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The role of floral strips on arthropod population dynamics in rice ecosystem

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Abstract

Background

Floral strips at field margins are well known to attract and support natural enemies of insect pest populations to reduce pest pressure in agroecosystem. While the benefits of floral strips have been widely studied in many crops, their role in rice-based ecosystems remains largely unexplored. We performed a field experiment using four rice varieties to investigate the role flower species Rongon (*Ixora coccinea*), Allamanda (*Allamanda cathartica*), Hasnahena (*Cestrum nocturnum*) and Madhobilota (*Hiptage benghalensis*) established as floral strips adjacent to rice plot on arthropods population dynamics. Herbivorous and predatory arthropods were sampled from each plot every seven days from vegetative to reproductive maturity. Arthropods communities were categorized according to taxonomic groups. Data on pollinator attraction towards floral species were recorded through visual count. Rice bug and rice stem borer infestation and yield parameters were also recorded.

Results

The abundance and diversity of Orthopterans, Hemipterans and Dipteran were reduced significantly with floral strips than control plot. Coleopterans population also decreased with floral strips but species-specific. The predatory Arachnids population increased with flower strips suggested that addition of flower resources benefits predators over control. Principal component analysis summarized that flower species distinctly separated arachnids and pollinators communities. Rice stem borer (% whiteheads) and rice bug (%) infestation also reduced with flower strips than control but differed among varieties. Dry grain weight increased with floral strips than control plot across varieties.

Conclusion

Our research has wider application to promote conservation biological control to reduce insecticides application for the management of herbivorous insects in rice agroecosystem.

Background

The integration of cultural pest management approaches with ecological principles is becoming popular as an effective pest suppression strategy. It involves designing ecosystems that support natural enemies of insects and pests by providing habitats and access to natural food resources (Gurr et al. 2011). A well-designed agroecosystem increases and stabilizes the conservation biological control of pests providing diverse habitats, supporting natural enemy populations, and enhancing ecosystem resilience (Geoff. Gurr et al. 2015; Hassan et al. 2016). Among different agroecosystem improvement strategies, enhancement of floral resources or addition of flower strips directly facilitates natural enemies and pollinators to access adequate pollen, nectar, and sugar (Kowalska et al. 2022). These

additional resources, alongside main crops, ensure a continuous food supply throughout the growing season. As a result, natural enemies reproduce more and live longer, increasing their population over harmful insects. Therefore, the dominance of the natural enemy population reduces pest abundance in agroecosystems through natural predation.

Rice fields are home to a variety of beneficial insects in addition to insect pests. These are either parasitoids or predators and together referred to as natural enemies. In general, egg parasitoids (*Trichogramma* sp. *Telenomus* sp. and *Tetrastrichus* sp.) and predators (earwigs, beetles, mirid bugs, and spiders) have been employed extensively as biological control agent (Heinrichs, 1994, Chakraborty, 2012). The ecosystem services from natural enemies as biological control reached about $ 4.5 billion per year globally (Fiedler et al. 2008; Losey & Vaughan, 2006). Natural foes like spiders and dragonflies help control pests such the rice stem borer and planthopper in rice habitats (Chaitanya et al. 2024). Natural enemies greatly decrease insect numbers, which helps to reduce use of chemical pesticides and thereby lowers related environmental and health concerns (Snyder & Ives 2003). Predators and parasitoids might target a pest at different times while it is present in the field (Wilby et al.2002), which can reduce it more effectively than a single enemy species (Snyder et al. 2003). This approach directly benefits farmers by minimizing pesticide costs and reducing health hazard (Benton et al. 2003). In addition, it indirectly minimizes insect pests being resistant to pesticides for secondary outbreaks and protect other components of environment from degradation. However, application of such approach especially in rice ecosystems is very limited due to intensive monocropping as well as less familiar with this technique in most of the rice growing countries in the world especially in Bangladesh (Lu et al. 2014 but see details in Westphal et al. 2015).

Rice is the staple food crop of Bangladesh, playing a crucial role in food security and economy. However, rapidly growing population is exerting immense pressure on rice production, leading to concerns about meeting future food demands. The continuous cultivation of rice monocropping increased pest resistance and conventional control methods became less effective. In general, farmers rely heavily on synthetic insecticides, as these provide quick and visible results in managing rice pests. Hence alternative options are required to insecticide dependency while ensuring sustainable pest management. The alternation of rice-based ecosystems to promote natural enemies of insect pests could be a promising option to overcome these challenges. However, due to intensive monocropping practices and farmers limited knowledge on integrated pest management techniques in rice growing areas in Bangladesh, the adoption of conservation biological control is not popular. In Bangladesh, agroecosystem is unfavorable for the natural enemies due to intensification of agricultural practices, high agricultural inputs such as imbalanced pesticides and fertilizers application, and disturbance by human activities. Hence, inclusion of flower strips could be an alternative and sustainable pest management approach in Bangladesh. Flower strips and hedgerows, which are usually planted along field boundaries, provide pollinators and natural enemies with food, shelter, oviposition sites, and overwintering chances (Tschumi et al. 2015; Holland et al. 2016; Kremen et al. 2019).. For example, one of the previous reports suggested that field margin crops increased the parasitoids populations that successfully controlled 60% of Lepidopteran insect pests in rice field (Landis & Menalled 1998).

However, research has been very limited in how addition of flower strips reduces the abundance and diversity of major rice insect pests as well as how selections of various floral resources influence the natural enemies and pollinators, respectively.

The concept of introducing flower strips has been intensively looked at other crops, especially vegetables and fruits (Aminatun et al. 2023; Campbell et al. 2017). However, despite compelling arguments that the addition of flower strips can enhance natural enemies of insect pests in agroecosystem, relatively few studies have explicitly examined this approach on rice-based system. To better understand how flower strips function as floral resources for natural enemies, we performed a field study using four distinct transplant Aman rice cultivars viz: BR-11, BR-51, BR-94 and Ranjit (traditional variety) providing flower strips around the plot temporarily and control plot (without providing flower strips). We selected these varieties due to their availability and commonly cultivated in farmer's field during Aman season. We hypothesize that addition of floral resources likely to provide additional food and habitat for natural enemies, especially for predators and parasitoids to increase their abundance and diversity. We hypothesized that addition of floral strips may reduce the insect pest population abundance and diversity than control plot due to increase natural enemy density. We also hypothesized that addition of floral strips may also increase the pollinator attraction that may promote pollination services as well as increase their hibernation sites.

Methodology

Experimental site, design, and treatments

The common garden field experiment was conducted at Entomology field laboratory, Sylhet Agricultural University, Bangladesh from August 2024 to January 2025. We tested three transplant Aman rice varieties: BR-11, BR-51, BR-94 released from Bangladesh Rice Research Institute (BRRI) and a traditional locally variety Ranjit that commonly cultivated by farmers. Seedlings of each Aman rice variety were raised in a nursery bed, and two-month-old seedlings were transplanted in the plots at 40 cm hill spacing and 40 cm row spacing. The plot size was 4 m in length and 4 m in width and the distance between plot to plot was 1 m. The total number of hills per plot was ~ 180 consisting of 3–4 plants/hill. Plots were prepared after removing all weeds and stubbles manually and required amount of cow dung and other key essential nutrients such as N, P, K, were added @ 300Kg/ha Urea, 100Kg/ha Ammonia and 120Kg/ha Potassium, respectively. The amount added to per plot was 480 gm N/plot, 330 gm P/plot and 390 gm K/plot at 15 days interval for three times during crop growing stage. The plot size should need to bigger, unfortunately with the land provided by university only able to accommodate maximum number of plots with satisfactory replication within this size. However, to overcome any potential error by flower strips treatments with control especially for fast mobile herbivores, natural enemies and pollinators, a net barrier was established between the plots with floral strips and control.

The four non-crop flowering hosts Rongon (*Ixora coccinea*), Allamanda (*Allamanda cathartica*), Hasnahena (*Cestrum nocturnum*), and Madhobilota (*Hiptage benghalensis*) were selected from a

commercial nursery. The collected plants were directly transplanted in previously prepared pot (size; 45.7 × 45.7 × 37.7 cm). The pot was filled with 30 L garden soil and prepared one week earlier before transplanting (the reason for using pot was the restriction of the establishment of permanent flowering strips by department as premises need to use by different faculty by rotation). The perennial flower plants were selected based on their unique color, fragrance, and suitable phenological characteristics after screening > 100 non-crop flowering hosts. The Rongon and Allmonda produced red and yellow big color flower with attractive floral scent. On the other hand, the Hasnahena and Madhobilota produced small but white and red color flower with strong floral scent. One month after rice seedlings were transplanted, sixteen potted plants (four individuals from each species) were placed around the plot (Fig. 1). The other sets of experimental plots did not receive any flowering plants. In total there were 24 plots (2 flowering treatments · 4 varieties · 3 replicates) in this experiment. We installed net barrier between the plot with flower strips in one part of the field and without flower or control in other part of the field to reduce the effects of flowering treatments in adjacent control plot.

Insect sampling

The abundance and diversity of key arthropod communities usually found in rice ecosystems belonging to the orders Coleopterans, Dipterans, Hemipterans, Lepidopterans, Orthopterans and Arachnids were collected every 7 days interval between 10.00 am to 13:00 pm from early vegetative stage to harvesting of the rice grains using aerial sweeping nets. We targeted to collect data on key predator species-Lady beetle, Mirid Bug, Rove beetle, Parasitic Wasp and Spiders and herbivores- Rice yellow stem borer, Rice bug, Rice Hispa, Brown Plant Hoppers, Green Leaf Hopper and Rice gall midges. However, the presence of Lady beetle, Mirid Bugs and Rove beetle were absent in many plots or remain low in number during the experimental data collection.

The sweeping was done three times per plot in a single day to collect maximum number of arthropods present in the plots. Data were summed across all observational time points and presented in number of individuals per plot. Pollinators abundance and diversity were also collected to understand the foraging behavior of key pollinators (honey bee, butterfly, solitary bee etc.) on floral strips every 7 days between 10:00 am to 13.00 pm. Each plot was observed 10 minutes for pollinator foraging behavior and summed across plot and presented as number of individuals visited per floral species. Major insect infestations in rice such as % stem borer infestations (% whiteheads/plot as proxy), % rice bug infestations and % unfilled grains were also recorded at seven days intervals and summed all time points and presented as % infestations per plot. Due to low availability of other herbivorous insect belongs to Lepidoptera compared to rice yellow stem borer, data presented as % rice yellow stem borer (RYSB) infestation per plot instead of taxonomic group Lepidoptera. Moreover, RYSB is the most key and destructive caterpillar in rice agroecosystem. The yield parameters such as shoot and root biomass were recorded after oven-dried at 70°C for 7 days. The dry grain weight (g) was recorded after two weeks of sun drying of rice grain.

Statistical analysis

All data were analyzed with R studio version 4.1.5 (R development core team, 2025). All data were checked for normality and homogeneity using Q-Q and residuals plots before being analyzed. To see the overall effects of floral resources and variety arthropod community abundance summarized in different taxonomic groups- Arachnid, Coleoptera, Diptera, Hemiptera, Hymenoptera and Orthoptera were analyzed with function glmm using Poisson family distribution where plot used as random factors and floral species and variety as fixed factors in the model. Pairwise comparisons were performed to see the significant difference with or without flower strips within variety using R packages 'emmeans' (Length, 2018). To explore further patterns in arthropod communities in response to floral strips and variety, we performed Principal Component Analysis (PCA) using 'factoMineR' and 'factoextra' pacakages from R free software. For further analysis to explore any separation among floral species based on pollinator abundance (summarized as honey bees, solitary bees, bumble bees, butterflies and other pollinators), PCA analysis was also performed based on the correlation matrix using 'factoMineR' and 'factoextra' packages from R free software. Data such as % RYSB infestation, % rice bug infestation, biomass (g) /plant, and grain weight (g)/plot were analyzed with linear mixed effect model (lmer) where variety and floral strips and their interaction effects were used as fixed factors and plot used as random factors (Bates et al. 2014). Pairwise comparisons were performed to see the significant difference with or without flower strips within variety using R packages 'emmeans' (Length, 2018).

Results

Arthropod community abundance and distribution in relation with floral resources and variety

The abundance of predatory Arachnid was significantly increased with floral resources than control and it remain consistent for varieties (Table 1; Fig. 2a). The Coleopteran herbivore was reduced while floral resources present than control however, only found significant in BR-11 and BR-51 (Table 1; Fig. 2b). There were significant main effects were found on Dipteran flies with floral resources and number of individuals per plot remain significantly lower with floral treatment than control (Table 1; Fig. 2c). The population of Hemipteran sucking herbivores-BPH and GLH were significantly affected by floral resources and remain significantly higher in control than floral strips treatment (Table 1 Fig. 2d). The availability of Hymenopteran population affected by the interaction with floral resources and variety (Table 1). The number of individuals per plot was increased significantly with floral resources but specific to variety BR-11 (Fig. 2e). The Orthoptera mostly grasshopper cover more than 50% insect population in the experimental field (Fig. 2f). The number of Orthoptera were significantly reduced due to the addition floral resources than control and it is significantly higher in control across four varieties (Table 1; Fig. 2f).

Table 1
Summary of the output of General Linear Mixed Model (GLMM) on arthropods communities. Model was run using floral resource (Fr) and variety (Var) and their interaction as fixed factor and plot as random factor. The chi-square (χ^2) value and corresponding P-value presented from model output.

Model	Floral resource (Fr)	Variety (Var)	Fr*Var
Arachnids	$\chi^2 = 30.95$, *P < 0.001*	$\chi^2 = 2.74$, *P = 0.43*	$\chi^2 = 2.21$, *P = 0.52*
Coleoptera	$\chi^2 = 7.63$, *P < 0.001*	$\chi^2 = 13.97$, *P < 0.001*	$\chi^2 = 6.12$, *P = 0.10*
Diptera	$\chi^2 = 52.70$, *P < 0.001*	$\chi^2 = 63.01$, *P < 0.001*	$\chi^2 = 3.21$, *P = 0.36*
Hemiptera	$\chi^2 = 303.41$, *P < 0.0001*	$\chi^2 = 16.35$, *P < 0.0001*	$\chi^2 = 24.38$, *P < 0.0001*
Hymenoptera	$\chi^2 = 0.41$, *P = 0.52*	$\chi^2 = 18.09$, *P < 0.0001*	$\chi^2 = 12.89$, *P < 0.001*
Orthoptera	$\chi^2 = 106.57$, *P < 0.0001*	$\chi^2 = 1.14$, *P < 0.001*	$\chi^2 = 8.43$, *P = 0.037*
DF	1	3	3

The principal component analysis-PCA suggested that presence of flower strips separated the arthropods communities. PC1 explained about 53.27% variation while PC2 represents 22.64% variation of the total arthropod communities (Fig. 3). The population of predatory Arachnids were significantly separated by flower strips that suggested predators remain plots with floral resources as hibernation sites including availability of food resources than control plot (Fig. 3).

Effects of flower species on pollinator abundance and diversity

In total 3781 pollinators were recorded in the field during the experimental period. Among pollinators 34.14% were honey bee, 19.07% wasp, 30.55% butterfly and 16.24% other minor pollinators respectively. The PC1 plot explained the 69.3% and PC2 plot explained 24.2% variation of total pollinator attraction towards floral species (Fig. 4). However, PCA plot showed distinct separation of pollinator choice for specific floral species suggested that pollinator attraction was variable with floral species. PCA plot showed that Allamanda and Madhobilata were significantly alter and separate the pollinators community than Hasnahena and Rongon (Fig. 4).

Effects of flower strip on insect infestation and grain yield

Our study suggested that there was reduction of percent rice bug and whiteheads (stem borer) infestations per plots with flower strips than control (Fig. 5a & 5c). The addition of flower strip reduced the formation of chaffy grain or unfilled grain than control due to reduction of rice bug infestation (Fig. 5b). The average biomass (shoot and root) production per plant was slightly increased in control than flower strip plots for BR-11 and BR-51 and opposite pattern found in Ranjit due to interaction

between variety and flower strips (Fig. 5d). Dry grain weight per plot significantly increased while floral strips present around the plot than absent due to the main effects of variety and floral resources (Fig. 5e). The dry grain weight was increased with floral strips than control irrespective to variety (Fig. 5e).

Discussions

Favoring natural enemies in agricultural systems is the goal of habitat management, an ecologically based method of conservation biological control (Landis et al. 2000). Introducing floral resources as flower strips in the crop field accelerates this process by attracting and supporting natural enemies near the crops. Previous studies found that providing flower strips in crop fields has significant positive outcomes in controlling insect pests, however, those studies were mostly confined to vegetable crops (Lu et al. 2014). Hence, we conducted this study to explore the role of flower strips on the abundance and diversity of major arthropods taxonomic groups and their level of infestations by key rice pests among transplant *Aman* rice varieties in Bangladesh. In addition, this study also investigated about the role of floral species on the abundance of predatory arthropods especially spider as well as attraction of pollinators communities in the plots.

Our study found that providing floral strips significantly reduced the number of individuals of rice insect pests belonging to major orders such as Coleoptera, Diptera, Hemiptera, and Orthoptera (Fig. 2). The reduction of harmful herbivorous insects was very consistent in Hemipterans pests especially sucking pests green leaf hopper (GLH) and brown plant hopper (BPH) (data presented as taxonomic group in Fig. 2d) that significantly reduced across the variety with floral treatments than control which is likely to be linked with increased abundance and diversity of predators such as Arachnids (Fig. 2a). Our results are in line with previous studies showing that diverse flower strips increase the Arachnids diversity, leading to increased predation and reduced hopper population in rice field (Ali et al. 2020, 2022; Yele et al. 2023). Another study also reported that addition of flower strips such as sesame flower increased predatory Mirid bugs population that prey on rice hopper (Zhu et al. 2014). Hence, in relation with previous and in this study, our inference is that addition of flower strips reduced key rice pests because floral species may provide foods for predatory arthropods such as nectars and pollen as well likely to support home for them in modified agroecosystems (Orre et al. 2007). However, in future studies, we need to give more attention to select diverse floral resources based on diversity in plant traits and nutritional parameters which may be able to provide sustainable benefits from flower strips to control rice insect pests through improving habitat infrastructures of rice agroecosystem.

Flower traits such as type, shape, size, fragment, and color influence the attraction and visitations of pollinators differently such as bees, butterflies and wasp (Liu & Huang 2013). In this study, we also investigate the pollinators attraction in relation with flower strips used in the rice field to see how the types of floral strips influence the pollinator attractions. Our study found that Allamanda and Madhobilata likely to be more influential floral resources to separate the pollinator communities while two other floral species had little role on the pollinator attraction (Fig. 4). Generally, flower strips that

consist of tall and attractive flowers with good sources of pollen, nectar and scented are more preferred by pollinators and parasitoids than small and less attractive and scented flowers (Aminatun et al. 2023; Bianchi & Wäckers 2008; Liu & Huang 2013). The floral species Allamanda produced large and yellow color flower that generally highly attractive for bees. In this study, almost 85 % bees were attracted to Allamanda due to its unique color and large flower shape The Madhobilata produced red but unique scented flower that also attracted more pollinators (Fig. 4). Our results are agreement with previous findings that found flower resources with attractive color and scent are more preferred by flower visitors and parasitic wasp than flower with less attractive and less sugar content (Bianchi & Wäckers 2008; Campbell et al. 2017; Kowalska et al. 2022). In our study, we have selected perennial flowering species which provided nectar and pollen for longer periods of time for flower visitors that considered key trait for the selection of floral species (Carrié et al. 2012). Previous study also found that the increase of parasitism depends on the longevity of parasitoids feeding on floral nectar from a plant for long periods of time even when the host was absent (Ali et al. 2023; Bianchi & Wäckers 2008). Our study suggested that the selection of best floral species with key influential floral traits a significant matter to success in conservation biological control in outdoor crop production.

Our study indicated that the level of infestation by rice bug and rice yellow stem borer (RYSB) likely to decrease with flower strips treatment than control. However, the level of reduction of infestation was specific to variety while some cases marginally statistically significant. There were many reasons that could support our findings. Rice bugs are commonly prey by Mirid bugs, parasitic wasp and wolf spider; however, the intensity of rice bugs attack is in milking stage while there may be less available predators and parasitoids to increase the predation of rice bugs eggs, larvae and adults (Van Den Berg & Soehardi 2000). A previous scientific study suggested that *Sesamum indicum* (Pedaliaceae) was well suited rice margin flowering crops that preferred by predatory mirid bugs(Zhu et al. 2014) which we did not use in this study. The similar trend also found in rice yellow stem borer as they are internal feeder, and very hard for parasitoids to find and parasitize them due to appropriate time for the occurrence of RYSB with availability of flower resources (Rahaman & Stout 2019). Hence, the importance of selecting suitable nectar producing flowering crops including the best time for availability of flowering likely to be crucial point to use floral strips as conservation biological control of insect pests.

Plant biomass increased with flower strip but specific to variety (especially in BR-11 biomass was significantly lower in flower strips than control). Previous study found that presence of flower strips reduced the feeding of leaves by chewing and sucking herbivore due to increase parasitism rate than control, hence may increase plant biomass (Tschumi et al. 2015; Willcox et al. 2024). Currently, rice production has been decreased due to high percentage of unfilled grain in Bangladesh (BBS 2024). The formation of unfilled grain may cause due to heavy infestation by rice bugs, rice hispa and nutritional deficiency. Our study found a decreased pattern of percent unfilled grain production among the varieties when flower stipes presents than control. Our results supported by many previous studies that documented flowering plants increased the pollination efficiency through increasing the visitation by pollinators as well as reduced the insects damage especially caterpillars and other hemipteran insects such as aphids, bugs, and whiteflies due to increase the predators and parasitoids visitations in the crop

field (Tschumi et al. 2015; Willcox et al. 2024). Increased pollinators and parasitic wasp attractions and visitations may reduce the unfilled grains apart from the rice bug infestations in this study (Fig. 4).

Our study provided a unique data of how we can manage rice insect pests through habitat management. More specifically, our study showed that incorporation of floral strips (part of habitat management) reduced herbivorous insect pest density of rice for major taxonomic orders of insects thorough improving habitat infrastructures that enhance natural enemy population density and their predation efficiency. Our study more broadly light-up that providing non-crop hosts benefited predator densities especially Arachnids abundance that likely to directly contributed to reduce insect pests of rice especially Coleoptera, Diptera, Hemiptera, and Orthoptera. Consequently, this increased grain yield per plot with floral strips than control. Our study provided knowledge on the necessity of agroecosystem management for farmers to increase natural enemies for the reduction of rice pest population density. This study thus helps to reduce the application of chemical insecticides and ensure safe production of cereals crops in Bangladesh.

Abbreviations

ANOVA
Analysis of Variance
BRRI
Bangladesh Rice Research Institute
BPH
Brown Plant Hopper
BR
Bangladesh Rice
F
Floral strips
GLH
Green Leaf Hopper
GLMM
General Linear Mixed Model
PCA
Principal Component Analysis
Q-Q plot
Quantile-Quantile plot
RYSB
Rice Yellow Stem Borer
Tukey HSD
Tukey’s Honestly Significant Differences
V
Variety

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

All authors carefully reviewed and approved the manuscript for peer review and publication.

Availability of data and material

Data are deposited in figshare.com and can be available through private link (https://figshare.com/s/7a4b8e08dd40ff06cf19)

Competing interests

The authors declare no conflicts of interest.

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Authors' contributions

Kamrul Hassan: conceptualization, funding acquisition data curation, investigation, methodology, visualization, writing—original draft preparation, writing—review and editing. **Md Fuad Mondal:** conceptualization, data curation, writing—review and editing. **Palash Mondal:** writing—review and editing. **Uffe N Nielsen:** writing—review and editing. **Mahfuza Pervin:** conceptualization, data curation, investigation, methodology, visualization, writing—original draft preparation, writing—review and editing.

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Figures

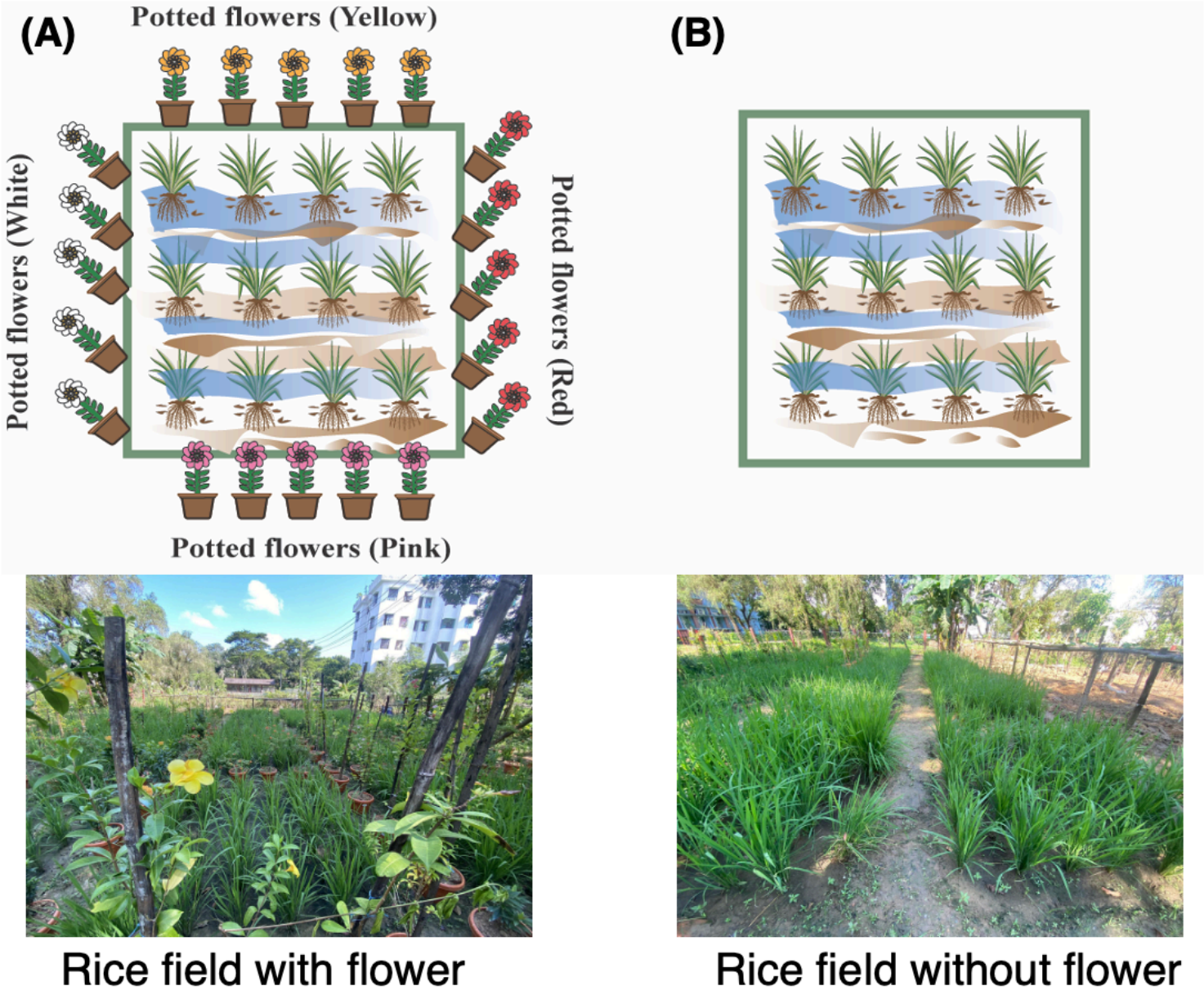


Figure 1

The schematic presentation of experimental design. Half of rice plots received with four perennial plants with four distinct colors (yellow, white, pink and red) as a source of floral strips (A) and control plot without floral strips (B). The treatments consisted of a factorial combination of four rice varieties with flowering hosts as strips and no-host control with three replications.

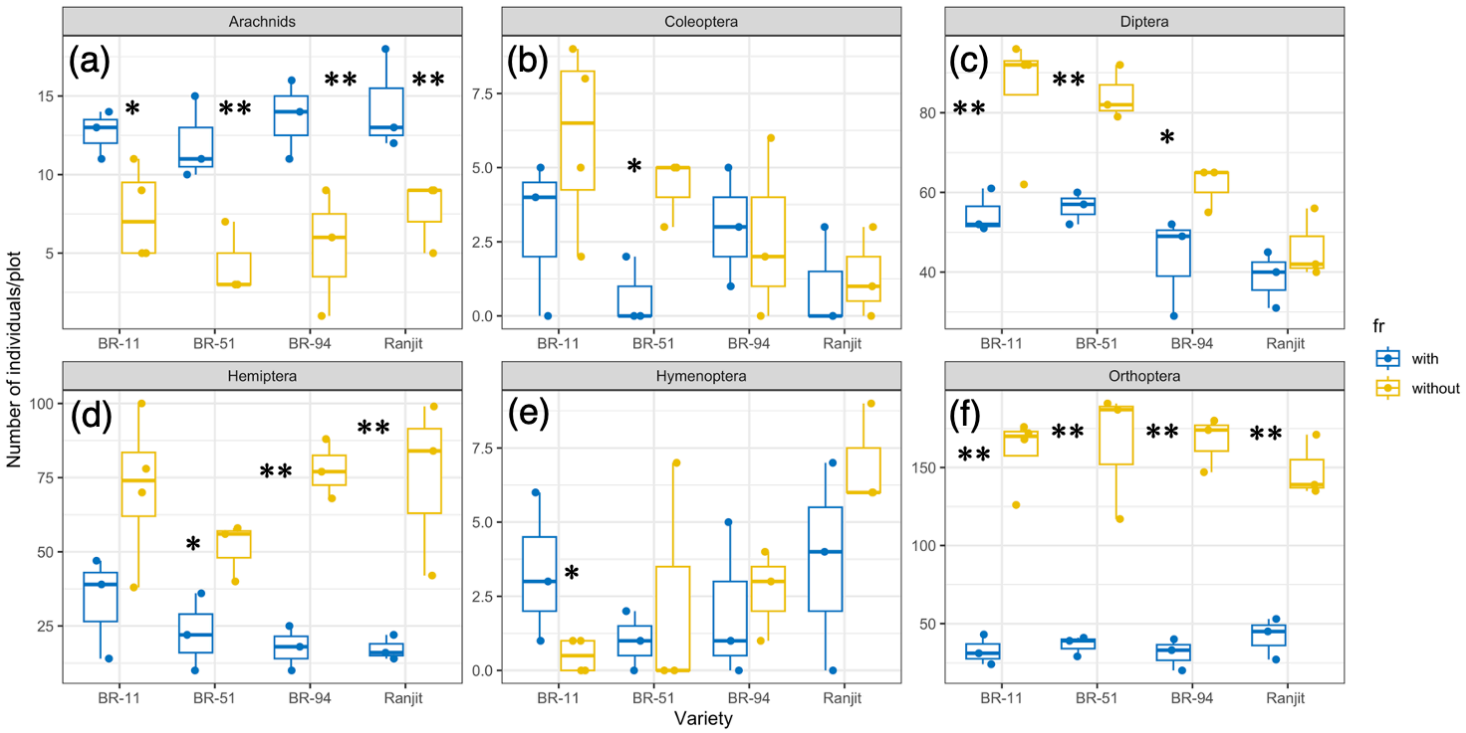


Figure 2

Boxplots showing the effects of flower strips on arthropod population; Arachnids (a), Coleoptera (b), Diptera (c), Hemiptera (d), Hymenoptera (e), and Orthoptera (f) in different transplant Aman rice varieties. The horizontal line inside the box plot represents the median. Means within a variety capped with Asterisk (*) are significantly different (mean comparison between flower strips and control treatments were estimated with R package ‘emmeans’ based on ANOVA: GLMM; *p < 0.05; **p < 0.01).

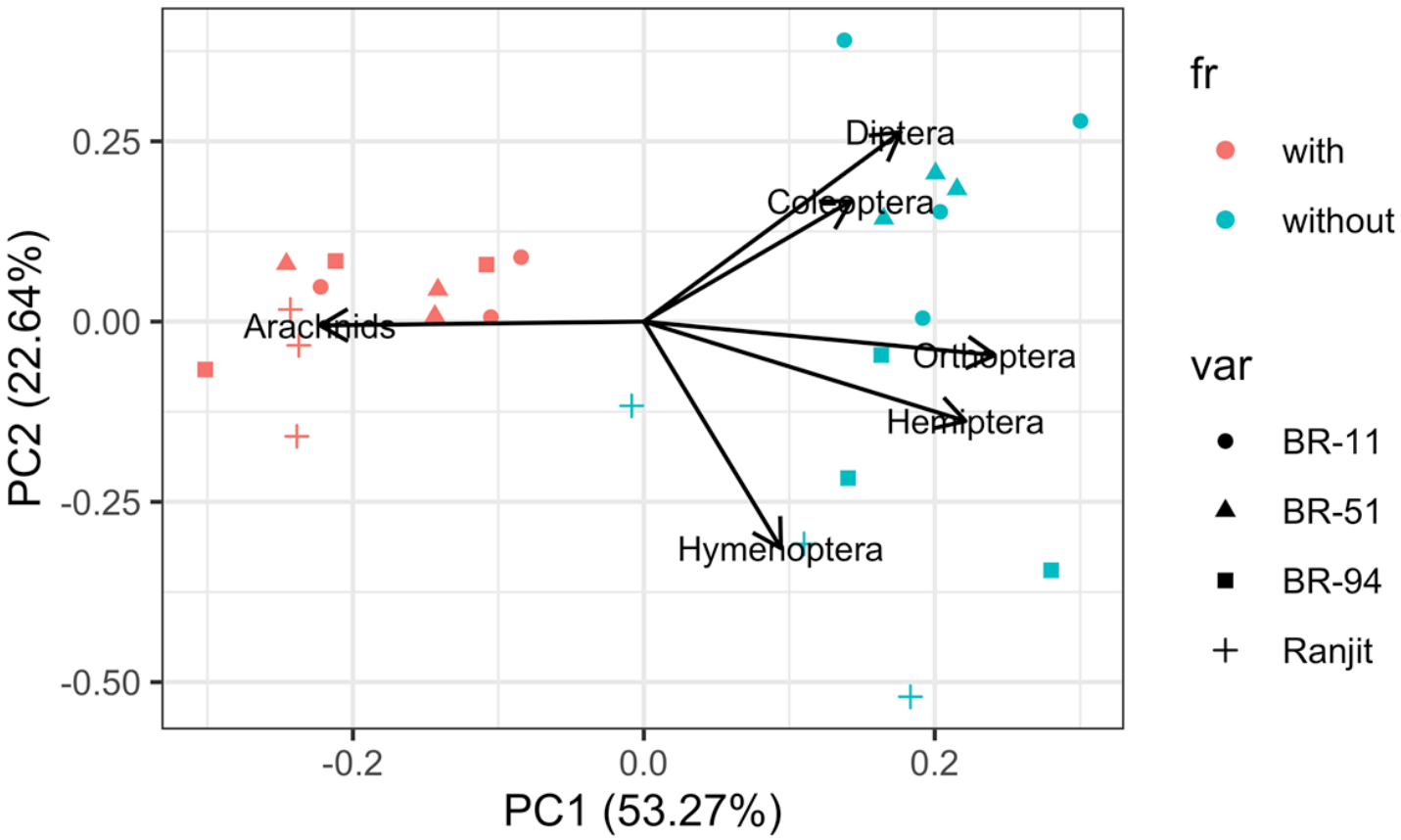


Figure 3

Principal Component Analysis (PCA) of arthropods community with floral species and variety. Group based on different colour and shape showing the distribution of arthropods community based on their abundance with floral resources and variety. The PC1 explained 53.27 % variation and PC2 for 22.64 % variation, respectively. Loading plot illustrating the contribution of orders on observed separation. Fr; flower strips and var; variety.

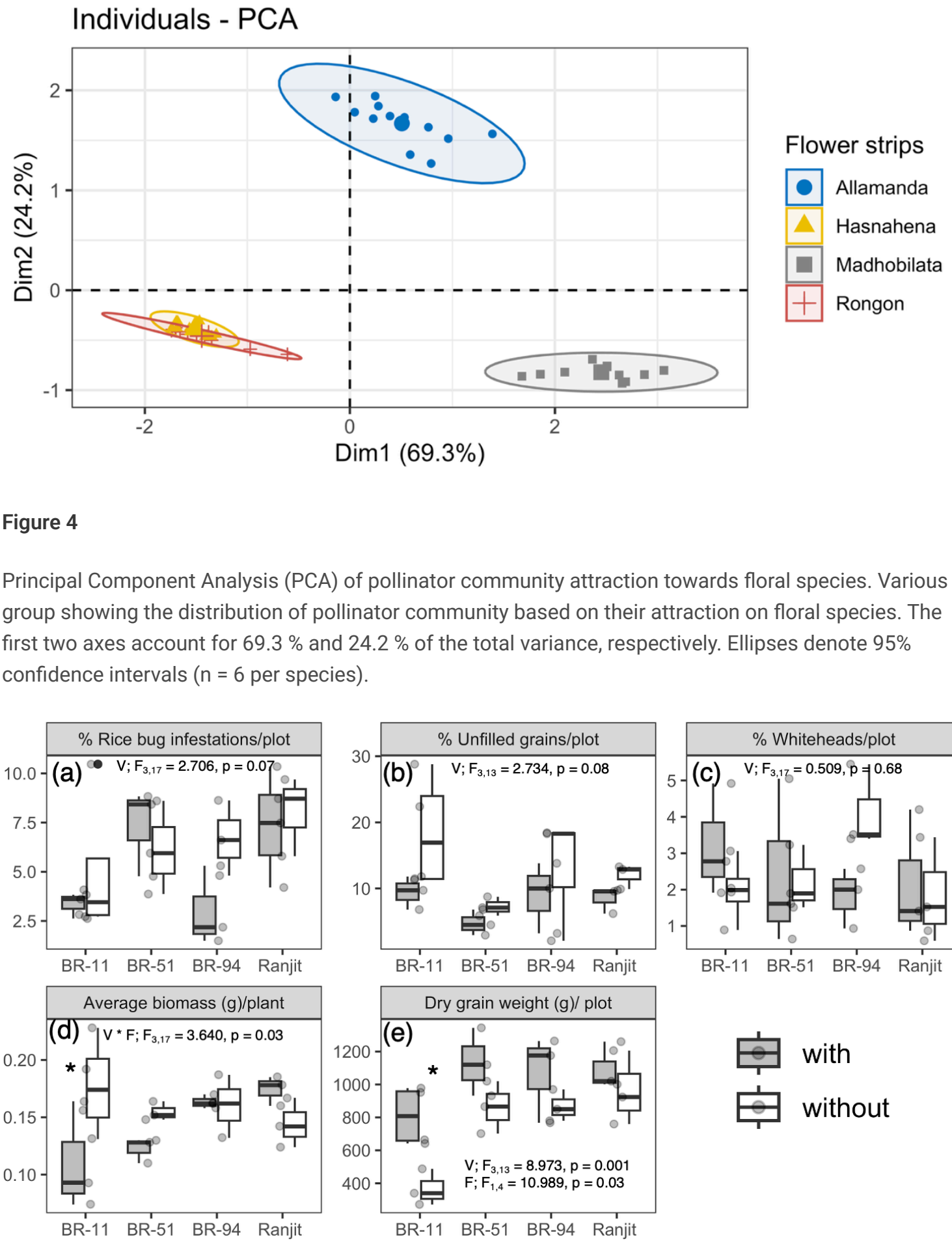


Figure 4

Principal Component Analysis (PCA) of pollinator community attraction towards floral species. Various group showing the distribution of pollinator community based on their attraction on floral species. The first two axes account for 69.3 % and 24.2 % of the total variance, respectively. Ellipses denote 95% confidence intervals (n = 6 per species).

Figure 5

Box plots showing the effects of flower strips on the percentage of rice bug infestation (a), unfilled grains (b), whiteheads-infestation by rice stem borer (c), dry biomass (d), and dry grain weight (e) in rice varieties. The horizontal line inside the box plot represents median. Asterisk (*) indicates significant difference between with or without flower strips within variety ($p < 0.05$) after Tukey's HSD test. V indicates main effects of varieties and F indicates the effects of flower strips and V*F indicated the interaction between after ANOVA using lmer function from R packages.