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EFFECT OF ECOLOGICAL ENGINEERING ON INCIDENCE OF KEY RICE PESTS

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ABSTRACT

Incidence of rice pests like white backed planthopper (WBPH) *Sogatella furcifera*, leaf folder *Cnaphalocrocis medinalis*, whorl maggot *Hydrellia sasakii* and stem borers- yellow stem borer *Scirpophaga incertulas* and the pink stem borer *Sesamia inferens* were studied in ecologically engineered rice fields during kharif 2019 and 2020. The WBPH population significantly reduced in fields planted with mixture of crop and flowering plants (0.66±0.25 and 0.83±0.44 WBPH/hill) during kharif 2019 and 2020, respectively. Rice plots planted with crops and flowering plants had lowest leaf folder damage in both the seasons (0.64±0.11% and 0.54±0.35%). Similarly, whorl maggot damage in mixture of crop and flowering plants found significantly reduced than control plots in both the seasons. Reduced pest activity in ecologically engineered fields significantly increased rice yield, particularly in rice plots planted with crops and flowering plants (5.60± 0.24 and 5.27± 0.06 mt/ ha). Study revealed that planting of crop and flowering plants around the rice field increased the natural enemy activity and reduced incidence of rice pests which eventually reduced the yield losses caused by insect pests and increased the rice grain yield.

Key words: Rice, Pusa Basmati 1121, flowering plants, ecological engineering, natural enemies, population incidence, integrated pest management

Rice *Oryza sativa* L. is the world's most important staple food crop (Khush, 2004) and India has the largest cultivated area under rice. Rice production is challenged by many biotic and abiotic stresses including insect pests and diseases (Behura et al., 2011). Pest management in rice agroecosystem is heavily dependent on insecticides and partially on host-plant resistance. Indiscriminate use of insecticides has created serious imbalances. Agricultural intensification and overuse of agrochemicals has resulted in a depletion of natural enemies (Matsumura et al., 2008). Ecologically sound IPM can counteract these with restoring the ecology of rice landscapes (Horgan et al., 2016). Ecological engineering is an approach with manipulation of habitats for the benefit of society and the natural environment. It mainly focuses on increasing the abundance, diversity and function of natural enemies in agricultural habitats by providing refuges and alternate or supplementary food resources (Gurr 2009; Lu et al., 2014; Lv et al., 2015; Landis et al., 2000). By planting flowers in an agroecosystem, farmers can provide resource subsidies for parasitoids, and thereby improving biological control of insect pests (Kean et al., 2003; Gurr et al., 2004). Ecological engineering is an extended and refined version of IPM and selection of appropriate flowering plants for enhancement of biological activity and conservation of natural enemies is important. These have been done have been done in many rice growing countries. But, in India, there are not many, and hence the present study with focus on incidence of some key insect pests.

MATERIALS AND METHODS

Experiments were conducted at the ICAR-Indian Agricultural Research Institute, New Delhi during kharif 2019 and 2020 with the rice variety Pusa Basmati 1121. Healthy rice seeds were treated with fungicide and sown @ 15 kg/ ha in lines on the well-prepared nursery beds on 27th/ 29th June during kharif 2019 and 2020, respectively. All the recommended agronomic practices were followed. Plots of size 5x 4 m, 1 m apart from each other with ridges on all sides were prepared. Transplanting was done on 22nd/ 30th July in kharif 2019 and 2020, respectively. Two seedlings/ hill were transplanted each at 15x 20 cm plant and row spacing, respectively. Ridges were prepared surrounding all the plots and gap filling was done after a week. No application of insecticide was done at any crop stage. Three field crops viz., sesamum, sunflower and soybean; and three flowering crops viz., marigold, balsam and gaillardia were selected for the study. Mix planting of crop and flowering plants and no-weeding plots were also included as the treatment. Accordingly, the treatments were designed as; T1= Field crops (sesamum+ sunflower+ soybean); T2= Flower crops (marigold+ balsam+ gaillardia); T3= Natural weeds (no weeding); T4= Field crops+ flower crops; T5= Control. The experiments were laid out in completely randomized block design (CRBD) having five treatments with four replications. Between replicates, 1m alley was provided to facilitate irrigation, fertilizer application and recording of observations.

Seeds of field crops like sesamum, sunflower and soybean were directly sown on the bunds adjacent to respective treatments. For flower crops like marigold, balsam and gaillardia nursery was raised and were transplanted on bunds adjacent to the respective treatments. All the crop and flowering plants were also raised in the plastic pots of size of 22.5x 15 cm and were transferred around the rice plots of respective treatments. Sowing and transplanting of all the crop plants and flowering plants on bunds as well as in the pots were done in staggered manner, so that the flowering occurs for longer duration. Randomly 10 hills/ plot were selected and tagged for observations on the incidence of the white backed plant hopper *Sogatella furcifera*, whorl maggot *Hydrellia sasakii* and leaf folder *Cnaphalocrocis medinalis* at 10 days interval starting from 40 days after transplanting and till harvest. For WBPH, hoppers/ hill, including nymphs were counted; for *H. sasakii*, number of leaves infested/ hill with % calculated, and with *C. medinalis*, number of folded leaved/ hill observed and % calculated; and for stem borers- yellow stem borer *Scirpophaga incertulas* and the pink stem borer *Sesamia inferens* it was % white ears at preharvest stage. Yield data was recorded after harvesting and expressed as mt/ ha. These data were subjected to two-way ANOVA and the significance evaluated with F-tests, while the treatment means by LSD (p= 0.05).

RESULTS AND DISCUSSION

The WBPH *S. furcifera* was observed infesting early in both kharif seasons, and its incidence differed significantly between the treatments (F=41.4, p<0.001 and F=18.54, p<0.001) and weeks (F=34.5, p<0.001 and F=68.62, p<0.001); significantly less incidence was in rice plots planted with flowering plants. In case of *C. medinalis,* damage was seen early in the season and significantly differed between the treatments (F=45.591, p<0.001 and F=82.19, p<0.001) and weeks (F=2.6, p=0.0026 and F=63.2, p<0.001) in both the seasons. Rice plots surrounded with crops and flowering plants exhibited least incidence (0.64±0.11 and 0.54±0.35); also, the plots planted with crop plants and flowering plants alone, suffered less damage. In case of *H. sasakii* damage was more prominent during vegetative stage at 41 and 44 DAT (36th SMW); it was observed more in kharif 2019 than that of 2020, with significantly less incidence when flowering plants alone and mixture of crop and flowering plants were in the plots. Two species of stem borers were observed during vegetative and reproductive stage, of which the dominant one was *S. incertulas* and other one was *S. inferens*, with insignificant incidence during vegetative stage. Preharvest white ears were recorded in all the treatments and % white ears were calculated. It was observed that their incidence was <economic threshold level (ETL) in all the treatments including control (F=3.9, p=0.028 and F=8.3, p<0.001); however, less white ears were observed in plots planted with crops, flowers and crops+ flowers. Yield differed significantly between the treatments in kharif 2020 (F=25.2, p<0.001), and not so during kharif 2019 (F=3.7, p=0.033), with significantly higher yield being with plots planted with crops+ flowers during kharif 2019 (5.60± 0.24 mt/ ha) and kharif 2020 (5.27± 0.06 mt/ ha) (Table 1).

The IPM as an approach has shown great potential for reducing the dependence on chemical control methods (Pretty et al., 1998; Atanassov et al., 2002). It involves integrating diverse tactics, including cultural, biological, and chemical control (Dent, 1991). Intensification of agriculture has reduced the farmland biodiversity and reduced the number of flowering plants and weeds, which natural enemies depend on for the food and nectar (Lu et al., 2014). Ecological engineering has great potential in rice IPM which involves the identification of optimal forms of botanical diversity which promote the natural enemies, but very little information available on the optimal fauna and flora to be employed for this cause. Earlier attempts in the field of ecological engineering studies found reduced pest population in main crop after planting flowering crops around the main field (Yu et al., 2001; Gurr et al., 2011; Liu et al., 2014; Zhu et al., 2015; Chen et al., 2016; Kong et al. 2016). Maintaining grasses and weeds around the rice fields, planting of sesame on bunds as a source of nectar, intercropping zizania in some fields, planting vetiver grass on roadsides and along irrigation canals and releases of *Trichogramma* spp. simultaneously had been reported to lower the pest activity in the rice fields (Chen et al., 2016; Zhu et al., 2015; Zhu et al., 2017).

Table 1. Incidence of key insect pests in rice and yield of rice (kharif 2019, 2020)

S. furcifera

Treatments	Incidence*								
	Kharif 2019					Kharif 2020			
	36 SMW	37 SMW	39 SMW	40 SMW	Mean± SE	36 SMW	38 SMW	39 SMW	Mean± SE
T1 Crops (sesamum+sunflower+soybean)	0.25± 0.15 (1.11± 0.07)	1.20± 0.31 (1.47± 0.11)	1.63± 0.13 (1.62± 0.04)	0.15± 0.09 (1.07± 0.04)	0.81± 0.36 (1.32± 0.14)^{c}	0.28± 0.05 (1.13± 0.02)	1.88± 0.16 (1.69± 0.05)	0.78± 0.38 (1.31± 0.14)	0.98± 0.47 (1.38± 0.17)^{b}
T2 Flowers (marigold+balsam+ gaillardia)	0.90± 0.24 (1.37± 0.08)	1.28± 0.18 (1.51± 0.06)	1.35± 0.34 (1.52± 0.11)	0.08± 0.05 (1.04± 0.02)	0.90± 0.29 (1.36± 0.11)^{c}	0.40± 0.15 (1.18± 0.06)	1.63± 0.17 (1.62± 0.05)	0.90± 0.32 (1.36± 0.11)	0.98± 0.36 (1.39± 0.13)^{b}
T3 Natural weeds	0.83± 0.34 (1.34± 0.12)	1.03± 0.21 (1.42± 0.07)	1.28± 0.14 (1.51± 0.05)	1.13± 0.28 (1.45± 0.10)	1.06± 0.09 (1.43± 0.04)^{b}	0.20± 0.09 (1.09± 0.04)	1.70± 0.45 (1.63± 0.13)	0.63± 0.13 (1.27± 0.05)	0.84± 0.45 (1.33± 0.16)^{b}
T4 Crops+Flowers	0.40± 0.18 (1.18± 0.08)	0.98± 0.18 (1.40± 0.07)	1.15± 0.13 (1.46± 0.04)	0.10± 0.06 (1.05± 0.03)	0.66± 0.25 (1.27± 0.10)^{d}	0.33± 0.13 (1.15± 0.06)	1.70± 0.41 (1.63± 0.13)	0.45± 0.31 (1.19± 0.12)	0.83± 0.44 (1.32± 0.16)^{b}
T5 Control	1.88± 0.11 (1.70± 0.03)	3.70± 0.22 (2.17± 0.05)	2.30± 0.16 (1.82± 0.05)	1.53± 0.13 (1.59± 0.04)	2.35± 0.48 (1.82± 0.13)^{a}	1.23± 0.10 (1.49± 0.03)	3.50± 0.20 (2.12± 0.05)	1.78± 0.11 (1.67± 0.03)	2.17± 0.69 (1.76± 0.19)^{a}
Mean± SE	0.85± 0.28 (1.34± 0.10)^{b}	1.64± 0.52 (1.59± 0.15)^{a}	1.54± 0.21 (1.59± 0.06)^{a}	0.60± 0.31 (1.24± 0.12)^{c}		0.48± 0.18 (1.20± 0.07)^{c}	2.08± 0.35 (1.73± 0.10)^{a}	0.90± 0.23 (1.35± 0.08)^{b}	

C. medinalis

Treatment	Damage (%)*											
	Kharif 2019							Kharif 2020				
	36 SMW	37 SMW	39 SMW	40 SMW	42 SMW	43 SMW	Mean± SE	36 SMW	38 SMW	39 SMW	41 SMW	Mean± SE
T1 Crops (sesamum+ sunflower+ soybean)	0.05± 0.05	0.61± 0.28	1.53± 0.30	0.93± 0.24	1.02± 0.18	0.84± 0.30	0.83± 0.19^{b}	0.34± 0.17	1.76± 0.19	0.58± 0.16	0.11± 0.11	0.69± 0.36b
T2 Flowers (marigold+ balsam+gaillardia)	0.09± 0.05	0.70± 0.09	1.21± 0.57	0.93± 0.51	0.72± 0.23	0.71± 0.21	0.72± 0.15^{b}	0.12± 0.07	1.26± 0.24	0.41± 0.08	0.09± 0.05	0.47± 0.27^{c}
T3 Natural weeds	1.87± 0.27	1.25± 0.34	0.86± 0.14	0.57± 0.06	0.71± 0.09	0.70± 0.13	0.99± 0.19^{b}	0.83± 0.12	2.03± 0.41	0.49± 0.26	0.54± 0.30	0.97± 0.36^{b}
T4 Crops+flowers	0.23± 0.09	0.56± 0.11	0.70± 0.12	0.97± 0.30	0.96± 0.33	0.45± 0.23	0.64± 0.11^{c}	0.22± 0.16	1.61± 0.28	0.23± 0.10	0.10± 0.10	0.54± 0.35^{c}
T5 Control	2.27± 0.23	2.35± 0.13	2.19± 0.51	3.09± 0.35	3.11± 0.54	1.73± 0.30	2.45± 0.22^{a}	2.08± 0.33	4.48± 0.29	2.77± 0.30	1.92± 0.22	2.81± 0.58^{a}
Mean± SE	0.90± 0.48^{b}	1.09± 0.33^{a}	1.23± 0.26^{a}	1.23± 0.45^{a}	1.30± 0.45^{a}	0.89± 0.21^{b}		0.71± 0.36^{c}	2.23± 0.57^{a}	0.90± 0.47^{b}	0.55± 0.35^{c}	

contd.

(contd. Table 1)

H. sasakii

Treatments	Damage (%)*										
	Kharif 2019						Kharif 2020				
	36 SMW	37 SMW	39 SMW	40 SMW	42 SMW	Mean± SE	36 SMW	38 SMW	39 SMW	41 SMW	Mean± SE
T1 Crops (sesamum+ sunflower+ soybean)	7.35± 0.66	6.08± 0.60	6.90± 1.02	5.40± 1.40	1.40± 0.18	5.42± 1.06^{b}	9.00± 0.55	3.50± 0.52	2.55± 0.17	0.00± 0.00	3.76± 1.90^{c}
T2 Flowers (marigold+ Balsam+ gaillardia)	8.90± 0.82	6.50± 0.94	6.58± 1.28	4.15± 0.48	1.53± 0.26	5.52± 1.24^{b}	9.38± 0.44	3.65± 0.60	2.68± 0.49	0.10± 0.10	3.95± 1.96^{c}
T3 Natural weeds	10.88± 1.27	5.18± 0.58	7.13± 0.98	4.95± 0.84	1.73± 0.36	5.97± 1.50^{b}	10.78± 1.43	4.40± 0.52	2.88± 0.55	0.15± 0.15	4.55± 2.25^{b}
T4 Crops+flowers	4.80± 0.47	5.48± 0.91	6.88± 0.78	6.35± 0.74	1.58± 0.19	5.00± 0.93^{b}	10.53± 0.65	3.20± 0.67	3.75± 0.64	0.00± 0.00	4.37± 2.21^{b}
T5 Control	10.83± 0.97	6.15± 0.48	8.85± 0.62	7.78± 0.55	3.75± 0.46	7.47± 1.20^{a}	12.65± 1.23	7.80± 1.00	6.00± 0.87	2.08± 0.30	7.13± 2.19^{a}
Mean± SE	8.56± 1.14^{a}	5.88± 0.24^{c}	7.27± 0.41^{b}	5.72± 0.63^{c}	1.99± 0.44^{d}		10.47± 0.64^{a}	4.51± 0.84^{b}	3.57± 0.64^{c}	0.47± 0.40^{d}	

T. incertulas and S. inferens incidence and yield

Treatment	White ears (%)		Yield (mt/ ha)	
	Kharif 2019	Kharif 2020	Kharif 2019	Kharif 2020
T1 Crops (sesamum+ sunflower+soybean)	0.9± 0.08^{c}	0.8± 0.05^{bc}	4.52± 0.24b	4.71± 0.07c
T2 Flowers (marigold+balsam+ gaillardia)	1.1± 0.1^{b}	0.9± 0.1^{bc}	4.80± 0.55a	4.97± 0.05b
T3 Natural weeds	1.5± 0.1^{ab}	1.2± 0.1^{b}	4.12± 0.31bc	4.44± 0.1d
T4 Crops+Flowers	1.1± 0.1^{b}	0.6± 0.03^{c}	5.60± 0.24a	5.27± 0.06a
T5 Control	1.8± 0.2^{a}	1.7± 0.2^{a}	3.99± 0.20c	4.27± 0.06d
F- value	3.9	8.3	3.7	25.2
LSD	0.5	0.4	1.0	0.2
p- value	0.028	<0.001	0.033	<0.001

Kharif 2019
Treatment, F = (41.4), LSD = (0.09), p<0.001
Week, F = (34.5), LSD = (0.08), p<0.001
Interaction (treatment × week), F = (3.8), LSD = (0.19), p<0.001
WBPH counts with same superscripts do not differ significantly.
*Mean of ten replications.
Data in parentheses *SQRT (X + 1)* transformed values

Kharif 2020
Treatment, F = (18.5), LSD = (0.12), p<0.001
Week, F = (68.6), LSD = (0.09), p<0.001
Interaction (treatment × week), F = (0.5), LSD = (NA), p=0.855
WBPH counts with same superscripts do not differ significantly.
*Mean of ten replications.
Data in parentheses *SQRT (X + 1)* transformed values

Kharif 2019
Treatment, F = (45.5), LSD = (0.31), p<0.001
Week, F = (2.6), LSD = (0.34), p=0.026
Interaction (treatment × week), F = (2.6), LSD = (0.76), p<0.001
Leaf folder damage % with same superscripts do not differ significantly.
*Mean of ten replications.

Kharif 2020
Treatment, F = (82.19), LSD = (0.30), p<0.001
Week, F = (63.22), LSD = (0.27), p<0.001
Interaction (treatment × week), F = (1.65), LSD = (NA), p=0.100
Leaf folder damage % with same superscripts do not differ significantly.
*Mean of ten replications.

Kharif 2019
Treatment, F = (8.51), LSD = (0.92), p<0.001
Week, F = (56.70), LSD = (0.92), p<0.001
Interaction (treatment × week), F = (2.82), LSD = (2.06), p<0.001
Whorl maggot damage % with same superscripts do not differ significantly.
*Mean of ten replications.

Kharif 2020
Treatment, F = (21.6), LSD = (0.83), p<0.001
Week, F = (253.1), LSD = (0.74), p<0.001
Interaction (treatment × week), F = (1.0), LSD = (NA), p=0.458
Whorl maggot damage % with same superscripts do not differ significantly.
*Mean of ten replications.

Egg parasitoids of planthoppers like *Oligosita* and *Anagrus* from common grassy flora near the ridge increased, while the population of planthoppers was reduced significantly with ecological engineering techniques (Zhu et al. 2015). The numbers of egg parasitoids, invertebrate predators, vertebrate predators like frogs and numbers of aquatic predators such as Odonata (damselflies) and Tetragnathidae were significantly higher than those in the control fields (Chen et al. 2016; Kong et al. 2016; Zhu et al. 2017). The application of ecological engineering technology has kept rice pest populations at low levels. Zhu et al (2014) proposed that presence of flowering plants like *Tagetes erecta, Trida procumbens, Emilia sonchifolia* and *Sesamum indicum* around the rice reduces the planthoppers, and increased the abundance of natural enemies like mirid bug. Planting of flowering plants like sesamum, tagetes, sunflower etc. on rice field bund and along the roadsides has been recommended for improving biological control and sustainable management of rice insect pests (Lu and Guo, 2015). Planting of sesamum around the rice fields has been a widely accepted. Egg parasitoids such as *Anagrus optabilis* and *A. nilaparvatae* are known to be significantly attracted by volatile compounds from sesamum flowers and leaves. It has also been reported that the, sesamum flowers also enhances the longevity of egg parasitoids for lepidopterous pests like pink stem borers, spotted stem borers and leaf folders and does not support these pests (Zhu et al., 2012; 2015).

Laboratory screening experiments proved that volatiles of *S. indicum*, *Impatiens balsamena*, *E. sonchifolia*, *Hibiscus coccineus T. procumbens* and *H. esulentus* attract and enhance the performance of *Anagrus* spp. (Zhu et al., 2013). Of these, *S. indicum*, *E. sonchifolia*, and *I. balsamena* were also attractive to *A. nilaparvatae,* and *S. indicum* flowers specifically enhance the life span of *A. nilaparvatae* and *A. optabilis*. Horgan et al (2016) reported lower leafhopper and WBPH abundance in the rice fields planted with string bean strips. In another study, banker plant system consisted of planting a grass species, *Leersia sayanuka*, adjacent to rice fields. BPH population densities were significantly lower in rice fields with banker plant system (Zheng et al., 2017). Chandrasekar et al. (2017) recommended the use weed strips of *E. colonum* (L.) and *E. crusgalli* in rice ecosystem to enhance the availability of mirid bugs. Rice bunds were increasingly recognized as near crop habitats that can be used for planting trap crops and other flowering plants for attraction and conservation of natural enemies. Present study on ecological engineering in rice revealed that planting of crops plants such as sesamum, sunflower and soybean and flowering crops such as marigold, balsam and gaillardia on the bunds around the main rice fields attract and enhance natural enemies.

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