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Large-scale IPM validation in Basmati rice (*Oryza sativa*) in Western Uttar Pradesh, India

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ABSTRACT

Pusa Basmati 1121, a high-yielding aromatic rice (*Oryza sativa* L.) variety released by ICAR-IARI in 2005, became widely popular among farmers of Punjab, Western Uttar Pradesh and Haryana in India due to higher yield and good price in the market. But, soon after its release, the variety was severely affected by bakanae foot rot disease (*Fusarium fujikuroi).* The ICAR-National Research Centre for Integrated Pest Management (NCIPM) synthesized an integrated pest management (IPM) module and validated it in large-scale at Bambawad village (District Gautam Budh Nagar, UP) in farmers' participatory mode during 2010-14. The trial was initiated on 40 ha in 2010, which was gradually increased to 80, 120, 200 and 286 ha during 2011, 2012, 2013 and 2014, respectively. The IPM module involved green manuring, seed treatment with carbendazim, seedling root dipping in *Pseudomonas fluorescens,* pest monitoring and need-based application of bioagents/ pesticides. Implementation of the module resulted in a significant reduction in the incidence of bakanae ranging from 0.05±0.01 to 10.18±4.05% in IPM fields against 1.22±0.27 to 46.5±6.30% in Farmers' practices (FP). Brown plant hopper (*Nilaparvata lugens*) population (average of the season) remained 7.74, 9.55, 1.22, 4.32 and 0.49 nymphs and adults/hill in IPM against 31.13, 14.16, 1.36, 7.24 and 0.82 in FP fields during 2010, 2011, 2012, 2013 and 2014, respectively. Regular pest monitoring and ETL-based application of pesticides in IPM helped in conservation of spider population in IPM as compared to FP with very low application of chemical pesticides, i.e. 103.2 g a.i./ha in IPM against 1214.4 g a.i./ha in FP. Analysis of rice grain samples for pesticide residue indicated carbendazim below detectable level. IPM trial also resulted in higher yield (36.01 q/ha in IPM against 26.24 q/ha in FP) and benefit- cost ratio (3.80 in IPM and 2.56 in FP) as compared to FP (Average of five years).

Key words: Bakanae, Basmati rice, Benefit- cost ratio, IPM, *Pseudomonas fluorescens*

India is the largest producer and exporter of Basmati rice (*Oryza sativa* L.) in the world. During 2014-15, out of total production of 8.2 million tonnes, a total of 3.7 million tonnes for INR (₹) 27 597.9 crore was exported (APEDA 2015). Since, there is no inbuilt resistance in Basmati rice to any of the insect pests and diseases, therefore, the yield potential is severely hampered by biotic stresses. Farmers, in general, are inclined towards applying high quantities of pesticides, which result in reduction of biodiversity of natural enemies, outbreak of secondary pests and development of resistance in pests. It also leads to rejection of several export consignments due to high pesticide residue in grains. ICAR- National Research Centre for Integrated Pest Management (NCIPM) has successfully validated IPM technology at village level in popular varieties of Basmati, mainly cv. Pusa Basmati 1 in western part of Uttar Pradesh, cv. Dehraduni Basmati (Type 3) and cv. Kasturi in Uttarakhand and Taraori Basmati in Haryana during 2000-06 (Garg *et al*. 2004, Garg *et al*. 2008). In 2005, ICAR-Indian Agricultural Research Institute (IARI) released a high yielding variety of Basmati, Pusa 1121 for the entire Basmati-growing region and by 2007 the variety was widely adopted by the farmers of Punjab, Western Uttar Pradesh and Haryana because of higher yield and good market price. Presently, this variety has spread over 84% of the total Basmati area in Punjab, 78% in Western Uttar Pradesh, 68% in Haryana, 30% in Uttarakhand, 8% in Jammu and Kashmir and grown over 1000 ha area in hill state of Himachal Pradesh (Anonymous 2013). But the variety has been found highly susceptible to foot rot or bakanae disease. The disease is caused by *Fusarium fujikuroi* Nirenberg [telomorph: *Gibberella fujikuroi* (Sawada) Ito] and is one of the important diseases in all the rice growing countries (Sharma and Thind 2007). Its incidence ranged from 1.2 to

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11.7 % in Uttar Pradesh, 2.1 to 3.2% in Uttarakhand, 10.5 to 40.0% in Punjab, 2.1 to 2.8% in Haryana, 2.4 to 13.6 % in Rajasthan and 1.8 to 8.7% in Bihar on different Basmati aromatic rice cultivars (Gupta *et al*. 2014). Bakanae infected rice seedlings die either before or after transplanting (Ilija *et al*. 2009) and in the main field also, the affected plants are killed before ear head formation or they produce only sterile spikelet (Sharma *et al*. 2011). To overcome the problem of bakanae along with other diseases and insect pests, ICAR-NCIPM synthesized and successfully validated IPM technology at village level in farmers' participatory mode in cv. Pusa Basmati 1121 at Bambawad village (District Gautam Budh Nagar, Western Uttar Pradesh) during 2010-14. Implementation of the technology has resulted not only on reduction in the incidence of insect pests and diseases but has also significantly reduced the chemical pesticide application with higher benefit-cost ratio. The present contribution is the compilation of the IPM technology synthesized and validated in cv. Pusa Basmati 1121 at Bambawad village during 2010-14 along with socio-economic analysis carried out during the IPM validation of the technology.

MATERIALS AND METHODS

Bambawad village (District Gautam Budh Nagar, UP, India; latitude 28.55^0 N; longitude 77.590º E) is about 70 km away from IARI Campus, Pusa (New Delhi). Baseline information collected from the village revealed that the village is 100% irrigated (Canal 90%; Tube well 10%) with 350 ha under basmati rice. Among the Basmati varieties of rice, cv. Pusa Basmati 1121 occupies 80% area whereas the other varieties, viz. cv. Sharbati and cv. Pusa Sugandh 3 contribute 10% each. Major insect-pests and diseases prevailing in Basmati rice are *Scirpophaga incertulas* (Walker) or yellow stem borer (YSB), *Cnaphalocrocis medinalis* (Guenee) or leaf folder (LF), *Nilaparvata lugens* (Stal) or brown plant hopper (BPH), bakanae foot rot and blast (*Pyricularia oryzae* Cav.). Based on the information collected, a holistic Integrated Crop Management module (IPM and agronomic practices) was synthesized. The module comprises: (i) Growing *Sesbania* or mung bean for green manuring: *Sesbania,* planted by middle of May and incorporated in soil at 45-55 days after sowing during land preparation. In case of mung bean (sown in April), plants were buried in the soil after picking of mature pods. (ii) Seed treatment with carbendazim @ 1g (a.i.)/kg seed for bakanae and sheath blight management. (iii) Planting of 2-3 seedlings/hill. (iv) Judicious application of fertilizer (60 N:50P:40K kg/ha) and $ZnSO_4$ @ 25 kg/ha. (v) Use of straw bundles (20/ha) for augmentation and conservation of spiders (Tanwar *et al*. 2008). (vi) One release of egg parasitoid, *Trichogramma japonicum* (supplied by Biological Control Laboratory, SV Patel University of Agriculture and Technology, Meerut) @ 150 000/ha against yellow stem borer (YSB) in September after appearance of YSB moths or its egg masses on leaves in paddy fields. (vii) Manual weed management. (viii) Seedling root dipping in *Pseudomonas fluorescens* solution (3.0×10^{10} cfu, 5ml/litre of water) for bakanae. (ix) Need-based application of chemical pesticides against insect pests and diseases based on economic threshold level (ETL) (Prakash *et al*. 2014).

The trial was initially conducted in 40 ha in 2010 and was gradually increased to 80, 120, 200 and 286 ha during 2011, 2012, 2013 and 2014, respectively. In IPM trials, buprofezin (@ 200 g a.i./ha) was applied once during 2010 (93.3% fields). 2011 (95% fields), and 2013 (27.5% fields), whereas in a few fields, instead of buprofezin, imidacloprid was applied (@ 25 g a.i./ha) in 2010 (9.7%) and 2011 (5.0%) against BPH based on ETL.

Farmers' practices (FP) generally followed in the area comprised of growing crop without green manuring and no seed treatment, planting of one seedlings/hill, higher doses of fertilizer (220N: 40P: 0K kg/ha), no pest monitoring and application of 2-4 chemical pesticides on the advice of pesticide dealers. Zinc sulphate was also used by a few farmers in FP fields but in low doses. Among chemical pesticides, cartap hydrochloride was applied in all the FP fields (@ 500 g a.i./ha; 1-3 applications) followed by buprofezin (@ 200 g a.i./ha; 55-85% fields), phorate (@ 1 000 g a.i./ha; 15-40% fields), carbofuran (@ 750 g a.i./ha 20-34% fields) and hexaconazole (@ 50 g a.i./ha), dichlorovos (@ 750 g a.i./ha) and streptocycline (@ 20 g a.i./ha) (5-15% fields). In general, 2-5 applications of these chemicals were carried out by the farmers.

Incidence or population of major insect pests and diseases along with beneficial spiders was recorded at weekly intervals from 40 IPM fields and 20 FP fields of 0.40 ha each by selecting 20 hills (five spots; four hills from each spot) per field. Records of all the inputs applied in fields and the grain yield were maintained to calculate benefit-cost ratio (Total return/total cost). Total cost included the material cost along with labour cost for land preparation, nursery sowing, transplanting, fertilizer application, hand weeding, pesticide application, etc. Soil analysis was carried out during 2013 in Division of Soil Science, ICAR-IARI, New Delhi for availability of organic carbon, nitrogen, phosphorus, potash and zinc in IPM and FP fields (five fields from each block) whereas microbial population was counted at Microbial Lab, ICAR-NCIPM. In the same year, rice grain samples from 10 fields (five samples each from IPM and FP fields; 50 g/sample) were analyzed at Division of Agricultural Chemicals, IARI for the presence of residues of carbendazim, carbofuran, buprofezin and phorate using Liquid Chromatography (LC/MS/MS). In 2014, twenty five rice grain samples (50 g/sample) collected from five IPM fields (five samples from each field) were mixed together to make one sample. Similarly, 25 grain samples were collected from five FP fields to make one sample. Both the final samples, i.e. IPM and FP were analyzed for carbofuran, phorate, buprofezin, dichlorovos and hexaconazole using Gas Chromatography Mass Spectrometry (GC/MS). Data collected on various parameters including weekly data on insect pests and diseases were subjected to student's t-test.

Farmers Field School (FFS) were organized at 15 days interval in adopted village during each crop season for dissemination of integrated pest management strategies. FFS included the training on identification of insect pests, diseases and beneficial, Economic Threshold Level (ETL) concept, use of bioagents and management tactics including safer pesticides.

RESULTS AND DISCUSSION

Pest incidence

Compilation of the data collected during 2010-2014 (Table 1) indicated that the mean infestation of YSB ranged from zero to 2.78±0.35% in IPM against 0.01±0.03 to 3.61±0.92% in farmers' practice (FP) (Table 1), which was much below the ETL of 10% on tiller basis. Differences between IPM and FP were statistically significant in most of the Standard Meteorological Weeks (SMW) during 2010, 2012, 2013 and 2014 crop seasons except in 2011, where the differences were statistically significant ($P < 0.05$) only in 37 SMW. In case of LF, the infestation ranged from 0.004±0.01 to 0.23±0.08% in IPM against 0.03±0.05 to 1.66±0.64% in FP and the differences were statistically significant ($P < 0.05$).

Brown plant hopper (BPH), a serious pest in this area, crossed the ETL (10-15 nymphs or adults/hill) during 2010, 2011 and 2013. While analyzing the trend, it was observed that during 2010, BPH population was 5.74±2.24 nymphs and adults/hill in 34 SMW in IPM, which gradually increased, reached a peak of 9.09±0.44 nymphs and adults/hill in 37 SMW and declined thereafter. In FP, the population was 8.06±2.75 nymphs and adults/hill in 34 SMW, which reached at its peak level of 68.7±55.2 nymphs and adults/hill in 37 SMW. During 2011, the population (0.93±2.65 nymphs and adults/hill) started appearing in 32 SMW in IPM, whereas in FP the population (2.01±0.31 nymphs and adults/hill) appeared in 33 SMW. Population reached a peak of 24.95±3.37 and 35.74±0.53 nymphs or adults/hill in both IPM and FP, respectively in 39 SMW. During 2012, the population, in general, remained low with highest population of 2.78±0.35 and 3.51±0.57 nymphs or adults/hill in IPM and FP, respectively, in 40 SMW. During 2013, the population started appearing in 34 SMW (0.004±0.02 nymphs or adults/hill) and 36 SMW (1.16±0.18 nymphs or adults/hill) and reached a peak in 40 (11.5±0.31 adults or nymph/hill) and 41 (18.2±3.24 adults or nymph/hill) SMWs in IPM and FP, respectively. The differences in BPH population between IPM and FP were statistically significant ($P < 0.05$) in most of the SMWs during 2010, 2011 and 2013 (Table 1).

Incidence of bakanae ranged from 0.05±0.01 to 0.73±0.32, 2.70±2.53 to 10.18±4.05 and 0.25±1.12 to 5.00 % in IPM against 1.22±0.27 to 5.13±0.31, 14.17±2.04 to 29.28±3.45 and 11.8±3.73 to 16.0±2.05% in FP during 2010, 2011 and 2012, respectively. During 2013, the disease incidence ranged from 7.50±2.56 to 46.5±6.30% in FP as compared to no disease incidence in IPM. During 2014, the incidence of bakanae ranged from 8.0±4.22 to 11.0±3.94% against no disease or traces in IPM (Table 1). Differences in

Table 1 Insect-pests, bakanae disease and spiders in Basmati rice in IPM and FP fields during 2010-14.

Crop season	IPM/ FP	Standard meteorological weeks											Mean
		32	33	34	35	36	37	38	39	40	41	42	
Yellow stem borer, Scirpophaga incertulus (% incidence on tiller basis)													
2010	IPM	0.14±0.05*	0.22±0.11*	0.11±0.06*	0.13±0.05*	0.13±0.06*	0.11±0.04*	0.08±0.03*	0.12±20.04*	0.11±0.04*	0.11±0.03*	0.11±0.04*	0.11
	FP	3.40±1.38	3.61±0.92	2.25±1.07	1.12±0.47	1.66±0.64	1.17±0.56	1.44±0.56	1.13±0.27	0.80±0.45	0.67±0.51	1.03±0.62	1.29
2011	IPM	0.01±0.04*	0.08±0.02*	0.12±0.14*	0.28±0.22**	0.05±0.13**	0.07±0.12*	0.0*					0.04
	FP	1.10±0.48	1.14±0.58	0.58±0.42	0.54±0.39	0.18±0.17	0.48±0.19	0.48±0.19					0.56
2012	IPM		0.0	0.0	0.0	0.11±0.14	0.18±0.08**	0.53±0.47	0.85±0.67	2.29±0.57	2.78±0.35*	2.27±0.21**	1.10
	FP		0.01±0.03	0.0	0.0	0.13±0.17	0.23±0.07	0.70±0.53	0.54±0.15	2.56±0.32	3.51±0.57	2.85±1.04	1.29
2013	IPM		0.04±0.12	0.09±0.15*	0.29±0.17*	0.21±0.21*	0.05±0.1*	0.02±0.07*	0.05±0.11*	0.15±0.18*	0.14±0.15*	0.18±0.14*	0.14
	FP		0.0	0.69±0.31	0.54±0.20	1.14±0.29	1.10±1.04	0.54±0.27	0.83±0.33	0.81±0.19	0.52±0.41	1.33±0.40	0.84
2014	IPM			0**	0.05±0.01*	0.02±0.07*	0.37±0.09*	0.04±0.00*	0.08±0.15*	0.02±0.07*	0*	0.01±0.06*	0.07
	FP			0.07	0.47±0.38	0.88±0.23	0.38±0.10	1.05±0.61	0.91±0.47	0.99±0.22	0.62±0.16	0.81±0.30	0.69
Leaf folder, Cnaphalocrocis medinalis (% incidence on leaf basis)													
2010	IPM	0.05±0.02*	0.09±0.05*	0.06±0.03*	0.08±0.03*	0.13±0.06*	0.11±0.04*	0.05±0.01*	0.12±20.0*	0.11±0.04*	0.05±0.01*	0.04±0.01*	0.08
	FP	1.11±0.59	1.03±0.20	1.47±2.49	0.66±0.29	1.66±0.64	1.17±0.56	1.22±0.27	1.13±0.27	0.80±0.45	0.72±0.22	0.67±0.18	1.06
2011	IPM	0.02±0.06*	0.22±0.65*	0.09±0.09*	0.08±0.09	0.08±0.20	0.16±0.78	0.004±0.01*					0.05

(Continued)

Table 1 (*Concluded*)

Crop season	IPM/ FP	Standard meteorological weeks 32	33	34	35	36	37	38	39	40	41	42	Mean
	FP	1.23±0.37	1.34±0.74	0.66±0.43	0.08±0.07	0.03±0.05	0.06±	0.17±0.23					0.34
2012	IPM		0.06±0.12*	0.06±0.03*	0.06±0.06*	0.12±0.07	0.16±0.08	0.22±0.09	0.23±0.08**	0.14±0.11*	0.14±0.06*	0.14±0.06*	0.15
	FP		0.19±0.13	0.16±0.07	0.34±0.15	0.33±0.10	0.31±0.11	0.68±1.65	0.33±0.11	0.23±0.11	0.31±0.09	0.31±0.09	0.35
2013	IPM		0.11±0.06	0.10±0.06*	0.16±8.82*	0.09±0.07*	0.06±0.07*	0.09±0.07*	0.05±0.06*	0.08±0.06*	0.07±0.07*	0.11±0.05*	0.09
	FP		0.10±0.04	0.27±0.80	0.28±0.10	0.30±0.06	0.47±0.39	0.33±0.28	0.21±0.08	0.18±0.05	0.18±0.06	0.28±0.07	0.28
2014	IPM	0.21± 0.08*	0.22±0.11*	0.22±0.08*	0.15±0.12*	0.17±0.13**	0.07±0.06*	0.06±0.05*	0.15±0.07*	0.15±0.10*	0*	0.15±0.11*	0.14
	FP	0.38±0.11	0.42±0.12	0.31±0.13	0.27±0.10	0.26±0.04	0.15±0.08	0.34±0.11	0.44±0.16	0.26±0.10	0.62±0.16	0.24±0.07	0.34
Brown plant hopper, Nilaparvata lugens (No./hill)													
2010	IPM			5.74±2.24*	7.45±0.639*	7.79±1.51*	9.09±0.44	8.62±0.54*					7.74
	FP			8.06±2.75	14.6±1.81	26.4±6.72	68.7±55.2	37.9±12.9					31.13
2011	IPM	0.93±2.65	0.50±0.46*	0.29±0.12*	0.28±0.12*	1.64±1.42*	4.54±1.55	4.05±1.08*	24.95±3.37*				9.55
	FP	0	2.01±0.31	1.42±0.64	1.41±0.19	4.19±0.80	4.47±0.44	9.12±3.03	35.74±0.53				14.16
2012	IPM	0.0	0.0	0.0	0.11±0.14	0.18±0.08	0.53±0.47	0.85±0.67	2.29±0.57	2.78±0.35*	2.27±0.21**	2.21±0.50	1.22
	FP	0.01±0.03	0.0	0.0	0.13±0.17	0.23±0.07	0.70±0.53	0.54±0.15	2.56±0.32	3.51±0.57	2.85±1.04	1.94±0.38	1.36
2013	IPM			0.004±0.02	1.02±0.40*	1.05±0.26	1.0±0.33*	1.28±1.42	7.34±2.19*	11.5±0.31*	7.85±2.06*	1.0±0.72*	4.32
	FP			0	0	1.16±0.18	1.47±0.45	1.14±0.24	5.43±1.01	12.0±0.1	18.2±3.24	12.7±1.15	7.24
2014	IPM					0*	0.21±0.08*	0.38±0.25	0.33±0.19	1.03±0.84	0.50±0.26*	0.99±0.27*	0.49
	FP					0.07±0.11	0.41±0.18	0.37±0.09	0.36±0.11	1.89±0.54	1.39±0.29	1.26±0.32	0.82
Bakanae foot rot disease, Fusarium fujikuroi (% incidence)													
2010	IPM	0.31±0.31*	0.58±0.30*	0.73±0.32*	0.62±0.44*	0.44±0.20*	0.46±0.25*	0.05±0.01*					0.32
	FP	4.64±0.91	4.37±0.94	5.13±0.31	3.12±0.59	3.27±0.67	3.76±0.87	1.22±0.27					2.87
2011	IPM	0*	10.18±4.05*	9.27±2.64*	7.82±2.99*	8.05±4.17*	4.86±0.83*	4.5±1.52*	2.70±2.53*				5.21
	FP	26±5.48	29.28±3.45	25.71±1.89	24.0±2.24	20.71±4.50	14.17±2.04	15.0±0	14.17±2.04				17.04
2012	IPM		0.25±1.12*	2.00±2.99*	0.75±1.83*	3.25±3.35*	5.00±0*	4.25±2.45*	2.25±2.55*	4.75±1.12*	4.44±2.36*	4.17±1.92*	3.31
	FP		14.00±3.84	11.8±3.73	16.00±2.62	15.25±3.02	15.30±3.02	14.8±2.55	15.50±2.24	16.00±2.05	13.4±3.75	14.0±3.08	14.67
2013	IPM		0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0
	FP		7.50±2.56	10.0±2.56	9.50±2.24	10.5±1.54	46.5±6.30	38.8±10.2	10.5±2.24	10.8±2.45	9.50±1.54	15,0±0	19.04
2014	IPM		0*	0*	0*	0*	0*	0*	0.5±2.21*	0*	0*	0*	0.05
	FP		10.5±1.58	10.0±0	9.50±3.69	9.50±1.58	10.0±2.36	8.0±4.22	11.0±3.94	9.50±1.58	10.0±0	10.0±0	9.8
Beneficial: Spider population (No. /hill)													
2010	IPM	10.88±2.92*	10.45±1.01*	10.54±0.51*	10.36±0.97*	9.89±0.71*	10.42±0.51*	10.63±0.46*	10.55±0.59*	11.22±1.31*	6.32±0.92*	6.54±0.46*	9.63
	FP	9.64±0.66	9.57±0.48	8.81±0.60	9.36±0.37	9.32±0.31	8.61±0.91	6.39±0.60	7.9±3.58	2.53±0.48	3.51±4.76	3.72±4.84	6.74
2011	IPM	10.1±1.74*	9.70±1.23*	9.75±1.01*	11.25±1.02*	9.88±1.81*	9.26±2.31	9.72±0.47*	9.24±0.93*				9.52
	FP	4.35±0.65	7.37±0.55	7.2±0.58	8.73±0.95	6.99±1.26	8.42±0.40	8.1±0.78	7.32±0.23				7.79
2012	IPM		1.58±0.45*	1.61±0.42*	3.28±1.17	4.88±0.40	7.83±2.51**	9.89±0.99*	10.28±0.6*	10.77±0.3*	10.69±0.53*	9.89±0.41*	8.29
	FP		1.06±0.41	2.22±0.86	3.49±0.50	4.70±0.52	6.27±1.55	7.66±1.09	7.30±0.24	7.14±0.56	6.31±1.21	7.58±0.48	6.20

*’t’ significant at 1% level ($P < 0.01$); ** ‘t ‘ significant at 5% level ($p < 0.05$); ± Standard deviation; IPM- Integrated Pest management fields; FP -Farmers’ practices.

Table 2 Available carbon, phosphorus, potash, nitrogen and zinc in soil from IPM and FP fields during 2013

IPM/FP fields	Organic carbon (%)	Available phosphorus kg/ha	Available potash kg/ha	Available nitrogen kg/ha	Available zinc mg/kg
Analysis of soil samples before transplanting of rice seedlings					
IPM	0.560±0.0578	45.7±29.7	119±24.5	339±65.0	2.33±0.628*
FP	0.464±0.115	36.8±13.1	117±30.6	268±82.8	1.05±0.154
Analysis of soil samples during mid-crop season (Sept.)					
IPM	0.622±0.0584	31.9±16.2	102±86.4	276±17.6	2.49±1.02*
FP	0.558±0.116	39.3±24.3	111±65.6	289±17.6	0.960±0.307

*'t' significant at 1% level (P< 0.01); ± Standard deviation.

the incidence of bakanae in IPM and FP, in most of the SMWs under observation, were statistically significant. Bakanae, a major menace in cv. Pusa Basmati 1121 is considered to be soil (Nishio *et al*. 1980, Sharma *et al*. 2011) as well as seed-borne (Sharma *et al*. 1987, Parate and Lanjewar 1987, Ma *et al.* 2008). For managing bakanae, available reports indicated that the seed treatment of rice with rice-associated antagonistic bacteria provided satisfactory reductions (Rosales and Mew 1997, Sharma *et al*. 2011). In the present study, seed treatment with carbendazim along with seedling root dipping in *P. fluorescens* proved effective in containing the bakanae disease. The result are further supported by recent investigations carried out in Punjab on nine fungicides against *Fusarium moniliforme* in cv. Pusa Basmati 1121 and other Basmati genotypes (Pannu *et al*. 2013), whose findings revealed that among nine treatments (carbendazim, tebuconazole, flusilazole + carbendazim, pencycuron, carboxin + thiram, azoxystrobin, tetraconazole, tebuconazole and trifloxystrobin + tebuconazole), seed treatment + seedling dip with carbendazim @ 0.2 % was found to be the most effective in reducing the disease. It was also inferred by the farmers' interaction during the surveys that the most efficient method for bakanae disease management is seed treatment with carbendazim @ 2.0 g/kg or carbendazim + thiram (1:1) @ 2.5 g/kg seed (Gupta *et al*. 2014).

Impact analysis

Soil nutrients: Analysis of soil samples collected from IPM and FP plots before transplanting of rice seedlings indicated higher level of organic carbon, available N, P, K and Zn in IPM as compared to FP (Table 2). Use of green manuring in wetland rice favourably influenced availability of several plant nurtients, improved the physical conditions of the soil, increased water retention and reduced leaching losses of nutrients (IRRI 1988, Tiwari 1995, Tilak 2004). Soil samples, in the present study, indicated 26.5 and 121.9% higher available N and Zn in IPM over FP, respectively. Analysis of soil samples, collected during the mid-crop season (September), also indicated higher organic C and Zn in IPM as compared to FP, though, the level of N was low as compared to FP due to application of higher doses of N by the farmers in FP.

Soil microbial counts: Results of soil analysis for soil

Table 3 Microbial population (colony forming units /g of soil) in IPM and FP fields during 2013

IPM/FP fields	*Pseudomonas* ($\times10^{11}$)	*Trichoderma* spp. ($\times10^{5}$)
Before transplanting of rice seedlings		
IPM	4.08±0.65**	1.8±0.27
FP	3.08±0.66	1.9±0.42
Mid season		
IPM	4.91±0.39	3.15±0.78
FP	5.02±1.75	2.21±0.54

**'t' significant at 5% level (P <0.05); ± Standard deviation.

microbial population, before transplanting of rice seedlings, indicated higher number of colony forming units (cfu) of *Pseudomonas* in IPM as compared to FP fields but during the mid-crop season the trend was changed, i.e. cfu count of *Pseudomonas* remained higher in FP as compared to IPM (Table 3). It is interesting to note that in case of *Trichoderma*, initially the cfu count was higher in FP as compared to IPM but during mid crop season the trend was changed and the number of cfu became higher in IPM as compared to FP. Fungal and bacterial bio-control agent may not be always compatible and it is quite possible that the situation would be different if both organisms were present in the rhizosphere, where condition may be favourable for growth and antibiotic production by *P. fluorescens*. Moreover, as two groups of microorganisms that occupy the same ecological niche and have the same nutritional requirements are bound to compete for nutrients (Janisiewicz and Bors 1995, Raaijmakers *et al*. 1995). This is a logical area for future investigation (Pan and Jash 2010). Soil microbial population, including bacteria, fungi and actinomycetes are considered to be the principal decomposers of organic matter in soil and their role in sustainable productivity has been reviewed earlier (Lee and Pankhurst 1992, Lata *et al*. 2000).

Pesticide residue: Seed treatment with carbendazim was an important component of IPM module and was followed in all the IPM fields during the validation trial. The chemical fungicide, though applied in small quantity, yet was found effective in suppressing the bakanae disease. Analysis of rice grain samples for pesticide residue indicated carbendazim below detectable level (Table 4). During 2013, buprofezin (Insect growth regulator) was applied by 2.8%

Table 4 Pesticide residue analysis of Basmati rice grain samples in IPM and FP fields during 2013

Sample no.	IPM		FP	
	Carbendazim*	Buprofezin**	Buprofezin**	Phorate*
1.	BDL	0.040	0.064	BDL
2.	BDL	0.030	0.051	BDL
3.	BDL	0.035	BDL	BDL
4.	BDL	BDL	BDL	BDL
5.	BDL	BDL	BDL	BDL

*BDL<0.03µg/kg; **BDL<0.02µg/kg.

IPM farmers against BPH in September/October and analysis of grain for residue analysis indicated that out of five grain samples collected, buprofezin was detected in three IPM samples (0.030-0.040 µg/kg). In case of FP, buprofezin was applied by 24.6% farmers against BPH whereas phorate or cartap hydrochloride was applied by most of the farmers at tillering stage of the crop against YSB and LF. Analysis of grain samples from FP fields indicated phorate below detectable level in all the samples whereas buprofezin was detected in two samples (0.051 and 0.064 µg/kg). During 2014, no chemical insecticide was applied in IPM fields except seed treatment with carbendazim. Residue analysis indicated carbendazim at a low level (0.007 µg/kg) in IPM, whereas no other pesticide residue was detected in IPM as well as FP. Residues analysis carried out earlier from Basmati rice IPM fields at Dudhli (Dehradun, Uttrakhand) and Saboli and Aterna village (Sonepat, Haryana) during 2008-11 indicated tricyclazole, propioconazole, chlorpyrifos, hexaconazole, pretilachlor, and λ-cyhalothrin BDL (<0.001– 0.05 µg/g) in 40 samples of Basmati rice grains and soil and 12 water samples (<0.001– 0.05 µg/L) (Arora *et al*. 2014). In present study while comparing the residue for buprofezin in grains of IPM and FP, the quantity of the chemicals detected was comparatively higher in grain samples of FP as compared to IPM.

Socio-economic analysis: In case of IPM, only 1.46 application of chemical pesticides (103.2 g a.i./ha) were undertaken against 2.8 application in FP (1214.4 g a.i./ha). Regular pest monitoring and ETL-based application of pesticides in present trial has not only reduced the chemical pesticide application cost but also protected the environment from hazardous pesticides as indicated by presence of higher number of beneficial spider population in IPM as compared to FP. IPM trial also resulted in higher yield (36.01 q/ha in IPM against 26.24 q/ha in FP) and benefit- cost ratio (3.90 in IPM and 2.56 in FP) in IPM plots as compared to FP (Table 5).

It is evident from the above results that regular pest monitoring along with adoption of IPM package resulted in significant reduction in the incidence of insect-pests and diseases in IPM fields as compared to FP. Green manuring in IPM has favoured the availability of nutrients along with N to the crop, which helped in reducing application of additional N, which could be one of the factors responsible for low incidence of insect-pests and diseases in IPM fields. As treatment of seed is a cheap insurance against possible disasters at a later stage, therefore, in the present IPM module, practice of treating seed with carbendazim along with seedling root bacterization with *P. fluorescens* proved effective in managing bakanae disease in Basmati rice with the chemical pesticide residue below detectable level. IPM technology also resulted in higher benefit-cost ratio with lesser application of chemical pesticides as compared to FP. Organizing FFS at regular interval adopted in the present trial, helped in developing strong linkages among farmers, scientists and extension workers and enabled farmers to understand the role of monitoring, concept of ETL and need based application of pesticides.

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Table 5 Yield and benefit-cost ratio in cv. Pusa Basmati 1121 in IPM and FP fields

Crop season	Number of chemical pesticide applications#		Amount of chemical pesticides# (g a.i./ha)		Total cost (₹)@		Total return (₹)		Yield (q/ha)		B-C ratio	
	IPM	FP	IPM	FP	IPM	FP	IPM	FP	IPM	FP	IPM	FP
2010	2	3.8	206.7	1876	20880	21305	79560	38760	33.2	16.2	3.8	1.8
2011	2	3.3	191.3	1542	24550	25670	57698	35498	33.9	20.9	2.4	1.4
2012	1	2.5	20	1189	26690	28487	79728	35498	39.8	33.2	3.6	2.8
2013	1.3	2.9	75	1159	25480	28740	131594	105222	34.63	27.69	5.16	3.66
2014	1.0	1.5	23	306	24841	28405	111650	89640	38.50	33.20	4.56	3.15
Mean	1.46	2.8	103.2	1214.4	24488.2	26521.4	92046	60923.6	36.01	26.24	3.90	2.56

Included the seed treatment with carbendazim in IPM. @ Total cost included labour cost for land preparation, nursery sowing, puddling, transplanting, fertilizer application, hand weeding, pesticide application etc. and material cost like seed, fertilizer, pesticides, biocontrol agents, irrigation etc. Rate of paddy: ₹ 2 400/q in 2010; ₹ 1 700/q in 2011; ₹ 2 400/q in 2012; ₹ 3 800/q in 2013; ₹ 2 900/q in IPM (An extra premium of ₹ 200/q was given to IPM farmers) and ₹ 2 700/q in FP during 2014.

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