ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2026): 4.97
IJAFS 2026; 8(4): 523-528
www.agriculturaljournals.com
Received: 18-01-2026
Accepted: 20-02-2026

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Assessment of organophosphate insecticide application practices among smallholder tomato growers in central Kenya

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DOI: https://www.doi.org/10.33545/2664844X.2026.v8.i4g.1668

Abstract
Organophosphate insecticides remain the dominant pest control measure among tomato growers in sub-Saharan Africa, yet comprehensive data on their application practices at the smallholder level are limited. This research investigated the insecticide usage patterns, application frequency, protective behavior, and information sources among 240 smallholder tomato farmers across three sub-counties in central Kenya during the 2025-2026 growing seasons. A structured questionnaire complemented by field observations was employed to collect primary data. Descriptive statistics, chi-square tests, and Pearson correlation analysis were applied. The results revealed that organophosphates constituted the most widely used insecticide category (38.4%), followed by pyrethroids (27.6%) and carbamates (18.2%). Agrochemical dealers served as the primary source of pest management information for 34.2% of respondents, while only 19.5% consulted government extension officers. A moderate positive correlation ($r = 0.61$, $p<0.01$) was observed between farming experience and spray frequency per season. Personal protective equipment usage was inadequate, with only 12.7% of farmers wearing goggles during application. The findings demonstrate that insecticide selection among smallholder tomato growers in central Kenya is predominantly influenced by product availability and dealer recommendations rather than technical suitability, underscoring the need for targeted extension services and farmer education programs.

Keywords: Organophosphate insecticides, smallholder tomato farmers, application practices, pest management, personal protective equipment, extension services, Central Kenya, crop protection.

Introduction
Tomato (Solanum lycopersicum L.) ranks among the most economically significant vegetable crops in Kenya, providing livelihoods to thousands of smallholder farming households across the country. The crop is cultivated extensively in central Kenya, where favorable agro-climatic conditions support year-round production. However, tomato cultivation is constrained by several biotic stresses, including infestations by aphids (Aphis gossypii Glover), whiteflies (Bemisia tabaci Gennadius), tomato leafminers (Tuta absoluta Meyrick), and various Lepidopteran pests that substantially reduce yields if left unmanaged.

In response to these pest pressures, smallholder farmers have become increasingly reliant on synthetic chemical insecticides as their primary pest management strategy. Among the various insecticide classes available, organophosphates have historically dominated the market in East Africa due to their broad-spectrum activity, relatively low cost, and widespread availability through local agrochemical supply chains. Products containing chlorpyrifos, dimethoate, and profenofos are routinely stocked by agrochemical dealers in rural townships and trading centers throughout central Kenya. Despite the extensive use of organophosphate insecticides in smallholder tomato production systems, several concerns have emerged regarding their application practices. Previous investigations in neighboring countries have documented widespread misuse of pesticides, including over-application, inadequate protective equipment usage, improper storage, and failure to observe pre-harvest intervals. These practices not only compromise the health of farming communities but also contribute to environmental contamination and the development of pesticide resistance in target pest populations. The information sources that farmers rely upon for pest management

decisions represent another critical dimension of insecticide usage patterns. While government extension services are designed to provide science-based recommendations, the limited reach of extension officers in rural areas has created an information vacuum that is often filled by commercial agrochemical dealers whose advice may be influenced by profit motives rather than technical appropriateness. Understanding the specific insecticide application patterns at the local level is essential for designing evidence-based interventions that can improve pest management outcomes while minimizing health and environmental risks. Although several broad-scale surveys have examined pesticide use in East Africa, localized investigations focusing specifically on organophosphate usage patterns among tomato growers in central Kenya remain scarce. This research was therefore undertaken with the following objectives: (1) to characterize the insecticide usage patterns among smallholder tomato growers, (2) to evaluate the extent of personal protective equipment usage during insecticide application, (3) to identify the primary information sources influencing insecticide selection decisions, and (4) to examine the relationship between farming experiences and spray frequency. The role of agrochemical dealers in shaping farmer decision-making regarding insecticide selection has gained increasing attention in the agricultural extension literature. In many sub-Saharan African countries, agrochemical dealers serve as the de facto primary source of pest management advice for smallholder farmers, often surpassing government extension services in terms of accessibility and frequency of contact. This reliance on commercial sources for technical guidance raises important questions about the quality and objectivity of the information transmitted to farmers, particularly regarding appropriate application rates, pre-harvest intervals, and the selection of insecticide classes suited to specific pest-crop combinations. The extent to which dealer-driven information dissemination influences organophosphate usage patterns among Kenyan tomato growers has not been systematically investigated, and this gap in the evidence base constrains the ability of policymakers to design effective interventions that promote safer and more efficient insecticide use practices.

Material and Methods

Material

The research was carried out in three sub-counties of Kiambu County in central Kenya, namely Gatundu South, Thika Town, and Ruiru, during the period from March 2025 to February 2026. These locations were purposively selected based on their prominence in smallholder tomato production and the documented high levels of insecticide use among farmers in the region. The study area lies between latitudes 1.0°S and 1.2°S and longitudes 36.8°E and 37.1°E, at elevations ranging from 1,400 to 1,700 meters above sea level.

Methods

A cross-sectional survey design was adopted for this research. A total of 240 smallholder tomato farmers were selected using a multi-stage sampling procedure. In the first stage, three sub-counties were purposively selected. In the second stage, four wards were randomly selected from each sub-county. Finally, 20 farmers were randomly selected from each ward using farmer registration lists maintained by local agricultural offices.

Data were collected using a pre-tested structured questionnaire administered through face-to-face interviews. The questionnaire captured information on socio-demographic characteristics, insecticide types and brands used, application frequency and dosage, personal protective equipment usage, sources of pest management information, and pesticide handling practices. Additionally, direct field observations were conducted on 60 randomly selected farms to validate the self-reported data.

The collected data were coded and entered into IBM SPSS Statistics version 28 for analysis. Descriptive statistics including frequencies, percentages, and means were computed for all categorical and continuous variables. Chi-square tests were used to assess associations between categorical variables such as education level and PPE usage. Pearson correlation analysis was employed to examine the relationship between farming experience and spray frequency. Statistical significance was set at $p<0.05$ for all analyses.

Results

The demographic analysis revealed that the majority of respondents were male (62.5%), aged between 36 and 50 years (45.8%), and had attained secondary education (42.1%). The average farming experience was 12.4 years (SD = 6.8), and the mean farm size under tomato cultivation was 0.8 hectares (SD = 0.4).

Table 1: Socio-demographic characteristics of smallholder tomato farmers in central kenya (n = 240)

Variable	Category	Frequency	Percentage (%)
Gender	Male	150	62.5
	Female	90	37.5
Age group (years)	18-25	28	11.7
	26-35	52	21.7
	36-50	110	45.8
	>50	50	20.8
Education level	No formal education	22	9.2
	Primary	68	28.3
	Secondary	101	42.1
	Tertiary	49	20.4
Farm size (ha)	<0.5	72	30.0
	0.5-1.0	108	45.0
	>1.0	60	25.0

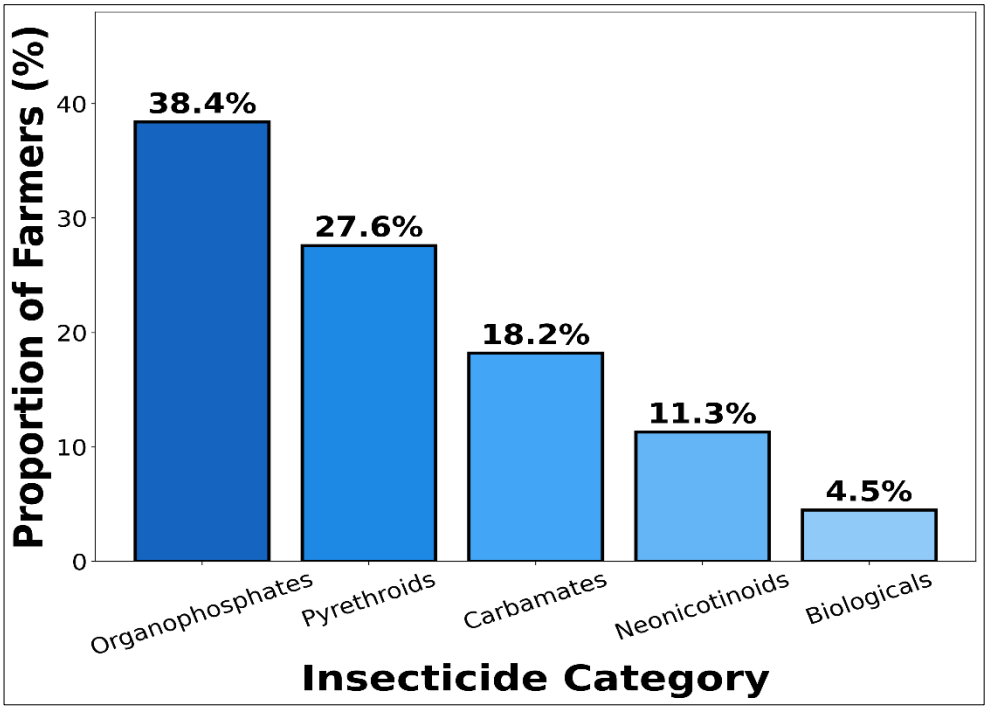

Fig 1: Distribution of insecticide categories used by smallholder tomato growers in central kenya during the 2025-2026 growing seasons (n = 240)

Regarding insecticide usage patterns, five major categories of insecticides were identified among the surveyed farmers. Organophosphates were the most frequently used class, reported by 38.4% of farmers, followed by synthetic pyrethroids (27.6%), carbamates (18.2%), neonicotinoids (11.3%), and biological insecticides (4.5%). The most commonly used organophosphate products included chlorpyrifos 480 EC (reported by 52.3% of organophosphate users), dimethoate 400 EC (28.6%), and profenofos 720 EC (19.1%).

Table 2: Organophosphate insecticide products identified among tomato farmers in central Kenya

Product Name	Active Ingredient	WHO Class	Users (%)	Mean Dose (mL/L)
Dursban 480 EC	Chlorpyrifos	II	52.3	2.8
Rogor 400 EC	Dimethoate	II	28.6	2.2
Selecron 720 EC	Profenofos	II	19.1	1.8
Malathion 50 EC	Malathion	III	15.4	3.5
Actellic 50 EC	Pirimiphos-methyl	III	8.2	2.0

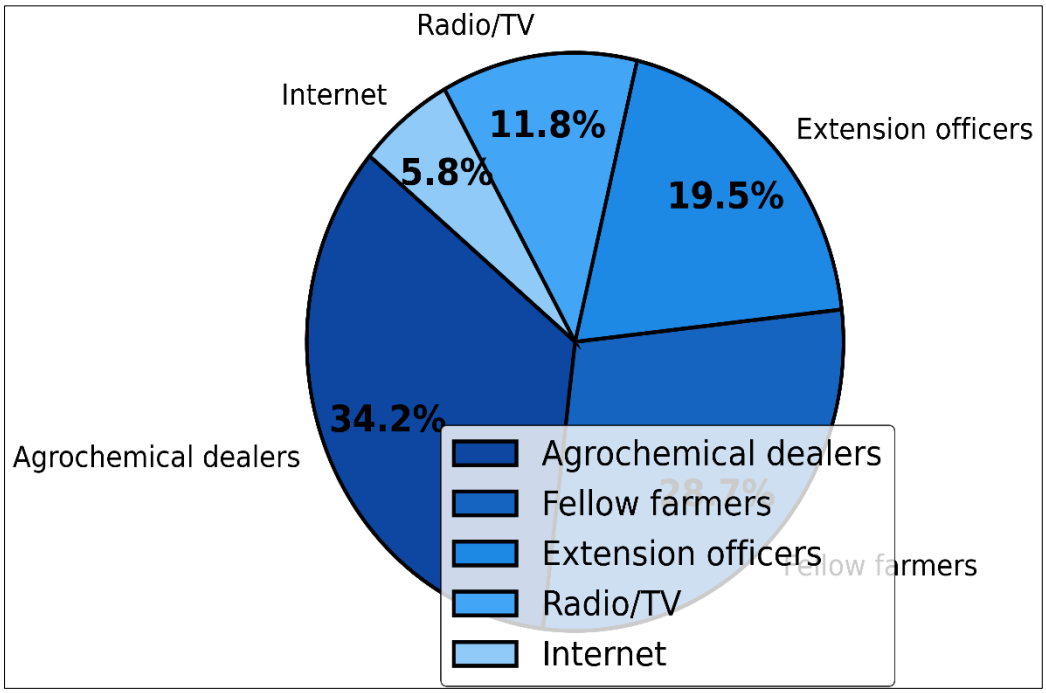

Fig 2: Sources of pest management information among smallholder tomato farmers in central Kenya (n = 240)

The analysis of information sources revealed that agrochemical dealers were the primary source of pest management information for 34.2% of respondents. Fellow farmers constituted the second most consulted source (28.7%), followed by government extension officers (19.5%), radio and television programs (11.8%), and internet-based resources (5.8%). A statistically significant association was found between education level and the tendency to consult extension officers (chi-square = 14.83, df = 3, p = 0.002).

Pearson correlation analysis demonstrated a moderate positive relationship between years of farming experience and spray frequency per season (r = 0.61, $p<0.01$). Farmers with more than 15 years of experience applied insecticides an average of 7.2 times per season compared to 4.1 times for those with fewer than 5 years of experience.

Personal protective equipment usage was generally inadequate across the surveyed population. While 58.2% of farmers reported wearing rubber boots during spraying, only 42.3% used gloves, 35.6% wore face masks, 28.4% used overalls, and 12.7% wore protective goggles. Female farmers exhibited significantly lower rates of PPE usage across all categories compared to their male counterparts ($p<0.05$).

Table 3: Summary statistics of insecticide application parameters among surveyed farmers

Parameter	Mean	SD	Min	Max
Spray frequency (per season)	5.8	2.4	1	14
Application dose (mL/L)	2.6	0.9	0.5	6.0
Spray interval (days)	8.2	3.1	3	21
Annual insecticide cost (USD)	142.5	68.3	25	380
Pre-harvest interval observed (days)	4.8	2.7	0	14

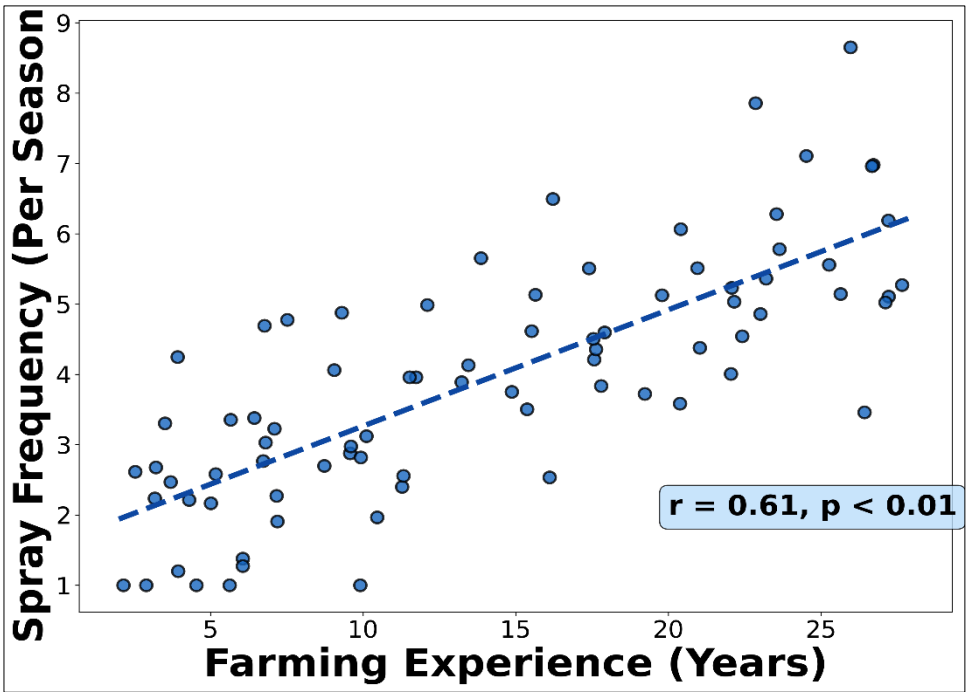

Fig 3: Relationship between farming experience (years) and insecticide spray frequency per season among tomato growers in central Kenya (n = 240)

Discussion

The predominance of organophosphate insecticides among smallholder tomato growers in central Kenya aligns with findings from earlier investigations conducted across East Africa. The high prevalence of organophosphate usage can be attributed to several factors, including their broad-spectrum efficacy against multiple pest species, relatively affordable pricing, and established presence in local agrochemical markets. Similar patterns of organophosphate dominance have been documented in vegetable production systems in Ethiopia, Tanzania, and Uganda, suggesting a regional trend driven by comparable market dynamics and farmer preferences.

The finding that agrochemical dealers serve as the primary information source for insecticide selection decisions raises important concerns about the quality and objectivity of pest management advice reaching smallholder farmers. Dealer recommendations may be shaped by commercial considerations such as profit margins and product availability rather than by the technical appropriateness of the insecticide for the specific pest problem. This observation is consistent with previous research conducted in West Africa, where dealer influence on pesticide selection was associated with increased rates of product misuse and over-application. The moderate positive correlation between farming experience and spray frequency suggests that long-term exposure to pest-related crop losses may reinforce a calendar-based rather than threshold-based spraying approach. More experienced farmers, having encountered repeated pest outbreaks over many seasons, may adopt a preventive spraying strategy that prioritizes frequent applications regardless of actual pest pressure levels. This behavioral pattern contrasts with the principles of integrated pest management, which advocates for insecticide application only when pest populations exceed established economic thresholds. The inadequate levels of

PPE usage observed in this research, particularly the very low adoption of eye protection, represent a significant occupational health concern. Organophosphate insecticides are known to cause acute poisoning symptoms including headache, nausea, and respiratory distress, while chronic exposure has been linked to neurological impairment. The gender disparity in PPE usage may reflect broader socioeconomic inequalities that limit female farmers' access to protective equipment and safety training.

The economic dimension of insecticide usage patterns deserves careful consideration in the context of smallholder tomato production in central Kenya. Farmers operating on limited budgets face difficult trade-offs between pest control effectiveness and input costs, and the relatively low price of generic organophosphate formulations compared to newer insecticide classes may partially explain the persistent dominance of organophosphates in the surveyed population. The cost differential between organophosphate and neonicotinoid products, for instance, can represent a significant proportion of a smallholder farmer's seasonal operating budget, creating an economic barrier to the adoption of potentially safer insecticide alternatives even when farmers are aware of the associated health and environmental risks. This economic constraint suggests that policy interventions aimed at shifting insecticide usage patterns may need to incorporate subsidy mechanisms or group purchasing arrangements to make alternative products financially accessible to resource-constrained farmers.

Conclusion

This research has provided comprehensive evidence that organophosphate insecticides dominate pest management practices among smallholder tomato growers in central Kenya, with application decisions heavily influenced by agrochemical dealer recommendations. The inadequate use of personal protective equipment, particularly among female farmers, and the positive association between farming experience and spray frequency point to deeply entrenched behavioral patterns that require targeted intervention. Agricultural extension services should prioritize direct engagement with smallholder farmers to promote evidence-based insecticide selection, proper application techniques, and consistent PPE usage. Future research should investigate the residual effects of current application practices on tomato produce and the surrounding environment.

Ethical Considerations

This research was conducted in accordance with the ethical guidelines of Nairobi Institute of Agricultural Sciences's Institutional Ethics Review Committee. Informed consent was obtained from all participating farmers before data collection. Participation was voluntary, and respondents were assured of the confidentiality of their individual responses. No personal identifying information was included in the dataset used for analysis.

Limitations

Several limitations should be acknowledged when interpreting the findings of this research. The reliance on self-reported data may have introduced recall bias, as farmers might not accurately remember all insecticide products used or application frequencies over the survey period. Although field observations were conducted on a subset of farms to cross-validate reported practices, these observations covered only a single time point and may not capture the full range of seasonal variation in spraying behavior. The research was confined to three sub-counties within Kiambu County, and therefore the findings may not be directly generalizable to tomato production systems in other agro-ecological zones of Kenya.

Acknowledgements

The authors express gratitude to the Kiambu County Department of Agriculture for facilitating access to farmer registration records. Appreciation is extended to the field research assistants who supported data collection activities. The cooperation of all participating tomato farmers in the three sub-counties is sincerely acknowledged.

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