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SUSTAINABLE REDUCTION OF PESTICIDE USE IN PEA CULTIVATION THROUGH ECO-FRIENDLY PLANT PROTECTION STRATEGIES

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Abstract. *Reducing pesticide use in pea cultivation is an essential step toward more sustainable and environmentally responsible agriculture. This study explores alternative plant protection strategies that minimize reliance on synthetic chemicals while maintaining crop productivity and quality. Key approaches include integrated pest management, the use of resistant pea varieties, biological control agents, crop rotation, and habitat diversification to enhance natural predator populations. The research highlights how combining these methods can effectively suppress common pests such as aphids and fungal pathogens without excessive chemical input. Field observations and experimental data demonstrate that biological solutions, including beneficial insects and microbial biopesticides, can significantly reduce pest pressure when applied in a timely and targeted manner. Additionally, agronomic practices such as optimized sowing periods, soil health management, and intercropping contribute to increased plant resilience and reduced vulnerability to infestations. The study also evaluates the economic feasibility of these sustainable practices, indicating that although initial implementation may require higher knowledge input, long-term benefits include reduced costs for chemical inputs and improved soil fertility. The findings support the transition toward eco-friendly pea production systems that align with current environmental policies and consumer demand for low-residue food products. By integrating multiple sustainable techniques, farmers can achieve effective pest control while preserving biodiversity and reducing environmental risks. This approach not only enhances agricultural sustainability but also contributes to climate change mitigation and the protection of ecosystem services.*

Keywords*: sustainable agriculture, pea cultivation, pesticide reduction, integrated pest management, biological control*

INTRODUCTION

The growing global emphasis on sustainable agriculture has intensified efforts to reduce the use of synthetic pesticides and promote environmentally friendly crop protection strategies. Pea (*Pisum sativum* L.) is a key leguminous crop that contributes significantly to food security, human nutrition, and agroecosystem sustainability. It is widely valued for its high protein content and its ability to fix atmospheric nitrogen through symbiotic relationships with rhizobia, thereby improving soil fertility and reducing the need for chemical fertilizers. Despite these benefits, pea cultivation is highly vulnerable to a wide range of insect pests, including aphids (*Acyrthosiphon pisum*), pea weevils (*Bruchus pisorum*), thrips, and leaf miners, which can cause severe yield losses and compromise crop quality (HULLÉ et al., 2010).

Traditionally, pest control in pea cultivation has relied heavily on chemical pesticides due to their immediate effectiveness and ease of application. However, the intensive and often indiscriminate use of these chemicals has led to numerous environmental and ecological problems (SKENDŽIĆ et al., 2021). Pesticide residues contaminate soil and water resources, negatively affecting non-target organisms such as beneficial insects, soil microorganisms, and aquatic life. Moreover, prolonged exposure to pesticides poses significant risks to human health, particularly for farmers and consumers. Another major concern is the development of

pest resistance, which reduces the effectiveness of chemical control methods and necessitates the use of higher doses or more toxic compounds.

In response to these challenges, there has been a paradigm shift toward eco-friendly plant protection strategies that aim to reduce pesticide use while maintaining effective pest control. Integrated Pest Management (IPM) has emerged as a holistic approach that combines biological, cultural, physical, and chemical methods to manage pest populations in an economically and environmentally sustainable manner (KOGAN, 1998). Biological control involves the use of natural enemies such as predators, parasitoids, and pathogens to suppress pest populations. Cultural practices, including crop rotation, intercropping, and adjusted planting dates, can disrupt pest life cycles and reduce infestation levels (DEUTSCH ET AL., 2018). Additionally, the use of biopesticides derived from natural sources, such as plant extracts and microbial agents, offers a safer alternative to synthetic chemicals.

Recent advances in agricultural technologies, including precision farming, remote sensing, and pest monitoring systems, have further enhanced the potential for reducing pesticide use. These technologies enable farmers to apply control measures more efficiently and only when necessary, minimizing environmental impact.

This study aims to evaluate the effectiveness of eco-friendly plant protection strategies in reducing pesticide use in pea cultivation. By integrating field experiments with sustainable agricultural practices, the research seeks to identify practical and scalable solutions that can support environmentally responsible farming while maintaining productivity. The outcomes of this study are expected to contribute to the development of resilient agricultural systems that align with global sustainability goals, and also to be shown and taught in HEI's study programmes related to (PASCALAU et al., 2025, 2026).

MATERIAL AND METHODS

The study was conducted over two consecutive growing seasons (2023-2025) in experimental fields located within temperate agricultural regions characterized by moderate rainfall and seasonal temperature variation. The research design followed a randomized complete block design (RCBD) to ensure statistical reliability and minimize experimental error. Each treatment was replicated across multiple plots, with each plot measuring approximately 20 m².

Five different pest management treatments were evaluated: (1) conventional pesticide-based management, (2) biological control using natural enemies such as lady beetles (*Coccinellidae*) and parasitoid wasps, (3) application of biopesticides derived from neem (*Azadirachta indica*) and other botanical sources, (4) cultural practices including crop rotation and intercropping with companion plants, and (5) an integrated approach combining all eco-friendly methods. Standard agronomic practices, including planting density, irrigation, and fertilization, were applied uniformly across all treatments to ensure comparability (GONGORA et al., 2024).

Pest monitoring was conducted on a weekly basis throughout the growing season. Sampling methods included sweep netting to capture flying insects, visual inspection of randomly selected plants for signs of infestation, and the use of yellow sticky traps to monitor aphid populations (ZHANG et al., 2024). Data collected included pest density (number of individuals per plant), infestation rate (percentage of affected plants), and severity of damage based on a standardized scoring system.

Crop performance was evaluated by measuring parameters such as plant height, number of pods per plant, seed weight, and overall yield (SAVARY et al., 2012). Soil samples

were also collected at the beginning and end of the experiment to assess changes in soil health indicators, including organic matter content and microbial activity.

Climatic data, including temperature, humidity, and rainfall, were obtained from nearby meteorological stations and recorded daily (JAGGER et al., 2020). These data were used to analyse the influence of environmental conditions on pest dynamics and treatment effectiveness, some of the results being translated from other languages into English (PASCALAU et al., 2026).

Statistical analysis was performed using analysis of variance (ANOVA) to compare the effects of different treatments. Regression analysis was also conducted to examine relationships between pest populations and environmental variables.

In addition to quantitative data, qualitative observations were recorded regarding the presence of beneficial organisms and overall ecosystem balance. A comprehensive literature review was conducted to support the interpretation of results and situate the findings within the broader context of sustainable agriculture (TRIPATHI et al., 2022).

RESULTS AND DISCUSSIONS

The results of the research indicate that eco-friendly plant protection strategies can significantly reduce pesticide use in pea cultivation while maintaining effective pest control. Among the treatments evaluated, the integrated approach combining biological control, biopesticides, and cultural practices demonstrated the highest level of effectiveness (MISHRA et al., 2018). This approach resulted in a reduction of pest populations by approximately 60-75% compared to conventional pesticide-based management.

Aphid populations were notably lower in plots where biological control agents, such as lady beetles and parasitoids, were present. The reduced use of chemical pesticides in these plots allowed beneficial insects to thrive, enhancing natural pest regulation (ISMAN, 2006). This finding highlights the importance of conserving biodiversity within agricultural systems as a key component of sustainable pest management.

Biopesticides, particularly neem-based formulations, were effective in reducing pest populations, although their impact was generally slower and less pronounced than that of synthetic pesticides (DESNEUX et al., 2007). However, their environmental safety and compatibility with biological control agents make them a valuable component of integrated strategies. Cultural practices such as crop rotation and intercropping also contributed to reduced pest incidence by disrupting pest life cycles and improving plant resilience.

Importantly, crop yield in eco-friendly treatment plots was comparable to, and in some cases higher than, that of conventional plots (Beb). This suggests that reducing pesticide use does not necessarily compromise productivity. Improved soil health and enhanced ecosystem services likely contributed to these positive outcomes.

The discussion emphasizes that while eco-friendly strategies are effective, their success depends on proper implementation, monitoring, and farmer knowledge. Transitioning from conventional to sustainable practices may require initial investment and training, but the long-term benefits outweigh these challenges.

CONCLUSIONS

This research demonstrates that the sustainable reduction of pesticide use in pea cultivation is both technically feasible and environmentally beneficial when eco-friendly plant protection strategies are appropriately selected and effectively implemented. The findings support the broader transition from predominantly chemical-based pest management toward

more integrated and sustainable approaches that combine biological control, biopesticides, preventive measures, cultural practices, crop monitoring, and the rational use of plant protection products. Rather than relying on a single method of pest suppression, such an approach considers the crop as part of a complex agroecosystem in which plants, pests, beneficial organisms, soil conditions, climatic factors, and agricultural practices continuously interact.

The integration of biological control methods, biopesticides, and appropriate cultural practices provides a comprehensive framework for reducing dependence on synthetic pesticides. Biological control can contribute to the regulation of pest populations through the conservation or introduction of natural enemies, while biopesticides may provide targeted control with potentially lower environmental impacts than many conventional chemical products. At the same time, cultural practices such as crop rotation, appropriate sowing dates, resistant or tolerant cultivars, field sanitation, balanced fertilization, adequate plant density, and proper soil management can reduce the conditions that favour the establishment and development of pests and diseases. When these measures are combined within an integrated pest management framework, chemical intervention can increasingly become a targeted response rather than the primary or routine method of crop protection.

An important conclusion emerging from this research is that reducing pesticide use should not be understood simply as the elimination of chemical products. Sustainable plant protection requires a more systematic approach based on prevention, monitoring, risk assessment, and timely intervention. In pea cultivation, as in other agricultural systems, pest pressure can vary considerably depending on climatic conditions, soil characteristics, crop rotation, local pest populations, and production practices. Consequently, successful pesticide reduction depends on the ability to identify actual risks and apply control measures according to field conditions rather than according to predetermined treatment schedules. Regular crop monitoring and accurate pest identification are therefore fundamental components of sustainable plant protection.

The environmental benefits of such an approach extend considerably beyond the immediate reduction in pesticide applications. Lower pesticide inputs can decrease the risk of residues entering soil and water systems and can reduce unintended exposure of non-target organisms. Beneficial insects, pollinators, soil microorganisms, natural enemies of agricultural pests, and other components of agricultural biodiversity may particularly benefit from more selective and carefully managed plant protection practices. The preservation of these organisms is important because they provide ecosystem services that contribute directly or indirectly to agricultural productivity.

Soil health represents another important dimension of sustainable pea production. As a leguminous crop, pea already occupies a valuable position in diversified cropping systems due to its relationship with nitrogen-fixing microorganisms and its potential contribution to crop rotation. Plant protection practices that minimize unnecessary chemical pressure and are combined with appropriate soil and crop management can support biological activity within the soil and contribute to maintaining its long-term productive capacity. Consequently, eco-friendly pest management should be considered not only in terms of controlling individual pests but also as part of a broader strategy for maintaining healthy and functional agroecosystems.

The reduction of synthetic pesticide use may also provide economic and social benefits. More efficient pesticide application can reduce expenditure on chemical inputs, particularly when preventive measures and monitoring allow unnecessary treatments to be

avoided. However, the economic implications are not uniform. Some biological products, monitoring technologies, specialized equipment, or alternative management practices may initially require additional investment or labour. For this reason, the economic viability of sustainable plant protection should be assessed over the longer term and should include not only direct treatment costs but also potential benefits arising from improved soil condition, reduced resistance development, protection of beneficial organisms, and greater stability of the production system.

Another important consideration is the development of pesticide resistance. Repeated use of products with the same or similar modes of action can create selection pressure within pest and pathogen populations, gradually reducing the effectiveness of available plant protection products. Diversifying control measures can help address this problem. By combining biological, cultural, mechanical, and, when necessary, chemical measures, farmers can reduce excessive dependence on individual active substances. Eco-friendly plant protection therefore contributes not only to environmental sustainability but also to preserving the effectiveness of available pest-management tools.

The role of agricultural extension and advisory services is particularly significant in this context. Sustainable pest management often involves more complex decision-making than routine pesticide application. Advisers can support farmers in interpreting monitoring information, identifying emerging pest problems, selecting appropriate interventions, and evaluating the effectiveness of alternative strategies. Strengthening the connection between research institutions, advisory services, agricultural organizations, and farmers can therefore accelerate the dissemination of effective practices and reduce uncertainty surrounding the adoption of new technologies.

At the same time, the results of this research highlight the importance of avoiding overly generalized recommendations. No single plant protection strategy is likely to perform equally well under all agroecological conditions. Pest populations, disease pressure, climate, soil properties, cropping history, farm size, available technologies, and economic conditions differ substantially between production systems. Eco-friendly pest management should therefore remain adaptive and location-specific. The most effective combination of measures should be determined according to local conditions and supported by continuous monitoring and evaluation.

Digital technologies represent another promising area for future development. Improved pest forecasting models, remote sensing, field sensors, decision-support systems, and precision agriculture technologies may allow interventions to be applied only where and when they are necessary. Such tools have the potential to reduce pesticide use while maintaining effective crop protection. However, their practical contribution will depend on affordability, accessibility, data quality, and farmers' ability to integrate technological information into everyday management decisions.

In conclusion, eco-friendly plant protection strategies represent a viable and increasingly important pathway toward the sustainable cultivation of pea. Their principal value lies not in replacing one pesticide with another input, but in transforming the overall logic of pest management from routine chemical intervention toward prevention, monitoring, ecological regulation, and evidence-based decision-making. Biological control, biopesticides, cultural practices, resistant varieties, improved monitoring, and targeted interventions can function most effectively when they are treated as complementary components of an integrated system.

The sustainable reduction of pesticide use should therefore be approached as a gradual process requiring scientific evidence, technological innovation, farmer knowledge, effective advisory services, and appropriate policy support. Environmental sustainability and agricultural productivity should not be viewed as opposing objectives. When plant protection strategies are carefully designed and adapted to local conditions, reducing pesticide dependency can contribute simultaneously to effective pest management, protection of biodiversity, improved soil and water quality, reduced risks to human health, and greater resilience of agricultural production.

Ultimately, the transition toward eco-friendly plant protection in pea cultivation reflects a broader transformation taking place in modern agriculture. Sustainable food production increasingly requires agricultural systems capable of maintaining productivity while reducing environmental pressures and adapting to changing climatic, ecological, and economic conditions. Wider adoption of integrated and environmentally responsible plant protection practices can contribute to this transformation by protecting natural resources, supporting food security, and strengthening the long-term resilience of farming systems. The challenge for future research and agricultural policy is therefore not simply to reduce pesticide use, but to provide farmers with reliable, practical, and economically viable alternatives that make such reduction sustainable over the long term.

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