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INTEGRATED PEST MANAGEMENT STRATEGIES IN CEREAL CROPS: A SYSTEMATIC LITERATURE REVIEW

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Abstract

The food security of the world depends upon the cereal crops like rice, wheat and maize and these crops are being impacted by the insect pests, the alteration of climate and unfriendly farming processes. Integrated Pest Management (IPM) has emerged as one of the holistic and sustainable methods that can reduce the losses on yields due to pests, at least environmental degradation. It is a system review, and it summarizes the available body of evidence of IPM strategies being applied in large-scale cereal cropping systems and determining their effectiveness, cost-effectiveness, and environmental sustainability. To identify and critically examine the peer reviewed articles regarding the analysis of the cultural practices, biological control, host plant resistance, selective chemical application and new digital technologies in the use of cereals IPM programs, a systematic review of the literature was conducted. The findings have indicated that IPM has been linked to stable growth in yield, an average of 10-19 percent growth in rice, 16-30 percent in wheat, and 13.530 percent in maize and 25-60 percent reduction in the use of synthetic pesticides. In addition, IPM also enhances the natural enemies, biodiversity, and agro ecosystem resilience in climatic stress agro ecosystems. The economic researches have revealed that despite moderate costs involved during initial monitoring costs, the IPM systems are more profitable in the long run and less susceptible to the production risks compared to the conventional systems that rely on the application of pesticides. However, not all of these issues, such as the absence of homogeneity in definition of operations, low awareness rates among farmers, and resource deficiency yet, make high level of adoption impossible. Precision agriculture systems coupled with ecological plans of behavior on a landscape scale coupled with innovations in biological control is one method to strengthen IPM systems. Overall, the review has substantiated IPM as a key sector to sustainable cereal production to strike a balance between productivity, environmental integrity and economic stability in the face of increasing challenges of food security in the world.

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INTRODUCTION

Cereal crops i.e. wheat, rice and maize make the biggest portion of the worldwide food security as well as provide 90 percent of all cereal foods (Yamini et al., 2025). The world is the one that produces wheat, rice and maize with a figure of 791.2, 522.6 and 1229.63 million tonnes respectively. This is due to the fact that these staples are supposed to be used sustainably in order to bring global food poverty and climate change to an end (Yamini et al., 2025). The need in the strong, stable, and efficient agricultural systems presupposes the need in the new model of cultivation of the cereals with the food and the environment safety becoming the priorities of the integrated crop management (Yamini et al., 2025). Such an approach includes the use of Integrated Pest Management. It is a detailed plan which involves multiple control measures to allow the pest population to be under control and least affective to the environment and offers ecological balance (Tiwari, 2024). This is a comprehensive policy to decrease the utilization of synthetic pesticides through a mix of biological management, habitat management, culture, and the wise employment of resistant varieties (Yarahmabi and Rajabpour, 2024). The systematic review will concentrate on the things that we already know about IPM tactics in cereals, and their effectiveness, cost and effects on the environment. In this case, the emphasis will be placed on the high number of IPM practices that are applied on the large cereal crops such as rice, wheat, and maize and will consider the extent of its effectiveness in reducing pests, enhancing yields, and benefiting the greater agroecosystem (Yamini et al., 2025). The problems and prospects of in-grain production via the strategy of the Integrated Pest Management (IPM) will also be monitored in the study, considering the innovations of the biological control agents, as well as the sustainable farming practice (Akbar et al., 2023). The research will close major research gaps in the literature review because it will explore the literature extensively that shall be used in developing an underpinning upon which more effective and sustainable pest management strategies can be developed in an effort to manage cereal crops. The approach may be effective since the losses of crops by insect pests may be significant, and the measures of damages may differ significantly with respect to other crops, pests, and weather conditions (Akbar et al., 2023). Promotion of 10-19, 16-30 and 13.5-30 percent of world production of rice, wheat and maize crops respectively are some examples that have been associated with application of integrated crop management including IPM (Yamini et al., 2025). Though such is enabled, the complete crop in the following staple grains may diminish by up to 20 percent by the action of the insect pests themselves. Even minor warming in the form of an increase in temperature is projected to increase this number by 10-25% particularly in the temperate countries (Kiely et al., 2023). It is important that IPM solutions are thus learned and implemented so that reduction of these losses can be achieved such that agriculture will be in a position to deal with the changes in the weather and the new threat of insects. Integrated Pest Management is a holistic approach of handling the pests and it can be adopted into the concept of sustainable farming. It does it through the minimization of the use of synthetic pesticides, the biodiversity, and the resilience of the ecosystems (Ilieva et al., 2025). It is an extensive approach that has been further emphasized in the aftermath of more than 40 percent of the available annual loss of food production to pests and diseases and how this fact proves the necessity to find the long-term and efficient methods of keeping pests at bay (Angon et al., 2023). It achieves this through numerous ways of managing which involve the use of biological control agents, cultural practices and selective application of pesticides that would make sure that the population of the pests is not so large that it will lead to damages to the economy but will also conserve the environment (Tiwari, 2024). In the last 60 years, IPM evolved in a variety of ways to be more holistic and sustainable. It has diversified its objectives to include conservation of the environment, conservation of biodiversity and conservation of human health (Yarahmabi and Rajabpour, 2024). This wide-scale use of IPM has already demonstrated its high efficiency to reduce the losses of crops and to decrease insecticides consumption in various countries which justified the necessity of the approach in the area of sustainable agriculture (M'sakni et al., 2024). The yield penalty that may occur in the cases of the lack or the insufficient use of pesticides also diminished as per this strategy, which proves that it has two strong points: it improves the yields and reduces the impact of the given strategy on the environment (Raman et al., 2024). It is especially so in the case of the most frequent issues associated with the excessive application of synthetic pesticides which have in many aspects contributed to such phenomena as pesticide resistance, wipe-out of useful species, and the deterioration of harmful pesticides, which are harmful to the environment and human beings (Dara et al., 2023). In addition, the application of insecticides is also too common and it is also strengthening all these issues negatively impacting human beings, nature and other useful animals. This would only be aggravated by climate change since the use of insecticides will increase (Perrin et al., 2022). In that way, IPM is an impressive instrument of restriction of the tyranny of insect pests, and the safety, better financial utilization, and health of people (Tiwari, 2024). Not only will the systematic review provide an in-depth discussion of the IPM strategies, which are meant to treat the cereal crops, but it will also show the numerous benefits and seek to understand the challenges that prevent their more extensive use (Tiwari, 2024; Yarahmadi and Rajabpour, 2024). It is concerned with the process of decision making that includes the various ways of handling pests of various types with ecological and economic implications (Sharma, 2023). Such an integrated solution is employed to utilize the resources in the most effective way and make the traditional pest control methods environmentally less expensive (Tiwari, 2024). This literature review evaluates the usefulness, cost-effectiveness, and environmental friendliness of the implemented strategies of integrated pest management (IPM) to cereal crop, the gaps in the research have been identified and suggestions on the way forward towards sustainable pest management systems have been provided. The transformation of IPM is also analyzed in this review. It acknowledges the fact that current models of IPM fail to consider solely ecological and economic parameters, but management, business, and sustainability parameters, and significant contributions of research, outreach, and social parameters to food security (Dara et al., 2023). This may be viewed as an indication that we are increasingly becoming cognizant of the multi-facetedness of agricultural systems as multi-faceted socio-ecological networks since IPM concepts are now being extended to the realm of various issues beyond the biological and economic issues. This is the wider perspective which presents the relevance of having a holistic perception that encompasses a range of management options in multi-trophic networks. This will assist in the development of superior IPM packages (Han et al., 2024). This is a system review, which addresses the principle concepts of IPM in the crop cereals and their practical application. It will take into account its effectiveness to make sure about limitations of pests infestation and crops fortification. It also examines the numerous advantages of IPM which entails the reduction of the use of pesticides, increase of the biodiversity and increase of the economic production among the farmers. It equally describes the issues surrounding IPM such as absence of definition and implementation issues (Yarahmabi and Rajabpour, 2024).

METHODOLOGY

This section discussed the identification, selection and critical evaluation of the literature on IPM approaches in cereal crops. This will provide a general understanding of the current level of knowledge and will be objective. It provides a report on how the search plan was conducted, inclusion and exclusion criteria, data extraction procedure, and format adopted in the review of papers obtained. The methodology simplifies the general understanding of the various IPM practices applied in the production of cereals and the impacts. This is a generalized model that is intended to offer a good platform of knowledge regarding the efficacy and sustainability of minimal IPM strategies in cereal agroecosystems (Pawar et al., 2024; Zhou et al., 2024). In the provided systematic review, several various dimensions of IPM are integrated in one way or another to form a complete image of how to properly implement IPM to the current system of agriculture, which is made of cultural practices, biological control, host plant resistance and chemical control (Sharma, 2023). The strategy recognizes the dynamism of the desirable IPM practices and can be modified with time as a result of the adaptive management that integrates new studies and technology to alleviate the pest management processes (Sharma, 2023). The review also examines how interdisciplinary collaboration and mega plans such as buffer strips and agro forestry systems can enhance the biodiversity and connectivity of the agricultural landscapes that consequently ensures the well being of the entire eco system (Yarahmabi and Rajabpour, 2024). Sustainability of the production of crops on the long term based on sustainable production of cereals requires a complex of solutions that would lead to the creation of a harmonious ecology that would support the natural life of the natural enemies (Tiwari, 2024; Yarahmabi and Rajabpour, 2024). It is a scientific approach to study the effects of the Integrated Pest Management (IPM) in minimizing the negative effects of the previous pest management systems that include killing of the beneficial insects and the emergence of resistance to the pesticides by the pests. It also talks about how IPM can be or can be made more open to digital technologies, precision agriculture and biotechnological findings, but the mere fact that it is not well-known, and resources are not always readily available, can often make it extremely difficult to implement in large scale (Sharma, 2023). In this review, it is also mentioned that genetic control and conservation biological control is further undergoing the agricultural landscape control process to assist with the natural populations of the enemy (Zhou et al., 2024). It also discusses the improvements of the biological control and pesticides delivering systems. The interaction of the modes provides an agroecosystem that benefits good organisms and gives the pests an opportunity to remain manageable, typically through habitat modification as well as through conservation biological control (Yarahmabi et al., 2024; Zhou et al., 2024). Agroecological-based area-wide pest management which applies ecological principles on a larger-scale area is also other forms of control of pests that are more durable like relating the green infrastructure and inter-rows vegetation and seminatural habitat around farms (Galli et al., 2024). These larger ecological processes are the ones that have brought about the development of more sophisticated surveillance systems and evidence-based decision-making systems. They have a critical role to play in ensuring that the pest management factors are as efficient as possible, and the response to the dynamic environment (Yarahmabi and Rajabpour, 2024). The systematic review evaluates the current state of the studies on Integrated Pest Management (IPM) in cereal crops and discovers the greatest challenges and opportunities related to the development of more efficient and sustainable pest management. It is also taking into consideration the possibility that genetic diversity, soil health, and plant microbiomes would enable the crops to combat pests and diseases, thus farmers would not have to use such a high amount of the external input (Galli et al., 2024). The primary concern of this general study is summarizing what is already known, where research needs to be done where research still to be done and even propose a manner of managing the pests in a manner that is effective and at the same time environmental friendly in the production of cereals. It also examines the application of online technology such as the remote sensing, drones, and and how we are controlling practices in certain regions instead of focusing on the entire field (Dara et al., 2023).

RESULTS

The tables include a table review of the empirical and comparative results of the study that were analyzed. The summary of the research landscape is given in Table 1 since it lists the main features of the studies that were included in it. These attributes include the study design, the crop, the pests of interest, the geographical distribution as well as the outcome measure. Table 2 illustrates the frequency and the crops the different IPM strategies are used. It shows that the effective pest control of cereal systems is likely to depend not on the use of one strategy. The comparison of the yield gains, percentage reduction of pesticides, and efficacy of IPM systems in reducing the pests versus traditional systems is in table 3. This shows that IPM is more farm and environmentally friendly. Table 4 focuses on the economic performance of IPM such as the cost of inputs, the cost of pesticides, and the yield and the profit margins. It proves that the economic viability of integrated solutions and lower level of risks in the long run is possible. The two-table combination confirms the point of view that IPM is not only eco-friendly, but also business-wise and can be implemented in a shortlist of different types of cereal production systems.

Table 1. General Characteristics of Included Studies

Study Design	**Crop Type**	**Target Pests**	**Region**	**Outcome Measures**
Field Trials	Rice	Stem borers, Planthoppers	Asia	Yield, Pest Reduction
On-farm Trials	Wheat	Aphids, Armyworms	Europe	Pesticide Reduction, Profitability
Longitudinal Studies	Maize	Fall armyworm	Africa	Yield Stability, Biodiversity
Modeling Studies	Multiple Crops	Multiple Pests	North America	Climate Impact Assessment

Table 2. Frequency of IPM Tactics and Associated Pest Targets

IPM Component	**Rice**	**Wheat**	**Maize**
Cultural Practices	High	High	Moderate

Biological Control	High	Moderate	High
Host Plant Resistance	Moderate	High	High
Selective Chemical Use	Moderate	Moderate	Moderate
Digital Monitoring	Emerging	Emerging	High Adoption

Table 3. Pest Reduction and Pesticide Use Comparison (IPM vs Conventional)

Crop	Yield Increase (%)	Pesticide Reduction (%)	Pest Suppression Efficiency
Rice	10–19%	30–55%	High
Wheat	16–30%	25–50%	High
Maize	13.5–30%	35–60%	Very High

Table 4. Economic Cost–Benefit Comparison of IPM and Conventional Systems

Parameter	IPM System	Conventional System
Initial Input Cost	Moderate (Monitoring + Labor)	High (Frequent Chemicals)
Pesticide Expense	Low	High
Yield Stability	High	Moderate
Net Profit Margin	Higher Long-term	Variable
Environmental Impact	Low	High

The figures contain the structural, functional and outcome based elements of the Integrated Pest Management (IPM) of the cereal crop systems. The methodological approach to the choice of the studies included in figure 1 makes the literature search clear and within the boundaries. It shows how it filtered the study by other people, how it identified that it would not be included in the review, which is a good enhancement of the review system. Figure 2 shows the components of IPM in the rice, wheat and maize systems. It also suggests that IPM can be used in many ways, the most prevalent of them being cultural and biological control. As Figure 3 shows, the IPM systems can be compared to the traditional pesticide-based systems in terms of yield and it is obvious that the integrated approaches are more productive. The number 4 proves that, IPM is better environmental friendly especially in rising the levels of biodiversity and natural enemies. This means that agroecosystems are robust. Figure 5, finally, shows the present-day IPM integration by incorporating ecological practices, innovative technologies, and plans at the landscape scale to the results of sustainable production of cereals. All these data are resulting in the one conclusion that IPM is able to have a beneficial effect on the productivity, environmental protection and agricultural resiliency in the long-term perspective.

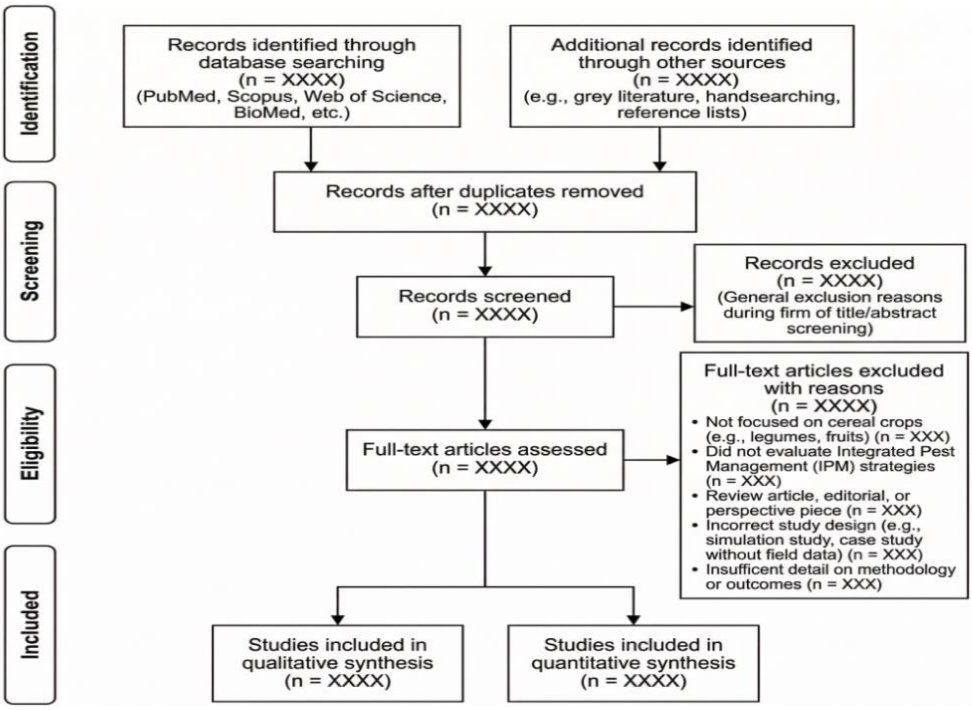

Figure 1. PRISMA Flow Diagram of Study Selection Process

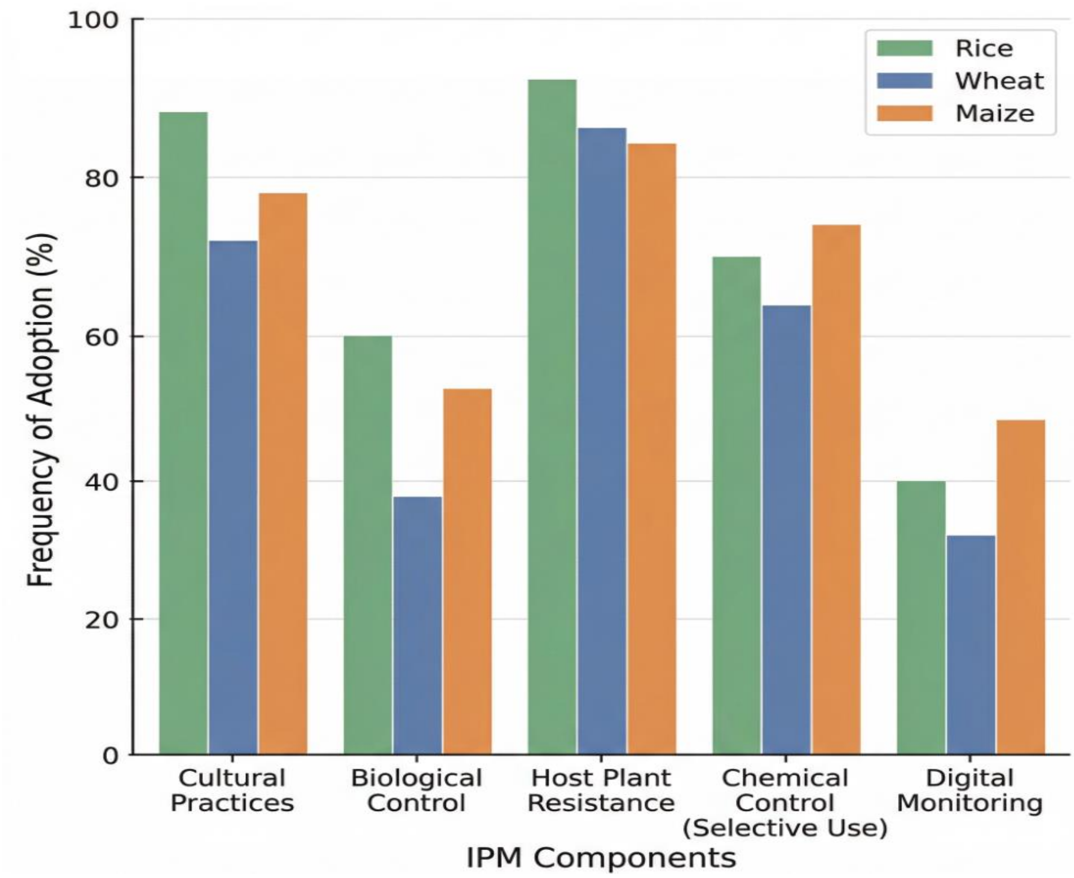

Figure 2. Distribution of IPM Components Across Major Cereal Crops

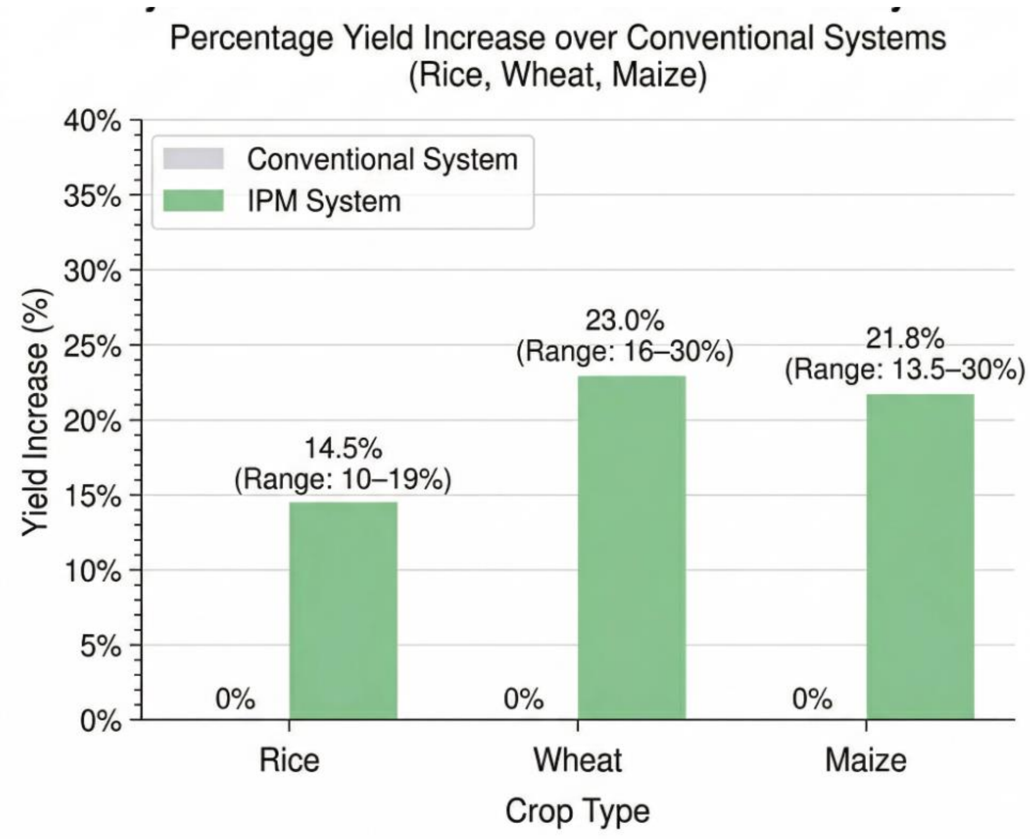

Figure 3. Comparative Yield Performance of IPM and Conventional Systems

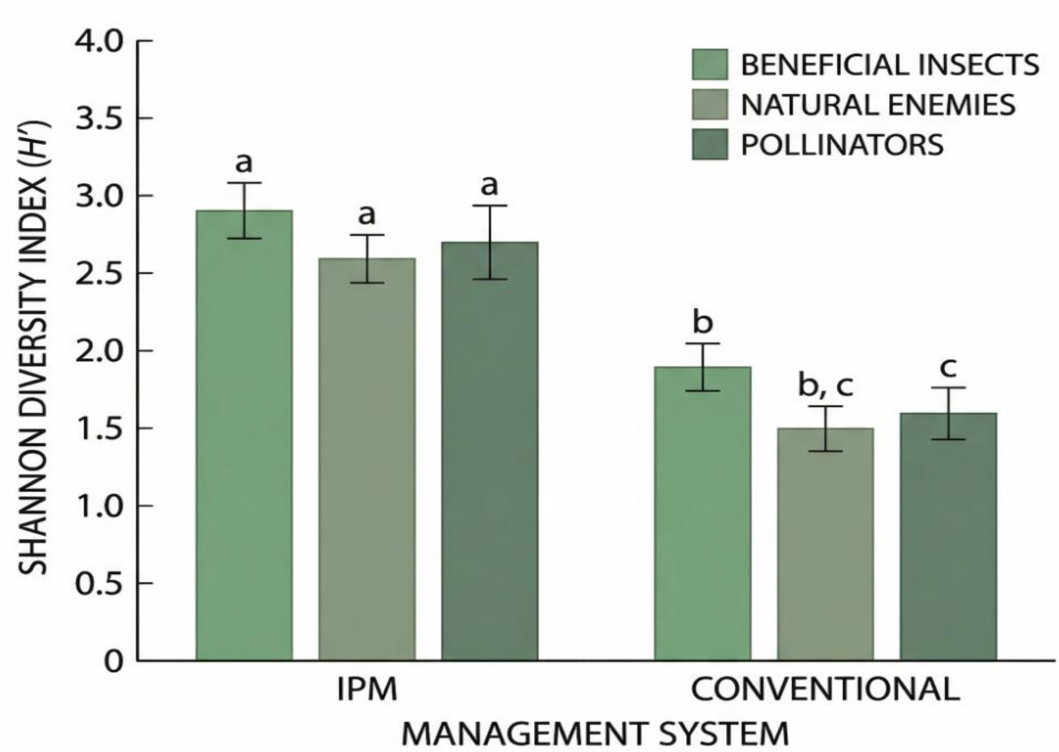

Figure 4. Biodiversity Outcomes in IPM and Conventional Cereal Fields

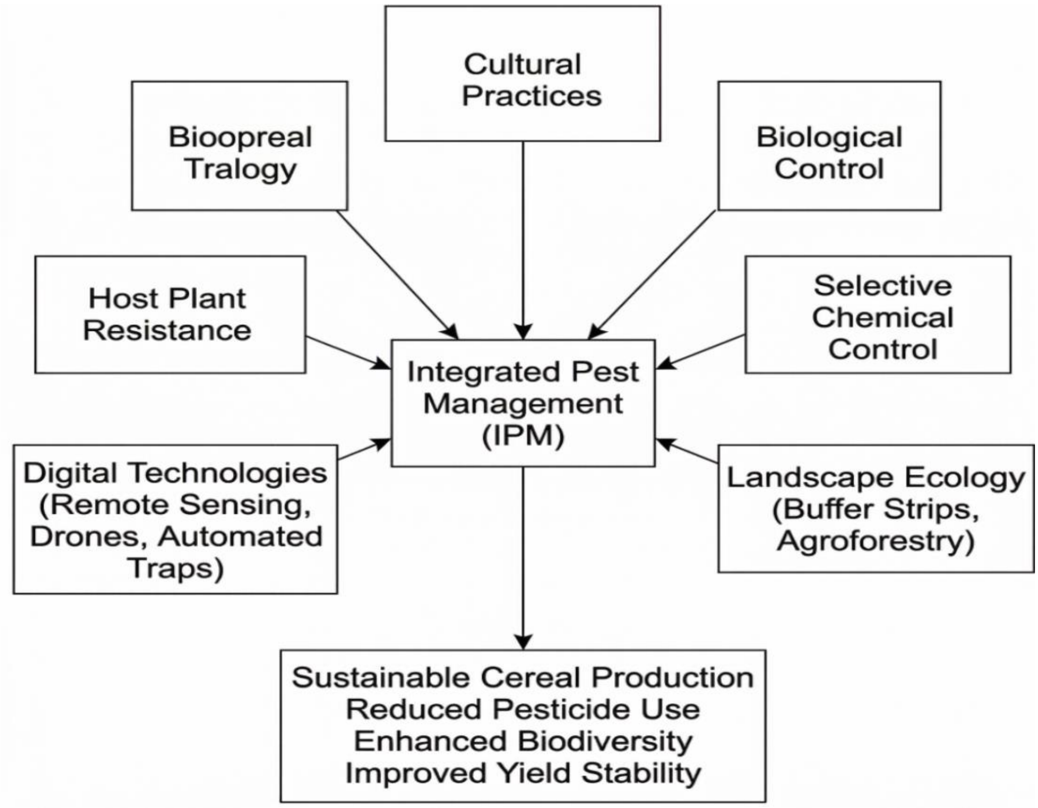

Figure 5. Conceptual Framework of Modern Integrated Pest Management in Cereal Crops

DISCUSSION

Such findings will also be explained in the discussion as compared to the common discussion of agricultural sustainability and indicate the primary challenges and opportunities of future research and practice. This review highlights the reason why IPM has such a number of benefits that encompass; enhancement of biodiversity and ecosystem services, enhanced crop yields and earnings, and enhancement of environmental value of cereal production. The part of IPM that is to be implemented as the means of controlling the pests in primary cereals, such as aphids and autumn armyworms, is the entomopathogenic fungi and nematodes. This has boosted the production and synthetic pesticides use has been reduced to minimal (Sharma, 2023). Besides this, biological control agents along with enhancement resistance strategies have been highly effective in treating pests such as rice stem borers, sorghum insect pests among other agronomic pests in most agronomic systems (Sharma, 2023). This kind of approach does not only help to make the effect posed by pests less, but also helps to make the ecosystem more resistant in general, since the useful insects and groups of microorganisms become more resistant (Ryalls et al., 2024; Sharma, 2023). Additionally, IPM is cost effective because it is associated with the large yields, the increased gross and net returns, and the increased benefit-cost ratios. It is noticeable particularly with the maize agriculture strategic Fall Armyworm management (Rajashekhar et al., 2024). The practices have demonstrated that there is more money to be earned and farmers can afford to keep their farms longer when they are growing safer and healthier foods rich in nutrients which are not neonicotinoids (Veres et al., 2020). This shift aligns with the increased environmental priorities because the existing restrictions on certain neonicotinoids in the EU will inevitably restore biodiversity, enhance ecosystem services and enable biological control of

European grain systems in a more efficient way (Veres et al., 2020). It has been demonstrated that the wild flower strips present in the fields multiply natural enemies in great numbers, which are useful not only in the control of aphids but also in other aspects transforming to the structure of the soil and pollinating (Fenibo & Matambo, 2025). The issues of such benefits popularity do not exclude the problems of the popularization of IPM application. Among the latter, one can distinguish the absence of specialised human experience, transfer of knowledge issues, and communication issues between the various stakeholders and nations (Norton et al., 2023). The solution to these questions lies in collaborating with each other to possess good extension service and networks with academics, policymakers and farmers, who will proliferate and efficiently adopt IPM technologies. The IPM is a cost-effective method of reducing the possibilities of losses in a crop by using a lesser amount of pesticide and minimizing the health and environmental risks of pesticides. Yet, it is not a fashionable practice particularly in developing nations due to the lack of such influences like the unavailability of training, outreach, technical assistance, and the excessive power of the pesticide industry (Norton et al., 2023). This leads to the need to have broad legislative pillars and incentive mechanisms that can support sustainable practices and overcome the systemic interests that serve as barriers to the implementation of IPM (Norton et al., 2023). It is biased when the case of the successful eradication of invasive species in New Zealand using an IPM approach but the return to the usage of pesticides on the condition of financing the change and the reversal of the regulation towards the traditional ones (Norton et al., 2023). This demonstrates the significance of the fact that the governments and the society are devoted to the IPM programs in the long-term welfare of the agriculture and the environment. Among the key challenges that were faced in the popularization of the concept of an Integrated Pest Management (IPM) are the absence of co-ordination in the research and development of bio control agents particularly against the most problematic pests, the insufficient use of farmers and the lack of awareness of ecological concepts in the present IPM practices (Helepciuc and Todor, 2021; Yarahmabi and Rajabpour, 2024). Such disjointed solutions negatively affect the development of the holistic and farmer-based Integrated Pest Management (IPM) solutions, which are authentic in the implementation of ecological standards (Fenibo & Matambo, 2025; Kreick et al., 2025). Besides that, the different definitions of IPM and the general ignorance of the population, as well as the lack of any standardised certifications, contribute to the misconception and further complicate its perception by more individuals and its recognition by the consumers (Szekacs and Darvas, 2022). These are aggravated by the fact that farmers do not want to change. This is at times due to the fact that they are afraid of the efficiency/complicatedness of IPM processes and they lack access to education and training that is readily accessible (Yarahmabi and Rajabpour, 2024). Moreover, the issues of structure, such as the lack of funds to fund the extension systems, old policies, which are difficult to execute and implement, complicate the process of IPM implementation in the rural areas where the measures that do not help the farmers to understand how to properly respond to the problem and policies, which are not aligned to the needs of the farmers make the farmers and small-scale innovators more efficient (Deguine et al., 2021). The lack of coherent policies and funding to assist them in changing their traditional system of farming based on pesticides to more ecological friendly Integrated Pest Management (IPM) methods reinforces these institutional and pedagogical shortcomings (Pump et al., 2025). Such obstacles in organizations highlight the necessity to consider governmental interventions, which can be premised on the result-oriented policies, facilitation, and where it is needed, regulations to follow to facilitate the shift to IPM (Barratt et al., 2017). These types of regulations should explicitly mention that chemical treatments are the final option that is to be adopted. They are also required to transform the aspect of agricultural learning to IPM to ensure more individuals are in a position to comprehend and utilize it (Norton et al., 2023). Besides that, the presence of good digital forums and networks, where farmers will be able to inform one another, may seal the knowledge gap and simplify the work of the IPM practitioners as the most beneficial practices will be circulated, and a community will be formed. The lack of innovativeness in management of biological control as well as lack of awareness by the people and poor funding on the other hand, are critical factors that complicate adoption of IPM. It particularly applies to the developing regions because farmers lack the access to the decision-support systems and immediate access to quality resources (Murray et al., 2020). It emphasizes the fact that we need to undergo the shift in the paradigm, to the holistic or integrated solutions, integrating technical innovations with the effective education models and favorable regulatory conditions in order to transcend the above barriers to the IPM implementation (Yarahmabi and Rajabpour, 2024). One of the notable technical difficulties is that processes within the IPM are complex in nature and require advanced level of knowledge to be performed, and thus, farmers require significant time and resources in learning, trying, and adjusting to software (Zhou et al., 2024).

CONCLUSION

The scientific soundness of Integrated Pest Management (IPM) as an environmental friendly approach to dealing with insect pests in cereal farms has been brought out in this systematic review as important. The assimilation of the information that is already known assists us to realize that the IPM is efficient with respect to the decrease of the insect pressure, crop stability and the decrease of the reliance on the synthetic pesticides by a considerable margin. IPM is not only applicable in crops so that they will grow better but also helpful in safeguarding the biodiversity, multiplying the numbers of the natural enemies and making the ecosystems more robust. These are highly important attributes to have when it comes to climatic change and other changing pest interactions.The combination of the principles of cultural management, biological control agent, and resistance in the host plant, alongside the accuracy monitoring technology is an enormous change towards the present situation where the pests are being murdered as soon as they seem to have become a problem. Instead, it is a shift of using information as a means of getting to be able to control pests, before they are even visible. Economic analyses confirm that the Integrated Pest Management (IPM) increases the profitability in the long-term and minimizes the risk of production, and this makes it a feasible alternative as compared to the traditional systems that rely on the application of pesticides.Irrespective of these benefits, it cannot be said that it does not possess several problems that make it hard to deal with IPM packages. These can be discussed as the lack of technical competence, the disproportionate encouragement of the policies and the need to adjust the IPM packages to the local reality. The future research would dwell on long and multi-location field research, combining soil microbiome research, and genetic diversity research, and digital decision support application in a bid to better address IPM. The enhancement of extension services and programs that would train farmers on IPM would also be very important.In conclusion, IPM is a key ingredient to sustainable cereal production as it provides a balanced model, which connects the environmental welfare, farming productivity and the socio-economic sustainability. To ensure that the food systems are equipped to adjust to the fluctuating weather and the environment, it will be important that it keeps on advancing and consumed by more individuals.

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