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Ecological engineering cropping methods for enhancing predator, *Cyrtorhinus lividipennis* (Reuter) and Suppression of Planthopper, *Nilaparvata lugens* (Stal) in Rice-Weeds in Strip Cropping system

K Chandrasekar, N Muthukrishnan and RP Soundararajan

Abstract
In the habitat manipulation for enhancing natural enemy activity, different weed species were raised as strip crops in and around rice field (var.CO 51) to enhance 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 strip crops. The attraction of *C. lividipennis* towards different leaf and flower sample of strip crops were also studied through eight-armed olfactometer under laboratory assays. Results revealed that the mean population of mirid bugs and BPH on rice crop varied from 2.86 to 5.71and 1.86 to 5.29 nymphs and adults per hill due to strip crops. Rice + *E. colonum* strip cropping system significantly increases populations of *C. lividipennis* on rice (5.71/hill) along with highest occurrence ratio (0.68), minimum population of BPH (1.86/tiller) and more CB ratio (1:1.44). This was followed by rice + *E. crusgalli*, rice + *C. difformis* and rice + *A. baccifera* strip cropping systems that effected for the mean population of 5.29, 4.57 and 4.29 mirid bugs per hill on rice respectively. Rice + *E. alba* strip cropping system however caused for the population of 3.57 mirid bugs per hill on rice, when compared to the mirid population of 2.86 per hill on rice alone. Similarly, population of mirid bugs on strip crops ranged from 1.29 to 3.86 per hill. Maximum mirid bug population (3.86/plant) was observed on *E. colonum* strip crop. *E. crusgalli* and *C. difformis* registered 3.48 and 2.00 mirid bugs per plant respectively. *A. baccifera*, *E. alba* and *M. quadrifolia* had mirid populations of 1.71, 1.43 and 1.29 per plant. This study concluded that *E. colonum* and *E. crusgalli* can be used as strip crops in rice ecosystem to enhance the availability of mirid bugs. In olfactometer studies, mirid bug attraction was higher towards *E. crusgalli* leaf (3.13) and flower (2.94).

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

1. Introduction
More rice production is demanded due to the rapid population growth of the world [1]. Three billion people depend on it as a major source of their subsistence diet [2]. It is planted on about 154 m ha or on about 11% of the world's cultivated land with an annual production of 700.7 million tons [3]. China and India, which account for more than one-third of global population, supply over half of the world's rice. Over 800 species have been identified damaging either standing or stored rice [4]. Pawar [5] listed 650 species of insect pests of rice from Philippines. Among these rice pests, about 20 of them are of economic importance. Rice planthoppers such as the brown planthopper (BPH), *Nilaparvata lugens* (Stal) and the white backed plant hopper (WBPH), *Sogatella furcifera* (Horvath) are considered dreaded insect pests of rice [6]. Ecological engineering is a relatively new concept of environmental manipulation for the benefit of man and the environment. These methods are best tools to conserve, enhance natural enemy population and increase their availability in the field. Ecological engineering pest management methods include use of cultural practices, usually based on vegetation management, to enhance biological control or the 'bottom-up' effects that act directly on pests [7]. The latter include methods such as trap crops, intercrops and maintaining certain weed strips along with main crop availability [8, 9]. Zhu [10] reported that the predation performance of *C. lividipennis* on BPH eggs was greatly enhanced after the parental adult feed on flowers of

four plant species *viz*., *Sesamum indicum*, *Tagetes eracta*, *Trida procumbens* and *Emilia sonchifolia*. Plant species which maximize the benefit to natural enemies and have no or weak benefits for the pest should be selected [11].

Materials and Methods

Study site and experimental design

The present investigation was carried out at Paddy Breeding Station (PBS), Tamil Nadu Agricultural University, Coimbatore, 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 rice variety CO 51 were transplanted in the main field at spacing of 20 x 20 cm. Weed species such as *Echinochloa colonum* (L.), *Echinochloa crusgalli* (L), *Cyperus difformis* (L.), *Ammannia baccifera* (L.), *Eclipta alba* (L) and *Marsilea quadrifolia* (L) were raised as strip crop. Normal agronomic practices like fertilizer application, manual weeding was carried out as per the crop production recommendation. No chemical pesticides were used throughout the season. For strip crops, all weed species were planted at that time of transplanting (Table 1).

Effects of non-rice crops 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 strip crops at the same period of time. However, in weed plants no BPH population was recorded.

Occurrence ratio

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

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

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].

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

Olfactometer studies

Olfactometer studies were conducted at Department of Agricultural Entomology, TNAU, Coimbatore in 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. This experiment was replicated four times. Using similar methodology, flower samples of weed plants were also tested.

Statistical analysis

The data were collected from all the experiments and mean values were calculated. Numerical values were transformed into 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 studies

The field study results on impact of strip crops on the incidence of BPH and mirid bug revealed that there was significant variation on different strip cropping systems. Mean population of *N. lugens* was 5.29 numbers /tiller on pure rice crop (Table 2 and Fig 1) when raised without any strip crops. Minimum population of *N. lugens* was observed in rice + *E. colonum* (1.86/ tiller). This was followed by rice + *E. crusgalli* and rice + *C. difformis* (2.30/tiller and 2.46/tiller) and rice + *A. baccifera* (2.86/tiller). The higher plant hopper population on rice and was observed in rice + *M. quadrifolia* (3.57/ tiller), rice + *E. alba* (3.38/ tiller).

Mean population of mirid bugs were significantly more (5.71/hill) in weed based strip cropping system than rice alone (2.86/hill). Rice strip cropped with *E. colonum* recorded the highest number of mirid bugs (5.71/hill) on rice plants. This was followed by rice + *E. crusgalli* (4.11/hill) and rice + *C. difformis* (3.45/hill). However rice + *A. baccifera*, rice + *E. alba* and rice + *M. quadrifolia* strip cropping systems registered lesser populations of mirid bugs viz., 4.29, 3.57 and 3.29 per hill.

E. colonum strip crop had the highest population of mirid bugs (3.86) followed by *E. crusgalli* (3.48) and *C. difformis* (2.00). However strip crops *viz*., *A. baccifera* (1.71/hill), *E. alba* (1.43/hill) and *M. quadrifolia* (1.29 /hill) had the least population. Strip crops *viz*., *E. colonum*, *E. crusgalli*, *C. difformis*, *A. baccifera*, *E. alba* and *M. quadrifolia* registered occurrence ratio of 0.68, 0.66, 0.44, 0.40, 0.40 and 0.39 for mirid bugs.

When grass plants allowed to flowering stage it may provide protein-rich pollen for the predators as well as structural habitat analogs [15]. The presence of weeds within or around crop fields influences the dynamics of the crop and associated biotic communities. Herbivore-natural enemy interactions occurring in a crop system can be influenced by the presence of associated weeds or by the presence of herbivores on associated weed plants [16]. Weeds offer many important requisites for natural enemies such as alternative prey/hosts, pollen, or nectar, as well as microhabitats that are not available in weed-free monocultures [17].

Another possibility is the availability of adult food in the form of pollen and nectar from the crop and weed hosts [18, 19]. Ecological engineering fields in Vietnam with bunds enriched with nectar rich flowers had significantly a higher parasitism and predation of planthopper eggs that are deeply embedded in the rice tissues [20]. Predators and parasitoids that play an important role in suppression of many pest species in the rice ecosystem require alternate food resources. The weed flora along field margins and nearby wasteland provides nectar, pollen and alternate prey as food [21].

In the present study, *E. colonum* as strip crop had more number of mirid bug population might be due to more number of pollen and nectar compared to other strip crops. In rice + *E.*

colonum strip cropping system, the population of *C. lividipennis* was 7.83, 6.73, 7.03 and 4.70 at 36, 43, 50 an57 DAT. After 57 DAT, there was reduction in the population of *C. lividipennis*. Community turn over in rice ecosystem was less in weeded ecosystem that in partially weeded ecosystem in first and second week of the crop growth. The reason was due to the availability of prey insects and alternate food resources from weeds in the partially weeded ecosystem. Coccinellid species colonies increase with the succession growth stage of the crop [22].

The yield of rice crop was higher in rice + *E. colonum* strip cropping system (5435 kg/ha) followed by rice + *E. crusgalli* (5331 kg/ha) and rice + *C. difformis* (5285 kg/ha). The remaining strip cropping systems had minimal yield. Rice alone without strip cropping system recorded the lowest yield (4457 kg/ha). The variation in yield may be due to the strip cropping system. In strip cropping system, the population of natural enemies was higher compared to pure rice crop. As the population of natural enemies was higher in strip cropping system, the pest population was decreased and yield variation may occur. The increase in yield of rice crop as well the yields of strip crops had impact on C:B ratio, which recorded 1:1.44 and 1:1.42 for rice + *E. colonum* and rice + *E. crusgalli* strip 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 strip crop. 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). Controls 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 controls 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 from the strip crops 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).

These findings are [23], who reported that both sexes of *C. carnea* have a significantly higher orientation preference for sunflower. The *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 [24].

Conclusion

From the above results, sunflower and cowpea 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.

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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 strip cropping systems on population of *Cyrtorhinus lividipennis* and *Nilaparvata lugens*

Strip cropping system	Mean *N. lugens* population (No./tiller)		Mean *C. lividipennis* population (No./plant)		Occurrence ratio	Yield (Kg/ha)		Cost Benefit ratio
	Main crop	Strip crop	Main crop	Strip crop		Main crop	Strip crop	
Rice + *Echinochloa colonum*	1.86 a	1.71 a	5.71 a	3.86 a	0.68	5435	-	1:1.44
Rice + *Echinochloa crusgalli*	2.30 b	1.45 b	5.29 b	3.48 b	0.66	5331	-	1:1.42
Rice + *Cyperus difformis*	2.43 b	1.43 b	4.57 c	2.00 c	0.44	5285	-	1:1.40
Rice + *Ammannia baccifera*	2.86 c	1.29 c	4.29 d	1.71 d	0.40	4868	-	1:1.29
Rice + *Eclipta alba*	3.38 d	1.14 d	3.57 e	1.43 e	0.40	4955	-	1:1.32
Rice + *Marsilea quadrifolia*	3.57 e	0.00 e	3.29 f	1.29 f	0.39	4753	-	1:1.26
Rice alone	5.29 f	-	2.86 g	-	-	4457	-	1:1.18
SED	0.02	0.01	0.01	0.01				
CD (P = 0.05)	0.04	0.03	0.03	0.02				

*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 weed plants in olfactometer

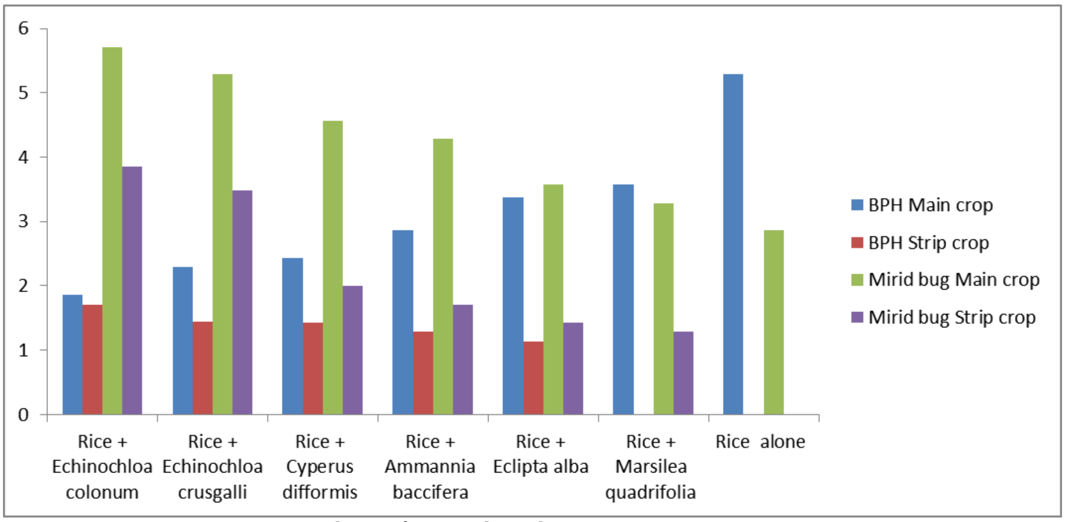
Treatments	No. of *C. lividipennis* (no./arm)*				
	5 MAR	10 MAR	15 MAR	20 MAR	MEAN
Echinochloa colonum	1.75 [b]	2.75 [b]	3.75 [b]	4.25 [b]	3.13 [b]
Echinochloa crusgalli	2.00 [a]	3.00 [a]	4.00 [a]	4.50 [a]	3.38 [a]
Cyperus difformis	1.75 [b]	2.00 [c]	2.75 [c]	2.75 [d]	2.31 [c]
Ammannia baccifera	0.75 [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 alone	0.00 [f]	0.50 [f]	0.75 [g]	1.00 [g]	0.56 [g]
SEd	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 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



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

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

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