Journal of Biological Control, 38(1): 87-91, 2024, DOI: 10.18311/jbc/2024/36394

Research Note

Comparing various bio-intensive pest management modules in rice

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ABSTRACT: Rice is the key cereal crop in the tropics, supporting diverse pests and natural enemy populations. Recurrent pest outbreaks and yield losses led farmers to rely on extensive insecticide application, disturbing the stability of rice ecosystems and increasing residues in the harvestable products. A study has been conducted to assess the impact of various modules of Bio-Intensive Pest Management (BIPM) on its conservational potential and sustainability in comparison with Farmers' Practices (FP) in Nalgonda district of Telangana state during *kharif*-2020. The BIPM practices included application of farm yard manure; rice husk ash; clipping of seedlings; alleyways and weekly release of *Trichogramma japonicum* in the main field; wet seed treatment and foliar application with *Pseudomonas fluorescens* (BIPM 1), *Trichoderma asperellum* strain TAIK1 (BIPM 2) and *Bacillus cabrialesii* strain BIK3 (BIPM 3). Whereas, FP 1 with need-based insecticide spraying and FP 2 with schedule-based insecticide spraying and Untreated control with (UC) with no intervention. The observations were taken by visual counts at 15-day intervals. The incidence of *Cnaphalocrocis medinalis* was highest in UC (9.50), followed by BIPM 1 (7.25) and least in FP 2 (2.50) whereas the highest mean population of *Apanteles* sp. was found in the untreated control (13.75), followed by BIPM 3 (9.50) and least in FP 2 (4.25). The Benefit Cost Ratios (BCR) of BIPM 3 (1.68) were highest followed by BIPM 1 (1.64) and least in FP 2 (1.40) elucidating that BIPM practices can be more economically feasible. The Shannon-Wiener Index for species diversity and species evenness was higher in BIPM treatments as compared to farmers' practices indicating the potential of these BIPM treatments in natural pest control and maintaining crop ecosystem stability.

KEYWORDS: BIPM, *Bacillus cabrialesii,* farmers practices, *Pseudomonas fluorescens*, *Trichoderma asperellum*

(Article chronicle: Received: 29-01-2024; Revised: 27-03-2024; Accepted: 30-03-2024)

Rice has been an Asian staple for over a millennium. Its submerged ecosystems support a greater biodiversity, including destructive pests and affluent natural enemy complexes. Rice is host to more than 128 species of insects of which,15 to 20 species are economically important, including brown plant hopper *Nilaparvata lugens* (Stal.), stem borer, *Scirpophaga incertulas* (Walker) and leaf folder *Cnaphalocrocis medinalis* (Guenee) (Kalode, 2005). Insect pests are one of the major limiting factors for rice production and result in low yields (Matteson, 2000) and accounting for about 27.9 per cent yield losses in India (Mondal *et al.,* 2017).

The growing population and need for food security, coupled with losses due to insect pests, drove farmers to rely excessively on synthetic insecticides. The ceaseless mono-culturing and ignorant use of pesticides have resulted in a great loss of natural arthropod diversity and ecosystem services. Over 98% of sprayed insecticides reach a destination other than the target species (Miller, 2004) leading to the emergence of pesticide resistance in almost all the major insect pests, environmental toxicity, pollution of water bodies and depletion of rhizosphere microflora, food safety hazards and human health concerns, etc., (Singh, 2012). Pesticides also have negative impacts on soil and water micro-flora and fauna. Nitrogen mineralizing bacteria and other beneficial fungal populations were negatively impacted by repeated application of pesticides (Kumar *et al.,* 2017).

BIPM can be a way forward to overcome the drawbacks of conventional rice production methods (Kaur *et al.,* 2007; Aggarwal *et al.,* 2016). Management systems that increase diversity in agroecosystems can extend the action of natural enemies of pests (Acosta *et al*., 2015). The use of biological control agents, including *Trichogramma* sp. has been the mainstay of IPM and is effective in controlling major rice pests (Bade *et al.,* 2006; Karthikeyan *et al.,* 2007; Senthil-Nathan *et al.,* 2006). The addition of *Pseudomonas fluorescens* strains to rice fields in India resulted in a 3-fold reduction of *C. medinalis* damage and influenced the predatory insects or parasitoids performance (Commare *et al.,* 2002; Saravanakumar *et al.,* 2008; Gadhave *et al.,* 2016). The following study was undertaken to understand the impact of various biointensive pest management packages on the pests, natural enemies and yield levels in rice in comparison with the FP.

A field experiment was conducted with rice variety KNM-118 during *kharif* 2020-2021 in a farmer's field in Nalgonda district of Telangana state, India. The total area of five acres was divided into five plots each representing a treatment i.e., BIPM 1, BIPM 2, BIPM 3, FP 1 and Untreated Control (UC). FP 2 is the plot from a neighbouring farmer. Further, these plots were divided into four blocks each representing a replication.

The BIPM practices included wet seed treatment (10g/Kg seed) and foliar application (20g/L of water) with *Pseudomonas fluorescens* (BIPM 1), *Trichoderma asperellum* strain TAIK1 (BIPM 2) and *Bacillus cabrialesii strain BIK3* (BIPM 3). The application of farm yard manure in the nursery (1Kg/m^2) and main field (5 tones/hectare); rice husk ash in the nursery (100g/m^2); clipping of seedlings; bird perches (4/treatment) and weekly release of fifty thousand adults of *Trichogramma japonicum* per treatment starting from 25 days after transplanting was followed in BIPM modules. Whereas the farmer's practice 1 (FP 1) followed recommended package of practices, need-based application of insecticides like carbofuran 3G @ 7-8 kg/ acre, Cartap hydrochloride 4GR @ 10 kg/ acre and farmer's practice 2 (FP 2) consisted of recommended package of practices, schedule based application of insecticides like carbofuran 3G @ 7-8 kg/ acre, Cartap hydrochloride 4GR @ 10 kg/ acre, Imidacloprid 17.8 SL @ 100 ml/acre and Pexalon @ 100 ml/ acre as decided by the farmer. There was no intervention in untreated control. The observations were taken by visual counts from quadrat (1m^2 area) at fifteen-day intervals after transplanting during the season for pest and natural enemy abundance and damage levels.

Statistical analysis

The data for pest and natural enemy abundance was suitably transformed and analyzed using ANOVA- RBD with 6 treatments having 4 replications each. The mean incidence was ranked using Dunken's mean range test through the OP-STAT online tool (Sheoran *et al.,* 1998). The data was analyzed for Diversity and Evenness using the online Biodiversity calculator BPMSG.

Insect pest abundance

The BIPM 1 and BIPM 3 were on par and recorded the highest incidence of leaf folder larvae with a mean population of 14.75 and 13.50 individuals per quadrat followed by BIPM 2, UC, FP 1 and least in FP 2 with a mean population of 9.25, 8.75, 7.00 and 5.50, respectively (Table 1). Though the incidence of pests like rice skipper, BPH, GLH, etc., were recorded they were far below the Economic Threshold Levels (ETL) and comparatively less abundant in BIPM treatments (Table 1).

The per cent damage caused by *C. medinalis* was highest in UC (10.52 %) followed by BIPM 1 with (7.03%), and least in FP 2 with 2.39%. The treatments did not differ significantly for damage caused by yellow stem borer (% white years) and per cent dead hearts were recorded across the treatments below ETLs (Table 2). Sharma *et al.,* (2018) observed that the mean leaf folder damage was 3.12, 1.90 and 5.41 per cent in BIPM, farmer's practice and untreated control, respectively. Saravanakumar *et al.* (2008) reported that the percentage of leaf folder damage in the *Pseudomonas* treated plot (4.71% at

Table 1. Insect pest incidence in different treatments

Treatments	BIPM 1	BIPM 2	BIPM 3	FP 1	FP 2	UC	CD (0.05)
Rice leaf folder	14.75 (3.97) ^{a}	9.25 (3.20) ^{b}	13.50 (3.81) ^{a}	7.00 (2.83) ^{c}	5.50 (2.54) ^{d}	8.75 (3.12) ^{b}	0.22
Rice skipper	0.50 (1.21) ^{bc}	0.00 (1.00) ^{c}	0.50 (1.21) ^{bc}	1.00 (1.41) ^{ab}	0.00 (1.00) ^{c}	1.25 (1.49) ^{a}	0.22
Rice cutworm	0.00 (1.00) ^{c}	0.75 (1.31) ^{b}	1.00 (1.41) ^{b}	2.25 (1.80) ^{a}	0.00 (1.00) ^{c}	2.00 (1.73) ^{a}	0.15
Brown plant hopper	0.25 (1.10) ^{c}	1.25 (1.49) ^{b}	1.25 (1.49) ^{b}	3.75 (2.18) ^{a}	1.75 (1.65) ^{b}	3.75 (2.18) ^{a}	0.25
Green leaf hopper	0.00 (1.00)	0.50 (1.21)	0.25 (1.10)	0.25 (1.10)	0.00 (1.00)	0.75 (1.31)	N/A

*Mean of four observations (visual counts from quadrat)
Figures in parenthesis are square root transformed values of insect pest abundance. Values in the row with the same alphabet superscript are not statistically different
(BIPM = Bio Intensive Pest Management; FP = Farmer's Practice; UC = Untreated Control; CD = Critical Difference at $p < 0.05$; N/A= Not Applicable).

Table 2. Per cent damage caused by leaf folder and yellow stem borer incidence in different treatments

Treatments	BIPM 1	BIPM 2	BIPM 3	FP 1	FP 2	UC	CD (0.05)
% damage by leaf folder	7.03 (15.17) [b]	4.37 (11.99) [c]	6.22 (14.42) [bc]	6.13 (14.29) [bc]	2.39 (8.80) [d]	10.52 (18.84) [a]	2.74
Stem borer (%Dead hearts)	1.86 (7.55) [a]	1.91 (7.76) [a]	2.00 (8.05) [a]	2.40 (8.91) [a]	0.25 (1.43) [b]	2.11 (8.33) [a]	2.46
Stem borer (%white ears)	0.63 (4.24)	0.65 (4.60)	0.47 (3.72)	0.17 (2.11)	0.25 (1.43)	0.35 (3.26)	N/A

*Mean of four observations (visual counts from quadrat)
Figures in parenthesis are angular transformed values for per cent damage. Values in the row with the same alphabet superscript are not statistically different.

75 DAT) was less as compared to untreated control (23.59% at 75 DAT) and the per cent damage in the pesticide-treated plot was 4.35% at 75 DAT.

Natural enemy abundance

The arthropod natural enemies like Braconids (*Apanteles* sp.) had the highest mean population in UC (13.75 per quadrat), followed by BIPM 3 (9.50 per quadrat) and least in FP 2 (4.25 per quadrat). The mean population of Ichneumonids, Carabids, Tetragnathids and Lycosids was found to be significantly highest in BIPM treatments with 1.00 to 1.25, 2.00 to 4.50, 28.00 to 42.00 and 35.00 to 36.50 individuals per quadrat during the season as compared to FP treatments and UC (Table 3). Commare *et al.,* (2002), reported that BIPM treatment with *Pseudomonas* sp. recorded a comparatively higher number of hymenopterans like *Apanteles* sp. (5-9 insects) whereas chemical-treated plots (0-2) had fewer insects per trap. *Xanthopimpla* sp. (Ichneumonidae) was found to cause significantly higher parasitism in organic (1.93%) than in conventional fields (0.60%) on leaf folder pupae (Sharma *et al*., 2018). Anitha and Paimala, 2014, observed similar results, that BIPM practices elevated the incidence of natural enemies like *Ophionea indica* (Carabidae). The results obtained by Aggarwal *et al*., 2016 and Anitha and Parimala, 2014 corroboration our studies where *Tetragnatha* and *Lycosid* species were the dominant spiders observed and higher numbers were seen in BIPM plots compared to conventional rice plots.

The heavy rainfall conditions of *kharif* season resulted in natural zoonosis of leaf folder larvae, with the highest number of diseased larvae being observed in UC (9.50 per quadrat), followed by BIPM 1 (7.25 per quadrat) and least in FP 2 (2.50 per quadrat) (Table 3). Entomopathogenic fungi, *Beauveria bassiana, Metarhizium anisopliae* and Granulosis virus were found infecting leaf folder larvae at later instars. Previous reports have shown that *Metarhizium* sp. and *Beauveria* sp. were effective against various stages of lepidopteran pests in the field (Kirubakaran *et al.,* 2014). The leaf folder suppression by entomopathogenic fungi and granulosis virus in BIPM treatments has not been addressed so far in earlier studies.

Diversity indices of natural enemy populations

The calculated Shannon-Wiener Index (H’) (Shannon, 1948) for diversity indicates that the diversity of arthropod natural enemy species present in BIPM 3 (2.44) is highest followed by BIPM 1 (2.20) and BIPM 2 (2.14) and the FP 2 (1.75) treatments are least diverse among the treatments. The Pielous’s Index (J) for evenness indicates how evenly the species are distributed in a particular habitat (Pielou, 1966). The BIPM treatments have a more even distribution of species as compared to FP 1, FP 2 and UC (Table 4). The studies conducted by Raut *et al.,* (2023) recorded less natural enemy diversity (odonatan and hymenopteran) in plots sprayed with Chlorpyriphos and methyl parathion when compared to unsprayed plots. They also reported that the plots sprayed with Cartap hydrochloride were on par with the unsprayed plots for the diversity of predator population and species evenness supporting the results obtained for FP 1 where need-based application of Cartap hydrochloride was followed (Table 4).

The benefit-cost ratio of various treatments

The treatment BIPM 3 recorded the highest yields with 3.39 tonnes per acre, followed by BIPM 1 (3.31 tonnes per acre), FP 1 (3.12 tonnes per acre), BIPM 2 (3.10 tonnes per acre), FP 2 (2.82 tonnes per acre) and least in UC with 2.65 tonnes per acre. The economics of crop production of various treatments in the *kharif* season showed that the maximum BCR was observed for BIPM 3, with a BC ratio of 1.68, followed by BIPM 1 with 1.64. The treatments BIPM 2, FP 1, FP 2 and UC had a BCR of 1.54, 1.55, 1.54, and 1.44 respectively (Figure 1). Sharma *et al*., (2018), also reported that BIPM modules had an increased yield of about 11.48% over the untreated control. The net returns were also highest in BIPM plots (Rs. 69008/- per ha), followed by the farmer’s practice module (Rs. 59238/- per ha) and untreated control (Rs. 528728/- per ha). The BIPM plots yielded 4.60 tonnes per hectare as compared to farmers’ practice with 3.10 tonnes

Table 3. Mean population of different natural enemy families and number of diseased leaf folder larvae in different treatments

Particulars	BIPM 1	BIPM 2	BIPM 3	FP 1	FP 2	UC	CD (0.05)
Braconidae	8.75 (3.12) ^{b}	8.50 (3.08) ^{b}	9.50 (3.24) ^{b}	5.00 (2.45) ^{c}	4.25 (2.29) ^{c}	13.75 (3.83) ^{a}	0.27
Ichneumonidae	1.00 (1.41) ^{a}	0.00 (1.00) ^{b}	1.25 (1.49) ^{a}	0.25 (1.10) ^{b}	0.00 (1.00) ^{a}	0.75 (1.31) ^{b}	0.20
Carabidae	4.50 (2.34) ^{a}	2.00 (1.73) ^{c}	3.00 (2.00) ^{b}	1.50 (1.57) ^{c}	0.25 (1.10) ^{d}	3.25 (2.06) ^{b}	0.21
Libellulidae	1.00 (1.39) ^{b}	1.00 (1.41) ^{b}	1.25 (1.49) ^{b}	1.75 (1.64) ^{ab}	1.00 (1.41) ^{b}	2.75 (1.91) ^{a}	0.36
Coenagrionidae	2.00 (1.73) ^{bc}	2.00 (1.72) ^{bc}	2.75 (1.93) ^{b}	2.00 (1.73) ^{bc}	1.25 (1.49) ^{c}	4.50 (2.34) ^{a}	0.23
Tetragnathidae	42.00 (6.56) ^{a}	39.25 (6.34) ^{b}	28.00 (5.38) ^{c}	23.50 (4.95) ^{d}	13.00 (3.74) ^{e}	39.50 (6.36) ^{b}	0.20
Lycosidae	36.50 (6.12) ^{a}	35.50 (6.04) ^{ab}	35.00 (6.00) ^{b}	24.75 (5.07) ^{c}	10.75 (3.43) ^{d}	34.23 (5.94) ^{b}	0.11
Diseased leaf folder larvae	7.25 (2.80) ^{ab}	4.38 (2.25) ^{bc}	4.13 (2.20) ^{bc}	5.13 (2.46) ^{bc}	2.50 (1.86) ^{c}	9.50 (3.23) ^{a}	0.63

*Mean of four observations (visual counts from quadrat)
Figures in parenthesis are square root transformed values for diseased larvae and natural enemies' populations. Values in the row with the same alphabet superscript are not statistically different.

Table 4. Diversity indices of natural enemy populations in different treatments

Diversity indices	Shannon-Wiener Index(H')	Pielou's Index(J)
BIPM 1	2.20	0.75
BIPM 2	2.14	0.70
BIPM 3	2.44	0.79
FP 1	1.83	0.65
FP 2	1.75	0.64
UC	1.92	0.68

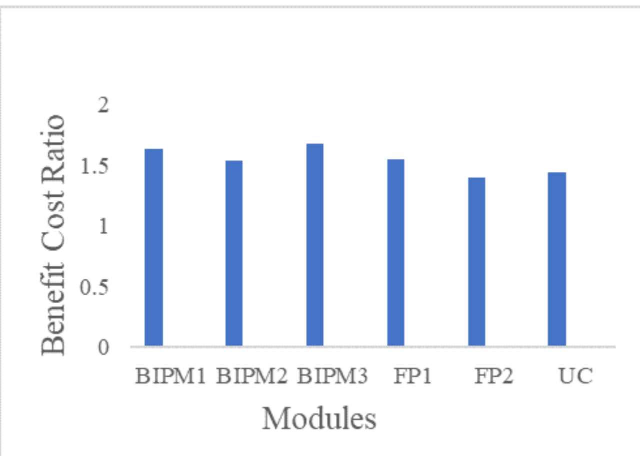

Figure 1. Benefit cost ratio of different treatments.

per hectare and chemical-based management plots with 4.40 tonnes per hectare (Mohapatra, 2008). Saravanakumar *et al.,* (2008) concluded that the grain yield (tonnes/hectare) is 5.46, 5.14 and 4.59 in Pseudomonas-treated, pesticide-treated and untreated control respectively. Borkakati and Das (2016) recorded higher yields in BIPM plots (4086kg/ha) as compared to 3672 kg/ha in farmers' practices.

Many studies have indicated that the *in-situ* conservation of natural enemy populations will lead to enhanced biological control. The BIPM strategies followed in our study have a great impact on improving natural enemy abundance and diversity which in turn led to harnessing the ecological services in a better way to obtain higher output with minimal investments. Further, the application of plant growth-promoting microbes like *Pseudomonas* sp., *Bacillus* sp. etc., were known to improve the below-ground biodiversity thus improving the soil health and had contributed to increased yield in the BIPM modules. A shift from conventional crop production to BIPM methods which are eco-friendly and sustainable can only assure the stability of farming communities in the long run.

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