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Diversity and Relative Abundance of Insect Pests and Natural Enemies in *Bacillus* Treated Rice

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at Indian Institute of Rice Research, Rajendranagar, Hyderabad to decipher diversity and relative abundance of insect pests, Hemipteran predators and Hymenopteran parasitoids in *Bacillus* treated rice crop during *Rabi*, 2020. Yellow pan traps, visual count, yellow sticky traps, sweep net and D-net methods were used for collecting insect specimens. A total of 777 individuals of pests belonging to 11 families, 920 predators belonging to 14 families and 3587 parasitoids belonging to 15 families were collected. The highest relative abundances of pests, predator and parasitoids were reported for families Cicadellidae (34.36%), Miridae (66.96%) and Eulophidae (53.28%) respectively. Visual counting for pests (43%) and predators (38%) and

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yellow sticky traps for parasitoids (89.66%) were found to be most effective methods of collection. The total abundance of natural enemies was found far higher than the pest individuals, this suggesting natural control of pests in the *Bacillus* treated rice crop kept the pest population under check.

Keywords: Insect pests; rice; field experiment; Bacillus; parasitoids.

1. INTRODUCTION

Rice (*Oryza sativa*. L) holds significant agricultural importance in Asia, where it contributes to 90% of global rice production [1]. The intensification of agricultural practices poses a significant threat to sustainable agriculture due to potential biodiversity deprivation and the resulting impact on ecosystem services [2,3]. Nowadays, environmentally friendly (EF) farming methods, which reduce reliance on pesticides and chemicals, including organic farming, gaining political and financial support globally EU, [4]. This support has led to a unexpected increase in global organic farming area, rising from 11 million hectares in 1999 to 72.3 million hectares by 2019 FiBL, IFOMA-Organics International, [5]. Additionally, rice fields are act as temporary wetlands, known for their instantaneous alterations in physical, chemical, and biological conditions, harbouring notably higher biodiversity, particularly among arthropods, in contrast to other agricultural crops. Within these ecosystems, arthropods occupy a pivotal role in the food chain, encompassing herbivores, decomposers, parasites, and predators of other organisms [6].

Biodiversity of insects is one of the most important tools in the ecological pest management (SARE, 2012). Many studies have demonstrated that EF farming practices enhance biodiversity and increase the abundance of various species compared to conventional farming [7-11]. But, the information on effect of seed treatment with bioagents along with organic manuring, on biodiversity and relative abundance of insect pests and natural enemies was less understood. Hence, the current study was carried out to evaluate the diversity and relative abundance of pests, Hemipteran and Hymenopteran natural enemies in organically treated plot by using *Bacillus* treated seeds of rice.

2. MATERIALS AND METHODS

The current experimental study was conducted in the fields of Indian Institute of Rice Research, Rajendranagar, Hyderabad during rabi, 2020. The rice variety BPT 5204 (Samba Mahsuri) seeds were treated with *Bacillus* @ 10g per kg seed and broadcasted in 10 sq. m. nursery area. 25-day-old seedlings were transplanted in to the well puddled plots of 900 square meters plots, keeping a spacing of 20 cm x 10 cm. The experiment was replicated three times. The nursery of 10 sq. m area, was applied with 5kg rice husk + 5kg vermicompost. In main field, 18 kg neem cake + 900 kg FYM per plot was applied and spray of *Bacillus* -10g per litre was done at 30,60 and 90 days after transplanting (DAT). Observations on abundance of pest and natural enemies in the plots were recorded at 30, 45, 60, 90, and 120 DAT during morning hours when insects were inactive. Various methods such as yellow pan traps (YPT) (3 traps per plot), visual counts (VC) and collections from randomly selected 20 hills in 1 m² quadrats (5 quadrats per plot), sweep netting (SN) across plots (five sweeps at five points), yellow sticky traps (YST) (5 traps per plot), and D-Net for collection of aquatic insects were used. Collected insects were categorized into orders and families. Hemipteran families were identified using keys Thirumalai and Kumar, [12] while Hymenopteran families were identified using keys [13]. Statistical analyses included calculations of the Shannon-Wiener diversity index (H’), Simpson diversity index (D), Margalef’s species richness index, and Pielou’s evenness index (J, Pests to natural enemy’s ratio using R studio version 4.3.1 (package "vegan”) Additionally, the relative abundance (RA) of each family was computed using the formula:

$$\text{Relative abundance (\%)} = n_i \times 100 / N,$$

Where, N represents the total number of individuals across all families, and ni denotes the number of individuals in the i^{th} family.

3. RESULTS AND DISCUSSION

In the current study, a total of 777 individuals of pests belonging to 11 families were collected. Cicadellidae (34.36%) found to be most abundant, followed by Delphacidae (26.90%) and Pentatomidae (15.96%) (Table 1). Visual count followed by sweep net found to contribute more per cent individuals of pests (Fig 1A). In contrast, a greater number of families were collected in the sweep net (10 families) followed by visual count (8 families) (Fig. 2). A total of 920 hemipteran predators belonging to 14 families were recorded. Miridae (66.96%) was the most dominant family followed by Geocoridae (6.09%) and Gerridae (5.87%) (Table 2). Visual count (38%) followed by yellow sticky traps (34%) were the effective methods of collection of the predators (Fig 1B). D-net (9 families) caught a greater number of families followed by visual counts (5 families) (Fig. 2). A total of 3587 parasitoids belonging to 15 families of Hymenoptera. The relative abundance of most dominant families was Eulophidae (53.28%), Trichogrammatidae (18.01%) and Scelionidae (16.89%) (Table 3). Yellow sticky traps (89. 66%) were found as effective method of collection of parasitoids (Fig 1C). But, a greater number of families were collected in the yellow pan traps (14 families) followed by yellow sticky traps (6 families) (Fig 2). The diversity indices of pests, hemipteran predators and hymenopteran parasitoids were represented in Table 4. Furthermore, pests to natural enemies' ratio was 0.172, which indicates that the population of pests were under the check by the most abundant natural enemies of Hemiptera and Hymenoptera (Fig. 3).

Table 1. Methods of collection of pests of rice and relative abundance of families in *Bacillus* treated rice

Families	Number of individuals	Methods of collection	Relative abundance (%)
Crambidae	65	SN,VC	8.37
Hespiriidae	16	SN,VC	2.06
Nymphalidae	4	SN	0.51
Erebidae	3	SN,VC	0.39
Acrididae	24	SN	3.09
Delphacidae	209	YPT,SN,VC,YST,DN	26.90
Cicadellidae	267	YPT,SN,VC,YST	34.36
Pentatomidae	124	SN,VC	15.96
Alydidae	36	SN,VC	4.63
Chrysomelidae	24	SN,VC	3.09
Cecidomyiidae	5	YST	0.64
Total	**777**		

(SN- Sweep Net; VC- Visual Count method; DN- D-Net Collection; YPT- Yellow Pan Trap; YST- Yellow Sticky Trap)

Table 2. Methods of collection of hemipteran predators and relative abundance of families in *Bacillus* treated rice

Families	Number of Individuals	Methods of Collection	Relative Abundance (%)
Miridae	616	YPT,VC,YST,DN	66.96
Pentatomidae	35	SN,YST	3.80
Geocoridae	56	SN	6.09
Veliidae	15	YPT,DN	1.63
Mesoveliidae	21	DN	2.28
Corixidae	5	DN	0.54
Gerridae	54	VC,DN	5.87
Nebidae	3	SN	0.33
Saldidae	19	YPT,DN	2.07
Coreidae	9	SN	0.98
Notonectidae	39	VC,DN	4.24
Hydrometridae	30	VC,DN	3.26
Micronectidae	14	DN	1.52
Reduvidae	4	VC	0.43
Total	**920**		

(SN- Sweep Net; VC- Visual Count Method; DN- D-Net Collection; YPT- Yellow Pan Trap; YST- Yellow Sticky Trap)

Table 3. Methods of collection of Hymenopteran parasitoids and relative abundance of families in Bacillus treated rice

Families	Number of Individuals	Methods of Collection	Relative Abundance (%)
Eulophidae	1911	YPT,SN,YST	53.28
Scelionidae	606	YPT,YST	16.89
Trichogrammatidae	646	YPT,YST	18.01
Braconidae	31	YPT,SN,YST	0.86
Ichneumonidae	66	YPT,SN,VC,YST	1.84
Diapriidae	18	YPT	0.50
Mymaridae	237	YPT,YST	6.61
Dryinidae	4	VC	0.11
Platygastridae	10	YPT	0.28
Torymidae	20	YPT	0.56
Ceraphronidae	10	YPT	0.28
Chalcididae	12	YPT	0.33
Eurytomidae	8	YPT	0.22
Cynipidae	3	YPT	0.08
Bethylidae	5	YPT	0.14
Total	**3587**		

(SN- Sweep Net; VC- Visual Count method; DN- D-Net Collection; YPT- Yellow Pan Trap; YST- Yellow Sticky Trap)

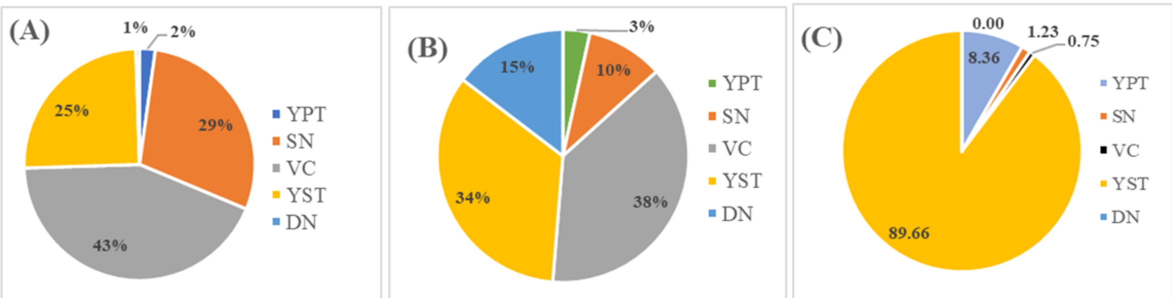

Fig. 1. Percent contribution of methods of collection to number of individuals (A) Pests (B) Hemipteran predators (C) Hymenopteran parasitoids in *Bacillus* treated rice

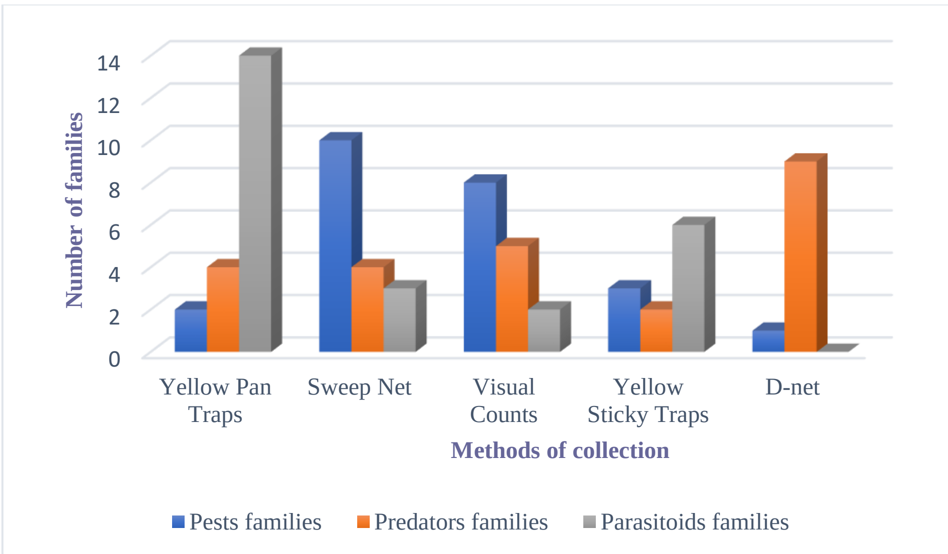

Fig. 2. Number of families in each method of collection (A) Pests (B) Hemipteran predators (C) Hymenopteran parasitoids in *Bacillus* treated rice

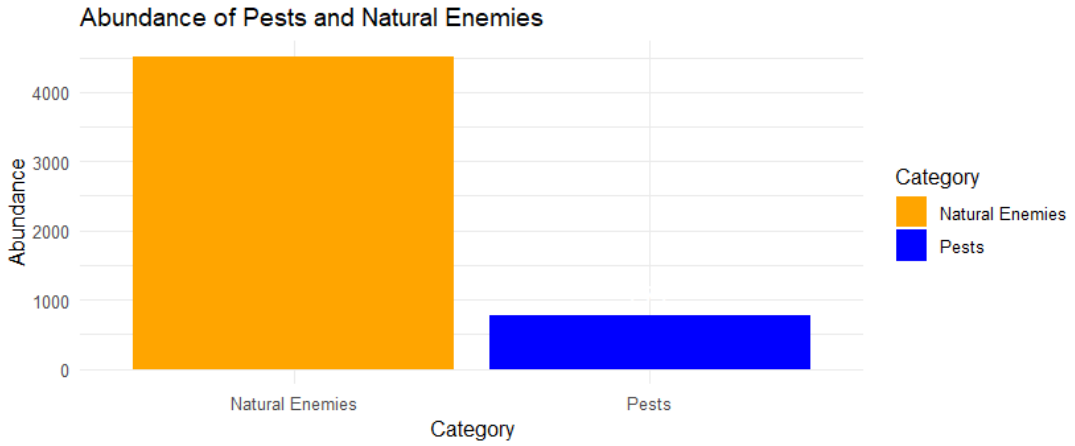

Fig. 3. Abundance of pests and natural enemies of Hemiptera and Hymenoptera in *Bacillus* treated rice

Table 4. Diversity indices of pests, Hemipteran predators and Hymenopteran parasitoids

Diversity Index	Insect Pests	Hemipteran Predators	Hymenopteran Parasitoids
Shannon weiner index	1.74	1.39	1.38
Simpson index	0.77	0.54	0.65
Margelef diversity index	1.50	1.90	1.71
Pielou's eveness index	0.73	0.53	0.51

Generally, herbivorous insects live along with insect predators, parasitoids, pollinators and decomposers, which can regulate the population of herbivorous insects [14,15]. Although, Settle et al, [16] stated that herbivorous insects were the more abundant in the rice crop than the other non-herbivore insects, but, the results in the present study contrasted this statement, due to more abundant natural enemies than phytophagous pests (Fig. 3). Furthermore, similar to the current study, Acosta et al. [17] also collected a total of 800 insects, 429 in the cut and 371 in the non-cut subarea. The arrested insects were arranged into different guilds such as entomophagous (grouping parasitoids and predators) (C = 29.4%; NC = 35%), phytophagous (C = 28.5%; NC = 33.2%), saprophages (C = 38.2%; NC = 27.5%), and finally other insects (C = 4 %; NC = 4.3%). Likewise, a field study conducted to assess the effect of organic manures on the incidence of insect pests of rice and reported that organically manured plots showed significant ($P<0.05$) decrease in gall midge (6.61-9.25 per cent) and leaf folder (11.75-13.46 per cent) incidence compared with the check (12.94 per cent and 22.70 per cent respectively) [18]. Similarly, Nayak and Nayak [19] recorded lowest incidence of leaf folder, brown plant hopper and whorl maggot in organic plots compared to both purely inorganic and combination of organic and inorganic nitrogen fertilizer sources. Percent increase of leaffolder, BPH and whorl maggot was 220.00, 326.76 and 147.72 per cent in purely nitrogen fertilizer source treatment. Our study recorded higher natural enemies recorded in *Bacillus* treated rice (Fig. 3), Similar results were reported by Paramasiva et al. [18] reported that natural enemy populations significantly ($P<0.01$) increased with organic treatments compared with the check i.e, ranged from 21.5 to 23.5 per hill with the organic treatments and 14.75 per hill with the check. Further, a total of 3,306 individuals belonging to 45 species of aquatic insects representing 30 genera, 20 families, and 7 orders were collected. However, the order Hemiptera was found to be most abundant contributing 28.89% of the total number of insects recorded, afterwards Diptera (24.80%), Coleoptera (24.41%), and Odonata (21.42%) were found as abundant [20]. Likewise, Ikhsan et al., [21] sampled rice ecosystem using four different methods such as sweep net, pitfall trap, malaise trap and yellow pan trap. They caught 4,701 individuals of insects constituting of 319 species representing 39 families of Hymenoptera. The highest number of species were in families of Braconidae, Formicidae, Scelionidae and Ichneumonidae, while the highest number of individuals were recorded in the families of Braconidae, Diapriidae, Scelionidae and Formicidae. Further, in a sampling during two planting seasons at 44, 52 and 66 DAT shown that the species richness in non-organic rice field was 7 to 13 species. In contrast, organic rice plot shown 22 to 33 species. In addition to that, the species evenness and heterogeneity in the organic fields were generally higher than those in the non-organic rice fields in the both seasons [22]. Hashim et al., [23] collected insects using sweep net and light trap methods. A total of 1936 insects comprising 28 species, 19 families and 7 orders were collected. 25 species of 19 families and 17 species of 13 families of were trapped during day and at night, respectively. Coleopterans with *Micraspis crocea* (223) from Coccinellidae and *Nilaparvata lugens* from Delphacidae (258) were dominant during day and night time, respectively. Order Odonata shown the highest diversity index (H'= 1.2587) whereas, Coleoptera has shown the higher richness index (Margalef = 5.8390) values for diurnal insect. Order Hemiptera has recorded the highest values for both diversity index (H'= 1.2655) and Margalef richness index (5.8390) for nocturnal insect.

4. CONCLUSION

The results of the present study shown the increased abundance of natural enemies of Hemiptera and Hymenoptera with reduced insect pest incidence due to complete avoidance of chemical pesticides. So that, this study giving complete package for keeping the pests below ETL through natural regulation of insect pests by supporting diversity and conservation of natural enemies.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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 writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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