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Validation Of Integrated Pest Management Practices Against Rice Pest Complex Through Participatory Trials

Samina Yasmin

Abstract

Integrated pest management is widely recommended for rice, but adoption remains limited when farmers do not see clear field-level economic benefits. Participatory trials were conducted in Haripur and Mansehra districts of the Hazara region to validate a locally adapted rice IPM package against farmer practice. At each location, IPM and farmer practice plots were compared side by side. The IPM package included resistant variety use, line sowing at recommended spacing, soil-test-based fertilizer management, weekly pest scouting, natural enemy conservation and need-based pesticide use. Pest observations focused on stem borer, leafhoppers and aphids. Natural enemies, grain yield and economic returns were also recorded. IPM plots reduced stem borer damage from 22.3% to 8.5% at Haripur and from 20.3% to 7.7% at Mansehra. Leafhopper abundance decreased from 7.4 to 2.8 per plant at Haripur and from 6.9 to 2.5 per plant at Mansehra. Aphid populations were also lower in IPM plots. Natural enemy abundance was higher under IPM, indicating reduced disruption of biological control. Mean grain yield increased from 3150 kg ha-1 under farmer practice to 3885 kg ha-1 under IPM, representing a 23.4% yield increase. The IPM package also produced a higher cost-benefit ratio of 1:3.6 compared with 1:2.4 under farmer practice. The results demonstrate that a participatory, locally validated IPM package can reduce pest pressure, conserve beneficial organisms, improve yield and increase profitability. Wider adoption should focus on farmer training, pest scouting skills and simple economic decision rules.

Keywords: Oryza sativa; rice IPM; participatory trials; stem borer; leafhopper; natural enemies; benefit-cost ratio; Hazara

1. Introduction

Rice (Oryza sativa L.) is a major staple crop and a key component of food security in Asia. Global production data show that rice remains one of the principal cereals in world agriculture (FAO, 2025). In Pakistan, rice also has economic value because of domestic consumption and export potential. In the Hazara region of Khyber Pakhtunkhwa, rice is cultivated in suitable valleys and irrigated areas, but productivity is constrained by insect pests, suboptimal crop management and variable pesticide practices.

Rice pest complexes usually include stem borers, leafhoppers, planthoppers, defoliators, sucking pests and a diverse community of natural enemies. Stem borers cause dead hearts during vegetative growth and white heads during reproductive stages, while leafhoppers and planthoppers cause direct sap-sucking injury and can transmit viral diseases. Classical rice pest literature emphasizes that pest injury and yield loss depend on crop stage, pest density, compensation ability, natural enemy activity and production situation (Heinrichs, 1994; Pathak & Khan, 1994; Savary et al., 2000a; Savary et al., 2000b).

Rice IPM is built on ecological principles rather than routine pesticide use. In tropical irrigated rice, the arthropod food web can suppress many early-season pests if natural enemies are conserved and unnecessary sprays are avoided (Way

& Heong, 1994; Matteson, 2000). Brown planthopper resurgence in Asia has repeatedly shown that indiscriminate insecticide use can destroy natural enemies and convert secondary pests into major threats (Bottrell & Schoenly, 2012). Therefore, effective rice IPM requires monitoring, resistant varieties, appropriate planting methods, fertilizer balance and need-based chemical intervention.

Participatory validation is important because IPM is knowledge-intensive. Farmer field school experience in Asia shows that farmer learning, field observation and group decision-making can reduce unnecessary pesticide use and improve ecological understanding (van den Berg, 2004; van den Berg & Jiggins, 2007; Feder et al., 2004). Communication studies in rice pest management also show that farmers may change management decisions when they test simple rules and observe pest-natural enemy relationships directly in their own fields (Heong & Escalada, 1997; Heong et al., 1998).

Recent IPM literature emphasizes that sustainable intensification depends not only on yield gains but also on reducing ecological disruption and improving farmer decision capacity (Pretty & Bharucha, 2015; Horgan, 2017). Ecological engineering approaches in rice further highlight the value of habitat management, predator conservation and decision support (Heong et al., 2021; Landis et al., 2000; Bianchi et al., 2006). The present study was therefore designed to validate a basket of IPM options through participatory rice trials in Haripur and Mansehra. The objectives were to compare pest incidence, natural enemy abundance, yield and economics between IPM and farmer practice plots.

2. Materials and methods

2.1 Study locations and participatory approach

Participatory trials were conducted at two rice-growing locations in the Hazara region: Hazara Agriculture Research Station, Haripur, and Agricultural Research Station, Baffa, Mansehra. These locations represent important rice production environments within Khyber Pakhtunkhwa. A participatory side-by-side design was used so that farmers and field staff could compare IPM and farmer practice under similar field conditions. At each location, ten farmers were selected. Each farmer maintained one IPM plot and one farmer practice plot, with each plot measuring 20 m x 15 m.

2.2 IPM package and farmer practice

The IPM package included use of a resistant rice variety, line sowing at 20 cm x 15 cm, fertilizer application guided by soil testing, weekly pest scouting, conservation of natural enemies and pesticide application only when economic thresholds were exceeded. Farmer practice plots followed local practice, which generally included variable sowing methods, non-uniform fertilizer use and pesticide application based on farmer judgment rather than formal scouting. The IPM concept was explained to participating farmers before plot establishment, and weekly observations were discussed in the field to support experiential learning. This structure followed the logic of farmer field-based IPM learning, where the field functions as both a production unit and a decision laboratory (van den Berg, 2004; Norris et al., 2003).

2.3 Pest and natural enemy monitoring

Weekly observations began after crop establishment and continued until physiological maturity. For stem borer, twenty plants per plot were examined for dead hearts and white heads, and total damage was calculated as percent affected plants. Leafhoppers were counted from ten randomly selected plants per plot and expressed as individuals per plant. Aphids were also counted on a per-plant basis. Natural enemies, including coccinellids, spiders and parasitoids, were recorded per plant. Observations emphasized both pest density and natural enemy presence because IPM decisions should consider the pest-natural enemy balance rather than pest numbers alone (Way & Heong, 1994; Heong et al., 2021).

2.4 Yield, economics and statistical analysis

Grain yield was recorded at harvest from each plot and converted to kg ha-1. Production costs included seed, fertilizer, pesticide and labor. Gross return was calculated using a grain price of Rs 40 kg-1, and net return was calculated by subtracting total production cost from gross return. Cost-benefit ratio was expressed as net return divided by total cost. Data were analyzed using analysis of variance, and means were compared between IPM and farmer practice plots at p <= 0.05 according to standard procedures for field experiments (Gomez & Gomez, 1984). Economic interpretation was guided by IPM decision principles and economic injury level theory (Pedigo et al., 1986).

3. Results

3.1 Stem borer incidence

Stem borer damage was consistently lower in IPM plots than in farmer practice plots. At Haripur, IPM plots recorded 5.2% dead hearts, 3.3% white heads and 8.5% total damage, while farmer practice plots recorded 14.5% dead hearts, 7.8% white heads and 22.3% total damage. At Mansehra, IPM plots recorded 7.7% total damage compared with 20.3% under farmer practice. These results indicate that the IPM package reduced stem borer damage by more than half at both locations.

Table 1. Stem borer infestation in IPM and farmer practice plots

Location	Treatment	% dead hearts	% white heads	Total damage (%)
Haripur	IPM	5.2	3.3	8.5a
Haripur	Farmer practice	14.5	7.8	22.3b
Mansehra	IPM	4.8	2.9	7.7a
Mansehra	Farmer practice	13.2	7.1	20.3b

Note. Means followed by different letters within a location differ significantly at p <= 0.05.

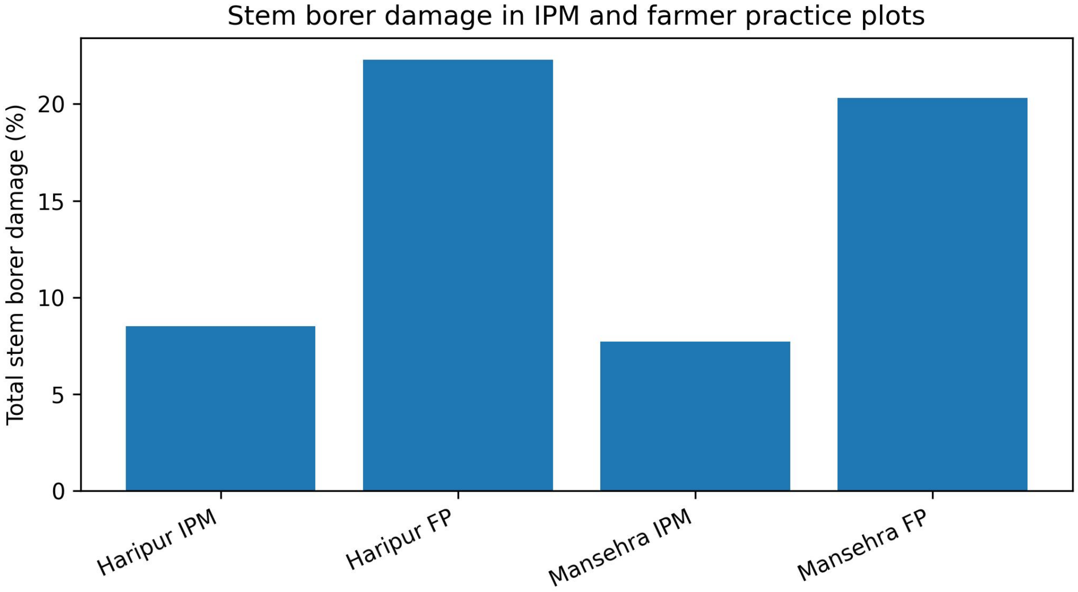

Figure 1. Stem borer damage under IPM and farmer practice at Haripur and Mansehra.

3.2 Leafhopper and aphid incidence

Leafhopper population was lower in IPM plots at both locations. At Haripur, IPM plots recorded 2.8 leafhoppers per plant compared with 7.4 per plant in farmer practice. At Mansehra, IPM plots recorded 2.5 leafhoppers per plant compared with 6.9 under farmer practice. Aphid populations followed the same pattern, with 3.2 and 2.9 aphids per plant under IPM at Haripur and Mansehra, respectively, compared with 8.6 and 8.1 under farmer practice.

Table 2. Leafhopper population in IPM and farmer practice plots

Location	Treatment	Leafhoppers/plant	Mean +/- SE
Haripur	IPM	2.8	2.8 +/- 0.3a
Haripur	Farmer practice	7.4	7.4 +/- 0.5b
Mansehra	IPM	2.5	2.5 +/- 0.3a
Mansehra	Farmer practice	6.9	6.9 +/- 0.5b

Note. Means followed by different letters differ significantly at p <= 0.05.

Table 3. Aphid population in IPM and farmer practice plots

Location	Treatment	Aphids/plant	Mean +/- SE
Haripur	IPM	3.2	3.2 +/- 0.4a
Haripur	Farmer practice	8.6	8.6 +/- 0.6b
Mansehra	IPM	2.9	2.9 +/- 0.3a
Mansehra	Farmer practice	8.1	8.1 +/- 0.5b

Note. Means followed by different letters differ significantly at p <= 0.05.

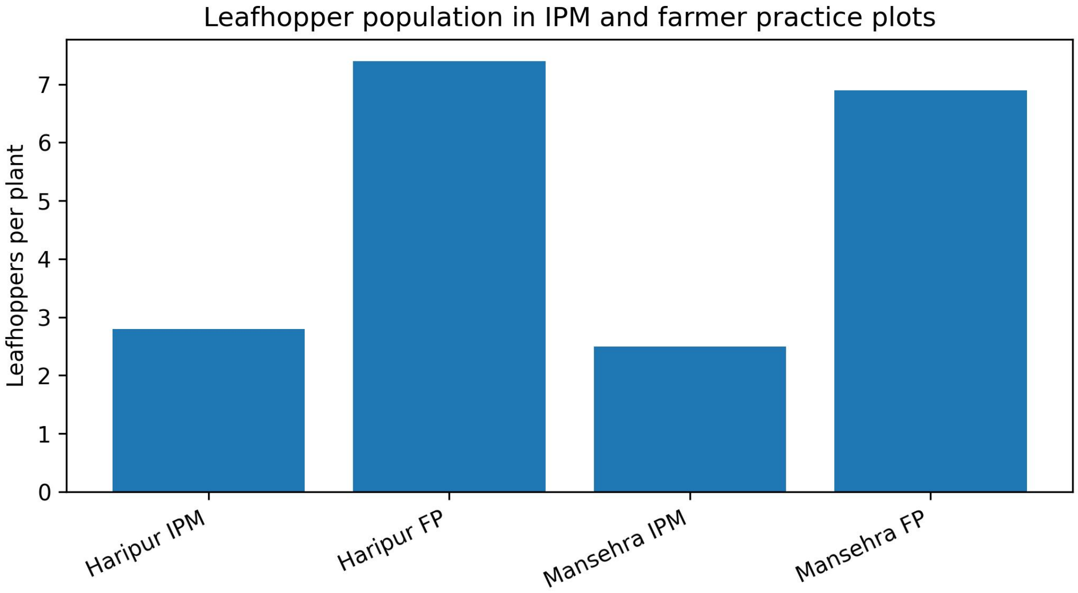

Figure 2. Leafhopper population under IPM and farmer practice at Haripur and Mansehra.

3.3 Natural enemy abundance

Natural enemies were more abundant in IPM plots than in farmer practice plots. At Haripur, IPM plots recorded 1.2 coccinellids, 0.8 spiders and 0.5 parasitoids per plant, compared with 0.5, 0.3 and 0.2 per plant under farmer practice. Mansehra showed the same trend. Higher natural enemy abundance under IPM suggests that reduced pesticide disturbance and better crop management favored beneficial arthropods.

Table 4. Natural enemy populations in IPM and farmer practice plots

Location	**Treatment**	**Coccinellids/plant**	**Spiders/plant**	**Parasitoids/plant**
Haripur	IPM	1.2	0.8	0.5
Haripur	Farmer practice	0.5	0.3	0.2
Mansehra	IPM	1.1	0.7	0.4
Mansehra	Farmer practice	0.4	0.3	0.2

Note. Values are mean natural enemy counts per plant.

3.4 Grain yield and economics

IPM plots produced higher yields than farmer practice plots at both locations. Haripur IPM plots yielded 3850 kg ha-1 compared with 3120 kg ha-1 under farmer practice. Mansehra IPM plots yielded 3920 kg ha-1 compared with 3180 kg ha-1 under farmer practice. The mean yield increase was 23.4%. Economic analysis showed that IPM reduced pesticide cost, increased net return and improved the cost-benefit ratio from 1:2.4 under farmer practice to 1:3.6 under IPM.

Table 5. Grain yield in IPM and farmer practice plots

Location	**IPM yield (kg/ha)**	**Farmer practice yield (kg/ha)**	**Yield increase (%)**
Haripur	3850	3120	23.4
Mansehra	3920	3180	23.3
Mean	3885	3150	23.4

Note. Yield increase was calculated relative to farmer practice.

Table 6. Economic comparison of IPM and farmer practice

Parameter	**IPM (Rs/ha)**	**Farmer practice (Rs/ha)**
Seed cost	2400	3000
Fertilizer cost	8500	7500
Pesticide cost	4200	9800
Labor cost	18500	16500
Total cost	33600	36800
Yield (kg/ha)	3885	3150
Gross return at Rs 40/kg	155400	126000
Net return	121800	89200
Cost:benefit ratio	1:3.6	1:2.4

Note. Cost-benefit ratio was calculated as net return divided by total cost.

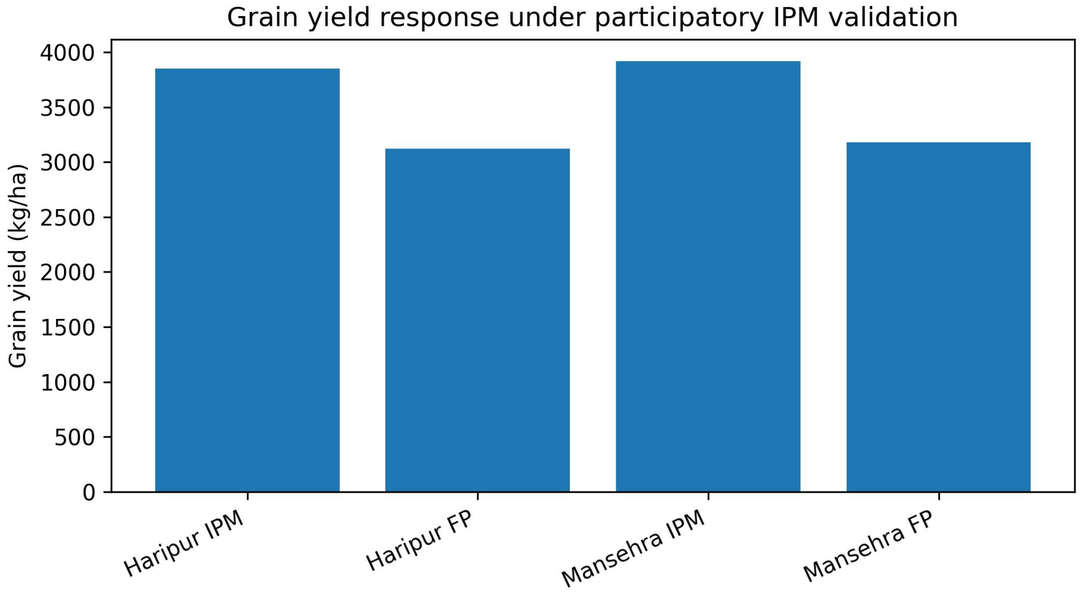

Figure 3. Grain yield under IPM and farmer practice at Haripur and Mansehra.

4. Discussion

The participatory trials showed that IPM reduced pest pressure and increased rice yield in both districts. Stem borer damage was much lower under IPM, indicating that the combination of resistant variety, line sowing, balanced fertilizer and need-based intervention was more effective than farmer practice. Rice stem borer injury can translate into yield loss through dead hearts and white heads, but the magnitude depends on crop stage and crop compensation ability (Heinrichs, 1994; Savary et al., 2000a). The reduced damage observed here suggests that early scouting and crop management reduced pest establishment before injury became severe.

Leafhopper and aphid populations were also lower under IPM. This is important because sucking pests are often encouraged by excessive nitrogen and poorly timed insecticide use. Rice IPM literature has repeatedly shown that early or unnecessary sprays can reduce predator populations and destabilize rice arthropod communities (Way & Heong, 1994; Matteson, 2000). The present finding of higher natural enemy abundance in IPM plots supports the ecological principle that conserving predators and parasitoids can improve pest regulation.

The higher natural enemy counts in IPM plots are particularly relevant for long-term sustainability. Coccinellids, spiders and parasitoids are important components of rice biological control. Habitat management and reduced insecticide disturbance can increase the functional role of these beneficial organisms (Landis et al., 2000; Bianchi et al., 2006). Ecological engineering approaches now recommended in rice systems similarly emphasize the use of plant diversity, field margins and reduced broad-spectrum spraying to support natural enemies (Heong et al., 2021).

The yield response was agronomically meaningful. Mean yield increased by 23.4% under IPM, while total production cost was lower because pesticide expenditure decreased sharply. This produced a higher cost-benefit ratio under IPM. The result is consistent with the broader IPM argument that profitability depends on both yield protection and cost control. Economic injury level theory states that pest control should be applied only when expected loss exceeds control cost (Pedigo et al., 1986). Farmer practice often violates this principle when pesticides are applied without pest scouting or threshold assessment.

The participatory design was a strength because it demonstrated the IPM package under conditions visible to farmers. Farmer field school and participatory IPM research shows that adoption improves when farmers observe field ecology, test recommendations and compare outcomes directly (van den Berg, 2004; van den Berg & Jiggins, 2007). In Indonesia and other Asian systems, farmer training has been associated with improved decision-making and reductions in pesticide misuse, although impact varies with training quality and institutional support (Feder et al., 2004; Heong & Escalada, 1997; Heong et al., 1998).

A key implication is that IPM adoption in Hazara should not be promoted as a list of separate practices. It should be taught as a decision process: select suitable varieties, plant in lines, manage nutrients, scout weekly, identify pests and natural enemies, and spray only when thresholds are exceeded. This is consistent with modern IPM definitions that treat pest management as an integrated ecological and economic system rather than a pesticide replacement campaign (Norris et al., 2003; Pretty & Bharucha, 2015; Horgan, 2017).

The study has limitations. It covered two districts and one season, so multi-year validation is required to capture seasonal weather variation and pest outbreak years. The farmer practice treatment also represents local practice during the trial period and may vary across villages. Nevertheless, the magnitude and consistency of pest reduction, natural enemy conservation and yield gain indicate that the tested IPM package is a strong candidate for wider demonstration and refinement.

5. Conclusion

The participatory IPM package reduced rice pest incidence, conserved natural enemies, increased yield and improved profitability in Haripur and Mansehra. Stem borer damage, leafhopper population and aphid abundance were all lower in IPM plots than in farmer practice plots. Mean grain yield increased from 3150 kg ha-1 under farmer practice to 3885 kg ha-1 under IPM, and the cost-benefit ratio improved from 1:2.4 to 1:3.6. The findings support wider promotion of locally adapted rice IPM through farmer training, field demonstrations and weekly scouting. Future work should validate the package across more villages, seasons and rice varieties and should develop simple threshold cards for farmer decision-making.

Declarations

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Conflict of interest: The author declares no conflict of interest.

Ethics statement: This study involved field observations and agronomic trials only; therefore, human or animal ethics approval was not applicable.

Data availability: The numerical data used for tables and figures are presented within the manuscript. Additional raw field sheets should be retained by the author for journal review, if requested.

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