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Implementing the systems approach in rice pest management : India context

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ABSTRACT

A basic IPM module for basmati rice as a part of integrated crop management accounting the pest prevalence and management has been developed. As the IPM module is location specific and dynamic, there is need of regular updating and fine tuning depending on the location and pest prevalence. The technology has been successfully validated and implemented during 1998 to 2019 in Pusa Basmati 1, Taraori Basmati, Dehraduni Basmati, Pusa Basmati 1121 in Haryana, Uttar Pradesh and Uttarakhand with minor modification and fine tuning. Adoptation of the IPM technology resulted in increase in rice grain yield to the tune of 21.6% in Pusa Basmati 1 at Shikohpur in Uttar Pradesh, 21.5% in Taraori Basmati at Chhajpur in Haryana, 19.5% in Type 3 in Uttarakhand, 14.5 to 22.7% in Pusa Basmati 1121 in Haryana and 38.2% in Pusa Basmati 1121 in Uttar Pradesh over farmer's practices (FP). In all the basmati rice trials, higher yield as well as Benefit : Cost (B:C) ratio was obtained in IPM as compared to FP. Implementation of IPM led to significant reduction in the uses of chemical pesticides. In case of IPM, on an avarage 1.46 application of chemical pesticides (103.2 g a.i./ha) were undertaken in Pusa Basmati 1121 against 2.8 application in FP (1214.4 g a.i./ha) at Bambawad, Uttar Pradesh. ICAR-NRRI, Cuttack developed and validated IPM module at Sigmapur (Cuttack, Odisha) non-Basmati rice variety Pooja for four kharif seasons i.e 2010-2013 using standard agronomic practices. The trial resulted in an increase of 47.1% yield over FP. Additional income of Rs. 9857/- per ha was also obtained in IPM over FP. On-Farm trial on validation of IPM module in non-Basmati rice (cv. Pooja) under rainfed low land condition conducted in 10 ha during rabi 2017 at Nagapur and Basudeipur villages in Khurda district of Odisha resulted reduction in the incidence of insect pests and diseases with higher population of natural enemies as compared to FP with B:C ratio of 1.26:1. Rice yield was recorded 5600 kg ha^{-1} in IPM as against 4900 kg ha^{-1} in FP. Recently, ICT based e-pest monitoring and advisory has become an important component for area wise implementation of IPM at state and national level. The programme has been successfully implemented in Odisha during 2010 and 2011 under RKVY. Implementation of the programme had resulted successful management of swarming caterpillar in 13 rice growing districts of Odisha during kharif 2010 and 2011. More precisely, the launching of riceXpert app by ICAR-NRRI in the year 2016 has facilitated the farmers for confident identification of insect pests and diseases and getting real-time pest solution instantly.

Key words: *Rice, insect pests, diseases, IPM, bsamti rice, system approach*

INTRODUCTION

India is the leading rice growing country in terms of area (43.86 million ha) and the second largest producer in the world (112.9 million tonnes), lagging behind China (148.9 million tonnes) (USDA Annual Report 2018-19). It is estimated that the current production of 106 mt of milled rice in India need to be enhanced to 140 mt to feed the estimated 1.6 billion population by 2050 (FAO, 2015). However, low productivity as compared to the other countries and stark difference in different states is a concern for India. In India, pest causes 33% production loss, weed causes 12.5% whereas insect 9.5% and disease 6.5 per cent besides other pests 4.5 per cent (DWR, Vision 2050). Intensive cropping system, *i.e.,* 2-3 crops a year, with more use of fertilizer monocultures and high-yielding cultivars were considered to be the most favourable conditions for pest build up. Over 800 species of insects in rice ecosystems have been reported worldwide. Out of these, 100 species attack rice while rest are considered as friendly insects (Pathak , 1970). Almost 20 insects are considered as pest of rice which include stem borers, gall midge, defoliators and sucking pest like leaf hoppers and plant hoppers that cause direct damage and transmit various diseases (Pathak et al., 1994). Among the lepidopterans, Yellow stem-borer (*Scirpophaga incertulas*) is still the major rice pest in almost all the ecologies whereas leaf folder (*Cnaphalocrocis medinalis*) has become a key pest in high-yielding varieties especially under irrigated conditions. Among the dipteran pests, Asian rice gall midge (*Orseolia oryzae*) is an important pest of rice in irrigated ecology but restricted to only some areas of eastern and southern India. Brown plant hopper (*Nilaparvata lugens*), White backed plant hopper (*Sogatella furcifera*) and Green leaf hopper (*Nephotettix virescens*) are important homopteran pests whereas the hemipteran gundhi bug (*Leptocorisa* spp.) are widely distributed in different rice-growing areas under irrigated and low land ecologies. Rice hispa (*Dicladispa armigera*), a coleopteran pest causes havoc in specific rice ecologies, *viz*., irrigated paddy fields as well as lowland boro rice cultivation in West Bengal, Asom and North-East Indian states. Caseworm (*Nymphula depunctalis*), a lepidopteran, is a pest of lowlying and waterlogged areas in eastern India. Among diseases, sheath blight *Rhizoctonia solani*, Bacterial blight (BB) *Xanthomonas campestris*, Brown spot *(Helminthosporium oryzae)* and Blast *(Pyricularia oryzae)* are the major ones that reduce yield of rice substantially. Of late, foot rot or bakanae disease (*Fusarium fujikuroi*; perfect stage: *Gibberella fujikuroi*) has emerged as a serious pest in Basmati rice.

Of various management practices by and large, only chemical pesticides served as the primary component in farming community due to easy availability on credit bases and with immediate results. However, indiscriminate and injudicious application of these chemical pesticides have not only destroyed natural enemies but have also disturbed their food supply, favouring the survival and reproduction of pests, thereby causing pest outbreaks, resurgence of insect pests and diseases. Global warming and climate change are also expected to have an adverse impact on rice productivity in coming years. According to International Food Policy Research Institute (IFPRI) report on climate change: Impact on agriculture and costs of adaptation, climate change results an additional price increases- 32 to 37% by 2050; rice production declines by 10% [International Food Policy Research Institute, Washington, D.C., updated October 2009].

Development and implementation of location specific, cost effective and eco-friendly IPM strategy has been found as an effective and sustainable solution for these problems. IPM is a decision support system for the selection and use of pest control tactics, singly or harmoniously coordinated into a management strategy, based on cost-benefit analyses that take into account the interests and impacts on producers, society, and the environment (Kogan, 1998). It aims to maximize the use of biological control. Globally, rice IPM was evolved through sustained efforts of several plant protection researchers. But its adoption never attained the desired level due to varied reasons. The strong influence of agrochemical manufacturers and distributors remained the primary reason for not implementing the holistic IPM strategy. The IPM in rice was pioneered in Indonesia following the 1986 Presidential instructions that banned the use of 57 chemical pesticides on rice and declared IPM as the National Pest Control Policy. The work on IPM in India was initiated in 1975 under the Operational Research Project and as a result of this by 1979 the number of insecticide sprays on rice had been cut down from original 4-6 rounds to 2 per crop in the target areas (Sankaran, 1987). During the last two decades significant progress has been made for validation and promotion of IPM in rice by SAUs, ICAR research institutes and Government sponsored schemes. In this direction, significant progresses have been made in basmati and non basmati rice (Garg et al., 2004, 2008, 2009; Mohapatra, 2008; Prakash et al., 2016: Mohapatra et al., 2016; Tanwar et al., 2011; Tanwar et al., 2016 a & b).

IPM module for basmati rice

In Northern India, Basmati rice is cultivated in about 1.6 million ha which fetches higher price in domestic and international market. In Basmati rice there is no in-built resistance in them to any of the pests. Therefore, the yield is severely hampered by biotic stresses. Being an export commodity, farmers do not hesitate to apply higher doses of chemical fertilizers and pesticides. However, such practices result in outbreak of the pests and diseases, residue problems in grains and rejection of many export consignments. Stringent norms imposed by European Union on the pesticides used for rice crops are also expected to impede the basmati rice exports from India.

ICAR-NCIPM developed a basic IPM module for basmati rice as a part of integrated crop management accounting the pest prevalence and management. IPM strategies were based on key agronomic components like in situ soil incorporation of green manure (*Sesbania*/*Vigna radiata*), balanced use of fertilizers with more emphasis on supplementation of potash and micronutrients and biotic stress management by regular crop and pest monitoring, augmentation and conservation of natural enemies, use of bio-pesticides and economic threshold level (ETL) based application of chemical pesticides. As the module is location specific and dynamic, therefore, it needs regularly updating and fine tuning depending on the location and pest prevalence. The module comprises:

♦ Growing *Sesbania* or mungbean for green manuring: *Sesbania* planted by mid of May and incorporated into soil at 45-55 days after sowing during land preparation. In case of mungbean, plants were buried in the soil after picking of mature pods. 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).

♦ Seed treatment with carbendazim @ 1 g a i per kg seed for seed borne diseases like bakanae, sheath blight etc.

♦ Planting of 2-3 seedlings per hill

♦ Judicious application of fertilizer (60 N : 50 P : 40 K kg/ ha) and $ZnSO_4$ @ 25 kg/ha

♦ Pest surveillance by engaging trained field scouts and installation of pheromone traps 8/ha for YSB monitoring

♦ Use of straw bundles (20 per ha) for augmentation and conservation of spiders (Tanwar et al., 2011)

♦ One release of egg parasitoid, *Trichogramma japonicum* @ 150,000/ha against yellow stem-borer (YSB) in September after appearance of YSB moths or its egg masses on leaves in paddy fields.

♦ Seedling root dipping in *Pseudomonas fluorescens* solution (3.0×10^{10} cfu; 5ml/L water) against bakanae for 30 minutes. 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) 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 diseases.

♦ ETL based application of chemical pesticides against insect-pests and diseases (Prakash et al., 2014).

♦ Post-harvest spray of *Trichoderma* formulation on standing stubbles to ensure organic decomposition of stubble, killing of resting structures of pathogens to ensure better crop-health in the following season.

IPM validation : Case studies

IPM validation trials were conducted in three locations in Haryana (two) and Uttar Pradesh (one). At all the locations, incidence of insect pests and diseases remained low in IPM as compared to farmers' practices (FP) (Table 1, Fig. 1). IPM technology resulted in increase in rice grain yield *i.e.*, 21.6% in Pusa Basmati 1 at Shikohpur, Uttar Pradesh 21.5% in Taraori Basmati (Dehraduni Basmati) at Chhajpur in Haryana, 19.5% in Type 3 in Uttarakhand, 14.5 to 22.7% in Pusa Basmati 1121 in Haryana and 38.2% in Pusa Basmati 1121 in Uttar Pradesh (Table 1) over FP. In all the basmati rice validation trials higher yield as well as Benefit :Cost (B:C) ratio was obtained in IPM as compared to FP (Table 2).

Among the egg parsitoids, *Telenomus* sp. was recorded parasitizing YSB egg masses in large numbers in IPM in at Chhajpur and Dehradun. Natural parasitisation due to *Telenomus* sp on YSB egg masses in Pusa Basmati 1 rice ranged from 50-60% in IPM

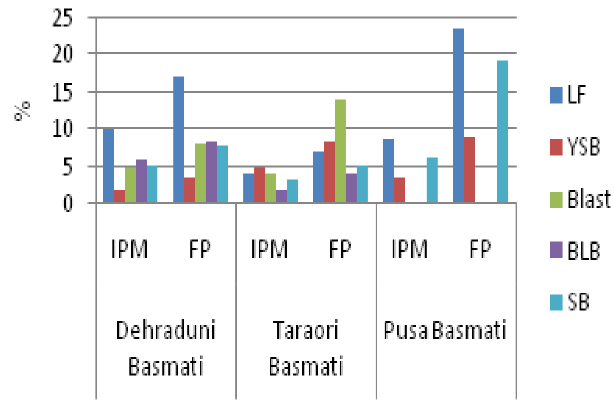

Fig.1. Incidence of insect pests and diseases in IPM and FP in different varieties of Basmati rice. (Source: Tanwar et al., 2016a.)

Table 1. Pest incidence of basmati rice plants under IPM and Farmers' Practices' (FP) in Haryana and Uttar Pradesh.

Insect Pest/disease	Sonipat, Haryana				Gautam Budh Nagar, UP	
	Atterna 2008 (1 yr)		Sibouli (Av. of 3 yrs., 2008-10)		Bambawad (Av. of 5 yrs 2010-14)	
	IPM	FP	IPM	FP	IPM	FP
Yellow Stem borer (%)	3.0	6.5	2.8	10.9	1.1	3.6
Leaf folder (%)	6.5	10.0	5.2	8.5	1.8	4.5
BPH (No./hill)	17.5	35.0	8.9	25. 7	3.3	9.4
Neck Blast (%)	7.0	18.0	5.9	14.3	0	0
BLB (%)	5.0	9.0	4. 7	10.5	0.8	2.3
Bakanae (%)	3.5	8.0	1.2	17.5	1. 8	17.9

(Source: Tanwar et al., 2016 a, b)

fields against less than 10% in FP fields. The parasitisation of YSB in Taraori Basmati was recorded up to 71% in IPM during *kharif* 2004 (Garg et al., 2008). The mean parasitisation of YSB to an extent of 43.2% by *T. dignus* has earlier been recorded in Ludhiana during September 1992 (Brar et al., 1994). Very high parasitisation of *Telenomus* sp had also been observed in Andhra Pradesh (Rao and Ali, 1976). Spiders have been reported to represent more than 90% of the natural enemies of brown plant hoppers in Korea in rice fields, (Lee et al., 1997) and their population is significantly reduced by the application of insecticides, especially carbofuran (Bae et al., 1994), which is widely used in rice fields. Results of trials conducted during 2010-14 at Bambawad have confirmed the conservation of spiders in all the IPM fields as compared to FP (Fig. 2).

Implementation of IPM has resulted significant reduction in the uses of chemical pesticides. 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) (Tanwar et al., 2016b). Regular pest monitoring and ETL-based application of pesticides in IPM trials have 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 (Fig. 2). Residues analysis carried out from Basmati rice IPM fields at

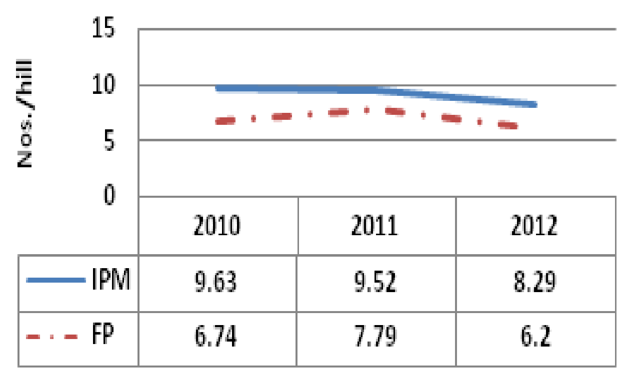

Fig. 2. Population of spiders in IPM and FP fields at Bambawad. (Source: Tanwar et al., 2016b)

Table 2. Yield and benefit-cost ratio under IPM and Farmers' Practices' (FP) in Haryana, Uttar Pradesh and Uttarakhand.

Basmati variety	Location	IPM Duration	Mean Yield (t/ha)		Mean Benefit-cost ratio	
			IPM	FP	IPM	FP
Pusa Basmati 1	Shikohpur (Uttar Pradesh)[1]	2000-02	55.7	45.8	2.8	2.0
Taraori Basmati	Chhajpur, Panipat (Haryana)[1]	2002-04	27.1	22.3	2.8	1.86
Dehraduni Basmati	Tilwarai, Dehradun (Uttarakhand)[1]	2005-06	22.7	19.0	3.2	3.08
Pusa Basmati 1121	Atterna, Sonipat (Haryana)[2]	2008	41.0	35.8	6.4	5.3
	Sibouli, Sonipat2 (Haryana)	2008-10	46.0	37.5	6.3	4.9
	Bambawad (Uttar Pradesh)	2010-14	36.0	26.2	3.7	2.3

(Source: [1]Garg et al., 2009; [2]Tanwar et al., 2016b; [3]Tanwar et al., 2016a)

Table 3. Yield, net return and B-C ration in IPM and FP fields at Singhmapur (Cuttack, Odisha).

Kharif	IPM			FP		
	Yield (t/ha)	Net return (Rs.)	B-C ratio	Yield (t/ha)	Net return (Rs.)	B-C ratio
2010	4.78	32612	2.14	3.47	22412	1.82
2012	4.93	43975	2.49	3.1	24250	1.67
2013	4.98	43294	3.1	3.41	43648	2.63
Mean	4.90	39960	2.58	3.33	30103	2.04

(Source: Prakash et al., 2016)

Dudhli (Dehradun, Uttrakhand) and Sibouli and Atterna villages (Sonepat, Haryana) during 2008-11 indicated presence of tricyclazole, propioconazole, chlorpyriphos, 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). At Bamabwad, 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 (Tanwar et al., 2016a).

IPM in non-basmati rice

ICAR-NRRI, Cuttack developed an IPM module for non-basmati rice growers of Odisha. The module comprised of seed treatment with carbendazim @1g a.e./kg seed, sowing dates not expanding more than 3 days, uniform transplanting of 20-25 days old seedlings with 15X20 cm spacing, periodic pest monitoring, application of cartap hydrochloride @1kg a.i./ha 30-35 days after transplanting and need based foliar application of the pesticides. The module was validated at Singhmapur (Cuttack, Odisha) (Prakash et al., 2016) with Pooja variety for four *kharif* seasons *i.e.,* 2010-2013 using standard agronomic practices. The trial resulted in an IPM enhancement of 47.1% yield and 26.47 % B-C ratio over FP. Additional income of Rs. 9857/- per ha was also obtained in IPM over FP (Table 3).

On-Farm trial on validation of IPM module in rice (Pooja variety) under rainfed low land condition was conducted in 10 ha during *rabi* 2017 at Nagapur and Basudeipur villages in Khurda district of Odisha (Anonymous, 2018). Soil analysis indicated 4.7 to 4.9 soil pH , 62.2 to 125.6 dSm^{-1} EC at 25^0C, 0.45 to 0.61% organic carbon and 282.2 to 326.1 kg/ha available nitrogen. IPM module comprised of seed treatment with carbendazim 50 WP @ 2g/kg seed, row planting (20 x 15 cm), fixing of pheromone traps 8/ha for monitoring yellow stem borer and routine field survey, application of chlorantraniliprole 18.5 SC @ 150ml ha^{-1} at 35 DAT and need based application of thiamethoxam 25 WG @ 100g ha^{-1} against BPH, and plantomycin 1g/l + copper oxychloride @2g/l of water against BLB. Nursery was sown during July 3-13, 2017 and transplanting was done during July 28 to August 5, 2017. Farmers' practices included transplanting without recommended spacing, no pest monitoring in nursery and main fields and application of carbofuran in the main field after observing the damage.

IPM implementation resulted in reduction in the incidence of insect pests and diseases with higher population of natural enemies compared to FP (Fig. 3

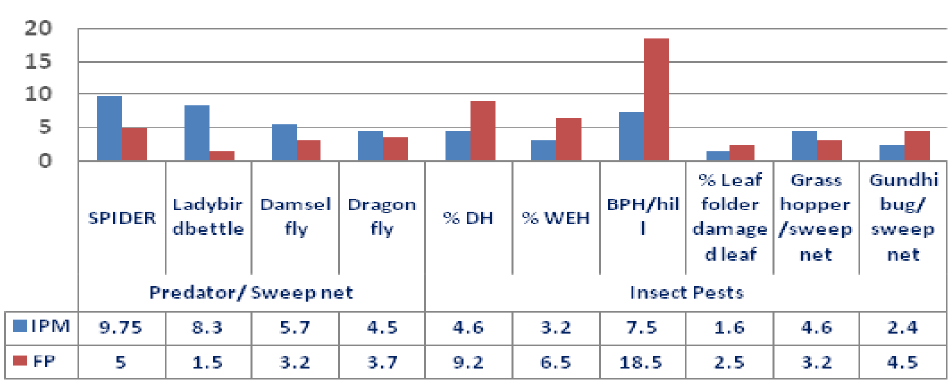

Fig. 3. Insect pests and beneficial in IPM and FP in different pest regimes (Odisha) during 2017.

and 4). Rice yield was recorded 5600 kg ha^{-1} in IPM as against 4900 kg ha^{-1} in FP (Anonymous, 2018).

In the recent past pest monitoring and advisory has become an important activity for implementation of IPM at state and national level. Information Communication Technology (ICT) based real time pest surveillance also known as e-pest surveillance, has emerged as an important tool to collect and transfer data on insect pests and diseases from remote villages to server located at main station through internet, compilation and display of information. E-pest surveillance and advisory system encompasses computer-based storage, transfer, retrieval, sharing, and reporting of pest data for appropriate and timely decision-making for better pest management (Singh et al., 2016). Awareness-cum-surveillance in rice in Odisha was successfully implemented in Odisha under awareness-cum-surveillance programme for pest monitoring and issue of advisory in 13 districts of Odisha covering 17.38 lakh ha paddy spread over 17606 villages under Rashtriya Krishi Vikas Yojana - 2nd Green Revolution, 2010-12. Implementation of the programme had resulted successful management of swarming caterpillar in 13 rice growing districts of Odisha during *kharif* 2010 and 2011 (Tanwar et al., 2010).

It is evident from the above multi-location validation and implementation trials that pest surveillance along with adoption of IPM practices have resulted in significant reduction in the incidence of insect-pests and diseases with conservation of natural enemies in IPM fields as compared to FP. Availability of nutrients along with Nitrogen to the crop through green manuring in IPM strategy has helped in reducing application of additional N-fertilizer, which could be one of the factors responsible for low incidence of insect-pests and diseases in IPM fields. As seed treatment is a cheap insurance against possible disasters at a later stage, therefore, in the IPM module, practice of treating seed with carbendazim along with seedling root in *P. fluorescens* has proved effective in managing seed and soil borne diseases in 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 farmer practise, thereby protecting our environment from hazardous chemical pesticides. Organizing farmer's field school (FFS) at regular interval adopted in different trials 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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