Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

J E Z S Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(5): 1778-1782

Received: 14-07-2017
Accepted: 15-08-2017

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Ecological engineering cropping methods for enhancing predator, *Cyrtorhinus lividipennis* (Reuter) and suppression of planthopper, *Nilaparvata lugens* (Stal) in rice- weeds as border cropping system

K Chandrasekar, N Muthukrishnan and RP Soundararajan

Abstract
Weed species were raised as border crops in and around rice field (*var*.CO 51) to enhance the activity of predatory mirid bug, *Cyrtorhinus lividipennis* (Reuter) and to mitigate brown planthopper (BPH), *Nilaparvata lugens* (Stal). *Echinochloa colonum* (L.), *Echinochloa crusgalli* (L), *Cyperus difformis* (L.), *Ammannia baccifera* (L.), *Eclipta alba* (L) and *Marsilea quadrifolia* (L) were used as border crops. The attraction of *C. lividipennis* towards different leaf and flower sample of weed plant were also studied through eight-armed olfactometer under laboratory assays. Results revealed that mean population of mirid bugs and BPH on rice crop varied from 1.85 to 4.47 and 2.42 to 4.45 nymphs and adults per hill. Rice + *E. colonum* border cropping system significantly influenced for the maximum population of *C. lividipennis* on rice (4.47/hill) along with highest occurrence ratio (0.89), minimum population of BPH (2.42/tiller) and more CB ratio (1:1.41). This was followed by rice + *E. crusgalli*, rice + *C. difformis* and rice + *A. baccifera* border cropping systems that recorded with mean population of 4.23, 3.94 and 2.95 mirid bugs per hill on rice respectively. Rice + *E. alba* border cropping system observed with less population of mirid bugs (2.42/hill) on rice where as the mirid population in rice alone was 1.85/hill. Similarly, population of mirid bugs on border crops ranged from 0.71 to 3.99 per hill. Maximum mirid bug population (3.99/plant) was observed on *E. colonum* border crop. *E. crusgalli* and *C. difformis* registered 3.71 and 3.43 mirid bugs per plant respectively. *A. baccifera*, *E. alba* and *M. quadrifolia* had mirid populations of 1.71, 1.29 and 0.71 per plant. This study concluded that *E. colonum* and *E. crusgalli* can be used as border crops in rice ecosystem to enhance the activity of mirid bugs. In olfactometer studies, mirid bug attraction was higher towards *E. crusgalli* leaf (3.81) and flower (4.06) samples.

Keywords: Ecological engineering, Pest management, weed species, Border cropping system, *N. lugens*, *C. lividipennis*, Olfactometer.

1. Introduction

Over 90 per cent of the rice is produced and consumed in Asia and 40 to 46 per cent of all irrigated cropland in Asia dedicated to rice production [1]. As the world human population continues to grow and the availability of agricultural lands decline, estimates are that the world must produce an additional 115 million tons of rice by 2035 to meet increasing global demands and it is responsible for driving science and policy around rice production since the beginning of the new millennium, particularly in Asia [2]. This has led to greater investment in science and technology for rice agriculture, an emphasis on intensifying rice production and on strengthening partnerships engaged in rice production, rice provisioning, and marketing [3]. Several decades of agricultural intensification and over use of insecticides have resulted in a depletion of natural enemy populations, as well as the development of pest populations that are increasingly resistant to insecticides and more virulent against rice varieties [4]. Furthermore, agricultural lands at a global scale have become depleted with functionally important species such as pollinators [5] and predatory amphibians [6]. Rice planthoppers such as the brown planthopper (BPH), *Nilaparvata lugens* (Stal) and the whitebacked planthopper (WBPH), *Sogatella furcifera* (Horvath) are considered as 'green revolution' induced pests [7].

Ecological engineering for pest management is a targeted approach to habitat manipulation where the attributes of a number of candidate plants are assessed to determine optimal ones to introduce into farming systems [8]. The mirid bug, *Cyrtorhrinus lividipennis* (Reuter)

(Hemiptera: Miridae) is an important zoophytophagous predator, preferring leaf and planthoppers eggs and young nymphs [9, 10]. It has been suggested that *C. lividipennis* may benefit from plant foods and survive in the crop even when prey is scarce or totally absent [11].

Materials and methods

Study site and experimental design

The present investigation was conducted at Krish Vigyan Kendra (KVK), Needamangalam, Thiruvarur during November to January, 2015. The experiment was laid in Randomized Block Design with seven treatments and three replications. The field plot size was 6 x 4 m^2. Twenty days old seedlings of *var*. CO 51 were transplanted in the main field at spacing of 20 x 20 cm. The weed species such as *Echinochloa colonum* (L.), *Echinochloa crusgalli* (L), *Cyperus difformis* (L.), *Ammannia baccifera* (L.), *Eclipta alba* (L) and *Marsilea quadrifolia* (L) were used to raise in the border of each plot. Normal agronomic practices like fertilizer application, manual weeding was carried out as per recommendation. No chemical pesticides were used throughout the season. The border crops, weed species were planted at that time of transplanting (Table 1).

Effects of weed as border crop on mirid bug population

Field experiments

Ten plants were selected randomly from each treatments and in situ count was taken during early morning hours at weekly intervals. In rice, total number of mirid bugs and BPH were observed from bottom of hills and was expressed as numbers/ hill. Observations were also taken in all the border crops at the same period of time.

Occurrence ratio

Similarly, by using *in situ* counts, occurrence ratio (OR) of predators and parasitoids as weeds as border crops was estimated by using following formula of Muthukrishnan and Dhanasekaran [12].

$$\text{OR} = \frac{\text{Population of natural enemies on weeds as border crops}}{\text{Occurrence of natural enemies on rice crop}}$$

Cost: Benefit Ratio (CBR)

Cost: Benefit Ratios were worked out for all the field experiments, using the formula of Akila Selvaraj and Sundara Babu [13].

$$\text{CB Ratio} = \frac{\text{Cost of produce}}{\text{Cost of cultivation + Cost of plant protection}}$$

Olfactometer studies

Olfactometer studies were conducted at Department of Agricultural Entomology, TNAU, Coimbatore by following Complete Randomized Design (CRD). Ten grams of healthy weed plant leaves were kept in the arm and were firmly closed with a lid. The inlet of the olfactometer on the top center place was connected to an aquarium pump (220-240 volt Ac) to release the pressure. Out of eight arms, leaf samples were kept in six arms and two arms were treated as control. Medical air was passed from aquarium pump at the rate of 4 lit/min into the olfactometer. Twenty numbers of mirid bugs (male and female) were released to the olfactometer through a central hole which also served as odour exit hole. Observations were made on the number of predators settled on each arms at 5, 10, 15 and 20 MAR (Minutes After Release) for their host preference. The experiment was replicated four times. Using similar methodology, this experiment was conducted for weed flower samples also.

Statistical analysis

The data were collected from all the experiments and mean values were calculated. Numerical values were transformed int square root transformations before subjecting them to statistical analysis [14]. Means in RBD analysis were separated by Least Significant Difference test (DMRT).

Results and discussion

Field experiments

The field study results on impact of border crops on the incidence of BPH and mirid bug revealed that there was significant variation on different border cropping systems. Mean population of *N. lugens* was 4.45 numbers /tiller on pure rice crop (Table 2 and Fig 1) when raised without any border crops. Minimum population of *N. lugens* was observed in rice + *E. crusgalli* (2.25/ tiller). This was followed by rice + *E. colonum* (2.42/ tiller) and rice + *C. difformis* (2.94/ tiller). The higher planthopper population on rice was observed in rice + *M. quadrifolia* (3.87/ tiller), rice + *A. baccifera* (3.44/ tiller) and rice + *E. alba* (3.58/ tiller) border cropped plots.

Mean population of mirid bugs were significantly more (4.47/hill) in weed based border cropping system than rice alone (1.85/hill). Rice border cropped with *E. colonum* recorded the highest number of mirid bugs (4.47/hill) on rice plants. This was followed by rice + *E. crusgalli* (4.23/hill) and rice + *C. difformis* (3.94/hill). However rice + *A. baccifera*, rice + *E. alba* and rice + *M. quadrifolia* border cropping systems registered lesser populations of mirid bugs *viz*., 2.95, 2.42 and 2.18 per hill.

E. colonum border crop had the highest population of mirid bugs (3.99) followed by *E. crusgalli* (3.71) and *C. difformis* (3.43). However border crop *viz*., *A. baccifera* (1.71/hill)), *E. alba* (1.29/hill) and *M. quadrifolia* (0.71/hill) had the least population. Border crops *viz*., *E. colonum*, *E. crusgalli*, *C. difformis*, *A. baccifera*, *E. alba* and *M. quadrifolia* registered occurrence ratio of 0.89, 0.88, 0.87, 0.58, 0.53 and 0.33 for mirid bugs.

The present study documented that among six different weeds, *Echinoclo colona* registered more population of natural enemies followed by

E. crusgalli and *Eclipta alba.* This is supported by [15] who found that weeds from families of Poaceae and Graminae were attracted complex of beneficial arthropods that aid in suppressing pest populations. Our findings are also in accordance with the reports of Abate [16]who studied effects of strip cropping in haricot bean, *Phaselous vulgaris* L. with maize (*Zea mays* L.) under weeded and un weeded conditions on the abundance of Tachinid parasitoids and predatory wasps, Tachinids were more abundant in strip cropped and weedy plots than in monoculture. Strip cropping had no effect on *Tiphia* spp. numbers whereas the wasp was 2-8 times more abundant in weedy than in weed free plots. Increased weed diversity does not always lead to increased predator activity because comparatively very minimum number of predators and parasitoids were registered in the weed with okra cropping system and there is no significant differences were observed between weeded and un weeded conditions

In the current research, *E. crusgalli* as border crop had more number of mirid bug population might be due to more number of pollen and nectar compared to other border crops. Bell pepper pollen increased the survival of predator, *Amblyseius cucumeris* and promoted population growth and reduced dispersal at times when their prey thrips were in short supply [17].

The resource abundance hypothesis predicts that plants, which offer more resources, have the potential to support more species and greater abundances of insect predators [18]. Weeds can serve as sources of nectar and pollen for natural enemies [19]. Andow [20]indicated that the presence of weeds might actually increase predator populations by providing food or other resources. Rice bunds with *Brachiaria* grasses are the homes of two species of cricket that are ferocious predators of pest eggs laid on leaves. Many spider species also depend on these grassy habitats [21].

The yield of rice crop was higher in rice + *E. colonum* border cropping system (5310 kg/ha) followed by rice + *E. crusgalli* (5280 kg/ha) and rice + *C. difformis* (5190 kg/ha). The remaining border cropping systems had minimal yield. Rice alone without border cropping system recorded the lowest yield (4435kg/ha). The variation in yield may be due to the border cropping system. In border cropping system, the population of natural enemies was higher compared to pure rice crop. As the population of natural enemies was higher in border cropping system, the pest population was decreased and yield variation may occur. The increase in yield of rice crop as well the yields of border crops had impact on C:B ratio, which recorded 1:1.41 and 1:1.40 for rice + *E. colonum* and rice + *E. crusgalli* border cropping system respectively.

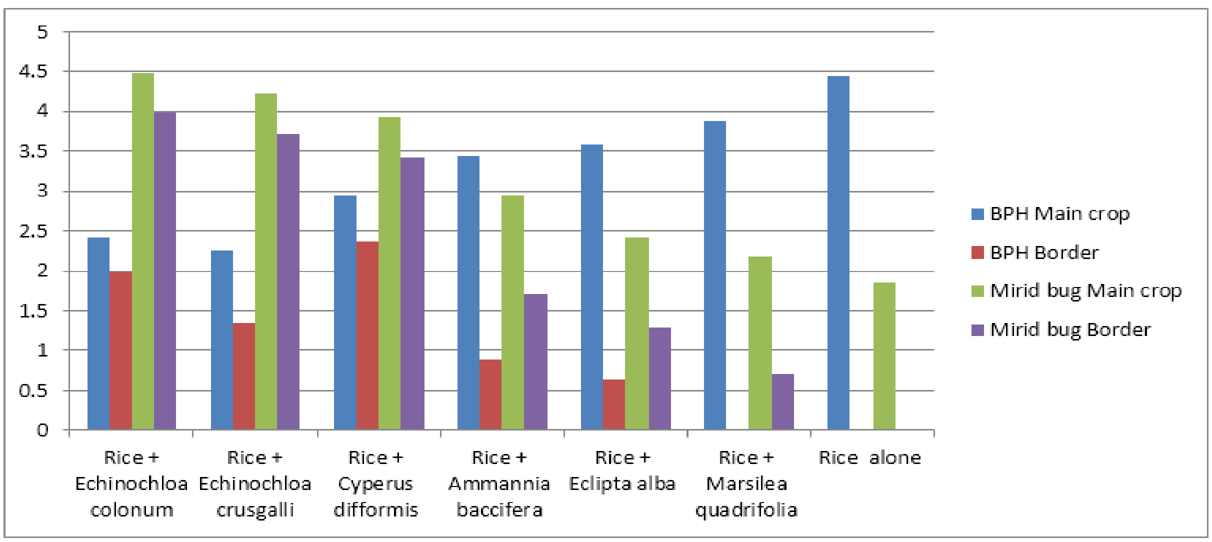
Olfactometer studies

Leaf sample

There was significant difference in the attraction of mirid bug in olfactometer arms due to different leaf and flower samples of weed plants. In Olfactometer studies, mirid bug attraction was very high at 5 MAR in *E. crusgalli* leaf sample (2.00) followed by *E. colonum* leaf (1.75). During 10 MAR the attraction of mirid bug population was very high in *E. crusgalli* leaf sample (3.00) followed by *E. colonum* (2.75). Control treatments had the lowest population (0.50). At 15 and 20 MAR, the mirid bug attraction was high in *E. crusgalli* leaf (4.00, 4.50) followed by *E. colonum* leaf sample (3.75, 4.25). At the same time, the control recorded lowest population (0.75, 1.00). The overall mean population was highly significant in *E. crusgalli* leaf sample (3.38) followed by *E. colonum* (3.13), *C. difformis* (2.31) and *A. baccifera* leaves (2.25). All the treatments registered significant attraction than in control and each recorded the lowest predator attraction of 0.56 (Table 3).

Flower sample

Flower samples of border weed plants were collected and kept in Olfactometer arms. Number of mirid bugs attracted towards various flower samples is given in Table 4. At 5 MAR, the mirid bug attraction was high in *E. crusgalli* (2.50), followed by *E. colonum* (2.00) and the lowest population was recorded in *A. baccifera* flowers (1.00). During 10 MAR, the attraction of mirid bugs was towards *E. colonum* (2.75) and *E. crusgalli* (2.50). At 15 MAR, the attraction was more in *E. colonum* (3.50) and *E. crusgalli* (3.00) and less in control (1.00). At 20 MAR, the attraction was more in *E. colonum* and *E. crusgalli* (3.75). The overall mean attraction was recorded high in *E. colonum* (3.00) followed by *E. crusgalli* (2.94), *E. alba* (2.38), *C. difformis* (1.94) and *A. baccifera* (1.19). Zhu [22] reported that, *Sesamum indicum*, *Emilia sonchifolia* and *Impatiens balsamena* appeared potentially suitable for supporting *Anagrus optabilis* and *Anagrus nilaparvatae* to the extent that adults were attracted to the odours of these flowers.



X axis -Treatments 1, Y axis - Population of BPH and Mirid

Fig 1: Influence of border crops on *Nilaparvata lugens* and *Cyrtorhinus lividipennis* population

Conclusion

From the above results, *E. colonum* and *E. crusgalli* could be recommended for creating flowering strips in the bunds of rice crop. It will increase the predator, *C. lividipennis* which leads to the suppression of rice planthopper infestation in rice main crop. The flowering plants can be sown in the appropriate time to make available the alternate food sources to natural enemies throughout the crop season.

Acknowledgement

The authors thankfully acknowledge Dr. S. Robin, Professor, Plant Breeding and Genetics, Professor and Head, Department of Rice, TNAU, Coimbatore for providing seed materials and helping in conduct of the experiments.

Table 1: Weed species and time of sowing

S. No	Weed species	Time of Planting
1	*Echinochloa colonum*	At the time of main plant transplanting
2	*Echinochloa crusgalli*	At the time of main plant transplanting
3	*Cyperus difformis*	At the time of main plant transplanting
4	*Ammannia baccifera*	At the time of main plant transplanting
5	*Eclipta alba*	At the time of main plant transplanting
6	*Marsilea quadrifolia*	At the time of main plant transplanting
7	Rice (CO 51)	At the time of main plant transplanting

Table 2: Effect of weed species as border cropping systems on population of *Cyrtorhinus lividipennis* and *Nilaparvata lugens*

Border cropping system	Mean *N. lugens* population (No./tiller)		Mean *C. lividipennis* population (No./plant)		Occurrence ratio	Yield (Kg/ha)		Cost Benefit ratio
	Main crop	Border crop	Main crop	Border crop		Main crop	Border crop	
Rice + *Echinochloa colonum*	2.42 ^{b}	1.99 ^{b}	4.47 ^{a}	3.99 ^{a}	0.89	5310	-	1:1.41
Rice + *Echinochloa crusgalli*	2.25 ^{a}	1.34 ^{c}	4.23 ^{b}	3.71 ^{b}	0.88	5280	-	1:1.40
Rice + *Cyperus difformis*	2.94 ^{c}	2.37 ^{a}	3.94 ^{c}	3.43 ^{c}	0.87	5190	-	1:1.38
Rice + *Ammannia baccifera*	3.44 ^{d}	0.88 ^{d}	2.95 ^{d}	1.71 ^{d}	0.58	4714	-	1:1.25
Rice + *Eclipta alba*	3.58 ^{d}	0.63 ^{e}	2.42 ^{e}	1.29 ^{e}	0.53	4845	-	1:1.29
Rice + *Marsilea quadrifolia*	3.87 ^{e}	0.00 ^{f}	2.18 ^{f}	0.71 ^{f}	0.33	4692	-	1:1.25
Rice alone	4.45 ^{f}	-	1.85 ^{g}	-	-	4435	-	1:1.18
SED	0.02	0.01	0.02	0.01			-	
CD (P = 0.05)	0.04	0.02	0.05	0.03				

*****Data are mean values of three replications
Figures were transformed by square root transformation and the original values are given
In a columns means followed by same letter(s) are not significantly different (P=0.05) by DMRT

Table 3: Behavioral bioassay of *Cyrtorhinus lividipennis* against leaf samples of different weed plants in olfactometer

Treatments	No. of *C. lividipennis* (no./arm)*				
	5 MAR	10 MAR	15 MAR	20 MAR	MEAN
Echinochloa colonum	1.75 ^{b}	2.75 ^{b}	3.75 ^{b}	4.25 ^{b}	3.13 ^{b}
Echinochloa crusgalli	2.00 ^{a}	3.00 ^{a}	4.00 ^{a}	4.50 ^{a}	3.38 ^{a}
Cyperus difformis	1.75 ^{b}	2.00 ^{c}	2.75 ^{c}	2.75 ^{d}	2.31 ^{c}
Ammannia baccifera	0.75 ^{d}	1.25 ^{d}	2.00 ^{e}	2.25 ^{e}	1.56 ^{e}
Eclipta alba	1.50 ^{c}	2.00 ^{c}	2.50 ^{d}	3.00 ^{c}	2.25 ^{d}
Marsilea quadrifolia	0.25 ^{e}	0.75 ^{e}	1.25 ^{f}	1.25 ^{f}	0.88 ^{f}
Rice (control)	0.00 ^{f}	0.50 ^{f}	0.75 ^{g}	1.00 ^{g}	0.56 ^{g}
S.Ed	0.01	0.01	0.01	0.01	0.01
CD (0.05%)	0.01	0.02	0.02	0.02	0.02

*Mean of 4 replications
** MAR Minutes After Release
Figures were transformed by square root transformation and the original values are given
In a columns means followed by same letter(s) are not significantly different (P=0.05) by DMRT

Table 4: Behavioral bioassay of *Cyrtorhinus lividipennis* against flower samples of different weed plants in olfactometer

Treatments	No. of *C. lividipennis* (no./arm)*				
	5 MAR	10 MAR	15 MAR	20 MAR	MEAN
Echinochloa colonum	2.00 ^{b}	2.75 ^{a}	3.50 ^{a}	3.75 ^{a}	3.00 ^{a}
Echinochloa crusgalli	2.50 ^{a}	2.50 ^{b}	3.00 ^{b}	3.75 ^{a}	2.94 ^{a}
Cyperus difformis	1.50 ^{c}	2.00 ^{d}	2.00 ^{d}	2.25 ^{c}	1.94 ^{c}
Ammannia baccifera	1.00 ^{d}	1.00 ^{e}	1.25 ^{e}	1.50 ^{d}	1.19 ^{d}
Eclipta alba	1.50 ^{c}	2.25 ^{c}	2.75 ^{c}	3.00 ^{b}	2.38 ^{b}
Marsilea quadrifolia	-	-	-	-	-
control	0.25 ^{e}	0.75 ^{f}	1.00 ^{f}	1.00 ^{e}	0.75 ^{e}
SEd	0.01	0.01	0.01	0.01	0.01
CD (0.05%)	0.02	0.01	0.02	0.02	0.02

*Mean of 4 replications
** MAR Minutes After Release
Figures were transformed by square root transformation and the original values are given
In a columns means followed by same letter(s) are not significantly different (P=0.05) by DMRT

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