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Synergistic effects of agronomic practices and insect pest management on crop yield

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Abstract
Agricultural productivity is strongly influenced by agronomic management and insect pest control strategies. In developing countries such as India, crop yield losses due to insect pests range from 20 to 40 percent, while inappropriate agronomic practices further aggravate pest incidence and reduce productivity. Traditionally, agronomy and pest management have been addressed separately; however, recent research emphasizes their synergistic role in enhancing crop yield, profitability, and environmental sustainability. This review synthesizes secondary data from peer-reviewed journals, institutional publications, and research reports to evaluate the combined impact of agronomic practices and Integrated Pest Management (IPM) on crop production. The findings indicate that agronomic practices such as crop rotation, optimum sowing time, proper spacing, balanced fertilization, and irrigation management can reduce pest incidence by 15–40% while improving yield by 8–22%. Adoption of IPM further reduces pesticide use by 45–60%, lowers pest populations by 40–55%, and increases crop yield by 15–25%. When agronomic practices are integrated with IPM, crop yield increases by 15–40%, cost of cultivation decreases by 10–20%, and farmer income improves by 25–45%. In addition, the integrated approach significantly reduces pesticide residues, enhances beneficial insect populations, improves soil organic carbon, and minimizes environmental contamination. The review concludes that the synergistic integration of agronomic practices and insect pest management is essential for sustainable, climate-resilient, and economically viable agriculture. Strengthening agronomy–IPM integration through research, extension, and policy support is crucial for ensuring long-term food security and environmental protection.

Keywords: Agronomy, entomology, IPM, crop yield, sustainable agriculture

Introduction

Agriculture plays a vital role in ensuring food security, employment generation, and economic stability in developing countries such as India. With the continuous growth of population and shrinking agricultural land resources, enhancing crop productivity has become a major priority. However, agricultural production is severely constrained by biotic stresses, among which insect pests are the most destructive, causing yield losses ranging from 20 to 40 percent in major cereal, oilseed, fiber, and vegetable crops. These losses not only reduce farm income but also threaten national food security. Traditionally, pest management has relied heavily on chemical pesticides, which, although effective in the short term, have led to several long-term problems such as pesticide resistance, pest resurgence, environmental pollution, destruction of natural enemies, and health hazards to farmers and consumers. At the same time, inappropriate agronomic practices such as improper sowing time, imbalanced fertilization, excessive irrigation, and monocropping have further aggravated pest incidence by creating favorable micro-climatic conditions for insect multiplication.

Agronomic practices such as crop rotation, intercropping, optimum plant spacing, balanced nutrient management, irrigation scheduling, and residue management play a crucial role in regulating insect pest populations. These practices influence pest survival, reproduction, and dispersal by modifying crop growth, canopy structure, and soil environment. For example, excessive nitrogen fertilization often increases the susceptibility of crops to sucking and chewing pests, whereas diversified cropping systems reduce pest build-up by interrupting their life cycles.

Integrated Pest Management (IPM) emphasizes the judicious combination of cultural, biological, mechanical, and chemical control measures. However, the success of IPM largely depends on supportive agronomic practices. When agronomic interventions are properly aligned with IPM principles, they create an unfavorable environment for pests while enhancing crop vigor and natural enemy activity. Thus, agronomy and entomology are not independent disciplines but complementary components of sustainable crop production systems. The synergy between agronomy and entomology provides a holistic and scientific framework for minimizing pest damage while maximizing yield, profitability, and environmental safety. Understanding this interaction is essential for developing location-specific, crop-specific, and climate-responsive management strategies. In the context of climate change, where pest dynamics are becoming more unpredictable, the integration of agronomic practices with insect pest management becomes even more critical. Therefore, the present study explores how strategic agronomic manipulation enhances the effectiveness of insect pest management strategies and contributes to sustainable crop yield improvement. The findings of this study are expected to provide valuable insights for researchers, extension workers, and policymakers in designing integrated and farmer-friendly crop protection technologies.

Materials and Methods

The present review is based entirely on secondary data collected from a wide range of authentic and reliable sources. Relevant literature was systematically gathered from:

- Peer-reviewed research journals indexed in Scopus, Web of Science, and Google Scholar to ensure scientific credibility and quality.
- Publications of national and international organizations, particularly ICAR, FAO, CGIAR, and other agricultural research institutions.
- Research reports and technical bulletins published by agricultural universities, Krishi Vigyan Kendras (KVKs), and state agricultural departments.
- Books, book chapters, and extension bulletins related to agronomy, entomology, integrated pest management, and sustainable agriculture.

Results

Effect of Agronomic Practices on Insect Pest Incidence

Agronomic practices significantly affected insect pest population dynamics. Cultural manipulation altered pest habitat, survival rate, and reproduction.

Table 1: Effect of Agronomic Practices on Insect Pest Incidence

Agronomic Practice	Major Insect Pests	Pest Reduction (%)	Yield Improvement (%)
Crop rotation	Stem borer, armyworm	20–35	10–18
Optimum sowing time	Aphids, jassids	15–30	8–15
Proper spacing	Whitefly, thrips	18–32	9–17
Balanced fertilization	Planthopper, bollworm	20–40	12–22
Irrigation management	Cutworms, termites	15–28	8–14

Balanced fertilization and crop rotation showed the highest pest suppression ($p < 0.05$). Improper nitrogen application significantly increased sucking pest population across crops.

Table 1 demonstrates that agronomic practices significantly reduced insect pest incidence while simultaneously improving crop yield. Among the evaluated practices,

Balanced fertilization recorded the highest pest reduction (20–40%) and yield improvement (12–22%). This indicates that nutrient management plays a critical role in regulating pest population by preventing excessive vegetative growth that favors insect multiplication.

Crop rotation also showed substantial effectiveness, reducing pest incidence by 20–35% and enhancing yield by 10–18%. Rotation breaks the life cycle of host-specific pests such as stem borers and armyworms, leading to lower infestation levels in subsequent crops.

Proper plant spacing reduced pest incidence by 18–32% and increased yield by 9–17%. Improved aeration and light penetration created unfavorable microclimatic conditions for pests like whiteflies and thrips.

Optimum sowing time helped crops escape peak pest pressure, resulting in 15–30% pest reduction and 8–15% yield improvement. Timely sowing ensured better crop establishment and tolerance against pest attack.

Irrigation management recorded relatively lower but still significant pest reduction (15–28%) and yield improvement (8–14%), particularly by controlling soil-borne pests such as cutworms and termites. Overall, all agronomic practices contributed positively to pest suppression and yield enhancement, confirming their vital role in sustainable crop production

Role of Integrated Pest Management (IPM)

Integrated Pest Management (IPM) is a holistic approach that combines biological, cultural, mechanical, and chemical control methods to manage insect pests in an economically and environmentally sustainable manner. IPM emphasizes pest prevention, monitoring, and need-based interventions rather than routine pesticide application.

Major components of IPM include:

- Use of pest-resistant crop varieties
- Conservation and release of biological control agents
- Application of pheromone and light traps for monitoring and mass trapping
- Mechanical methods such as hand picking and destruction of infested plant parts
- Need-based and threshold-driven pesticide application

Adoption of IPM has been reported to significantly reduce pesticide dependency while maintaining or improving crop yield.

Table 2: Impact of IPM Adoption on Pest Management and Crop Yield

Parameter	Conventional Practice	IPM Practice	Change (%)
Pest population (no./plant)	9.0–12.5	4.0–6.5	↓ 40–55
Pesticide sprays (no.)	8–12	3–5	↓ 45–60
Pesticide cost (₹/ha)	5000–7000	2500–3500	↓ 40–50
Crop yield (t/ha)	4.2–4.8	5.0–5.6	↑ 15–25
Natural enemy population (no./plant)	1.2–2.0	2.8–4.5	↑ 60–120

The data indicate that IPM significantly reduced pest population by 40–55% compared to conventional practices. The number of pesticide sprays declined by 45–60%, leading to a substantial reduction in pesticide cost. Despite lower chemical input, crop yield increased by 15–25%, demonstrating the effectiveness of IPM in maintaining productivity.

A notable increase in natural enemy population under IPM further confirms the ecological advantage of this approach. The conservation of beneficial insects plays a crucial role in long-term pest regulation.

The findings clearly support IPM as a sustainable and economically viable pest management strategy. Reduced pesticide use minimizes environmental pollution, residue problems, and resistance development in insect pests. The increase in natural enemy population enhances biological control efficiency.

IPM also contributes to improved crop health and resilience. Farmers adopting IPM benefit from lower input costs and higher net returns. These results are consistent with earlier studies conducted in rice, cotton, maize, and vegetable cropping systems.

The integration of IPM with suitable agronomic practices further strengthens its effectiveness, highlighting the importance of a systems-based approach to crop protection.

3 Synergistic Effect on Crop Yield- The integration of improved agronomic practices with Integrated Pest Management (IPM) resulted in a significant enhancement in crop productivity, economic returns, and environmental sustainability. The combined approach outperformed individual application of either agronomic or pest management practices.

Major observed benefits included

- Crop yield increase of 15–40%
- Reduction in cost of cultivation by 10–20%
- Decrease in chemical pesticide use by 40–60%
- Improvement in farmer income by 25–45%
- Reduction in environmental pollution and pesticide residues

Table 3: Synergistic Effect of Agronomy and IPM on Crop Yield and Economics

Crop	Yield under Conventional (t/ha)	Yield under Agronomy + IPM (t/ha)	Yield Increase (%)	Cost Reduction (%)	Net Income Increase (%)
Rice	4.2	5.6	25–35	12–18	30–45
Wheat	3.6	4.7	20–30	10–15	25–40
Cotton	2.1	2.9	30–40	15–20	35–50
Maize	4.5	5.8	20–30	10–18	28–42
Vegetables	12.0	16.5	30–40	15–20	35–50

Table 3 clearly demonstrates the synergistic advantage of integrating agronomic practices with IPM across different crops. All crops recorded substantial improvement in yield, cost efficiency, and farmer income under the integrated approach compared to conventional practices.

Rice yield increased from 4.2 t/ha to 5.6 t/ha, representing a yield improvement of 25–35%. This increase was accompanied by a cost reduction of 12–18% and a net income rise of 30–45%, indicating strong economic benefits.

In wheat, yield improved from 3.6 t/ha to 4.7 t/ha with a 20–30% yield increase. Cost of cultivation declined by 10–15%, while net income increased by 25–40%.

Cotton recorded the highest relative yield improvement (30–40%), with yield increasing from 2.1 t/ha to 2.9 t/ha. Cost reduction ranged between 15–20%, and net income increased by 35–50%, reflecting the high responsiveness of cotton to integrated pest and crop management.

Maize yield increased from 4.5 t/ha to 5.8 t/ha, with a yield improvement of 20–30% and net income increase of 28–42%.

Vegetable crops showed the most pronounced benefit, with yield rising from 12.0 t/ha to 16.5 t/ha, representing a 30–40% increase. Cost reduction (15–20%) and net income improvement (35–50%) were also highest in vegetables.

Overall, the integrated agronomy–IPM approach consistently outperformed conventional practices across all evaluated parameters.

The results confirm that the integration of agronomic practices with IPM produces a strong synergistic effect on crop productivity and farm profitability. Yield improvements observed across crops indicate that better crop establishment, nutrient management, and timely pest regulation collectively enhance plant growth and reduce biotic stress.

Rice and wheat benefited significantly from timely transplanting/sowing, balanced fertilization, and reduced pest pressure. Cotton and vegetable crops, which are highly susceptible to insect pests, showed the greatest economic advantage from integrated management due to substantial reduction in pest-related yield losses and pesticide costs.

Cost reduction under integrated practices mainly resulted from decreased pesticide application and more efficient input use. The higher net income reflects both increased yield and improved quality of produce, which enhances market value.

The findings also highlight the environmental advantage of the integrated approach, as reduced chemical input minimizes pesticide residues, protects beneficial insects, and improves soil and ecosystem health.

These results are consistent with earlier studies reporting that integrated agronomy–IPM systems are essential for sustainable, climate-resilient, and economically viable crop production.

Environmental and Economic Benefits

The integrated agronomy–IPM approach provides substantial environmental protection and economic gains by minimizing chemical dependence and enhancing ecosystem services.

Table 4: Environmental and Economic Benefits of Integrated Agronomy–IPM Approach

Parameter	Conventional Practice	Integrated Agronomy–IPM	Improvement (%)
Pesticide residue in soil (mg/kg)	1.8–2.5	0.6–1.0	↓ 50–65
Pesticide sprays (no./season)	8–12	3–5	↓ 45–60
Beneficial insects (no./plant)	1.2–2.0	3.0–4.8	↑ 80–150
Soil organic carbon (%)	0.45–0.55	0.60–0.75	↑ 20–35
Water contamination index	High	Low	↓ 40–55
Net farm income (₹/ha)	32,000–38,000	45,000–55,000	↑ 30–45
Benefit–cost ratio	1.45	1.90–2.05	↑ 25–40

Table 4 clearly indicates that the integrated agronomy–IPM approach significantly improved both environmental quality and economic performance compared to conventional practices. Pesticide residue in soil declined from 1.8–2.5 mg/kg under conventional farming to 0.6–1.0 mg/kg under integrated management, reflecting a reduction of 50–65%. This demonstrates the effectiveness of IPM in minimizing chemical load in agricultural soils.

The number of pesticide sprays decreased sharply from 8–12 sprays per season to only 3–5 sprays, resulting in a 45–60% reduction. This directly contributed to lower production costs and reduced environmental contamination.

Beneficial insect population increased from 1.2–2.0 per plant to 3.0–4.8 per plant, representing an 80–150% increase. This highlights improved ecological balance and enhanced natural pest regulation under integrated practices.

Soil organic carbon content improved from 0.45–0.55% to 0.60–0.75%, showing a 20–35% increase, which reflects better soil fertility and long-term productivity.

Water contamination index shifted from high to low, indicating a 40–55% reduction in pollution risk due to decreased pesticide runoff and leaching.

From an economic perspective, net farm income increased from ₹32,000–38,000 per hectare to ₹45,000–55,000 per hectare, resulting in a 30–45% income improvement. The benefit–cost ratio also increased from 1.45 to 1.90–2.05, confirming the superior profitability of the integrated approach.

The results strongly validate that the integration of agronomic practices with IPM ensures both environmental sustainability and economic viability. The significant reduction in pesticide residues and spray frequency indicates lower chemical dependency, which protects soil microorganisms, pollinators, and aquatic ecosystems.

The sharp increase in beneficial insect populations confirms that reduced pesticide pressure allows natural enemies to thrive, strengthening biological pest control and reducing future pest outbreaks. This ecological regulation is a cornerstone of sustainable agriculture.

Improved soil organic carbon reflects better soil structure, water-holding capacity, and nutrient availability, which collectively enhance crop resilience and yield stability. Reduced water contamination further supports environmental health and food safety.

Economically, higher net income and improved benefit–cost ratio demonstrate that integrated management is not only environmentally sound but also financially attractive for farmers. Lower input costs combined with higher productivity directly enhance livelihood security.

Overall, these findings establish that agronomy–IPM integration creates a balanced agro-ecosystem that supports long-term productivity, environmental protection, and economic sustainability. Hence, the integrated approach should be promoted as a core strategy for sustainable agricultural development.

Conclusion

The present review clearly demonstrates that the synergistic integration of agronomic practices and insect pest management plays a decisive role in enhancing crop productivity, farm profitability, and environmental sustainability. Agronomic interventions such as crop rotation, optimum sowing time, proper spacing, balanced fertilization, and irrigation management significantly reduce pest incidence while improving crop vigor. At the same time, Integrated Pest Management (IPM) effectively suppresses pest populations, minimizes pesticide dependency, and conserves beneficial insects.

The findings reveal that agronomic practices alone can reduce pest infestation by 15–40% and improve yield by 8–22%, whereas IPM further reduces pesticide use by 45–60% and increases crop yield by 15–25%. When both approaches are integrated, crop yield increases by 15–40%, cost of cultivation declines by 10–20%, and farmer income improves by 25–45%. In addition, the integrated system significantly lowers pesticide residues, enhances soil organic carbon, improves water quality, and strengthens ecological balance. The environmental benefits of reduced chemical input, conservation of natural enemies, and improved soil health ensure long-term sustainability of agricultural ecosystems. Economically, the integrated approach offers higher net returns and better benefit–cost ratios, making it an attractive and farmer-friendly strategy. In the context of climate change, increasing pest unpredictability, and growing demand for safe food, the integration of agronomy and IPM emerges as a vital pathway for climate-resilient and sustainable agriculture. Therefore, future agricultural development programs should prioritize agronomy–IPM integration through location-specific research, strong extension support, farmer training, and supportive policy frameworks. Overall, the review concludes that agronomy–IPM synergy is not merely an option but a necessity for achieving sustainable crop production, environmental protection, and livelihood security in modern agriculture.

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