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SPECIES DIVERSITY AND CROP STAGE IN RELATION TO PREDATORY POTENTIAL OF SPIDERS ON RICE BROWN PLANT HOPPER *NILAPARVATA LUGENS* (STÅL)

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ABSTRACT

This study investigated the spider diversity, species, and predatory efficiency of various spider species predating on the rice brown plant hopper *Nilaparvata lugens* (Stål). The experimental period was divided into three phenological stages viz., active tillering, panicle bearing-grain filling and grain maturity. Diversity indices such as Shannon-Wiener diversity index, Simpson diversity indices, species richness and species evenness index were calculated. Twelve predatory spider species from nine families were recorded and their population was observed to increased with growth stages. Adjusted mortality rates were calculated and predatory potential was observed to follow the order as *Plexippus paykulli >Pardosa pseudoannulata >Oxyopes hindostanicus> Neoscona theisi > Thomisius >Atypena formosona >Tetragnatha nitens > Bianor angulosus > Araneus sp. > Clubiona sp. > Theridion sp.> Ostearius melanopygius.*

Key words: *Nilaparvata lugens*, *Pardosa pseudoannulata*, spider, rice, phenological stages, *Plexippus paykulli*, ecosystem, mortality rates, diversity indices, predatory potential, ecosystem

Worldwide there are several constraints in rice production; amongst them, significant annual losses are caused by insect pests and diseases (Kumar, 2022). The brown plant hopper (BPH) *Nilaparvata lugens* is one of the most damaging insect pests in Asia. This pest also act as a vector for viral diseases like rice grassy stunt (Satoh et al., 2013) and ragged stunt (Kurniawati et al., 2023). The excessive use of pesticides in rice leads to the development of pesticide-resistance, pesticide-induced outbreaks of insect pests and raises the cost of production (Tudi et al., 2021). This problem leads to IPM which is based on ecological principles and is compatible with an environmentally congenial agricultural system (Pedigo, 1996). Utilizing natural enemies, such as parasitoids, predators, and pathogens is a key component of the IPM (Chandra et al., 2017). Among predators, spiders being ubiquitous obligate carnivorous, feed on different types of prey in cropping systems (Daravath and Chander, 2022). Ecosystem of irrigated rice crop are temporary wetland because within a single period of cultivation, rice agroecosystem represents three major temporary ecological phases as aquatic, semiaquatic and dry (Fernando, 1995). It is important to study the effect of crop phenological stages on spider biodiversity of rice crop and *N. lugens* management. A diversity index is a numerical indicator of the number of various types (like species) present in a dataset (a community), and it can also take into account the evolutionary relationships (such as richness, divergence, or evenness) among the individuals distributed across those types (Chao et al., 2016). Therefore, this study was aimed to explore the spider species during different phenological stages in rice to identify changes along with the crop cycle and their predatory potential against *N. lugens*. This will help to generate ecological information that will help implement IPM.

MATERIALS AND METHODS

The present study was carried out at the Rice Research Area, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana (30°54'N; 75°48'E, 247 masl) during kharif 2019, 2020 and 2021; *N. lugens* population used were reared on TN1 plants at 30°C with 75± 5% RH and a photoperiod of 14:10 (L:D) h. To get newly emerged nymphs, oviposition cages were used. Spider species were collected from the crop raised following all agronomic practices as recommended by the Punjab Agricultural University package and practices but without the application of insecticides (Anonymous, 2019). Sampling was done from plot of 1500 m^2 area, starting 30 days after transplanting (DAT) until maturity at an interval of three days for all the rice phenological stages (active tillering, panicle bearing-grain filling and grain maturity stage).Various methods such as aspirator, sweep net or by manually picking were used. Predatory potential of collected spiders were tested individually in plastic vials of size 50 ml with five, seven and ten number of 4-5th instar *N. lugens* nymphs with small pieces of leaf sheath portion of rice variety TN1 as food. After 24 hr of starvation, spider species were introduced @ one spiders/ vial. The number of nymphs either consumed or killed by each spider species were counted and recorded after one day. For the identification of species, preserved spider specimens were deposited at the National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru, India. The preserved specimens were also analysed critically under stereomicroscope (50x) with keys given by Barrion and Listenger (1995). Diversity indices such as Shannon-Wiener diversity index (H′), Simpson diversity indices (D), species richness (S) and species evenness index (E) were used (Chao et al., 2016). Adjusted mortality rate (AMR) were used to obtain a single value for comparative analysis (Nakaji et al., 2004). One-way ANOVA followed by post-hoc comparison with Tukey's honestly significant difference (HSD) was used to test the significance of treatments.Statistical analyses were performed using v. 13.0 statistical program (SPSS, 2004). To draw the figures Sigma Plot, vers. 10.0 (Systat Software, San Jose, California, USA) was used following Wagan et al. (2017).

RESULTS AND DISCUSSION

Spiders are capable of controlling insect pests especially sap sucking insects (Wagan et al., 2019). Twelve predatory spider species belonging to nine families were collected (Table 1). Spiders in rice fields make up to 80% of the entire predatory community (Radermacher, 2020). During initial stage of active tillering, four species were recorded viz., *Tetragnatha nitens, Neoscona theisi, Oxyopes hindostanicus* and *Pardosa pseudoannulata.* All these persisted throughout the cropping season. During panicle bearing-grain filling stage, other species viz., *Plexippus paykulli, Atypena formosana, Bianorangulosus, Araneus* sp. and *Clubiona* sp were observed. These persisted until the grain maturity stage. Towards maturity some additional species were also observed which includes *Ostearius melanopygius, Theridion* sp. and *Thomisius* sp.

During all the three phenological stages, significant differences were observed in Shannon-Wiener diversity index (H′), Simpson diversity indices (D), species richness (S) and species evenness index (E) (Table 2). Shannon-Wiener diversity index (H′) is sensitive to changes in the abundance of rare species and it was observed that Shannon index increased with phenological stages and maximum value (4.78) was observed during maturity. Simpson diversity indice (D) is the most commonly used one to study diversity and its value of D declined with advancement of growth and varied from 8.76 to 13.29. Aydın (2021) also observed maximum Shannon-Wiener index (H') in natural habitats indicating maximum diversity and presence of rare spider species. Similar results were also observed by Ravi et al. (2022) with maximum H' index during reproductive and ripening phases.

Table 1. Predatory spiders on *N. lugens* (kharif 2019, 2020 and 2021)

Family	Guild	Species
Tetragnathidae	Long-jawed/ orb-weavers	*Tetragnatha nitens*
Araneidae	Orb-weaving spiders	*Neoscona theisi, Araneus* sp.
Salticidae	Jumping spiders	*Plexippus paykulli Bianor angulosus*
Oxyopidae	Lynx spider	*Oxyopes hindostanicus*
Lycosidae	Wolf spider	*Pardosa pseudoannulata*
Thomisidae	Crab spiders	*Thomisius* sp.
Linyphiidae	Sheetweb spider	*Ostearius melanopygius, Atypena formosona*
Clubionidae	Sac spider	*Clubiona* sp.
Theridiidae	Tangle-web spiders	*Theridion* sp.

Table 2. Diversity indices of spiders at rice phenological stages

Rice phenological stages	Shannon-Wiener diversity index (H')	Simpson's diversity index (D)	Species evenness index (E)	Species richness (S)
Active tillering	1.33	13.29	0.68	1.28
Panicle bearing-grain filling	4.02	9.63	1.85	1.81
Grain maturity stage	4.78	8.76	1.92	1.87

A total of four predatory species were recorded during active tillering stage; during panicle bearing-grain filling stage, nine species were recorded among which four species were recorded in active tillering stage also. A total of twelve species were recorded during grain maturity stage, which includes nine species observed during active tillering and panicle bearing-grain filling stages; species richness values for three stages were 1.28, 1.81 and 1.87, respectively. Evenness index also increased with advancement of growth stages (0.68 to 1.93). These results corroborate with the earlier work by Bao et al. (2018) in crop stages of irrigated rice. The collected spider species showed voracious feeding behaviour against *N. lugens* nymphs and a significant difference in the feeding efficacy index of spider species were observed at 5 ($F=48.15$, $p<0.01$, d.f=11), 7 ($F=66.66$, $p<0.01$, d.f=11), and 10 ($F=105.14$, $p<0.01$, d.f=11) nymphs densities (Fig. 1); *P. paykulli* was the most active and prodigious as the AMR were 92.5, 91.37 and 88.88%, respectively at all the three *N. lugens* nymph densities. In the phonological stages, the AMR were maximum for *P. paykulli* and *P. pseudoannulata.* Present results are also substantiated by the work of Daravath and Chander (2017) on *P. pseudoannulata*. Significant *N. lugens* mortalities were caused by *O. hindostanicus* and *N. theisi.* The Oxyopidae and Araneidae are among the most abundant and dominant families (Butt et al., 2019).

On the whole, the prey consumption rate follows the descending order as, *P. paykulli* >*P. pseudoannulata* >*O. hindostanicus*> *N. theisi* > *Thomisius* sp. >*A. formosona* >*T. nitens, B. angulosus* > *Araneus* sp. > *Clubiona* sp. > *Theridion* sp.> *O. melanopygius.* Previous studies indicated that large scale outbreak of *N. lugens* is associated with excessive insecticide use (Heinrichs et al., 1982; Wu et al., 2020). In order to reduce these adverse impacts non-chemical methods such as natural enemies can be used. Among the natural enemies, spiders are the most abundant and diverse generalist predators in many agroecosystems. The present study observed that all the twelve species are able to kill and consume *N. Lugens* nymphs. Maximum predatory spiders became most active with the advancement of growth stages.

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AUTHOR CONTRIBUTION STATEMENT

Gurjot Kaur: Writing- Original Draft; Preetinder Singh Sarao: Conceptualization and editing.

CONFLICT OF INTEREST

No conflict of interest.

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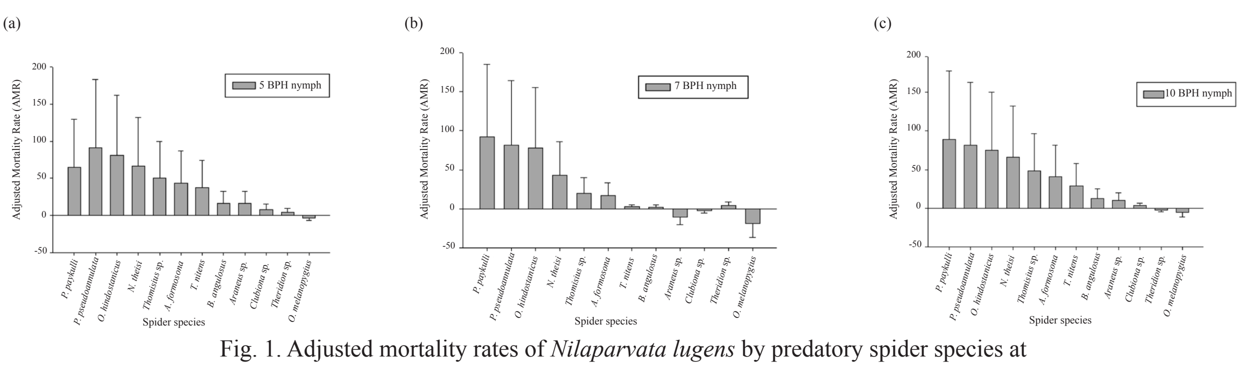

Fig. 1. Adjusted mortality rates of *Nilaparvata lugens* by predatory spider species at different nymph densities a) 5 BPH nymph/ vial b) 7 BPH nymph/ vial c) 10 BPH nymph/ vial

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