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Sustainable Crop Protection Through Improved Choices With Public And Private Extension

Ratna Sahaya[a], R.C. Maurya[a], Pallavi Srivastava[b], Vijay Kumar Yadav[c] and Sadhvi[d]

[a] Krishi Vigyan Kendra, Dhaura, Unnao-209881, U.P., India;
[b]IU, Lucknow, U.P., India;
[c]Dr. R.M.L. Awdh University, Ayodhya, U.P., India;
[d]VBS Purvanchal University, Jaunpur, U.P., India.

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ABSTRACT

Whether farmers benefit more from pest management guidance provided by public agencies versus private entities affiliated with agrochemical companies remains a critical question in agricultural policy. Transitioning toward more sustainable farming depends fundamentally on the choices farmers make regarding technology and production inputs, choices that are shaped by access to information and peer learning. Advisory services are especially valuable when new or complex technologies are involved, supplementing knowledge gained through farmer-to-farmer exchange. Pest management decisions, in particular, are frequently guided by extension services, making these services central to contemporary agricultural policy debates. Global trends indicate that pest pressure is intensifying—driven partly by climate change and the growing commercialization of advisory services—while societal concern over pesticide-related environmental and public health risks continues to mount. Pesticide resistance is also emerging as a major challenge. In this context, extension services carry significant responsibility, as farmers' pest management choices affect not only their own livelihoods but also the wellbeing of surrounding communities and the broader public. Consequently, extension guidance should be directed toward holistic strategies that maximize collective welfare.

Introduction

Prior studies have established that extension services with commercial ties to pesticide manufacturers tend to increase farmers' reliance on chemical inputs (Wiebers et al., 2002). Research on farmer responses to invasive pests such as Drosophila suzukii reveals a spectrum of behaviors: some growers overuse pesticides without improving monitoring practices, while others voluntarily account for broader externalities of their spraying decisions, including

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Corresponding Email- ratnaasahay@gmail.com

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environmental damage, development of resistance, and impacts on human health. It is hypothesized here that public extension services, unlike commercially oriented providers, are more inclined to factor in the societal benefits of reducing pesticide use (Schnyder and Auerswald, 2019). Publicly employed advisors have both the mandate and the motivation to highlight adverse consequences of chemical overuse—such as negative effects on ecosystems, health risks to consumers, farm workers, and nearby residents, as well as the acceleration of pesticide resistance. They are also positioned to recommend strategies that minimize chemical dependency.

This paper examines the hypothesis that farmers advised by private, commercially linked services are more prone to applying synthetic insecticides, while those receiving public sector advice are more likely to adopt non-chemical preventive strategies. D. suzukii, a recently established invasive pest, serves as the empirical case study given its high economic impact (Asplen et al., 2015). Infested fruit is typically unsaleable and often rejected at the point of supply, making the pest particularly costly. As the proportion of damaged fruit rises, sorting and inspection costs escalate and overall productivity declines. Responses to D. suzukii have included both synthetic contact insecticides and non-chemical prophylactic interventions (Knapp et al., 2019a). Access to reliable information is critical because experimentation with novel control strategies at the farm level requires substantial investment of time, capital, and risk tolerance (Park and Lohr, 2005). Empirical findings from this study are consistent with the working hypothesis: farmers guided by public advisors more frequently adopt preventive measures such as netting, while those advised by private extension providers more commonly resort to synthetic pesticides.

Sustainable Crop Protection Practices

Herbicide Use in Arable Crops: Chemical weed control through herbicides is the most widely practiced approach in conventional arable farming; unlike fungicide and insecticide applications, herbicide use tends to be routine and widespread (Jørgensen et al., 2019). The rationale partly lies in preventing seed dispersal that could increase weed pressure in subsequent growing seasons. Reducing herbicide dependence requires proactive efforts to bring weed populations below economically significant thresholds. Diversified crop rotation is among the most effective strategies available to farmers seeking to achieve this goal (Adeux et al., 2019; Guinet et al., 2023). Complementary tactics include selecting competitive cultivars, adjusting sowing timing and patterns, introducing weed-suppressive cover crops, and increasing planting density. Although no single measure is typically sufficient alone, combining multiple approaches can yield substantial results (Riemens et al., 2022). When cultural and preventive interventions collectively reduce weed pressure to manageable levels, mechanical weeding techniques such as harrowing may become viable alternatives to chemical control. While mechanical methods are generally less effective per pass than herbicides, their adequacy increases when weed populations are already low, as fewer surviving weeds translate to negligible crop yield impacts. This illustrates that while pesticide-free weed management is achievable, it demands coordinated multi-measure strategies—a consideration that should inform how researchers and policymakers assess farmer adoption of sustainable practices.

Fungicide Use in Apple Production: In apple orchards, fungicides represent the dominant category of pesticide applied, and fungal pathogens constitute the most serious disease threat to the crop. Among the principal diseases affecting apples—including apple scab (

Insecticide Use in Oilseed Rape Production: Insect pest pressure represents a major challenge across many crops, and oilseed rape is particularly significant as a driver of pesticide use in European agriculture. Key pests such as the cabbage stem flea beetle (

Suitable Indicators for Assessing the Uptake of Sustainable Crop Protection Approaches

Evaluating the adoption of sustainable crop protection is not straightforward, particularly because sustainable approaches typically involve bundles of complementary measures whose combined effect may differ substantially from the sum of individual components assessed in isolation. A further complication is that farm-level data on pesticide use are sparse and difficult to obtain in a timely manner (Mesnage et al., 2021), and data on adoption of non-chemical or preventive practices are even scarcer (Möhring et al., 2024). This data scarcity imposes real constraints on the selection of appropriate uptake indicators in research and policy evaluation contexts, frequently necessitating reliance on proxy measures rather than ideal first-best indicators.

Ex-Ante and Ex-Post Assessments to Study Sustainable Crop Protection

Ex-ante analysis of farmer decision-making draws on a wide range of methodological tools, spanning qualitative inquiry, experimental economics, simulation, and mathematical optimization. The appropriate methodology is shaped substantially by the policy context in question. Agent-based models, sector-level models, and farm-scale bio-economic frameworks are among the most widely employed tools for forward-looking assessment, incorporating constraints on farmer decision-making and specifying objective functions such as profit or utility maximization. These modeling approaches allow researchers to simulate farmer behavioral responses to changes in market conditions, policy environments, and biophysical circumstances. A comprehensive understanding of pesticide use patterns and

available alternatives is a precondition for credibly evaluating the adoption and impacts of sustainable crop protection practices. Increasingly, ex-ante assessments supplement simulation and optimization tools with survey methods and experimental designs that directly elicit farmer preferences and decision logic, rather than inferring them from assumed objective functions. Methodological frameworks including discrete choice experiments and the Theory of Planned Behaviour have been applied to examine farmer adoption intentions (Sok et al., 2021; Bakker et al., 2021).

System Perspectives Are Required

Reducing pesticide-related risks requires a systems-level perspective that reaches beyond individual farm management decisions. Although the analysis presented here focuses predominantly on farm-level behavior, the agri-food system context is indispensable for understanding the broader transition to sustainable crop protection, since many of the drivers of farmer behavior are themselves shaped by other actors throughout the food supply chain (Engel et al., 2019). Effective and equitable policy must therefore engage all stakeholders across the food value chain—input suppliers, farmers, processors, retailers, and consumers. Systemic change can be facilitated by creating market conditions that reward low-pesticide production systems, for instance through labelling, procurement standards, or financial incentives. The analytical insights derived from studying individual farmer behavior must be embedded within this holistic systems framework, taking into account legislators, technology developers, supply chain operators, and consumer behavior. Farmer behavior within these systems is shaped by a complex and interactive set of forces including personal beliefs, economic incentives, social norms, and institutional structures, which are themselves mutually reinforcing (Engel et al., 2019). Barriers to innovation adoption can emerge at both the individual and system level (Kuntosch and König, 2018), and effective policy must be designed with this complexity in mind.

Conclusion

This study has examined the adoption of sustainable crop protection practices in European agriculture through an interdisciplinary lens, integrating agronomic knowledge, behavioral insights, and methodological tools for policy analysis. Four core challenges have been identified. First, sustainable crop protection approaches consist of multi-measure combinations that are rarely treated as integrated systems in existing research or policy frameworks. Second, current definitions of adoption and related policy success metrics tend to rely on narrow, easily measured indicators. Third, while a diverse range of factors shapes farmer adoption decisions, behavioral dimensions remain understudied relative to their potential importance. Fourth, the tools currently used for policy analysis are inadequate for capturing the full range of relevant characteristics, including both the complex effects of pest management policies and the behavioral determinants of farmer decision-making. Addressing these gaps will be essential to designing effective policies that support the transition to more sustainable crop protection systems.

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