# Stated Farmers' Preferences and Willingness to Pay for Climate Resilient Potato Varieties in Kenya: A Discrete Choice Experiment.

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## Abstract

Despite sustained efforts by various research organizations in developing and disseminating climate resilient varieties, adoption of climate resilient potato varieties (CRPVs) remains low in Sub-Saharan Africa. This has been majorly attributed to limited coordination between formal research institutions and farmers hence sidelining farmers' preferences especially smallholder farmers. Considering farmer preferences in the breeding process may yield optimal combination of varietal attributes hence increasing adoption. Therefore, this study used a discrete choice experiment to investigate farmers' preferences and mean Willingness to Pay (WTP) for various attributes of CRPV. Results indicate that farmers have a strong preference for high resistance to pests and diseases as compared to other attributes which include low water requirements, short maturation period and high yield. Despite farmers preferring low prices for CRPV attributes, we also note that they were low price responsive. A small change in price did not affect their preferences for other CRPV attributes. This study emphasizes on the need for participatory breeding efforts that embed traits preferred by farmers hence satisfying the demands of different population segments based on age, gender and education level.

**Key Words:** Climate-resilient-potato-varieties; Preferences, Willingness-to-pay; Discrete-choice experiment.

**JEL Code:** Agricultural and Natural Resource Economics; Environmental and Ecological Economics: Agriculture see: www.aeaweb.org/jel/guide/jel.php?class=Q

**1.0 Introduction**

Potato production in Sub-Saharan Africa (SSA) is highly threatened by climate change and variability. Reduced precipitation due to prolonged drought has adversely affected seasonal yields. On the other hand, global warming has exacerbated emergence of new pests and diseases, cases of late blight and bacterial wilt. A high reduction of potato yields by 56% was reported during the 2016-2017 drought in Kenya (International Potato Center, 2017).

Previous studies however show that, potato production levels can double up without expanding the area under production by developing, disseminating and adoption of climate resilient varieties (Paker *et al.,* 2019). This has prompted research organization such as Kenya Agricultural and Livestock Research Organization (KALRO) and International Potato Center (CIP) into developing potato varieties that are climate smart. These varieties are said to be high-yielding and resistant to various pests and diseases. Despite various efforts by the Government of Kenya to promote breeding programs for improved potato varieties and their dissemination, there is limited coordination between formal research institutions and farmers. This has resulted into sidelining farmers' preferences especially smallholder farmers leading to lower adoption rates (Sánchez *et al.,* 2017).

A study by Kimathi *et al.* (2021) shows that adoption of climate resilient potato varieties is still significantly low among potato farmers from Meru County, Kenya, at an actual population adoption rate of 6.3% against a potential adoption rate of 30% if all farmers were to be exposed to these climate resilient varieties. However, limited evidence exists regarding how climate resilient potato variety attributes influence adoption. Sibiya *et al.* (2013) argues that considering farmer preferences and priorities in the breeding process may yield optimal combination of varietal attributes hence increasing adoption rates. Cramer (2018) recommends that systems for accelerated delivery of climate resilient varieties need to be massively upgraded so as to embrace the full procedure from trait discovery to varietal deployment and seed system development. One of the identified gaps and needs for improved climate smart breeding include knowledge in terms of better understanding of the future trait preferences of different food system actors (Balié *et al.,* 2019).

In this research, we use a discrete choice experiment to investigate farmers' preferences and mean Willingness to Pay for various attributes of climate resilient potato varieties; information that is valuable in designing efficient participatory breeding programs that may result into development of farmer-preferred climate resilient potato varieties and hence boosting adoption rates. The study further explores preference heterogeneity of climate resilient potato attributes based on age, education level and gender of the farmer.

**2.0 Literature Review**

Climate variability refers to the short term fluctuations of weather events that occur from year to year. It is characterized by seasonal changes in precipitation and temperatures of varying severity and duration. Over the past years, hunger and malnutrition incidences have increased significantly and the available food does not match the growing population in Kenya. The arid and semi-arid areas are the most affected with food insecurity (Atsiaya et al., 2019). Increasing temperatures and frequent droughts have deteriorated the state of smallholder farmers who depend on rain-fed agriculture in these areas. Droughts have led to severe food insecurity and malnutrition in various parts of the world (FAO, 2011). Climate variability has brought about unpredictability in rainfall patterns, increased incidences of pest and diseases in both plants and animals reducing agricultural productivity and production (Patrick et al., 2020; Wekesa et al., 2018). More so, the rural poor are the most vulnerable to these adverse impacts of the climate variability in Kenya (Kogo et al., 2020). This calls for adaptation strategies to cope with these challenges.

Adaptation on the other hand refers the process where strategies to reduce the impact of consequences of climate variability are developed, enhanced and implemented (UNDP, 2004). It includes a collection of activities that are needed to adjust development, manage risks, which include economic, socio-cultural and environmental to reduce vulnerability of economies, populations and ecosystems to the impacts of climate change and variability. It is necessary and a must, given that the IPCC fourth assessment report gives a confirmation that even if all measures to reduce the greenhouse gases emissions are put in place, the world will still continue to experience the effects of climate change and variability for the next several decades because the amount of greenhouse gases already emitted to the atmosphere are too high. Some impacts of climate change and variability like droughts are unavoidable hence; adaptation remains a principle way to cope with such (IPCC, 2014).

To counteract the effect of climate variability, numerous actors in agricultural sector are promoting farming practices and technologies called climate smart agriculture (CSA) among other coping strategies. These practices and technologies include crop rotation, agro-forestry, intercropping, maintenance of soil cover, minimum tillage, residue retention, conservation of water, improved livestock management, climate resilient crop varieties and animal breeding to adapt to future hostile conditions. Compared to convention methods of production in agriculture, CSA has been documented to register stable and higher yields and thus stable income from farming leading to high resilience in some regions (Wekesa et al., 2018). Various communities use these practices as strategies to cope and adapt to climate change and variability. According to FANRPAN (2013), CSA can be described as farming that increases productivity, resilience and income sustainably.

To curb the adverse effects of climate variability on potato production in Kenya, KALRO and CIP have developed potato varieties that are climate smart in the last 15 years characterized by heat tolerance, resistance to drought and resistant to pests and diseases (Paker et al., 2019). The varieties include Unica, Wanjiku, Lenana, Chulu and Nyota as shown in Table 1. Use of climate resilient varieties is one of the most popular adaptation practice among smallholder farmers in SSA (International Potato Center, 2017).

**Table 1: Climate Resilient Potato Varieties with their Characteristics**

| **Climate Adaptability Characteristics/ CRPVs** | **Unica** | **Nyota** | **Lenana** | **Chulu** |
|---|---|---|---|---|
| **Maturation Period** | 3 months | 3-4 months | 3-4 months | 3-4 months |
| **Yield** | >40T/Ha | >40T/Ha | >40T/Ha | >40T/Ha |
| **Resistant/Tolerance to Pests and Diseases** | Slightly resistance to late blight, highly resistant to Potato Virus X(PVX), and Potato Leaf Roll Virus(PLRV) | Tolerant to late blight | Tolerant to PLRV, late blight and PVX | Tolerant to late blight and PVX |

| | | | | |
|---|---|---|---|---|
| **Agro-ecological zones to be grown** | Lowlands and highlands tropics (1400-3500m above sea level) | Highlands tropics(1500-3500m above sea level) | Highlands tropics(1500-3500m above sea level) | Highlands tropics(1500-3500m above sea level) |

*Source: NPCK Catalogue (2019)*

However, adoption of these climate resilient potato varieties is said to be low in Kenya despite the associated benefits. A study by Kaguongo *et al.* (2008) shows that adoptions rates for improved potato varieties in Uganda are higher than those of Kenya by 24.8%. To improve adoption rates of smallholder potato farmers, their preferences in developing improved potato varieties should be given a priority. Use of improved of potato varieties is said to be a pathway to climate change resilience, increased production, and food security in Kenya (Kyamanywa et al., 2011).

## 3.0 Methodology

### 3.1 Study Area and Data

The study was carried out in Meru County, Kenya, which has an overall land area of 693,620 hectares (Ha) and the altitude lies between 2230-2900m above the sea level. The estimated potato producing area is 17,534Ha with a production of 196,434T (CIP,2019). The county is made up of four main agro-ecological zones characterizing the area; the upper and lower highlands where potatoes are mainly grown, and the upper and lower midlands (Jaetzold *et al.*, 2007).

A Discrete Choice Experiment (DCE) was conducted where structured DCE questionnaires which comprised of choices generated from the experimental design were administered to sampled farmers by well-trained enumerators to aid in data collection. The sample was drawn from smallholder potato farmers in the different agro-ecological zones of Meru County using multistage sampling technique. In the first stage, Meru County was selected purposively because it is among the highest potato producing counties in Kenya. The second stage involved purposive selection of three out of the nine sub-counties based on potato production levels and climatic conditions which include; Imenti South, Imenti Central and Buuri Sub-counties. In the third stage, four wards (Abothuguchi West, Abogeta West, Kiirua/Naari, Kibirichia) were randomly selected from the three sub-counties and finally, a random sample of 384 farmers was selected from the wards using simple random sampling technique. Table 2 shows the distribution of the sample size in the county.

**Table 2: Sample Size Distribution**

| Wards | Population | Percentage | Sample Size Proportion |
|---|---|---|---|
| Abothuguchi West | 35,901 | 30.51% | 117 |
| Abogeta West | 30,338 | 25.78% | 99 |
| Kiirua/Naari | 27,031 | 22.97% | 88 |
| Kibirichia | 24,409 | 20.74% | 80 |
| **Total** | **117,679** | **100%** | **384** |

**Source:** (Ngugi et al., 2013)

### 3.2 Experimental Design

Revealed and stated preference methods are the two main approaches in eliciting individual preferences for priority setting in economic evaluation. Revealed preference approach involves analysis of individual preferences revealed by real market behavior. This approach is limited in that attributes are usually collinear in market data, making it difficult to predict the effect of independent variation in an attribute. On the other hand, stated preference approach involves asking consumers to state their preference for hypothetical scenarios that comprise different attributes with different levels. Stated preference approach is usually preferred as it addresses the multicollinearity problem of the revealed preference approach by allowing for sufficient variation in the data. Some of the stated preference methods include Contingent Valuation Method (CVM) and Discrete Choice Modelling (DCM).

Among all the variants of DCM, Discrete Choice Experiment (DCE) is the most popular due to its validated economic theory. It is based on the Lancaster theory of consumption which states that consumers derive utility from characteristics or attributes of a product rather than the product as a whole (Lancaster, 1966). In this study, DCE method was used to determine the key attributes preferred by farmers for climate resilient potato varieties and willingness to pay for each attribute. This is because it provides quantitative information on the relative importance of various varietal characteristics that influence farmer choices as well as trade-offs between the range of levels that constitute the influential attributes and probability of choice (De Brún *et al.*, 2018). First order interactions for attributes and socio-economic characteristics of farmers were analyzed to account for sources of preference heterogeneity. Farmers were presented with various hypothetical scenarios where they were supposed to choose different attributes described by their levels as presented in the choice sets.

The experiment involved three stages:

### *3.2.1 Selection of Attributes and levels*

In the first stage, potential attributes and the attribute levels were identified based on the characteristics of climate resilient potato varieties and literature. A Focus Group Discussion comprising of 30 experienced farmers, decentralized seed multipliers, village-based potato advisors, agricultural extension officers and researchers was conducted to validate the attributes and attribute levels proposed for the experiment. Table 3 shows the potential attributes and their levels based on literature and validated by FGD.

**Table 3: Attributes and Attribute Levels of Climate Resilient Potato Varieties**

| Attributes | Description | Levels |
|---|---|---|
| Resistance to pests and diseases | Whether the variety is resistant to pests and diseases or not | Yes<br>No |
| Water Requirements | The amount of water the variety requires to grow | High<br>Low |
| Yield per Hectare | Yield in Tonnes per Hectare | High (40T/Ha)<br>Low (20T/Ha) |
| Maturation Period | How long it takes for the potato to be ready for harvest | Short (<3 months)<br>Long (>3 months ) |
| Input Price (50kg bag) | Input price for every 50kg bag of potato seeds | 2000, 2500, 3000 |

One of the negative effects of climate change is increased emergence of pests and diseases. Climate change factors such as higher humidity, increased temperatures and unseasonal rainfalls are said to increase the severity of potato diseases such late blight, bacterial wilt, potato leafroll virus and potato virus Y (Quiroz *et al.,* 2018). Therefore, resistance of climate resilient potato variety to pests and diseases was included as a potential attribute and was described by two levels; whether the variety preferred is resistant to pests and diseases or not. The amount of water required to grow CRPVs was also included as a potential attribute and was described by two levels; high or low water requirements. Reduced precipitation due to climate change has necessitated use of irrigation as an adaptation practice by farmer (Esayas *et al.,* 2019). However, most smallholder farmers lack enough resources to invest in irrigation equipment. More so, lack of access to adequate farming water limits smallholder farmers from adopting irrigation as an adaptation strategy.

The yield attribute was also included to capture the preferred yield per hectare by farmers. It was described using two levels; High yields (40T/Ha) and Low yields (20T/Ha). Mukherjee *et al.,* (2017) reported that the average potato productivity in India is 23T/Ha whereas International Potato Center in its 2017 annual report argued that the average productivity of quality seeds was 35-45T/Ha. To ensure food security through increased productivity without increasing the size of farming land, there is need to breed improved varieties that have high yield. Previous studies show that some farmers preferred varieties with short maturation period while others preferred varieties that mature late to ensure food security and sustainable income. Kolech *et al.* (2015) reported that farmers preferred potato varieties that are drought resistant, resistant to pests and diseases and mature early. Maturation period was included as a potential attribute described by two levels; short (<3months) and long (>3months) to determine the preferred maturation duration for CRPVs by smallholder potato farmers in Meru county.

The last attribute was the price attribute. This is the input price or buying price for every 50kg bag of CRPV seeds. The input price was set around the mean of the buying price for the most popular variety in the county named *Shangi*. The price for the certified *Shangi* variety is around 2500 Kenya shillings per 50Kg bag seed as reported from FGD. The input price was set to have three levels; 2000, 2500 and 3000 Kenya Shillings. The price attribute was an important attribute used in obtaining willingness to pay a premium for the other attributes (Sánchez *et al.,* 2017).

### *3.2.2 Designing choice cards*

The second stage involved designing of choice cards whereby choice cards were constructed based on their attributes and attribute levels. Each choice card had two unlabeled scenarios of climate resilient potato varieties and one opt-out option showing a farmer who is not willing to uptake a climate resilient potato variety. D-efficient design was used to reduce the number of choice cards. The SAS software was used to generate the design as is the most widely applied package for experimental designs (Kjær, 2005). The design had a D-efficiency of 96.85% which was a relatively good measure of D-Optimality. A design is said to be D-Optimal if it yields data that enables estimation of parameters with low standard errors and the design can extract the maximum amount of required information from the respondents. The A-efficiency was 93.10% implying that variance matrix generated estimates that were sufficiently reliable. The G-efficiency was 100% which makes precise response predictions for choice experiments (Oyinbo *et al.,* 2019; Otieno *et al.,* 2019; Alemu *et al.,* 2017; Kessels *et al.,* 2006). The design generated 12 choice situations which were blocked into 4 profiles and each farmer was presented with 3 choice cards each representing a choice set. An example of a choice card is presented in Figure 1.

| **Climate resilient potatoes attributes** | **Option A** | **Option B** | **Neither A nor B** |
|---|---|---|---|
| Drought and Disease Resistant | Not | Resistant | |
| Water Requirements | Low | High | |
| Yield | 40T/Ha | 20T/Ha | |
| Maturation Period | Long (> 3 months) | Short ( <3 months) | |
| Input Price per 50kg bag | 2500 | 2000 | |
| Which option would you prefer? | | | |

**Figure 1:** Choice card sample

### *3.2.3 Econometric Model*

The final stage involved econometric analysis of DCE which was based on the Random utility theory (Louviere *et al.*, 2010). This means that the total utility derived from adopting CRPVs can be decomposed into a deterministic and unobservable stochastic error components depending on the attributes preferred by farmers. Mixed logit model using 100 Halton draws was used in the estimation of farmers' preferences. Lecocq (2008), argued that 100 Halton draws were sufficient to yield unbiased estimates considering accuracy and time factors. The mixed logit model was used because it accounts for preference heterogeneity by allowing for variations across respondents for coefficients of variables that enter the model. The model also does not exhibit the restrictive IIA (Independence of Irrelevant Attributes) property as in the conditional logit model and accounts for correlation in unobserved utility over repeated choices (Van den Broeck *et al.*, 2017). The utility ($U_{ijk}$) derived by farmer *i* from choosing alternative j in the choice card k was given by: -

$$U_{ijk} = \alpha_i ASC + \beta_i X_{ijk} + \varepsilon_{ijk}$$
$$\beta_i = \delta_i \beta + \gamma \eta_i + \delta_i \eta_i \quad (1)$$

Where;

$X_{ijk}$= Vector of attributes

$\beta_i$=Vector of individual specific parameters

$\varepsilon_{ijk}$=idiosyncratic error

$\beta$= Vector of mean attribute utility weight

$\delta_i$= Person-specific scale heterogeneity of the idiosyncratic error

$\eta_i$= Vector of individual specific deviation from the mean

$\gamma$= Scalar parameter governing variance of residual taste heterogeneity

ASC= Alternative Specific Constant

ASC accounts for when a farmer opts out and it captures attributes not included in the choice experiment hence catering for non-response bias. It is usually a dummy variable; 0=uptake of climate resilient variety and 1=otherwise.

The specification of the choice probability equation was;

$$P_{ijk|l} = \frac{\exp(\beta_i X_{ijk})}{\sum_{j=1}^{ji} \exp(\beta_i X_{ijk})} \quad (2)$$

To identify sources of heterogeneity, interactions between preferences and farmer characteristics were computed.

Values of Willingness to Pay (WTP) for different varietal attribute levels were derived as: -

$$Marginal\ WTP = -\frac{\beta_{attribute}}{\beta_{price}} \qquad (3)$$

STATA Version 15 was used to estimate parameters for the mixed logit model. The variables used in analysis and how they enter the model are shown in Table 4. All the variables entered the model as random parameters assuming a normal distribution except for the price attribute that was specified as fixed and assumed to have a lognormal distribution in order to facilitate estimation of WTP. Hole *et al.* (2012) argued that restricting the sign of coefficients to be either positive or negative for all respondents maybe desirable in some cases and thus, lognormal distribution acts as an alternative to normal distribution.

**Table 4: Variables used in Econometric Analysis**

| **Variable** | **Description** |
|---|---|
| Resistance | Variety is resistant to pests and diseases (1=Yes, 0=Otherwise) |
| Water Requirements | The amount of water the variety requires to grow (1=Yes, 0=Otherwise) |
| Yield | Yield of the variety in Tonnes per Hectare (1=Yes, 0=Otherwise) |
| Maturation Period | How long it takes for the potato to be ready for harvest (1=Yes, 0=Otherwise) |
| Price | Input price for every 50kg bag of potato seeds (2000, 2500, 3000) |

## 4.0 Results and Discussion

### 4.1 Farmers' preferences for improved CRPVs

Table 5 shows results for farmers' preferences for improved CRPVs. The log likelihood was -417.018 whereas chi-square was 108.83 and statistically significant at 1% level of significance. This shows that all the variables included in the econometric model were statistically sufficient and the model had a good fit. All the variables included in the model were positive and significant at 1% except for input price which was negative and significant at 10% level of significance. This further reveals that the attributes and attribute levels considered in the model were essential in determining farmer preferences for CRVPs. The standard deviations for all parameter estimates were statistically significant at 1% level of significance with the exception of the standard deviation for High yield which was significant at 5% level of significance. This shows the presence of preference heterogeneity among farmers who participated in the experiment validating the suitability of mixed logit model for analysis of this objective.

**Table 5: Farmers' preferences for improved CPRVs**

| **Variable** | **Coefficient** | **Standard error** | ***p*-Value** |
|---|---|---|---|
| Resistant to pests and diseases | 7.755 | 1.933 | 0.000*** |
| Low water requirement | 2.341 | 0.661 | 0.000*** |
| High yield (30T/Ha) | 2.061 | 0.540 | 0.000*** |
| Short maturation period(<3 months) | 2.017 | 0.546 | 0.000*** |
| Input price (per kg) | -0.024 | 0.014 | 0.085* |
| ***Derived standard deviations of parameter distributions*** | | | |
| Resistant to pests and diseases | 5.275 | 3.90 | 0.000*** |
| Low water requirement | 2.455 | 0.700 | 0.000*** |
| High Yield | -1.787 | 0.761 | 0.019** |
| Short Maturation Period(<3 months) | -1.488 | 0.537 | 0.006*** |
| **Goodness of fit** | | | |
| Log Likelihood | -417.018 | | |
| LR Chi2 (4) | 108.83*** | | |
| *n* (respondents) | 384 | | |
| *n* (choices) | 3456 | | |

***, **, * =level of significance at 1%, 5% and 10% respectively.

Farmers not only consider productivity of potato varieties when making decision on whether to adopt or not, but they also consider the adaptability of potato varieties to the changing factors of climate that have adverse effects on potato crop. Results indicate that farmers preferred CRPVs that were resistant to pests and diseases. The estimated coefficient for resistant was positive and significant at 1% significance level. The magnitude of the coefficient was high (7.755) and almost thrice the magnitude of all other attributes. This reveals that even though farmers preferred potato varieties with high yield, short maturation period and low water requirements; resistance to pests and diseases was their most preferred attribute. This can be explained by changes in climatic conditions for instance, increased temperature and humidity which increase the severity of pests and diseases such as late blight and bacterial wilt. Therefore, in attempt for farmers to adapt to climate change and increase resilience, they seek for potato varieties that are highly resistant to pests and diseases. This finding is consistent with previous studies Gamboa *et al.* (2018), Sánchez *et al.* (2017) and Kassie *et al.* (2017) who reported that farmers preferred varieties that were resistant to pests and diseases to reduce yield loss amid climate change.

The estimated coefficient for low water requirement was positive and significant at 1% level of significance. The magnitude of the coefficient (2.341) indicate that low water requirement was the second most preferred attribute after resistance to pests and diseases. Due to the negative effects of factors of climate change such as unseasonal rainfall and reduced precipitation, farmers prefer potato varieties that require less water to grow so as to ensure yield stability even in seasons of poor rainfall. More so, farmers from drier agro-ecological zones are usually limited in terms of access to water hence varieties with low water requirements were more favorable. Similar results were reported by Asrat *et al.* (2010) who highlighted that farmers preferred varieties that were tolerant to environmental stress factors such as poor rainfall.

The coefficient of high yield (2.061) was positive and significant at 1% level of significance revealing that potato farmers from Meru County preferred varieties that were high yielding (30T/Ha). This finding was as expected for a rational decision maker trying to maximize utility. High yielding varieties are preferred by farmers as they ensure food security, increased income from sales and hence reduced household poverty. Climate change leads to yield loss and reduced productivity. Kivuva *et al.* (2014) argued that farmers preferred high yielding varieties in order to counter production constraints. The attribute of short maturation period (<3 months) had a positive and significant coefficient at 1% level of significance and a magnitude of 2.017. This indicates that potato farmers preferred varieties that matured faster. Varieties that mature fast are usually less affected by adverse effects of climate change such as poor rainfall, frost, potato blight and drought (Gamboa *et al.,* 2018).

The price attribute was negative and significant at 10% significance level. This indicates that farmers preferred lower prices for CRPVs holding all other factors constant. This finding was as expected since the sign of the price attribute was actually imposed by choosing log normal distribution. Similar results were reported by Van den Broeck *et al.,* (2017) and Pambo *et al.,* (2014). However, the absolute magnitude of the price coefficient was relatively small revealing that potato farmers in Meru county were low-price responsive. A small change in price did not affect their preferences for other CRPV attributes. This was contrary to (Wanyama *et al.*, 2019) who reported high-price responsiveness for low income consumers. The contrast shows that farmers in Meru county valued environmentally adaptable potato varieties despite the price mark up.

**4.2 Sources of Preference Heterogeneity**

The middle part of Table 5 shows significant values for the standard deviations of the random estimates which reveals presence of preference heterogeneity. This means that preferences for CRPV attributes were allowed to vary across different farmers with similar observed characteristics. To show possible sources of preference heterogeneity, interactions between random parameters and farmer characteristics were estimated using mixed logit model (Pambo *et al.,* (2014). After iterative process of model estimation and comparison using simulated log likelihood procedure, interactions that were significant and produced a good fit for the model were reported in Table 6. These included; gender_HY which represented the interaction between gender of the farmer and High Yield (HY) attribute, Age_Lwr which was the code for interaction between age and low water requirement attribute, Educ_HY which was the code for education and high yield, and finally Educ_Res which represented the code for education and resistant attribute.

The top part of Table 6 shows the mean estimates for preferred CRPV attributes (discussed in Table 5), the middle part shows the interactions whereas the third part shows the standard deviations for the parameter estimates. The lower panel of Table 6 shows the goodness of fit for the model. Comparing results of the two tables (Table 5 and 6), inclusion of interactions improves the overall model fit since the log likelihood reduces to -425.380.

**Table 6: Potential Sources of Preference Heterogeneity**

| **Variable** | **Coefficient** | **Standard error** | ***p*-Value** |
|---|---|---|---|
| Resistant to pests and diseases | 5.240 | 0.935 | 0.000*** |
| Low water requirement | 2.858 | 0.728 | 0.000*** |
| High Yield (30T/Ha) | 0.054 | 0.643 | 0.933 |
| Short Maturation Period(<3 months) | 2.336 | 0.715 | 0.001*** |
| Seed Price (per kg) | -0.024 | 0.013 | 0.057* |

| | | | |
|---|---|---|---|
| ***Interactions*** | | | |
| gender_HY | 0.513 | 0.297 | 0.085* |
| Age_Lwr | -0.020 | 0.012 | 0.081* |
| Educ_Res | -0.221 | 0.118 | 0.061* |
| Educ_HY | 0.222 | 0.092 | 0.015** |
| ***Derived standard deviations of parameter distributions*** | | | |
| Resistant to pests and diseases | 2.788 | 0.327 | 0.000*** |
| Low water requirement | 1.333 | 0.275 | 0.000*** |
| High Yield | 0.248 | 0.174 | 0.155 |
| Short Maturation Period(<3 months) | 2.037 | 0.695 | 0.003*** |
| **Goodness of fit** | | | |
| Log Likelihood | -425.380 | | |
| LR Chi2 (4) | 87.40*** | | |
| *n* (respondents) | 384 | | |
| *n* (choices) | 3456 | | |

***, **, * =level of significance at 1%, 5% and 10% respectively.

The interaction between gender and high yield denoted by gender_HY had a positive and significant coefficient at 10% level of significance. This shows that being male increased the preference for high yielding potato varieties by 51.3%. This can be explained by the fact that most male farmers are business-oriented and practice agribusiness unlike female farmers who in most cases farm potato for household food and nutrition security. Male farmers prefer potato varieties with higher yield so as to boost their income levels from increased sales. This finding is consistent with Patel-Campillo *et al.* (2018) who argued that females majored in potato farming mainly for the food security of the household.

The interaction between age of the farmer and low water requirement attribute denoted by Age_Lwr had a negative and significant coefficient at 10% significance level. Age reduced the preference for potato varieties requiring low water to grow by 2%. Older farmers shifted their preference from low water requirements. This can be explained by the fact that older farmers are usually more endowed in terms of resources than younger farmers and therefore can afford to acquire irrigation equipment making water requirements a less preferred attribute. Simtowe *et al.* (2016) argued that older farmers are less constrained in terms of financing farming practices.

The interaction between education and resistant to pests and diseases denoted as Educ_Res yielded a negative and significant coefficient at 10% level of significance. Farmers' preference for resistant varieties shifted downwards by 22.1% with increase in education level. More educated farmers did not place much importance to the resistance attribute besides the attribute being the most preferred generally. A possible explanation is that educated farmers are more knowledgeable in terms available pesticides suitable for use and are aware of their appropriate application. More so, educated farmers have alternative sources of income and therefore are able to afford such recommended pesticides hence do not place much importance on the resistance attribute. This finding is contrary to Chandio *et al.* (2018) who argued that education enhanced farmer ability to recognize risks associated with climate change such as severity of pests and diseases hence preferring varieties that are resistant. Further, results show that the interaction between education and high yield had a positive and significant coefficient at 5% level of significance revealing that preference for high yielding varieties increased by 22.2% with higher level of education.

This study revealed that gender, age and education level of the farmer were significant sources of preference heterogeneity for preferred CPRV attributes including resistant to pests and diseases, yield and water requirements. However, the derived standard deviation for the maturation period attribute was still significant at 1% implying that heterogeneity in preference for maturation period was caused by other factors other than the socio-economic factors included in the model.

### 4.3 Willingness to pay for Improved Climate Resilient Potato Varieties

This sub-section presents results for the estimation of Willing To Pay for CRPVs. The price attribute represented the purchasing price for CPRV seeds and was captured as price per 50kg bag which is the most popular recommended packaging method for potato seeds in Kenya. However, for purpose of favorable econometric modelling, the price variable entered the model as Kenya Shillings per Kilogram implying that the WTP values should be multiplied by 50 since the price variable was divided by 50 during estimation.

The price coefficient enabled estimation of Marginal Rate of Substitution (MRS) between improved CPRVs attributes and money interpreted as marginal willingness to pay for a change in each attribute. The effect of each attribute was not predetermined and therefore, the willingness to pay values could take any sign. Positive values show the amount farmers would be willing to pay to acquire preferred attributes whereas negative values indicate the discount farmers would demand for accepting less preferred attributes for CRPVs. Table 7 shows the estimated WTP values for each of the CPRV attributes.

**Table 7: WTP Values for CPRV Attributes**

| **Variables** | **Marginal WTP** | **Lower CI** | **Upper CI** |
|---|---|---|---|
| Resistant to pests and diseases | 327.740 | -88.740 | 741.221 |
| Low water requirements | 98.954 | -33.167 | 231.075 |
| High Yield (30T/Ha) | 87.083 | -29.208 | 203.373 |
| Short Maturation Period(<3 months) | 85.256 | -28.913 | 199.424 |

CI, Confidence Interval at 95% confidence level

The willingness to pay estimates highlight the extent to which potato farmers value CRPV attributes. A first observation is that WTP values for CRPV attributes average around the same value except for the resistant to pests and diseases attribute whose WTP value was over three times more than all other attributes. This means that farmers were willing to pay more for the resistant to pests and diseases attribute than for any other attribute despite the price mark up. This is justified as pests and diseases comprise of the most important challenge facing potato production in Kenya. (Maligalig *et al.,* 2018; Kivuva *et al.,* 2014) reported that the main factors constraining potato production include occurrence of pests and diseases and limited access to quality seeds.

Looking further into the details of Table 7, potato farmers in Meru County would be willing to pay an average of Ksh 327.740 per Kg for varieties resistant to pests and diseases, Ksh 98.954 per Kg for varieties that have low water requirements, Ksh 87.083 per Kg for high yielding varieties (30T/Ha) and above, and Ksh 85.256 per kg for varieties with short maturation period (<3 months). However, it should be noted that this analysis was based on stated preference data which is subject to hypothetical bias. Thus, WTP values should be interpreted as high preferences rather than a strategy to develop feasible price mark-up for CRPVs (Gamboa *et al.,* 2018).

**5.0 Conclusion and Recommendations**

Results reveal that farmers have a strong preference for CRPVs with high resistance to pests and diseases as the most important potato crop trait as indicated by the high value of willingness to pay and a high coefficient value. Other CRPV preferred attributes include low water requirements, short maturation period and high yield. Farmers also prefer lower prices for CRPVs but were low-price responsive. Preference heterogeneity varies by socioeconomic characteristics. Male farmers prefer high yielding varieties, older farmers (>35 years) shifted their preference from low water requirement attribute and the more educated a farmer was, the less the preference for resistance to pests and diseases attribute. Breeding efforts should embed traits for CRPVs preferred by farmers. Results indicate that CRPVs have a high potential for diffusion should ongoing breeding programs focus on development of potato varieties that are highly resistant to pests and diseases, have high yielding potential with low water requirements and short maturation period (<3months).

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