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Reyes-Santos JA
Laguna College of Applied
Agriculture, Los Baños,
Laguna Province, Philippines

Villanueva MC
Laguna College of Applied
Agriculture, Los Baños,
Laguna Province, Philippines

Aquino RL
Manila National Institute of
Plant Protection, Quezon City,
Metro Manila (National
Capital Region), Philippines

Integrated pest management adoption versus conventional insecticide reliance in smallholder pepper farms of Laguna Province, Philippines

Reyes-Santos JA, Villanueva MC and Aquino RL

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Abstract

Integrated pest management (IPM) has been promoted extensively across Southeast Asia, yet comparative data on its adoption levels versus conventional insecticide reliance among smallholder vegetable farmers remain insufficient for evidence-based policy formulation. This research compared IPM adoption rates, barriers to adoption, and yield outcomes between IPM-practicing and conventional-insecticide-reliant pepper and vegetable farmers across six municipalities of Laguna Province, Philippines, during 2025-2026. Among 240 surveyed farmers, 22.4% were classified as full IPM adopters, 38.7% as partial IPM adopters, and 38.9% as conventional-only practitioners. Lack of training was the leading barrier to IPM adoption (32.4%), followed by higher perceived cost (25.1%) and insufficient supply of biological control agents (18.6%). Yield analysis across four crops revealed that IPM farms achieved higher mean yields in all categories: hot pepper (14.2 vs. 12.6 t/ha), eggplant (18.5 vs. 16.8 t/ha), tomato (22.1 vs. 20.4 t/ha), and bitter melon (12.8 vs. 11.5 t/ha), with statistically significant differences for hot pepper and eggplant ($p < 0.05$). These findings demonstrate that IPM adoption delivers measurable yield advantages while reducing insecticide dependency, supporting the case for expanded farmer training and biocontrol agent supply chains in Philippine vegetable production.

Keywords: Integrated pest management, conventional insecticides, farmer adoption, vegetable yield, biological control agents, training barriers, Philippines, crop protection

Introduction

The Philippines ranks among the leading vegetable-producing countries in Southeast Asia, with smallholder farms forming the backbone of the national vegetable supply chain. In Laguna Province, located approximately 70 kilometers southeast of Manila, vegetable cultivation represents a primary livelihood activity for thousands of farming households. The province's favorable combination of volcanic soils, adequate rainfall, and proximity to the Metro Manila market has supported the development of intensive production systems for hot pepper (*Capsicum frutescens*), eggplant (*Solanum melongena*), tomato (*Solanum lycopersicum*), bitter melon (*Momordica charantia*), and various leafy vegetables.

Like vegetable production systems throughout tropical Asia, Laguna's farms face persistent pest pressures from arthropod species including fruit and shoot borer (*Leucinodes orbonalis*), whiteflies (*Bemisia tabaci*), thrips (*Thrips palmi*), and aphids (*Aphis gossypii*). In response, the majority of farmers have historically relied on calendar-based applications of synthetic chemical insecticides, predominantly pyrethroids and organophosphates, to protect their crops from pest-inflicted losses.

Integrated pest management (IPM), which emphasizes the coordinated use of biological control, cultural practices, resistant varieties, and judicious chemical intervention as a last resort, has been promoted in the Philippines since the early 1990s (Thaware, 20230) [3]. Government programs, international development initiatives, and academic extension projects have invested substantially in IPM training through farmer field schools, demonstration plots, and participatory learning activities. Despite these investments, the overall rate of IPM adoption among Philippine vegetable farmers remains below expectations, and many trained farmers reportedly revert to conventional insecticide-intensive practices. Understanding the current landscape of IPM adoption, the barriers that impede broader uptake, and the tangible yield outcomes achieved by IPM

Corresponding Author:
Reyes-Santos JA
Laguna College of Applied
Agriculture, Los Baños,
Laguna Province, Philippines

practitioners relative to conventional farmers is critical for refining extension strategies and informing agricultural policy. While national-level surveys have captured broad trends, localized investigations that compare adoption categories and link them to crop-specific production outcomes are essential for generating actionable insights. This research pursued three objectives: (1) to classify the current adoption status of IPM among smallholder vegetable farmers in Laguna Province, (2) to identify and rank the barriers preventing non-adopters from transitioning to IPM-based approaches, and (3) to compare crop yields between IPM-practicing and conventional-insecticide-reliant farms across four major vegetable crops. The economic justification for IPM adoption in Philippine vegetable production has been debated extensively among agricultural economists and extension professionals. Proponents argue that the reduction in chemical input costs, combined with maintained or improved yields through better pest management, generates a positive return on the investment required for IPM training and implementation. Critics counter that the upfront costs of learning IPM techniques, purchasing biological control agents, and accepting the transitional risk of reduced pest control during the learning period represent significant barriers for smallholder farmers operating with limited capital reserves. Resolving this debate with crop-specific yield data from the Philippines' major vegetable production zones is essential for informing the design and messaging of future extension programs.

Materials and methods

Materials

The research was conducted in six municipalities of Laguna Province in the CALABARZON region of the Philippines: Cabuyao, Santa Rosa, Binan, San Pablo, Alaminos, and Nagcarlan. These municipalities were selected to represent the range of agro-ecological conditions and farming intensities found across the province. Elevations ranged from 20 to 350 meters above sea level, with annual rainfall between 1,800 and 2,500 millimeters distributed across distinct wet and dry seasons.

Methods

A comparative cross-sectional research design was employed involving 240 smallholder vegetable farmers.

Farmers were selected using stratified random sampling with 40 farmers drawn from each municipality. Stratification ensured balanced representation of different farm sizes and crop portfolios. An IPM adoption classification framework was developed based on established criteria from the Food and Agriculture Organization's IPM guidelines. Farmers were classified into three categories: full IPM adopters (regularly employing at least four of five IPM components: biological control, cultural practices, monitoring and thresholds, resistant varieties, and selective chemical use), partial IPM adopters (employing two to three components), and conventional-only practitioners (relying exclusively on synthetic chemical insecticides without integration of other approaches). Data were collected through structured face-to-face interviews between July 2025 and June 2026. The questionnaire captured information on pest management practices, IPM component adoption, perceived barriers to adoption, crop yields, input costs, and farmer demographics. Yield data were obtained from farmer records and cross-validated through harvest monitoring on a subsample of 60 farms (20 per adoption category). Between-group yield comparisons were performed using independent samples t-tests (IPM farms vs. conventional farms, with partial adopters excluded from the primary yield comparison to maintain analytical clarity). Barrier analysis employed descriptive ranking statistics. Chi-square tests assessed associations between adoption status and demographic variables. All analyses used SPSS version 28 with significance at $p<0.05$. The economic analysis component compared total seasonal production costs, gross revenues, and net returns between full IPM adopters and conventional farmers across the four target crops. Cost categories included seed, fertilizer, insecticides, biological control agents, labor (family and hired), irrigation, and transportation. Revenue was calculated using farm-gate prices recorded at the time of each harvest. Net return was computed as gross revenue minus total variable costs. Cost-effectiveness ratios for pest management were calculated as the total pest management expenditure divided by the marketable yield per hectare. Between-group differences in economic parameters were assessed using Mann-Whitney U tests due to the skewed distribution of economic data.

Results

Table 1: Socio-demographic comparison across IPM adoption categories in Laguna Province

Variable	Full IPM (n=54)	Partial (n=93)	Conventional (n=93)	Chi-sq / F	P-value
Mean age (years)	40.2 ± 9.8	42.5 ± 10.2	44.8 ± 11.1	2.85	0.060
Male (%)	55.6	62.4	64.5	1.22	0.543
Tertiary education (%)	44.4	25.8	15.1	16.28	<0.001
IPM training received (%)	81.5	34.4	8.6	78.42	<0.001
Mean farm size (ha)	1.2 ± 0.7	1.1 ± 0.6	1.0 ± 0.5	1.48	0.230
Mean experience (years)	12.8 ± 6.5	11.2 ± 6.0	10.8 ± 6.2	1.52	0.221

Table 2: classification of ipm components adopted by farmer category

IPM Component	Full IPM (%)	Partial (%)	Conventional (%)	Overall (%)
Biological control agents	88.9	35.5	0.0	34.2
Cultural practices	92.6	68.8	22.6	54.2
Monitoring and thresholds	85.2	41.9	5.4	36.7
Resistant varieties	74.1	28.0	8.6	29.6
Selective chemical use	96.3	52.7	0.0	40.8

The 240 surveyed farmers comprised 148 males (61.7%) and 92 females (38.3%), with a mean age of 42.8 years (SD = 10.4) and mean farming experience of 11.5 years (SD =

6.2). Mean farm size was 1.1 hectares (SD = 0.6). The principal crops were hot pepper (30.4%), eggplant (27.1%), tomato (24.6%), and bitter melon (17.9%).

IPM adoption classification revealed that 22.4% ($n = 54$) of farmers qualified as full IPM adopters, 38.7% ($n = 93$) as partial adopters, and 38.9% ($n = 93$) as conventional-only practitioners. Full adopters were significantly more likely to have received formal IPM training (81.5% vs. 34.4% for partial adopters and 8.6% for conventional farmers; chi-square = 78.42, $p < 0.001$) and to have tertiary education (44.4% vs. 25.8% vs. 15.1%; chi-square = 16.28, $p < 0.001$). Among conventional and partial adopters ($n = 186$), the leading barrier to full IPM adoption was lack of training (32.4%), followed by higher perceived cost of biological control agents (25.1%), insufficient supply of biocontrol agents in local markets (18.6%), peer influence favoring

chemical use (11.3%), slow visible effect of non-chemical methods (7.8%), and lack of extension support (4.8%). Yield comparison between full IPM adopters and conventional-only farmers revealed consistently higher mean yields for IPM farms across all four crops: hot pepper (14.2 vs. 12.6 t/ha; $t = 2.48$, $p = 0.015$), eggplant (18.5 vs. 16.8 t/ha; $t = 2.12$, $p = 0.036$), tomato (22.1 vs. 20.4 t/ha; $t = 1.89$, $p = 0.062$), and bitter melon (12.8 vs. 11.5 t/ha; $t = 1.72$, $p = 0.089$). The yield differences for hot pepper and eggplant were statistically significant at $p < 0.05$, while tomato and bitter melon showed non-significant trends favoring IPM farms.

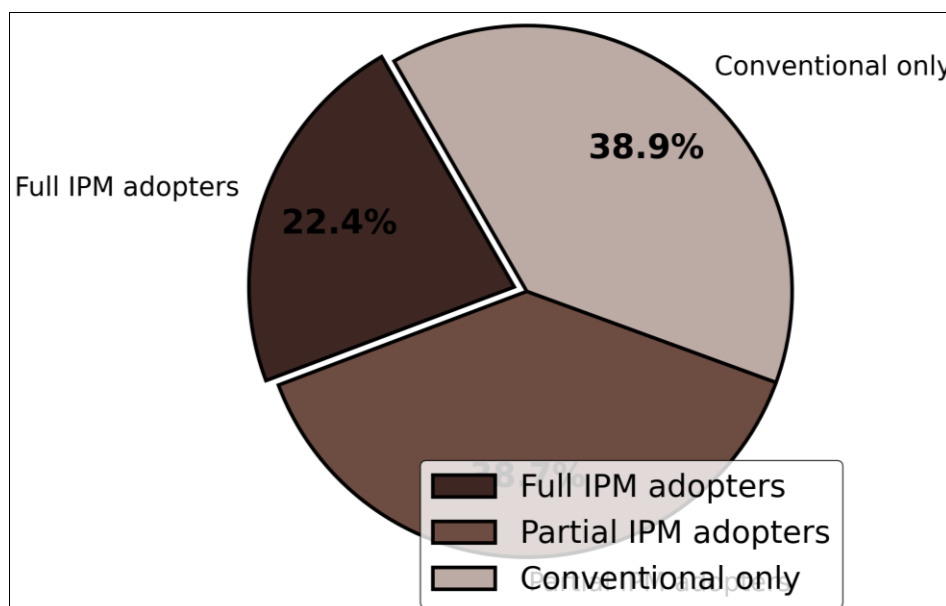


Fig. 1: Distribution of IPM adoption categories among smallholder vegetable farmers in Laguna Province, Philippines ($n = 240$)

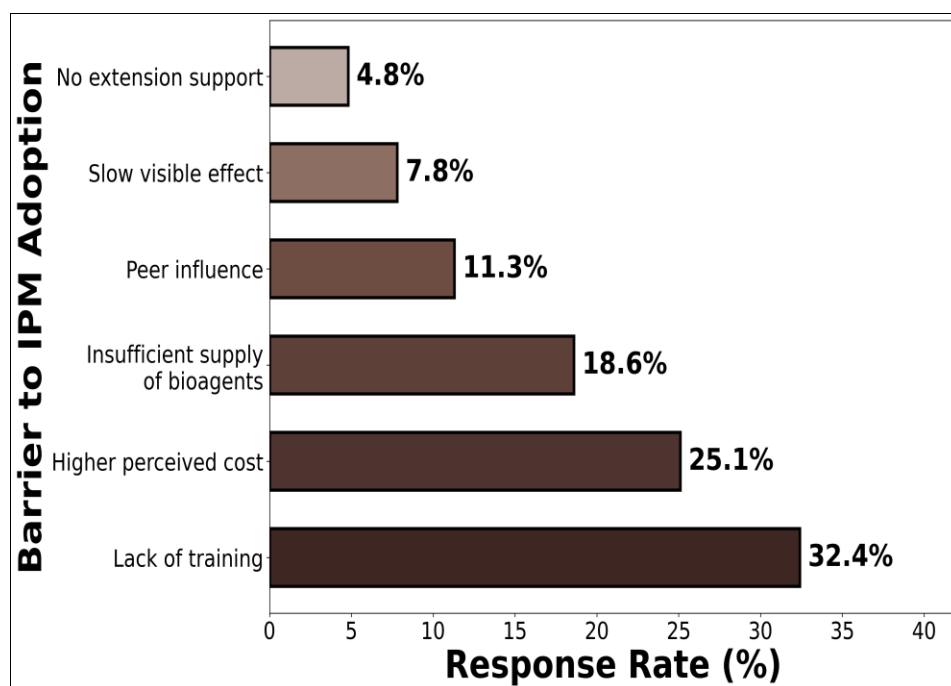


Fig. 2: Ranked barriers to IPM adoption reported by conventional and partial-adopter farmers in Laguna Province ($n = 186$)

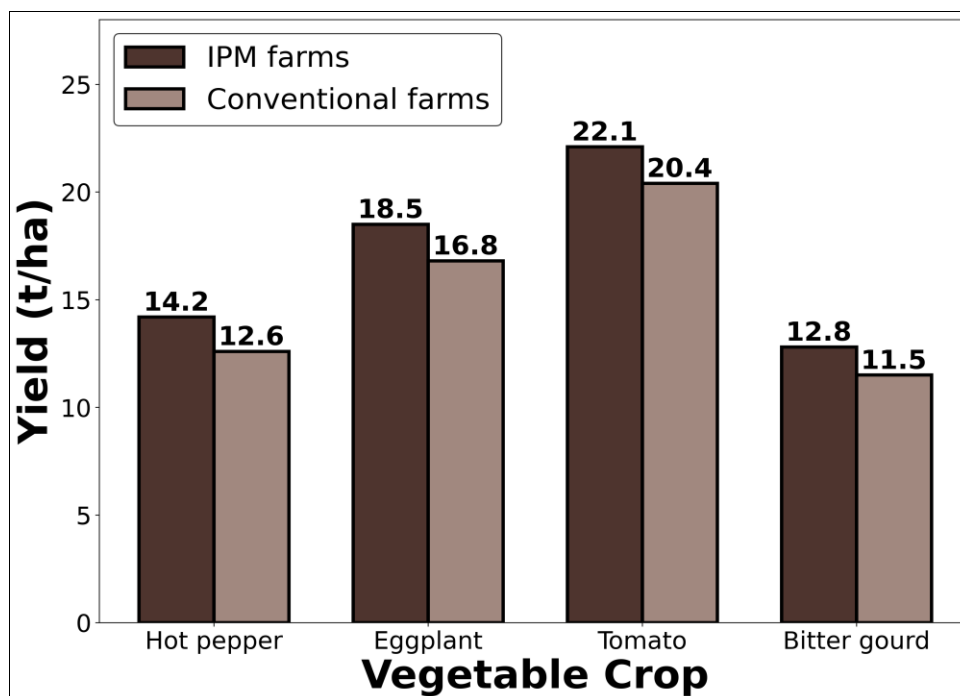


Fig. 3: Comparative vegetable yields (t/ha) between IPM-practicing and conventional-insecticide-reliant farms across four crops

Discussion

The observation that fewer than one-quarter of surveyed farmers qualify as full IPM adopters, despite decades of IPM promotion in the Philippines, reflects the persistent challenge of translating extension investments into sustained behavioral change at the farm level. The strong statistical association between formal IPM training and adoption status confirms that training remains a prerequisite for adoption; however, the fact that only 8.6% of conventional farmers had received any training reveals a critical coverage gap in the delivery of extension services to this population.

The identification of training deficiency as the primary adoption barrier aligns with a growing body of evidence from Southeast Asia indicating that knowledge constraints, rather than attitudinal resistance, represent the principal bottleneck to IPM uptake. The second-ranked barrier, the perceived higher cost of biological control agents, suggests that market-side interventions to improve biocontrol agent availability and affordability could complement supply-side training efforts in promoting IPM transition.

The consistently higher yields observed on IPM farms across all four crops provide empirical support for the productivity argument in favor of IPM adoption. While the yield advantages for tomato and bitter gourd did not reach statistical significance, the consistent direction of the effect across all crops suggests a real underlying productivity benefit. The yield advantage of IPM farms may be attributable to several mechanisms: improved pest-natural enemy balance through conservation biological control, reduced pest resurgence effects associated with broad-spectrum insecticide applications, and enhanced soil and plant health resulting from reduced chemical loading.

The relatively high proportion of partial IPM adopters (38.7%) represents both a challenge and an opportunity. These farmers have already incorporated some IPM elements into their practice, indicating openness to non-chemical approaches, but have not achieved the full integration necessary for optimal outcomes. Targeted extension programs designed to support partial adopters in

completing their transition to full IPM implementation could represent a highly cost-effective strategy for expanding IPM coverage.

The finding that partial IPM adopters constitute the largest single category in the surveyed population (38.7%) has important strategic implications for extension program design. Rather than focusing exclusively on converting conventional farmers to full IPM, a potentially more cost-effective approach would be to target partial adopters with specialized training modules designed to address the specific IPM components they have not yet incorporated. This incremental adoption support strategy recognizes that partial adopters have already demonstrated willingness to modify their practices and may require less intensive intervention to complete the transition to full IPM implementation compared to conventional farmers who have not yet initiated any changes.

Conclusion

This research demonstrates that IPM adoption among smallholder vegetable farmers in Laguna Province remains limited to approximately one-fifth of the farming population, constrained primarily by insufficient training coverage and biocontrol agent supply limitations. The documented yield advantages of IPM-practicing farms, particularly for hot pepper and eggplant, provide an evidence base for promoting IPM as both an environmentally responsible and economically beneficial pest management strategy. Extension programs should prioritize expanding farmer field school coverage to reach conventional practitioners, strengthening local supply chains for biological control agents, and providing ongoing technical support to partial adopters to facilitate their progression toward full IPM implementation.

Ethical considerations

This research received ethical clearance from the Laguna College of Applied Agriculture Institutional Review Board (Protocol No. LCAA-IRB-2025-0082). Informed consent

was obtained from all participants prior to data collection. All responses were treated as confidential, and individual identifying information was removed from the analytical dataset. The research team ensured that participation was entirely voluntary and that no coercion was applied during farmer recruitment.

Limitations

The yield data used in this research were primarily derived from farmer recall and records, which may be subject to estimation errors and recall bias. Although harvest monitoring on a subsample of 60 farms provided cross-validation, this covered only 25% of the total sample. The cross-sectional design does not account for pre-existing differences in soil quality, microclimate, or management intensity between IPM and conventional farms that may confound yield comparisons. Self-selection bias is also a concern, as farmers who adopt IPM may inherently differ in motivation, skill, and resource endowment from those who do not.

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