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Large scale validation and refinement of integrated pest management strategy for basmati rice (*Oryza sativa*) in farmers' participatory mode

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ABSTRACT

Rice (*Oryza sativa* L.) is an economically important food crop and its yield is severely affected by insect-pests and diseases. The study was carried out during rainy (*kharif*) season of 2020 to 2023 at village Nidana, Rohtak, Haryana to manage pest problems with minimum use of pesticides, in basmati rice cv. PB1718 under farmers' participatory mode using integrated pest management (IPM). The results revealed that IPM proved effective in significantly reducing yellow stem borer incidence (21.91%), brown plant hopper (45.95%), bakane disease (86.02%), bacterial leaf blight (78.92%) and blast (55.30%), along with an increase in natural enemy population i.e. spiders compared to farmer practice (FP). The population of spiders was higher in IPM (1.07/hill) compared to FP (0.22/hill). IPM practice has advantage in reducing the cost of cultivation (15.60%) by decreasing number of pesticides application (48.72%) as well as amount of pesticides' active ingredient (82.29%). The total grain yield under IPM increased by 8.48% over FP because of reduced pest incidence and adoption of good agriculture practices. The benefit-cost ratio in IPM (2.80) was superior to FP (2.17) with 29.51% higher net return. The refined IPM strategies proved economically viable, provided an effective pest suppression in an eco-friendly manner by conserving natural enemies through minimisation of pesticide applications, and thus adoptable under farmers' field conditions.

Keywords: Bakane disease, Basmati rice, Biological control, Farmers practice, IPM, *Pseudomonas fluorescens*, Refinement of IPM, Rice leaf folder, Yellow stem borer

Rice (*Oryza sativa* L.) is a staple food crop that supports the livelihood for millions of farmers worldwide (Longkumer *et al.* 2024). India is the second-largest producer and the first-largest exporter of rice in the world. Indo-Gangetic plains in north India are the major basmati rice-producing area. During last five years (2019–20 to 2023–24) India has earned ₹1.74 trillion from the export of 22.83 million MT basmati rice and ₹1.84 trillion from 64.29 million MT non-basmati rice (APEDA 2024). The intensive and non-judicious use of chemical pesticides has negative impact on the soil, groundwater, and atmosphere (Bajwa *et al.* 2015) and deteriorated the natural ecosystem (Parras-Alcantara *et al.* 2013). Despite this, the yield potential of rice is severely hampered by many biotic stresses, especially the insect-pests and diseases. Yellow stem borer (YSB), leaf folder (LF), brown plant hopper, gundhi bug, bakane, bacterial leaf blight (BLB), blast, brown spot and sheath blight are important pests in rice-growing areas of the world (Tanwar *et al.* 2016). Several biotic stresses were addressed through systematic crop improvement and management efforts with judicious use of chemical pesticides in India (Prakash *et al.* 2014). Basmati rice being an export commodity is always under pressure from European Union and USA, due to indiscriminate pesticide application, many times export consignment has been rejected even by other countries (Chaba 2021). Therefore, to reduce pesticide load and meet the Maximum Residue Limit (MRL) parameters for export purpose, there is a need to bring the maximum area of Basmati rice under integrated pest management (IPM). Integrated pest management is a holistic approach to pest management that emphasises the use of multiple strategies to manage pest population in an effective and environmentally sensitive manner (Chatterjee *et al.* 2021, Hajjar *et al.* 2023). IPM approach mainly depends on regular visiting and monitoring of the crop pest and has been vastly recognized at the global scale as a management tool to achieve agricultural sustainability (Pretty and Bharucha 2015). The complexity of IPM modules with large number of interventions makes it difficult for the farmers to choose

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suitable practices to their conditions. Therefore , with the above points keeping in mind, the IPM programme was designed and implemented at village level in Rohtak district of Haryana during *kharif* 2020–2023 with the objective to refine, validate and promote the IPM in basmati rice.

MATERIALS AND METHODS

Collection of baseline information: The IPM trial was conducted during rainy (*kharif*) season of 2020 to 2023 in 200 ha at village Nidana (28°57'13.5"N, 76°29'14.1"E; at an elevation of 221 m amsl), Rohtak, Haryana. The baseline information was collected from the village by organising farmers' meeting. During the meeting, various questions about basic information of the village i.e. cultivable area, area under different crops, cropping pattern, crop rotation, varieties grown, source of irrigation, source of seeds, major pest problems, source of crop protection advisories, cultivation practices, cost of cultivation, cost of crop protection, knowledge about IPM, pest and natural enemies identification, average yield of rice in the village, were asked and consensual responses of the farmers were recorded.

Design of IPM strategy: Based on the baseline information and pest problems, IPM strategy was formulated. It consisted of (i) Green manuring with *Sesbania* or mung bean; (ii) Soaking of seeds in 2% salt solution (NaCl) to discard unhealthy seeds; (iii) Seed treatment with *Trichoderma harzianum* (1×10^8 cfu/g) @10 g/kg seed for bakane and sheath blight management; (iv) Seedling root dip in *Pseudomonas fluorescens* (3.0×10^{10} cfu/mL) solution @5 mL/L of water for 30 min against bakane; (v) Installation of pheromone traps @5/ha for YSB monitoring; (vi) Placement of straw bundles for spider conservation after 15 days of rice transplanting @20 bundles/ha; (vii) One release of egg parasitoid, *Trichogramma japonicum* @1,50,000/ha after appearance of moths or egg masses of YSB in paddy fields in the month of September; (viii) Hand weeding and need based use of weedicides Bispyribac Sodium 10% SC @200 mL/ha; (ix) Need-based application of chemical pesticides against insect pests and diseases based on economic threshold level (ETL) in accordance with Prakash *et al.* (2014).The paddy straw bundles were first placed in the sorghum field for 15 days for charging with spiders. Subsequently, in rice fields, these bundles were fixed vertically with bamboo sticks so that the lower portion of the bundle remained 15 cm above the water level. The egg parasitoid, *Trichogramma japonicum* were supplied by Biological Control Laboratory, SVB Patel University of Agriculture and Technology, Meerut, Uttar Pradesh

Farmers practice (FP) consisted of rice crop cultivation without green manuring and seedling root dip treatments with calendar based application of chemical pesticides, planting one seedling/spot and application of high doses of nitrogenous fertilisers (urea 450 kg/ha); no pest monitoring and resorting to 3–5 sprays of cocktil of chemical pesticides.

Implementation of IPM strategy: The IPM programme was initiated in 2020 with participation of 10 farmers in 20 ha basmati rice (PB1718) area in the village Nidana of district Rohtak, Haryana. The area coverage under IPM was increased gradually in the consecutive years, i.e. making it 100 ha in 2021, 120 ha in 2022 and 200 ha in 2023. The increase in area could be attributed to an increased awareness about benefits of IPM technology and self-mobilisation of a greater number of farmers to participate in IPM programme. Farmers' field schools were organized at 15 days interval to educate and convince the farmers about the adverse effects of pesticides and pesticide residue problems in export consignment of basmati rice, and benefit of IPM in managing pest problems with minimum use of pesticides. Farmers were trained about identification of pests and natural enemies, economic threshold levels of different pests, good agriculture practices, installation of pheromone traps for pest monitoring and straw bundles for spider conservation, seedling root dip treatment with *Pseudomonas fluorescens* at regular intervals in the fields. Critical IPM inputs such as *Trichoderma harzianum, Trichogramma japonicum,* pheromone traps for YSB and Azadirachtin 1500 ppm were provided to the farmers.

Refinement of IPM strategy: Based on the response of the farmers during first two years and keeping in mind the availability of critical IPM inputs to make IPM strategy suitable for adoption in long run by the farmers in the village, the IPM strategies was refined by excluding couple of interventions such as straw bundle and *Tricho*card and retaining only simple adoptable IPM interventions as per local conditions. The refined IPM strategy thus consisted of soaking of seeds in 2% salt solution (NaCl) to discard unhealthy seeds, seed treatment with *Trichoderma harzianum* 10 g/kg seed (NCIPM T9 strain), green manuring of main field, seedling root dip treatment with *Pseudomonas fluorescens*, balanced plant nutrition and water management, installation of pheromone traps for YSB monitoring @5/ha, regular field monitoring at weekly intervals, application of Azadirachtin 1500 ppm @5 mL/L water at low level of pest infestation, need based application of safer chemical pesticides based on economic threshold level (ETL), hand weeding and need based use of Bispyribac Sodium 10% SC @200 mL/ha. The refined IPM strategy was further validated and promoted on large scale.

Observations: Observations on pests and natural enemies were recorded at weekly interval from five fields from each IPM and FP. Data were recorded at five random spots per acre field and at each spots four hills were observed for total number of tillers, total number of leaves, dead hearts (%) and white ears (%) due to yellow stem borer, damaged leaves with live leaf folder larvae, number of brown plant hoppers per hill, number of spiders per hill, and per cent incidence of different diseases such as bacterial leaf blight (BLB), blast, bakane and sheath blight. Data on input cost, yield, and pesticide applications from IPM and FP fields were also recorded. Weekly data on pests and natural enemies were subject to statistical analysis with student t test (p<0.05) using r software. IPM fields were compared with farmers practice (FP) fields which were managed by the farmers with injudicious application of pesticides, fertilisers and water etc.

RESULTS AND DISCUSSION

Baseline information: The baseline information was collected from the village revealed that, the crops were 100% irrigated (Canal 50%; Tube well 50%) with an area of 1000 ha cultivated land. About 800 ha is under rice, with >90% of the area being under *basmati* rice. Pusa Basmati 1718, PB 1121, and PB 1509 are the main varieties grown. Pusa Basmati 1718 was cultivated in about >50% of the area in the village, whereas Pusa Basmati 1121 and PB 1509 occupied <40% and <10%, respectively. Key pest problems faced by the farmers included Bakane (*Fusarium moniliforme*), blast (*Magnaporthe grisea*), bacterial leaf blight (*Xanthomonas oryzae* pv. *oryzae*), sheath blight (*Rhizoctonia solani*), brown plant hopper (*Nilaparvata lugens*), yellow stem borer (*Scirpophaga incertulas*), and leaf folder (*Cnaphalocrosis medinalis*). Farmers were entirely (100%) dependent on pesticide dealers and companies for plant protection advisories. Knowledge about Integrated Pest Management (IPM), pest identification, and natural enemies was almost nil, calendar-based blanket application of pesticides was the scheduled activity followed by the farmers, which included granular application of chlorantraniliprole, spray of pymetrozine, tricyclazole, tebuconazole+trifloxystrobin, chloropyriphos, lambdacyhalothrin, and acephate. The expenditure on control of insect pests and diseases was >₹ 12,500/ha. The average paddy yield was about 40–45 q/ha. Planting of one seedling/spot with 35–40 days old nursery was the common farming practice followed in the village.

Pest status: The seasonal mean infestation of yellow stem borer (YSB) was reduced in IPM compared to FP by 27%, 31%, 28%, and 7.5% during 2020, 2021, 2022, and 2023, respectively (Table 1). Weekly infestations of yellow stem borer were significantly lower (p<0.05) in IPM compared to FP during five weeks (34th, 38th, 39th, 40th, 42nd SMW) in 2020, nine weeks (31st–35th, 38th, 41st–43rd SMW) in 2021, five weeks (32nd–34th, 38th–39th SMW) in 2022, and four weeks (32nd–33rd, 42nd–43rd) in 2023. The maximum percentage of dead heart was noticed during the 31st–32nd Standar Meteorological Week (SMW) of 2023 (6.1% in IPM and 6.6% in FP), and the white ear percentage was highest in the 43rd SMW of 2023 (4.4% in IPM, 10.1% in FP) (Fig. 1). The leaf folder population was lower in IPM in 2020, but it was higher or at par with FP thereafter.

Table 1 Scenario of pests and natural enemies in rice IPM and FP fields at Nidana, Rohtak, Haryana during *kharif* 2020–2023

Year	Treatment	YSB (%)	LF (%)	BPH (No./hill)	Bakane (%)	BLB (%)	Blast (%)	Spider (No./hill)
2020	IPM	1.81± 1.15	4.99±1.7	00	0.38±0.48	1.05±0.57	00	3.85±0.18
	FP	2.48±0.67	6.63±0.74	00	4.63±1.17	4.35±1.95	00	0.54±0.19
	% Difference in IPM over FP	-27.02	-24.74	00	-91.79	-75.86	00	612.96
	SMW when t-test p value is <0.05	34, 38-40, 42	33, 38-43	NS	31-43	33-43	NS	31-43
2021	IPM	1.45±0.44	5.17±3.09	1.14±1.73	0.83±0.47	0.51±0.55	1.35±1.90	0.95±0.19
	FP	2.13±0.66	2.62±1.61	2.37±2.56	1.31±0.61	0.81±0.81	2.15±2.61	0.19±0.18
	% Difference in IPM over FP	-31.98	97.21	-51.95	-37.14	-37.14	-37.14	392.00
	SMW when t-test p value is <0.05	31-35, 38,41-43	33, 35-42	37-43	NS	42	37	31-37, 39-43
2022	IPM	0.52±0.38	2.62±1.76	0.83±1.39	0.10±0.16	0.06±0.12	0.10±.22	1.18±0.37
	FP	0.73±0.61	2.08±1.35	1.52±2.02	1.49±0.88	0.68±0.66	0.88±1.35	0.22±0.22
	% Difference in IPM over FP	-28.77	25.96	-45.39	-93.29	-91.18	-88.64	436.36
	SMW when t-test p value is <0.05	32-34, 38-39	33, 36, 40, 43	39-42	32-43	36-37, 40-43	36-38, 42	31-36, 39-43
2023	IPM	2.54±2.13	5.52±9.02	0.62±0.99	0.11±0.15	0.58±1.22	0.19±.0.38	1.23±0.33
	FP	2.74±3.61	5.80±11.70	1.41±1.89	0.95±0.76	2.16±4.01	0.55±0.65	0.36±0.20
	% Difference in IPM over FP	-7.30	-4.83	-56.03	-88.42	-73.15	-65.45	241.67
	SMW* when t-test p value is <0.05	32-33, 42-43	36,38, 40	39-41, 43	33-34, 36-39, 41, 43	35-37, 38, 42,43	36-37, 42	32-36, 38-43

#Values are the mean of 13 weeks ±standard deviation; YSB, Yellow stem borer; LF, Leaf folder; BPH, Brown plant hopper; BLB, Bacterial Leaf Blight; SMW, Standard Meteorological Week; IPM, Integrated pest management; FP, Farmer practice.

The leaf folder population remained below the economic threshold level (ETL) throughout the study except in 2023, where it crossed the ETL during 37th–38th SMW, with a peak population of 33.6% in IPM and 43% in FP. This was managed by single application of recommended insecticide. The population of brown plant hopper (BPH) was reduced by 51.95%, 45.39%, and 56.03% in IPM over FP during 2021, 2022, and 2023, respectively. BPH remained below ETL throughout the study period, with its peak population (no./hill) being 4.0 in IPM and 5.65 in FP during the 41st SMW in 2021. The reduction in bakane incidence compared to FP was 91.79%, 37.14%, 93.19%, and 88.42% during 2020, 2021, 2022, and 2023, respectively, with the maximum incidence of 4.63% in 2020 (Table 1). The difference was significant in IPM compared to FP during most of the SMWs throughout the year. The incidence of BLB was 75.86%, 37.14%, 93.29%, and 88.42% lower in IPM compared to FP during 2020, 2021, 2022, and 2023, respectively. Blast incidence was negligible in 2020, whereas during 2021 to 2023, it was 37.14%, 88.64%, and 65.45% lower in IPM compared to FP, respectively. The IPM module proved to be effective in managing pest problems thus confirming the earlier observation of Karthikeyan *et al.* (2010) and Tanwar *et al.* (2016) who reported the effectiveness of rice IPM module containing seed and seedling root dip treatment for bakane, release of egg parasitoids, pheromone traps, alternate spray of neem based formulation and safer chemical pesticides against YSB and LF.

Natural enemies conservation: IPM implementation resulted in a significant reduction (average of 4 years) in the number of pesticide applications by >48% and the amount of active ingredients used by >82% in IPM fields compared to FP fields (Table 2). Year-wise pesticide use in IPM fields indicated that the number of sprays and the amount of active ingredients remained almost constant in IPM fields across all four years, whereas in FP, the amount of chemical active ingredients reduced significantly over successive years, 1665.25 g in 2020; 1250 g in 2021; 1139 g in 2022; and 653.25 g in 2023. IPM reduced pesticide use by 85% (Fitt 2011), with 42% increase in yield had earlier been recorded by Pretty *et al.* (2006). The reduction in pesticide use in FP was attributed to increased awareness among farmers about new insecticide molecules used at lower doses. The population of predatory spiders was significantly higher in IPM (0.95–3.85/hill) compared to FP (0.22–0.54/hill) throughout the study during most of the SMW (Fig. 2), due to the judicious use of safer pesticides in IPM fields compared to FP fields as reported earlier by Tanwar *et al.* (2022), who observed >82% increase in spider population in IPM over FP.

Economic analysis: The pooled (4-year average) data on yield and economics (Table 2) revealed that IPM implementation resulted in an 8.48% increase in yield, >15.60% reduction in input costs, and 29.51% increase in net return compared to FP. The benefit-cost ratio (BCR) in IPM was 2.8, whereas in FP it was 2.17. The BCR increased gradually in successive years for both IPM and FP owing to increased rice yield compared to 2020 and 2021. Yield was low in both IPM and FP due to drought in 2020 and heavy rain in 2021 at the time of maturity, thus confirming the earlier studies of Sharma *et al.* (2008), Karthikeyan *et al.* (2010) and Tanwar *et al.* (2022) who reported higher net return in IPM over FP. The yield was lower in both IPM and FP fields during 2020 and 2021 compared to 2022 and 2023, due to adverse weather events, including drought conditions in 2020 and heavy rain with gusty winds at the time of maturity, causing lodging of crops and resulting in lower yields (Sridevi and Chellamuthu 2015).

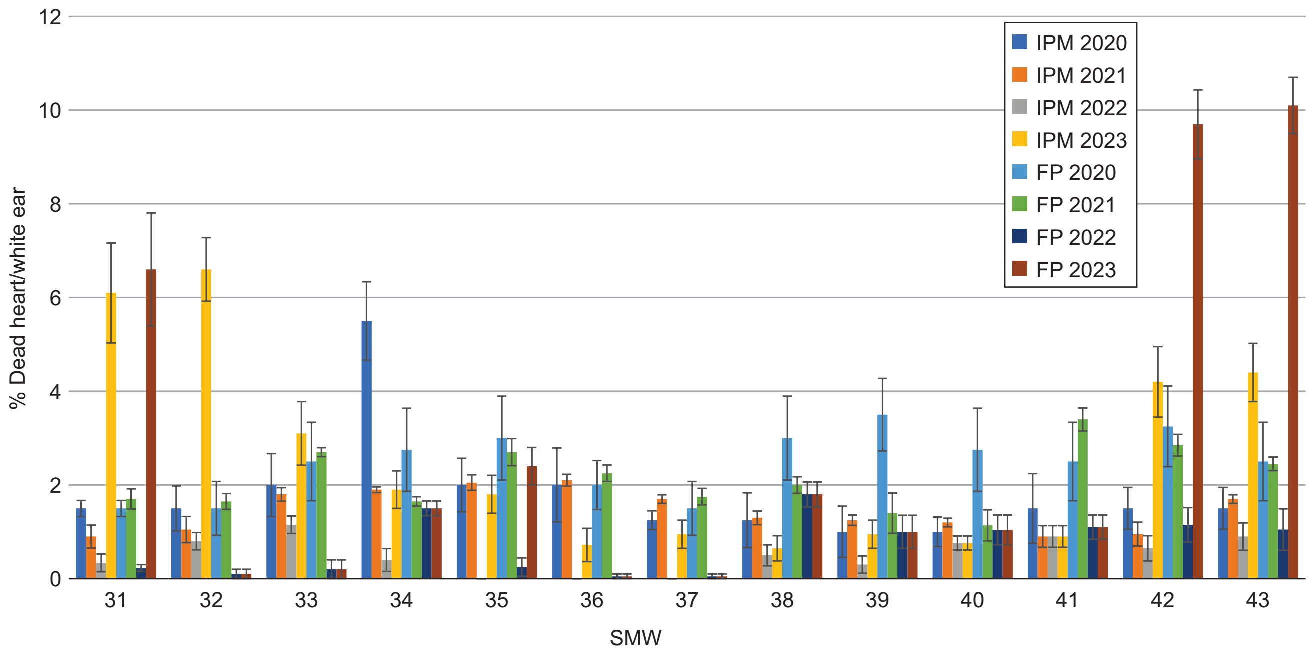

Fig. 1 Weekly infestation of yellow stem borer in Basmati rice in IPM and FP Fields during 2020–2023.
IPM, Integrated pest management; FP, Farmers practices; SMW, Standard Meteorological Week.

Table 2 Effect of IPM on reduction of chemical pesticides applications, yield and economics in basmati rice fields

Year	Treatment	Number of chemical pesticides applications	Amount of active ingredient (g ai/ha)	Yield (q/ha)	Cost (₹/ha)	Gross income (₹/ha)	Net income (₹/ha)	B:C ratio
2020	IPM	2	222.75	35.5	53185	88750	35565	1.67
	FP	5	1665.25	33.7	64760	84250	19490	1.31
	Difference (%) in IPM over FP	-60	-86.67	5.34	-17.8	5.34	133	
2021	IPM	3	252.00	38.00	55344	133000	77656	2.40
	FP	5	1250.00	34.70	67998	121450	53452	1.79
	Difference (%) over FP	-50	-79.84	9.51	-18.6	9.51	63.99	
2022	IPM	2.00	142	47.50	58735	199500	140765	3.4
	FP	4.50	1139	43.50	66810	182700	115890	2.7
	Difference (%) in IPM over FP	-55.56	-87.5	9.20	-12.1	9.20	21.50	
2023	IPM	3.00	216.75	46.50	54470	199950	145480	3.67
	FP	5.00	653.25	42.50	63146	182750	119604	2.89
	Difference (%) in IPM over FP	-40	-66.82	9.40	-13.8	9.4	20.68	
Pooled (4 years)	IPM	2.5	208	41.9	55433	155300	99866	2.80
	FP	4.88	1177	38.6	65678	142787	77109	2.17
	Difference (%) in IPM over FP	-48.72	-82.29	8.48	-5.60	8.76	29.51	

IPM, Integrated pest management; FP, Farmers practices, Market rate (₹/q) of paddy was ₹2500, ₹3500, ₹4200 and ₹4300 in 2020, 2021, 2022 and 2023, respectively. Total cost included labour cost for land preparation, nursery sowing, puddling, transplanting, fertiliser application, hand weeding, pesticide application, etc. and material cost such as seed, fertiliser, pesticides, biocontrol agents, and irrigation.

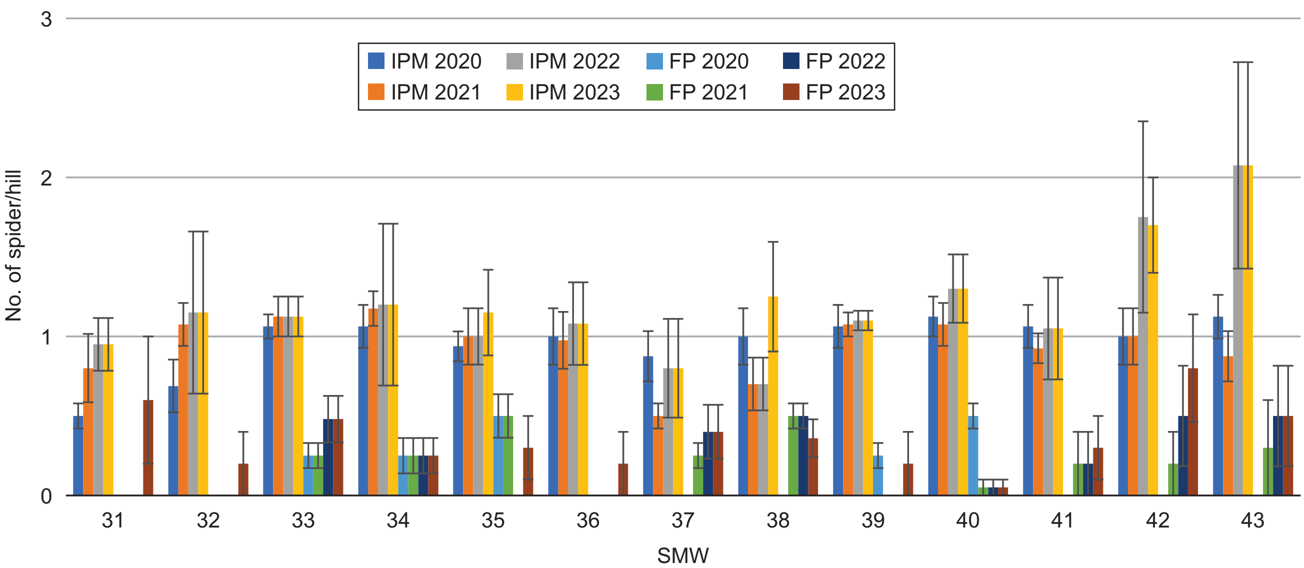

Fig. 1 Weekly infestation of yellow stem borer in Basmati rice in IPM and FP Fields during 2020–2023.
IPM, Integrated pest management; FP, Farmers practices; SMW, Standard Meteorological Week.

Knowledge improvement: Farmer field schools and meetings organized at regular interval in the village helped in developing strong linkages among farmers, scientists and extension workers and enabled 100% of IPM farmers to identify the major pests and natural enemies (spiders), and understand the role of monitoring, seed treatment, seedling root dip treatment, field sanitation and weed removal, concept of ETL and need based application of safer pesticides in pest management. These findings are in agreement with Dhakal and Poudel (2020) who reported Farmers Field School as the most effective way to increase IPM knowledge among rice farmers.

The study concluded that the wide area validation of IPM strategy in basmati rice in 200 ha comprising seed treatment, seedling root dip treatment, use of neem based pesticides, and judicious use of safer pesticides along with good agriculture practices, provided better yield with less input, less pesticides application along with conservation of natural enemies with high net return and benefit-cost ratio, there by proving ecologically safe, economically viable and adoptable under farmers field conditions.

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