**Knowledge, attitude and practice on use of agricultural biologicals in Kenya: a smallholder farmers’ perspective**

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**Abstract**

Agricultural biologicals can be sustainable options for the management of plant pests and diseases, and lead to enhanced crop production. They can reduce reliance on synthetic agricultural inputs, which often come from non-renewable sources, and can pose risks to the environment and farmers. However, in comparison to Europe and the Americas the use of biologicals in Sub-Saharan Africa is low. To obtain a better understanding of the low adaption, we carried out a Knowledge, Attitude and Practice (KAP) analysis among smallholder farmers in Kenya regarding the use of agricultural biologicals. 275 farmers were interviewed in the counties Kajiado, Kiambu and Machakos. The majority of farmers (76%) were deemed to have relevant knowledge of agricultural biologicals even though some of the inputs they referred to as biologicals were in fact not, and the majority (76%) were not trained with regards to agricultural biologicals. Almost half of the farmers (40%) in the three counties obtained information on biologicals from neighbors while agro-dealers were key advisors to farmers regarding agricultural inputs in general. Kajiado County had the highest level of reported use of biologicals (47% of farmers). Knowledge and attitude did not differ significantly (p<0.01) across the three counties, however, there was significant variation in practices. Years of farming and knowledge of agricultural biologicals positively correlated but not attitude and practice. Evensufficient knowledge of agricultural biologicals did not translate to increased use. This means that knowledge of biologicals alone is not sufficient to ensure the use of biologicals among smallholder farmers in Kenya.

**Keywords**

Agricultural biologicals**,** smallholder farmers, knowledge, attitude, practice.

**Introduction**

Agricultural biological products consist of living organisms or derivatives of these. These can, for example, be microorganisms, plant extracts, beneficial insects, or other organic matter. Agricultural biologicals is an umbrella term for a large number of modes of action, and they can be biostimulants (plant growth/productivity enhancement products); biopesticides (plant protection or biocontrol products) or biofertilizers (plant nutrition products) (Adesemoye, 2017). Farmers apply agricultural biologicals to either complement chemical products as part of an integrated pest management (IPM) system or solely to improve growth and product value, and for protecting plants from disease, insect pests and competiting weeds. Agricultural biologicals can be parts of sustainable agricultural production because they can be safer for the users, the environment and non-target organisms and also accommodate beneficial organisms to protect crops (Grzywacz, Cherry and Gwynn, 2009).

In the past, efforts have been made to identify, develop and promote agricultural biologicals in Africa, but there has been a very slow uptake with little impact compared to the funding provided (Grzywacz, Cherry and Gwynn, 2009; Akutse et al., 2020) even with the evidence that agricultural biologicals have the potential to suppress pests and enhance yields (Tembo et al., 2018). For example, the use of biological pesticides 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 (Olson, 2015). This, despite the identification of biologicals in lab studies with potential use in African agriculture (Mulugeta et al 2020). 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 (Constantine et al., 2020). The adoption of alternatives to pesticides can be enhanced by increasing stakeholder involvement (Ratto et al., 2022). This study therefore sought to document smallholder farmers’ knowleledge and attitude of agricultural biologicals and subsequent usage practices in Kenya.

**Materials and methods**

**The study sites**

The study was undertaken in three counties in Kenya, namely, Machakos, Kajiado and Kiambu. Kajiado and Kiambu neighbor the capital city Nairobi, produce a variety of vegetables and supply the city populace while Machakos 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 1,600- 1,800 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 market. Kiambu is a peri-urban county that borders Nairobi city (1.1748° S, 36.8304° E) and the elevation ranges between 1,100 and 3,900 meters 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. These three counties were identified as counties that had reported to have heavy usage of pesticides in vegetables, and because the farm sizes are small, farmers tend to practice intensive farming.

**Data collection**

A survey was conducted between February and March 2022 using a questionnaire with both open and closed questions. 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 minutes 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 pretested and validated by 15 farmers 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 agricultural biologicals, their accessibility, perceived efficacy, their application, their benefits and advantages over conventional inputs, types of agricultural biologicals used and any policies and regulations on the use of agricultural biologicals in Kenya. Observations were also made and documented on the farmers’ practices. The data were captured using ODK collect Application, which is an open-source Android app that replaces paper forms used in survey-based data gathering.

**Data analysis**

**Data was downloaded from the kobotoolbox website repository into excel sheets in Microsoft Excel 2021. The data was cleaned by redoing the variables, removing and imputing missingness in readiness for descriptive and inferential statistics. Categorical variables in social demographics were illustrated in tables as percentage proportions while continuous variables were illustrated as means and standard deviations. The knowledge questions were coded into sufficient and insufficient knowledge depending on the responses given. Sufficient knowledge was given a value of 1 and insufficient knowledge a value of 0. The recoded values were used to determine the total knowledge score. Attitudes were coded into preferrable and not-preferrable attitudes for agree and strongly agree responses and disagree and strongly disagree responses respectively. Preferable attitudes were given a value of 1 while no-preferred attitude responses were given a value of 0. A sum of the individual scores was used to determine the total attitude score for each respondent farmer. Practices were coded into valid and invalid practices regarding biologicals. Valid responses were given a score of 1 while invalid practices’ responses were given a value of 0. Similarly total practices scores were derived from the sum of individual scores for each farmer.**

**Association between social demographics and knowledge, attitudes and practices, was determined by use of a chi-square test of association using a 95% confidence interval. A Pearson’s correlation coefficient was used 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 on knowledge, attitude and practices regarding biologicals.**

**Results**

**Social Demographics**

**The majority of farmers were aged between 36 and 50 years (72%) with a primary school education (42%). The majority were married (79%) and average household income ranged between 5000 and 10000 Kenya shillings. The household head was mainly the male in the house and the household had done farming for an average of 13 years.**

| **Social Demographics** | Frequency |
| --- | --- |
| **Age** |  |
| 18-35 | 5 (1.8%) |
| 36-50 | 198 (72%) |
| 51-60 | 46 (17%) |
| Above 60 | 26 (9.5%) |
| **Education level** |  |
| No 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** |  |
| 10000-20000 | 103 (38%) |
| 5000-10000 | 111 (41%) |
| Below 5000 | 58 (21%) |
| **Head of household** |  |
| female | 38 (14%) |
| male | 237 (86%) |
| **Farming years** | 13 |

**Smallholder farmers’ knowledge and use of agricultural biological**

| Knowledge Statement | Knowledge Prevalence |
| --- | --- |
| Pesticide purpose |  |
| Insufficient | 46 (17%) |
| Sufficient | 229 (83%) |
| Fertilizer purpose |  |
| Insufficient | 46 (17%) |
| Sufficient | 229 (83%) |
| Knows pesticide type |  |
| Insufficient | 183 (67%) |
| Sufficient | 92 (33%) |
| knows pesticide content |  |
| Insufficient | 197 (72%) |
| Sufficient | 78 (28%) |
| Human health effects |  |
| Insufficient | 275 (100%) |
| Animal health effects |  |
| Insufficient | 59 (21%) |
| Sufficient | 216 (79%) |
| Environment effects |  |
| Insufficient | 60 (22%) |
| Sufficient | 214 (78%) |
| Crop production effects |  |
| Insufficient | 174 (64%) |
| Sufficient | 99 (36%) |
| Mitigation |  |
| Insufficient | 50 (20%) |
| Sufficient | 203 (80%) |
| Input choice |  |
| Insufficient | 67 (24%) |
| Sufficient | 208 (76%) |

**Overall Knowledge**

| Knowledge level | **Frequency (%)** |
| --- | --- |
| Insufficient | 73 (27%) |
| Sufficient | 202 (73%) |

In the three counties of Kajiado, Kiambu and Machakos the majority (76%) of farmers were deemed to have relevant knowledge of agricultural biologicals. About 50% of farmers in Kajiado, 21% in Kiambu and 18% in Machakos indicated that they were using agricultural biologicals (Table 1) and when prodded further to explain what agricultural biologicals are, they gave the following response: substances with short post-harvest intervals; sourced from plants; pheromones; and biological control. An example of a biological pesticide used in the survey area was *Bacillus thuringiensis* (Bt) based biopesticides. Additionally, most farmers described farmyard manure as a biological input. It was evident that knowledge and definitions varied depending on what the farmers have been exposed to and some responses did not fall into the category of agricultural biologicals.

**Table 1: Farmer knowledge and use of agricultural biologicals**

|  |  |  |
| --- | --- | --- |
| County | Use (%) | Type of biologically based on farmer knowledge |
| Kajiado | 47.0% | Farmyard manure |
| Kiambu | 21.0% | Farmyard manure, plant extracts |
| Machakos | 18.0% | Substances with short PHI, pheromone traps, biopesticides, biological control agents |
| Relevant knowledge | 24% |  |

**Sources of information on biological**

Most farmers interviewed indicated that their main sources of information on agricultural biologicals are neighbours or colleagues, agro-dealers and through training sessions by NGOs (Table 2). This implies that if neighbours and agro-dealers have irrelevant or inadequate knowledge, the same is passed to the farmers***.***

**Table 2: Sources of information on agricultural biologicals**

|  |  |  |  |
| --- | --- | --- | --- |
| Sources of information | **Counties** | | |
| Kajiado (N=95) | Kiambu (N=108) | Machakos (N=72) |
| Agro-dealers | 19.0% | 28.0% | 21.0% |
| Extension officers | 13.0% | 4.0% | 0.0% |
| Neighbour/colleague | 33.0% | 32.0% | 57.0% |
| Newspapers | 3.0% | 0.0% | 0.0% |
| Social media | 4.5% | 8.0% | 0.0% |
| Through training sessions by research institutions | 19.0% | 16.0% | 14.0% |
| Tv/radio | 7.5% | 12.0% | 7.1% |

**Training on agricultural biologicals*:*** Most of the 275 farmers interviewed were not trained on any aspects of agricultural biologicals and neither were their wives/spouses (Table 3).

**Table 3: Smallholder farmers’ training on agricultural biologicals**

|  | **Kajiado (N=95)** | **Kiambu (N=108)** | **Machakos (N=72)** |
| --- | --- | --- | --- |
| Have you or your wife/spouse been trained on agricultural biologicals? |  |  |  |
| Yes | 7.4% | 2.8% | 2.8% |
| No | 76.0% | 71.0% | 72.0% |
| Don’t Know | 13.0% | 13.0% | 12.0% |
| Not Applicable | 4.2% | 13.0% | 12.0% |

**Practice of agricultural biologicals** **usage**

| Practices Statement | Practices Prevalence |
| --- | --- |
| usse agricultural inputs |  |
| Invalid | 21 (7.7%) |
| Valid | 253 (92%) |
| agricultural input |  |
| Valid | 253 (100%) |
| bought safer pesticide |  |
| Invalid | 230 (84%) |
| Valid | 44 (16%) |
| Biological use times |  |
| Invalid | 146 (64%) |
| Valid | 83 (36%) |
| use biologicals |  |
| Invalid | 194 (71%) |
| Valid | 79 (29%) |
| used biologicals last farming season |  |
| Invalid | 39 (38%) |
| Valid | 63 (62%) |
| biologicals use frequency |  |
| Invalid | 22 (25%) |
| Valid | 65 (75%) |

Overall Practices

| Practices level | **Frequency (%)** |
| --- | --- |
| Invalid | 78 (28%) |
| Valid | 197 (72%) |

Less than 50% of the 275 farmers interviewed in Kajiado, Kiambu and Machakos reported to be using agricultural biologicals and the low number of users were recorded in Machakos, 18% (Table 4).The majority of farmers in Kajiado and Kiambu reported to be using agricultural biologicals every season while in Machakos, the majority reported using them in some seasons (Table 4).

**Table 4: Farmers using biological and the frequency of use**

|  | **Kajiado (N=95)** | **Kiambu (N=108)** | **Machakos (N=72)** | |
| --- | --- | --- | --- | --- |
| % of farmers using biological |  |  |  | |
| Yes | 46.0% | 20.0% | 18.0% | |
| No | 54.0% | 80.0% | | 82.0% |
| **Frequency of use of biological** |  |  |  | |
| Every season | 62.0% | 64.0% | 23.0% | |
| Seldom e.g. once in a life | 25.0% | 14.0% | 0.0% | |
| Some seasons | 13.0% | 9.1% | 54.0% | |

**Challenges of using Agricultural biologicals**

When farmers were asked about the challenges associated with the use of agricultural biologicals, the most cited challenge was a lack of knowledge in using agricultural biologicals (23% in Kajiado, 20% in Kiambu and 22% in Machakos), followed by low efficacy associated with the agricultural biologicals and absence of supplementary input ingredients as the biggest impediments to their use (Table 5).

**Table 5: Farmers’ challenges on the use of agricultural biologicals**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Kajiado (N = 101)** | **Kiambu (N = 116)** | **Machakos (N = 78)** |
| **Challenges in using agricultural biologicals** |  |  |  |
| Absence of supplementary inputs ingredients | 11.0% | 23.0% | 17.0% |
| Lack of knowledge in using biological | 23.0% | 20.0% | 22.0% |
| Lack of support services after sale | 0.0% | 10.0% | 0.0% |
| Low efficacy | 19.0% | 23.0% | 28.0% |
| Preservation /storage challenge | 6.4% | 3.3% | 5.6% |
| Not applicable (farmers not using biologicals) | 2.1% | 10.0% | 11.0% |
| Others (other reasons) | 38.0% | 10.0% | 17.0% |

**Attitude to agricultural biologicals**

Regarding attitude, 63% had a negative attitude toward agricultural biologicals. The majority of farmers interviewed reported that agricultural biologicals are not effective with only 32% in Kajiado, 27% in Kiambu and 15% Machakos reporting that they were effective (Table 6). Nevertheless, 88% of the farmers in Kajiado and Machakos, and 72% in Kiambu indicated their willingness to use agricultural biological (Table 6) given the negative effects of synthetic pesticides on their health and the environment. This could probably be attributed to the fact that most farmers consider farmyard manure as a biological input. This could also be due knowledge by farmers of other benefits of agricultural biologicals and not necessarily immediate disease control. Further, 60% in Kajiado, 56% in Kiambu and 68% in Machakos believed that the use of agricultural biologicals is advantageous (Table 6) by linking the use of agricultural biologicals and the production of healthy food (62% of the farmers in Kajiado, 53% Kiambu and 69% in Machakos) and increased yields (53% in Machakos). ~~Nevertheless, a considerable number of farmers in the three counties were not able to associate agricultural biologicals and the production of healthy foods or high yields~~ (Table 6).

**Table 6: Farmers’ attitude towards agricultural biologicals**

| Attitude Statement | Attitude Prevalence |
| --- | --- |
| Biologicals increase yield of crops |  |
| Preferrable | 148 (54%) |
| Unpreferrable | 126 (46%) |
| Biologicals increase incomes |  |
| Preferrable | 141 (52%) |
| Unpreferrable | 128 (48%) |
| biologicals advantageous |  |
| Preferrable | 179 (65%) |
| Unpreferrable | 95 (35%) |
| Biologicals can produce healthy food |  |
| Preferrable | 178 (65%) |
| Unpreferrable | 94 (35%) |
| recommend biologicals |  |
| Preferrable | 191 (72%) |
| Unpreferrable | 74 (28%) |
| government support biologicals |  |
| Preferrable | 132 (50%) |
| Unpreferrable | 132 (50%) |
| Biologicals risk free |  |
| Preferrable | 14 (5.2%) |
| Unpreferrable | 255 (95%) |
| biologicals environmentally safe |  |
| Preferrable | 14 (5.3%) |
| Unpreferrable | 249 (95%) |
| biologicals use unconditional |  |
| Preferrable | 32 (12%) |
| Unpreferrable | 236 (88%) |

**Overall Attitude**

| Attitude level | **Frequency (%)** |
| --- | --- |
| Preferrable | 139 (51%) |
| Unpreferrable | 136 (49%) |

|  |  |  |  |
| --- | --- | --- | --- |
|  | **County** | | |
|  | **Kajiado**  **(N=95)** | **Kiambu**  **(N=108)** | **Machakos**  **(N=72)** |
| Are agricultural biologicals effective? |  |  |  |
| No | 67.0% | 59.0% | 77.0% |
| Yes | 32.0% | 27.0% | 15.0% |
| Are you considering use of agricultural biologicals? |  |  |  |
| Yes | 88.0% | 72.0% | 88.0% |
| No | 8.4% | 19.0% | 5.6% |
| I am not sure | 3.2% | 8.3% | 6.9% |
| Does the use of agricultural biologicals offer any advantages? |  |  |  |
| Agree | 60.0% | 56.0% | 68.0% |
| Disagree | 7.4% | 2.8% | 2.8% |
| Neither agree nor disagree | 33.0% | 40.0% | 29.0% |
| Does the use of agricultural biologicals guarantee food safety? |  |  |  |
| Agree | 62.0% | 53.0% | 69.0% |
| Disagree | 7.4% | 3.7% | 1.4% |
| Neither agree nor disagree | 28.0% | 44.0% | 28.0% |
| Does the use of agricultural biologicals increase crop yields |  |  |  |
| Agree | 43.0% | 44.0% | 53.0% |
| Disagree | 11.0% | 5.6% | 8.3% |
| Neither agree nor disagree | 46.0% | 51.0% | 38.0% |

Farmers interviewed in Kajiado indicated that the use of agricultural biologicals results in increased income while the majority of those in Kiambu county seemed not to either agree or disagree and in Machakos there was an equal number of farmers that agreed and disagreed with the statement (Table 7). The availability of information on agricultural biologicals***,*** most farmers interviewed reported that information on agricultural biologicals is not readily available (Table 7). When interviewed on the risks associated with agricultural biologicalsmost farmers perceived agricultural biologicals as risk-free. However, there were a number of farmers who were not sure of the effect of the agricultural biologicals. For example, 41% of the farmers in Kajiado, 41 % in Kiambu and 31% in Machakos neither agreed nor disagreed on the safety of agricultural biologicals (Table 7).

|  | **County** | | |
| --- | --- | --- | --- |
| **Characteristic** | **Kajiado**  **(N=95)** | **Kiambu**  **(N=108)** | **Machakos**  **(N=72)** |
| Does the use of agricultural biologicals increase income for farmers? |  |  |  |
| Agree | 47.0% | 40.0% | 43.0% |
| Disagree | 11.0% | 4.6% | 9.7% |
| Neither agree nor disagree | 38.0% | 56.0% | 44.0% |
| Is the information on agricultural biologicals easily available? |  |  |  |
| Agree | 20.0% | 25.0% | 21.0% |
| Disagree | 53.0% | 31.0% | 38.0% |
| Neither agree nor disagree | 20.0% | 44.0% | 39.0% |
| Are there risks associate with use of agricultural biologicals? |  |  |  |
| Agree | 45.0% | 55.0% | 65.0% |
| Disagree | 8.4% | 3.7% | 2.8% |
| Are agricultural biologicals environmentally safe? |  |  |  |
| Agree | 47% | 47% | 62% |
| Disagree | 6.3% | 6.5% | 1.4% |
| Neither agree nor disagree | 36% | 45% | 35% |

**Table 7: Farmers’ perceptions on effectiveness, risks and availability of information on agricultural agricultural biologicals**

On whether, the use of biologicals was influenced by market preferences, about half of the farmers interviewed in the three counties of Kajiado (49%), Kiambu (52%) and Machakos (47%) were not sure whether market preferences or conditions do influence the use of agricultural biologicals. On the ease of use of agricultural biologicals, 41% of farmers in Kajiado disagreed that agricultural biologicals are easy to use while 47% in Machakos and Kiambu were not sure of the ease of use of agricultural biologicals as compared to conventional inputs. Only 32% in Kiambu and 26% in both Machakos and Kajiado of farmers in the three counties indicated that it is easier to use agricultural biologicals than it is to use conventional pesticides (Table 8). On affordability of agricultural biologicals: About half of the farmers interviewed (44% of the farmers in Kajiado, 46% in Kiambu and 51% in Machakos) were not sure of the cost of the agricultural biologicals compared to conventional inputs. In terms of government support for the use of biologicals, 53% of the farmers in Kajiado, 47% in Machakos and 44% in Kiambu counties were not sure whether the government supports the use of agricultural biologicals or not while 48% in Kiambu county disagreed that government supports the use of biological (Table 8).

**Table 8: Farmer’s attitude on information, availability, affordability, ease of use and government support on the use of agricultural biologicals and recommending agricultural biologicals to other users.**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **County** | | |
|  | **Kajiado**  **(N=95)** | **Kiambu**  **(N=108)** | **Machakos (N=72)** |
| Does the produce market influence the use of agricultural biologicals? |  |  |  |
| Agree | 35% | 24% | 31% |
| Disagree | 8.4% | 22% | 21% |
| Neither agree nor disagree | 49% | 52% | 47% |
| Are agricultural biologicals easy to use? |  |  |  |
| Agree | 26% | 32% | 26% |
| Disagree | 41% | 20% | 22% |
| Neither agree nor disagree | 24% | 47% | 47% |
| Are agricultural biologicals affordable? |  |  |  |
| Agree | 32% | 40% | 38% |
| Disagree | 17% | 13% | 11% |
| Neither agree nor disagree | 44% | 46% | 51% |
| Does your community support the use of agricultural biologicals? |  |  |  |
| Agree | 37% | 21% | 19% |
| Disagree | 8.4% | 27% | 31% |
| Neither agree nor disagree | 45% | 47% | 47% |
| Does the government support the use of agricultural biologicals? |  |  |  |
| Agree | 9.5% | 5.6% | 11% |
| Disagree | 29% | 48% | 40% |
| Neither agree nor disagree | 53% | 44% | 47% |

**Association of knowledge, attitude, and practice with farmers’ demographic characteristics in the three counties**

To calculate whether a farmer was deemed to have sufficient knowledge, a positive attitude, or conducting a good practice with regards to agricultural biologicals relative values based on an arbitrary cut-off of 50% of the highest possible value for the answers in each category. Consequently, farmers scoring >6.5 out of 11 for knowledge, >3.5 out of 7 for attitude and > 3 out of 6 for practice were thought to have sufficient knowledge, a positive attitude, or conducting a good practice, respectively.

The overall score for an individual with the highest score is 11. Therefore, an overall mean score of 6.5? or above indicates overall sufficient knowledge. The highest score for attitude is 7, thus a mean score of below 3.5 indicate negative attitude towards agricultural biologicals while a mean score of 3.0 for practices indicates an overall poor practices level on agricultural biologicals. There were no differences in knowledge across the three different counties (p = 0.7). The same trend was observed in attitude scores across the three counties (p = 0.3). However, the practice score was significantly different in the three counties (p<0.001), where Kajiado had a significant score of 6 above the mean (Table 9). Regarding education level, the attitudes and practices of agricultural biologicals were generally higher for degree and certificate holders as compared to secondary, primary and no-schooling groups, these differences were found to be significant (Table 9). Knowledge and practices did not differ significantly across marital status, however, attitudes differed across marital status with separated individuals having the larger significant scores compared to the rest which was equal as indicated in Table 9.

There were significant differences in mean scores of knowledge based on income. Households with incomes of Kenyan Shilling (Ksh) 0-5000 and Ksh 10001-20000 (p < 0.001), 0-5001 and Ksh 5000-10000 (p < 0.001) and Ksh 0-5000 and above 20000 (p < 0.001). The knowledge scores were lowest for low-income earners (0-5000) in comparison to higher-income earners (Ksh 10,000 and above).

A significant difference in attitude was observed between Ksh 0-5000 earners and Ksh 5001 to 10000 earners (p < 0.01) with a more positive attitude among farmers with higher income (Table 9).

Although the p-value for attitude score was equivalent to 0.05, the post hoc analysis between monthly income and practices did not give significant differences at any level.

**Table 9: Relationship between Knowledge, attitudes and practices of agricultural biologicals with farmer’s demographics divided into residency (county), age, educational level, marital status, gender, and income level.**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Counties** | **Kajiado N = 95** | **Kiambu**  **N = 108** | | **Machakos**  **N = 72** | | **Mean**  **N = 275** | | | | **Significance** |
| Knowledge - score | 6.5 | 6.7 | | 6.6 | | 6.6 | | | | p = 0.7 |
| Attitudes - score | 3.2 | 2.8 | | 3.18 | | 3.01 | | | | p = 0.3 |
| Practices - score | 3.8 | 2.7 | | 2.5 | | 3.0 | | | | p<0.001 |
|  |  |  | |  | |  | | | |  |
| **Age** | **18-35**  **N = 5** | **36-50**  **N = 198** | | **51-60**  **N = 46** | | **60 +**  **N = 26** | | **Mean**  **N=275** | | **Significance** |
| Knowledge-score | 6.8 | 6.8 | | 6.1 | | 6.2 | | 6.6 | | p = 0.1 |
| Attitudes-score | 4.2 | 3.0 | | 3.2 | | 2.8 | | 3.0 | | p = 0.6 |
| Practices-score | 4.4 | 3.0 | | 3.20 | | 2.9 | | 3.0 | | p = 0.2 |
|  |  |  | |  | |  | | | |  |
| **Educational level** | **Bachelors**  **Degree N=12** | **Certificate/**  **Diploma N=41** | | **Secondary**  **N=116** | | **Primary**  **N=99** | | **NO**  **Schooling**  **N=7** | **Mean**  **N=275** | **Significance** |
| Knowledge-score | 7.6 | 6.8 | | 6.2 | | 6.9 | | 6.0 | 6.6 | p = 0.06 |
| Attitudes-score | 4.3 | 3.0 | | 2.5 | | 3.4 | | 3.3 | 3.0 | p= 0.008 |
| Practices-score | 4.7 | 3.5 | | 2.8 | | 3.0 | | 3.1 | 3.0 | p= 0.001 |
| **Marital status** | **Divorced**  **N = 3** | **Married**  **N = 216** | | **Separated**  **N = 2** | | **Single**  **N = 42** | | **Widowed**  **N = 11** | **Mean**  **N = 275** | **Significance** |
| Knowledge-score | 7.3 | 6.5 | | 7.5 | | 7.1 | | 6.0 | 6.6 | p = 0.4 |
| Attitudes-score | 3.3 | 2.9 | | 6.5 | | 3.7 | | 2.9 | 3.0 | p = 0.03 |
| Practices-score | 3.3 | 2.9 | | 4.0 | | 3.3 | | 3.7 | 3.0 | p = 0.3 |
|  |  |  | |  | |  | |  |  |  |
| **Gender** | **Male**  **N = 237** | | | **Female**  **N = 38** | | | | | **Mean**  **N=275** | **Significance** |
| Knowledge-score | 6.0 | | | 6.7 | | | | | 6.6 | p=0.07 |
| Attitudes-score | 3.0 | | | 3.0 | | | | | 3.0 | p=0.9 |
| Practices-score | 3.2 | | | 3.0 | | | | | 3.0 | p=0.4 |
| **Income level** | **0-5,000**  **N = 58** | | **5,001-10,000**  **N = 111** | | **10,001-20,000**  **N = 61** | | **20,001 or above**  **N = 42** | | **Mean**  **N=275** | **Significance** |
| Knowledge-score | 5.3 | | 6.8 | | 7.2 | | 6.9 | | 6.6 | p<0.001 |
| Attitudes-score | 1.9 | | 3.3 | | 3.49 | | 2.9 | | 3.0 | p<0.001 |
| Practices-score | 2.6 | | 2.9 | | 3.38 | | 3.3 | | 3.0 | p = 0.049 |
| Years of farming | **1-5 Years,**  **N = 92** | | **6-10 Years,**  **N = 76** | | **11-20 Years,**  **N = 65** | | **Above 20 Years, N = 42** | | **Mean,**  **N=275** | **Significance** |
| Knowledge-score | 6.5 | | 6.7 | | 6.8 | | 6.43 | | 6.6 | p= 0.8 |
| Attitudes-score | 3.0 | | 3.3 | | 2.9 | | 2.71 | | 3.0 | p = 0.6 |
| Practices-score | 2.8 | | 3.2 | | 3.0 | | 3.29 | | 3.0 | p= 0.3 |

Association between Social Demographics and Knowledge attitude and practices

Knowledge

| **Characteristic** | **Insufficient**, N = 73 | **Sufficient**, N = 202 | **p-value** |
| --- | --- | --- | --- |
| Age |  |  | 0.052 |
| 18-35 | 2 (2.7%) | 3 (1.5%) |  |
| 36-50 | 44 (60%) | 154 (76%) |  |
| 51-60 | 19 (26%) | 27 (13%) |  |
| Above 60 | 8 (11%) | 18 (8.9%) |  |
| Education level |  |  | 0.7 |
| no schooling | 2 (2.7%) | 5 (2.5%) |  |
| primary education | 36 (49%) | 80 (40%) |  |
| secondary education | 23 (32%) | 76 (38%) |  |
| college training certificate diploma | 9 (12%) | 32 (16%) |  |
| bachelor degree and above | 3 (4.1%) | 9 (4.5%) |  |
| Marital status |  |  | 0.2 |
| single | 8 (11%) | 34 (17%) |  |
| married | 57 (79%) | 159 (79%) |  |
| windowed | 5 (6.9%) | 6 (3.0%) |  |
| separated | 0 (0%) | 2 (1.0%) |  |
| divorced | 2 (2.8%) | 1 (0.5%) |  |
| Household income |  |  | <0.001 |
| 10000-20000 | 17 (23%) | 86 (43%) |  |
| 5000-10000 | 24 (33%) | 87 (44%) |  |
| Below 5000 | 32 (44%) | 26 (13%) |  |
| Head of household |  |  | 0.011 |
| female | 17 (23%) | 21 (10%) |  |
| male | 56 (77%) | 181 (90%) |  |
| farming years | 12 (12) | 13 (10) | 0.2 |

Attitude

| **Characteristic** | **Invalid**, N = 78 | **Valid**, N = 197 | **p-value** |
| --- | --- | --- | --- |
| Age |  |  | 0.3 |
| 18-35 | 3 (3.8%) | 2 (1.0%) |  |
| 36-50 | 53 (68%) | 145 (74%) |  |
| 51-60 | 16 (21%) | 30 (15%) |  |
| Above 60 | 6 (7.7%) | 20 (10%) |  |
| Education level |  |  | 0.012 |
| no schooling | 2 (2.6%) | 5 (2.5%) |  |
| primary education | 27 (35%) | 89 (45%) |  |
| secondary education | 25 (32%) | 74 (38%) |  |
| college training certificate diploma | 16 (21%) | 25 (13%) |  |
| bachelor degree and above | 8 (10%) | 4 (2.0%) |  |
| Marital status |  |  | 0.3 |
| single | 13 (17%) | 29 (15%) |  |
| married | 57 (73%) | 159 (81%) |  |
| windowed | 6 (7.7%) | 5 (2.6%) |  |
| separated | 1 (1.3%) | 1 (0.5%) |  |
| divorced | 1 (1.3%) | 2 (1.0%) |  |
| Household income |  |  | 0.050 |
| 10000-20000 | 37 (49%) | 66 (34%) |  |
| 5000-10000 | 28 (37%) | 83 (42%) |  |
| Below 5000 | 11 (14%) | 47 (24%) |  |
| Head of household |  |  | 0.5 |
| female | 13 (17%) | 25 (13%) |  |
| male | 65 (83%) | 172 (87%) |  |
| farming years | 14 (11) | 12 (11) | 0.10 |

Practices

| **Characteristic** | **Preferrable**, N = 139 | **Unpreferrable**, N = 136 | **p-value** |
| --- | --- | --- | --- |
| Age |  |  | >0.9 |
| 18-35 | 3 (2.2%) | 2 (1.5%) |  |
| 36-50 | 101 (73%) | 97 (71%) |  |
| 51-60 | 23 (17%) | 23 (17%) |  |
| Above 60 | 12 (8.6%) | 14 (10%) |  |
| Education level |  |  | 0.2 |
| no schooling | 4 (2.9%) | 3 (2.2%) |  |
| primary education | 50 (36%) | 66 (49%) |  |
| secondary education | 58 (42%) | 41 (30%) |  |
| college training certificate diploma | 20 (14%) | 21 (15%) |  |
| bachelor degree and above | 7 (5.0%) | 5 (3.7%) |  |
| Marital status |  |  | 0.2 |
| single | 26 (19%) | 16 (12%) |  |
| married | 103 (74%) | 113 (84%) |  |
| windowed | 7 (5.0%) | 4 (3.0%) |  |
| separated | 2 (1.4%) | 0 (0%) |  |
| divorced | 1 (0.7%) | 2 (1.5%) |  |
| Household income |  |  | 0.004 |
| 10000-20000 | 55 (40%) | 48 (35%) |  |
| 5000-10000 | 63 (46%) | 48 (35%) |  |
| Below 5000 | 18 (13%) | 40 (29%) |  |
| Head of household |  |  | >0.9 |
| female | 20 (14%) | 18 (13%) |  |
| male | 119 (86%) | 118 (87%) |  |
| farming years | 12 (10) | 13 (12) | 0.8 |

**Correlation between knowledge attitude and practices**

| term | Knowledge score | Attitude score | Practices score |
| --- | --- | --- | --- |
| Knowledge score | NA | 0.3183048 | 0.2000496 |
| Attitude score | 0.3183048 | NA | 0.4174757 |
| Practices score | 0.2000496 | 0.4174757 | NA |

**Discussion**

Agricultural biologicals are touted as a stepping stone for sustainable agriculture of the future because they can be safer, renewable options and replace more hazardous agrochemicals. They are not only safe for beneficial but can also trigger the beneficial themselves to protect crops. Despite the potential to revolutionize agricultural production, especially in sub-Saharan Africa, their use is limited in the region (Grzywacz, Cherry and Gwynn, 2009). One of the limitations of agricultural biologicals is unaffordability, unavailability, perceived low efficacy and requirements for special storage conditions for some of them (Constantine et al., 2020). To be better able to pinpoint hurdles for smallholder farmers to adapt agricultural biologicals we performed KAP analysis in three Kenyan counties.

Farmers interviewed were aged between 36-50 years and the majority had attained secondary education level and the majority earned their livelihoods from farming. Farmers in the three counties produced the same crops during the rainy and dry seasons where they used irrigation except in Machakos county where a higher number produced maize and beans. Most of the farmers in the three counties produced mainly for their consumption and sold the surplus (so-called market gardening). However, some farmers in Machakos county also sold to the export market even though they could not precisely name the destination countries of their produce.

Land ownership plays a critical role in land investment and directly affects productivity. This is because farmers do not make long-term investments in land that they do not own (Mbudzya et al., 2022) and plant short-duration crops like vegetables, cereal crops, and pulses. Across the three counties, the majority of farmers in Kajiado and Machakos owned the farming land while in Kiambu the majority were producing on family land. This could partly explain the choice of vegetables as a preferred crop in the latter county. The other reason for choosing vegetables could be due to the short duration for crop maturation and the high prices they fetch in the market compared to cereals and pulses.

The majority of farmers in the three counties reported using agricultural inputs with pesticides as the mostly 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 health effects on users and the environment (Ohayo-Mitoko et al., 2000; Okelo, 2005; Asfaw, 2008, Macharia et al., 2009). This agrees with a similar study we conducted in Ethiopia, where farmers reported that they used agricultural inputs viz. fertilizers, certified seeds, herbicides, fungicides, insecticides, calcium carbonate, manure, or compost. Moreover, farmers provided that crop loss reduction and improving productivity were the key reasons why the majority used pesticides and fertilizers, respectively (Mulugeta et al., under review).

Our study revealed that the agro-dealers are the main source of information regarding pesticide use for smallholder farmers. Vis-à-vis the similar study we conducted in Ethiopia, the majority of the participating farmers (73.3%) in Ethiopia got information from extension service officers in addition to agro-dealers (Mulugeta et al., under review). However, most of the agro-dealers lack background training in agriculture in general and specifically pesticides and have learned on the job or trained by NGOs and companies dealing in agrochemicals. Therefore, it is possible that farmers receive inadequate or inappropriate information on the use of pesticides further aggravating the situation.

Knowledge on agricultural biologicals was highest among the farmers who had obtained university level of education and were among the lowest category of farmers after those who had no formal education. This could explain why knowledge of agricultural biologicals is irrelevant among the farmers interviewed. Additionally, whereas agro-dealers are the main source of information on pests and diseases and synthetic pesticides, neighbours are the main source of information on agricultural biologicals.

According to the responses, the definition of agricultural biologicals depended on what the individual farmers have interacted with for example some defined agricultural biologicals as pesticides with short pre-harvest intervals, biological control organisms, plant extracts, pheromones and even manure. Thisimplies that the farmers could not precisely define the agricultural biologicals. In contrast, according to our previous study in Ethiopia, we deemed 60% of the farmers knowledgeable towards biologicals based on the definition farmers gave (Mulugeta et al., under review). About 50% of farmers in Kajiado reported using agricultural biologicals, which was more than half the farmers using agricultural biologicals in Kiambu and Machakos counties. Most smallholder farmers in Kajiado and Kiambu reported that they use agricultural biologicals every season while majority of farmers in Machakos seldom used agricultural biologicals.

Among the farmers who reported using agricultural biologicals, lack of knowledge on the use of agricultural biologicals was reported to be the biggest challenge followed by perceived low efficacy and preservation and storage. This observation agrees with previous findings in the region that the use of agricultural biologicals is constrained by slow action on pests (lack of knockdown effects), short-shelf life and requirements of special storage conditions for some products (Chandler et al., 2011; Constantine et al., 2020). Additionally, the majority of the farmers reported that neither they nor their wives/spouses have been trained on agricultural biologicals and the information they have were gathered from neighbours. This further indicates there are possibilities of misinformation on agricultural biologicals.

Farmers from the three counties portrayed different attitudes towards efficacy, potential use, advantages, health and safety, availability of information regarding agricultural biologicals, ease of use as well as affordability. Similarly, the farmers had varied responses when it came to community and government support for the use of agricultural biologicals, and whether they can recommend the use of agricultural biologicals to fellow farmers. More than half the farmers reported they would not recommend biologicals to others as safer alternatives to conventional chemicals (Mulugeta et al., under review). For example, 88% of farmers in Machakos and 72% in Kiambu said they would consider the use of agricultural biologicals. However, this is contradictory to responses to other questions in the questionnairewhere they stated agricultural biologicals to be ineffective. This could be explained by the fact that most farmers considered farmyard manure as an agricultural biological and the explanations given about agricultural biologicals during the interviews. The farmers thought that the use of agricultural biologicals is advantageous in terms of the safety of food produced (61%), however, 41% of farmers in Kiambu and Kajiado and 31% in Machakos neither agreed or disagreed with the safety of agricultural biologicals. This could reflect that there is a lack of information regarding the agricultural biologicals. This could be attributed to the fact that agro-dealers most of whom did not have a background in agriculture or were trained on agricultural biologicals are the key advisors to smallholder farmers. Slightly more than 50% of the farmers thought that the use of agricultural biologicals improves crop yield. Mulugeta et al., (Under review) reported that more than 70% of the farmers agreed biological to be advantages to produce healthy food, increasing crops yield, and improving income. According to the farmers, the agricultural biologicals are neither easy to use nor affordable. One of the challenges in the uptake and use of agricultural biologicals is the requirement for special storage conditions and short shelf-life for some which directly affects their cost (affordability) (Sachdev and Singh, 2016). On whether the farming community in the three counties and the government support the use of agricultural biologicals, almost half (50%) 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 that the farmers are not receiving adequate information regarding government policies or initiatives related to agricultural biologicals. In contrast, 71% farmers in Ethiopia agreed about the government support the use of biological (Mulugeta et al., Under review).

Overall, the majority of farmers had relevant knowledge of agricultural biologicals and poor attitudes and good practices on agricultural biologicals. This contradicts with the report we made from Ethiopia, where farmers had a positive attitude towards biological and the knowledge and practice was lower compared to the attitude (Mulugeta et al., Under review).. The association between knowledge and attitude toward agricultural biologicals did not differ significantly between the three counties. However, the practice of the use of agricultural biologicals was significantly higher in Kajiado. Attitudes and practices were positively influenced by a higher level.

**CONCLUSION**

This study confirms the previously reported low use of agricultural biologicals and higher use of conventional chemical pesticides in region. Despite the presence of registered agricultural biologicals in the Kenyan market, demand and availability are low, probably due to a lack of information. Smallholder farmers perceived the agricultural biologicals 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 agricultural biologicals. Despite these associated shortcomings farmers reported being willing to adopt their use. The results of this study underscore the need for more awareness to promote the use of agricultural biologicals.

**References**

1. Akutse, K.S., Subramanian, S., Maniania, N., Dubois, T. and Ekesi, S., 2020. Biopesticide research and product development in Africa for sustainable agriculture and food security–experiences from the International Centre of Insect Physiology and Ecology (ICIPE). Frontiers in Sustainable Food Systems, p.152.
2. Chandler, D., Bailey, A.S., Tatchell, G.M., Davidson, G., Greaves, J. and Grant, W.P., 2011. The development, regulation and use of biopesticides for integrated pest management. Philosophical Transactions of the Royal Society B: Biological Sciences, 366(1573), pp.1987-1998.
3. Constantine, K.L., Kansiime, M.K., Mugambi, I., Nunda, W., Chacha, D., Rware, H., Makale, F., Mulema, J., Lamontagne‐Godwin, J., Williams, F. and Edgington, S., 2020. Why don't smallholder farmers in Kenya use more biopesticides?. Pest management science, 76(11), pp.3615-3625.
4. Copping LG 2001. The Biopesticide Manual, 2nd ed. Farnham, UK, British Crop Protection Council, p. 528.
5. dos Santos, R.M., Diaz, P.A.E., Lobo, L.L.B. and Rigobelo, E.C., 2020. Use of plant growth-promoting rhizobacteria in maize and sugarcane: Characteristics and applications. Frontiers in Sustainable Food Systems, 4, p.136.
6. Grzywacz, D., Cherry, A. and Gwynn, R., 2009. Biological pesticides for Africa: why has so little of the research undertaken to date resulted in new products to help Africa's poor?. Outlooks on Pest Management, 20(2), p.77.
7. J. J. Okello, Compliance with international food-safety standards, the case of green bean production in Kenyan family farms [Ph.D. Dissertation], Michigan State University, East Lansing, Mich, USA, 2005.
8. Macharia, I., Mithöfer, D. and Waibel, H., 2009. Potential environmental impacts of pesticides use in the vegetable sub-sector in Kenya. African Journal of Horticultural Science, 2(138-151).
9. Mbudzya, J.J., Gido, E.O. and Owuor, G., 2022. Effect of land tenure security on agricultural productivity among small scale farmers in Kenya: a conditional mixed processes analysis. Cogent Food & Agriculture, 8(1), p.2139805.
10. Mulugeta, T., Muhinyuza, J.B., Gouws-Meyer, R., Matsaunyane, L., Andreasson, E. and Alexandersson, E., 2020. Botanicals and plant strengtheners for potato and tomato cultivation in Africa. Journal of Integrative Agriculture, 19(2), pp.406-427.
11. Ohayo-Mitoko, G.J., Kromhout, H., Simwa, J.M., Boleij, J.S. and Heederik, D., 2000. Self-reported symptoms and inhibition of acetylcholinesterase activity among Kenyan agricultural workers. Occupational and environmental medicine, 57(3), pp.195-200.
12. Olson, S. (2015). An analysis of the biopesticide market now and where is going Outlook. Pest Manag. 26, 203–206. doi: 10.1564/v26 oct 04.
13. Ratto, F., Bruce, T.J.A., Chipabika, G., Mwamakamba, S., Mkandawire, R., Khan, Z., Mkindi, A., Pittchar, J., Chidawanyika, F., Sallu, S.M. and Whitfield, S., 2022. Biological control interventions and botanical pesticides for insect pests of crops in sub-Saharan Africa: A mapping review. Frontiers in Sustainable Food Systems, 6.
14. Regnault-Roger, C. and Philogène, B.J., 2008. Past and current prospects for the use of botanicals and plant allelochemicals in integrated pest management. Pharmaceutical Biology, 46(1-2), pp.41-52.
15. S. Asfaw, Global agrifood supply chain, EU food safety standards and African small-scale producers, the case of high value horticultural exports from Kenya [Ph.D. thesis], Leibniz University of Hanover, Hanover, Germany, 2008.
16. Sachdev, S. and Singh, R.P., 2016. Current challenges, constraints and future strategies for development of successful market for biopesticides. Climate Change and Environmental Sustainability, 4(2), pp.129-136.
17. Tembo, Y., Mkindi, A.G., Mkenda, P.A., Mpumi, N., Mwanauta, R., Stevenson, P.C., Ndakidemi, P.A. and Belmain, S.R., 2018. Pesticidal plant extracts improve yield and reduce insect pests on legume crops without harming beneficial arthropods. Frontiers in Plant Science, 9, p.1425.
18. Adesemoye, T.O., 2017. Introduction to biological products for crop production and protection. University of Nebraska-Lincoln, Extension.