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Integrated pest management in rainfed rice production systems of India – a farmers' participatory study

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ABSTRACT

On farm adaptive trials were carried out under the World Bank aided National Agricultural Technology Project (NATP) to develop and verify location specific IPM technologies suitable for rainfed rice production systems in Orissa, West Bengal, Andhra Pradesh and North Eastern states of Assam and Manipur during wet seasons of 2001 to 2003. The trials consising of three treatments: (i) farmers practice (FP) involving conventional practices of the farmers, (ii) scheduled treatment (ST) involving application of insecticides based on a regular schedule and (iii) Integrated Pest Management (IPM) treatment – with a set of optimized location specific pest control components adopted on need basis, were conducted at 10 sites in each of the 5 locations viz., Cuttack, Titabar, Imphal, Warangal and Kalyani. The results indicated that incidence of insect pests, diseases and weeds was lower in IPM and ST treatments than FP. The cost benefit ratio was higher in IPM treatment providing higher net returns to farmers. There was also increase in natural enemy populations in IPM treatments due to reduction in pesticide use. Impact studies showed that there was increase in awareness among the farmers in adoption of environment friendly components like: tolerant varieties in case of gall midge and brown plant hopper (BPH), use of pheromone traps for monitoring yellow stem borer, release of Trichogramma egg parasitoid against leaf folder, balanced application of fertilizers, formation of alley ways and water management.

Key words: *Integrated pest management, rainfed rice, farmers' participatory study*

In India, rice is grown in 44.6 million hectares of which 24.6 m ha comes under rainfed rice based production system. The current level of 87 million tonnes (2003-04) of rice production in the country has to be raised to 128 million tonnes by 2010 to meet the growing needs of increasing population. To meet the future demand there is a need to raise productivity particularly in the rainfed production system in order to bring it on par with that of irrigated ecosystem. Biotic stresses are the major limiting factors in rice production in rainfed ecosystems. Among the biotic stresses, insect pests and diseases are dominant because the warm and humid climate in the rainfed rice areas is conducive for their incidence and multiplication. Integrated Pest Management (IPM) is the most appropriate approach to overcome these biotic stresses and obtain sustainable rice yield with least damage to the environment. Earlier, demonstrations of location specific IPM strategies through large scale trials involving government agencies as well as methods involving farmers participatory approach in irrigated ecosystems have yielded positive results (Razak, 1986; Sankaran, 1987; Krishnaiah and Reddy, 1989). However, methods involving direct farmers participation and experiential learning have been more effective (Matteson *et al.*, 1994; Heong and Escalada, 1997).

In view of this background, efforts were made by the Directorate of Rice Research, Hyderabad through an All India Network Project under the National Agricultural Technology Project (NATP) of Indian Council of Agricultural Research (ICAR) during 2000-2004, to develop and verify location specific IPM technologies suitable for rainfed rice production systems of Andhra Pradesh, Orissa, West Bengal and northeastern states of Assam and Manipur. Novel eco-friendly components such as pest resistant cultivars, use of pheromone traps, release of egg parasitoids and need based pesticide application were included in IPM package for verification and demonstration on farmers fields through farmers participatory approach. A multi-institutional linkage mechanism involving Indian Council of Agricultural Research (ICAR) institutes, state agricultural universities (SAU), state departments of agriculture and other related departments supported the efforts made under the project.

MATERIALS AND METHODS

On farm adaptive trials were carried out to quantify the yield gap on the farmers fields and realize potential yields by controlling pests through IPM. The trials, were undertaken at 5 locations *viz.*, Cuttack, Orissa; Titabar, Assam; Imphal, Manipur; Warangal, A.P. and Kalyani, West Bengal during wet seasons.

Five villages (Table 1) were identified at each location and in each village, two sites (replications) were selected for the on-farm trials. At each site, there were three treatments *viz.*, (i) farmers practice (FP) involving conventional practices of the farmers, (ii) scheduled treatment (ST) involving application of insecticides based on a regular schedule irrespective of pest incidence and (iii) IPM treatment (IPM) consisting of a set of optimized location specific pest control components (Tables 2-6). A plot size of 1 ha. was maintained per treatment. Within each plot 5 quadrates of 50 m^2 were marked and observations were recorded on incidence of insect pests and natural enemies, diseases and weeds. The observations were recorded at fortnightly interval beginning 15 days after transplanting (DAT). Yields were recorded from the five quadrates per treatment. The pooled data for three years (2001-2003) from each location were subjected to suitable transformation for analysis of variance to determine the significance of differences between treatments using F-test. The treatment means were compared by using least significant difference (LSD) at $p<0.05$.

Table 1. Villages included at each location for on farm trials (2001-03)

Location	Target districts	Villages
CRRI, Cuttack,Orissa	Dhenkanal	Kandabindha, Kasiadihi, Saduamunda, Kumaramunda and Balrampur
AAU, Titabar, Assam	Jorhat	Khatowal, Dakhinpat, Bajalbari, Cherelli and Begenkhuwa
CAU, Imphal, Manipur*	Imphal East, Imphal West, Thoubal and Bishnupur	Khundrakpam, Lamsang, Moidangpok, Kachikul, Konthoujam, Ngairangbam, Hiyangthang, Nambol, Tabunghkok, and Mongjam
ARS, Warangal (ANGRAU) Andhra Pradesh	Warangal	Keshavpur, Tirumalangadi, Madegudem, Gangaram and Bangarupalli
BCKVV, Kalyani, West Bengal	Bankura and Birbhum	Gorabari, Ghurisia, Taraulia, Joydeb More and Gopalpur

* At this location, ten villages were identified and one site was selected in each village for on-farm trial

Table 2. Details of Treatments in the on farm trial, Cuttack, Orissa

Farmers' practice (FP)	No protection measures were taken
Scheduled treatment (ST)	Application of butachlor @ 1.5 kg a.i.ha^{-1} at 5 DAT.
	Application of phorate 10G @ 1.0 kg a.i.ha^{-1} at 15 DAT
	Application of monocrotophos 35EC @500g a.i.ha^{-1} at 40 and 60 DAT.
IPM treatment (IPM)	Monitoring pheromone traps were set up after 15 days of planting and depending on the onset of yellow stem borer moth population, pheromone traps were installed @ 20 traps ha^{-1}
	Trichogramma japonicum egg parasitoids @ 100,000 ha^{-1} were released twice depending on the incidence of yellow stem borer moths during 2001 only.
	Monocrotophos 35EC @ 500g a.i.ha^{-1} was applied depending on the incidence of case worm, leaf folder, whitebacked planthopper, thrips and whorl maggot. Spot application of phorate 10G was made wherever mealy bug incidence was noticed.

Table 3. Details of treatments in the on-farm trial, Titabar, Assam

Farmers practice (FP)	Variety: Mahsuri and Ranjit
	Fertilizer: Fertilizer application imbalanced and lower than the recommended dose
	Spacing: Planting was haphazard and plant population was lower than the optimum.
	Pesticide: No pesticide was applied
	ITKs: incorporation of *Eupatorium odoratum* and neem leaves
Scheduled treatment (ST)	Seed treatment with Bavistin @ 1g kg^{-1} of seed
	Application of carbofuran 3G@ 1kg a.i. ha^{-1} in nursery at 5 to 7 days before uprooting of seedlings
	Application of chlorpyriphos 20 EC 500 g a.i. ha^{-1} thrice at 20, 40 and 70 DAT as foliar spray
IPM treatment (IPM)	Use of tolerant variety (Ranjit – 155 days)
	Seed treatment with Bavistin @ 1 g kg^{-1} of seed
	Nursery treatment with carbofuran as in ST.
	Timely planting by July.
	Optimum plant population (spacing -20 x 20 cm)
	Balanced fertilizer application (NPK-40:20:20 kg ha^{-1})
	Split application of Nitrogen
	Clean cultivation
	Regular pest monitoring (use of pheromone traps @ 8 traps ha^{-1} in case of YSB).
	Release of *Trichogramma* egg parasitoids
	Need based application of pesticides
	ITK: use of bamboo perches,incorporation into soil of *Eupatorium odaratum* leaves, twigs and neem leaf.

Table 4. Details of Treatments in the on farm trial, Imphal, Manipur

Farmers' practice (FP)	One application of monocrotophos 0.03% or endosulfan 0.05% at 20 to 35 DAT
Scheduled treatment (ST)	Seed treatment with Carbendazim + Mancozeb @ 1 g/kg of seed
	Twice application of monocrotophos 0.05% at 15 and 35 DAT followed by one application of chlorpyriphos 0.05% at 65 DAT
IPM treatment (IPM)	Use of CAU Selection-1, a variety resistant to gall midge and blast Clean cultivation
	Balanced and split application of nitrogenous fertilizer (N,P,K @ 60:40:30 kg/ha - 30:40:30 kg N,P,K as basal + 15 kg N at maximum tillering stage + 15 kg N at panicle initiation stage).
	Regular pest monitoring in nursery and main field by the use of pheromone traps @ 8 traps/ha in case of yellow stem borer
	Need based application of pesticides (details as in ST)

Table 5. Details of Treatments in the on farm trial, Warangal, Andhra Pradesh

Farmers practice (FP)	Application of phorate 10G @ 2 kg/acre
	Two applications of chlorpyriphos 20 EC and fenburacarb 50 EC @ 500 g a.i. ha^{-1}
Schedule treatment (ST)	Two to three applications of monocrotophos or/and chlorpyriphos
IPM treatment (IPM)	Use of gall midge tolerant variety WGL 14377
	Application of weedicide, Diargyl @ 80 g/ha
	Monitoring of YSB using sex pheromone traps @ 8 traps ha^{-1}
	Need based application of chlorpyriphos, monocrotophos or imidacloprid

Table 6. Details of Treatments in the on farm trial, Kalyani, West Bengal

Farmers practice (FP)	One spray application of cypermethrin at 20 - 25 DAT. One spray application of chlorpyriphos at 70-80 DAT
Scheduled treatment (ST)	Seed treatment with thiram @ 2 g/kg of seed
	Seed bed treatment with carbofuran 3G @ 1 kg.a.i./ha in nursery
	Application of carbofuran 3 G @ 1 kg a.i. ha^{-1} at 15 DAT
	Application of butachlor 5G @ 13 kg ha^{-1}
	Spray application of chlorpyriphos @ 500 g a.i. ha^{-1} against insect pests and ediphenphos @ 250 ml ha^{-1} against diseases at 35 DAT
	Spray application of chlorpyriphos @ 500 g a.i. ha^{-1} against insect pests and propiconazole @ 200 ml/ha against diseases at 50 DAT
	Spray application of imidacloprid @ 100 ml/ha at 70 - 90 DAT
IPM treatment (IPM)	Seed treatment with thiram 2g/kg of seed
	Use of BPH tolerant variety, Chaitanya in Birbhum district
	Application of weedicide, butachlor 5G @ 13 kg ha^{-1}
	Monitoring of YSB using sex pheromone traps @ 8 traps ha^{-1}
	Release of egg parasitoids, *Trichogramma japonicum* and *T. chilonis* @ 1,00,000 adults ha^{-1} starting from 15 DAT
	Spray application of propiconazole 25 EC @ 200 ml ha^{-1} at 30 DAT
	Spray application of cartap hydrochloride 500 g a.i. ha^{-1} at reproductive stage
	Cultural practice - alternate wetting and drying at 7 days interval at 50-60 DAT in rainfed low land areas and single irrigation at 20 DAT in rainfed upland against mealy bug and termite.

RESULTS AND DISCUSSION

The salient findings and their impact are discussed location-wise as under:

Central Rice Research Institute, Cuttack

Incidence of insect pests and natural enemies. The incidence of silver shoots ranged from 1.9 to 6.4% across the treatments (Table 7). Under the scheduled treatment, the application of phorate 10G @ 1kg a.i./ha could control silver shoot incidence to an appreciable degree. The dead heart incidence at vegetative stage ranged from 3.9 to 6.5%, while white ear head incidence ranged from 3.0 to 11.4%. The IPM and ST treatments recorded significantly less damage compared to FP. The brown planthopper populations were also significantly less in ST (26.5 hoppers/10 hills) and IPM (27.1 hoppers/10 hills) compared to FP (64.7 hoppers/10 hills). Leaf folder and case worm incidence was also less in IPM (2.3 & 2.1% DL) and ST (2.9 & 2.1% DL) than FP (5.6 & 5.4%DL).

Among the natural enemies, predators such as spiders and mirid bugs were dominant. Their populations were higher in FP and IPM treatments than ST.

Disease incidence. Incidence of brown spot, bacterial leaf blight (BLB), sheath blight, blast and false smut were observed at all the sites in traces, hence they did not warrant any control measures.

Weed incidence. The weed flora in the experimental

Table 7. Insect pest incidence in different treatments in on farm trials, Cuttack, Orissa (2001-2003)*

Treatment	Gall midge (% SS)	Yellow stem borer		Leaf folder	Case worm	Brown planthopper
		% DH	% WE	(% DL)	(% DL)	(No./10 hills)
IPM	4.5b	3.9a	4.0a	2.3a	2.1a	27.1a
ST	1.9a	3.3a	3.0a	2.9a	2.3a	26.5a
FP	6.4b	6.5b	11.4b	5.6b	5.4b	64.7b

* Overall mean of observations in 10 sites, SS- silver shoots, DH- dead hearts, WE- white ears, DL- damaged leaves, Within a column values followed by different letters are significantly different at P=0.05

fields comprised of the sedges and grasses like *Cyperus iria, C. rotundus, Panicum repens, Leptochloa chinensis, Echinochloa colonum, E. crus-galli, Paspalum conjugatum,* and *Fimbristylis miliaceae.* The broad leaf weeds included *Eclipta prostrata, Marsilea minuta, Sphenochlea zeylanica, Burgia ammanioides, Cleome viscosa, Aeschynomene indica, Ludwigia parviflora, Scirpus articulatus* and *Ipomeae aquatica.*

In the butachlor applied plots (ST) grasses were better controlled whereas Almix (metasulfuron methyl 10% + chlorimuron ethyl 10%) controlled the sedges and broad leaf weeds effectively. Highest weed control efficiency (WCE) of 83.4% was observed in IPM treatment at 60 DAT whereas at 30 DAT highest WCE was recorded in ST (69.7%).

Grain yield and economics. The grain yields were the highest (Table 11) in IPM plots (6.1 t ha^{-1}) followed by ST plots (5.8 t ha^{-1}) and both were superior to FP (4.1 t ha^{-1}). There was reduction in pesticide use to one to two applications in IPM leading to significantly higher cost benefit ratios (1:9.5) compared to in scheduled treatment (1:5.1), while FP did not yield any net returns.

Assam Agricultural University, Titabar

Incidence of insect pests and natural enemies. The incidence of silver shoots ranged from 5.6 to 7.1% in the treatments. The dead heart incidence at vegetative stage ranged from 4.7 to 10.8%, while white ear head incidence ranged from 4.4 to 8.6%. Leaf folder and case worm incidence varied from 3.5 to 5.8 and 2.6 to 6.3 % DL, respectively across the treatments. Overall, the insect pest incidence was less in the IPM and ST treatments than FP.

Among the natural enemies, predators such as spiders, coccinellids, ground beetles and dragon/damsel flies were prevalent. The population of natural enemies was highest in FP followed by IPM and significantly low in ST.

The disease and weed incidence was negligible.

Grain yield and economics. The grain yield was the highest (Table 11) in IPM (5.3 t ha^{-1}) followed by ST plots (4.7 t ha^{-1}) and both were superior to FP (3.9 t ha^{-1}). The cost benefit ratios were higher in IPM treatment (1:2.8) than ST (1:2.4) and FP (1:2.2).

Central Agricultural University, Imphal

Incidence of insect pests and natural enemies. The pest incidence was moderate. Incidence of silver shoots was 2.3% in IPM significantly lower than that of ST (5.5%) and FP (5.7%). Gundhi bug populations were also lowest in IPM (3.3 per 20 hills) compared to FP (4.9 per 20 hills) and ST (5.2 per 20 hills). The green leafhopper (GLH) populations were similar across the treatments (5 hoppers per 20 hills). The incidence of defoliators like leaf folder, case worm, whorl maggot and grass hopper as well as stem borer damage at harvest was low and below 5%. The mean infestation data of these pests revealed no discernible differences among the treatments. Overall, the insect pest incidence was lower in the IPM and ST treatments than FP.

Among the natural enemies, predators like spiders and coccinellids, were predominant. The population of coccinellids was higher in IPM treatment (3.2) compared to FP treatment (2.7). However, no discernible differences were observed in the spider populations among the treatments.

Disease incidence. The mean infestation data revealed that the incidence of neck blast at harvest was lower in IPM (1.00%) as compared to ST (3.23%) and FP (2.67%).

Weed incidence. The weed flora comprised of *Alternanthera philozeroides, Azolla pinnata, Echinochloa colonum, Echinochloa crusgalli, Eleocharis dulcis, Jussia suffroticosa, Leersia hexandra, Marsilea quadrifolia, Monchoria vaginalis, Oxalis corniculata, Scirpus mucronatus* and *Sogittaria sagittifolia.*

There were wide variations in total population and biomass of weeds in different villages. The weed pressure was high as compared to ST and FP treatments during wet season 2002. However in succeeding years, i.e., 2003 and 2004 the weed pressure was lowered in IPM treatment as compared to ST and FP treatments (Table 8). Overall, the IPM treatment recorded lower weed pressure during both the crop growth stages compared to FP treatment. In most cases, the weed population and dry matter per unit area were more in reproductive stage as compared to vegetative stage of the crop.

Table 8. Year-wise mean population and biomass of weeds in on farm trials, Imphal Manipur (2001-2003)

Year	Tillering stage			Reproductive stage		
	FP	ST	IPM	FP	ST	IPM
2001	173.37 (69.81)	199.14 (73.92)	266.67 (82.26)	108.75 (51.63)	112.62 (52.02)	155.62 (70.43)
2002	174.80 (73.07)	179.00 (73.92)	145.78 (97.05)	117.00 (87.10)	116.60 (100.91)	110.00 (101.66)
2003	141.69 (28.54)	-	159.15 (27.41)	154.38 (39.94)	-	141.15 (36.42)

Figures in parentheses indicate dry weight of total weeds in grams.
FP - Farmers' practice, ST - Scheduled treatment, IPM - Integrated pest management

Grain yield and economics. The grain yield was the highest (Table 11) in ST (4.6 t ha^{-1}) followed by IPM plots (4.2 t ha^{-1}) and FP (4.0 t ha^{-1}). However, the cost benefit ratios were significantly higher (Fig) in IPM treatment (1:2.0) than ST (1:1.6) and FP (1:1.4).

Agricultural Research Station (ANGRAU), Warangal

Table 11. Location-wise grain yield and economics of different treatments (2000-2003)*

Treatment	Yield (t ha^{-1})	CBR
Cuttack		
IPM	6.1a	**1:9.5**
ST	5.8a	**1:5.1**
FP	4.1b	**1:1.0**
Titabar		
IPM	5.3a	**1:2.8**
ST	4.7a	**1:2.4**
FP	3.9b	**1:2.2**
Imphal		
IPM	4.2a	**1:2.0**
ST	4.6a	**1:1.6**
FP	4.0a	**1:1.4**
Warangal		
IPM	4.0a	**1:3.1**
ST	4.0a	**1:2.2**
FP	3.5a	**1:1.6**
Kalyani		
IPM	4.5a	**1:1.5**
ST	4.7a	**1:1.2**
FP	3.8b	**1:0.9**

***** Overall mean of 10 sites, CBR- Cost benefit ratio, IPM : Integrated pest management; ST : Scheduled treatment FP : Farmers practice. Within a column values followed by different letters are significantly different at P=0.05

Incidence of insect pests. The incidence of brown planthopper (BPH), which is not a regular pest in this region was unusually high during 2001-02. The IPM plot planted with gall midge resistant variety WGL-14377 showed significantly higher BPH populations (52.9 hoppers $hill^{-1}$) than ST (13.4 hoppers $hill^{-1}$) and FP (29.0 hoppers $hill^{-1}$), because the variety is susceptible to BPH. However, the incidence of gall midge and yellow stem borer (YSB) which are the key pests in this region was low (<3.5%). The white ear incidence due to YSB was upto 6.1% in FP and comparatively lower in IPM treatment (3.6%) and ST (4.2%). The mean infestation data of these pests revealed no discernible differences among the treatments. Overall, the insect pest incidence was less in the IPM and ST treatments than FP (Table 9).

Grain yield and economics. Despite high incidence of BPH in one year, the mean grain yield was the highest in IPM (4.0 t ha^{-1}) comparable to ST (4.0 t ha^{-1}) and both the treatments showed higher yields than FP (3.5 t ha^{-1}). IPM treatment (1:3.1) showed the highest cost benefit ratio (Table 11) followed by ST (1:2.2) and FP (1:1.4).

Bidhan Chandra Krishi Vishwa Vidyalaya, Kalyani

Incidence of insect pests and natural enemies. Incidence of mealy bug, termite, yellow stem borer, leaf folder and brown planthopper were observed. Incidence of mealy bug and termite was observed in rainfed upland and the infestation ranged from 1.1 to 4.3 and 1.8 to 3.7 per cent, respectively. Stem borer incidence varied from 2.5 to 9.1% DH at vegetative stage while the white ear incidence was negligible. Leaf folder incidence also was moderate varying between 2.0 and 9.1% DL. The data on brown planthopper revealed that their populations were observed in lowland areas

Table 9. Insect pest incidence in different treatments in on farm trials, Warangal, A.P. (2001-2003)*

Treatment	Gall midge(% SS)	Yellow stem borer			Brown planthopper (No.hill^{-1})
		(% DH) 30 DAT	(% DH) 50 DAT	(% WE)	
IPM	0.9a	1.4a	1.4a	3.6a	52.9c
ST	1.3a	2.1a	2.1a	4.2a	13.4a
FP	3.4b	3.4a	3.3a	6.1b	29.0b

* Overall mean of observations in 10 sites, SS- silver shoots, DH- dead hearts, WE- white ears, Within a column values followed by different letters are significantly different at P=0.05

and were significantly higher in FP treatment (14.7 hoppers hill^{-1}) compared to IPM (2.8 hoppers hill^{-1}) and ST (3.4 hoppers hill^{-1}) treatments. The green leaf hopper incidence was low ranging from 1.7 hoppers hill^{-1} to 3.8 hoppers hill^{-1} across the treatments which was below the economic threshold level of the crop (Table 10). Overall, the insect pest incidence was low in IPM and ST treatments compared to FP.

Among the natural enemies, incidence of both parasites and predators was observed. Stem borer egg parasitism due to *Tetrastichus schoenobii* ranged from 9.0 to 43.0 per cent in the treatments, while leaf folder larval parasitism varied between 9.9 to 42.9 per cent. Among the predators, spiders were predominant throughout the crop growth. The levels of both parasitism and predator populations were significantly higher in IPM and FP treatments than ST.

Table 10. Insect pest incidence in different treatments in on farm trials, Kalyani, West Bengal, (2001-2003)*

Treatment	Mealy bug* % DP	Termite* % DP	Yellow stem borer** (% DH)	Leaf folder** (% DL)	Brown planthopper** (No. hill^{-1})	Green leafhopper** (No.hill^{-1})
IPM	1.4a	2.7ab	5.7b	4.5a	2.8a	2.9ab
ST	1.1a	1.8a	2.5a	2.0a	3.4a	1.7a
FP	4.3b	3.7b	9.1c	9.1b	14.7b	3.8b

* Mean of 2 sites and 4 observations, **Mean of 10 sites and five observations, DP - damaged plants, DH- dead hearts, DL- damaged leaves, Within a column values followed by different letters are significantly different at P=0.05

Disease incidence. Incidence of brown spot, bacterial leaf blight (BLB), sheath blight blast and false smut were observed at all the sites in traces, hence they did not warrant any control measures.

Weed incidence. The weed flora comprised of purple nut sedges (*Cyperus rotundus*), morphula (*C iria*), Umbrella sedge (*C difformis*), grasses like branyard grass (*Echinochloa crusgalli*), jungle rice (*E. colonum*), Bermunda grass (*Cynodon dactylon*), Torpedo grass (*Panicum repens*) and broad leaf weed like *Eclipta alba*. Among the treatments, ST and IPM treatments recorded lower weed population at tillering stage than that of FP plots, however the differences were less discernible at reproductive stage.

Grain yield and economics. The ST plots yielded the highest recording 4.7 t ha^{-1} followed by IPM plots with yields of 4.5 t ha^{-1}, which was on par. However, both the treatments were significantly superior to Farmers practice (3.8 t ha^{-1}). Though the ST treatment gave maximum yield, the IPM treatment showed superior cost benefit ratio (Table 11), while there were no net gains in FP treatment.

Impact of the studies

Geographical and economic impact. During the entire period of study, the efficacy of Integrated Pest Management (IPM) in rainfed rice pest management was verified and demonstrated over a total area of 450 ha which included 678 farm families in 75 villages spread over 10 districts in the five states.

At all the sites, the cost benefit ratios were higher in IPM treatment providing higher net returns to farmers. At Cuttack and Warangal, the higher net returns were mainly due to reduction in pesticide use to one or two applications in IPM compared to four applications in the Scheduled treatment (ST). At Imphal, there was significant reduction in costs due to cultivation of gall midge resistant variety, CAU-1 in the IPM plots. At Titabar and Kalyani also, the IPM treatment was economically more profitable than ST and FP.

Technological impact. At all the locations, there was a significant change in knowledge levels of the farmers after exposure to on farm trials. This can be attributed to frequent interaction of the farmers with scientists and technical staff through the participatory approach, exposure to improved crop management techniques, opportunity to visit rice research station and attend farmers training programmes, field days etc. related to rice production and protection technology etc.

Among the IPM components, there was increase in awareness among the farmers adoption of environment friendly components such as use of pheromone traps for monitoring yellow stem borer, tolerant varieties in case of gall midge and BPH, release of *Trichogramma* egg parasitoid against leaf folder, balanced application of fertilizers, formation of alley ways and water management. At Cuttack, there was significant incresase in levels of awareness in farmers related to identification of insect pests and diseases, use of pheromone traps, release of egg parasitoids and need based pesticide application. At Titabar, there was increase in adoption levels of balanced fertilizer application, maintenance of optimum plant population, use of pheromone traps as well as need based pesticide application. At Imphal, the advantage of cultivation of gall midge resistant variety, CAU-1 in significantly reducing the pesticide application had impact on the farmers. There was also increase in awareness on the utility of balanced fertiliser application, optimum plant population and need based pesticide use among the farmers. At Warangal, cultivation of gall midge resistant WGL 14377 variety was readily accepted by the farmers. Through the participatory approach, the farmers also realized the necessity of need based pesticide application in overcoming the unusual outbreak of brown planthopper in the IPM treatment fields because of the susceptibility of WGL 14377 variety to this pest. The utility of integrating two or more IPM components like resistant variety, balanced fertliser application and need based pesticide application could be effectively demonstrated at this centre. At Kalyani, use of BPH resistant variety Chaitanya in low lands, use of pheromone traps and need based pesticide application had impact on the farmers.

Environmental impact. At all the locations, the populations of natural enemies such as spiders, mirid bugs, coccinellids etc. were significantly higher in IPM and FP treatments due to a significant reduction in pesticide use, compared to ST. The reduced quantity of pesticide in the IPM treatment also highlighted the advantage in terms of safety regarding human health.

Earlier, Walters (1991) pointed out that demonstration of expertise in a given domain stimulates perception of trustworthiness and Heong and Escalada (1997) successfully demonstrated this through simple participatory on farm experiments. Similarly, Gururaj Katti *et al* (2002), demonstrated that it was possible to convince the farmers through their direct participation in field trials to adopt the right approach towards pest management in irrigated rice ecosystems. This study has shown the feasibility of successfully extending the farmers participatory approach to develop and verify holistic IPM strategies to alleviate pest and disease problem in rainfed rice production systems also.

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REFERENCES

Gururaj Katti, Pasalu IC, Rao PRM, Varma NRG and Krishnaiah K 2002. Farmers Participatory Approach to Improve Pest Management Decision Making in High Production Systems of Rice in Andhra Pradesh - A Case Study. 2002. pp. 81-89 in :Sarath Babu, B, Varaprasad, KS, Anitha K, Prasada Rao, RDVJ, Chakrabarty, SK and Chandurkar, PS (Eds.). 2002. Resources management in plant protection, Volume II, Plant Protection Association of India, Hyderabad, India, p.201

Heong KL and Escalada MM 1997. Perception change in rice pest management: a case study of farmers evaluation of conflict information. J Applied Communications 81(2): 3-13

Krishnaiah K and Reddy PC 1989. Operational Research Project on Integrated Control of Rice Pests in Medchal area, Ranga Reddy district, A.P. Achievements and Constraints. Annual Rice Workshop, HAU, Hissar, April 19-22: 1989, 9

Matteson PC, Gallagher KD and Kenmore PE 1994. Extension of integrated pest management for planthoppers in Asian irrigated rice:empowering the user. In: R.F. Denno and T.J. Perfect (Eds.), Planthoppers:Their ecology and management pp 656-685. London: Chapman and Hall.

Razak RL 1986. Integrated pest management in rice crop. Pl Prot Bull 38:1-4

Sankaran T 1987. Biological control in Integrated Pest control- Progress and Perspectives in India. Proceedings of the National Symposium on integrated Pest Control Progress and Perspectives, October 15-17, 1987 (Eds) Mohan Das N and George Koshy PP. 545

Walters G 1991. Extensions of extension: Socialization and credibility constraints on private crop production advisors. J Applied Communications, 75 (2): 30-41