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Surveys and Needs Assessments

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Gendered barriers and opportunities for scaling integrated pest management practices along the mango value chain in Kenya

Beatrice Muriithi[1,*], Rachael Franchini[2], Paige Kolhoff[2], Victoria Seekman[2], Lydia Grossman[2], Kelvin Mulungu[1], Holger Kirscht[1], Samuel Ledermann[2], Fathiya Mbarak Khamis[1]

[1]International Centre of Insect Physiology and Ecology (icipe), P.O. Box 30772-00100, Nairobi, Kenya[2]International Development Studies, Elliott School of International Affairs, The George Washington University, Washington, DC, USA *Corresponding author, mail: bmuriithi@icipe.org

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Mango (*Mangifera indica* L.) is an important source of food and income in Kenya, but production is hampered by the proliferation of invasive fruit flies (*Bactrocera dorsalis*). The International Centre of Insect Physiology and Ecology (*icipe*) and its partners have over the past 2 decades developed and disseminated an integrated pest management (IPM) package of interventions that effectively reduce fruit fly populations, but adoption is relatively low. In response to this low adoption, the authors conducted desk- and field-based qualitative and quantitative studies to better understand the gendered barriers and opportunities for scaling IPM practices along the mango value chain in Kenya. Twenty-four gender-disaggregated focus groups, 118 farmer surveys, and 63 key informant interviews with value chain actors were conducted. The results show that lack of access to IPM inputs, market constraints, and access to training are among the key barriers to and motivations for adopting IPM strategies in Embu County, Kenya.

Key words: gender, value chain, integrated pest management, Kenya, East Africa

Mango (*Mangifera indica* L.) is an important food and cash crop with a prominent role in the livelihoods of many smallholder farmers and economies of countries in sub-Saharan Africa (SSA) (Lux et al. 2003). In Kenya, mango contributes 5% of the agricultural gross domestic product (GDP), 2% of the national GDP, 5.75% of the total fruit export in value, and employment opportunities along the value chain (Horticultural Crops Directorate 2020, USAID 2021). However, the production and export of mango are constrained by several factors, especially the proliferation of pests such as the tephritid fruit fly, *Bactrocera dorsalis* (Ekesi et al. 2016). The mango-infesting oriental fruit fly represents a critical problem for mango production in Kenya, contributing to high pre- and postharvest losses of over 80%–100% if no management strategies are put in place (Ekesi et al. 2006) and overreliance on harmful pesticides, as well as affecting domestic and international market access. Since 1999, the International Centre of Insect Physiology and Ecology (*icipe*) and its partners have developed, promoted, and disseminated an integrated pest management (IPM) package aimed at curbing the fruit fly populations in SSA.

Integrated pest management is a holistic, sustainable approach to managing agricultural pests that integrates different techniques—genetic, physical, biological, and chemical—and minimizes the use of chemical pesticides and their subsequent adverse effects on environmental and human health (Deguine et al. 2021, 37). The International Centre of Insect Physiology and Ecology's fruit fly IPM package includes (a) spot application of food bait, (b) male annihilation technique (MAT), (c) use of biopesticide, (d) releases of parasitoids, and (e) use of orchard sanitation (Korir et al. 2015, Ekesi et al. 2016). Although proven effective in suppressing pest populations and reducing fruit damage, uptake of this approach remains low among farmers in Kenya (Midingoyi et al. 2019, Wangithi et al. 2021). Furthermore, despite the well-established benefits of this approach, chemical pesticides are still heavily used in agricultural settings across Kenya, and control of potentially devastating pests

such as fruit flies remains primarily dependent on the use (and often misuse) of these substances (Korir et al. 2015, Wangithi et al. 2021).

Many existing studies have explored the drivers of IPM adoption, mainly focusing on farmers (e.g., Muriithi et al. 2020, Khan et al. 2021, Otieno et al. 2023). These studies however rarely consider the influence of key actors along the mango value chain on the adoption and disadoption of IPM. Disadoption here refers to those who stopped using the strategies and went back to conventional fruit fly management strategies (Otieno et al. 2023). Given the key role that these actors play in the economic ecosystem of mango farming, examining their role in IPM (dis)adoption is crucial to understanding the incentives and disincentives for farmers adopting the practices. Furthermore, previous studies have overlooked intrahousehold decision-making in implementing and adopting IPM, which can impact women farmers' abilities to adopt and access IPM, suggesting important gendered differences in adoption rates. Therefore, this study was undertaken to understand the factors that influence the adoption of IPM among men and women mango farmers and the effect of other actors along the mango value chain on their adoption or disadoption decisions in Embu County, Kenya.

Study design and implementation

This study utilized information obtained from a systematic review of existing mango value chain literature and a qualitative survey conducted among key mango value chain actors. The literature review was used to map out the relevant actors targeted for a qualitative survey (e.g., Horticultural Crops Directorate 2020, Bien and Soelm 2022). The survey was conducted in Embu County (Fig. 1), selected purposefully due to the predominance of mango production in Kenya (Horticultural Crops Directorate 2020). Furthermore, following the same criteria, 2 subcounties of Embu County, namely Manyatta and Runyenjes, were selected for the survey (Fig. 1).

We conducted 24 gender-disaggregated focus group discussions (FGDs) with 132 mango farmers (50% women), 118 individual surveys with the FGD participants (50% women) (Table 1), and 63 key informant interviews (KIIs) with value chain actors in March 2022, allowing us to capture gendered differences in mango farmers' experiences of pest management and the mango market and value chain. The number of respondents for FGDs and individual surveys was split evenly between the Embu subcounties of Manyatta and Runyenjes (Table 1). The selection of participants was facilitated by the local agricultural extension agents, using the following selection criteria: (a) 5 women or 5 men were to be randomly selected for each group, (b) all participants in a group should represent different villages within their subcounty, and (c) participants should not be from the same household (e.g., husband and wife). Each FGD was composed of at least 5 participants and included a mix of IPM adopters, nonadopters, and disadopters. Focus group discussions were gender disaggregated, with 12 male-only groups and 12 female-only groups, to capture the different constraints that men and women face in the mango value chain. The focus groups lasted approximately 1.5–2 h, facilitated by an enumerator in the local language, and were followed by short individual-level interviews of some of the FGD participants. The KIIs targeted agrodealers (36), mango buyers (16), IPM scientists and researchers (5), IPM manufacturers (3), a processor (1), a large export company (1), and a retailer (1).

The focus group discussions centered mainly on pest management strategies used by the farmers, perceptions, and experiences with IPM, and gender dynamics in mango production and pest management. Focus group facilitators guided the discussions according to a common set of questions for each group but allowed the discussions to progress according to the topics and questions raised by the farmers themselves; thus, while all groups discussed pest management strategies and experiences with IPM, the extent of discussion on topics such as health, the mango market, and climate change differed across the groups. The post-FGD survey questionnaire collected individual demographic data of a few FGD participants (Table 2), as well as individualized data on farmers' experiences with IPM (e.g., IPM accessibility, components adopted, postadoption impacts on daily life and mango production, and reasons for adopting or not adopting). The key informant interviews with the other mango

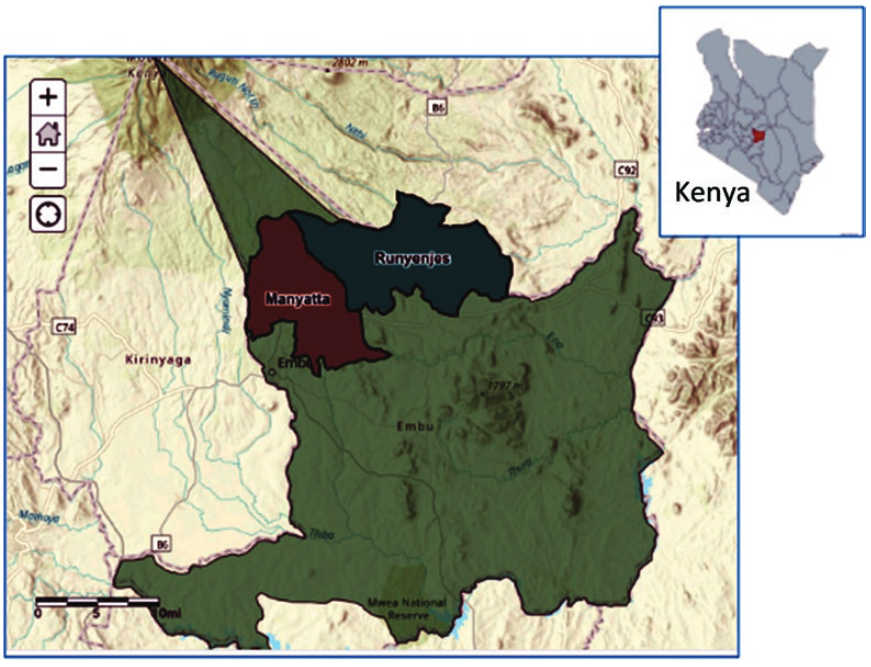

Fig. 1. Map of Embu County of Kenya, showing 2 subcounties (Manyatta and Runjenyes) where the surveys were conducted.

Table 1. Number of men and women who participated in the FGD from Embu County, Kenya

County	Subcounty	Men	Women	Total
Embu	Manyatta	40	32	72
Embu	Runyenjes	26	34	60
	Total	66	66	132

Table 2. Selected Characteristics of individual survey respondents conducted after the FGD

Feature	Men	Women	Total
Identified as IPM adopter	48	47	95
Identified as household head	56	24	80
Average age (years)	59	54	56
Average number of mango trees owned	308	178	242
Average years of farming experience	19	14	17
Total survey participants	59	59	118

value chain actors examined each actor's involvement in mango production and pest management, aiming to understand how each actor might impact or is impacted by mango fruit fly IPM adoption.

Data were coded and analyzed thematically using qualitative analysis software (ATLAS.ti). These data collected from the post-FGD survey were quantitative in nature and therefore were analyzed in Excel to obtain basic statistical information about the sample population, especially for comparing male farmers' responses to women farmers' responses. These data were also used to contextualize the qualitative data from the focus groups.

Summary of findings and discussion

The following section will present an overview of the mango value chain, followed by an analysis of the major factors reported as barriers and opportunities for IPM adoption in our study. These factors include constraints and opportunities related to the mango value chain, such as considerations of current production and market trends, as well as factors related to the IPM adoption process, including farmers' perceptions of and exposure to IPM, access to training, and concerns for human and environmental health. A holistic analysis of the data suggests that access to and participation in training is one of the most significant motivating factors for IPM adoption, while feelings of discouragement about the mango market serve as the most prominent barrier to adoption.

The mango value chain

The mango value chain in Kenya consists of several actors involved in the production, purchasing, processing, marketing, exporting, and sale of Kenyan mangoes. A visual representation of the mango value chain in Kenya, compiled from a review of the literature (e.g., Gor et al. 2012, Horticultural Crops Directorate 2020, Bien and Soelm 2022, Osena et al. 2022) and corroborated by field research in Embu County, is presented in Fig. 2. The majority of the smallholder farmers sell their produce to brokers at farm gate, with the highest production (over 70%) consumed in the local market (Horticultural Crops Directorate 2020).

Mango production trends

As highlighted in the previous literature, our study revealed that mango farmers in Embu are currently facing multiple production challenges, including increasing pest infestation rates, increasing pesticide resistance, and the rising cost of pesticides (Fintrac 2015, Korir et al. 2015, Wangithi et al. 2021). Pest upsurges are driving mango pre- and postharvest loss, as severely infested fruit cannot make it to market, and suspected fruits suffer market rejection (Fintrac 2015). Ninety-four percent of women respondents and 100% of men FGD respondents reported experiencing mango loss due to fruit flies, and 86% of respondents reported losing 20% or more of their production due to pests. These losses directly translate into decreased income for farmers, which increases the pressure to either spend more on pesticides, despite cost and pesticide resistance challenges (67% of farmers in the FGDs expressed having experienced pesticide resistance directly), or to pursue other means of curbing the pest populations. Focus group participants who had adopted IPM cited reduced pest-related losses of between 30% and 90%, and some claimed that IPM adoption had reduced spoilage rates by 80%–90%. Furthermore, IPM users and nonusers claimed that the difference between IPM-produced mangoes and mangoes produced without the use of IPM was visible in terms of quality and that there is a noticeable yield gap between the 2 categories of producers. This perception aligns with previous studies that have found that mango farmers who practice IPM experience significantly higher yields and incomes than those who do not (Kibira et al. 2015, Midingoyi et al. 2019). These observable quality and quantity impacts, combined with farmers' frustrations with increasing pest populations and pesticide resistance, motivate farmers to adopt IPM. Over half of survey respondents who had adopted IPM cited an improved quality of mangoes as a contributing reason to their adoption, with one-third of them mentioning decreased losses, and nearly a quarter specifically attributing their adoption of IPM to the rising cost of pesticides.

However, as also reported by Wangithi et al. (2021), even farmers who do use IPM still rely on pesticides to some extent: 22 of 24 focus groups, regardless of each individual's adoption status, recognized pesticides as a critical component for mango farming, and only 19% of post-FGD survey respondents reported that they did not spend money on pesticides in the last season (70% of farmers who did not spend on pesticides were IPM adopters) citing that their crop was not affected by other pests other than fruit flies which they effectively managed using the IPM practices. This suggests that even if pesticides fail and there is proof of IPM success in the community, it is difficult to escape the traditional mindset of pesticide usage. One IPM manufacturer called this mindset a barrier to selling their IPM products, stating that farmers feel that if they do not spray their crops, they are not managing any pests. This perception is fostered by some mango buyers who stated that they preferred mangoes that had been sprayed because they perceive that it is not easy to produce clean (uninfested by pests) mangoes with the use of IPM over pesticides. Such perception may discourage farmers from experimenting with IPM and other nonchemical means of pest management, suggesting the need to sensitize all relevant actors across the value chain about IPM benefits.

Another production-side challenge that farmers are contending with is changing weather conditions, driven by climate change as also reported in other studies (e.g., Nyang'au et al. 2021). Researchers and farmers alike mentioned unpredictable rainfall patterns—where rain is delayed or starts earlier than expected—as impacting pest populations and mango growth, although it is unclear exactly what effect climate change will have on the fruit fly populations. One researcher explained that if heavy rains come earlier, mango flowers will be aborted, decreasing yields; conversely, if rains come later and are lighter, flowering will be

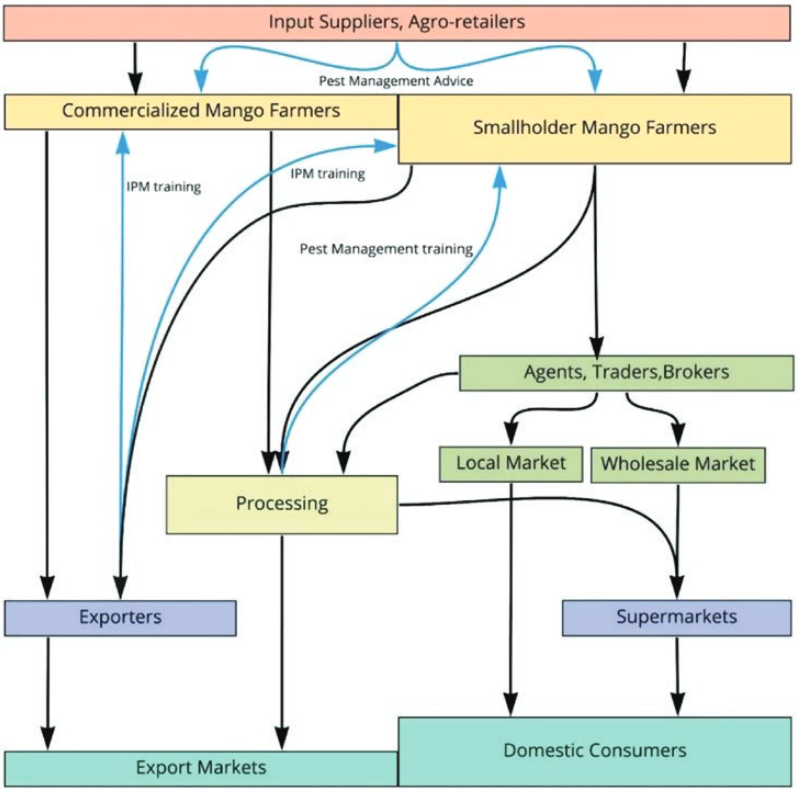

Fig. 2. A map of the mango value chain describing the flow of the produce and inputs from the input suppliers to consumers in Kenya.

triggered, increasing yields. Both scenarios would affect the mango harvest periods. Additionally, the broader research on the impacts of climate change on pest management in sub-Saharan Africa suggests that a changing climate is increasing some pest populations, decreasing others, and causing the emergence of new pests in agriculture (Mafongoya et al. 2019). Given this, farmers require knowledge of these changing pest dynamics on their farms for proper management strategies to be established. One of the *icipe* researchers interviewed claimed that if mangoes can withstand these changes, attesting to the crop's hardiness in times of drought, farmers will be more incentive to invest in the long-term success of these trees through adopting IPM.

Market trends

Our desk- and field-based research revealed that the weak and inundated local mango market is a barrier to investing in mango production and IPM adoption in Kenya. The existing literature and farmers themselves cited the lack of an accessible and fair market as a major disincentive for growing mangoes and emphasized that it especially discourages farmers' investments in pest control methods. According to Osena et al. (2022), brokers purchase mangoes in Embu for around 0.02 USD per mango and then sell the same fruit for around 0.26 USD per piece in Nairobi. Although some literature demonstrates that IPM can increase the net income of mango growers by reducing losses and increasing yield (e.g., Midingoyi et al. 2019, Wangithi et al. 2022), farmers in 17 of 24 focus groups stated that due to the low payoff of the mango market, along with high prices of fruit fly traps and bait, it is often not financially sound for farmers, especially small-scale farmers, to invest in the labor and inputs required to grow infestation-free, saleable mangoes. Three focus groups also noted that most mango varieties ripen at the same time, inundating the local market and deflating the prices of mangoes, making it difficult for farmers to receive a fair price if they sell their produce at the local markets.

Furthermore, farmers rely heavily on brokers, who are farmers' main connection to the market (21 of 24 focus groups highlighted reliance on brokers as a major market challenge). Farmers repeatedly mentioned in the focus group discussions that they have limited to no bargaining power, as brokers typically come to the farms and harvest fruit before giving their prices. Subsequently, the farmers are forced to take the given prices otherwise they incur loss from the harvested mangoes if not collected in good time. Existing research on the mango value chain reflects this dynamic, noting that farmers are often forced to sell their produce at the brokers' chosen price, as they often require farmers to harvest mango prior to completing a sale agreement and then purposefully arrive late as mangoes are on the verge of going bad (Osena et al. 2022). These issues may be a disincentive for farmers to devote effort to their mango trees, including pest management techniques like IPM. In fact, over half of the focus groups (9 male FGDs and 4 female FGDs) discussed the trend of farmers abandoning mango production in favor of more lucrative crops, especially khat (*Catha edulis*), a cash crop with stimulant properties that contribute to a host of societal issues.

These market problems have an even more significant impact on women farmers. Focus groups and key informant interviews revealed that although women are heavily involved in mango production, they are often excluded from marketing activities, further decreasing their ability to make market-informed decisions about their crops. The absence of women in marketing activities was noted both in female focus groups and in value chain interviews: agrodealers described the commercial agricultural market as a male-dominated field, and buyers explained that women face unique barriers to participation in mango marketing, including a lack of time for business, especially due to household responsibilities; lack of farm ownership;

and lack of access to household money. These conditions render women farmers even more distant from the market than their male counterparts, increasing their chances of being taken advantage of by brokers and contributing to feelings of discouragement, further disincentivizing the adoption of IPM. Similar findings were observed by Gichungi et al. (2020) who reported reduced roles of women in mango production and marketing after the introduction of the fruit fly IPM innovations.

Although the lack of an accessible and fair market appears to function mainly as a disincentive to adopt, some farmers in the focus groups did point out that after using IPM, they could receive a higher price for their mangoes because of the noticeable quality improvement. However, this perk seems to be buyer dependent. Seventy-five percent of buyers interviewed through the KIIs did not have a preference for pesticide-free mangoes and were not willing to pay a higher price for IPM-produced mangoes over mangoes produced using pesticides, contributing to some farmers' frustration with receiving the same low prices for their mangoes after investing in IPM. Researchers held that market factors, such as the perceived value of pesticide-free mangoes, dominate adoption rates. These data confirm that farmers will not adopt IPM unless they believe they can get a higher price for mangoes produced by IPM. Similarly, if farmers cannot secure better prices for IPM-produced mangoes, they may be inclined to disadopt, and other farmers in the community could be wary of adopting. A minority of buyers, however, expressed diverging opinions related to customer preferences and health concerns, and one buyer shared that their customers had explicitly requested pesticide-free mangoes. These demand-side factors could increase IPM adoption, especially as concerns over the use of chemicals to grow food rise.

An additional finding is that the export market serves as a motivator for adopting IPM, albeit often an out-of-reach motivator for small-scale farmers. Although this market has stringent quality standards, calling for infection-free fruit and low to no pesticide use, it offers higher incomes for farmers (Grant et al. 2015). Representatives from the large-scale exporter stated that IPM adoption is necessary to participate in the export market and therefore mandates farmers with export contracts to be trained on and use IPM. A mango buyer echoed this idea, saying that many farmers do not export their produce because of the low adoption of IPM. Researchers also spoke to the potential of the export market to drive the adoption of IPM, noting that the higher payout offered by exporting motivates farmers to improve their pest management strategies. However, the export market is mostly inaccessible to small-scale farmers due to their inability to meet the quality and quantity standards usually required for export contracts, lack of linkages to exporters, and lack of the capital to invest in technologies like IPM that would make their farm eligible for market entry (Fintrac 2015). This suggests that the export market is a stronger motivator for large-scale farmers than it is for small-scale farmers, although as farmers of all sizes become more aware of the high standards demanded by foreign markets, IPM adoption rates may improve.

The organic market functions as a motivator for adoption similar to the export market but is still quite small in Kenya. This is due in part to low consumer demand for organic produce, with many value chain actors expressing that most customers do not care whether their mangoes are sprayed with chemical pesticides or produced sustainably. However, multiple value chain actors expressed optimism that the organic market is growing as consumer concerns over food safety are rising. As this market expands, farmers may be incentivized to adopt IPM as it will aid them in meeting the standards required to sell organic produce. However, one IPM manufacturer emphasized that switching from nonorganic to organic farm operations is expensive and labor intensive. Furthermore, according to a researcher, there is a lack of understanding from the farmer side about what organic certification entails, and on the consumer side, a lack of awareness of what organic means. Similarly, some value chain actors expressed that consumers would likely go for the less expensive (nonorganic) fruit given the choice at the market. Overall, our findings suggest that the organic market's ability to contribute to farmers' adoption of IPM is largely dependent on local perspectives on the benefits of organic produce and the population's ability to pay the organic premium.

Overview of motivating and demotivating factors in IPM adoption

Our findings suggest that the farmers' and value chain actors' perceptions of IPM can impact adoption rates. Eighteen of 24 groups (66% of women's groups and 83% of men's groups) either stated outright that IPM was viewed positively in the community or reflected on positive experiences with IPM.

These perceptions were mainly rooted in the improvements in the quality of life that adopters associated with implementing IPM (Tables 3 and 4). The most common change experienced was an increase in income, which 77% of adopters in the post-FGD survey cited (Table 3), with more men (90%) reporting the increase in income than women (64%) (Table 3). This finding is consistent with a sentiment shared by 70% of the focus groups that discussed decisions surrounding access to income from mango farming: women, even if involved in mango production, have little control over income, and mainly men decide who has access to income and how it is distributed, further corroborating with Gichungi et al. (2020) who reported reduced roles of women in mango production and marketing after adopting the fruit fly IPM innovations. When asked about changes in their mango production, responses were similarly mostly positive. The most common changes reported were increased quality (79%), increased yields (59%), and decreased postharvest loss (36%) (Table 3). These positive changes were also reported at the IPM adoption motivating factors (Table 4), including improved quality of mangoes (57%), higher mango income (42%), and reduced mango losses (33%). Building capacity of farmers through training was reported by the majority (66%) of the survey respondents who had adopted IPM as a motivating factor (Table 4). Other IPM adoption motivating factors include human health and environment concerns (12% and 8%, respectively).

Positive perceptions of IPM along the value chain similarly seem to spur adoption. The large-scale exporters, processors, and some buyers were excited about IPM as a means to improve the product they sell. However, we found that perceptions among mango value and supply chain actors ranged from indifference to mild interest in mangoes produced using IPM. Notably, agrodealers, who represent one of the most important spaces for informal training and discussions about pest management, and buyers, who reflect consumer demands, were highly ambivalent towards IPM.

Though a smaller minority, some farmers expressed negative views toward IPM in the focus groups. However, these perspectives often reflect misconceptions about technology or frustration with cost barriers, rather than ineffectiveness. The majority (61%) of those who were not using IPM cited limited knowledge about how IPM works, while 44% said the IPM products were not accessible and hence their demotivation from IPM adoption (Table 4). Thirty-nine percent of the non-IPM users claimed that IPM was too costly and that after implementing IPM they were still suffering yield losses, making them feel the cost was not justifiable, while only 4% of them cited disbelief in IPM effectiveness as a barrier to adoption

(Table 4). They also voiced that compared with other methods, such as spraying pesticides or using traditional pest management methods like smoking to scare the fruit flies away (Wangithi et al. 2021), IPM was not as effective. However, researchers attested that claims of ineffectiveness of IPM components like the male annihilation traps largely stem from misunderstandings or incorrect use of the component. For example, some farmers may miss the right timing of setting up the traps or replacing the rules as also observed by Wangithi et al. (2021) and Otieno et al. (2023). Even when they are rooted in misconceptions, negative perceptions may make other farmers wary of investing in new technologies (Doss 2006) such as IPM. Manufacturers of IPM products shared that there are also counterfeit IPM products on the market which distort farmers' perspectives of how well IPM works, resulting in disadoption and discouraging others from adopting.

In the sections that follow, we elaborate further on the key IPM adoption motivating and demotivating factors that require the attention of development partners and policymakers.

Access to training and knowledge

There was strong evidence throughout the mango value chain that the best way to ensure the adoption of IPM is to train farmers. Overall, farmers were eager to learn more about IPM and have more opportunities to receive training. About half of the survey participants had some experience with IPM through training participation (53% of male respondents and 47% of female respondents), and it is evident that this kind of exposure triggers adoption. During the post-FGD surveys, 66% of adopter respondents listed training on IPM as a key reason why they adopted (Table 4), and only 2 farmers who had attended training in the past were nonadopters, a 97% success rate of the individual survey respondents. Other actors along the value chain are aware of the benefits of training and knowledge sharing, and IPM manufacturers, exporters, processors, and research organizations all mentioned training as a critical strategy to improve adoption.

Training combats lack of knowledge and misinformation, which are limiting factors to IPM adoption widely recognized in the existing literature (Alwang et al. 2019, Deguine et al. 2021, Khan et al. 2021). Manufacturers of IPM products and the large-scale exporter identified misconceptions and lack of knowledge about IPM as a challenge that slows down the adoption rate. Lack of knowledge was identified by 61% (82% of male respondents and 42% of female respondents) of nonadopters as a contributing factor to nonadoption (Table 4). Twelve of 24 focus groups (7 male groups and 5 female groups) explicitly mentioned that lack of knowledge surrounding IPM is an area of frustration. Farmers alleged that agrodealers are not knowledgeable about IPM, even if they are selling IPM inputs. These findings mirror the experience of other farmers in Africa and worldwide, who also largely cite lack of sufficient training on IPM strategies, which are often perceived as overly complex, and lack of available technical support, as the biggest barriers to adoption (Parsa et al. 2014, Day et al. 2022).

Training also promotes knowledge sharing within the community, which is otherwise impeded by a lack of extension services, the absence of extension officers, and little follow-up from IPM supporting agencies (Day et al. 2022). One IPM manufacturer confirmed the need for more training on IPM in Kenya, noting the small number of actors administering training and their limited capacity for follow-up training. Agrodealers surveyed attributed a lack of interest in IPM from their customers to a general lack of knowledge and access to training. Discrepancies between female and male adoption rates could be due to women's limited access to critical productive resources and information (Muriithi et al. 2020). Although the proportion of respondents who had attended IPM training was similar for men and women, only one female respondent had attended more than one training, compared with 11 men who had done so. Some women from the focus groups shared that they needed permission from their husbands to participate in training, and that training was difficult to attend due to time constraints imposed by household responsibilities. Some agrodealers suggested that training targeted specifically toward women farmers would help mitigate some of these access issues and bring more women into the value chain.

Tailoring IPM training to reach more women is just one of many engaging and participatory practices that have the potential to improve adoption rates. The researchers emphasized the importance of not just training but also having repeated and follow-up sessions to encourage sustained adoption. The best training sessions, according to these researchers, include a demonstration of the products because it allows the farmers to try out the technologies for themselves

Table 3. Changes observed by the 95 individual survey respondents after adopting IPM in Embu County

	Female (n = 48)	%	Male (n = 47)	%	Total (n = 95)	%
Changes in family life						
Increase in income	30	63.83%	43	89.58%	73	76.84%
Decreased labor time	13	27.66%	14	29.17%	27	28.42%
Decreased costs	14	29.79%	10	20.83%	24	25.26%
Improved Health	12	25.53%	9	18.75%	21	22.11%
Increased labor time	3	6.38%	10	20.83%	13	13.68%
Increased costs	5	10.64%	6	12.50%	11	11.58%
Decrease in income	2	4.26%	3	6.25%	5	5.26%
None	8	17.02%	0	0.00%	8	8.42%
Changes in mango production						
Increased quality	30	63.83%	45	93.75%	75	78.95%
Increased yields	33	70.21%	23	47.92%	56	58.95%
Decreased postharvest loss	14	29.79%	20	41.67%	34	35.79%
Increased postharvest loss	3	6.38%	8	16.67%	11	11.58%
Decreased quality	4	8.51%	1	2.08%	5	5.26%
Decreased yields	4	8.51%	0	0.00%	4	4.21%

Source: Post-FGD Survey.

Table 4. Summary of the factors motivating 95 of the survey respondents to adopt IPM and demotivating 23 of them not to adopt the IPM in Embu County

IPM motivating factor	Female (n = 48)	%	Male (n = 47)	%	Total	%
Training/exposure	31	65.96	32	66.67	63	66.32
Improved quality of mangoes	25	53.19	30	66.67	54	56.84
Higher income	16	34.04	24	50.00	40	42.11
Lower mango losses	13	27.66	18	37.50	31	32.63
Cost of pesticides	14	29.79	9	18.75	23	24.21
Concern for health	8	17.02	3	6.25	11	11.58
Concern for environment	1	2.13	8	16.67	8	8.42
Word of mouth/referral	3	6.38	6	12.50	8	8.42
Other	5	10.64	2	4.17	7	7.37
IPM demotivating factors	**Female (n = 11)**	**%**	**Male (n = 12)**	**%**	**Total**	**%**
Lack of knowledge	5	41.67	9	81.82	14	60.87
Accessibility	4	33.33	6	54.55	10	43.48
Cost	5	41.67	4	36.36	9	39.13
I don't think it works	0	0.00	1	9.09	1	4.35
Not interested	2	16.67	0	0.00	2	8.70

Source: Post-FGD Survey.

and make their own decisions on whether to adopt, which increases rates of sustained adoption. Many actors along the mango and IPM value chains provide farmers with formal and informal IPM training. All IPM manufacturers interviewed, and the large-scale exporter regularly hold formal training sessions for farmers that feature capacity-building activities such as seminars and demonstrations. Manufacturers also provide training on a weekly or biweekly basis coordinated by field officers who tailor-make the IPM training for target stakeholders in the specific community. Manufacturers also partner with other entities such as women's and youth groups, local organizations, and exporters, who assure market access to farmers and, therefore, the value of IPM adoption. Additionally, IPM training sessions are mandatory for farmers with export contracts with the large-scale exporter that was interviewed, ensuring adoption and encouraging sustained adoption. In these trainings, the exporter partners with technical agronomists who help advise the farmers and IPM suppliers who make IPM knowledge and inputs accessible to farmers. Furthermore, the company promotes the usage of male annihilation traps and encourages the adoption of biological controls, emphasizing the prevention of pests over the management of pest infestations. Training sessions are guided by a needs assessment and can include activities such as farmer field days, farm tours, dialogs about farmer needs, and the use of demonstration plots.

Access to inputs

The cost of adopting IPM was cited as a critical reason for nonadoption and disadoption, and this barrier is especially important to consider for small-scale farmers. In the post-FGD survey, 36% of male nonadopters and 42% of female nonadopters reported that the cost of the IPM was a barrier to adoption for them (Table 4). Farmers estimated the cost of a trap at around 300–400 KES (about USD 2.50–3.20 during the time of the survey), and given that multiple traps (10–12 per hectare) need to be used for peak effectiveness, this is too expensive for many smallholder farmers. However, for larger-scale farmers, traps were seen as more cost-effective because using the traps is not labor intensive and therefore does not require hired labor, whereas spraying pesticides does. As such, the cost of traps can be a motivating factor for adoption by large-scale farmers since it is less expensive for them than chemical methods. The field sanitation component of the IPM package has the same effect, but for small-scale farmers. Focus groups discussed that small-scale farmers can easily and cheaply employ this technique by themselves since field sanitation requires no equipment, meaning that the cost of using this component is just the cost of labor. It was also noted in the focus groups that large-scale farmers have to hire laborers to clean their orchards, making it less cost-effective. Some value chain actors spoke on the long-term cost-effectiveness of IPM, and this was backed up by existing literature that showed IPM lowered expenditures on pesticides for mango growers (Muriithi et al. 2016). While IPM may be more cost-effective compared with synthetic pesticides for farms of all sizes, as shown by the 25% of adopters with farms ranging from 15 to 600 trees who cited decreased costs after adopting IPM, the initial costs of inputs and hired labor, coupled with lack of access to credit, act mainly as a barrier to adoption of IPM. The former observation agrees with a recent study by Mulungu et al. (2023), which observed that smallholders with fewer mango trees benefit more from most IPM practices.

Input availability is also a factor in IPM adoption. Availability of IPM inputs in local agrodealers varied considerably across the study area, a sentiment discussed in focus groups and confirmed by the agrodealers themselves. Of the 36 agrodealers interviewed, 22 (61%) did sell some IPM inputs, most commonly male annihilation traps and protein baits, and many noted that traps and protein bait were readily available in the market, though some noted that their IPM business was hampered by limited and unreliable stock from suppliers. This issue can be partially explained by the small number of IPM manufacturers, though this space could expand as it gains more demand and therefore more profitable from increased sales: one organization sold less than 10,000 units in 2012 but between 60,000 and 70,000 units in 2021. Ten of 24 focus groups shared that traps were not being sold at the local agrodealer shops and that knowing where to buy the components was a large barrier. However, other groups said that traps were available at the stores. Some participants said that traps could be easily replicated at home with old trash, like laundry detergent bottles, and this was a way to circumnavigate the availability barrier. Among survey respondents, 33% of female nonadopters and 55% of male nonadopters cited accessibility as a primary barrier (Table 4).

The most commonly adopted components of *icipe*'s IPM package were MATs, or the use of pheromone-based traps, and field sanitation, the process of collecting and destroying all infested fruits, due to their relative availability compared to the rest of the package. Of the respondents who had adopted IPM, 5% had adopted 3 components, 38% had adopted 2 components, and 55% had adopted 1 component. Men were more likely than women to have adopted more than one component; 54% of male respondents adopted 2 or more components compared to only 32% of female respondents. Other components of the package (food bait, biopesticides, and parasitoids) were not accessible at traditional agrodealers. Very few agrodealers reported selling biopesticides; furthermore, many farmers had never heard of the parasitoids—a component that must be administered by organizations like *icipe* as it involves the release of exotic parasitoids into the environment—and it was never mentioned among agrodealers, suggesting that this component is rarely available to the average farmer. Given that research has found that the effectiveness of IPM increases relative to the number of components adopted (Midingoyi et al. 2019), the low average number of components adopted is notable.

Human and environmental health

Though mentioned infrequently relative to other factors, concerns for human and environmental health do seem to contribute to increased adoption of IPM. Twelve percent of adopter survey respondents stated that health was a contributing factor for adoption and 8% said the same of concern for the environment (Table 4). Though motivating factors for adoption were similar across both genders, a higher percentage of female adopters (17%) identified health as a motivating factor for adoption, compared with just 6% of male adopters (Table 4). This gap could be attributed to differing ideas about men's and women's health: one women's group explained that they believed using pesticides brings health complications for women because the tools needed to spray are heavy and the activity is very tiresome. Women also more frequently reported an improvement in health after adopting IPM in comparison to men. Focus groups that discussed the division of labor between men and women within mango production explained that women often do not control mango marketing or household income, which may explain why women were more likely to be motivated to adopt IPM for reasons outside of income—such as health and the environment—than men, who overwhelmingly cited income-based reasons for adoption. Similar observations were made by Gichungi et al. (2020).

While findings show that some farmers know the health benefits of reduced pesticide exposure in mango production, one researcher acknowledged the wide gap between the large body of research about IPM generated by scientists and the farmers themselves. Furthermore, knowledge of the human and environmental health benefits of pesticide-free and organic produce seems to be lacking at the mango consumer level. Without the awareness of the adverse effects of pesticides on human and environmental health, farmers may not feel incentivized to switch to more sustainable methods and consumers may not feel incentivized to purchase organic produce, reducing interest in IPM along the mango value chain and discouraging uptake of IPM among farmers. Similarly, other value chain actors noted that the domestic organic market is limited, and buyers and retailers often lack insight into the pest management practices used on farms. Raising awareness of the negative effects of pesticides on human health among buyers, retailers, and consumers could be of particular use in expanding the market for organic produce in Kenya, fueling greater interest in IPM along the mango value chain and directly encouraging greater uptake of IPM among farmers.

Recommendations

Increase training and access to IPM inputs for value chain actors

The findings from key informant interviews consistently indicate that the mango and IPM value chains play a key role in farmers' decision-making for pest management. From agrodealers to retailers, value chain actors act as both sources of information and training as well as influential players in farmers' access to mango markets. While some actors along the value chain, such as IPM manufacturers, are already active in IPM promotion due to their business, others represent an untapped opportunity for IPM dissemination. Agrodealers in particular are influential in farmers' pest management practices and yet often promote pesticides over IPM methods. Spreading awareness among agrodealers about IPM, as well as connecting them to IPM suppliers and mango farmers using IPM, could increase their buy-in. In addition, strengthening farmer groups could also provide an avenue for promoting IPM among the farmers. This could, in turn, promote greater uptake and knowledge about IPM among small-scale farmers. Similarly, mango buyers have frequently acted as a barrier rather than a motivator to adopting IPM. This is partly due to mango buyers' lack of insight into the pest management practices of the farmers they buy from. There is, however, evidence from the value chain interviews that the higher quality, "cleaner" mangoes produced using IPM could fetch higher prices for farmers and buyers alike. Promoting greater awareness of the quality benefits of IPM and the price premium it offers on the market could create greater momentum for IPM at the buyer level.

Similarly, organizations disseminating IPM information and products should facilitate more partnerships between mango farmers and IPM processors, exporters, and retailers. Interviews with these actors suggest that they have more direct access to the organic and export markets and actively seek out high-quality, pesticide-free mangoes. Fostering greater connections between these businesses and small-scale farmers could encourage greater uptake of IPM and a corresponding increase in income for farmers.

Scale up training efforts to emphasize consistent, recurring, and widespread training for farmers

The evidence from our focus groups, survey, and interviews consistently indicated the efficacy of training as a method to increase IPM adoption. However, our findings also pointed to an unmet need for consistent and repeated training, which serve to both refresh knowledge on IPM techniques and distribute potentially costly or inaccessible inputs.

Based on our findings, one of the best ways to improve IPM adoption is to make it easier for farmers to find and afford the necessary inputs. Some agrodealers interviewed stocked IPM inputs, but many did not, and farmers consistently communicated that they did not know where to find traps or bait. Furthermore, when these products are available, their price is often too steep for a small-scale farmer to justify without certainty of the effectiveness of the product. Effective training can alleviate this risk by allowing farmers to try out the techniques for themselves and see the results. Training sessions present an ideal space to distribute IPM inputs like traps, and many value chain actors who administer training mentioned that they occasionally will give out inputs.

Enhance awareness of the health risks associated with pesticides in the consumer market

The individual survey results suggested that farmers are aware of some negative effects that pesticides have on human health and the

environment, and a minority of farmers listed these as their primary motivating factors in adoption. However, knowledge of the health benefits of pesticide-free and organic produce seems to be lacking at the consumer level. Even while multiple value chain actors noted a desire for "clean" produce at the buyer and consumer level, buyers and retailers often lack insight into the pest management practices used on farms and focus more on the presence of pests as an indicator of cleanliness. Raising awareness of the negative effects of pesticides on human health could be of particular use in expanding the market for pesticide-free produce in Kenya, which would fuel greater interest in IPM along the mango value chain and directly encourage greater uptake of IPM among farmers.

Expand research on connections between IPM adoption and market factors

Our desk-based research revealed that very limited information was available on the mango market, including supply and demand trends relevant to understanding farmers' motivations for managing (or not managing) pest populations. Throughout the focus groups, post-FGD survey, and KIIs, the lack of local market for mangoes was a consistent theme, and numerous value chain actors mentioned that farmers are unlikely to adopt improved pest management methods for their mangoes if there is no market payoff for doing so. Among the significant global body of research on IPM, there is little focus on the connections between IPM uptake and market factors. Greater research focus on this connection would contribute to a more holistic understanding of why farmers may or may not adopt IPM practices.

Conclusion

The data collected include the status of mango production, pest control methods, and perceptions of IPM. These data, combined with relevant findings in the existing literature on the mango value chain (e.g., Bien and Soelm 2022) and IPM usage and adoption (Kibira et al. 2015, Muriithi et al. 2016, Midingoyi et al. 2019, Mulungu et al. 2023), provide evidence that various factors influence the sustained adoption of *icipe*'s fruit fly IPM package. Our findings suggest that farmers face constraints related to IPM's accessibility as well as challenges with the mango produce market as a whole.

Despite the variety of benefits of the fruit fly IPM that farmers reported, sustained adoption of the innovations among mango growers in Kenya lags behind its potential. Through the desk review, focus groups, surveys, and interviews, the research team gleaned a range of valuable insights regarding factors that influence sustained IPM adoption, positively and negatively, for mango growers in Kenya. After considering the interactions between mango value chain actors, gender dynamics, and the various identified factors influencing IPM adoption (i.e., current production and market trends; perceptions of IPM; access to training, knowledge, and inputs; and concern for human and environmental health), it is evident that improving the fruit fly IPM adoption in Kenya will require a comprehensive, intersectional, and multifaceted approach. However, progress can be made in addressing the barriers that men and women farmers face in adopting IPM by making use of the motivations and opportunities that are present along the value chain, especially within training and knowledge sharing.

While organizations like *icipe*, IPM manufacturers, and at least one large-scale exporter are already working to address one of the largest barriers to adoption by providing IPM training to farmers, there is an opportunity to expand training and outreach to include other actors along the value chain that disseminate pest management information in their regular interactions with farmers, particularly agrodealers. However, while IPM training proved to be the largest motivator for sustained adoption, it is not a panacea for improving the uptake of IPM. Farmers must be able to recoup their investment into IPM components in order to adopt the strategy for the long term, but a lack of an accessible and fair mango market discourages them from making this investment. Therefore, market elements that act as disincentives, such as a dependence on brokers, a lack of bargaining power, low consumer knowledge regarding the benefits of organic produce, and difficulty accessing the more lucrative export and organic markets, must also be addressed to ensure farmers receive fair prices that reflect their investment in the quality of their produce. Additional research to examine the connections between the mango market and IPM adoption is needed to develop solutions to what we found to be the most prominent barrier to adoption. Developing a more holistic understanding of the mango market's impact on farmers' pest management decisions, as well as working closely with value chain actors to disseminate IPM information, could help improve IPM adoption and increase its positive impacts on poverty reduction, food security, and health among mango growers in Kenya.

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Author Contributions

Beatrice Muriithi (Conceptualization [Equal], Funding acquisition [Equal], Methodology [Equal], Project administration [Equal], Supervision [Equal], Writing—review & editing [Equal]), Rachael Franchini (Conceptualization [Equal], Data curation [Equal], Formal analysis [Equal], Investigation [Equal], Methodology [Equal], Project administration [Equal], Writing—original draft [Equal], Writing—review & editing [Equal]), Paige Kollhoff (Conceptualization [Equal], Data curation [Equal], Formal analysis [Equal], Investigation [Equal], Methodology [Equal], Project administration [Equal], Writing—original draft [Equal], Writing—review & editing [Equal]), Victoria Seekman (Conceptualization [Equal], Data curation [Equal], Formal analysis [Equal], Investigation [Equal], Methodology [Equal], Project administration [Equal], Writing—original draft [Equal], Writing—review & editing [Equal]), Lydia Grossman (Conceptualization [Equal], Data curation [Equal], Formal analysis [Equal], Investigation [Equal], Methodology [Equal], Project administration [Equal], Writing—original draft [Equal], Writing—review & editing [Equal]), Kelvin Mulungu (Conceptualization [Equal], Funding acquisition [Equal], Methodology [Equal], Project administration [Equal], Supervision [Equal], Writing—review & editing [Equal]), Holger Kirscht (Conceptualization

[Equal], Funding acquisition [Equal], Methodology [Equal], Project administration [Equal], Supervision [Equal], Writing—review & editing [Equal]), Samuel Ledermann (Conceptualization [Equal], Methodology [Equal], Project administration [Equal], Supervision [Equal], Writing—review & editing [Equal]), and Fathiya Mbarak Khamis (Funding acquisition [Equal], Project administration [Equal], Supervision [Equal], Writing—review & editing [Equal])

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