider  | Araneidae  |
| 55. | *Argiope bruennichi* Scopoli | Wasp spider  | Araneidae  |
| 56. | *Tetragnatha straminea* Emerton | long-jawed orb weaver  | Tetragnathidae |
| 57. | *Neoscona theisi* Walckenaer | Orb spider  | Araneidae  |

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 & Mahapatra (2023)** documented 93 spider species across 17 families in the Rabi season and 13 families in the Kharif season, withAraneidae exhibitingthe highest 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 damselflies/dragonflies, 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, Forticulaauricularia, Cyrtorhinuslividipennis, and Agriocnemis pygmaea as key predators and Trichogramma japonicum, Telenomusrowani, and Tetrastichusschoenobii as parasitoids in rice fields, which is in agreement with the present investigation.

**Table 3:Diversityof 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 (Eh)** | 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 3 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=0.83) 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 (Eh​=0.86) and Kuhoxu (Eh​=0.85), suggesting a well-balanced distribution of individuals among species, with no single species dominating. Among insect pests, Medziphema exhibits the highest evenness (Eh=0.81), whereas Singrijan

 (Eh=0.72) and Kuhoxu (Eh=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.

Table 4 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, 2.32 and 2.25 in case of natural enemies at Medziphema, Singrijan and Kuhoxu respectively.** Gamma diversity is **the total Diversity of across all locations which is recorded as2.308 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**.

**Table 4.: 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 enemiesdiversity:** | **Location** |
|  | **Medziphema** | **Singrijan** | **Kuhoxu** |
| Alpha Diversity α | 1.99 | 2.06 | 2.04 |
| Beta Diversity β | 0.00 |
| Gamma Diversity γ | 2.05 |

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.

**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 present study area.

4. Conclusion

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.

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 recording the highest diversity for natural enemies.

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.

Competing interests

Authors have declared that no competing interests exist.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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