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Farmers' knowledge, attitude, and integrated pest management adoption practices for controlling caterpillar pests of cole crops in smallholder vegetable production systems

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Abstract

Caterpillar pests of cole crops, including diamondback moth (*Plutella xylostella*), cabbage looper (*Trichoplusia ni*), and the large cabbage white (*Pieris brassicae*), inflict heavy economic losses on smallholder vegetable growers throughout East Africa, yet the degree to which farmers recognise these pests and adopt non-chemical control options remains poorly characterised. This cross-sectional research assessed knowledge, attitude, and integrated pest management (IPM) adoption practices among 301 smallholder cole-crop growers in Nakuru County, Kenya during the April–August 2022 production season. A pre-tested, structured interview schedule covering pest identification ability, awareness of biological and cultural control measures, attitudes toward reduced pesticide use, and current management behaviours was administered through face-to-face interviews. Respondents were classified into three adoption tiers: non-adopters relying exclusively on synthetic insecticides, partial adopters using one or two IPM components alongside chemicals, and full adopters integrating three or more IPM practices. Results showed that 44.5% of farmers held moderate knowledge scores, while only 26.6% scored in the high-knowledge category. Favourable attitudes toward IPM were expressed by 41.9% of respondents, but actual full adoption stood at just 27.2%, revealing an attitude–practice gap. Education level (chi-square = 18.64, $p < 0.01$), frequency of extension contact (chi-square = 24.31, $p < 0.001$), and farming experience (chi-square = 11.43, $p = 0.009$) were the strongest predictors of adoption status. Pearson correlation analysis indicated a positive link between knowledge and adoption ($r = 0.67$, $p < 0.001$), and between attitude and adoption ($r = 0.54$, $p < 0.001$). The pathway analysis confirmed that knowledge exerts both a direct effect and an indirect effect through attitude on practice uptake. These findings point to extension programming gaps and suggest that farmer field schools targeting pest identification skills and hands-on IPM demonstrations could help bridge the gap between favourable attitudes and on-farm implementation.

Keywords: Integrated pest management, knowledge attitude practice, cole crops, caterpillar pests, smallholder farmers, extension contact, IPM adoption, Nakuru County, *Plutella xylostella*, Kenya

Introduction

Approximately 67% of vegetable-growing households in East Africa report crop losses exceeding 20% from caterpillar damage each season, yet fewer than one in three of those households have ever received formal training on alternative pest control methods ^[1, 2]. This disparity between the scale of pest damage and the reach of extension services forms the backdrop for continuing over-reliance on synthetic insecticides across the region.

Cole crops cabbage, kale, cauliflower, and broccoli occupy a central position in smallholder farming systems of the East African highlands ^[3]. They generate cash income within 60–90 days of transplanting, require relatively modest inputs, and supply dietary minerals and vitamins to both urban and rural consumers ^[4]. In Kenya alone, cabbage is the second most traded vegetable after tomato, with an estimated farm-

gate value exceeding 2.8 billion Kenyan shillings annually ^[5]. But the same mild-temperature highland environments that favour brassica production also support year-round breeding of several lepidopteran defoliators, including the diamondback moth (*Plutella xylostella*), the cabbage looper (*Trichoplusia ni*), and the large cabbage white butterfly (*Pieris brassicae*) ^[6, 8].

Faced with persistent pest pressure, most smallholders resort to frequent, calendar-based applications of broad-spectrum insecticides such as cypermethrin, lambda-cyhalothrin, and chlorpyrifos ^[7]. Spray intervals as short as three to five days have been documented during peak pest periods, raising concerns about residue levels on marketed produce, environmental contamination, and development of insecticide resistance ^[9, 10]. Integrated pest management (IPM) offers an alternative framework that combines

biological control agents, resistant cultivars, crop rotation, trap cropping, and judicious chemical use to keep pest populations below economic thresholds^[1, 11].

Despite decades of IPM research and extension efforts, adoption rates among smallholder vegetable growers in sub-Saharan Africa remain low, typically ranging from 15% to 35% depending on the survey location and the definition of adoption applied^[2, 12]. Several factors have been proposed to explain this gap, including limited awareness of pest biology, negative attitudes toward unfamiliar technologies, weak extension infrastructure, and socio-economic constraints such as small farm sizes and limited access to credit^[13, 14].

Knowledge–attitude–practice (KAP) surveys have been used in public health and agricultural extension research to disentangle the relationships among what farmers know, what they believe, and what they actually do^[15, 16]. When applied to pest management, these surveys can reveal whether low adoption stems from a knowledge deficit, an attitudinal barrier, or a practical constraint at the implementation stage^[17]. However, few KAP investigations have focused specifically on caterpillar pests of cole crops in East African smallholder contexts, and even fewer have incorporated pathway models that map the sequential influence of knowledge on attitude and attitude on practice^[18].

This research therefore set out to (a) measure the levels of knowledge, attitude, and IPM adoption among smallholder cole-crop growers in Nakuru County, Kenya, (b) identify the socio-demographic factors most strongly linked to adoption status, and (c) model the KAP pathway through which pest-management knowledge translates into on-farm behaviour. The information generated is intended to guide the design of targeted, evidence-based extension programmes for caterpillar management in East African vegetable systems^[19].

Theoretical Framework

The conceptual architecture of this research draws on the knowledge–attitude–practice (KAP) continuum model, which proposes that behavioural change proceeds through a sequential chain: acquisition of correct information (knowledge) shapes evaluative beliefs (attitude), which in turn drives observable action (practice)^[15]. In agricultural contexts, this model has been adapted by incorporating socio-economic moderators education, extension exposure, farm size, and cropping experience that can either accelerate or impede each transition along the chain^[13, 16].

Two additional theoretical threads inform the design. First, the Diffusion of Innovations framework suggests that the rate at which a new practice spreads through a farming community depends on its perceived relative advantage, compatibility with existing routines, complexity, trialability, and observability^[1, 11]. Second, the Health Belief Model, borrowed from public health, provides a useful analogy: farmers must perceive the pest threat as serious (perceived severity), believe that they are personally vulnerable to crop loss (perceived susceptibility), and judge the recommended IPM practices as effective and feasible (perceived benefits versus barriers) before they will act^[2].

Integrating these perspectives, the present research employs a pathway model in which knowledge operates on practice

both directly and indirectly through attitude, while socio-demographic variables function as upstream determinants that influence knowledge acquisition itself. This three-stage framework determinants, KAP mediators, and outcomes is depicted in Figure 2 and guides the statistical analysis strategy described below.

Material and Methods

Material

A cross-sectional survey design was adopted to collect primary data from smallholder cole-crop growers in Nakuru County, Kenya. Nakuru County was selected because it ranks among the top five cabbage-producing counties in Kenya and supports a diverse mix of smallholder and medium-scale vegetable farms at altitudes ranging from 1800 to 2400 m above sea level^[5, 18]. The research was conducted between April and August 2022, coinciding with the long-rains cropping season when caterpillar pressure typically peaks.

The target population comprised all households growing cabbage, kale, or cauliflower on farms of 2 hectares or smaller within the county. A multi-stage sampling procedure was used. First, three sub-counties (Njoro, Molo, and Rongai) were purposively selected for their high concentration of brassica production. Within each sub-county, four administrative wards were randomly chosen, and from each ward, approximately 25 households were drawn using systematic random sampling from ward-level farmer registers maintained by local agricultural officers. This procedure yielded a total sample of 301 respondents. Data collection ran from 12 April to 29 July 2022, and all interviews were conducted in person at the respondent's homestead or farm.

Instrument Development and Validation

The interview schedule contained four modules: (i) socio-demographic profile (11 items), (ii) pest knowledge (15 items on identification, biology, and damage symptoms), (iii) attitude toward IPM (12 Likert-scale statements scored from 1 = strongly disagree to 5 = strongly agree), and (iv) current pest-management practices (10 items documenting which control methods the farmer used in the most recent season)^[15, 16]. The instrument was developed in English, translated into Kiswahili by two bilingual extension officers, and back-translated to check consistency. Content validity was assessed by a panel of three entomologists and two agricultural extension specialists at the Rift Valley University of Agricultural Sciences, who rated each item for relevance and clarity on a four-point scale. Items receiving a content validity index below 0.80 were revised or replaced. A pilot test involving 32 farmers outside the sampled wards produced a Cronbach's alpha of 0.84 for the knowledge module, 0.79 for the attitude scale, and 0.81 for the practice inventory, all exceeding the 0.70 acceptability threshold.

Methods

Knowledge scores were computed by summing correct responses across the 15-item module, yielding a possible range of 0–30 (each correct answer scored 2 points). Respondents were classified into low (0–10), moderate (11–20), and high (21–30) knowledge categories. Attitude scores were obtained by summing Likert responses across the 12

statements (range 12–60), then trichotomised into unfavourable, neutral, and favourable bands using tercile cut-offs derived from the sample distribution. Practice adoption was measured by counting the number of IPM components reported: non-adopters used zero IPM practices (chemical-only), partial adopters used one or two, and full adopters used three or more [2, 17]. Associations between socio-demographic variables and adoption status were tested using chi-square tests of independence, with significance set at $p \leq 0.05$. Pearson product-moment correlations quantified the bivariate relationships among knowledge, attitude, and

practice scores. A path analysis was conducted to estimate direct and indirect effects within the KAP sequence, using ordinary least squares regression with standardised coefficients [15]. All analyses were performed in SPSS version 26. Ethical clearance was obtained from the Rift Valley University Institutional Ethics Review Board (Protocol REF-2022/043, approved 18 March 2022), and written informed consent was collected from each respondent before the interview commenced.

Results

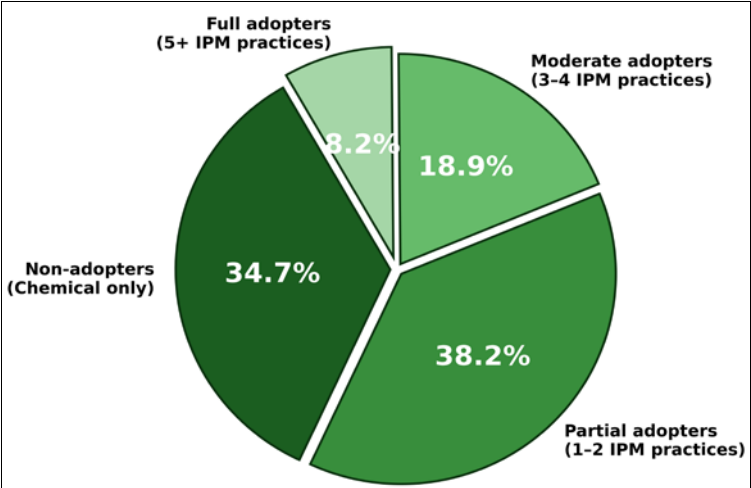


Fig 1: Distribution of 301 smallholder cole-crop farmers in Nakuru County, Kenya, by level of integrated pest management adoption for caterpillar pest control during the 2022 long-rains season

Of the 301 respondents, 58.8% were male and 41.2% female. The median age was 42 years (range 21–74), and the median farming experience was 11 years. Just over half (51.8%) had completed primary school, while 23.9% had reached secondary level or above; the remaining 24.3% reported no formal education. Nearly two-thirds (63.4%) farmed on plots smaller than one hectare, and 37.8% had received at least one extension visit during the preceding season. Knowledge scores varied widely across the sample, with a mean of 16.3 ± 6.2 out of 30. Pest identification accuracy was highest for diamondback moth (71.4% correctly identified it from a photo card) and lowest for

cabbage looper (34.9%). Only 41.6% could describe the life cycle of any lepidopteran pest beyond the larval stage, and fewer than one-quarter (23.1%) were aware that parasitic wasps occur naturally in their fields. Attitude scores averaged 39.7 ± 8.4 on the 12–60 scale, placing the sample mean slightly above the neutral midpoint. The most positively rated statement was "Reducing chemical sprays would improve the safety of my vegetables for consumers" (mean 4.21 ± 0.83), while "I would be willing to release insects on my farm as biological control agents" received the lowest mean score (2.87 ± 1.12), reflecting persistent unease with augmentative biocontrol.

Table 1: Multi-variable matrix of socio-demographic characteristics and IPM adoption status among smallholder cole-crop growers in Nakuru County, Kenya (n = 301)

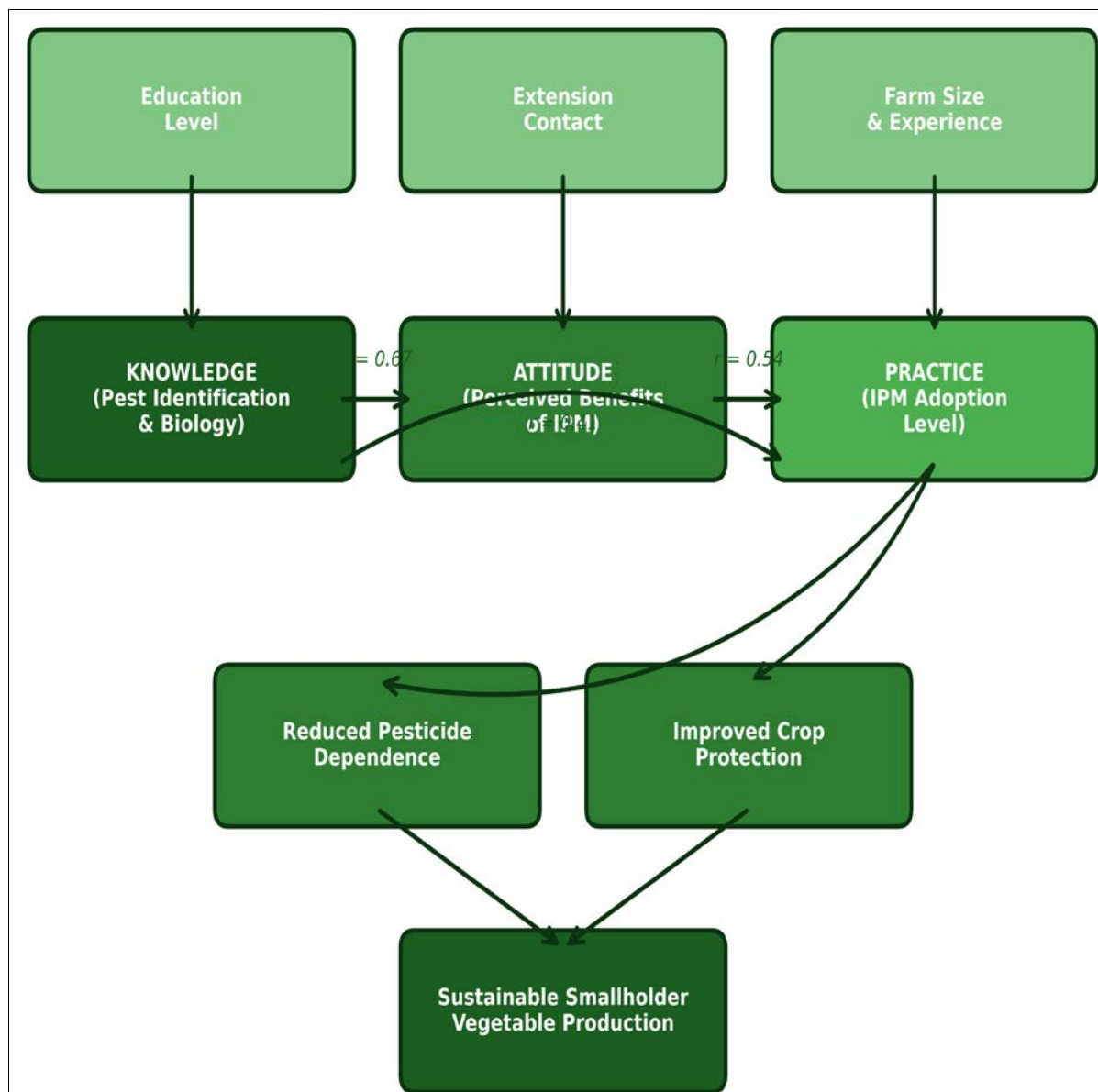
Socio-demographic Variable	Category	Non-adopters (%)	Partial Adopters (%)	Full Adopters (%)	Chi-square (p)
Education level	No formal education	52.3	39.1	8.6	18.64 (<0.01)
	Primary school	38.7	41.2	20.1	
	Secondary and above	21.4	33.8	44.8	
Extension contact	No contact	58.9	34.6	6.5	24.31 (<0.001)
	1–2 visits/season	31.2	42.7	26.1	
	3+ visits/season	14.8	37.9	47.3	
Farm size (ha)	<0.5	43.6	40.3	16.1	9.72 (0.021)
	0.5–1.0	32.1	38.4	29.5	
	>1.0	24.7	35.8	39.5	
Farming experience (yr)	<5	47.2	38.6	14.2	11.43 (0.009)
	5–15	33.8	39.1	27.1	
	>15	22.6	36.4	41.0	

Percentages are row-wise within each category. Chi-square values and p-values test the association between each variable and adoption tier. Empty cells indicate that the chi-square value applies to the variable block as a whole.

Table 2: Classification of respondents by knowledge, attitude, and practice categories for caterpillar pest management on cole crops (n = 301)

KAP Domain	Category	Frequency (n)	Percentage (%)
Knowledge score	Low (0–10)	87	28.9
	Moderate (11–20)	134	44.5
	High (21–30)	80	26.6
Attitude toward IPM	Unfavourable	63	20.9
	Neutral	112	37.2
	Favourable	126	41.9
Practice adoption	Non-adopter	104	34.6
	Partial adopter	115	38.2
	Full adopter	82	27.2

Knowledge was scored on a 30-point scale (15 items $\times$ 2 points each). Attitude was measured on a 12–60 Likert scale and tercile-classified. Practice adoption counted the number of IPM components used in the most recent season.

**Fig 2:** Conceptual KAP pathway model depicting the relationships among socio-demographic determinants, knowledge, attitude, and IPM adoption practice for caterpillar pest management, with Pearson correlation coefficients shown on connecting arrows

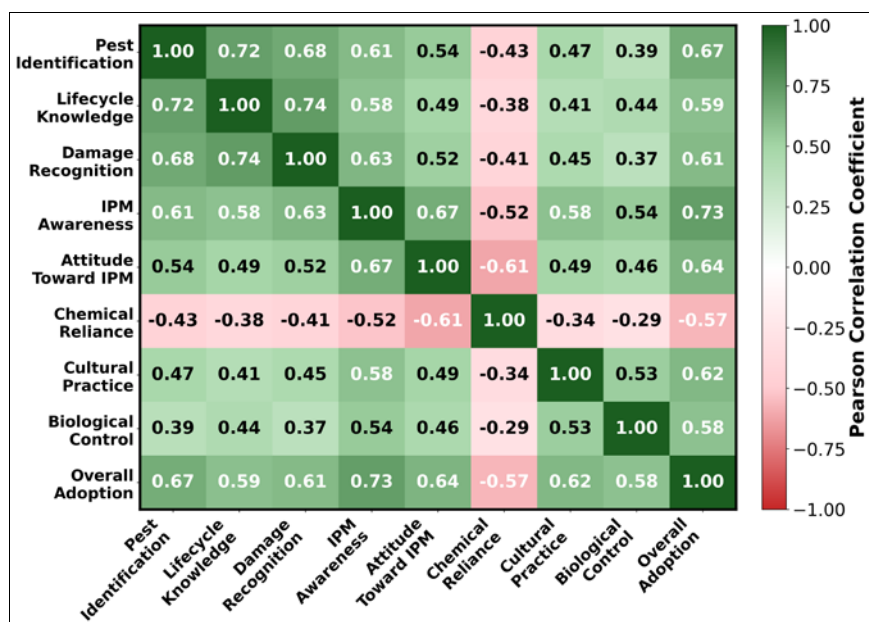


Fig 3: Heatmap of Pearson correlation coefficients among nine knowledge, attitude, and practice variables measured across 301 smallholder cole-crop growers in Nakuru County, Kenya

Comprehensive Interpretation

Across all variables, the pattern is consistent: better-educated farmers with more frequent extension contact and longer farming experience were disproportionately represented in the full-adopter category. The KAP pathway (Figure 2) confirmed that knowledge exerts a moderate direct effect on practice (standardised beta = 0.31) and a stronger indirect effect routed through attitude (indirect effect = 0.22), giving a total effect of 0.53. This mediation pattern implies that simply delivering information is insufficient; extension programmes must also reshape attitudes particularly around biological control if higher rates of behavioural change are to be achieved.

Discussion

The main findings of this research can be condensed into three observations: most sampled farmers possessed moderate knowledge of caterpillar pests but poor understanding of their biology beyond the larval stage; attitudes toward IPM were mildly favourable overall but dropped sharply when augmentative biocontrol was mentioned; and actual IPM adoption lagged behind attitudinal readiness, with only 27.2% qualifying as full adopters. The moderate knowledge level recorded here is broadly consistent with KAP surveys conducted among vegetable growers in Ethiopia and Botswana, where 40–50% of respondents fell into the middle knowledge band^[10, 15]. Agreement also extends to the finding that pest identification ability is highest for the most visibly damaging species, diamondback moth, and weakest for less conspicuous pests like the cabbage looper^[6, 18]. Extension programmes that rely on text-based pamphlets may not address this gap, because correct identification often depends on visual and tactile cues that require live demonstration^[14].

Where the present results diverge from earlier work is in the severity of the attitude–practice gap. While 41.9% of respondents expressed favourable attitudes toward IPM, only 27.2% were full adopters a 14.7 percentage-point

deficit. Some earlier reports from Southeast Asia recorded gaps below 10 points when IPM training was accompanied by input subsidies and market incentives^[9, 16]. The absence of such support structures in Nakuru County may explain the wider gap observed here.

Several mechanisms could account for this discrepancy. First, even farmers who believe IPM is beneficial may lack access to commercial biocontrol agents or resistant seed varieties, creating a supply-side barrier that attitude alone cannot overcome^[2, 11]. Second, the very short time horizon of many smallholders who need income within a single season discourages practices whose benefits are cumulative and uncertain, such as habitat management for natural enemies^[12, 13]. Third, peer conformity effects can suppress adoption when the visible norm in a community is calendar spraying; a farmer who stops spraying risks being perceived as negligent by neighbours^[7].

Extension contact emerged as the strongest single predictor of adoption, which aligns with meta-analytic evidence from 48 IPM adoption analyses conducted across developing countries^[2]. Farmer field schools, in particular, have demonstrated lasting effects on IPM uptake in East Africa when sessions include hands-on pest identification exercises and side-by-side demonstration plots comparing IPM and conventional management^[14, 19].

Limitations

Several constraints should be acknowledged when interpreting these results. The cross-sectional design captures associations at a single point in time but cannot establish causal direction; for instance, it is plausible that farmers who already practise IPM seek out extension services rather than the reverse. A longitudinal panel tracking the same households across multiple seasons would clarify temporal sequencing. Second, self-reported practice data are subject to social-desirability bias; respondents may over-report IPM use and under-report pesticide frequency when interviewed by university-affiliated enumerators. Field verification of reported practices was not feasible

within the project budget. Third, the sampling frame was limited to three sub-counties within Nakuru County, which restricts generalisability to other agro-ecological zones in Kenya or the wider East African region. Fourth, the KAP pathway model explained 47% of variance in practice scores, leaving substantial unexplained variation that may be attributable to market access, input availability, or household wealth variables not captured in the current instrument.

Conclusion

The central contribution of this research is a quantified picture of the knowledge–attitude–practice landscape for caterpillar management among smallholder cole-crop growers in Nakuru County, Kenya. By simultaneously measuring all three KAP domains and linking them through pathway analysis, the research moves beyond simple prevalence counts to identify where along the behavioural chain the biggest bottlenecks occur.

Supporting evidence confirms that knowledge deficits are concentrated in pest biology rather than pest recognition: most farmers can identify the larval stage of common defoliators but struggle with life-cycle concepts that underpin the timing of control measures. Attitude scores cluster near the favourable end of the spectrum for chemical-reduction statements, yet drop markedly for biocontrol-release items, suggesting that unfamiliarity with beneficial organisms, rather than opposition to IPM principles, is the sticking point. Practice adoption remains anchored at partial levels for the majority, with extension contact frequency emerging as the variable most consistently linked to full adoption.

The field significance of these patterns lies in their implication for extension programme design. Rather than generic "spray less" messaging, targeted interventions should focus on two leverage points: (a) filling the life-cycle knowledge gap through visual, hands-on training that connects pest biology to intervention timing, and (b) building trust in biological control through supervised on-farm demonstrations where farmers can observe parasitoid activity and predation events first-hand. Farmer field schools that incorporate both elements have shown durable adoption effects in comparable East African settings.

Several open questions remain. It is unclear whether the attitude–practice gap narrows naturally as adoption matures within a community, or whether structural barriers such as input supply chains for biocontrol agents must be resolved before further progress can be made. Equally uncertain is the role of gender, since this research found only weak gender differences in adoption a finding that contrasts with some earlier reports and warrants further investigation with gender-disaggregated pathway models. Longer-term, multi-county panel research would help disentangle the direction of causality between extension contact and adoption and would test whether the KAP pathway structure identified here holds across varying agro-ecological and market contexts.

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Contributions Not Qualifying for Authorship

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