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Demonstration of Ecological Engineering based Pest Management in Rice *Oryza sativa* L. through Farmers Participatory Approach

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ABSTRACT

Background: Rice is one of the predominant cereal crop grown in Dharmapuri district of Tamil Nadu state, India in approximately 4000 hectares with a average productivity of 4500 kg/ha. Hoppers, stem borer, leaf folder, gall midge and ear head bugs are the major insect pests for which farmers resort management practices. Instead of curative management, farmers mostly use the insecticide as prophylactic management which leads to unwarranted problems. Though integrated pest management has been advocated as an alternate strategy, farmers are reluctant to use all the components of IPM and rely on mostly on insecticides. In this context, the ecological engineering pest management can form a better alternative, which also coincides with the age old practice of growing border crops in this region.

Methods: The potential of ecological engineering pest management (EEPM) was assessed in comparison with Integrated Pest Management (IPM) and Farmers Practice (FP) in five farmer's fields. Based on the results, ten and twenty front line demonstrations were conducted during consecutive years to study the performance of EEPM in Dharmapuri district.

Result: The number of hopper/hill, per cent dead heart, per cent white ears in the EEPM was 10.65, 7.07 and 9.65 and in the IPM module 10.18, 8.40 and 11.55 and in the farmers practice 6.73, 10.73 and 12.75 respectively. The natural enemies *viz*., coccinellids/hill and spiders/hill were more in EEPM (2.00 and 3.15) and least in the farmers practice (0.40 and 0.86). The number of hoppers/hill, per cent dead heart, number of coccinellids/hill and number of spiders per hill was 8.40, 6.00, 3.00 and 1.40 in EEPM and 6.20, 5.40, 1.20 and 0.60 in farmers practice respectively in the 2016-17 front line demonstrations. The EEPM module recorded 8.1, 8.65, 3.5 and 1.75 hopper/hill, per cent dead heart, coccinellids/hill and spiders/hill in 2017-18 front line demonstrations. The farmers were able to save Rs. 5000/- from the plant protection cost apart from getting additional revenue in EEPM. The combination of border crops, influence of border crop on rodent damage in rice ecosystem and benefits of providing separate niche area than border crop are the researchable areas. In spite of above constraints the EEPM can be followed in rice ecosystem with the locally available crop combination to reduce the insecticide usage and increase the beneficials.

Key words: Border crop, Ecological engineering pest management, Integrated pest management, Natural enemies, Rice.

INTRODUCTION

The predominant cereal rice is the staple food for more than fifty per cent of worlds population. Asia is one of the major rice growing regions of the world. In India as per 2018-19 estimates rice was cultivated in an area of 43 million hectares with a production of 118 million tonnes. Rice is grown in an approximate area of 4000 ha with a productivity of 4800 kg/ha in Dharmapuri district. The area under crop cultivation is shrinking every year because of urbanization and industrialization. As there is less chance of increasing area under any crop in any region the productivity has to be increased through high yielding varieties and improved production and protection technologies. Horgan *et al*., 2016 predicted that world must produce an additional 115 million tonnes of rice by 2035 to meet the increasing global demands. The rice production faces challenges such as global temperature increase, extreme weather events and declining biodiversity.

Among the yield limiting factors in rice cultivation, the damage caused by insect pests and diseases are the major concern for the rice farmers. Though 120 species of insects are reported to cause damage in rice, 15 to 20 insects are economically important (Kalode, 2005).

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Farmers usually resort to the chemical insecticide application for the management of insect pests. Farmers use insecticides as prophylactic rather than curative. The overreliance of the chemical insecticides apart from causing resistance in the target pest, residue in the produce and resurgence in the minor pests also led to ecological adversity and health related problems (Wakil, 2001). Integrated pest management comprising of cultural, mechanical, biological and chemical methods has been widely advocated to overcome insecticide resistance, residue and resurgence problems. Though in some areas promising headways has been observed in the adoption of integrated pest management strategies, the non-availability of quality inputs in some of the IPM components hinders the wider adoption. Hence the farmers usually prefer application of synthetic insecticides for insect pest management.

The limitations in the above management methods resulted in search of new management strategies in Rice ecosystem. Ecological engineering based pest management has been emerging as a new pest management approach which has been practised in many South East Asian countries. Ecological engineering mainly focuses on increasing the abundance, diversity and function of natural enemies in agricultural habitats by providing refuges and alternate or supplementary food sources (Gurr, 2009). Habitat manipulation aims to provide the natural enemies of pests with resources such as pollen, nectar, alternate prey, physical refugia, alternate hosts and liking sites (Sreelatha and Jesu Rejan, 2018). In this context, to evaluate the potential of ecological engineering based pest management with integrated pest management (IPM) and farmers practice (FP), on farm trails were conducted in the farmers fields. Based on the encouraging results from on farm trail and chance to combine with other management modules, the performance of ecological engineering pest management was studied through front line demonstrations in Dharmapuri district.

MATERIALS AND METHODS

Habitat manipulation through cultural methods to enhance biological control is the major base for the ecological engineering-based pest management (EEPM). The ecological engineering based pest management is new concept among the Dharmapuri district farmers and hence to assess the efficacy of ecological engineering concept on farm trials were conducted in five farmers' fields during 2015-16 in cluster village *viz.,* Naripalli village, Harur block, Dharmapuri district (12.04828 N, 78.67506 E). The bunds which are used as pathways between fields and also as irrigation channels has been used to raise the bund crops. The EEPM module was compared with Integrated pest management (IPM) module and farmers (FP) practice. The components of both modules are described as follows:

EEPM (M1):	➢ Raising combination of crops such as sunflower (100 g), sesame (100 g), mustard (50 g), cowpea (100 g), marigold (20 g) and black gram (100 g) on the bunds to enhance the biological control. ➢ Seed treatment with *Pseudomonas fluorescens* @ 10 g/kg and seedling dip with *Pseudomonas fluorescens* @ 10 g/lt at the time of transplanting. ➢ Installation of pheromone traps @ 12/ha to monitor the incidence of stem borer. ➢ Strict avoidance of insecticide usage up to 45 DAS. ➢ Application of *Bacillus thuringiensis* @ 2 g/lt or Spinosad @ 1 ml/lt or Chlorantraniliprole 18.5% SC @ 0.3 ml/lt.
IPM (M2):	➢ Seed treatment with *Pseudomonas fluorescens* @ 10 g/kg and seedling dip with *Pseudomonas fluorescens* @ 10 g/lt at the time of transplanting. ➢ Installation of pheromone traps @ 12/ha to monitor the incidence of stem borer. ➢ Release of *Trichogramma japonicum* or *T chilonis* @ 1 lakh/ha on appearance of stem borer egg masses. ➢ Mass trapping of yellow stem borer male moths by installing pheromone traps @ 20 traps/ha at 20 days after transplanting. ➢ Based on the ETL, application of insecticides for the management of hoppers, leaf folder, gall midge, stem borerImidacloprid 17.8SL @ 0.5 ml/lt or buprofezin 25% SC @ 1.5 ml/lt or ethofenoprox 10% EC @ 1 ml/lt for the management of hopperCartap hydrochloride 4% granules @ 25 kg/ha or cartap hydrochloride 50% SP @ 2 g/lt or Chlorantraniliprole 18.50% SC @ 0.3 ml/lt for the management of stem borer and leaf folder.
FP:	➢ Prophylactic application of insecticides at different crop stages.

The rice variety Co 51 was used for the on farm trial and all the agronomic practices were kept uniform for both the EEPM and IPM methods. In each farmer field, 1000 m^2 area was allotted for the management modules. Approximately 10-20 m distance between each management module or a field of 200-500 m^2 has been kept to avoid overlapping effect of different management module. In the EEPM module the sowing of border crop has been completed 4-7 days before transplanting (Fig 1). The bunds were cleaned for raising the border crops. The incidence of insect pests, abundance of natural enemies was enumerated at fortnight intervals. The plant protection cost associated with each module and yield parameters were recorded. Based on the results of on farm trial front line demonstration of the EEPM was conducted in 10 and 20 farmer's fields respectively during 2016-17 and 2017-18 in Harur, Pappireddipatti and Palacode blocks of Dharmapuri district. During 2017-18 outbreak of gall midge was noticed in most of the rice growing regions of the district. Based on this precedence, the gall midge incidence in the front line demonstration was also enumerated for the EEPM and farmers practice. The farmers response towards the adoption of ecological engineering method, their advantage over their practice, cost saving towards the plant protection, difficulties in raising bund crops, knowledge on the different composition of bund crops, economics of the cost of cultivation were gathered from the farmers.

RESULTS AND DISCUSSION

The results of the on farm trials conducted in five farmer's fields to compare the ecological engineering pest management, integrated pest management and farmers practice were given in Table 1. The number of hopper/hill, per cent dead heart, per cent white ears in the EEPM was 10.65, 7.07 and 9.65 and in the IPM module 10.18, 8.40 and 11.55 and in the farmers practice 6.73, 10.73 and 12.75 respectively. The natural enemies *viz*., coccinellids/hill and spiders/hill were more in EEPM (2.00 and 3.15) and least in the farmers practice (0.40 and 0.86). The integrated pest management module recorded 1.38 and 2.35 coccinellids and spiders/hill. Among the management module assessed the EEPM module recorded 14.14% increased yield than the farmers practice with a net income and BCR of Rs.99,440/ha and 1.80.

Based on the encouraging results from the on farm trails, front line demonstrations were conducted during 2016 -17 and 2017-18 in ten and twenty farmers field respectively. The results of front line demonstration fell in line with on farm trials (Table 2 and 3). The number of hoppers/hill, per cent dead heart, number of coccinellids/ hill and number of spiders per hill was 8.40, 6.00, 3.00 and 1.40 in EEPM and 6.20, 5.40, 1.20 and 0.60 in farmers practice respectively in the 2016-17 front line demonstrations. The EEPM module recorded 8.1, 8.65, 3.5 and 1.75 hopper/hill, percent dead heart, coccinellids/hill and spiders/hill in 2017-18 front line demonstrations. The farmers practice recorded 10.95, 13.70, 0.60 and 0.40 hopper/hill, per cent dead heart, coccinellids/hill and spiders/hill respectively. The per hectare net income and BCR during 2016-17 and 2017-18 was Rs. 38,860/- and 1.60 and RS. 47,335/- and 1.76 in EEPM.

The plant protection cost associated with EEPM and FP is given in Table 4. Farmers had to spent approximately Rs. 2000/ha towards the preparation of bunds for sowing the seeds of border crops. Though the farmers saved Rs. 5000/- from the plant protection cost in the EEPM, > 65 per cent of the farmers opined that making separate arrangement for border crop sowing is difficult task for them (Table 5). About 55 per cent of the farmers informed that they were able to reduce the number of insecticide spray through the EEPM.

Raising border crops around the rice fields in EEPM encourages the activity of beneficial insect population in the

Fig 1: In the EEPM module the sowing of border crop has been completed 4-7 days before transplanting.

main crop. Shanker *et al*., (2013) recorded more number of coccinellids in the forbs/weeds present in the field bunds. The availability of resources such as nectar have been shown to improve longevity, searching efficiency and realised parasitism of parasitoid species (Mitsunaga *et al*., 2004). *Sesamum indicum* as border crop in rice increases the realized parasitism of egg parasitoids *Anagrus nilaparvatae* and *A. optabilis* (Lu *et al*., 2015 and Zhu *et al*., 2014). The weed host *Tagetes erecta* found along the paddy field bunds attracts predator *Cyrtorhinus lividipennis*. The bund crops had significant effects on the diversity and abundance of natural enemies and pollinators with cucumber, squash, luffa and bitter gourd attracting large numbers of both pollinators and beneficial parasitoid wasps (Horgan *et al*., 2016).

Tailored flower strips apart from encouraging beneficial insect population also provides chance of additional income for the farmers (Timothy *et al*., 2011). The rice fields with intercrops of corn had lower abundance of plant hoppers and adoption of this strategy may be useful as part of an integrated pest management strategy for the sustainable rice production (Yao *et al*., 2012). IPM module exhibited significant superiority over all other modules in suppressing the yellow stem borer, *S. incertulas* infesting rice both in terms of minimizing the per cent dead hearts and per cent white ears (Rani *et al*., 2020). Alam *et al.* (2016) recorded lowest percentage of dead hearts (1.03) and white heads (2.00) in the IPM plots. The authors also concluded that IPM practices are an effective strategy for obtaining high rice yields while protecting the environment and creating a more sustainable agro ecosystem. In the present on farm trial, sesame has been included as one of the components of border crop along with other crops. The increased activity of coccinellids and spiders in the EEPM module than the other modules in the present study corroborate with the above findings.

Divya and Nethaji Mariappan, (2020) revealed that IPM practices was effective with minimal effect on natural enemies *viz*., spiders 10.95/ 10 hill and coccinellid 9.95/ 10 hill and significantly superior over EEPM and farmers practice. These findings were contrary to the present results from the on farm trial and front line demonstration. In the above study, two crops *viz*., marigold and blackgram has been raised in the paddy field borders and pheromone traps @ 12/ha was advocated in the EEPM. But in the present investigation apart from raising combination of crops as border crop the other management strategies such as seedling dip, pheromone traps and need based one insecticide application has been

Table 1: Performance of different management modules in on farm trail.

Parameters*	Farmer's practice	IPM	EEPM
Number of hopper/hill	6.73	10.18	10.65
Per cent of stem borer (Dead heart)	10.73	8.40	7.07
Per centof stem borer (White ears)	12.75	11.55	9.65
No. of coccinellids/hill	0.40	1.38	2.00
No. of spiders/hill	0.86	2.35	3.15
No. of productive tillers	34.20	38.80	40.80
Grain yield (q/ha)	37.80	39.60	45.20
Per cent yield increase than FP	-	4.76	14.14
Gross income (Rs/ha)	64,140	58,000	55,200
Net income (Rs/ha)	83,160	87,120	99,440
Plant protection cost (Rs/ha)	12,750	8,500	5,500
BCR	1.30	1.50	1.80

*Mean of five farmer field observation.

Table 2: Performance of ecological engineering based pest management module in front line demonstrations during 2016-17.

Parameters*	Farmers practice	EEPM
Number of hopper/hill	6.20	8.40
Per cent of stem borer (Dead heart)	5.40	6.00
No. of coccinellids/hill	1.20	3.00
No. of spiders/hill	0.60	1.40
No. of productive tillers	30.20	33.20
Grain yield (q/ha)	40	41
Per cent yield increase than FP	-	2.50
Gross income (Rs/ha)	88,000	90,200
Net income (Rs/ha)	23,100	38,860
BCR	1.35	1.60

*Mean of ten farmer field observation.

Table 3: Performance of ecological engineering based pest management module in front line demonstrations during 2017-18.

Parameters*	Farmers practice	EEPM
Number of hopper/hill	10.95	8.1
Per cent of stem borer (Dead heart)	13.70	8.65
Incidence of gall midge	25.5	18.5
No. of coccinellids/hill	0.6	3.5
No. of spiders/hill	0.4	1.75
No. of productive tillers	31.40	32.00
Grain yield (q/ha)	42.05	44.95
Per cent yield increase than FP	-	6.89
Gross income (Rs/ha)	1,02,590	1,09,235
Net income (Rs/ha)	36,065	47,335
BCR	1.54	1.76

*Mean of twenty farmer field observation.

Table 4: Plant protection cost associated with EEPM and farmers practice (Cumulative of both seasons).

Particulars	EEPM(Rs/ha)	FP(Rs/ha)
Seed treatment with BC agents (10 kg seeds)	500	500
Bund formation and sowing of seeds around the bund	2000	-
Insecticide spraying (Min 4 sprays @ Rs. 1500-1750/spray for chemical and Rs.1000/spray for spraying cost @ Rs.40/tank)	-	12,750
Need based spraying of Biopesticides Rs. 1500/biopesticide and spraying	3000	-
Total	5500	10,500

Table 5: Adoption of Ecological Engineering based pest management method.

Particulars	Percentage
Farmers awareness about EEPM method	<10%
Willingness of the farmers to learn the new concept	60%
Farmers awareness about IPM method	80%
Formation of bunds is the major problem	65%
Observing more natural enemies	70%
Reduced number of insecticide spray	55%

included in the EEPM module. The additional components might have favoured the better performance of EEPM than IPM and farmers' practice.

The eco rice farmers had higher input and output-oriented technical efficiency scores which were insignificant compared to those with normal rice (Tu and Yabe, 2015). The farmers fields and ecologically engineered fields produced similar rice yields but the ecologically engineered fields saved US$150/ha on insecticides and gained US$120/ha from the sesame seed that was produced on the bunds (Lu *et al*., 2015). The net profit and BCR in the front line demonstration was not significant between EEPM and farmers practice. But in EEPM the cost spent towards plant protection is 50 per cent less than the farmers' practice. The results of present study are in agreement with the above findings. Region specific crop combination for raising border crop, influence of border crops on the biological fitness of natural enemies, establishment of local niches instead of border crops and other vertebrate problems due to border crops in the rice field bunds are some of the areas which needs thorough investigation.

CONCLUSION

The on farm trials conducted to evaluate the ecological engineering pest management in rice with integrated pest management and farmers practice revealed that the EEPM recorded lower incidence of plant hopper and stem borer and more prevalence of natural enemies. The cost associated with plant protection was least in the EEPM than IPM and FP. The difference of net profit and BCR was non-significant for all the methods in the present front line demonstration. As per the farmers feedback 65% of farmers felt that formation bunds for raising border crop is labour intensive and requires more effort and 55% expressed that they were able to reduce the number of insecticide spray in EEPM. Hence EEPM can be combined with the other management strategies to reduce the use of insecticides in rice and also increase the arthropod diversity in rice ecosystem.

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