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Farmers' Knowledge, Perceptions, and Management Practices of False Codling Moth (*Thaumatotibia leucotreta*) in Smallholder *Capsicum* sp. Cropping Systems in Kenya

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Abstract: False codling moth (FCM) *Thaumatotibia leucotreta* Meyrick (Lepidoptera: Tortricidae) is currently the main pest of phytosanitary concern in international trade, causing rejection and decline of horticultural produce from Kenya exported to the European Union (EU). Overreliance on synthetic insecticides to control this pest is ineffective and unsustainable in the long run, whereas continuous use of pesticides results in high levels of residues in the produce. To gather farmers' knowledge, attitudes, and practices used by smallholder farmers to manage this pest, a field survey was carried out in 10 *Capsicum* sp. (Solanales: Solanaceae)-producing counties in Kenya. Data were collected using semi-structured questionnaires administered through face-to-face interviews and focus group discussions involving 108 individual farmers, 20 key informants, and 10 focus group discussions. The majority of the respondents (83.33%) were aware of the FCM infesting *Capsicum* sp. About three quarters of the farmers (76.85%) reported yield losses and unmarketable quality of FCM-infested *Capsicum* sp. Most farmers interviewed (99.07%) used insecticides as a management tool. In contrast, only 39.81% of the farmers applied integrated pest management strategies including use of biological control agents and intercropping with repellent plants to control this pest. The results show that FCM is perceived as a significant threat to the horticultural industry of Kenya. Training needs for smallholder farmers and key informants to avoid overreliance on synthetic chemical pesticides and to maintain export goals to the EU where identified.

Keywords: biological control; false codling moth; horticultural industry; integrated pest management; pesticide use

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1. Introduction

Horticulture is Kenya's third-highest foreign exchange earner after tourism and tea, generating about USD 1 billion annually [1]. The fruit and vegetable sub-sectors are essential in attaining food and income security and improving livelihood for smallholder farmers who produce 100% of the fruit and vegetables consumed locally and up to 80% of those exported [2]. One of the goals of Kenya's vision 2030 for agriculture is to maintain and sustain 10% of its gross domestic product (GDP) contribution. To achieve this, vital subsectors like floriculture, fruit, and vegetable production, including spices, must be safeguarded against the negative impacts imposed by dangerous insect pests. A particular case in point is that of bell pepper (*Capsicum annum* L., Solanales: Solanaceae) and roses (*Rosa* sp. L., Rosales: Rosaceae), whose contribution is on the declining trend due to regular interceptions in the European union (EU) markets owing to the presence of the quarantine pests and high chemical pesticide residues. According to the horticultural crops directorate of Kenya, in 2018, the total value of *Capsicum* sp. including sweet pepper, African bird's eye (ABE), long cayenne, and bullet pepper produced in Kenya was USD 8.315 million.

The horticulture subsector, despite experiencing growth, is confronted with several challenges such as fluctuating market demands, dynamic and rigorous market regulations, unpredictable weather patterns, and the emergence of new pests and diseases. False codling moth (FCM) [*Thaumatotibia leucotreta* (Meyrick) (Lepidoptera: Tortricidae)] is one of the major constraints in the production of fruit, vegetables, and flowers in Kenya, and is currently accounting for a large percentage of interceptions of *Capsicum* exported from Kenya to the EU member states [3]. The FCM is thought to have originated in the Ethiopian zoogeographic province and is currently widely distributed in sub-Saharan Africa, where it has been reported in over 40 countries [3,4]. This pest has more than 70 host plants, including cotton (*Gossypium* sp., Malvales: Malvaceae), citrus (*Citrus* sp., Sapindales: Rutaceae), coffee (*Coffea arabica*, Gentianales: Rubiaceae), corn (*Zea mays*, Poales: Po-aceae), macadamia (*Macadamia* sp., Proteales: Proteaceae), mango (*Mangifera indica*, Sapindales: Anacardiaceae), okra (*Abelmoschus esculentus*, Malvales: Malvaceae), peppers (*Capsicum* sp., Sonanales: Solanaceae), roses (*Rosa* sp., Rosales: Rosaceae), avocado (*Persea americana*, Laurales: Lauraceae), tea (*Camellia sinensis*, Ericales: Theaceae), and sorghum (*Sorghum bicolor*, Poales: Poaceae), among others [5]. The larvae of FCM burrow into fruit, seeds, pods, and flowers of the host plant resulting in damage and losses up to 30% [3,6]. Feeding damage on host plants predisposes them to secondary infections by fungal and bacterial pathogens [5].

In Kenya, FCM was a minor pest until recently [7]. However, its status has changed into that of an important insect pest, posing a threat to the production and marketing of a wide range of crops in Tropical–Mediterranean–Caribbean–Pacific countries. The FCM adversely affects crop quality and yield, and it imposes restrictions on the international trade of susceptible agricultural commodities in global markets [3]. In 2011, the false codling moth (FCM) gained inclusion in the European and Mediterranean Plant Protection Organization's alert list after larvae were discovered on roses from Africa. The presence of FCM in the Netherlands in 2009 raised significant concerns. Subsequently, the EU conducted a pest risk analysis between 2011 and 2012, leading to the categorization of FCM as a regulated quarantine pest (A2). Without effective control measures, there is a risk of FCM establishing itself in the EU through trade. Presently, FCM stands as a top priority pest, and all EU imports have been required to be FCM-free since 2013. [8–10]. This means that all imported material in the EU should be free from the pest [8]. Beginning 2014 onwards, effects of this legislation started having negative implications on trade between African countries and the EU, with 80% of all interceptions of *Capsicum* from Kenya being occasioned by the presence of FCM [6].

As a mitigation measure to save the integrity of Kenyan plant exports, Kenya Plant Health Inspectorate Service (KEPHIS) has of recent raised the production standards. Currently, Kenyan farmers can only export *Capsicum* sp. to the EU market if grown under a protected environment (greenhouse/screenhouse), which is not affordable to a majority of smallholder resource-poor farmers [6]. The inspection rate for *Capsicum* sp. has also been raised from the previous 5% to 10% to the current 50% [11]. The number of licenced *Capsicum* sp. exporters has also been reduced by the regulator, Horticultural Crops Directorate (HCD), from 63 (2015) to 33 (2018) and 15 (2020) [6]. This was done in a bid to save reputation of Kenyan export produce at the expense of earnings of small-scale farmers. From 2014, Kenyan exports other than roses and *Capsicum* sp., which have been intercepted due to the presence of FCM, include million stars (*Gypsophila* sp., Caryophyllales: Caryophyllaceae), green corn, okra, carnations (*Dianthus* sp., Caryophyllales: Caryophyllaceae), custard apple (*Annona* sp., Magnoliales: Annonaceae), and eggplant (*Solanum melongena*, Solanales: Solanaceae) [12].

The economic impact of this pest is contingent on mitigation efforts undertaken by affected countries. If no mitigation measures are applied, severe consequences will continue to fall on *Capsicum* sp., as was witnessed in Ghana, for instance, where the EU Commission instituted a ban on *Capsicum* sp. imports from October 2015 to 2018 [3]. The value of *Capsicum* sp. produced in Kenya is currently estimated at USD 8.3 million [13]. The evocation of exporting licenses led to a shift in cultivation to other less risky horticultural crops, evidenced by the continuous reduction in the space under *Capsicum* sp. cultivation. Additionally, farmers have explored alternative Asian markets, which have lower returns to mitigate the oversupply caused by stringent EU markets conditions [6].

Several management approaches, including cultural (field sanitation and fruit bagging), chemical, and biological control have been implemented. Pesticides such as pyrethroids (cypermethrin; IRAC code 3:A), benzyl urea (triflumuron; IRAC code: 15), spinosyn group (spinetoram; IRAC code 5), and acetamiprid (IRAC code 4:A) have been applied for managing FCM [14]. Even though FCM resistance to chitin inhibitors has not been reported in Kenya, this cannot be ruled out as it has been reported in other countries [15]. Pesticide control faces complications due to requirements by the international markets to reduce pesticide use on fruits and vegetables [6].

Intercropping can be utilised as a push and pull measure to counter FCM. Ovipositional preference studies of FCM in Kenya showed that FCM's has strong ovipositional preference to oranges compared to sweet pepper, chili pepper, and eggplant [16]. Post-harvest treatments like irradiation and cold treatments are less common in developing countries, including Kenya, due to high costs. Although hot water treatment for bell pepper against FCM is effective, its limited use is attributed to associated costs [17–19]. Cold treatment has been shown to reduce the quality of *Capsicum* and fruits like citrus by inducing chilling injury if the period of exposure to these treatments is exceeded [20,21]. Djieto-Lordon et al. discovered that yellow pepper is more susceptible to FCM than red pepper in Cameroon [22]. However, breeding for resistance is time-consuming. Current synthetic chemical control practices are not affordable especially to smallholder farmers, leading to unsatisfactory results, as seen in the high interception rates of Kenyan horticultural produce. This necessitates a search for sustainable and effective management strategies for this pest. Gathering baseline information on farmers' knowledge, perceptions, and practices can provide lead ideas in the development of alternative management strategies. Farmers' knowledge and attitudes have been shown to have positive impact on the pesticide use behaviour and the usefulness of IPM strategies in managing production constraints [23].

Evaluation of farmers' knowledge, perceptions, and practices on crop pest is essential in development and sustainable use of new technologies [24]. However, no previous study has assessed these aspects of FCM in smallholder *Capsicum* cropping systems in Kenya. Involving farmers in the process of creating new technologies to tackle pest problems not only gives researchers a window to tap into local farmer expertise, but also speeds up the uptake of newly partnered technologies to manage pest problems [25]. This study, therefore, aimed at generating baseline information on FCM infestations in *Capsicum* cropping systems by investigating farmers' knowledge, perceptions, and current management practices in order to identify pest management challenges and intervention opportunities. We aimed at (1) assessing farmers' knowledge of FCM and identify critical knowledge gaps, (2) understanding farmers' perceptions of FCM in *Capsicum* production, and (3) assessing current FCM management practices and identify their challenges and opportunities to inform the development of a sustainable pest management strategy.

2. Materials and Methods

2.1. Study Sites

The study was conducted between April and September 2021 in ten counties covering the key *Capsicum*-sp.-growing agroecologies in Kenya (Figure 1). These were Kilifi (3°21″ to 3°50″ S and 39°12″ to 39°42″ E), Taita Taveta (3°10″ to 3°24″ S and 37°36″ to 37°48″E), Kitui (1°12″ to 1°24″ S and 37°04″ to 37°41″ E), Kirinyaga (0°36″ to 0°42″ E and

37°10″ to 37°22″ E), Kajiado (1°10″ to 3°03″ S and 36°15″ to 37°40″ E), Makueni (1°39″ to 2°20″ S and 37°38″ to 38°00″ E), Machakos (1°05″ to 1°30″ S and 37°14″ to 37°28″ E), Murang'a (0°56″ to 1°0″ S and 37°02″ to 37°11″ E), Nairobi (1°15″ to 1°16″ S and 36°42″ to 36°44″ E), and Kiambu (1°05″ to 1°15″ S and 36°04″ to 36°20″ E). These areas cut across the lowlands (Kilifi) with elevation of 0–800 m above sea level (asl) to lower midlands (Makueni, Machakos, Taita Taveta, Kitui, and Kirinyaga), with elevation of 801–1500 m asl to upper midlands (Murang'a and Kajiado), with elevation between 1501–1700 m asl and highlands (Kiambu and Nairobi), and with elevation of 1501–2200 m asl. These areas receive bi-modal rainfall with long rains experienced in March–May and short rains experienced from November to January. The primary cropping system in these counties comprises cereal crops intercropped with food legumes and *Capsicum* sp. *Capsicum* sp. was the main crop surveyed in this study which is cultivated in both the primary and minor seasons through rainfed agriculture and irrigation.

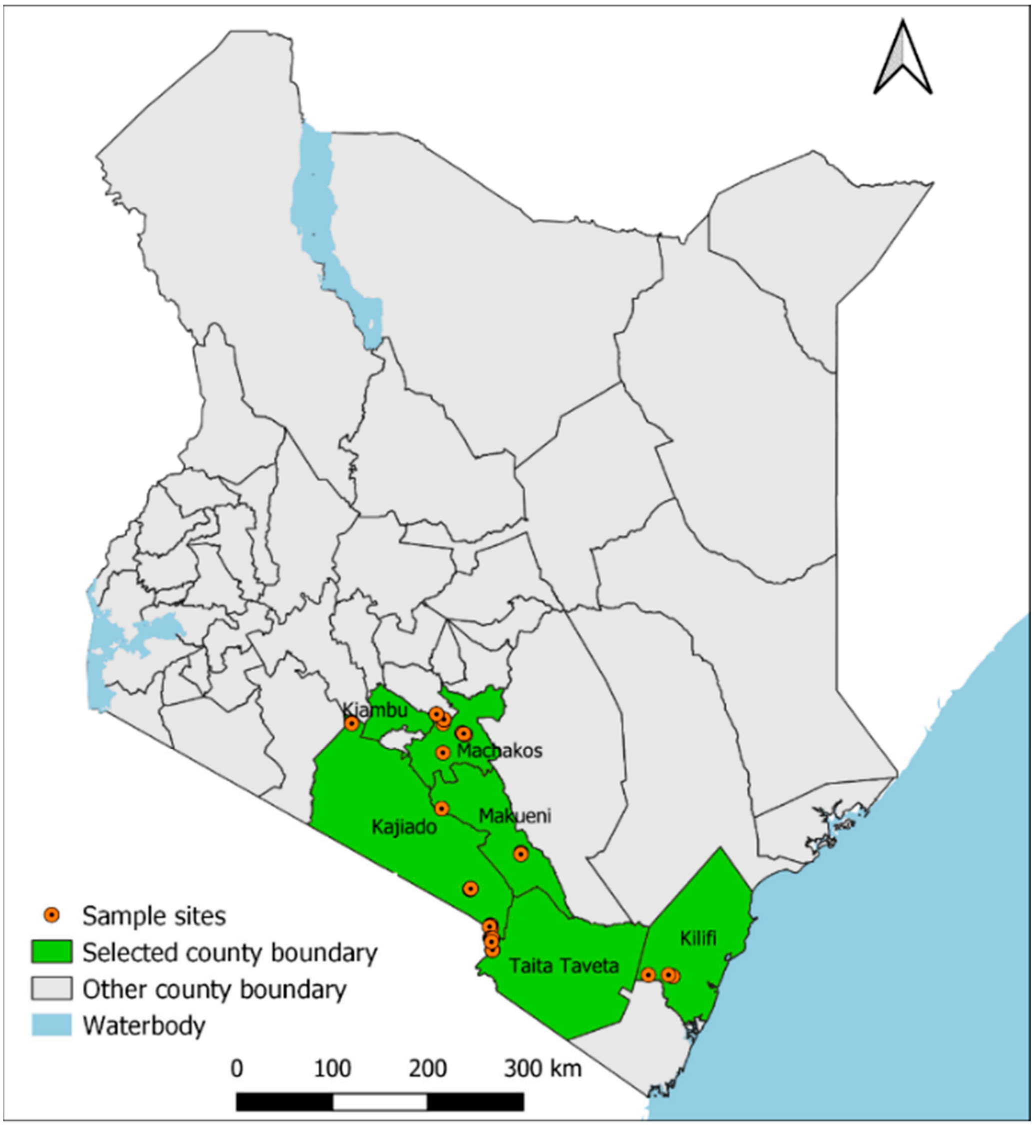

Figure 1. Kenyan map showing the study sites where surveys for the false codling moth were conducted.

2.2. Sampling Procedure

A multistage sampling procedure was used to select the area and farmers for the survey. A national stakeholders' workshop on FCM was held in August 2018 at Kenya Agricultural and Livestock Research Organization (KALRO) Katumani in Machakos County, bringing together research scientists, policymakers, farmer representatives, and agricultural extension service providers from counties. Severely affected counties were identified during the workshop, and a follow-up field survey was planned with *Capsicum* sp. as the focus crop. Within a county, different administrative wards were chosen for the survey based on the intensity of *Capsicum* sp. farming according to the records of the ministry of agriculture. Areas producing the crop were identified with the help of county agricultural officers. Afterwards, purposive sampling was done with the help of ward agricultural extension officers (WAEOs) and farmer group leaders to identify smallholder farmers growing *Capsicum* sp. for the survey. In all the counties visited, county agricultural officers (CAOs) and ward agricultural extension officers were interviewed as key informants. Farmer groups were identified with the help of WAEOs, and subsequent interviews were arranged to coincide with days in the week when they were conducting their group meetings.

2.3. Data Collection

Data were collected using quantitative and qualitative methods of farm-level cross-sectional surveys [26,27], which involved a combination of individual farmers and key informants' face-to-face interviews using a semi-structured questionnaire and focused group discussions. The combination of these methods of data collection was aimed at obtaining in-depth understanding of farmer knowledge, perspectives [28], and management practices of a *Capsicum* sp. crop, as well as its production constraints, particularly insect pests.

In total, 108 farmers were interviewed by the enumerators comprising a group of researchers who took part in the development of the questionnaire (supplementary material: Appendix). Farmer interviews were conducted with the help of local agricultural extension officers and farmer leaders who always accompanied the enumerators during the survey. Interviews with farmers took place on their farms to ascertain that the main crop grown was *Capsicum* sp. The geographical coordinates of each surveyed farm were recorded using a Global Positioning System (GPS) receiver. To avoid limiting farmers' responses, most of the questions were "open" ended [24]. The information collected included (i) farmer's socio-economic profile (age, gender, education level, household size, land size, and ownership); (ii) farm characteristics (farm size, crops grown, the area under food and cash crops, the target market and prices for cash crops, and yields); and (iii) production limitations (inputs, pests, loss attributed to pests, farmer's ability to identify FCM and its damage, FCM challenge, and control methods and their effectiveness). Other questions included farmers' awareness of horticultural crops export interceptions due to pests and pesticide residues, the role of extension and research services in combating pest problems, and the role of cultural practices like intercropping in tackling pest challenges. It took enumerators 30 to 45 min to administer one questionnaire.

In total, 20 key informants were interviewed. At least one ward extension officer (WEO) and one county crops officer were interviewed per county. This category is vital in FCM management, as it represents initiators and policy implementers at the ward, county, and national levels. In addition, they have frequent interaction with farmers and are aware of their perspectives and management efforts in pest management. Apart from policy implementation, this category interacts more often with most *Capsicum* sp. farmers either on their farms or agriculture offices compared to our interactions during the survey. They receive farmers' complaints regarding pests and diseases, and are responsible for advising farmers on the best possible mitigation measures. Extension officers are more aware of farmers' perspectives and current management efforts in managing pests. Data were collected using a semi-structured questionnaire by the same group of five researchers who carried farmers' interviews. Key issues captured in the questionnaire of the key informants' included: (i) awareness of FCM and ability to identify FCM in different stages, (ii) ability to scout for FCM, (iii) level of losses to farmers due to FCM and regions where prevalence and attacks of FCM are severe, (iv) range of crops affected and the damage thresh-old,

(v) if inspections are done to check FCM presence, (vi) whether efforts (policies) have been placed by counties to conduct field days for the education of farmers especially women and youth about FCM and if any mitigation efforts have been put in place to combat FCM at county agricultural level, and (vii) current management strategies to control key crop pests with more emphasis on FCM. It took key informants approximately 15–30 min to fill this questionnaire.

Ten focused group discussions (FGD) were carried out through organized community meetings, comprising one focused group discussion per county. Each focused group discussion was comprised of 18–34 farmers. The findings from the FGD survey were integrated with individual farmer interviews, for corroboration and supplementing farmer knowledge and perspectives [28]. The farmer groups were assembled with the help of WAEOs, ward-level government administration officials, and farmer group leaders. During the focused group discussion meetings, guiding questions were asked to initiate debate and generate information on the key aspects of *Capsicum* sp. farming. The discussions were guided using the semi-structured questionnaire (supplementary material: Appendix). Discussion covered key areas of *Capsicum* sp. production, its production constraints with a key focus on insect pests especially FCM, their management, and the challenges the respondents faced in controlling them.

2.4. Data Analyses

Survey data were analysed using descriptive statistics, including frequencies, means, tables, proportions, and percentages. Chi-square tests was used to analyse data on socio-demographic factors (such as gender, land ownership, and education level) and *Capsicum* agroecology variables (including the number of crops planted, irrigation vs. rainfed agriculture foe watering, and types of *Capsicum* sp. grown). Additionally, chi-square tests was also applied to analyse data on perceptions, awareness, cultural farming practices (such as intercropping), and current management methods (biological, cultural, and chemical) related to FCM, considering variations in regions, ages, gender, and educational level. Analysis of variance (ANOVA) using the F-test was used to analyse data on household size, age of respondents, *Capsicum* sp. prices, and land size across different agroecological zones. Multiple comparisons of means were made using Tukey HSD. Karl Pearson's coefficient of correlation (R) was used to check for relevant linear relationships between variables in *Capsicum* sp. agroecology. Ranks were assigned to key informants based on key identification efforts in place of differentiate the level of awareness and mitigation among key informants across the different surveyed counties. All data were analysed using Statistical Package for Social Sciences (SPSS) version 20. The level of significance was set at 95%.

3. Results

3.1. Socio-Demographic Profile of Respondents

The age of the respondents ranged from 19 to 75 years, with a mean age of 35.94 ± 10.68 (SD) years (Table 1). About 17.59% of the respondents were above 43 years, with the oldest being a 75-year-old male and the youngest was a 19-year-old lady. The 60th percentile of the ages of respondents fell in the 19–37 years age group, classified as youth. The age of the respondents differed across the agroecological zones with older farmers being found in the lowlands and low midlands compared to the upper midlands and highlands (Table 1). The majority of respondents were male (66.67%), as depicted in Table 1. There were significant differences on the spread of gender across the different agroecological regions, with more males dominating the highlands and low mid-lands, while females were more prevalent in the upper midlands. Most of the respondents (93.51%) had attained formal education and could identify FCM in the local dialect, Swahili, and English languages (Table 1). Almost one out of ten of the respondents (10.18%) had attained primary level education (eight years of basic education), over half (52.78%) had attained secondary education (twelve years of basic education), and nearly a third of the respondents (30.56%) had tertiary level education (post-secondary education). Only 6.48% of the respondents had not gone through any formal education. Education levels did not differ across the agroecological zones (Table 1).

Table 1. Social-economic characteristics of *Capsicum* sp. smallholder farmers interviewed during the survey for false codling moth infestation in three agroecological zones of Kenya.

Variable	Agroecological Zones: Lowlands and Lower Midlands N = 43	Upper Midlands N = 24	Highlands N = 41	Mean N = 108	Significance
Age (years)	40.31	33.70	32.73	35.94	*F* = 6.70, *df* = 2, *p* = 0.001
Gender (%)					
Male	81.40	37.50	68.29	66.67	X^2 = 14.42, *df* = 2, *p* = 0.001
Female	18.60	62.50	31.71	33.33	
Education level (%)					
Never attended	4.65	8.33	7.32	6.48	X^2 = 2.85, *df* = 6, *p* = 0.827
Primary	6.98	16.67	9.75	10.18	
Secondary	55.81	41.67	56.10	52.78	
Tertiary	32.56	33.33	26.83	30.56	
Household size	5.02	3.90	3.21	4.10	*F* = 3.50, *df* = 2, *p* = 0.030
Land ownership (%)					
Yes	67.44	62.50	34.15	53.70	X^2 = 10.32, *df* = 2, *p* = 0.006
No	32.56	37.50	65.85	46.30	

Household size ranged from 1–14 members, with an average mean size of four members (Table 1). The majority of the respondents interviewed (74.10%) had household sizes between four and seven members. Significantly, household size varied across the three agroecological zones, with larger sizes observed in lowlands and the low midlands zone (Table 1). Household size did not correlate with the land size held by respondents ($R = 0.07$, $p = 0.500$), but it did increased with the age of farmers ($R = 0.69$, $p < 0.001$). Therefore, the lowlands and lower midlands had significantly larger mean household sizes compared to the upper midland and the highlands (Table 1). More than half of the respondents (53.70%) owned their land, and land ownership differed significantly across respondents in different agroecological zones. A higher percentage of the respondents owned land in the lowlands and low midland areas compared to the high-land (Table 1).

3.2. *Capsicum* sp. *Agroecology*

The majority of the farmers (65.71%) interviewed practiced horticultural farming on an acre of land or less, with a mean land size of 2.94 acres. Land sizes under *Capsicum* sp. differed across agroecological zones, with smaller land sizes found in the highland areas ($R = 0.47$, $p < 0.001$, Table 2). Most *Capsicum* sp. farms (64.81%) depended on irrigation, while 35.19% of farmers were under rainfed production. Notably, bell pepper was mostly grown under irrigation, while chili pepper heavily depended on rainfed agriculture (Table 2). Approximately, (53.70%) of *Capsicum* sp. farmers owned their land, while the remainder leased it. A higher proportion of land lessees were found in the highland zone. Leasing rates of land differed across the regions, with the highlands having rates as high as USD 800 per acre per year, inclusive of the irrigation system. In the lowlands, lower mid-lands, and upper mid-lands, leasing rates ranged from USD 100–300 per acre per year, excluding the irrigation system. Due to irrigation being part of the leasing cost in the highlands, 82.93% of farms in this region were under irrigation. In the upper midlands, 70.83% were under irrigation; this figure was largely contributed by Kajiado County (Kimana and Rombo Wards), where *Capsicum* sp. farming took place under irrigation schemes with underground water outlets. The lowlands and lower midlands had only 44.19% of farms under irrigation. This region had a larger proportion of chili pepper compared to bell pepper (Table 2). Chili pepper, being a perennial crop with fewer agronomic requirements, was grown alongside other crops by 57.41% of farmers, while only 42.59% cultivated *Capsicum* sp. as monocultures (Table 2). Some chili crops were as old as seven years, yet these plantations were poorly managed, characterized by weeds and plants infested with pests and diseases, leading to fruit deformation.

Table 2. *Capsicum* sp. agroecology in surveyed smallholder farms across three agroecological zones in Kenya.

	Agroecological Zones				
Variable	**Lowlands and Low Midlands N = 43**	**Upper Midlands N = 24**	**Highlands N = 41**	**Mean N = 108**	**Significance**
Land size (Acres)	4.94	3.42	0.62	2.93	$F = 2.10$, $df = 2$, $p = 0.100$
Mode of watering (%)					
Rainfed	55.81	29.17	17.07	35.19	$X^2 = 14.30$, $df = 2$, $p = 0.001$
Irrigation	44.19	70.83	82.93	64.81	
Number of crops (%)					
1 (*Capsicum* sp. only)	39.54	50.00	41.50	42.59	
2	18.60	25.00	26.80	23.15	$X^2 = 2.90$, $df = 6$, $p = 0.822$
3	30.23	16.67	19.50	23.15	
≥4	11.63	8.33	12.20	11.11	
Type of *Capsicum* sp. grown (%)					
Hot chili	34.88	25.00	7.31	22.22	$X^2 = 11.21$, $df = 4$, $p = 0.024$
Bell pepper	46.51	50.00	75.61	58.33	
Hot chili and bell pepper	18.61	25.00	17.08	19.45	
Price bell pepper (USD/Kg)	0.85	0.78	0.80	0.82	$F = 1.50$, $df = 2$, $p = 0.200$
Price chili pepper (USD/Kg)	0.64	0.58	0.60	0.61	$F = 1.80$, $df = 2$, $p = 0.200$
	Mode of water supply				
	Rainfed N = 38	Irrigation N = 70		Mean N = 108	
Hot chili	42.11	11.43		22.22	$X^2 = 15.15$, $df = 2$, $p = 0.001$
Bell pepper	36.84	70.00		58.33	
Hot chili and bell pepper	21.05	18.57		19.45	

The *Capsicum* sp. agroecology surveyed revealed the cultivation of various main food crops, including maize (*Zea mays* L., Poales: Poaceae), common beans (*Phaseolus vulgaris*, Fabales: Fabaceae), *Dolichos lablab* (Fabales: Fabaceae), millet (*Pennisetum glaucum*, Poales: Poaceae), sorghum (*Sorghum bicolor*, Poales: Poaceae), cowpea (*Vigna unguiculata*, Fabales: Fabaceae), pigeon pea (*Cajanus cajan*, Fabales: Fabaceae), and vegetables such as kales (*Brassica oleracea var. viridis*, Brassicales: Brassicaceae), cabbage (*Brassica oleracea*, Brassicales: Brassicaceae), spinach (*Spinacia oleracea Caryophyllales*: Amaran-thaceae), indigenous vegetables like amaranths (*Amaranthus viridis*, Caryopyllales: Amaranthaceae), spider plant (*Cleome gynandra*, Asparagales: Asparagaceae), black nightshade (*Solanum nigrum*, Solanales: Solanaceae), and bananas (*Musa paradisiaca*, Zingibarales: Musaceae). Other horticultural crops grown alongside *Capsicum* included mangoes (*Mangifera indica*, Sapindales: Anacardiaceae), cashew nuts (*Anacardium occidentale*, Sapindales: Anacardiaceae), avocado (*Persea americana*, Laurales: Lauraceae), okra (*Abelmoschus esculentus*, Malvales: Malvaceae), eggplant (*Solanum melongena*, Solanales: Solanaceae), beetroot (*Beta vulgaris*, Caryophallales: Chenopodiaceae), courgettes (*Cucurbita pepo*, Cucurbitales: Cucurbitaceae), watermelon (*Citrullus lanatus*, Cucurbitales: Cucurbitaceae), oranges (*Citrus sinensis*, Sapindales: Rutaceae), lime (*Citrus aurantiifolia*, Sapindales: Rutaceae), butternut (*Cucurbita moschata*, Fagales: Juglandaceae), cucumber (*Cucumis sativus*, Cucur-bitales: Cucurbitaceae), coriander (*Coriandrum sativum*, Apiales: Apiaceae), green maize (*Zea mays* L., Poales:

Poaceae), pawpaw (*Carica papaya*, Brassicales: Caricaceae), French beans (*Phaseolus vulgaris*, Fabales: Fabaceae), custard apple (*Psidium guajava*, Magnoliales: Annonaceae), onion (*Allium cepa*, Asparagales: Amaryllidaceae), tomatoes (*Solanum lycopersicum*, Solanales: Solanaceae), thyme (*Thymus vulgaris*, Lamiales: Lamiaceae), oregano (*Origanum vulgare*, Lamiales: Lamiaceae), starflower (*Trientalis borealis*, Asperagales: Liliaceae), lettuce (*Lactuca sativa*, Asterales: Asteraceae), coconut (*Cocos nucifera*, Aracales: Aracaceae), rockets (*Eruca vesicaria*, Brassicales: Brassicaceae), and red cabbage (*Brassica oleracea var*. *capitata f. rubra*, Brassicales: Brassicaceae).

The mean price and modal price range of bell pepper was USD 0.8 ± 0.2 per kg, while that of chili pepper was USD 0.60 ± 0.30 per kg. However, bell pepper rice exhibited significant variation, ranging from as low as USD 0.30 per kg to as high as USD 1.30 per kg, depending on seasons, farmer marketing channels like forward contracting to supply hospitality sectors, contract farming with well-established intermediaries like supermarkets and exporters, and the variety of *Capsicum* sp. grown (yellow varieties fetch a market price of up USD 1.30 per kg). The demand for bell pepper remained consistently high throughout the year compared to chili pepper, leading some chili farmers to sell for as low as USD 0.10 in Kajiado County to prevent overgrowth. The price of bullet chili and Habanero chili fetched as high as USD 1.20 per kg.

3.3. Farmer Awareness, Perception, and Experience of False Codling Moth

The majority of interviewed farmers (83.33%) were aware of false codling moth (FCM) across the three agroecological zones and acknowledged the presence of the pest in either bell pepper or chilies (Table 3). They described the pest as "kiwiliwili", a Swahili term for caterpillar, noting that its mother usually operates at night and prefers to hide in weedy places. Farmers acknowledged flying activities of adult moths, mainly observed from late evening to late in the night. The shape of this moth was likened to diamondback moth (*Plutella xylostella*) by most of the farmers. Over three quarters (76.85%) of the respondents interviewed reported a 20–30% harvest loss due to FCM. These losses were due to unmarketable quality resulting from shape deformation and excessive fruit drop at early stages.

A majority of farmers (60.19%) believed that hot weather favours pest multiplication. According to them, hatching is almost 100.00% during the hot dry season. However, a few (28.70%) were of a different opinion, according to them pest multiplication is favourable during the wet rainy season due to food abundance. A smaller percentage (11.11%) alleged that the pest population is higher during both the rainy and hot seasons, making pest populations challenging to control due to quicker multiplication of insect populations (Table 3).

The awareness of FCM varied based on farmers educational level (X^2 = 15.66, df = 8, p = 0.001). While 83.33% of the respondents were aware of FCM, more than half (57.14%) of those without formal education were unaware of FCM, as opposed to all (100.00%) farmers who with tertiary education and could identify the pest. There were no differences in the awareness of FCM based on gender (X^2 = 0.30, df = 1, p = 0.585) or age bracket (X^2 = 2.64, df = 4, p = 0.621). However, the mean age of males (M = 37.50, SD = 11.10) was slightly high compared to females (M = 32.70, SD = 9.20), and this gender age difference was significant (t (106) = 2.20, p = 0.028). Only 46.30% of the farmers were aware of the minimum pesticide residue level requirements in international markets, and this lack of awareness was not influenced by locality of the farmer or gender.

Almost all farmers (99.07%) applied synthetic chemical insecticides to control FCM in their *Capsicum* sp. crops (Table 4a). The application of insecticide did not significantly differ across agroecological zones (Table 4a). More than half of the farmers interviewed (60.19%) solely relied on synthetic chemical insecticides for FCM control, neglecting other pest management strategies, including integrated pest management practices. Among the 107 farmers applying insecticide sprays, most of them did not give a good scoring on its effectiveness. Out of score rating of 5 (1 = ineffective, 2 = less effective, 3 = moderately effective, 4 = effective, 5 = very effective), only 11.21% gave a rating of 4–5, while the rest, 88.79%, gave a rating of between 1–3 indicating that chemical insecticide sprays were not delivering the expected results (Table 4a). Even though most farmers, 99.07%, were applying pesticides, only 29.90% used personal protective equipment's (PPEs) on a regular basis or always, while almost four out of ten (42.06%) hardly used PPEs, and 28.04% said they have never used any PPE while applying pesticides. More than a third of the surveyed farmers (39.81%) were using other pest management strategies, such as field sanitation and biological methods (like biopesticides), simultaneously.

Table 3. Smallholder *Capsicum* sp. farmers' awareness of false codling moth across gender, educational level, and age in three agroecological zones in Kenya.

Variables	**Agroecological Zones**						
	Lowlands and Low Midlands N = 43		**Upper Midlands N = 24**		**Highlands N = 41**	**Mean N = 108**	**Significance**
False codling moth infestations awareness (%)							
Yes	90.70		87.50		73.17	83.33	$X^2 = 5.03$, $df = 2$, $p = 0.081$
No	9.30		12.50		26.83	16.67	
False codling moth infestation awareness (%)	Gender						
	Male N = 72			Female N = 36		Mean N = 108	$X^2 = 1.20$, $df = 1$, $p = 0.300$
Yes	86.11			77.78		83.33	
No	13.89			22.22		16.67	
False codling moth infestation awareness (%)	Education level						
	Never attended school N = 7	Primary N = 11	Secondary N = 57		Tertiary N = 33	Mean N = 108	$X^2 = 15.66$, $df = 3$, $p = 0.001$
Yes	42.86	81.82	78.94		100.00	83.33	
No	57.14	18.18	21.06		0.00	16.67	
False codling moth infestation awareness (%)	Age (years) of respondents						
	(19–24) N = 22	(25–31) N = 15	(32–37) N = 28	(38–43) N = 24	(≥44) N = 19	Mean N = 108	$X^2 = 2.64$, $df = 4$, $p = 0.621$
Yes	77.27	93.33	78.57	83.33	89.47	83.30	
No	22.73	6.67	21.43	16.67	10.53	16.70	
Seasonal variation of false codling moth population (%)							
Hot dry season	67.44		54.17		56.10	60.19	
Rainy season	25.58		29.17		31.70	28.70	$X^2 = 2.28$, $df = 4$, $p = 0.684$
Both seasons	6.98		16.66		12.20	11.11	
Aware of minimum pesticide residues requirements (%)							$X^2 = 1.77$, $df = 2$, $p = 0.413$
Yes	53.49		45.83		39.02	46.30	
No	46.51		54.17		60.98	53.70	
Aware of minimum pesticide residue requirements (%)	Gender						
	Male N = 72			Female N = 36		Mean N = 108	$X^2 = 0.30$, $df = 1$, $p = 0.585$
Yes	44.44			50.00		46.30	
No	56.56			50.00		53.70	
Awareness of minimum pesticide residue requirements (%)	Education Level						
	Never attended school N = 7	Primary N = 11	Secondary N = 57		Tertiary N = 33	Mean N = 108	$X^2 = 4.60$, $df = 3$, $p = 0.200$
Yes	14.29	63.64	49.12		42.42	46.30	
No	85.71	36.36	50.88		57.58	53.70	

Table 4. (**a**) Current false codling moth management strategies in smallholder *Capsicum* sp. farms utilizing pesticides and integrated pest management across three agroecological zones in Kenya. (**b**) False codling moth management strategies in smallholder Capsicum sp. farms using intercropping across education level, awareness to pesticide residue requirements, gender, and three agroecological zones in Kenya.

(a)

Variable	**Agroecological Zones**					
	Lowlands and Low Midlands N = 43	**Upper Midlands N = 24**	**Highlands N = 41**		**Mean N = 108**	**Significance**
Synthetic pesticides (%)						X^2 = 1.65, *df* = 2, p = 0.438
Yes	100.00	100.00	97.56		99.07	
No	0.00	0.00	2.44		0.93	
Pesticides efficacy (%)	Lowlands and low midlands N = 43	Upper midlands N = 24	Highlands N = 40		Mean N = 107	X^2 = 7.02, *df* = 8, p = 0.535
Ineffective	9.30	12.50	12.50		11.21	
Less effective	48.84	50.00	65.00		55.14	
Moderately effective	27.91	20.83	17.50		22.43	
Effective	9.30	4.17	2.50		5.61	
Very effective	4.65	12.50	2.50		5.61	
Protective usage (%)	Lowlands and low midlands N = 43	Upper midlands N = 24	Highlands N = 40		Mean N = 107	X^2 = 2.82, *df* = 6, p = 0.831
Never	25.58	25.00	32.50		28.04	
At times	44.18	45.83	37.50		42.06	
Regularly	16.29	25.00	20.00		19.63	
Always	13.95	4.17	10.00		10.27	
Integrated pest management (IPM) (%)	Lowlands and low midlands N = 43	Upper midlands N = 24	Highlands N = 41		Mean N = 108	X^2 = 4.31, *df* = 2, p = 0.116
Yes	27.90	50.00	46.34		39.81	
No	72.10	50.00	53.66		60.19	
IPM efficacy (%)	Lowlands and low midlands N = 12	Upper midlands N = 12	Highlands N = 19		Mean N = 43	X^2 = 8.95, *df* = 8, p = 0.346
Ineffective	0.00	8.33	21.05		11.63	
Less effective	16.67	0.00	10.53		9.30	
Moderately effective	25.00	41.67	10.53		23.26	
Effective	33.33	25.00	42.10		34.88	
Very effective	25.00	25.00	15.79		20.93	
Efficacy (%)	IPM N = 43		Sprays N = 107		Mean N = 150	X^2 = 41.34, *df* = 4, p < 0.001
Ineffective	11.63		11.22		11.33	
Less effective	9.30		55.14		42.00	
Moderately effective	23.26		22.42		22.67	
Effective	34.88		5.61		14.00	
Very effective	20.93		5.61		10.00	
	Education Level					
IPM (%)	Never N = 7	Primary N = 11	Secondary N = 57	Tertiary N = 33	Mean N = 108	X^2 = 5.16, *df* = 3, p = 0.160
Yes	42.86	54.55	45.61	24.24	39.81	
No	57.14	45.45	54.39	75.76	60.19	
	Awareness of pesticide residue requirements					
IPM (%)	Aware N = 43		Unaware N = 65		Mean N = 108	X^2 = 12.85, *df* = 1, p < 0.001
Yes	67.44		32.31		39.81	
No	32.56		67.69		60.19	

Table 4. *Cont.*

(a)

Variable	**Agroecological Zones**				
	Lowlands and Low Midlands N = 43	**Upper Midlands N = 24**	**Highlands N = 41**	**Mean N = 108**	**Significance**
	Gender				
IPM (%)	Male N = 72		Female N = 36	Mean N = 108	$X^2 = 5.58$, $df = 1$, $p = 0.018$
Yes	31.94		55.56	39.81	
No	68.06		44.44	60.19	

(b)

	Agroecological Zones					
Intercropping (%)	Lowlands and low midlands N = 43	Upper midlands N = 24	Highlands N = 41		Mean N = 108	$X^2 = 0.27$, $df = 2$, $p = 0.872$
Yes	20.93	16.67	22.22		20.37	
No	79.07	83.33	77.78		79.63	
	Education Level					
Intercropping (%)	Never N = 7	Primary N = 11	Secondary N = 57	Tertiary N = 33	Mean N = 108	$X^2 = 3.33$, $df = 3$, $p = 0.343$
Yes	28.57	0.00	22.81	21.21	20.37	
No	71.43	100.00	77.19	78.79	79.63	
	Awareness of pesticide residue requirements					
Intercropping (%)	Aware N = 43		Unaware N = 65		Mean N = 108	$X^2 = 0.74$, $df = 1$, $p = 0.390$
Yes	16.28		23.07		20.37	
No	83.72		76.93		79.63	
	Gender					
Intercropping (%)	Male N = 72		Female N = 36		Mean N = 108	$X^2 = 0.03$, $df = 1$, $p = 0.866$
Yes	20.83		19.44		20.37	
No	79.17		80.56		79.63	

In contrast to synthetic chemical pesticides, 24 farmers, representing 55.81% of those using both pesticides and other integrated pest management strategies (such as crop rotation, yellow sticky traps for thrips control, and general use of botanicals like neem extracts and intercropping; Table 4b) rated integrated pest management strategies as more effective than using pesticide alone. Influential factors in the adoption of integrated pest-management strategies included gender ($X^2 = 5.58$, $df = 1$, $p = 0.018$) and awareness of pesticide residue requirements in international markets ($X^2 = 12.85$, $df = 1$, $p = < 0.001$).

3.4. Key Informants' Meetings and Interviews

All the key informants were aware of FCM and its damage on a variety of crops (Table 5). The majority of the key informants (80.00%) struggled to identify adult features of FCM, such as fringed wings or the moth's size, occasionally confusing it with e other moth pests like *Tuta absoluta* and diamondback moths. However, they could easily identify the dark brown to pink colouration of the FCM larvae. Only Kajiado and Machakos counties had deployed traps as a scouting tool for FCM, mainly in rose farms and a few *Capsicum* sp. farms doing export business (Table 5). This trapping activity was performed by the extension officers, not farmers themselves, indicating a gap in FCM knowledge among *Capsicum* farmers who were not actively scouting for the pest. Key informants from Machakos, Kajiado, and Nairobi reported the pest to be widely spread, primarily in riverine areas, while for Kitui and Makueni (lower midlands), FCM was considered seasonal and not widespread, with its effects predominantly felt during the hot season. Only three extension officers from Kajiado, Nairobi, and Machakos conducted field surveys and plant clinics to inspect FCM in smallholder farms.

Table 5. Ability of Key informants in Kenyan counties to identify false codling moth.

County	Based on Damages	As Caterpillar on Produce	As Adults Using Traps/Scouting	On Citruses, Oranges, Avocado, Mango, Macadamia.	On *Capsicum* sp. and Vegetables	On Inspection & Scouting Done on Plant Clinics	By Efforts Placed for Policy Action	Outcry from Farmer Due to False Codling Moth (FCM)	Cultural/Biological in Addition to Pesticides (No = Pesticides Only)	Ranking of Awareness & Mitigation Yes 7–9 = High Yes 5–6 = Mid Yes 0–4 = Low
Nairobi	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	High
Kilifi	Yes	Yes	No	Yes	No	No	No	No	Yes	Low
Murang'a	Yes	Yes	No	Yes	No	No	No	No	Yes	Low
Kajiado	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	High
Taita-Taveta	Yes	Yes	No	Yes	Yes	No	No	No	No	Low
Kiambu	Yes	Yes	No	Yes	No	No	No	No	Yes	Low
Kirinyaga	Yes	Yes	No	Yes	No	No	No	No	No	Low
Kitui	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Medium
Machakos	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	High
Makueni	Yes	Yes	No	Yes	No	No	No	Yes	No	Low

The discussion with key informants and field assessment reports by the county agricultural officials revealed high incidents of FCM reported by farmers in Nairobi, Kajiado, Kitui, Machakos, and Makueni counties. In contrast, key informants from Kilifi, Taita Taveta, Muranga, Kirinyaga, and Kiambu reported that they had not received reports of FCM from farmers, suggesting it might be a problem not yet detected in Capsicum. These counties reported being affected by other pests like thrips and fall armyworm, emphasizing that FCM had not attracted attention and policy need compared to other pests mentioned above. Only ten key informants from five counties (Kajiado, Nairobi, Kitui, Machakos, and Makueni) reported detecting larvae of FCM on *Capsicum*. The rest of the key informants said that they have never found FCM larvae on *Capsicum* and other vegetables, but it was instead spotted in fruits. All key informants had encountered FCM larvae on different fruits and vegetables: oranges (*Citrus sinensis*, Sapindales: Rutaceae), avocadoes (*Persea americana*, Laurales: Lauraceae), macadamia (*Macadamia* spp., Proteales: Proteaceae), mangoes (*Mangifera indica*, Sapindales: Anacardiaceae), lemons (*Citrus limon*, Sapindales: Rutaceae), guavas (*Psidium guajava*, Myrtales: Myrtaceae), cashew nuts (*Anacardium occidentale*, Sapindales: Anacardiaceae), eggplant (*Solanum melongena*, Sola-nales: Solanaceae), okra (*Abelmoschus esculentus*, Malvales: Malvaceae), cucumber (*Cucumis sativus*, Cucurbitales: Cucurbitaceae), and courgettes (*Cucurbita pepo*, Cucurbitales: Cucurbitaceae) (Table 5). There were numerous mentions of damages and rejection of roses (*Rosa* sp., Rosales: Rosaceae) from the Athi river in Machakos and Kajiado counties that were exported to the EU. Most officers reported 30–50% losses due to quality issues and rejection of produce in the international export market. Key informants from Murang'a, Kilifi, Kitui, and Kiambu reported that farmers were applying IPM methods like crop rotation, the use of botanical sprays like neem, and sanitation practices like regular weeding, as confirmed by WAEOs of Taita-Taveta and Kajiado counties. It was reported that farmers sourced most of their pesticides from neighbouring Tanzania, and FCM had not attracted intervention action from county government.

4. Discussion

Most respondents, including both farmers (83.33%) and key informants, were aware of FCM and its negative impacts on the *Capsicum* sp. and other crops. They reported losses occasioned by this pest, leading to lower fruit quality and the unmarketability of infected fruit. However, when questioned about FCM at different life stages, the majority of the farmers (83.33%) and key informants (80.00%) did not know features that differentiate FCM from other moths. Farmers would rely mostly on the damage inflicted on the fruit and the colour of the larvae to identify FCM pest and differentiate it from other moth pests. Smallholder farmers have been reported to have difficulties in pest recognition and understanding pest ecology [29,30] with similar results reported from Benin, where farmers used descriptive rather than specific names of pests [31]. Such lack of knowledge on pest identification among farmers emphasizes the need for training that would enable them to understand the biology and behaviour of key pests and allow them to effectively manage the pests. Farmers knowledge on FCM was positively influenced by their education level, as all farmers who had attained tertiary level education were aware of FCM. Farmers ability to read and access agricultural information from extension service brochures contributed to increased awareness of FCM among this group. Access to agricultural information by farmers has been noted in many studies to be one of the keys to improve farmers' awareness of farm production challenges, including pests, and helps build famers' confidence in decision-making to tackle such production constraints [32]. Farmer's awareness of FCM was not influenced by gender and age. However, the study had more men compared to women participants. In sub-Saharan Africa, it is common that women are predominantly involved in farming activities, especially subsistence farming, even though men act as household heads and are most likely the respondents of studies such as this. Due to continual farming activities, women acquire experience and are more familiar with farm occurrences, as opposed to their male counterparts who are generally engaged more in offfarm activities. Age is more often negatively correlated with literacy levels in sub-Saharan Africa [33], and most elderly farmers are rated as illiterate while young ones are rated as literate. Because most of the respondents in this survey were literate, age thus did not influence the awareness of FCM moth.

All farmers who participated in the survey, irrespective of age, education level, and gender, cultivated *Capsicum* sp. The majority of the farmers had formal education, and, therefore, opinions regarding different pests in their farms were not likely influenced by different levels of education across different agro-ecologies. Most farmers interviewed were typically smallholders, with an average landholding size of 2.93 acres. More men participated in *Capsicum* sp. farming compared to women. This finding could be attributed to several factors like land ownership, risk-aversion, and a lower likelihood to lease land. The majority of all women involved in *Capsicum* sp. farming were landowners emanating from Kiambu. Of the 36 females interviewed, the majority, 72.2%, are landowners, and only ten (27.8%) utilize the lands under lease agreements. Women contributed only 17.2% of total land leased compared to men, who formed 82.7%; this difference was significant (X^2 = 4.67, df = 1, p = 0.031). Ownership and access to land are key factors influencing women's role in agriculture [34]. Additionally, most communities in Kenya are patriarchal, and most females do not inherit land from their parents, unlike their male relatives. This fact also explains the low land ownership among females [35]. The horticultural industry is capital intensive, and prices of agricultural produce fluctuate remarkably, especially for farmers not involved in contract farming, as was the case in the study areas. Most of the youths (19–37 years) involved in horticulture had completed college training, with some specializing in agriculture and opting for self-employment. While 47.60% of youth owned the land they farmed, irrespective of their gender, the remaining 52.30% leased land. Thus, land ownership was not a hindering factor for horticultural farming among the youth. The new trend of youths in horticulture can be attributed to the lack of white-collar jobs in Kenya, with the unemployment rate reaching a peak of 67% among the youth [36].

Most farmers had mixed cropping systems where they grew one or more crops on their farms in addition to *Capsicum* sp. for their subsistence needs. Although the majority of these crops grown alongside *Capsicum* sp. are also hosts of FCM, the authors are of the opinion that the non-host intercrops, especially those with insect-repellence properties, can be used as intercrops with the *Capsicum* sp. to help manage the pest. Crafting such intercropping systems by combining those crops with FCM repellence and attraction among the ones farmers are already intercropping with *Capsicum* sp., or finding new ones with economic value to farmers, can be an acceptable and sustainable strategy to manage FCM, since most *Capsicum* sp. farmers are already practising intercropping as a common cropping system. Indeed, such intercropping strategies have been developed and successfully used in other cropping systems such as cereals (maize and sorghum) to manage lepidopteran pests, including stemborers (*Chilo partellus*, Lepidotera: Crambidae.) and fall armyworm (*Spodoptera frugiperda*: Lepidoptera: Noctuidae) [37–39]. Based on our on-farm sampling, there were varietal differences concerning the FCM infestations in different *Capsicum* sp. varieties. African bird's eye (ABE) chillies (*Capsicum frutescens*) were least affected by FCM compared to other varieties. The farmers interviewed also confirmed this observation. This observation can provide an opportunity for seed breeders to breed for FCM resistance by isolating the genes of interest from the *C. frutescens* chillies and introgressing them in susceptible varieties for use as FCM management strategy. These genes can be crossed with other close relatives like bell pepper (*C. annuum*), which were more susceptible to induce tolerance. Breeding for resistance by crossing susceptible crops with a resistant close relative has been pointed out as one of the sustainable and cost-effective pest management strategies in the long run [22,40].

Current management strategies are mainly synthetic chemical control using pesticides and physical protection utilizing greenhouses. These methods are not sustainable and cost-effective for smallholder farmers, necessitating the need to develop affordable management strategies that resource poor farmers can utilise. Additionally, detection of presence and damage caused by FCM on *Capsicum* sp. and other fruit crops is not easy. Farmers are not aware of the pest activities in the fields until they notice FCM characteristic exit holes in their produce or when their produce is rejected at exit points during phytosanitary inspections or after it has been intercepted at international market destinations [6]. This fact is aggravated by nocturnal behaviour of the adult moths and internal feeding of the larvae, and it is challenging to detect oviposition sites on fruit. Scouting thus plays a pivotal role in the management of this pest.

Although a high number (99.07%) of the farmers reported using synthetic chemical control means to manage FCM, they reported that this was not effective in managing the pest populations. In addition, it was costly and reduced their profit margins. To reduce cost on pesticides, farmers in counties neighbouring Tanzania, such as Taita Taveta and Kajiado, were procuring pesticides from Tanzania, which are cheaper, but some are banned or restricted for use in Kenya. Such chemical pesticides sourced from Tanzania include insect nerve chloride antagonist pesticide Thiodan© (hexachlorohexa-hydromethano-2,4,3-benzodioxathiepin 3-oxide, IRAC code 2:A), multisite fungicide Nordox© (cuprous oxide, FRAC code M:1), nerve receptor disruptor pesticide Confidor© (imidacloprid, IRAC code 4:A), Demethylation inhibitor fungicide triflumizole© (carbox-amidine, FRAC code G:1), quinone outside inhibitor fungicide linuron© (3(3,4-dichlrophenyl)-1-methoxy-1-methylurea, FRAC code C:3), melanin biosynthesis inhibitor fungicide carbosulfan© (1-benzofuran, FRAC code I:1), insect enzyme inhibitor Profecron© (profenofos 40% + cypermethrin 4%), and IRAC Code 1:A insect enzyme inhibitor Furdan© (Carbofuran, IRAC code 1:A). Cross-border trade in agricultural synthetic chemical pesticides is a common phenomenon among Kenya and her neighbours [41]. Some compounds easily sourced from Tanzania, like Carbofuran, have restricted use in Kenya, and it poses a danger to deteriorating standards set by Kenya's agrochemicals regulator.

Farmers also cited pest resistance, high population density of FCM hiding during the day, and laying eggs at night as additional reasons for the pesticide's ineffectiveness against FCM. The number of *Capsicum* sp. growers in the visited areas had drastically reduced as noted in the farmers' interviews due to FCM emergency as a major pest of *Capsicum* sp. This observation corroborated a KEPHIS report from 2015, which noted reduction of *Capsicum* sp. growers due to FCM menace. Moreover, farmers also noted the hazardous effect of these pesticides to themselves and the environment. We found that women were hardly taking part in pesticide application from our interactions with farmers. A woman farmer disclosed that she had to pay men to assist her with synthetic chemical pesticide application in her *Capsicum* sp. fields. She explained that the men she hired to spray never used personal protective equipment (PPE) when spraying, despite the risks, which can be attributed to lack of PPE or awareness of the harmful effects of direct contact of pesticides with the body. Indeed, pesticide contamination and poisoning in smallholder vegetable producers has been reported in sub-Saharan Africa due to the exposure during the pesticide application [42–45].

Integrated pest management approaches for FCM among the interviewed farmers were not commonly adopted, with only 39.81% of the interviewed farmers integrated chemical control with other pest control methods, including biological control methods such as the use of natural enemies like parasitoids, predators, and biopesticides. Six out of ten farmers (60.19%) were not interested in using IPM strategy for the FCM management. They gave varying reasons regarding IPM use, including lack of awareness of the available IPM methods as well as their efficacy in controlling the FCM pest compared to the synthetic chemical pesticide applications, which give instant results when applied in infested farms, especially when they find the larvae on the fruits or for the other insect pests that feed on the surface of the crop plants. Most farmers were sceptical of some of the biological control products that are just brought to them by researchers without the farmers themselves participating in their trials, especially in on-farm trials for the farmers to crosscheck their performance in their farms. Others believed that biologicals were less effective as they had proven their results in their farms, which could be attributed to wrong dosage or application rate, as most farmers indicated that they did not follow the manufacturers' instructions to save on the costs. Of these respondents, many had not repeated the application exercise through consecutive cropping seasons and checked for improvements in performance in proceeding seasons. However, synthetic chemical pesticide effects do not last for long, as pest build-up takes place after some weeks or months. Biologicals have proven to be effective for suppression of moths after long periods of their application, but their effect is manifested in the long run. However, most farmers are unwilling to be patient for this extended period [46,47].

Although IPM is a holistic pest management strategy comprising various aspects, including nature-based solutions like use of natural enemies, cultural methods such as field sanitation [25], pest scouting and monitoring, setting up economic threshold numbers and applying synthetic chemical pesticides only when necessary, few farmers adopted this strategy for managing FCM in *Capsicum* sp. production. None of the farms visited could reach all these parameters; not even one farm had a simple light trap for pest monitoring. Awareness of international market requirements on pesticide residues and gender were factors influencing the adoption of IPM where more women adopted IPM compared to that of men. *Capsicum* sp. farmers growing for the export market, whose produce had been intercepted, were keen not to make such losses, and were willing to try IPM pest-management methods to reduce pesticide residues on their crops. More than half of all females (55.56%) were under IPM, compared to 31.94% of all males under the same category. This difference in application of IPM across gender was found to be significant. Since women are the ones mostly involved with farm activities in sub-Saharan Africa [48,49], their experience acquired over farming with different pest-management strategies makes them more aware of the effective pest-management strategies [32]. Combining these IPM strategies with other agroecological-based approaches can offer a sustainable way of *Capsicum* sp. production. Indeed, agroecological approaches have been shown to improve food security, nutrition, and food safety [50].

5. Conclusions

It was evident that most farmers could readily identify the FCM pest directly on their crops as a caterpillar or identifying it based on the damage it causes, such as excessive fruit drops and exit holes on fruit. However, a larger number of farmers and extension officers could not identify and describe adult moth features pointing to the need to build the capacity of farmers and agriculture extension officers to be able to detect and monitor this pest. Management strategies currently employed by farmers to deal with FCM mainly physical protection measures, such as utilizing greenhouses and synthetic chemical insecticide applications. However, these methods are not sustainable and cost-effective for smallholder farmers. Hence, there is a pressing need to develop management strategies that are sustainable and affordable for resource-poor smallholder *Capsicum* sp. farmers, leveraging some of the farmer practices, like intercropping. Scouting and monitoring of FCM activities was lacking for all farmers and most key informants. There is an urgent need to educate farmers and key informants on the available options to monitor pests, including the use of light and pheromone traps. African bird's eye (ABE) chillies (*Capsicum frutescens*) were found to be least affected by FCM compared to other varieties, offering a potentially less costly alternative in FCM management. Additionally, there is a need to train farmers on the safe use of chemical pesticides, including the use of protective gear, as many farmers apply pesticides without any adequate protection. Most farmers still rely on synthetic chemical control, as they are unaware of the biological technologies or the outcomes they bring forth. Despite numerous biological options for pest management arising from research on safer and sustainable options in Africa, the adoption of these technologies remains low. Therefore, improving *Capsicum* sp. production systems relies on establishing effective mechanisms to transfer relevant locally available technology from research stations to farmers. Future research needs to focus on developing sustainable FCM management strategies in *Capsicum* sp. cropping systems, including intercropping and other biological control options.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/horticulturae10040331/s1. Appendix: Survey questionnaire: Baseline studies for the development of an integrated 'push-pull' management strategy for False Codling Moth among the smallholder horticultural farmers in Kenya.

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