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ORIGINAL RESEARCH ARTICLE

Determinants of adoption of Bt cotton among smallholder cotton producers in Kitui and Kisumu counties, Kenya.

Collins Kaisha[1], Robert Mbeche[1], Josiah Ateka[1]

[1]*Department of Agricultural Resource Economics, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya*.

Corresponding author email: collinskaisha@gmail.com

ABSTRACT

The Government of Kenya acknowledges the importance of the cotton industry in the country's development agenda, particularly under the manufacturing pillar. To revitalize the industry, the government approved *Bacillus thuringiensis* (Bt) cotton for commercial production in 2019. Bt cotton is promoted on the grounds that it is resistant to pests such as bollworms which can lead to a reduction in the use of pesticides, improve productivity, and in the long run deliver increased profits to farmers. While Bt Cotton has been promoted since 2019, evidence of its adoption among smallholder farmers is limited. This study assessed the determinants of Bt-cotton adoption among smallholder cotton producers in Kitui and Kisumu counties, Kenya. Data were collected through a cross-sectional survey of 389 households that were selected randomly in Kisumu (192 households) and Kitui Counties (197 households). Among the total sampled households (389), 242 were cotton farming households and 147 were households that were not growing cotton. However, in this study context, the analysis proceeded with the 242 cotton-growing households. Data were analyzed using descriptive statistics and Heckman's two-stage regression model. The descriptive results showed that nearly half (47.5%) of the cotton-producing households were involved in producing the Bt cotton variety. Heckman's two-stage model showed that increased access to land for farming (p=0.002), access to extension service (p=0.025), and expected benefits of Bt cotton (early maturity (p=0.000), and better quality of fibre had a positive influence (p=0.010) on adoption, while the distance to the output market (p=0.004) and soil fertility (p=0.076) had a negative influence on adoption. The results further showed that the intensity of adoption increased with household expenditure (p=0.012), access to credit (p=0.096), and having a positive perception of Bt cotton being drought tolerant (p=0.024). Larger household sizes (p=0.096), Bt cotton early maturity attribute (p=0.002), crop diversification (p=0.044), and increased access to land (p=0.002) had a negative influence on the intensity of adoption. The results revealed that farm and farmer characteristics, economic, and institutional factors, and attributes of Bt cotton are found to be determinants of the adoption of Bt cotton. The study recommends that the public and

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private sectors promote access to extension services, markets, and credit to improve the uptake of Bt cotton in Kenya.

Keywords: Adoption, Bt cotton, smallholder, Heckman two-stage model

1.0 Introduction

The cultivation of cotton (Gossypium hirstum L.) has the potential to improve the economic status and livelihoods of smallholder farmers in Kenya, making it a promising crop for agricultural development in the country (KAM, 2018**).** Despite having potential, the production of cotton by smallholder farmers in Kenya is constrained by several factors including poor farming practices, unpredictable weather patterns, weak cotton farmers' cooperatives, lack of rural financing, high input costs, poor seed quality, pest and disease attack, insufficient extension services and poor marketing systems (Fibre Crop Directorate, 2021; Opee, 2018). In recognition of the aforementioned challenges, the prevalence of pest infestation, with the African bollworm (Helicoverpa *armigera*) being the most destructive (Fibre Crop Directorate, 2021; ISAAA, 2021; Mulwa et al., 2013). As a consequence, productivity in the sub-sector has been on a declining trend falling from an annual peak of 303 Kg/Ha in 2006 to below 110 Kg/Ha in 2020 (USDA FSA, 2024) as shown in Figure 1.

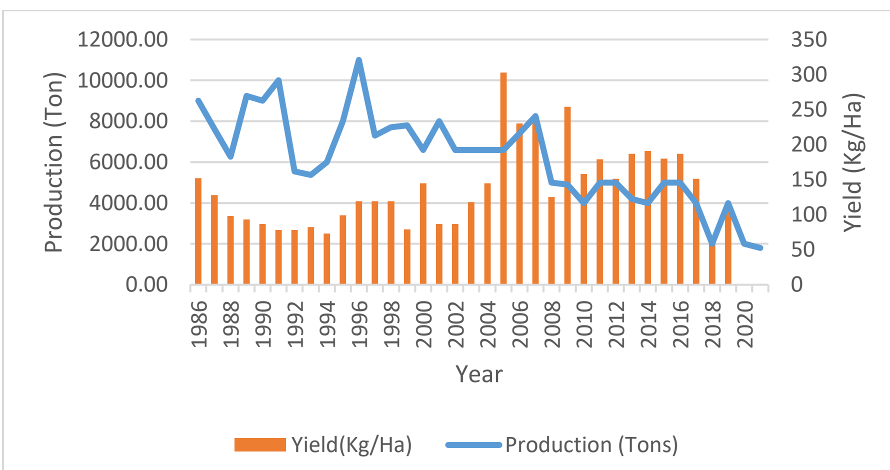

Figure 1: Trends in overall Cotton production (Tons) and yields (Kg/Ha) in Kenya (1986-2020)
Source: Data from FAOSTAT, (2022), and USDA FSA (2024)

To address the declining productivity, the Government of Kenya approved the cultivation of Bacillus *thuringiensis* (Bt) cotton for commercial production in 2019 (Fibre Crop Directorate, 2021; ISAAA, 2021; NBA, 2015). *Bacillus thuringiensis* (Bt) cotton is a genetically modified insect-resistant plant cotton variety (The Maureen & Mike Mansfield Center, 2015). The decision was made as a

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key strategy to boost cotton production and enhance productivity owing to its advantages over conventional cotton including resistance against bollworm attacks, higher yields, and relatively low production costs associated with pesticides and their application (Kedisso et al., 2023; USDA, 2022; ISAAA, 2021). However, as cotton production remains low, there are no official figures on the commercial uptake and utilization of Bt cotton among smallholder cotton farmers in Kenya.

Globally, there is an emerging body of literature on the adoption of Bt cotton (Ahmad et al., 2018; Bilal et al., 2012; Gouse et al., 2003; Liu and Huang 2013; Mal et al., 2015; Muhammad Arshad et al., 2007; Wang et al., 2015; Qiao et al., 2015; Sanou et al., 2019), which revealed the extent of adoption of Bt cotton and factors that statistically influenced its adoption among farmers. However, this literature (Ahmad et al., 2018; Bilal et al., 2012; Liu and Huang 2013; Mal et al., 2013; Mal et al., 2015; Muhammad Arshad et al., 2007; Wang et al., 2015; Qiao et al., 2015) is skewed towards Asia with limited research in Sub-Saharan Africa (SSA) (Gouse et al., 2003; Gudeta et al., 2023; Mulwa et al., 2013; Sanou et al., 2019;) In addition, the studies in SSA only focused on promoting the potential traits of Bt cotton (Gudeta et al., 2023; Mulwa et al., 2013). Therefore, this study aimed to fill this gap by assessing the determinants of Bt-cotton adoption among smallholder cotton producers in Kitui and Kisumu counties, Kenya.

2.0 Methodology

2.1 Description of the study area

The survey was conducted in Kitui and Kisumu Counties, in the Eastern and Western parts of Kenya respectively as shown in Figure 2.

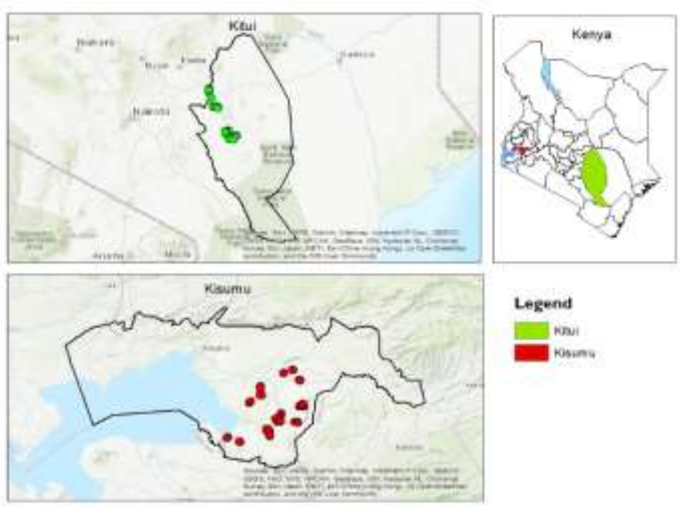

Figure 2: Map showing Kitui and Kisumu Counties

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The Counties were selected for several reasons. First, they are among the counties where cotton farming is practiced in Kenya and Bt cotton variety was introduced among farmers in 2019 (Fibre Crop Directorate, 2021). Secondly, the counties are located in different agro-ecological zones. The elevation of Kitui County varies from 400 to 1800 meters above sea level (County Government of Kitui, 2020). According to (MoALFC, 2021), the county is one of Kenya's most drought-vulnerable areas because of its semi-arid environment. The range of normal yearly precipitation is 400–1000 mm, with an average of 750 mm per year. In the long rainy season, which runs from March to May, precipitation is unpredictable and erratic; in the short rainy season, which runs from October to December, it is more dependable in terms of both distribution and amount. On the other hand, Kisumu County at an elevation of between 1100-1835 meters above sea level (County Government of Kisumu, 2018), experiences mean annual temperatures between 21°C and 23°C, making for a year-round climate that is generally warm and humid. The first rainy season in the county runs from March to May, while the second one is from November to December. The county's average yearly rainfall falls between 1200 and 1500 mm (MoALF, 2018). In Kitui County, the study targeted Kitui East and Mwingi West sub-counties and in Kisumu County, the study targeted Nyando and Nyakach Sub-Counties which are key cotton sub-counties in the selected counties.

2.2 Data collection

Data for this study were collected through a cross-sectional survey of 389 households. Both quantitative and qualitative data were collected from the households with structured questionnaires which were administered in person. Prior, to the actual data collection the tool was pre-tested with non-sampled respondents to check its reliability, and amendments to the questionnaire were made where required. The study considered in-person interviews to be reliable due to their ability to achieve a higher response rate and allow for clarification and follow-up. The survey collected detailed information on smallholder farmers' demographic, socioeconomic, institutional, and farm characteristics that would influence adoption decisions, and intensity of adoption of Bt cotton. The study proceeded with the farmer's evaluation of selected Bt attributes using a five-point Likert scale ranging from 1 (for strongly disagree) to 5 (for strongly agree). The study also conducted key informant interviews and two focused group discussions per region (Kitui and Kisumu Counties) targeting the cotton farmers to supplement data from the household interviews on Bt cotton production. Six key informants included extension officers from the Fibre Crop Directorate, and Ministry of Agriculture, and the Officials of the cotton farmer's cooperative society.

2.3 Sample size and sampling procedure

The sample size determination formula given by (Cochran et al., 1977) was utilized by the study to determine a representative sample size for the cross-sectional survey in the study areas. The formula is expressed as:

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$$n = \frac{z^2}{4e^2} = \frac{1.96^2}{4(0.0497)^2} = 389$$

Where:
n = sample size
e =acceptable sampling error ($e = 0.0497$)
$z = z$ Value at reliability level or significance level; $z =$ 1.96. The reliability level is 95% or the significance level is 0.05.
This gave a sample size of 389.

The study used a multistage sampling procedure to select the sampled households. In the first stage, Kitui and Kisumu counties were purposively selected. The counties are among the 24 counties that practice cotton farming and are located in different agro-ecological zones. In the second stage, two leading sub-counties were purposively selected in the county (Kitui East and Mwingi West sub-counties for Kitui, Nyando, and Nyakach Sub-counties for Kisumu). In the third stage, two wards were selected in each of the sampled sub-counties based on the concentration of cotton farmers, making a total of 8 wards. In the final stage, a linear systematic random selection of households was used where the first household to be interviewed was selected randomly and the succeeding respondents were systematically picked after every third household with the guidance of ward agriculture officers and village elders. This resulted in a total of 389 households, in Kitui (192 households) and Kisumu (197 households) Counties. From the 389 households sampled, 242 were cotton farming households, and 147 were non-cotton growing households. However, in this study context, the study analysis proceeded with the 242 cotton-growing households.

2.4 Data analysis

In contrast to the conventional binary regression approaches (probit or logit), that have been employed in other studies (Ahmad et al., 2018; Ateka et al., 2021; Maina et al., 2012; Padaria et al., 2016) investigating the probability of adopting new agricultural technologies or not, our objective goes beyond to comprehend the intensity of adoption of Bt cotton. Heckman (1979), explains that when a farmer's decision-making process requires multiple steps to adopt new technology, models having two-step regressions are used to account for selection bias that arises during the decision-making process. Consequently, we considered the Heckman's two-stage model (Heckman, 1979). Several studies that analyze such joint decisions have utilized this model (Ali et al., 2018; Kansiime et al., 2014; Orinda et al.,2017; Ouma et al., 2011).

The two-step Heckman model involves two stages. The first is a probit model to analyze the determinants of adoption (selection model), while in the second stage, Ordinary Least Square (OLS)

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was applied to examine the determinants of the intensity of adoption (Outcome model). If d^*i is the latent variable describing a farmer's decision to adopt on the level of adoption and d_i and y_i are their observed counterparts, respectively. Based on the specification by (Heckman, 1979). the two stages can be specified as:

$$d_i^* = \alpha z_i + Vi \quad (1)$$

$$y_i = \beta xi + \varepsilon_i \quad (2)$$

Where

$d_i^* = \{1 \; if \; d_i^* > 0 \; 0 \; if \; d_i^* \leq 0$ and $y_i = \{y_i^* \; if \; y_i > 0 \; and \; d_i^* > 0 \; 0, if \; otherwise$

Where z_i is the vector of the variables explaining whether a farmer adopts the Bt cotton variety, x_i is a vector of variables explaining the intensity of adoption, and v_i and ε_i are the error terms.

3.0 Findings and discussions

3.1 Descriptive characteristics of sampled households

Table 1 summarizes the differences in household characteristics between adopters of Bt-cotton (those who were growing Bt-cotton in the 12 months preceding the study) and non-adopters. The results reveal that nearly half (47.5%) of the cotton-producing households were involved in farming the Bt cotton variety. There were significant statistical differences between the two groups on various household characteristics. Households participating in growing Bt cotton were more likely older (mean age of 63.3 years), they had more experience in both overall crop farming (an average of 30.2 years) and cotton farming (about an average of 13.0 years) compared to non-adopters.

Table 1: Descriptive statistics on cotton-growing households in Kitui and Kisumu Counties

Continuous variables	Pooled (n=242)	S.D	Adopters (n=115)	Non-adopters (n=127)	P-Value
Demographics					
Household size	5.2	2.4	5.1	5.3	0.55
Age of HH	61.5	14.3	63.3	59.8	0.06*
Farm characteristics					
No. Parcels of land	1.4	0.7	1.5	1.4	0.37
Total land size	3.4	2.9	4.4	2.5	0.00***
No. of crops Grown	4.2	1.3	4.4	4.0	0.02**
Cotton land size	1.1	1.0	1.4	0.9	0.00***
Crop farming exp. (Yrs.)	27.0	14.7	30.2	24.0	0.00***
Cotton farming exp. (Yrs.)	10.9	0.7	13.0	8.9	0.01**
Institutional factors					
Distance					
Input Mkt (Km)	6.5	6.3	6.6	6.3	0.66
Cotton output Mkt (Km)	2.5	3.4	2.4	2.5	0.74

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Other crop output Mkt (Km)	4.0	3.8	3.9	4.0	0.83
Tarmac road (Km)	10.8	0.6	12.6	9.2	0.00***
Economic factors					
Ann. Income from livestock	37965.4	52235.7	46625	27862.5	0.17
Ann. Income from crops (Cotton excluded)	72689.3	122285	79895.3	66164.2	0.38
Ann. Income from nonfarm Activities	70781.8	122638.2	78306.1	66164.2	0.36
Total annual income	103681.8	140721.6	120191.3	88732.3	0.08*
HH expenditure (weekly)	3391.7	2089.2	3376.957	3405.0	0.92
Categorical variables	Measurement	Pooled (n=242) %	Adopters (n=115) %	Non-adopters (n=127) %	P-Value
Demographic characteristics					
Gender HH	Male	77.3	80	74.8	0.34
Education level HH	Informal	14.5	15.7	13.4	0.62
	Primary	63.2	62.6	63.8	0.85
	Post-Primary	22.3	21.7	22.8	0.84
Wealth Index	Poorest	27.3	19.1	34.7	0.01**
	Middle	33.5	28.7	37.8	0.14
	Wealthiest	39.3	52.2	27.6	0.00***
Farm characteristics					
Soil fertility	Good=1	83.5	88.7	78.7	0.04**
Institutional factors					
Access Extension	Yes=1	39.7	50.4	29.9	0.00***
Access to Credit	Yes=1	14.5	16.5	12.6	0.39
Farmer Group/ association	Yes=1	86.0	87.0	85.0	0.67

, **, *, Denotes significance levels at 10%, 5%, 1% respectively; HH= Head of the Household; Mkt = Market*

The results further revealed that the proportion of wealthier households in the sample was higher among the participants of Bt cotton growing (52.2%) compared to non-participants (27.6%). Equally, they received a significantly higher annual income an average of about KES 120191.3 (translating to KES 10,015.9 per month and KES 323.1 per day ($1.97 per day)). However, there were no significant differences in household size, gender, level of education of the head of the household, household expenditure, income from the crop (excluding cotton), and sale of livestock (or its products) between the adopters and non-adopters.

The results show differences in farm characteristics exist between Bt cotton adopters and non-adopters. Participating households accessed larger farm sizes (an average of 4.40 acres) for crop production. As expected, they had a large size of land under cotton production (an average of 1.35 acres compared to non-adopters (an average of 0.88 acres). This result is consistent with (Ahmad et al. 2018) and Mal et al., 2015) who also identified that adopters of Bt cotton accessed relatively large sizes of land for farming. The proportion of households who considered the soil fertility of their farm as good was higher adopters (88.7%) compared to non-adopters (78.7%). The results further revealed that the Bt growing households were located much farther from the nearest tarmac road at an average of about 12.6 Km. However, there were no significant differences in distance to the input and output market from the farm and the number of parcels of land accessed by the farmer.

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The results revealed a differential in access to institutional arrangements between Bt cotton variety adopters and non-adopters. The Bt cotton-growing households had higher access to extension services (50.4%) compared to non-adopters (29.9%). The possible explanation is that extension service was reported to be need-based and Bt cotton-producing households tended to seek more knowledge and training on the production of Bt cotton and inputs from the service agents. Studies (Mbeche et al., 2022; Mwangi et al., 2022) have shown that access to extension services is crucial in the acquisition of pertinent knowledge on the existence, advantages, and practical applications of various farm technologies among farmers. However, there were no significant differences in the level of access to credit and farmer groups between the adopters and non-adopters

3.2. Awareness of Bt cotton and assessment of its attributes among smallholder cotton farmers.

The study identified that among the non-adopters (n=127) interviewed, only 58.3 % were aware of the Bt cotton variety. The study results revealed that based on the weighted mean score of 3.5, smallholder cotton farmers had fairly positive perceptions about the attributes of the Bt cotton. Over half of the cotton farmers (56.1%), agreed that Bt cotton variety was early maturing high yielding (50.3%), had high-quality fiber (52.9%), and used less pesticides (50.3%) while less than half of the respondents (n=127) agreed that Bt-cotton was pest resistant (48.2%), and disease resistant (45.5%). On the other hand, about half of the respondents (41.8 %) disagreed that Bt cotton could not withstand drought. Interviewed farmers had reported that the study areas had received low rainfall which affected the performance of Bt cotton during the study period. This suggests that there is a need for further research to understand the performance of Bt cotton under limited rainfall conditions.

3.3. Determinants of adoption of Bt cotton among cotton farmers in Kenya.

Table 2 presents the results of the Heckman Two-stage model on determinants of adoption of Bt cotton and the intensity of participation among smallholder cotton farmers The analysis covered various indicators of household socioeconomic characteristics, farm characteristics, institutional arrangements, and the perceived attributes of Bt cotton.

The results show that while the household socioeconomic characteristics did not have a significant influence on the household's decision to adopt Bt Cotton, two variables – household size and expenditure had a significant influence on the intensity of adoption. The household size had a negative influence on intensity adoption at a 10 percent significance level. This implied that households with more members were less likely to increase the area of land under Bt cotton. The possible explanation is that as the household size increases, the demand for food commodities also increases. Our findings corroborated with those of (Ehiakpor et al., 2021 and Musafiri et al., 2022) who reported that family size negatively determined agricultural technology adoption. The unexpected results on household size disagreed with those of (Bryan et al. 2013 and Mwaura et al. 2021) who found family size positively influenced the adoption of agricultural technologies.

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Conversely, our study results revealed that household expenditure had a positive influence on the intensity of adoption of Bt cotton at a 5 percent significance level. This implies that the households with higher household expenditure were more likely to increase the intensity of adoption of Bt cotton. This may be because cotton production is resource intensive meaning that only farmers with available financial resources can scale its production. Cotton is mainly produced in the short cropping season in both study counties – a period when most households have to allocate a large percentage of their available income to purchasing food products because the main food crops (maize and beans) are not produced during that season. The average cost per acre of producing cotton under the rain-fed system is estimated at KES 43,800 (Fibre Crop Directorate, 2021). The high cost is partly associated with expenses for weeding, spraying, and harvesting, and pesticide costs which accounted for almost 51.7% of the input costs. However, literature (Giller et al., 2021; Livingstone et al., 2011) has characterized agricultural households in SSA as poorly resourced, and therefore they are limited to practicing farming at a larger scale.

With regard to farm characteristics, our results revealed that while land size had a positive and significant ($p<0.01$) influence on cotton farming households' adoption of Bt cotton, while it had a negative and significant ($p<0.01$) influence on the intensity of adoption. The positive influence of land size on adoption decisions is not surprising because farmers with large sizes of land can allocate a portion of their land for trials of the new Bt cotton varieties to observe their performance before they proceed to full adoption. The findings are consistent with other Bt cotton studies (Mal et al., 2015; Padaria et al., 2016) which found that households with larger land sizes were likely to adopt Bt cotton. Conversely, households with larger sizes of farming land were less likely to allocate a larger portion of their farming land to growing Bt cotton. The negative influence on the intensity of adoption may be because such households considered Bt cotton farming to be input-intensive, especially on foliar fertilizer, labour, and pesticides. Interviews and field observations showed that households preferred to practice Bt cotton on a smaller portion of land for a start, in part because of cost implications and uncertainty about its profitability. (Abara & Singh.,1993), argued that technology adoption is less likely on small farms since it is associated with high fixed costs.

Table 2. Heckman's two-stage model results on determinants of adoption of Bt cotton in Kitui and Kisumu counties

	Section Model (Adoption of Bt cotton)			Outcome Model (Intensity of adoption)		
Variables	Coef.	St. Err.	p>|z|	Coef.	St. Err.	p>|z|
Household socioeconomic characteristics Household size	-	-	-	-.0165*	.0099	0.096
Age of HH	.0196	.0134	0.143	.0002	.0018	0.908

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Gender HH	-.125	.3741	0.737	.0490	.0493	0.320
Education - Informal	.3072	.5831	0.598	-.0225	.0775	0.772
Education - Primary	.3783	.3402	0.266	-.0805	.0515	0.118
Crop farming experience (Yrs)	-.0108	.0129	0.402	.0006	.0017	0.714
Cotton farming experience (Years)	.0134	.0142	0.345	-.0028	.0018	0.120
Log household income	-	-		-.0069	.0182	0.705
Log household expend	-	-		.0983**	.0390	0.012
Wealth Index- Poorest	-.1500	.4744	0.752	-	-	-
Wealth Index- Middle wealthy	.2800	.3735	0.453	-	-	-
Farm characteristics						
No. Parcels of land	-.2032	.2263	0.369	-.0382	.0263	0.147
Cotton land size	-.0719	.1925	0.709	-.0183	.0188	0.329
No. of crops Grown	.0845	.1055	0.423	-.0315**	.0156	0.044
Total land size	.3498***	.1114	0.002	-.0236***	.0075	0.002
Land fertility (Good =1)	-.7273*	.4094	0.076	.0099	.0566	0.861
Institution factors						
Access Extension	.6479**	.2881	0.025	-.0100	.0419	0.812
Farmer Group/ association	.097	.3993	0.808	-.0396	.0592	0.503
Access to Credit	.2778	.4208	0.509	.0856*	.0513	0.096
Input Market (Km)	.0121	.0266	0.649	.0030	.0034	0.375
Cotton output Market (Km)	-.1143***	.0395	0.004	-	-	-
Other Crops output Market (Km)	-.0114	.0448	0.798	-.0071	.0054	0.193
Tarmac road (Km)	.0227	.0231	0.325	-.0031	.0033	0.338
County (Kitui =1)	.2101	.4735	0.657	-.0568	.0649	0.381
Perceived attributes of Bt cotton						
Early Maturity	.9599***	.2027	0.000	-.1411***	.0460	0.002
High Yield	.0406	.2042	0.842	.0229	.0284	0.419
Pest resistant	.1706	.2692	0.526	.0317	.0298	0.288
High-quality fiber	.5609***	.2174	0.010	-.0155	.0369	0.675
Less use of pesticide	.1395	.2135	0.514	.0033	.0302	0.914
Drought tolerant	-.2309	.1599	0.149	.0453**	.0201	0.024
Disease Resistant	-.1975	.2455	0.421	.0210	.0314	0.503
_cons	-7.573***	1.716	0.000	1.311***	.4011	0.001
Lambda λ (Inverse Mill)	.1749**		0.016			
Rho	-0.9606					
Sigma	.18208					
Wald chi2(28) = Wald chi2(28); Prob > chi2 = 0.0010						

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, **, *, Denotes significance levels at 10%, 5%, 1% respectively. HH= Head of the Household*

The results show that soil fertility characterized as good had a negative influence on the adoption of Bt cotton at a 10 percent level of significance. This implied that households that considered their soils to be fertile were less likely to adopt Bt cotton. This may be because these households were able to grow diverse food crops. Interviews with farmers in the study areas showed that food crops were grown on the parcel(s) or area(s) of the farm which they perceived to be fertile while growing cotton was done on parcels of land they perceived to have poor fertility. The finding conforms with that of (Mal *et al.*, 2013)who found that farmers in North India were more likely to grow Bt cotton when the available land (or a certain portion of land) is not fertile (sandy and/or sandy loam-type soil). The results further show that the number of crops grown on a farm had a negative and significant ($p<0.05$) influence on the intensity of adoption of Bt cotton. This can be explained that households that cultivated diverse crops were less likely to increase the intensity of adoption of Bt cotton. This could be explained by the fact that cultivating more crops resulted in the farming land being subdivided which reduced the land size under cotton production.

The findings on institutional characteristics show that household access to extension services had a positive and significant influence on the adoption of Bt cotton at 5 percent. This was expected since agricultural extension agents are the main channels to disseminate agricultural information and technologies to cotton farmers. The study conforms with studies in other contexts (Andati et al., 2022; Ateka et al., 2021; Kagimbi et al.,2024; Odinya et al. 2022) which found that access to extension services positively and significantly influenced the adoption of new agricultural technologies in Kenya. Access to the extension has the potential to minimize the risks by reducing information asymmetries, especially for resource-poor farmers. Our findings show that access to credit had a positive and significant ($p<0.10$) influence on the intensity of adoption of Bt cotton. This implies that cotton farming households that have access to credit in terms of cash or in-kind could access inputs such as fertilizer, pesticides, and labor which are important in Bt cotton production, and as a result, they may be able to increase the land area allocated to Bt cotton production. The findings are consistent with those of Gichangi *et al.* and Mwangi and Kariuki et al.who identified that access to credit positively influenced the adoption of agricultural technologies.

The study results further show that distance to the nearest cotton lint market had a negative and significant ($p<0.01$) influence on the adoption of Bt cotton, implying that households that lived far from the cotton output market were less likely to participate in Bt cotton growing. This is explained by the fact that such households tend to incur higher costs of transportation of cotton lint and by extent reduction of farm profit. The findings are consistent with the findings of Ogada *et al.* (2014)

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who found that transportation costs negatively influenced the farmers' adoption decisions on organic fertilizer and improved maize varieties.

The study also considered the influence of farmer perceptions of Bt attributes on the decision and intensity of Bt adoption. The results show that farmer's perception of the early maturity attribute of Bt cotton had a positive and significant ($p<0.01$) influence on the adoption of Bt cotton. Cotton varieties that mature early can enable households to start generating income within a short period after planting thus improving the farmer's household welfare. The study finding is in line with the observations of Perez *et al*. 2010, Bryan *et al.* 2013, and Ziro *et al.* 2023, that agro-ecosystem participants have been pushed to adopt early maturity and drought-resistant crop varieties as climate change adaptation strategy. In contrast, households that considered Bt cotton as early maturing were less likely to allocate large size of their land towards Bt cotton farming. The possible explanation is that Bt cotton is identified to start producing cotton balls early compared to the conventional variety which would require farmers to begin the spraying program to control pests such as African bollworms immediately. However, cotton farmers in the study areas reported to be relying on the 100% subsidized pesticides provided by the Government of Kenya through the Fibre Directorate which are not supplied on time and when the supply was made in sufficient quantities. As a result, farmers allocated smaller areas to Bt cotton compared to conventional Bt varieties.

The results further show that the high-quality fibre attribute of Bt cotton had a positive and significant influence on the adoption of Bt cotton at 1 percent. In the study area, cotton fibre lint was categorized into two, Grade A and Grade B, which had an average buying price of KES 54.20/Kg and KES 25.80/Kg respectively. This implies that farmers who chose to adopt Bt Cotton were influenced by their desire to get better quality fibre and therefore better incomes. The finding compares well with those of Braunack et al, Gouse *et al.* 200), and Qaim *et al.* 2006 who found that Bt cotton adopters had experienced higher fibre quality, average yields, and revenue that offset the cost. Our findings further show that the households that had a positive perception of the drought tolerant attribute of Bt cotton were more likely to increase the intensity of adoption of Bt cotton. This was expected since the study areas, especially Kitui, received low rainfall of an annual precipitation range of 400-1000 mm (MoALFC, 2021) which is considered unreliable; therefore farmers are driven towards growing crop varieties that are drought tolerant to avoid crop failure. The positive influence of drought-tolerant attributes on the adoption of crop varieties is well documented in the literature (Muinga et al., 2019; Otieno et al., 2011; Simtowe et al., 2021; Timu et al., 2014).

4.0 Conclusion

This study has revealed that nearly half (47.5%) of the cotton-producing households were involved in producing the Bt cotton variety. Heckman's two-stage model results showed that farm and

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farmer characteristics, institutional factors, and attributes of Bt cotton were driving factors in the adoption and intensity of adoption of Bt cotton among smallholder farmers. Based on our findings, the study suggests the need for policy measures to improve the uptake of Bt cotton among Cotton farmers in the study areas. The Ministry of Agriculture and Non-Government organizations (NGOs) should intensify the provision of extension services on Bt cotton farming through demonstrations, farm visits, dissemination of Bt cotton seeds, and sensitization meetings. Access to credit was identified as an important factor influencing the level of uptake of Bt cotton. As such, the study recommends formal sources including commercial banks, Microfinance Institutions, and NGOs should supply affordable and timely credit to cotton farmers either in cash or non-cash form (In-Kind), especially during the production phase to purchase farm inputs like pesticides and fertilizers.

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5.2 Declaration of competing interests

The authors declare no competing interests.

6.0. References

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