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Knowledge, attitude, and practice (KAP) analysis of agricultural biologicals among smallholder farmers across three counties in Kenya

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ABSTRACT

Agricultural biologicals (agrobiologicals) can be sustainable options to manage plant pests and diseases and enhance growth. This can reduce reliance on synthetic inputs, which often come from non-renewable sources and pose risks to the environment and farmers. However, the use of agrobiologicals in Sub-Saharan Africa (SSA) is low. To understand factors leading to low adoption of Agrobiologicals in Kenya, we performed a Knowledge, Attitude and Practice (KAP) analysis among smallholder farmers in three counties in Kenya regarding agrobiologicals. 275 farmers were interviewed in Kajiado, Kiambu and Machakos counties. The farmers' knowledge on agrobiologicals was low and varied across the counties; 18–47 % of respondents were deemed knowledgeable. The main source of knowledge was neighbours (32–57 % depending on the county). Regarding the information flow, agro-dealers were the main source of information for agricultural inputs in general. More than 70 % of the farmers were not trained in employing agrobiologicals, and 70 % of the farmers stated that agrobiologicals are not effective. Still, between 46 % (Kajiado) and 18 % (Machakos) used agrobiologicals in their farming practices. The number of years in farming positively correlated with knowledge of agrobiologicals, but not attitude and practice. Possibly, the low knowledge regarding agrobiologicals influenced attitude and practice; however perceived sufficient knowledge of agrobiologicals did not translate into an increased use, indicating that knowledge alone is not sufficient to ensure use among smallholder farmers. These findings call for new strategies to promote agrobiologicals to smallholder farmers in SSA.

1. Introduction

Agricultural biological (agrobiologicals) is an umbrella term for living organisms or derivatives of these, which can be used to manage abiotic and biotic stresses, and/or enhance plant growth. They can, for example, be microorganisms, plant extracts and beneficial insects, and have a large number of modes of action, acting as biostimulants (plant growth enhancement products), resistance inducers, biopesticides, pheromones (plant protection products), predators or biofertilizers (plant nutrition products) [1]. Farmers apply agrobiologicals as part of integrated pest management (IPM) [2,3], but there are challenges related to retailer and advisor knowledge and terms and definitions are complex [4]. They can complement agrochemical products to reduce chemical usage or solely to improve protection, growth and product value. Agrobiologicals can be part of sustainable agricultural production because they can be safer for the users, the environment and non-target organisms in the field [5].

In the past, efforts have been made to identify, develop and promote agrobiologicals, especially biopesticides, in Africa, but there has been a very slow uptake with little impact compared to the funding provided

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[5,6] even with evidence that agrobiologicals have the potential to suppress pests and enhance yields [7]. For example, the use of biopesticides in Africa is estimated at 3 % of the world's biopesticide market, but there is little information available on the adoption rates of biopesticides on the continent [8]. This is one of the reasons why the East African Community (EAC) developed and launched the East African regional bioeconomy strategy 2021/2022–2031/2032 in June 2022. The strategy identifies and prioritizes sustainable development, food security, environmental management and promotes production and use of bio-based products and agricultural inputs (such as agrobiologicals) to reduce the use of synthetic pesticides [9]. The strategy is aiming to grow the East African agrobiologicals market that currents stand at approximately US$400 million annually [9].

This, despite the identification of agrobiologicals in laboratory studies with potential use in African agriculture [10]. Furthermore, there is a need for them to be made more available to smallholder farmers [11]. A study carried out in Kenya among smallholder farmers on why they have not adopted the use of biopesticides identified perceptions of their effectiveness, availability and cost as key reasons [12,13]. Previous studies on perceptions showed that farmers are aware of the risk associated with chemical pesticides but cite lack or inadequate information regarding the availability of safer alternative pest control products as a hindrance to adoption [14,15]. Additionally, Knowledge, Attitude and Practice (KAP) analyses have been shown to differ between regions of the same country and to be influenced by education level and age [16,17]. However, it is not known whether this is the situation in Kenyan counties with regard to agrobiologicals, and therefore, there is a need to establish factors that facilitate or hinder the use of agrobiologicals in Kenya on a regional level. Farming experience is known to influence adoption of new technologies, for example the use of agrobiologicals for pest management in agriculture [18,19].

A KAP analysis can be used to test the extent of knowledge of a known situation; approve or disprove hypotheses and generate new information. The objective of KAP analyses is to generate information on what is known, believed, and practiced within a certain area of study. Compared to technology adoption models, KAP studies provide a scientific categorization that forms the basis for exploring the potential success or failure of initiatives [20] and they are vital constituents of behavioral change models [21]. Where else the technology acceptance model presupposes that users' behavioral intentions, which are based on their perceptions of the technology's utility and perceived ease of use, predict whether or not technology will be accepted [22]. KAP surveys can uncover misconceptions and misunderstandings that could pose challenges to behavior change [23]. Using predetermined questions in standardized questionnaires, insight into both quantitative and qualitative data can be gained. The KAP model is suitable for this kind of study and has been used previously used in studies on sustainable agriculture in the past [24].

Previous KAP studies in Kenya and the wider SSA region have revealed factors that lead to low rate of adoption of alternatives to pesticides in pest management. Among others, these factors include lack of technical support, lack of knowledge (awareness), perceived low efficiency and safety [25–27]. However, the use of agrobiologicals in pest management is relatively new concept in SSA including Kenya, and there are very few KAP studies on their use in Kenya and including the three counties where the study was carried out. The objective of this study was also to generate information to compare agrobiologicals use between Kenya and other countries in SSA. Understanding the practice of agrobiologicals usage vis-a-vis farmers' knowledge and attitude may indicate the area of intervention to promote agricultural practice using agrobiologicals.

This study therefore carried out a survey on smallholder farmers' knowledge, attitude and practice regarding agrobiologicals in three counties in Kenya to identify key actors and the information flow to better understand how adaption of agrobiologicals can be enhanced.

2. Materials and methods

2.1. The study sites

The study was undertaken in three counties in Kenya, namely, Machakos, Kajiado and Kiambu. Kajiado and Kiambu neighbour the capital city Nairobi, produce a variety of vegetables and supply the city populace. Machakos, meanwhile, is located about 70 km from the city (1.5177° S, 37.2634° E) with an altitude of 1000–1600 m above sea level. Farmers in the county produce vegetables for both local and export markets alongside subsistence farming. Agriculture is the major source of livelihood in Machakos County, employing about 73 percent of the population and contributing approximately 70 percent to household incomes. Kajiado County is located 80 km south of Nairobi (2.0981° S, 36.7820° E) and the elevation ranges from 1600–1800 m above sea level. Crop farming is the main economic activity and is mainly practiced in the southern and western parts of the county along rivers and springs. There is substantial production of vegetables mainly for household consumption and sale to the local markets. Kiambu is a peri-urban county that borders Nairobi city (1.1748° S, 36.8304° E) and the elevation ranges between 1100 and 3900 m above sea level. Agriculture is the leading sector in terms of employment, income earnings and overall contribution to the socio-economic well-being of the people. The study sites were purposively selected due to the higher pesticides use associated with vegetable production-compared to the other counties in Kenya [28,29]. The proximity to Nairobi city from these three counties means there is a ready market for vegetables. Machakos county has a proportion smallholders farmers growing vegetables for export market and therefore there is conscious use of pesticides. These three counties were identified as counties that had been reported to have heavy usage of pesticides in vegetables, and because the farm sizes are small, farmers tend to practice intensive farming due to the profitability of vegetable production compared to food crops [30,31]. Previous studies in Kiambu county reported misuse of pesticides including use of banned active ingredients [28,29]. The counties represent different agroecological zones in Kenya where vegetables are produced either under irrigation or rainfed production systems. Additionally, Kajiado which is classified as semi-arid and characterized by livestock farming is increasingly adopting vegetable production under irrigation to cope with climate change.

2.2. Study design and sampling technique

In the majority of KAP surveys, an interviewer uses a structured and regular schedule to gather data [15]. Systematic random sampling is employed when one wants to randomly sample a population but details about the population are not available. This study employed a cross-sectional study design where 275 farmers were sampled from three counties (Kiambu, Kajiado and Machakos) in Kenya in 2022 to gather data on agrobiologicals' knowledge, attitudes and practices (KAP). Probability and non-probability sampling techniques were used in this study to arrive at a sample size of 275 vegetable farmers in the three counties. Purposive sampling was the non-probability sampling technique that was used to purposively select the three counties as the primary areas of study. The three counties where the study was undertaken were purposively selected based on their significance in vegetable production and hence high usage of pesticides based on available information. Secondly, systematic random sampling technique was the probability sampling technique employed to randomly select vegetable farmers in the three counties.

2.3. Inclusion criteria

Farmers included in the study comprised of individuals involved in farming the whole year, specifically farmers using irrigation to water and grow their vegetables. Therefore, farmers along streams and rivers in the three counties that perennially grew vegetables were strictly included in the study.

2.4. Data collection

A survey was conducted in February and March 2022 using a questionnaire with both open and closed-ended questions. The questions were grouped into general information, Knowledge, attitude and practice (annexed -questionnaire).

Face-to-face interviews were conducted involving farmers and agro-dealers. A total of 275 smallholder farmers (95 in Kajiado, 108 in Kiambu and 72 in Machakos) were interviewed. Simple random sampling was used to select farmers in different sub-counties within the three counties to be interviewed. Six enumerators were involved in data collection, and it took about 20 min to interview each farmer. The farmers were interviewed on their farms. Before the commencement of the interviews, consent was sought from farmers by explaining the purpose of the interview and allowing them to decide whether to continue with the interview or opt out. The questionnaires were pre-tested and validated by 15 farmers in Machakos county before data collection commenced. Data collected included: area under production, age and gender of people involved in farming, types of crops grown and access to market, use of inputs and types of inputs used, knowledge and awareness of agrobiologicals, their accessibility, perceived efficacy, their application, their benefits and advantages over conventional inputs, types of agrobiologicals used and any policies and regulations on the use of agrobiologicals in Kenya. Observations were also made and documented on the farmers' practices. The data were captured using ODK collect Application version 2021, which is an open-source Android app that replaces paper forms used in survey-based data gathering.

2.5. Data analysis

Data were downloaded from the Kobo Toolbox website into Microsoft Excel 2021. The data were cleaned by redoing the variables, removing values and inputting missing values in readiness for descriptive and inferential statistical analysis.

Association between social demographics and knowledge, attitudes and practices, was determined by a chi-square test of association using a 95 % confidence interval. The Chi-square test was used to determine if there was a relationship between two categorical variables, or if the difference between observed and expected results was due to chance. The basic idea behind the use of the chi-square test is to compare the observed values in the data to the expected values that would verify the null hypothesis. A Pearson's correlation coefficient was calculated to determine the correlation between knowledge, attitudes and practices. Logistic regression analysis was used to determine the influence of social demographics, farm characteristics, training, household incomes related to knowledge, attitude and practices regarding agrobiologicals. The adjusted odds ratios with 95 % confidence intervals were used to determine the statistically significant independent factors. The goodness of fit test was conducted using the Hosmer-Lemeshow test [31].

2.6. Scoring method of knowledge, attitude and practice

Knowledge, attitude and practice required scoring and were scored as follows. Knowledge's every response deemed correct was given score of 1, if deemed incorrect a score of 0 was given. High scores indicated adequate knowledge while low scores indicated lower or lack of knowledge on the specific variable. There were 24 questions on knowledge. The scores of each variable were summed up to provide a knowledge score for each farmer. The summed scores were turned into percentage of correct responses with scores above 80 % considered as sufficient knowledge, attitude and practice. The attitude section contained responses in five categories ranging from strongly disagree to strongly agree and were coded from 1 to 5 Since there were 12 questions to assess the attitude, the overall score for a farmer ranged from 12 to 60. The practices section was scored as the attitude with 1 for every response deemed correct or otherwise 0.

2.7. Agrobiologicals dissemination workshop

A dissemination workshop where the KAP analysis was presented was held on 26th July 2023 in Machakos county for 20 farmers from three focus counties (Machakos, Kajiado and Kiambu) together with the county director of agriculture in Machakos. Paper information material and posters based on information of the survey results were shared with farmers. Views of the farmers were collected during a plenary session.

3. Results

3.1. Social demographics

Most household heads were male (86 %). 72 % of all interviewed farmers were middle aged individuals aged between 36 and 50 years, followed by the age span 51–60 at 17 %. Elderly farmers only comprised 9.5 % and those under 36 years comprised 1.8 %. Most farmers had primary school (42 %) and secondary school (36 %) education, while only 15 % had college training and 4.4 % had a degree level of education while 2.5 % had not attained any formal education. The majority of the farmers were married (79 %), 15 % were single, 4 % were widowed while 2 (0.7 %) were separated. Accordingly, 41 % had a household income ranging between KSh5000 and KSh10000 while 38 % had incomes ranging between KSh10000 and KSh20000. Therefore, a majority of the farmers' household incomes ranged between KSh5000 and KSh20000. 21 % earned less than KSh5000 in their monthly household income. The mean farming experience was 13 years (Table 1).

3.2. Assessment of knowledge

Assessment of knowledge among the sampled farmers showed that the majority understood what agrobiologicals entailed, whereby 65 % indicated that agrobiologicals were organic farming practices without the use of pesticides. The farmers understood that agrobiologicals were separate from chemical pesticides. However, only 13 % had been trained on agrobiologicals, and 87 % had never attended any training that focused on the use or introduction of agrobiologicals. Most farmers (83 %) understood the use of agrobiologicals as fertilizers whose main purpose was to increase yields. According to the findings of this study,

Table 1
Social demographics for smallholder farmers in Kajiado, Kiambu and Machakos counties.

Social Demographics	Categories	Number	%
Gender	Male	237	86
	Female	38	14
Age Group	18–35	5	1.8
	36–50	198	72
	51–60	46	17
	Above 60	26	9.5
Education level	No formal schooling	7	2.5
	Primary education	116	42
	Secondary education	99	36
	College training (certificate, diploma)	41	15
	Bachelor's degree and above	12	4.4
Marital status	Single	42	15
	Married	216	79
	Windowed	11	4.0
	Separated	2	0.7
	Divorced	3	1.1
Household income (KSh)	10000–20000	103	38
	5000–10000	111	41
	Below 5000	58	21
Farming years	Years	13 (11)	

farmers had varied definitions of agrobiologicals and some were way off the correct definition.

In addition, 83 % of the farmers knew the purpose of using pesticides that is management of pests and diseases. However, 72 % of the farmers did not know the contents of the pesticides they bought while 67 % did not know the types or classes of pesticides that they regularly used. The majority of farmers knew and agreed that pesticides were harmful to animals, had negative impacts on the environment and adversely impacted human health while maintaining that pesticides did not negatively affect crop production (64 %) (Table 2).

3.2.1. Association between social demographic characteristics of farmers and knowledge of agrobiologicals

Education level ($\chi^2 = 13.2$, $P = 0.047$) and household income ($\chi^2 = 23$, $P < 0.007$) had statistically significant associations with the level of agrobiologicals knowledge (Table 3). The farmers who had attained college and university level were associated with higher levels of knowledge on Agrobiologicals.

3.3. Assessment of association between attitude and demographic factors

Among the farmers interviewed, 20 % of the farmers agreed and 35 % strongly agreed that agrobiologicals are advantageous, and 24 % agreed and 47 % strongly agreed that agrobiologicals were cheaper and risk free (Table 3). In addition, 28 % agreed and 48 % strongly agreed that agrobiologicals were better than conventional inputs. A similar percentage agreed that agrobiologicals increase yields, produce healthy food and are safe for the environment. Between 20 % and 25 % agreed and between 39 % and 55 % strongly agreed that they would support agrobiologicals in their communities, that agrobiologicals do not have special storage conditions and that governments should support the use of agrobiologicals. 70 % of farmers preferred agrobiologicals (20 % agreed and 50 % strongly agreed; Table 3).

The majority of farmers were positive towards agrobiologicals and no social demographic factors that had statistically significant association with attitudes towards agrobiologicals (Table 5).

3.4. Practices

The majority (71 %) of the farmers interviewed took actions deemed appropriate to minimize the impacts of pesticides. 31 % had stopped using pesticides due to their harmful impacts. A majority of the farmers (76 %) had agrobiologicals as part of their agricultural input choices; however, only 29 % had been using agrobiologicals, and the frequency of use ranged between never having used agrobiologicals to rarely using agrobiologicals. In the previous two cropping seasons only 30 % had used agrobiologicals at least once and only 23 % had used agrobiologicals in the preceding season. Nevertheless, 61 % of the farmers would recommend agrobiologicals as an agricultural input of choice (Table 4).

Table 2
Smallholder farmers' knowledge and use of agrobiologicals in Kajiado, Kiambu and Machakos counties.

Knowledge Questionnaire Items	Correct Response (n %)	Incorrect Response (n %)
Biologicals definition	180 (65 %)	95 (35 %)
Biologicals training	35 (13 %)	240 (87 %)
Fertilizer use purpose	229 (83 %)	46 (17 %)
Knows pesticide contents	78 (28 %)	197 (72 %)
Knows pesticide type	92 (33 %)	183 (67 %)
Pesticide use purpose	228 (83 %)	47 (17 %)
Pesticides affect animal health	216 (79 %)	59 (21 %)
Pesticides affect crop production	100 (36 %)	175 (64 %)
Pesticides affect environment	214 (78 %)	61 (22 %)
Pesticides affect human health	229 (83 %)	46 (17 %)

Table 3
Smallholders farmers' attitude towards agrobiologicals in Kajiado, Kiambu and Machakos counties.4

Attitude Questionnaire items	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Biologicals are advantageous	5 (1.8 %)	8 (2.9 %)	113 (41 %)	54 (20 %)	95 (35 %)
Biologicals are cheaper	35 (13 %)	11 (4.0 %)	34 (12 %)	66 (24 %)	129 (47 %)
Biologicals are risk free	12 (4.4 %)	8 (2.9 %)	78 (28 %)	71 (26 %)	106 (39 %)
Biologicals better than conventional inputs	33 (12 %)	17 (6.2 %)	34 (12 %)	58 (21 %)	133 (48 %)
Biologicals increase incomes	15 (5.5 %)	13 (4.7 %)	42 (15 %)	77 (28 %)	128 (47 %)
Biologicals increase yields	11 (4.0 %)	12 (4.4 %)	64 (23 %)	62 (23 %)	126 (46 %)
Biologicals produce healthy food	9 (3.3 %)	6 (2.2 %)	89 (32 %)	77 (28 %)	94 (34 %)
Biologicals are safe for environment	20 (7.3 %)	6 (2.2 %)	78 (28 %)	63 (23 %)	108 (39 %)
Community supports biologicals	62 (23 %)	13 (4.7 %)	21 (7.6 %)	51 (19 %)	128 (47 %)
Biologicals' use has no conditions	24 (8.7 %)	15 (5.5 %)	18 (6.5 %)	68 (25 %)	150 (55 %)
Does government support use of biologicals	110 (40 %)	10 (3.6 %)	8 (2.9 %)	15 (5.5 %)	132 (48 %)
I prefer biologicals	39 (14 %)	18 (6.5 %)	25 (9.1 %)	56 (20 %)	137 (50 %)

Table 4
Farmers practice of agrobiologicals usage by smallholder farmers in Kajiado, Kiambu and Machakos counties.6

Practices Questionnaire items	Correct Response	Incorrect Response
Actions taken to minimize pesticide impacts	196 (71 %)	79 (29 %)
Agricultural input choice	208 (76 %)	67 (24 %)
Frequency of using	65 (24 %)	210 (76 %)
Have you ever bought safe pesticide?	44 (16 %)	231 (84 %)
Would you recommend	168 (61 %)	107 (39 %)
Do you seasonally use	83 (30 %)	192 (70 %)
Have you ever stopped using a pesticide?	86 (31 %)	189 (69 %)
Have you used biological last cropping season?	63 (23 %)	212 (77 %)
Do you use	79 (29 %)	196 (71 %)

3.4.1. Association between practice on agrobiologicals and levels of education

A chi-square test of independence showed that appropriate practice on agrobiologicals was dependent upon levels of education ($\chi2 = 24$, $P < 0.001$) as well as household incomes ($\chi2 = 15.1$, $P < 0.039$) of farmers (Table 7). Those farmers with higher education level have increased chances that they have been trained on some of the aspects of agrobiologicals and also they have ability to read and comprehend on their on their own. However, there was no association was found between knowledge and age group, gender of the head household and number of years in farming.

3.5. The relationship between independent variables and the odd ratios of a farmer deemed having sufficient knowledge, positive attitude and valid practices regarding agrobiologicals

The analysis showed that when a farmer was male, the odds of having sufficient agrobiologicals knowledge increased by 103 % (AOR = 2.03 CI = (0.71, 6.10), P = 0.2), and the odds of having a positive attitude increased by 11 % (AOR = 1.11, CI = (0.20, 4.50), P = 0.9) while the odds of having valid practices reduced by 20 % (AOR = 0.80, CI = (0.25, 3.01), P = 0.7) (Table 5). However, the differences between male and females were not statistically significant. Regarding the level of education, farmers with higher education level had statistically significant higher odds of 44 % of having sufficient knowledge on agrobiologicals compared to those without any formal education (AOR = 1.44, CI= (0.04, 4.15), P 0.005) (Table 5). However, the attitude towards agrobiologicals was the same across all levels of education. Nevertheless, farmers with higher education levels had 18.8 higher odds of valid agrobiologicals practices compared to those without any formal education, a difference that was statistically significant (AOR = 18.8, CI = (1.53, 569), P = 0.041). Household income showed that low income earners had 76 % odds of not having sufficient education when compared with high income earners, a difference that was again statistically significant (AOR = 0.23, CI = (0.11, 0.48), P < 0.001). Farming experience showed that for every additional year in farming the odds of biological knowledge increased by 1.02, odds of positive attitude increased by 0.99 and the odds of valid practices increased by 1.04. The results showed that only the odds of valid practices were statistically significant with yearly increase in farming experience (AOR = 1.04, CI = (1.00, 1.08), P = 0.041) (Table 5).

3.6. Dissemination workshop

To follow up on the KAP analysis a dissemination workshop was held in July 2023 where farmers who previously participated in the survey received the feedback on the outcome of the survey. From the discussion after the dissemination, it became evident that farmers still see many hurdles to incorporate agrobiologicals into their farming systems. For example, farmers spray routinely or follow calendar sprays, do not carry out soil testing but rather apply fertilizers as routine, do not regularly consult the agricultural extension officers but rather rely on advice from agro-dealers. Furthermore, they felt that agro-dealers should be regulated to control products being sold to farmers. The farmers explained the reasons for low adoption of agrobiologicals because they perceived them as (i) slow in action, (ii) expensive and (iii) not available in smaller packages.

4. Discussion

Agrobiologicals are believed to be a steppingstone towards a more sustainable agriculture because they can be safer, renewable options replacing more hazardous agrochemicals. Despite the potential to revolutionize agricultural production their use is limited in sub-Saharan Africa [5]. One of the hurdles for the adoption of agrobiologicalsis is the perception that they have low efficacy, are costly, sometimes unavailable, and might require special storage conditions [12.13]. However, these perceptions could either be facts or assumptions or both depending on type of agrobiologicals. This could be partly attributed to misinformation by farmers as far as what agrobiologicals are. For example, a previous study carried out by Center for agriculture and biosciences International (CABI) on biological control agents revealed that farmers could not precisely define or identify biological control agents (13). This means that farmers' knowledge could be misleading or lead to misinformation. A similar study carried out in Ethiopia [10] showed that even though majority of farmers (62 %) who took part in the study were reported to have sufficient knowledge on agrobiologicals they did not associate them with safety. Even though some of the perceptions, for example requirement for special storage conditions for agrobiologicals could be true, it has does not apply to all categories of agrobiologicals. Additionally, the sometimes lack a clear knockdown effect of agrobiologicals often associated with synthetic pesticides does not necessarily make agrobiologicals ineffective over time. Misinformation has been shown to hinder adoption of new technologies [32–34].

To be better able to pinpoint hurdles for smallholder farmers to adapt agrobiologicals we performed KAP analysis in three counties in Kenya.

The majority of farmers interviewed were males aged between 36 and 50 years who had attained secondary education level and earned their livelihoods from farming. The majority reported using agricultural inputs with pesticides being the most used one. Prodded further the farmers reported that they use pesticides to reduce yield loss attributed to pests and diseases even though the use of pesticides can have negative side-effects on users and the environment [35–38]. These views agree with a related KAP study among smallholder farmers we conducted in Ethiopia [26].

The majority of the farmers said they took deliberate action to reduce

Table 5
Relationship between deemed sufficient knowledge, positive attitude and valid practices regarding agrobiologicals among smallholder farmers in Kajiado, Kiambu and Machakos counties.8

Independent Variable	Levels of Independent Variables	Sufficient Knowledge			Positive Attitude			Valid Practices		
		AOR	95 % CI	p-value	AOR	95 % CI	p-value	AOR	95 % CI	p-value
Head of household	Female	–	–		–	–		–	–	
	Male	2.03	0.71, 6.10	0.2	1.11	0.20, 4.50	0.9	0.80	0.25, 3.01	0.7
Age Group	18–35	–	–		–	–		–	–	
	36–50	1.39	0.15, 10.9	0.8	3.58	0.40, 27.3	0.2	0.55	0.05, 7.52	0.6
	51–60	0.76	0.07, 6.62	0.8	4.18	0.39, 40.1	0.2	0.39	0.03, 6.03	0.5
	Above 60	0.89	0.08, 8.96	>0.9		0.00,	>0.9	0.33	0.02, 5.89	0.4
Education level	No formal schooling	–	–		–	–		–	–	
	primary education	0.45	0.05, 2.55	0.4	0.00		>0.9	1.13	0.13, 26.6	>0.9
	secondary education	0.60	0.07, 3.51	0.6	0.00		>0.9	2.65	0.30, 64.5	0.4
	college training (certificate, diploma)	0.49	0.05, 3.14	0.5	0.00		>0.9	3.81	0.40, 96.6	0.3
	Bachelor degree and above	1.44	0.04, 4.15	0.005	0.00	0.00, 14	>0.9	18.8	1.53, 569	0.041
Marital status	Single	–	–		–	–		–	–	
	Married	0.45	0.18, 1.06	0.080	1.43	0.48, 3.84	0.5	0.97	0.39, 2.69	>0.9
	Windowed	0.44	0.09, 2.19	0.3	0.82	0.10, 8.06	0.9	1.88	0.28, 11.4	0.5
	Separated	0.47	0.02, 14.0	0.6	9	0.00, NA	>0.9	4.66	0.12, 174	0.4
	Divorced	0.34	0.01, 4.72	0.4	0.17	0.00, 6.59	0.3	0.64	0.02, 9.99	0.8
Household income	10000–20000	–	–		–	–		–	–	
	5000–10000	0.80	0.42, 1.51	0.5	1.41	0.59, 3.45	0.4	0.65	0.29, 1.40	0.3
	Below 5000	0.23	0.11, 0.48	<0.001	0.87	0.33, 2.38	0.8	0.98	0.39, 2.41	>0.9
Farming years	Years	1.02	0.99, 1.05	0.2	0.99	0.95, 1.04	0.8	1.04	1.00, 1.08	0.041

the use of pesticides, even though they did not specify what actions they took. Few farmers reported low frequency of use of agrobiologicals, however, they indicated that they had bought safer pesticides in the last few years. Even though farmers said they would recommend use of agrobiologicals, they were in fact not extensively using them.

Knowledge on agrobiologicals was highest among the farmers who had obtained university level of education who, however, were a minority; however, whereas the level of education and household income positively influenced the knowledge on agrobiologicals, there was no association between knowledge on agrobiologicals and gender of the household head, farmers' age, marital status or years of farming. Similar findings were reported by Kamano et al., 2021 [17] who found that higher or sufficient knowledge does not necessarily translate to good practice and positive attitude. Their study showed that farmers had knowledge on risks associated with consumption of maize contaminated with aflatoxin but nevertheless consumed the contaminated maize. Yassin et la., 2002 [39] reported similar findings where farmers in Gaza continued to use pesticides even though they were aware of the hazards associated with their use.

Even though years of experience did not influence practice, previous studies have reported that farming experience influences adoption of new technologies and innovations as farmers tend to switch from traditional to modern farming technologies over time [40,41]. Thus, this observation that years of farming experience did not influence practice on agrobiologicals could be attributed to the fact agrobiologicals is a relatively new concept in Kenya and farmers have not interacted with the concept for a long time.

According to the responses, the definition of agrobiologicals depended on what the individual farmers had interacted with. For example, some farmers defined agrobiologicals as pesticides with short preharvest intervals, biological control organisms, plant extracts, pheromones and even manure. This implies that the farmers could not define the agrobiologicals with high precision.

Among the farmers who reported using agrobiologicals, lack of knowledge on the use of agrobiologicals was reported to be the biggest challenge followed by perceived low efficacy and preservation and storage. This observation agrees with previous surveys in Kenya that the use of agrobiologicals is constrained by slow action on pests (lack of knockdown effects), short shelf life and requirements of special storage conditions for some products [2,12]. While using agrobiologicals, some level of damage must be acceptable among farmers since they lack knockdown effect.

The social demographic characteristics, i.e., age, gender of the head of household, marital status and of the interviewed farmers did not influence their generally positive attitude towards agrobiologicals. However, the farmers from the three counties portrayed different attitudes towards agrobiologicals, e.g., efficacy, health and safety, availability of information and affordability. Similarly, the farmers had varied responses regarding community and government support for the use of agrobiologicals, and whether they would recommend the use of agrobiologicals to fellow farmers.

A majority of farmers (55 %) said agrobiologicals were advantageous while almost half of the interviewed farmers (47 %) thought agrobiologicals are cheaper. Regarding safety of the agrobiologicals majority of farmers said they are safe compared to synthetic pesticides. Additionally, farmers responded that they would consider the use of agrobiologicals and recommend them to other farmers, which is similar to observations made in the Ethiopia in similar a study [26]. A majority of farmers (65 %) thought agrobiologicals have less risks compared to the synthetic pesticides, which is similar to study carried out among Ethiopian smallholder farmers [26]. Previous studies on attitude on adoption of alternatives to synthetic pesticides showed that farmers in Kenya and Uganda had positive attitudes towards the alternatives to synthetic pesticides [42].

Regarding whether the government supports the use of agrobiologicals, half of the farmers were not sure. During the interactions with the farmers in Kajiado, Kiambu and Machakos, it was observed that the government extension service providers had little interaction with farmers. This might lead to the farmers not receiving adequate information regarding government policies or initiatives related to agrobiologicals. In contrast, 71 % farmers in Ethiopia agreed about the adequate government support the use of biological [26].

Understanding the information flow regarding agrobiologicals among smallholder farmers is important. The majority of the farmers reported that neither they nor their wives/spouses have been trained on using agrobiologicals and that the information they had was gathered from neighbours. This could lead to the spread of misinformation on agrobiologicals. Our study revealed that the agro-dealers are the main source of information regarding pesticide use for smallholder farmers. Similar findings were reported in Kenya [43]. This is clearly different from the related KAP analysis in Ethiopia were the majority of the participating farmers (73 %) received information from extension service officers from the government [26]. Though the majority of the farmers thought that the use of agrobiologicals is advantageous in terms of the safety of food produced, 41 % of farmers in Kiambu and Kajiado and 31 % in Machakos agreed or disagreed regarding the safety of agrobiologicals.

Interestingly, most of the agro-dealers lack background training in agriculture in general and specifically pesticides. Many have learned on the job or been trained by NGOs and companies dealing in agrochemicals (personal observations). Therefore, it is possible that farmers receive inadequate or inappropriate information on the use of pesticides and possible alternatives such as agrobiologicals. Additionally, whereas agro-dealers were the main source of information on pests and diseases and synthetic pesticides, neighbors were, nevertheless, the main source of information on agrobiologicals. Reliance on information from neighbors could either be due to the unavailability of agricultural extension officers to advise farmers or due to the trust and reliability of information from fellow farmers (neighbors) [55]. A study carried out in Kenya and Uganda revealed that farmers rarely report pest problems to extension officers [24]. This shows the existing gap in information flow that is usually filled by agro-dealers. A future strategy could be to provide training to agro-dealers and involve them in the necessary local testing and validation of agrobiologicals.

According to the farmers, the agrobiologicals are neither easy to use nor affordable. One of the challenges in the uptake and use of agrobiologicals is the requirement for special storage conditions and short shelf-life for some, which directly affects their affordability [46]. These concerns were reiterated during the dissemination workshop held to share the findings of the KAP analysis. From this workshop and the KAP analysis it is clear that farmers' views need to be considered before proposing solutions or designing projects that are supposed to help farmers adopt agrobiologicals. An appropriate introduction on the use of agrobiologicals should also be followed up with continuous monitoring of outcomes taking the farmers everyday challenges in pest and disease management into account. Farmers in the three counties produce vegetables such as tomatoes, crucifers, French bean and indigenous vegetables. Tomato production is predominantly intensive production and there is heavy use of pesticides [43]. The adoption of alternatives to pesticides can be enhanced by increasing stakeholder involvement [46]. Their experience of the use of synthetic pesticides could possibly negatively influence their attitude towards agrobiologicals since they lack knock down effect.

5. Conclusion

Overall, the majority of farmers had sufficient knowledge, positive attitudes and good practices regarding agrobiologicals. This agrees with a previous study in Ethiopia, where farmers had a more positive attitude compared to knowledge and practice [26]. The association between knowledge and attitude toward agrobiologicals did not differ significantly between the three counties. However, the practice of using agrobiologicals was significantly higher in Kajiado. Attitudes and practices were positively influenced by a higher level of education.

This study confirms the previously reported low use of agrobiologicals and higher use of conventional chemical pesticides in the counties specifically and Kenya in general. Despite the presence of registered agrobiologicals in the Kenyan market, demand and availability are low, probably due to a lack of information. Smallholder farmers perceived the agrobiologicals to have low efficacy, short shelf-life and to be costly. In addition, farmers thought that their communities and government did not support the use of agrobiologicals. Despite these reported shortcomings, farmers are willing to adopt them. This study underscores the need for more awareness and promotion if an increased use of agrobiologicals is desirable and should be achieved.

CRediT authorship contribution statement

Allan Mweke: Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Erik Alexandersson:** Writing – review & editing, Resources, Methodology, Funding acquisition, Conceptualization. **Tewodros Mulugeta:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Mesia Ilomo:** Writing – review & editing, Validation, Methodology, Data curation. **Quenton Kritzinger:** Writing – review & editing, Validation, Project administration, Data curation, Conceptualization. **Lerato Matsuanyane:** Writing – review & editing, Resources, Project administration, Funding acquisition, Data curation. **CeCecilia Moraa Onyango:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Data curation, Conceptualization.

Consent to publish

All authors read and approved the publishing of this article.

Ethical approval

Not applicable.

Disclosure statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jafr.2024.101614.

Data availability

Data will be made available on request.

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