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Research Article

Gendered Participation in Plant Protection Practices within Rice-Based Cropping Systems of Punjab, Pakistan

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ABSTRACT

Gender plays a critical role in shaping participation, access to resources, and decision-making in agricultural plant protection practices. This study investigated gender-based differences in crop protection roles, training access, and knowledge dissemination among rice farmers in the rice cropping zone of Punjab. Demographic analysis revealed significant socio-economic disparities between male and female farmers. Male respondents were older, more educated, possessed larger landholdings, and had greater farming experience than female respondents ($p < 0.05$). Although participation in crop protection activities appeared nearly equal between genders, clear differences emerged in the nature of responsibilities performed. Men were significantly more involved in hazardous activities such as pesticide application and pesticide waste disposal, whereas women showed significantly greater participation in the use of biopesticides ($p < 0.01$). No significant gender difference was observed in Integrated Pest Management practices, indicating shared involvement in knowledge-based pest monitoring and decision-making. Access to agricultural training was generally low, with a pronounced gender gap; only 22.5% of women had received formal training compared to 43.1% of men. Training content also reflected gendered segmentation, with women receiving more integrated multi-topic training, while men had greater exposure to soil management. Respondents identified improved access to resources, recruitment of female extension workers, and pest identification training as the most important interventions for enhancing gender equity in plant protection. In conclusion, the study highlighted substantial gender disparities in agricultural knowledge, training access, and task allocation, emphasizing the need for gender-inclusive extension services and equitable resource distribution for sustainable crop protection systems.

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Introduction

Agriculture remains the backbone of many developing economies, with rice serving as a staple food crop for billions of people worldwide. In rice-based cropping systems, plant protection, encompassing pest management, pesticide application, and integrated pest management

(IPM), constitutes a critical component of agricultural production that directly influences crop yields, food security, and farm profitability (Seck et al., 2012). However, how farmers engage in plant protection activities is not gender-neutral; it is shaped by complex socio-cultural norms, resource access patterns, and institutional biases

that systematically differentiate the experiences of men and women farmers (Njuki et al., 2022).

Globally, women constitute a substantial proportion of the agricultural labor force, estimated at approximately 43-50% in developing countries (FAO, 2011). In sub-Saharan Africa and parts of Asia, women's participation in specific agricultural tasks can reach 60-90%, particularly in labor-intensive activities such as weeding, harvesting, and post-harvest handling (Lastarria-Cornhiel, 2006). Despite this significant contribution, women farmers have historically been rendered "invisible" in agricultural policy, research, and extension services, with men being viewed as the primary farmers and decision-makers (Peterman et al., 2010).

Plant protection presents unique gender dimensions that warrant focused scholarly attention. The use of pesticides, both chemical and biological involves health risks, technical knowledge requirements, and decision-making processes that are often gendered (Shekhar et al., 2024). Research from across Africa and Asia has documented that while men are typically the primary applicators of chemical pesticides, women are exposed through multiple pathways: working in recently sprayed fields, washing pesticide-contaminated clothing, disposing of empty containers, and performing other agricultural tasks in treated areas (Olirk et al., 2025).

The Tanzania-based study by Olirk et al. (2025) found that although pesticide spraying was typically performed by men, poor or unmarried women also undertook this task, and women had limited access to training on safe pesticide handling, while protective gear was rarely used. Similarly, research in Ghana and Mali revealed that women are significantly less aware of pesticide dangers and IPM techniques than men, exposing them to pesticides through a variety of pathways that often remain unseen by researchers and extension agents who tend to focus on field-level observations rather than gendered labor patterns (Christie et al., 2015).

The health implications of these gendered exposure patterns are profound. Women may be more vulnerable to pesticides than men due to biological factors, with particular risks during pregnancy and lactation potentially affecting fetal and child development (Raanan et al., 2016). The JoVE study on pregnancy, childcare, and pesticides in Tanzania documented that financial pressures force many women to work during pregnancy and postpartum, sometimes bringing infants into horticultural environments, creating intergenerational health risks.

A critical barrier to equitable plant protection outcomes lies in the gender gap in access to agricultural extension and training services. The Food and Agriculture Organization reports that farms managed by women are, on average, 24% less productive than those managed by men, with this gap widening to 66% in some contexts, such as Niger, and 46% in Northern Nigeria (FAO, 2023). These productivity differentials stem largely from unequal access to information, training, and resources rather than differences in farming capability.

Most agricultural extension systems continue to cater primarily to men due to several systemic problems. Extension service providers often fail to view women as clients of rural advisory services in their own right, instead treating them as farm helpers or secondary actors (Manfre et al., 2013). The services delivered rarely address the challenges rural women face, including the burden of unpaid care and domestic work, limited mobility, low literacy levels, and restrictive social norms that constrain their participation in training activities.

The critical review by Maulida et al. (2025) highlights that, despite women constituting a significant proportion of the agricultural labour force, gender dynamics have often been neglected in agricultural extension and advisory services, resulting in unequal opportunities compared to men. This limited access significantly hinders rural women's adoption of new technologies, knowledge, and practices, creating a persistent "input gap" that translates into differences in productivity and returns (Palacios-López and López, 2015).

Over the past few decades, the recruitment of more female extension workers has been advocated as a strategy to increase women's access to extension services. Research demonstrates that women extension workers can better accommodate women farmers' preferred meeting times and are less constrained by cultural norms that limit interaction between women and men. However, men continue to dominate the agricultural extension workforce globally, in Iran, only 7% of extension workers are women (Kafraj and Mohammadi, 2014), while in Ghana, women make up about 19.6% of the extension workforce (Nyarko and Kozári, 2021).

The FAO and CORAF regional training on gender-sensitive rural advisory services emphasised that increasing women's representation in these roles is critical for more inclusive outreach, which, in turn, requires improving gender sensitivity within agricultural extension departments to attract and retain

women extension agents. The Uganda plant clinic study further revealed that all plant doctors in Tororo district were men. While advice was usually the same for everyone, some women felt they received different guidance, focusing more on cultural pest control methods than on pesticides (Kokoi, 2025).

Rice cultivation presents specific plant protection challenges due to the crop's vulnerability to diverse pests and diseases, the prevalence of waterborne application methods, and the intensive management required throughout the growing season. In rice-based cropping systems, understanding how gender shapes involvement in pesticide application, biopesticide use, IPM practices, and disposal of agricultural chemicals is essential for designing effective and equitable interventions (IRRI, 2024).

Despite growing recognition of women's roles in agriculture, limited empirical research has systematically examined gender differences across the full spectrum of plant protection activities within a single cropping system. Existing studies often focus on either pesticide exposure, extension access, or knowledge gaps in isolation, without comprehensively analyzing how demographic characteristics, training access, training content, and task allocation intersect to produce gendered outcomes in plant protection.

This study addresses these research gaps by conducting a comparative analysis of gender roles in plant protection within a rice cropping zone. Specifically, the study aims to:

1. Examine the demographic profiles of male and female farmers engaged in rice production, including age, education, landholding size, and farming experience;
2. Assess the extent and nature of male and female participation in crop protection activities;
3. Analyze gender differences in the performance of specific plant protection tasks, including pesticide application, biopesticide use, IPM practices, and pesticide disposal;
4. Investigate gender disparities in access to and content of training on plant protection; and
5. Document farmer-identified recommendations for improving gender equity in plant protection extension services.

By integrating analysis across these dimensions, this study provides a comprehensive understanding of how gender shapes engagement with plant protection in rice-based systems. The findings aim to inform gender-sensitive extension policies, training curricula, and intervention strategies that recognize women as active

participants in plant protection while addressing the structural barriers that limit their access to knowledge, resources, and safe working conditions.

Materials and Methods

Study area

Sialkot, located in Punjab, is one of Pakistan's prominent rice-producing districts, known for cultivating both fine aromatic and coarse-grain rice varieties, such as Super Basmati, Kisan Basmati, and IRRI-9 (Raza and Anwer, 2015). Sialkot, along with other districts such as Gujranwala, Sheikhupura, and Hafizabad, forms the main rice-growing region of Punjab, accounting for a large share of the country's Basmati rice yield.

Study population and sample

The current study was conducted in the district of Sialkot, which is one of the leading rice-producing districts in the Punjab province. District Sialkot comprises four tehsils: Sialkot, Pasrur, Daska, and Sambrial. The study population comprised all rice farmers in district Sialkot.

Multistage sampling was applied in the study. In the 1st stage district Sialkot was selected. In the 2nd stage, all four tehsils were selected. In the 3rd stage, four union councils were chosen randomly from each tehsil. In the fourth stage, 20 (10 male and 10 female) respondents were selected conveniently, bringing the sample size to 320, with equal distribution of male (160) and female (160). Convenient approach was adopted due to practical and socio-cultural constraints, particularly (i) absence of a comprehensive and updated sampling frame of farmers (ii) limited accessibility to farmers, especially female respondents and (iii) time and logistical constraints in field data collection. In order to reduce bias and enhance diversity, equal representation of all tehsils and multiple union councils was ensured. Male and females were equally included at a 50:50 ratio, and selection of respondents from different villages and farming backgrounds was ensured.

Sampling frame

Due to the unavailability of an official and complete registry of rice farmers, a formal sampling frame could not be established. Therefore, respondents were identified with the assistance of (i) local agricultural extension personnel and (ii) village leaders and key informants. Moreover, inclusion criteria were as follows:

1. Individuals actively engaged in rice cultivation,
2. Residents of the selected union councils and

3. Willingness to participate in the study.

Instrumentation, data collection and analysis

The present study employed an interview schedule as a research instrument. The interview schedule was prepared with the research objectives in mind. Research reports, scholarly articles, and periodicals were carefully reviewed for the preparation of the research instrument. The interview schedule included closed-ended questions. Five-point Likert scales were used for respondents' in-depth responses.

Data were collected via face-to-face interviews. Questions were explained in the local to the respondents because the narrative language of the respondents was Punjabi, so the local language was suitable, respondents were comfortable in the local language, and they were able to understand the aim of the study when it was explained to them in the local language.

Collected data were analyzed using the Statistical Package for the Social Sciences (SPSS). Frequency, percentages, mean, t-test, and chi-square tests were applied to the data.

Ethical approval

The present study is a part of the PhD thesis of the first author. This study was approved by the supervisory committee and the Directorate of Graduate Studies. Moreover, during interviews, respondents' information was kept anonymous. Formal verbal consent was obtained from the respondents before the interview, and respondents were given an authority to withdraw from the interview at any stage, if they felt anything unethical or immoral.

Results

The demographic analysis presented in Table 1 revealed a distinct socio-economic profile differentiating male and female respondents involved in rice production. Male farmers were found to be significantly older (59 years) and more educated (10 years) than female farmers (48 years; 5 years). Moreover, men reported

significantly larger landholdings (14.6 ha) and nearly double the farming experience (27 years) compared to women (11.3 ha; 15 years). These foundational differences are statistically significant ($p < 0.05$) and provide a critical backdrop for the subsequent analysis of gender-specific roles, knowledge levels, and practices in plant protection. The disparity in education and experience, in particular, might have profound implications for the adoption of safe pesticide handling practices and integrated pest management strategies among women farmers in the rice cropping zone.

The analysis of roles in crop protection, presented in Table 2, revealed a nuanced pattern of gender participation. Although the overwhelming majority of respondents confirmed their involvement, the distribution initially appeared nearly equal, with both genders representing approximately 50% of the total affirmative responses. However, these findings suggest that, despite the apparent parity in participation, the specific responsibilities, decision-making authority, and extent of involvement in plant protection activities might be differentiated along gender lines.

Table 3 elucidates the specific domains of plant protection where gender roles diverge. A statistically significant gendered division of labor was observed. Men reported significantly greater involvement in the high-risk tasks of pesticide application ($t = 3.750$, $p < 0.01$) and pesticide waste disposal ($t = 6.046$, $p < 0.01$). Conversely, women reported significantly higher involvement in the use of biopesticides ($t = -5.658$, $p < 0.01$), suggesting a gendered distinction between hazardous chemical control and safer alternatives. Notably, no significant gender difference was found in the practice of Integrated Pest Management (IPM) ($p > 0.05$), indicating that knowledge-based monitoring and decision-making are shared domains. These findings highlight a 'hazard gap', where men are more involved in the most dangerous chemical tasks, while women lead in the application of safer, biological alternatives.

Table 1. Comparative demographic characteristics of male and female farmers in the study area.

Criterion	Mean $\pm$ SD		t	P
	Male	Female		
Age	59.06 $\pm$ 15.32	47.62 $\pm$ 7.84	8.408	0.000
Education	10.03 $\pm$ 4.014	4.90 $\pm$ 5.152	9.926	0.000
Land size	14.56 $\pm$ 14.91	11.34 $\pm$ 7.075	2.466	0.014
Farming experience	26.81 $\pm$ 15.53	15.16 $\pm$ 9.216	8.155	0.000

Table 2. Gender-wise participation in crop protection activities among respondents.

Role in crop protection	Total		Male		Female	
	F	%	f	%	f	%
Yes	320	100	160	50	160	50
No	0	0	0	0	0	0
Total	320	100	160	50	160	50

Table 3. Gender-wise comparison of participation in crop protection practices.

Crop protection practice	Gender	Mean	Sd	T value	P
Pesticide application	Male	3.14	1.680	3.750	0.00
	Female	2.46	1.509		
Use of biopesticides	Male	3.93	1.556	-5.658	0.00
	Female	4.70	.671		
IPM	Male	3.33	1.662	-0.544	0.587
	Female	3.41	1.015		
Disposing off the pesticides	Male	3.10	1.607	6.046	0.00
	Female	2.19	0.962		

Access to training, a key determinant of adopting safe and effective plant protection practices, was found to be highly gendered. As shown in Table 4, overall training coverage was low, reaching only 32.8% of all respondents. However, a significant disparity exists between male and female farmers. Although 43.1% of men reported receiving training, only 22.5% of women, less than half that proportion, had similar access ($\chi^2 = 17.03$, $p < 0.05$). Consequently, over 77% of women engaged in rice production are operating without the benefit of formal instruction in pest identification, pesticide safety, or alternative methods such as IPM. This training gap, when viewed alongside women's lower educational attainment (Table 1), creates a significant knowledge deficit with direct implications for their safety, the effectiveness of their plant protection efforts, and the overall sustainability of pest management in the zone. The findings point to an urgent need for gender-inclusive extension strategies that actively target female farmers. Building on the findings of unequal access to training, Table 5 examines the specific content of training received by gender. Crop protection emerged as the

dominant training theme, reported by 70% of all trained respondents. Among trained individuals, the gender gap in crop protection-specific training was relatively narrow, with 72.5% of trained men and 67.5% of trained women receiving instruction on this topic. This indicates that when women do access training, the content is appropriately aligned with the core needs of plant protection.

However, significant gendered segmentation was observed in other training areas. Exclusive training in crop production was reported by women (5%), while exclusive training in soil management was reported by men (5%). Notably, a higher proportion of women (27.5%) than men (22.5%) received training on multiple topics, suggesting that extension approaches targeting women may be more integrated and holistic.

These patterns reveal that gender not only determines *whether* a farmer receives training, but also *what kind* of training they receive. The exclusion of women from soil management training, despite their active role in the field, represents a missed opportunity for holistic farm development.

Table 4. Gender-wise distribution of training received by respondents.

Trainings received	Total		Male		Female	
	F	%	f	%	f	%
Yes	105	32.8	69	43.1	36	22.5
No	215	67.2	91	56.9	124	77.5
Total	320	100	160	50	160	50

Chi 2: 17.03 P<0.05.

Table 5. Gender-wise distribution of respondents receiving training on different agricultural topics.

Training topics	Total		Male		Female	
	F	%	f	%	f	%
Crop production	8	2.5			8	5
Crop protection	224	70	116	72.5	108	67.5
Soil management	8	2.5	8	5		
Multiple topics	80	25	36	22.5	44	27.5
Total	320	100	160	100	160	100

When asked to propose solutions to improve gender equity in plant protection, respondents prioritised interventions that address structural and institutional barriers. The frequency distribution of the suggestions is illustrated in Figure 1. Enhanced access to resources (78%) emerged as the most pressing need, indicating that knowledge alone is insufficient without the means to implement it. The strong demand for female extension workers (72%) underscores the cultural and communication barriers that limit women's access to agricultural advice. Furthermore, the call for pest identification training (68%) highlights a gap in

current extension curricula, which tend to emphasize application techniques over diagnostic skills.

Interestingly, household-level training (48%) and social media engagement (45%) received relatively lower priority, suggesting that though these approaches have merit, farmers still place greater trust in institutional support and direct resource provision. The findings collectively suggest that a multi-pronged strategy, combining gender-sensitive staffing (female extension workers), resource support, and targeted technical training, is necessary to bridge the gender gap in plant protection in the rice cropping zone.

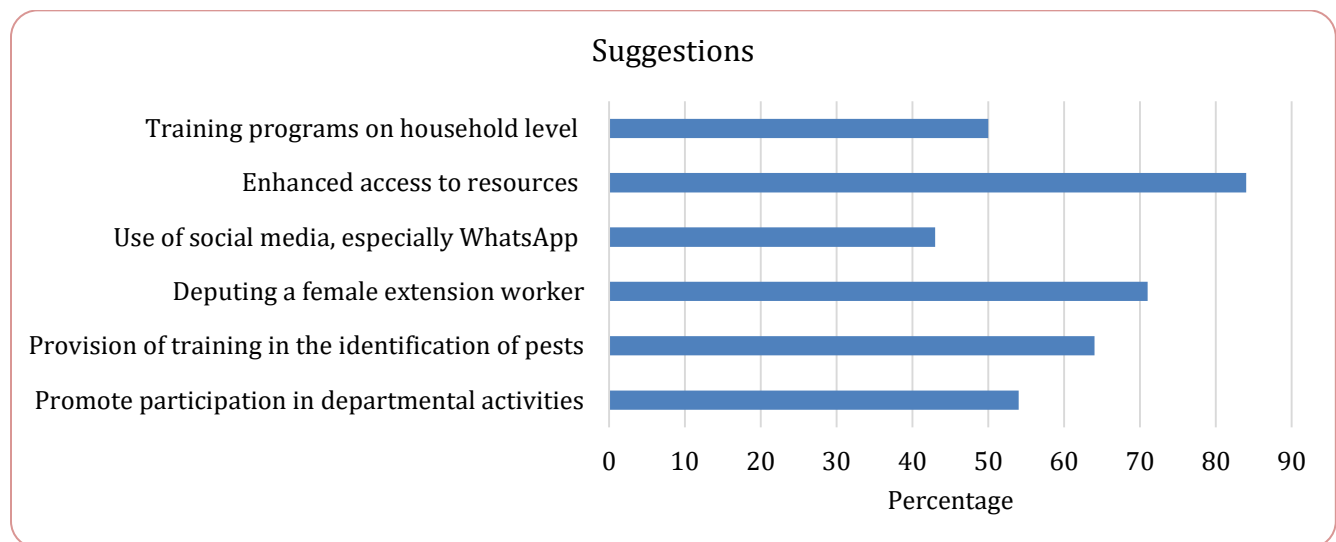


Figure 1. Suggestions made by study respondents.

Discussion

The findings of this study provide critical insights into the gendered dynamics of plant protection in the rice cropping zone, revealing significant disparities in demographic profiles, participation, access to training, and preferred interventions. This discussion interprets these results in the context of existing literature and outlines their implications for policy and extension practice.

The demographic profile (Table 1) established a

fundamental distinction between male and female respondents. Men were significantly older, more educated, and possessed nearly double the farming experience of women. This aligns with broader agricultural literature documenting the generational and educational divides between male and female farmers in South Asia (Southard and Randell, 2022). The finding that women have significantly fewer years of formal education (4.90 years vs. 10.03 years for men) is particularly concerning, as

education is a strong predictor of the ability to read pesticide labels, understand safety instructions, and adopt complex innovations like IPM (Dewi et al., 2022; Dhungana et al., 2025). This educational disadvantage, combined with lower farming experience, positions women as potentially more vulnerable to the health risks associated with improper pesticide handling.

Table 4 reveals that only 22.5% of women have received any formal training on the subject. This participation-training gap is significantly wider for women than for men (43.1% trained). This finding echoes the concept of the “invisible farmer”, where women’s substantial contributions to agriculture are systematically overlooked by extension services (Luqman et al., 2014; Akter et al., 2017; Mishra et al., 2024). The statistically significant chi-square value ($\chi^2 = 17.03$, $p < 0.05$) confirms a systemic gender bias in the delivery of agricultural knowledge. This disparity persists despite decades of research highlighting that increasing women’s access to extension services can significantly boost agricultural productivity and household welfare (Buehren et al., 2019).

The analysis of specific plant protection tasks (Table 3) reveals a nuanced but distinct gender-based division of labor, consistent with the “feminization of agriculture” literature, which suggests that as men migrate or specialize, women absorb a broader range of responsibilities, though often with less support (Feldberg, 2022; Hanna et al., 2023). Men were found to be significantly more involved in the high-risk tasks of pesticide application and pesticide disposal. This finding is consistent with studies from other developing countries that identify pesticide application as a masculinized task, often associated with the physical demands of operating spray equipment and the cultural perception of risk-taking as a masculine trait (Tham-Agyekum et al., 2023; Olirk, 2025).

Conversely, women reported significantly higher involvement in the use of biopesticides. This is a novel and important finding. It may reflect a “safety delegation”, in which women are assigned or assume responsibility for less toxic, often homemade pest control solutions, while men continue to manage the more hazardous chemical options. This aligns with research suggesting that women are often the custodians of traditional ecological knowledge and are more amenable to low-cost, low-input technologies (Ramirez-Santos et al., 2023; Vaksibhai and Thakar, 2025). It also has positive implications for promoting sustainable agriculture, suggesting that women may be more receptive to bio-pesticides.

The finding of no significant gender difference in IPM practices is encouraging. It suggests that the monitoring and decision-making processes inherent in IPM are shared domains. This parity provides a foundation for gender-inclusive IPM programs, as both men and women demonstrate baseline involvement. However, the lack of formal training for women (Table 4) means their IPM knowledge is likely informal and may not incorporate the latest scientific recommendations (Christie et al., 2015).

The high male involvement in pesticide disposal is alarming, given the environmental and health risks. Improper disposal (e.g., rinsing containers in water channels) poses risks to the entire community, including women who may not be directly involved in the task but use the contaminated water for domestic purposes (Sengupta and Banerjee, 2015).

Table 5 reveals that although crop protection is the dominant training topic for both genders, the secondary training areas are sharply segmented by gender. Men receive training on soil management, whereas women receive training on crop production. The finding that a higher proportion of women receive training on “multiple topics” might indicate a compensatory approach by extension agents who recognize women’s lower baseline knowledge. However, the complete exclusion of women from soil management training is a missed opportunity, as soil health is fundamental to the productivity of the plots they manage. Numerous studies have reported that women had lesser opportunities to receive farm-related training than men (Iftikhar et al., 2009; Luftu-ul-Hasnaen et al., 2009).

The suggestions provided by respondents offer a clear, farmer-validated roadmap for intervention. The overwhelming demand for enhanced access to resources (78%) emphasizes that knowledge transfer without material support is inadequate. This aligns with the sustainable livelihoods framework, which highlights that human capital (training) must be matched with physical, financial, and social capital to effect real change (Oltular, 2025).

The second-highest priority, deputing a female extension worker (72%), directly addresses the participation-training gap identified in Table 4. This finding is strongly supported by the literature advocating for gender-sensitive extension models. Female extension agents can better navigate socio-cultural barriers, build trust with women farmers, and serve as role models (Ragasa et al., 2013; Adebayo and Worth, 2022). The demand for pest identification training

(68%) indicates a desire among farmers to move beyond “spraying by calendar” toward informed decision-making, a cornerstone of IPM. This suggests that current training programs may be too focused on product application rather than diagnostic skills.

The relatively lower, though still substantial, support for social media (45%) reflects the realities of the digital divide in rural areas, particularly among older and female populations (Ahmed, 2024). Although digital tools hold promise, they cannot replace the trusted, interpersonal relationship farmers have with extension agents, especially for women with limited phone access.

Conclusion

The current study set out to examine the gendered dimensions of plant protection in the rice cropping zone, with a specific focus on demographic profiles, participation patterns, training access, and the division of labor in pest management activities. The findings reveal that gender is a significant determinant of how farmers engage with plant protection, influencing not only their roles and responsibilities but also their access to the knowledge and resources necessary to perform these tasks safely and effectively.

The demographic analysis established foundational differences between male and female farmers, with men being significantly older, more educated, and more experienced. These disparities set the stage for understanding the subsequent findings on training and task allocation. Crucially, the study found that while plant protection is a universal responsibility, with 100% of both male and female respondents affirming their involvement, access to formal training is highly unequal. Less than one-quarter of women had received any training, compared to nearly half of men, representing a systemic gender bias in extension service delivery.

The division of labor in specific plant protection tasks revealed a complex but distinct pattern. Men dominated the high-risk activities of chemical pesticide application and disposal, while women were significantly more involved in the use of biopesticides. This “hazard gap” suggests that women are being delegated safer alternatives, but without the corresponding training and resources to maximize their effectiveness. The shared involvement in Integrated Pest Management offers a promising entry point for gender-inclusive programming, but the lack of formal training for women undermines their ability to implement IPM principles effectively.

The study also uncovered a significant training-content gender gap. When women do receive training, they are more likely to receive instruction on multiple topics, suggesting a holistic but potentially superficial approach. However, they are completely excluded from technical domains such as soil management, which remains an exclusively male training preserve. This segmentation reflects and reinforces gendered stereotypes within agricultural extension curricula.

Finally, farmers themselves provided a clear roadmap for change, prioritizing enhanced access to resources, the deployment of female extension workers, and targeted training in pest identification. These farmer-driven recommendations validate the study’s findings and offer practical pathways for intervention.

In conclusion, this study demonstrates that women in the rice cropping zone are active and essential participants in plant protection, yet they remain largely invisible to and unsupported by formal extension systems. Bridging this gap is not merely a matter of equity; it is a prerequisite for sustainable agricultural development, improved household health, and food security.

Authors’ Contributions

MS conducted the study, collected the data, and wrote the manuscript. IA supervised the entire study and performed language editing. MI performed data curation, data analysis, and reporting of the results. NA carried out the final editing of the manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

Sustainable Development Goals Targeted

SDG 2: Zero Hunger

SDG 5: Gender Equality

SDG 12: Responsible Consumption and Production

Policy Addressed

The findings underscore the need for gender-responsive agricultural extension policies in line with the FAO Gender Equality Policy (2020-2030), and the FAO/WHO International Code of Conduct on Pesticide Management, particularly regarding women’s access to plant

protection training, safe pesticide handling, and inclusive advisory services.

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