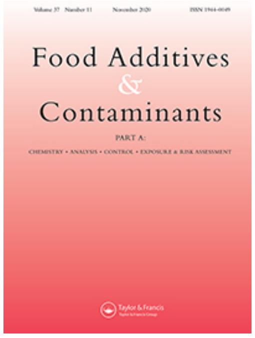

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Assessment of willingness-to-pay for Aflasafe KE01, a native biological control product for aflatoxin management in Kenya

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ABSTRACT

Contamination of key staples with aflatoxins compromises the quality of food and feed, impedes trade, and negatively affects the health of consumers whereas acute exposure can be fatal. This study used the Contingent Valuation Method (CVM) on a sample of 480 farmers in counties prone to aflatoxin contamination to assess the willingness to pay (WTP) by farmers for Aflasafe KE01, a promising biological control product for the management of aflatoxin contamination of key staples in Kenya, compare its cost with that of a similar product in use in Nigeria, and determine factors likely to affect its adoption. Four hundred and eighty households from four counties identified as aflatoxin hotspots in Kenya were purposively selected and interviewed using a semi-structured questionnaire. The mean WTP per kilogram of Aflasafe KE01, using Contingent Valuation Method in the four counties ranged from Kenya Shillings (Ksh) 113 to 152/kg compared to a cost of Ksh. 130/kg, the price of a similar product, Aflasafe™, in Nigeria. Factors that positively influenced farmers' WTP included information from crop extension services and access to credit. To facilitate the adoption of Aflasafe KE01 or any other biocontrol product in Kenya and elsewhere, there is a need for increased education efforts through extension services to farmers about aflatoxins. Strategies to ensure that the biocontrol product is integrated into the credit scheme of the technological packages to farmers need to be considered.

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Aflatoxins; biological control; Aflasafe KE01; Kenya; Contingent Valuation Method (CVM); Willingness to Pay (WTP)

Introduction

Aflatoxins are toxic secondary metabolites produced[1] by fungi belonging to *Aspergillus* section Flavi (Frisvad et al. 2019). In Kenya, an unnamed lineage designated as Lethal Aflatoxicosis Fungus is an important source of contamination associated with acute aflatoxicosis events (Probst et al. 2007). A wide range of commodities such as cereals, oilseeds, spices, tree nuts, milk, meat and dried fruits are contaminated by aflatoxins (Mehan et al. 1991; Cotty et al. 1994; Williams et al. 2004; Schmidt 2013; Udomkun et al. 2017). The frequent occurrence of aflatoxin contamination in maize and peanuts poses a serious threat to the health of a majority of people in sub-Saharan Africa as these two crops constitute a significant proportion of the staple diets (Shephard 2003; Agong 2006; Hell and Mutegi 2011). The ubiquitous aflatoxin-producing fungi may infect the crops during pre-harvest and post-harvest stages making food and feed unsafe for human and animal consumption (Hell and Mutegi 2011; Udomkun et al. 2017). Extensive aflatoxin contamination in food systems in sub-Saharan Africa has resulted in significant social and economic losses with respect to impaired health and productivity of humans and animals, increased food spoilage, and inability to market agricultural products internationally (Wu 2014).

Aflatoxicosis incidences in Kenya are well documented with the worst recorded case occurring during the 2004–2005 cropping season (Azziz-Baumgartner et al. 2005; Lewis et al. 2005). In 2010, over 10% of Kenyan maize, mainly from Eastern Kenya, was condemned by the then Ministry of Public Health and Sanitation, after several laboratories confirmed high levels (up to 830 ng/g) of aflatoxin in the samples tested (Villers 2017; Mutegi et al. 2018).

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Different strategies to control aflatoxin contamination have been recommended and their pros and cons and degrees of efficacy discussed widely. These include breeding for resistance, good agricultural practices, biological control, post-harvest measures, physical methods, chemical methods, genetic engineering and enforcement of regulatory measures (Jaime-Garcia and Cotty 2004; Hell et al. 2008; Waliyar et al. 2008; Hell and Mutegi 2011; Lizaraga-Paulin et al. 2013; Wu et al. 2013; Bandyopadhyay et al. 2016). Despite the numerous recommendations on aflatoxin management that are awash in the literature, contamination of key staples such as maize by the toxins remains high in sub-Saharan regions due to poor percolation of knowledge about solutions, time and labour intensiveness of some of the technologies, inadequate knowhow on use of technologies, and ethical aspects, as well as climate change that favours aflatoxin accumulation even when mitigation measures are in place (Bandyopadhyay et al. 2016).

One of the aflatoxin contamination mitigation technologies that has successfully reached commercialisation level in several countries in Africa and whose upscaling and out scaling efforts are underway is biological control (Bandyopadhyay et al. 2016). In Kenya, four native atoxigenic strains of *A. flavus* that cannot produce aflatoxin were identified (Probst et al. 2011) and serve as the active ingredients of the multi-strain biocontrol product Aflasafe KE01. Following efficacy and safety evaluations, the Pest Control Products Board (PCPB) registered the product for aflatoxin mitigation in maize in 2015 (Bandyopadhyay et al. 2016). Upon application at the recommended rate of 10 kg/ha, the atoxigenic strains in Aflasafe KE01 produce a large number of spores on sorghum grain carriers, which act as a food source, and competitively displace the toxigenic strains of *A. flavus* from the crop environment.

Application of the product in maize fields in Kenya has demonstrated significant levels of efficacy. At the Kenya government's Galana–Kulalu irrigation scheme in Kilifi County, over 96% of the maize met the European Union regulatory threshold of 4 ng/g (Bandyopadhyay et al. 2016) compared to neighbouring farms where almost 50% of the maize did not meet the Kenyan regulatory threshold of 10 ng/g aflatoxin content (unpublished data). High efficacies were also obtained by farmers in Meru County, where over 80% of maize from treated fields met the Kenyan regulatory threshold while only 33% of the maize from untreated farms in the region met the threshold (Unpublished).

Like other novel agricultural inputs and technologies, the full benefits of the product can only be realised if upscaling and out scaling of the product are done through a well-informed process. Some questions need to be answered for scaling to happen: what is the price that farmers are ready to pay for the product and what are the effective strategies to facilitate the scaling of the new product. This study therefore aimed at 1) determining the farmers' willingness to pay (WTP) for the product, and 2) identifying factors that inform their decision on WTP.

Methodology

Description of the study area

The study was carried out in 2014 in four counties; Makueni, Machakos, Kitui (eastern region) and Tana River (coastal region). The four counties are aflatoxin hotspot areas where recurrent outbreaks of aflatoxicosis have been reported and consignments of maize have been condemned for being highly contaminated with aflatoxins (Anonymous 2009). They are considerably different in agro-ecological conditions and socio-economic development. The annual rainfall in Makueni County ranges from 500 to 1050 mm, while that of Machakos County ranges from 500 to 900 mm (Jaetzold et al. 2006). Kitui and Tana River Counties are predominantly arid and semi-arid with annual rainfall ranging from 150 to 650 mm and 400 to 750 mm, respectively (Jaetzold et al. 2006).

Smallholder subsistence agriculture is the dominant economic activity in Machakos, Makueni and Kitui Counties while commercial agriculture is practiced in Tana River County, through irrigation. Intercropping of maize and legumes is common practice in the four counties. Several small-holder farmers grow fruits and rear livestock, mainly cattle, sheep, goats and chicken. The poverty level in Tana River County is at 76.9% (Republic of Kenya

2013), while that of Makueni, Machakos and Kitui Counties is 49%, 60% and 63%, respectively, all higher than the national average of 46% (KDHS and ICF Macro 2010).

Sampling procedure

The four counties – Makueni, Machakos, Kitui and Tana River – were purposively selected since they are also amongst areas where field trials on the efficacy of Aflasafe KE01 were undertaken (Figure 1).

Farmers were divided into two categories depending on whether or not they had participated in the efficacy trials during the 2012–2013 cropping cycle. Farmers who took part in the field efficacy trials were referred to as trial farmers while those who had not participated were referred to as non-trial farmers. Trial farmers were also divided into two; treatment and control farmers. Treatment farmers were those who applied Aflasafe KE01 while the control farmers were those who did not apply the biocontrol product. Trial farmers were perceived to have information regarding the product as their farms had been selected by the International Institute of Tropical Agriculture (IITA), the Kenya Agricultural and Livestock Research Organisation (KALRO) and ACDI-VOCA personnel who sensitised them on the technology before the trials were conducted. The trial farmers were also involved in the application of the product in the field. A hypothetical scenario was, therefore, not necessary for this group of farmers.

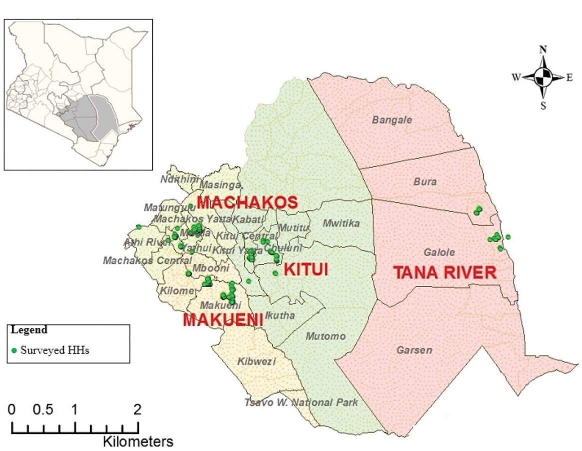

Figure 1. Distribution of sampled households (HH) in Tana River, Makueni, Machakos and Kitui Counties of Kenya.

Non-trial farmers were those who hailed from sub-counties where no Aflasafe KE01 efficacy trials had been conducted. These farmers were perceived not to have any prior information related to the product. To elicit WTP for this category of farmers, a hypothetical scenario was created to help them understand the product.

The four counties were grouped into three study group categories. For the purpose of this study, both treatment and control farmers in Tana River were categorised as one group referred to as Tana River because the treatment and control plots were close to each other and therefore the farmers were trained together and the information they had was similar. The trial farmers from Machakos, Makueni and Kitui Countries were referred to as lower eastern trial farmers while the non-trial farmers were referred to as lower eastern non-trial farmers. The trial and non-trial farmers were far apart.

Sample size description

In Tana River region, some farmers who participated either as treatment or control in the efficacy trials were not available at the time of this study. Therefore, out of 72 who participated in the efficacy trials before, 32 farmers were selected from the two distinctive irrigation schemes managed by the National Irrigation Board (NIB), namely Bura and Hola.

Systematic sampling was used to select farmers who belonged to the treated and control groups in the efficacy trials in Makueni (Kaiti and Wote districts), Machakos (Kathiani district) and Kitui (Nzambani district) Counties. A total of 77 farmers were selected out of 97 who participated in the efficacy trials as treatment farmers and 57 out of 98 who participated as control farmers.

Another 314 farmers in Makueni, Machakos and Kitui Counties were selected and interviewed. A systematic sampling approach was used whereby every fifth farmer out of 436 in Makueni and fourth farmer out of 330 and 285 in Machakos and Kitui, respectively, was selected for interview. They were selected from a list of farmers provided by the local area administration office and consisted of those who had not participated in the efficacy trials of Aflasafe KE01 (non-trial farmers) and who were perceived not to have information about the product. The non-trial farmers were selected from Kathonzweni in Makueni County (109 farmers), Mwala in Machakos County (110 farmers) and Katulani in Kitui County (95 farmers).

Data collection

Trained enumerators administered a semi-structured questionnaire to the 480 households in the four counties to capture primary data. The respondent was either the household decision maker or the spouse. The questionnaire included an introductory section, a detailed description of the biocontrol product to be valued, the current status with regard to field efficacy trials and the payment mode (hypothetical) through which the farmers would access the product. The questionnaire also enabled the collection of the respondent's socio-demographic characteristics.

Key informant interviews were also conducted with extension officers from each of the selected agriculture and irrigation county offices. The interviews aimed at capturing the current situation of aflatoxin contamination problem of maize and also on the readiness of farmers to adopt the biocontrol technology. The availability of supporting infrastructure for the adoption of the technology was also discussed. Household interviews were conducted and information gathered on the amount of money farmers were willing to pay for the product and the factors likely to influence their WTP.

Bidding process

The study used the Contingent Valuation Method (CVM). Estimates of the value of novel products/new agricultural inputs through CVM have become crucial tools to agribusinesses in guiding decision-making (Lusk and Hudson 2004). Iterative bidding was used with the view of encouraging respondents to consider their preferences carefully through the provision of rounds of discrete bids. The bidding game helped to elicit farmers' maximum WTP amounts.

The respondents were asked whether they would pay each of a series of amounts that ascended or descended from a specified starting point of Ksh. 130/kg of the product. The initial amount was based on the prevailing cost of Aflasafe, a similar product in use in Nigeria priced at USD 1.5/kg (ca 130 Ksh/kg). A bid of ± Ksh 20 was used to elicit the maximum amount that a farmer would be willing to pay. If a farmer's response was a YES (or NO) to the initial bid amount, an increment or decrement of Ksh 20 was offered until the maximum amount the farmer would be willing to pay was attained (Wattage 2002). To ensure incentive compatibility, farmers were informed they would use their cash or buy through credit from agro-dealers and repay after crop sale. They were also informed of the recommended application rate of 10 kg per hectare.

Protest answers were judged by first asking the respondent/farmer if they were willing to pay for the product and if not, the reasons why they were not willing to pay any amount. The average amount the farmers were willing to pay for the product was estimated from the values recorded.

Data analysis

The questionnaire data were captured in a Statistical Package for Social Sciences (SPSS) and thoroughly cleaned before analysis. SPSS was used to generate descriptive statistics such as means and percentages and to run the CVM to estimate farmer s` WTP amounts and to identify significant factors influencing WTP.

The WTP values from the iterative bidding elicitation form a continuous dependent variable that accepts zero values. Ordinary least square (OLS) regression model using STATA was conducted to assess the relative importance of factors hypothesised to influence the WTP of farmers. The model also allowed inclusion of respondents' socio-economic factors as independent variables into the WTP function.

The dependent variable was the Maximum WTP (Max WTP) which was the amount of money a household would be willing to pay for the product.

The maize farmer WTP function for Aflasafe KE01 was assumed to be:

$$WTPi = f(Yi, Ei, Ai, Mi \ldots)$$

Where: WTP = Willingness to Pay; Y = Income; E = Education; A = Age and E = Membership in Agricultural groups.

The estimated model was therefore written as:

$$WTPi = Xi\beta i + \mu$$

where X was a vector of explanatory variables, β was a vector of coefficients and μ was

a random variable accounting for unobservable characteristics. This allowed the use of OLS to estimate the explanatory variables that influenced the farmers' WTP.

The independent variables used to assess the factors that are likely to affect WTP for Aflasafe KE01 and their direction of influence are outlined in Table 1.

Results and discussion

Socio-economic characteristics of the households

The average age of the household head was 44, 51 and 52 years for Tana River County, lower eastern trial, and lower eastern non-trial farmers, respectively. The average age in the four study areas concurred with the national population findings where 57.2% of household heads are aged 40 years and above (G.O.K KIHBS Basic Report 2006).

Interestingly, the percentage of male-headed households was 56% for Tana River, 37% for lower eastern trial farmers and 40% for lower eastern non-trial farmers. Therefore, the majority of the households in lower eastern region were headed by females. The implications of female-headed households on other socio-economic inclinations at household level need further investigations. However, there is a possibility that respondents answered the question on who headed the family based on who was undertaking most agricultural activities and not necessarily making decisions on any income generated directly or indirectly from the agricultural activities. Past studies have pointed to broad participation by women in subsistence agriculture where there is hardly any income, while ownership of the land rested in the men (Ng'ang'a 2019). The average household size was six persons for Tana River and five for both trial and non-trial households in lower Eastern Kenya, findings that concur with those of a previous study by Jaetzold et al. (2006) in lower Eastern Kenya.

The average number of years of schooling was six for households in Tana River and ten and nine for trial and non-trial families in lower Eastern, respectively. The national status report (GOK 2010) showed that the majority (51%) of Kenyans in lower Eastern Kenya had attained primary school education. Our data thus also confirms that there is a low level of the population that makes it to tertiary level education in the three counties. Educational level may affect the uptake of technologies that have technical information requiring understanding for correct use. To promote adoption in counties with low levels of education, the label of products such as Aflasafe KE01 should have illustrations and simple language that can be translated to local dialects and/or Swahili so that the users can easily understand instructions.

Table 1. Description of hypothesised independent variables used to assess farmers' willingness to pay for Aflasafe KE01 in Kenya.

Variable name	Symbol	Description of the variable	Expected sign
Access to crop extension	Extcon	1 = accessed within last normal year, 0 = No access	+
Credit access	CreditAcc	1 = access credit within last one year, 0 = no access	+
Awareness of bio-fungicide	AwareBio	Dummy 1 = aware, 0 = not aware	+
Experienced Aflatoxin contamination	AflaConta.	Dummy 1 = Yes, 0 = No	+
Experienced maize loss to diseases	Disease	Dummy 1 = Yes, 0 = No	+
Household size	Hhsiz	Number of the household members	+
Contract agreement of sale	CntrtAgrmt	Dummy 1 = Have a contract agreement 0 = No contract	+
Years of main livelihood activity	Experience	Number of years of practicing main livelihood activity	+
Income	Hhinc	Natural log of household income	+
Agricultural group membership	MbrAgric	Dummy for membership to group 1 = Yes, 0 = No	+
Maize production	Prodn	The quantity of maize harvested in 90 kg bags last season	+
Age (Years)	Age	Age of the household head/decision-maker	+
Area under cultivation	AreaCult	Acres under cultivation	+
Land tenure	Tenure	1 = Formal ownership of land, 0 = No formal ownership	+
Distance to market	DistMkt	Distance to the local market in km or miles or minutes???	-
Education	HEDUC	Number of years of schooling completed	+
Initial bid amount	Initamt	1 = if the household said yes to the initial amount; 0 = Otherwise	-
Gender	Gender	Gender of the household head 1 = Male, 0 = Otherwise	±
Perception of product effectiveness	PercEffective	Whether a farmer perceives the product to be effective 1 = Yes, 0 = Otherwise	-
Main occupation of the household head	Occup	1 = On- farm activities 0 = Off-farm activities	+
Bura	Bura	The respondent residence 1 = Bura, 0 = Otherwise (Hola)	±

Majority of the farmers (66%) in Tana River County belonged to agricultural groups, compared to farmers in lower eastern. For example, only 24% of non-trial farmers from lower eastern belonged to agricultural groups. Most households in Tana River County had joined an agricultural group to access irrigation water and other agricultural inputs under the National Irrigation Board (NIB). Farmers in lower eastern region mainly practiced rain-fed agriculture and sourced inputs directly depending on the timings of planting in their farms. The incentive to join the groups in Tana River was also boosted by the fact that farmers were provided with an option of selling their produce through the NIB.

Majority (>85%) of the respondents practiced agriculture as their primary occupation, confirming an observation in previous reports (KARI 2012), where over 80% of the rural population in Kenya derives their sustenance from agricultural-related activities. Off-farm occupations included formal salaried employment in the private sector and public service as well as self-employment.

Farmers' WTP for Aflasafe KE01

Amongst households in Tana River, 93.6% were willing to use this biocontrol product in future. The remaining 6.4% mentioned seasonality of aflatoxin contamination and the occurrence of toxigenic fungi in the soil, and the possibility of the carrier sorghum germinating in the soil, as reasons for being not willing to use the product in future.

Among the trial farmers in lower eastern, 99.3% were willing to use the product. The remaining 0.7% of the farmers did not want to use the product as they awaited results of soil health studies from a previous exercise in their farms. The three responses (0.7%) were treated as protest bids since their resultant WTP value of zero was as a result of an unrelated aspect of soil health data that they expected to be reported back to them, rather than an attribution to the lack of usefulness of the product. The responses nevertheless demonstrated the need to provide community feedback by researchers when participatory studies are undertaken as it influences how farmers will respond to future work by agricultural players. Amongst non-trial farmers from lower eastern, 99.7% were willing to pay for Aflasafe KE01. There is a possibility that the one respondent who was unwilling to use the product ignored or was not aware of the chronic implications of consuming grain that surpassed the Kenyan regulatory threshold of 10 ng/g, as there may be no notable immediate effects depending on the levels.

Estimation of WTP

The minimum amount that the farmers were willing to pay per kilogram of Aflasafe KE01 was Ksh 30 (about USD 0.35) across the 3 farmers' categories, while the maximum amount was Ksh 250 (USD 2.94), 510 (USD 6.0) and 490 (USD 4.9) for Tana River County, lower eastern trial, and lower eastern non-trial farmers, respectively.

The mean WTP per kg was Ksh 113 (USD 1.33) (std. dev 52.0), Ksh 152 (USD 1.79) (std. dev 101.7) and Ksh 147 (USD 1.73) (std. dev 93.4) for farmers in Tana River County, lower eastern trial farmers and lower eastern non-trial farmers, respectively. The mean WTP of the trial and non-trial farmers in lower eastern region was not significantly different (Figure 2). The higher WTP in lower Eastern Kenya can be explained by the previous fatal recurrent aflatoxicosis outbreaks witnessed in the region and the resulting increased level of awareness amongst the farming population, which was further heightened by the government following the outbreaks. Although maize in Tana River County has been condemned due to high levels of aflatoxins contamination, the plausible explanation for their low WTP could be because land is not permanently allocated to farmers thus reducing incentives for long-term investments for improvement of soil health through biocontrol application. Also, several aflatoxin awareness campaigns by previous public and private initiatives could not adequately reach

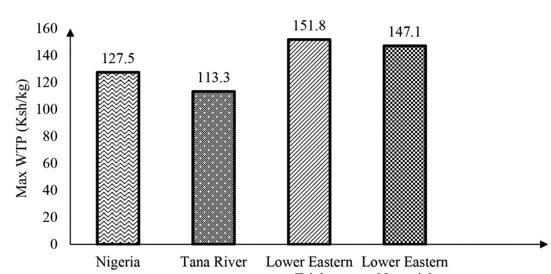

Figure 2. Kenyan farmers` willingness to pay (WTP) for Aflasafe KE01 compared to equivalent cost of Nigeria's Aflasafe.

farmers in Tana River County due to its geographical locations and travel restrictions. Nevertheless, the WTP for the product was positive in the region. Only WTP in Tana River was lower compared to the WTP of a similar product in Nigeria (Ayedun et al. 2017).

Factors influencing farmers WTP

The explanatory variables hypothesised to influence farmers' WTP, and their expected relationships with the dependent variable are summarised in Table 2. The independent variables were tested for the presence of multicollinearity, heteroscedasticity and omitted variable/mis-specification errors before the model was run. Variance Inflation Factor (VIF) was used to quantify the severity of multicollinearity. The mean VIF for Tana River was 2.6 (range: 1.71 to 3.50), that for lower eastern trial farmers was 1.36 (range: 1.05 to 2.26) while that of lower eastern non-trial farmers was 1.17 (1.06 to 1.33). The linear correlation coefficient (r) hence showed that none of the explanatory variables was strongly collinear with the others by VIF for the three target groups in Tana River, lower eastern trial farmers and lower eastern non-trial farmers.

The model was also tested for heteroscedasticity using the Breusch-Pagan/Cook–Weisberg test. The tests in the three trial areas satisfied the OLS assumption of homoscedasticity (Table 3). Table 4 shows OLS model estimates for the factors that influenced the WTP for the biopesticide. The explanatory variables took both qualitative and quantitative form. The factors that positively influenced farmers' WTP were access to extension services, credit utilisation, awareness about Aflasafe KE01, contract agreement, household income, gender, age, being from Bura sub-county and initial bid amount. Those that were found to negatively influence WTP were household size, distance to market, perception about product effectiveness and years of practice of the main livelihood activity.

Access to extension services positively influenced WTP of farmers in Tana River County at 10% (p = .053). The county extension services in Tana River were boosted by the NIB through the provision of access to information and services. Households in Tana River County that have received information through extension services were more aware of effects associated with aflatoxin contamination and were willing to pay more to prevent contamination (Kumar and Popat 2008; Niyaki et al. 2010). The possible reason for lack of influence of extension services on WTP in lower eastern could be due to lean resource allocation through county governments for extension services. A similar study done in Nigeria to assess the WTP for Aflasafe found access to extension services, education level and income to positively influence WTP (Ayedun et al. 2017). Credit

Table 2. Descriptive statistics of explanatory variables hypothesised to influence maximum willingness to pay for Aflasafe KE01.

	Tana River County, n = 32			Lower eastern (trial), n = 134			Lower eastern (non-trial), n = 314		
Variables[2]	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)
Extcon	0	1	0.50 (0.51)	0	1	0.65 (0.48)	0	1	0.40 (0.49)
CreditAcc	0	1	0.69 (0.47)	0	1	0.10 (0.30)	0	1	0.05 (0.21)
Hhsiz	1	18	6 (3.81)	1	15	5 (2.41)	1	17	5.11 (2.30)
AwareBio	0	1	0.97 (0.18)	0	1	0.87 (0.34)	0	1	0.06 (0.23)
CntrtAgrmt	0	1	0.97 (0.18)	0	1	0.08 (0.28)	0	1	0.04 (0.19)
Aflaconta	0	1	0.41 (0.50)	0	1	0.93 (0.26)	0	1	0.28 (0.45)
DistMkt	1	4	1.1 (1.15)	1	15	2.21 (2.65)	1	15	3.17 (1.84)
MbrAgric	0	1	0.66 (0.48)	0	1	0.49 (0.50)	0	1	0.24 (0.43)
Hhinc(ln)	9.21	11.61	9.70 (0.72)	9.21	11.74	9.88 (0.82)	9.21	11.73	9.73 (0.734)
Prodn	3	80	21.43 (14.64)	0.8	95	16.46(15.41)	0.5	75	11.05(11.52)
HEDUC	1	18	6.44 (4.33)	1	19	9.9 (4.22)	1	19	9.18 (4.14)
Disease	0	1	0.56 (0.50)	0	1	0.31 (0.46)	0	1	0.36 (0.48)
Gender	0	1	0.56 (0.50)	0	1	0.37 (0.48)	0	1	0.40 (0.49)
Age	23	74	44.1 (15.29)	24	87	51.4 (14.15)	23	92	52.03 (15.78)
Experience	2	40	10 (10.79)	4	54	22 (12.10)	1	72	21 (14.68)
PercEffective	0	1	0.91(0.30)	0	1	0.79(0.41)	0	1	0.55(0.50)
Occup	0	1	0.88 (0.34)	0	1	0.84 (0.36)	0	1	0.85 (0.36)
Bura	0	1	0.59 (0.50)						
AreaCult	1.5	6	2.95 (0.97)	1	40	4.57 (4.34)	0.38	20	3.95 (3.31)
Tenure				0	1	0.41 (0.49)	0	1	0.35 (0.48)
Initamt	0	1	0.41 (0.50)	0	1	0.55 (0.50)	0	1	0.55 (0.50)

[2]For explanation of variables, see Table 1. SD- Standard deviation

Table 3. Test for heteroskedasticity and Ramsey test for willingness to pay of Aflasafe KE01 in Kenya.

	Tana River County farmers	Lower eastern trial farmers	Lower eastern non-trial farmers
Breusch-Pagan/Cook-Weisberg test for heteroskedasticity	$\chi^2(1) = 0.66$ Prob $>\chi^2= 0.4155$	$\chi^2(1) = 1.14$ Prob $>\chi^2= 0.2850$	$\chi^2(1) = 4.53$ Prob$>\chi^2= 0.2333$
Ramsey RESET test	F (3,10) = 1.69 Prob > F = 0.2309	F (3,108) = 1.98 Prob >F = 0.1215	F (3,293) = 2.05 Prob >F = 0.1076

availability significantly influenced WTP positively for all the three groups of farmers (Table 4). Past studies have documented access to credit as an essential aspect in enabling farmers to access and purchase farm inputs (Assa et al. 2013).

Household income positively influenced WTP for Aflasafe KE01 in lower Eastern Kenya. Income has also been reported to positively influence consumers' WTP for genetically modified maize meal in Kenya (Kimenju et al. 2005), an indication of farmer's attitude towards new technology, assuming that education and income source are positively correlated. While Marechera and Ndwiga (2015) found formal education to positively influence WTP for Aflasafe products, our results did not confirm this relationship in the three sites.

Household size negatively influenced the WTP for the product by households in Tana River (p = .100) and lower eastern non-trial (p = .001) locations. This finding corroborates similar results with Aflasafe in Nigeria (Ayedun et al. 2017). Although household size was expected to positively affect WTP especially where the size is attributed to human capital (Horna et al. 2007), the negative relationship in our study could be attributed to a reduction in household disposable income to purchase an input such as Aflasafe KE01. Muhammad et al. (2015) reached a similar conclusion for certified organic products. Awareness about the biological control product positively influenced WTP for the product in lower eastern non-trial households (p = .023). Farmers who are

Table 4. Factors influencing willingness to pay for Aflasafe KE01 for the three farmers' categories from Tana River and lower Eastern regions in Kenya.

		OLS Regression model estimates					
		Dependent variable: Max WTP					
		Tana River County		Lower eastern (Trial area)		Lower eastern (non-trial area)	
Variables[3]	Expected sign	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Constant		107.77	0.217	3.27	0.000***	4.02	0.000***
Extcon	+	30.51	0.053*	0.06	0.395	0.01	0.851
CreditAcc	+	36.94	0.013**	0.21	0.064*	0.21	0.020**
Hhsiz	+	−3.10	0.100*	−0.02	0.235	−0.03	0.001***
AwareBio	+			0.11	0.363	0.19	0.023**
CntrtAgrmt	+			0.16	0.156	0.26	0.018**
Aflaconta	+	−2.36	0.924				
DistMkt	-	3.32	0.585	−0.003	0.792	−0.02	0.071*
PercEffective	-	−15.56	0.064*				
MbrAgric	+	−8.67	0.545	0.10	0.179	0.02	0.698
Hhinc	+	−1.25	0.881	0.08	0.061*	0.05	0.067*
Prodn	+			0.002	0.363	0.0003	0.868
HEDUC	+	−0.05	0.974	−0.004	0.643	−0.005	0.316
Disease	+	8.96	0.515				
Gender	±	−9.50	0.408	−0.10	0.183	0.07	0.089*
Experience	+	−0.89	0.097*	−0.01	0.060*	−0.002	0.181
Age	+			0.01	0.028**		
Occup	+	−0.52	0.977	−0.004.	0.959	0.061	0.260
Bura	±	20.98	0.086*				
AreaCult	+	−2.43	0.688	0.01	0.211	0.0003	0.983
Tenure	+			−0.06	0.435	0.023	0.576
Initamt	-	79.31	0.000***	0.973	0.000***	0.898	0.000***
No. of obs.			30		129		313
F(16,13)			10.30	F(17,111)	15.77	F(16,296)	43.03
Prob.>F			0.0001		0.000		0.000
Adjusted R-squared			0.8369		0.6623		0.6831
Root MSE			21.01		0.34886		0.3231

[3]For explanation of variables, see Table 1.

*, ** and *** implies statistically significant at 10%, 5% and 1% respectively

aware of a new product are more willing to pay for it compared to those with no knowledge (Singh et al. 2008; Aryal et al. 2009). The greater motivation of farmers in lower eastern to use the product could also be explained by the high incidences of aflatoxicosis and aflatoxin contamination in the region (Azziz-Baumgartner et al. 2005; Lewis et al. 2005; Mwihia et al. 2008; Daniel et al. 2011) which elevated awareness about existence of the problem and the desire to address it.

Despite not participating in previous Aflasafe KE01 trials and hence having minimal knowledge about the product, a contract agreement with the maize buyers positively (p = .018) influenced WTP amongst non-trial farmers in lower eastern region at 95% confidence level. Contract arrangements provide an assurance to farmers of the availability of a ready market for their maize, which acts as a motivation for engagement and WTP. Such markets are becoming more stringent with safety requirements for produce that they procure as they target use in therapeutic foods and for vulnerable groups such as children, women and the elderly. The distance to market negatively influenced WTP for non-trial households in lower eastern (p = .071; 90% confidence level) while the perception of the effectiveness of the product negatively (p = .064) influenced WTP at 90% confidence level for farmers in Tana River County. Long distances for procuring inputs or selling outputs discourage farmers (Nelson and Temu 2005) as their production and transaction costs increase. This was less likely to be an issue in Tana River County, where the farmers' produce was procured by the NIB at farm level. User perceptions influence WTP for new technologies whereby farmers with a negative attitude about the product are likely to pay less (Steur et al. 2010). This is however anticipated since it is the first time that a biological control product is being introduced at commercial scale for the management of aflatoxins in Kenya.

Being a male positively (p = .089) influenced WTP amongst lower eastern non-trial farmers at 90% confidence level. Women tend to be more risk averse as compared to men hence are less likely to adopt new technologies in contrast to their male counterparts (Boucher et al. 2008; Fletschner et al. 2010). Male-headed households also have greater access to resources and information that enables them to more readily adopt novel technologies (Odendo et al. 2009) compared to women. As noted earlier (Ng'ang'a 2019), decision-making including what to purchase is usually vested amongst men.

The number of years a farmer had grown maize negatively influenced WTP for both Tana River (p = .097) and lower eastern trial farmers (p = .060) at 90% confidence level. Although it is expected that a maize farmer would be more knowledgeable about crop protection practices with more experience in maize cultivation, the interviews revealed that majority of the farmers believed that the aflatoxin problem was primarily a post-harvest problem. Moreover, aflatoxin contamination may not carry any physical manifestation, and it does not reduce or increase crop yield. In the absence of any adverse and immediate health consequences (Schmidt 2013), farmers growing maize for many years may not see the need to invest in management efforts.

The age of the household head in lower eastern positively (p = .028) influenced WTP, while being from Bura positively (p = .086) influenced WTP for the trial farmers in Tana River. Even though not further investigated to understand why WTP was positively influenced by older farmers, it could be that the majority of the farmers involved in agriculture in lower eastern are from the older generation, while the younger generation migrated to urban centres in search for employment, a trend replicated in many other parts of the country (FAO 2018). Witnessing the devastating effects of the recurrent aflatoxicosis outbreaks in the region may also have influenced the WTP for the older farmers. The WTP for this biocontrol product in Bura was positive compared to Hola, yet they are neighbouring areas within the same county and with similar socio-economic and agricultural activities. Perhaps, the difference in the outcome was because awareness-raising activities in Bura irrigation scheme (where all farming activities take place in Bura area) were more heightened compared to Hola irrigation scheme (where all agricultural activities in Hola are centred). In addition, more biocontrol efficacy trials coupled with education efforts by IITA, the Department of Agriculture, and NIB had been conducted over several seasons in Bura, compared to the Hola scheme.

The initial bid amount positively influenced the WTP for Aflasafe KE01 at 90% confidence level for all the three categories of farmers. This was contrary to what was hypothesised, as the initial bid was to influence the magnitude of WTP negatively as explained by the law of supply and demand. This shows that the respondents believed that the initial bid amount presented to them could be the right amount to pay for the product and hence based their valuation on that amount.

Conclusion and recommendations

The aim of the study was to assess farmers' WTP for Aflasafe KE01, a biological control product for aflatoxin mitigation in maize in Kenya. *Ex-ante* estimation of WTP is important since it provides prior information on prospects for scaling a viable technology. This also helps in formulating policies to expand the potential markets for the novel product. The values for WTP are higher than the amount charged for a similar product in Nigeria except for farmers in Tana River County. This shows a positive appreciation for the product and subsequently provides a basis for pricing considerations by relevant stakeholders.

Given the importance of credit on WTP, access to credit from lending organisations should be promoted by ensuring affordable rates for borrowing. Aflasafe KE01 could be included in the technological package with other agricultural innovations that the government makes available to farmers.

Awareness about Aflasafe KE01 positively influenced WTP. Therefore, awareness efforts should be stepped up through initiatives such as the Agriculture Ministry's and associated institutions' field days, farmer field and business schools and through extension workers. Awareness creation would also help to create a market for the product hence directly supporting scaling efforts. In addition, awareness raising can lead to an improved understanding about the correct use of the product for enhanced effectiveness. Incorrect use could adversely affect the efficacy of the product, leading to low adoption by farmers in future.

Developing distribution networks close to farmers is a major consideration for scaling up for the product to reach the ultimate beneficiaries. Such networks must favour accessibility by end users situated away from urban centres to reduce transaction costs (e.g., transportation, convenience) that farmers incur when accessing agricultural inputs.

The approach towards scaling up must consider the heterogeneous nature of maize farmers in Kenya, one that accommodates the resource-poor majority who depend on maize as their staple, as well as those who – despite being a minority of less than 30% – trade in maize as an income source, and have a major role to play in sustaining the use of Aflasafe KE01.

Note

1. The conversion rate used at the time of data collection was one dollar to Ksh 85.

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Declaration of interest statement

The authors receive no direct financial benefit from the manufacturing and marketing of aflatoxin biocontrol products mentioned in this article. The Aflasafe name is a Trademark of the International Institute of Tropical Agriculture (IITA). IITA used to manufacture Aflasafe for use in Nigeria, Senegal, Kenya, Burkina Faso, The Gambia, and Ghana. Manufacturing and distribution responsibilities have been licensed to private or public sector entities in a few African nations. In Kenya, KALRO manufactures Aflasafe KE01. IITA charges a small licensing fee to manufacturers for use of the Aflasafe name and cost associated with technology transfer and technical backstopping. C. Mutegi, R. Bandyopadhyay and V. Manyong are employed by IITA.

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