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ADOPTION OF CLIMATE-SMART *DROUGHTTEGO*® VARIETIES IN KENYA

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ABSTRACT

African Agricultural Technology Foundation (AATF) promotes *DroughtTEGO®* drought-tolerant maize hybrids developed by Water Efficient Maize for Africa (WEMA) project in partnership with CIMMYT, Monsanto and five National Agricultural Research Systems for Kenya, Uganda, Tanzania, Mozambique, and South Africa to address the impact of drought occasioned by climate change. To determine the level of adoption and use of *DroughtTEGO®* maize hybrids in Kenya, a survey was conducted involving 642 farming households from six counties. The results indicated a high rate of awareness of at least one of the *DroughtTEGO®* varieties (61%). The adoption rate stood at 26% with WE1101 maize hybrid being the most widely known and adopted due to its availability and high yields. Expected adoption was calculated at 89% with about 65% new farmers adopting the *DroughtTEGO®* hybrids. Lack of full information on the productivity, non-availability of the seed when required and the varieties being expensive compared to other locally available varieties were found to be key barriers to its adoption. The econometric results reveal statistical differences between the variables that influence awareness and adoption of *DroughtTEGO®* hybrid seed. Variables that determined adoption included age of the household head, fellow farmers and demonstration sites as the primary main source of seed information. Other variables were record-keeping, women's control of household resources, perception of food security, price, and location. Well-thought-out strategies that target these variables can be effective in attracting new adopters. Thus, the study recommends, promotional messages and extension approaches appropriate to both the young and the aged, better seed pricing strategies, women's control of household resources to be encouraged, and specific locations with low probability of adoption should be given priority. Steps could include the promotion of the varieties through on-farm demonstrations with wider coverage, strengthening of the extension service and allocation of resources for extension activities in Kenya. Other broad recommendations that emanated from the study included timely availability and delivery of quality *DroughtTEGO®* seed and availability of credit facilities. It is important to investigate the case of adopters who discontinued using these varieties.

Key words: Technology adoption, climate-smart, maize hybrid, food security, *DroughtTEGO®*

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INTRODUCTION

In Kenya, maize (*Zea mays* L.) is considered an essential food crop and accounts for about 65% of total staple food caloric intake and 36% of total food caloric intake. Maize plantations also account for about 56% of cultivated land in Kenya [1]. The main maize producing counties include Trans-Nzoia, Nakuru, Nandi, and Uasin Gishu in the Rift Valley that accounts for about 74% of the national maize output. Other counties with high acreage include Kakamega, Vihiga, Busia, Bungoma Migori, Narok, Nyeri, Meru, Embu, and Machakos.

Maize consumption in Kenya is high and has experienced an upward trend with about 1.3 times increase in consumption over 10 years, from 2005 to 2016 [2]. Despite the importance of maize in Kenya, the yields have remained low under rain-fed agriculture in many regions due to low and erratic rainfall, high evapotranspiration rates, low soil fertility and land degradation [3]. Recent studies estimate yields at 1.4 t/ha compared with average global maize production of 5.6 t/ha [4]. In 2014, the Kenya National Bureau of Statistics (KNBS) estimated total maize production in Kenya at 3.5 million ton [5]. In the same year the country imported over 10 million bags (≈ 1 million ton) of maize from neighbouring Uganda and Tanzania to meet the deficit [6].

Frequent drought events due to climate change have contributed significantly to low maize yields. This has been worsened by outbreaks of new pests and diseases such as Fall Armyworm (FAW) and Maize Lethal Necrosis (MLN) disease. Kenya is also classified as a water-deficient country where irrigation-based farming is limited [7]. The development of climate-smart drought-tolerant varieties has the potential to improve crop productivity and efficiency in the use of resources. The Water Efficient Maize for Africa (WEMA) Project partnership developed conventional hybrids that are adapted to low–mid-altitude agro-ecologies in East and Southern Africa including Kenya, Uganda, Tanzania, Mozambique, and South Africa, currently marketed under the *DroughtTEGO*® brand. The African Agricultural Technology Foundation (AATF) implemented the WEMA Project with respective National Agricultural Research Systems over 10 years (2008–2017).

Through several on-farm demonstration sites, the *DroughtTEGO*® varieties yielded an average of 4.9 t/ha under good agronomic practices as compared to 3.2 t/ha for commercial checks and 1.7 t/ha for Kenyan national yield average [8]. These varieties provide an opportunity to enhance maize productivity in many parts of Africa. However, many socio-economic and biophysical constraints limit the smallholder farmers' ability to adopt such technology. Thus, it is necessary to develop effective and efficient strategies to transfer such technologies to farmers. Without basic information about the level of adoption of the technology, it is difficult to formulate policies for increasing adoption and subsequent agricultural productivity.

A few studies have investigated modern maize variety adoption in developing countries, which report adoption rates ranging from 10% to 44% [9, 10, 11, 12, 13, 14, 15]. The objective of our study was to assess the level of adoption of the climate-smart *DroughtTEGO*® hybrid maize seed among smallholder farmers in Kenya.

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MATERIALS AND METHODS

Quantitative and qualitative data generated from both sampled households and interviews with key stakeholders and informants were used. A multi-stage, clustered, randomized sampling procedure was employed. The study focused on five regions of Kenya where most of the *DroughtTEGO*® dissemination activities were conducted, namely: Western, South rift, Central highlands, Nyanza and lower Eastern (Figure 1).

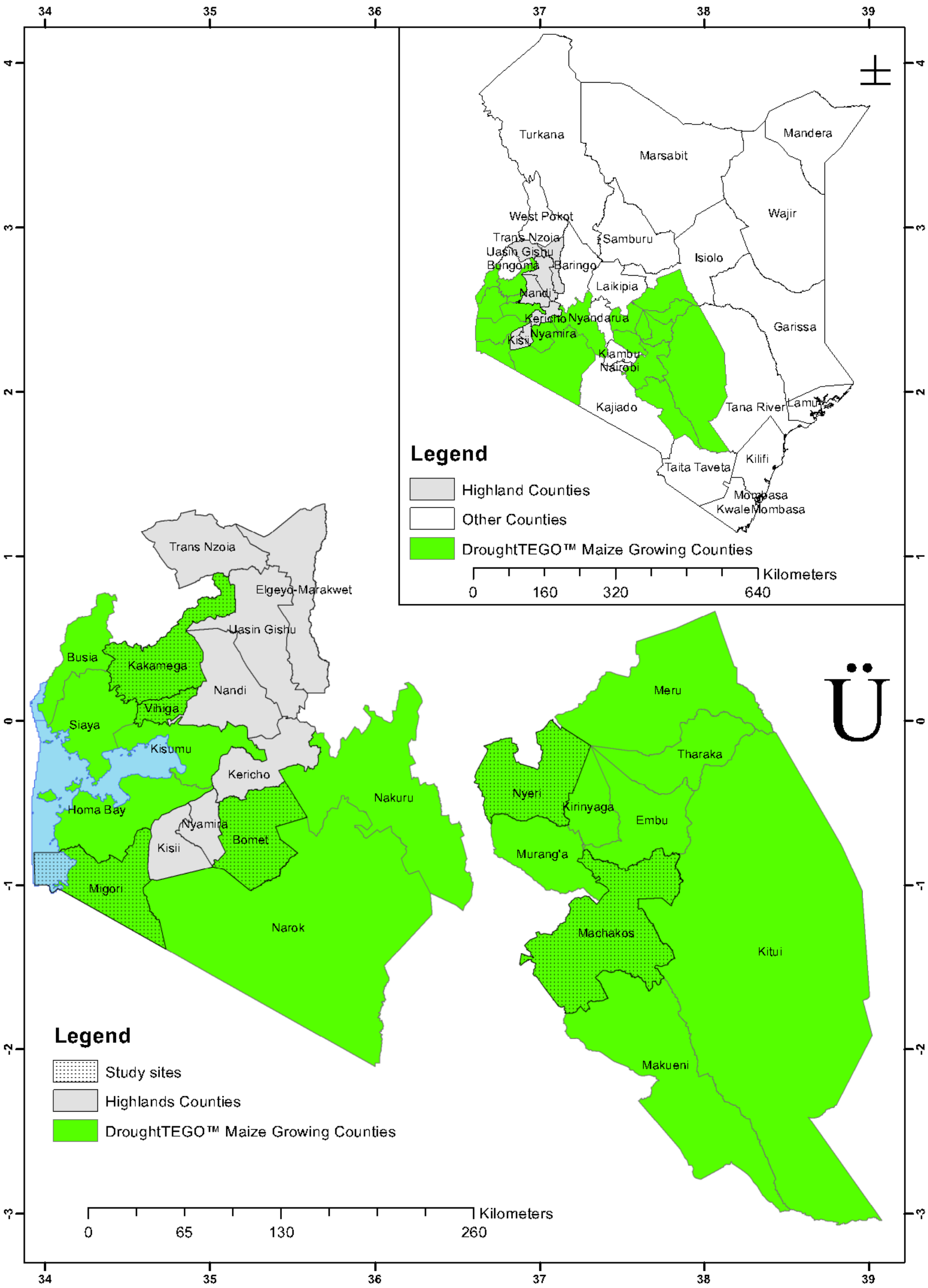

Figure 1: DroughtTEGO® growing counties and the study area sites

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A total of 642 maize farming households were identified for the study. One county was sampled in each region except for western Kenya where two counties were selected due to a large number of counties and areas under maize farming (Table 1). Probability proportional to size (PPS) sampling technique using the number of counties per region as strata was applied to arrive at sample size per region. At the sub-county level, one administrative location was purposefully selected, and households were sampled with the help of AATF and Rural Outreach Program-Africa technical field staff. To enhance data validity and reliability, intensively trained enumerators used a questionnaire developed by the research team to interview farmers. Global Positioning System (GPS) was used to capture the precise location/coordinates of the sampled households and hence digitally map all the households/villages visited in the survey.

Empirical methods

Like many other decision models, the farmers' choice to switch from using their own production methods they are familiar with to newly introduced methods is guided by their need for profit maximization. The decision to adopt a new modern variety in relation to the old local variety is based on comparison of marginal net benefits of one against the other. Thus, farmers' adoption of *DroughtTEGO*® seeds is a choice based on its profitability and risks associated with it.

The underlying assumption in such a scenario is anchored in the adoption model, whereby the farmers base their decisions on utility, rather than profit maximization. This assumption is reasonable in our case because maize in most cases is grown on a semi-subsistence basis.

In this study, adoption is defined as a binary variable (adoption of any *DroughtTEGO*® varieties = 1, non-adoption = 0). The main models used for analyzing factors influencing binary dependent variables include the Logit and Probit models. Both models are estimated by maximum likelihood. However, it is difficult to justify the choice of one distribution to the other on theoretical grounds [16, 17].

Previous studies in developing countries have suggested that a wide range of economic, social, physical and technical aspects of farming influence the adoption of agricultural technologies. Most of these variables were included as independent variables in the regression equation below, whose variables are described in Table 2.

ADOPTION = f (AGE, AGESQ, EDUCATION0, EDUCATION1, EDUCATION2 EDUCATION3, GENDER, HHSIZE, DRATIO, EXTENSION FARMER, DEMOS, FARMSIZE, INCOME, RECORD, WOMEN, STAPLE, OWN, FOODSEC, PRICE, COUNTY Dummies).

The household characteristics hypothesized to influence the adoption of *DroughtTEGO*® varieties included: 1) age of the household head and its square (AGE, AGESQ), 2) education (EDUCATION), 3) gender of the household head (GENDER), and 4) dependency ratio (DRATIO). Labour availability is included by considering available family labour (HHSIZE). Access to information on improved technologies captured through contacts with extension officers (EXTENSION), other farmers as the main source of information (FARMER) and demonstration (DEMOS) variables. Lack of access to cash or credit can significantly limit the adoption of improved technologies, hence, asset endowment is included through two proxies' variables: total land size (FARMSIZE) and household total income (INCOME).

In this study, income derived from maize production was deliberately excluded to avoid problems of endogeneity. Other variables included were: 1) record keeping (RECORD), 2) maize as the main staple food (STAPLE), 3) own production of staple food (OWN), 4) food security in the last two years (FOODSEC), 5) women control of the household resources (WOMEN), 6) perception of seed prices (PRICE) and 7) county dummies (COUNTY Dummies). The conventional approach to adoption study considers age to be negatively related to adoption. This assumes that with age, farmers become more conservative and less amenable to change [18]. Education enhances the ability of farmers to acquire and synthesize new information. Education is associated more with the timing of adoption rather than with adoption itself [19].

It is hypothesized that male-headed households are more likely to seek the latest information about new technologies than female-headed households. Household size (HHSIZE) is in most cases used as a proxy to account for labour availability. In general, a farm with a larger number of workers is more likely to adopt new technologies that require more labour. The non-availability of family labour can also actually impair the use of technologies that would require more labour than the family could provide [20]. On the other hand, labour constraints may be a motivation to adopt timesaving new technologies. Thus, the household size (HHSIZE) and the dependency ratio (DRATIO) were both hypothesized to increase adoption.

Household wealth and farm characteristic variables considered to influence the adoption of *DroughtTEGO*® maize seeds include farm size (FARMSIZE) and total income (INCOME). Farm size in most of the societies in Africa is used as a proxy for wealth. This means that farmers who have relatively large farms will be more likely to adopt *DroughtTEGO*® maize seeds and vice versa. External sources of income provide the means to acquire new technologies [18]. However, Mbaga-Semgalawe and Former [21] reported an opposite effect where external income reduced new technologies adoption.

Information is acquired through both informal and formal sources such as the media, extension personnel visits, village *barazas* (gatherings), demonstration sites, meetings, farmer groups, and formal education. Awareness of the *DroughtTEGO*® variables (EXTENSION, FARMER, DEMOS) is expected to have positive influences on the adoption of these varieties. Information generally reduces the uncertainty about a technology's performance and may change an individual's assessment from purely subjective to objective over time [22]. All the above variables were cross-checked for the problem of multicollinearity, through the simple correlation matrix and Variance Inflation Factor (VIF) before the estimation. Variance Inflation Factor far less than 10 and a VIF value of greater than 10 is an indication of potential serious multicollinearity [23, 24].

Likewise, for endogeneity checks, none of the independent variables was suspected to be explained within the equation in which it appeared. Additionally, to check the robustness of the models, other 'restricted' models were estimated in which subsequently insignificant variables were excluded. It is important to note the statistical quality of the models, and that the direction of the signs did not change, and the coefficients deviated only marginally.

RESULTS AND DISCUSSION

DroughtTEGO® adoption characteristics

Most farmers (62%) were familiar with at least one *DroughtTEGO*® variety; hence, the awareness exposure bias is limited. WE1101 was the most widely known (41%) of the 16 varieties available at the time of the study, while WE3101 was known only by 0.2 % of the farmers (Figure 2). Overall, adoption was 26% of the total sample adopting 1-6 of these varieties. The reason adduced by farmers in the study area for low adoption rate of other *DroughtTEGO*® varieties was lack of knowledge about them. Of the sampled households, 8% planted both *DroughtTEGO*® and other maize varieties, 20% other varieties; while 72% of the adopters grew pure *DroughtTEGO*® varieties. The non-*DroughtTEGO*® varieties grown by the farmers included DUMA 43 (20%), DK8031 (14%), H517 (11%), H614 (11%), PIONEER 3253 (8%), H516 (7%), H513 (6%), WH505 (6%), WH507 (6%), and H624 (4%).

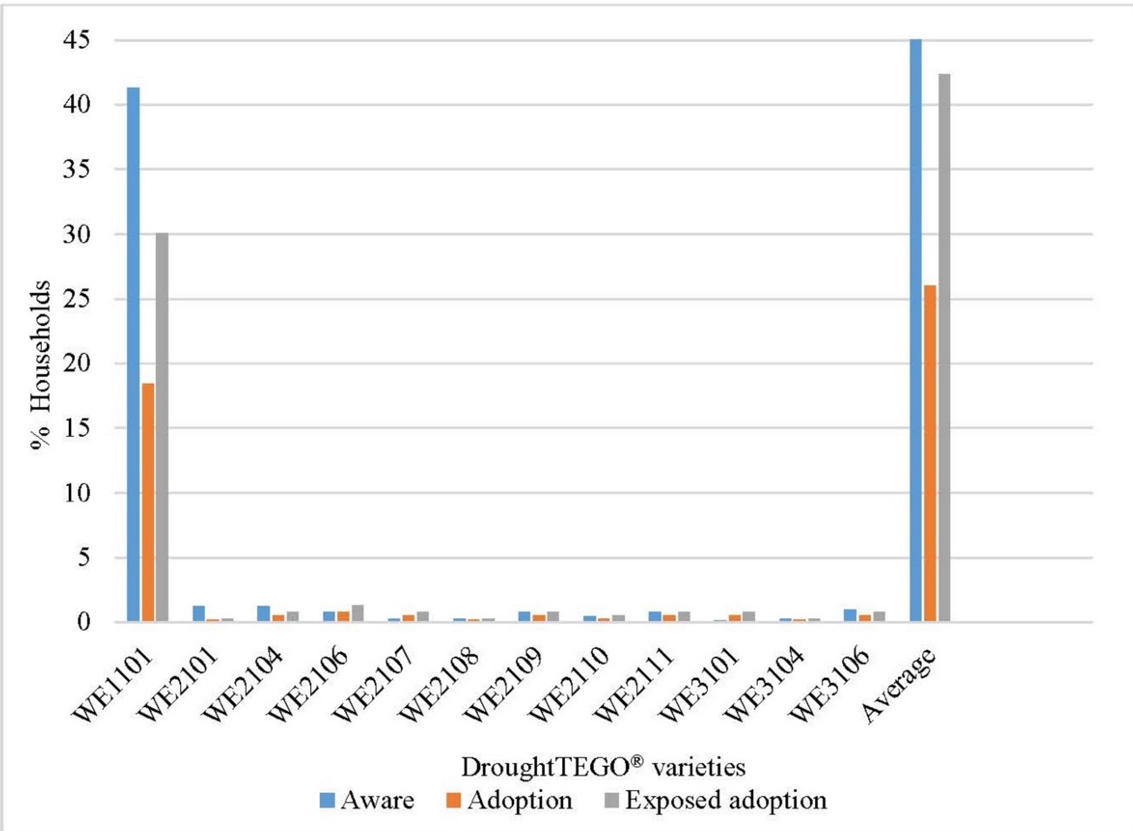

Figure 2: *DroughtTEGO*® variety awareness and adoption by survey respondents (%)

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Significant differences were observed among the counties and maize varieties adopted. The highest adoption was observed in Kakamega (65%) and lowest in Machakos (6%). By 2016, according to One Acre Fund study report, only 6% had adopted WE1101 in Kenya [25]. This current study shows 26% adoption of various *DroughtTEGO*® hybrids representing a 20% improvement, with WE1101 having the highest adopters. Adoption rates of improved maize varieties ranged from 10% to 25% in Tanzania, Angola, Ethiopia, Malawi, and Mozambique [26]. Major reasons for non-adoption of farm-level technologies in East Africa are lack of awareness of the technologies, unavailability of improved seed, inadequate information and resources, high seed price, and lack of information [10, 27]. The seed companies that marketed *DroughtTEGO*® hybrids included Dryland Seeds Ltd, Elgon Kenya, Olerai Seeds Ltd, VetAgro EA, Ultravetis, East Africa Seeds, Leldet Ltd, Crop Africa, and ETG that received Humanitarian-use Licenses (HULs) to commercialize the varieties from AATF.

About 38% of the respondents obtained information on *DroughtTEGO*® seed from other farmers, relatives or parents (Figure 3). Radio and TV also contributed significantly to farmers' sources of information. Government extension was another important source of information on the varieties for many farmers through direct interventions using demonstrations on new crop varieties. Seed and grain retailers appear to be a minor source of information to farmers since they accounted for only 12% for new varieties.

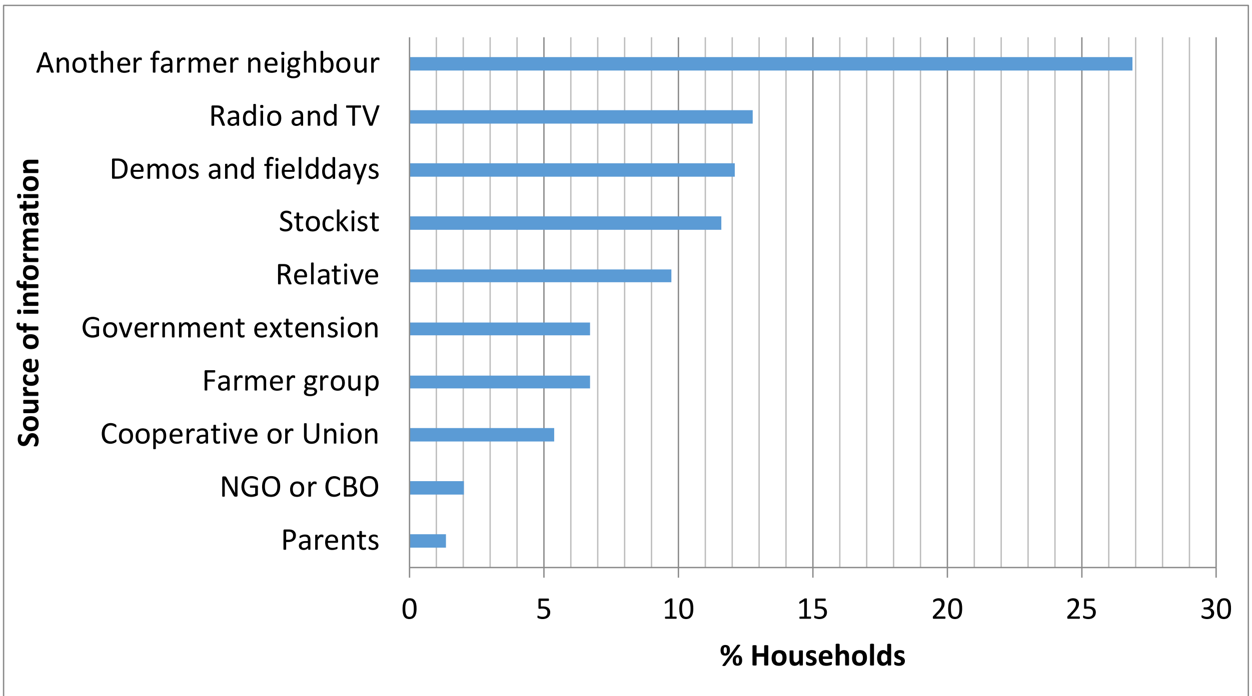

Figure 3: Main source of information about *DroughtTEGO* seeds

In this study, it was evident that promoting the *DroughtTEGO*® hybrids varieties to farmers using project extension staff, NGOs, Community Based Organizations (CBOs) and government extension, and through the establishment of many demonstration plots

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and field days was very effective in stimulating adoption. Previous studies have revealed that strong extension services have a positive impact on technology adoption [28, 29]. Again, inactive government extension service leads to low adoption rates for technologies [30, 31].

Many farmers acquired their seed through cash transactions (85%). Use of recycled seed (farm-saved seed) was also found to be one of the seed sources, though limited to only 2%, while about 7% of respondents indicated having gotten the seed as free give-away packs from AATF and Ministry of Agriculture Livestock and Fisheries (MoALF) extension officers. Others indicated that they exchanged maize seed with other crops seed like Irish potatoes and beans (3%) and borrowed seed (1%). Many farmers acquired their seeds through cash transactions, which is a positive indicator for sustainable adoption and diffusion.

Although the use of recycled seed (farm-saved seed) was also found to be one of the seed sources, recycling of grain as seed is not recommended in maize production because genetic integrity of hybrids deteriorates rapidly from one generation to the next, due to selfing or inbreeding in addition to contamination from foreign pollen. The consequence of recycling grain as seed is declined yields of between 5% for Open Pollinated Varieties (OPV) and 30% for hybrid varieties [32].

The most popular varieties as indicated by the number of farmers planting them included WE1101 and WE2106 ($p < 0.01$). The most important reasons for their popularity were: 1) high yields, 2) drought resistance, 3) fast maturation and sweet flour. Most farmers indicated that they preferred *DroughtTEGO*® yields in grain form than in green form ($p < 0.01$). Based on stakeholder information it was also clear that many farmers perceived some *DroughtTEGO*® varieties to have good tolerance to drought in addition to higher yield and maturity attributes compared to other commercial hybrids in the market, which were critical to the farmers in the adoption of the new varieties. This was also supported by views from government extensions officers, who believed that *DroughtTEGO*® varieties performed better in conditions of limited rainfall.

Overall, many households reported improved food security (Figure 4). Most (63%) farmers that had adopted *DroughtTEGO*® seed reported that their food security status had improved, and they derived some income from the sale of surplus grain harvested over the three years compared to non-adopters (32%). This result was statistically significant ($p < 0.01$). The above results were backed by 20% higher income for adopters compared to non-adopters.

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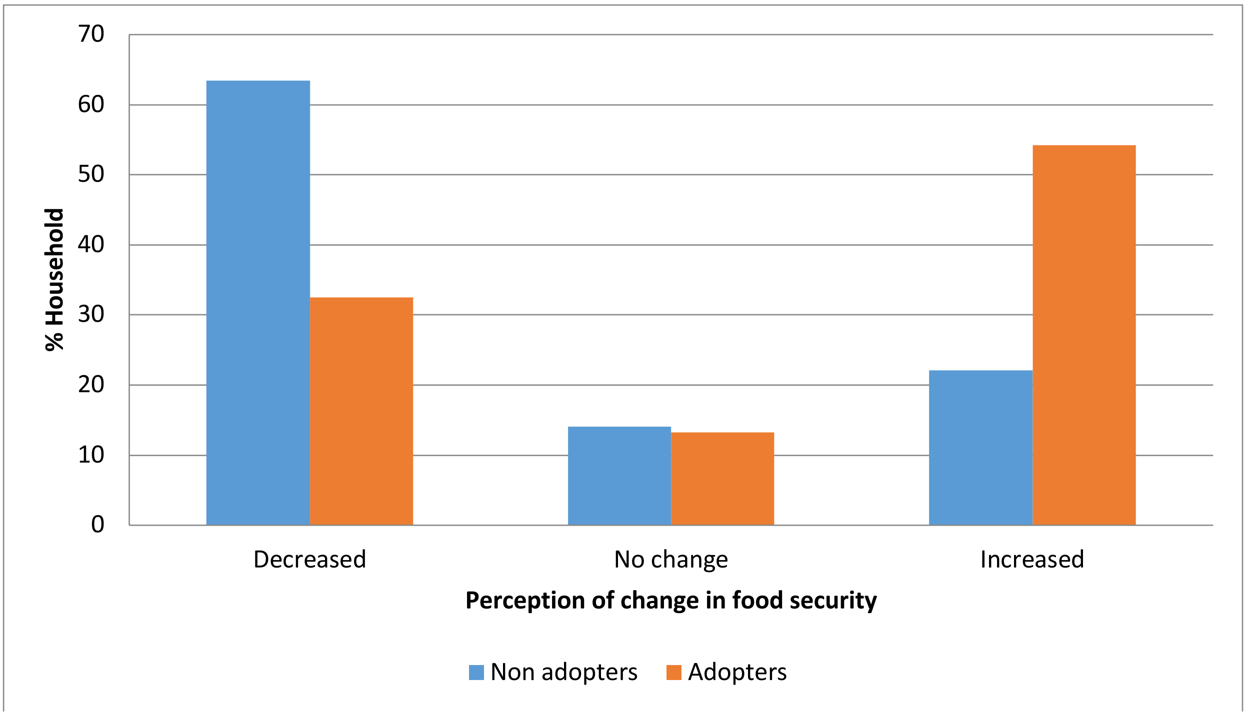

Figure 4: Perception of change in food security over time by adoption status

Asked whether they would adopt these varieties in the future, about 89% believed that they would grow them. Within this figure, about 65% were new farmers who were trying the new varieties for the first time. The amount of *DroughtTEGO*® seed required by the farmers in 2018 was calculated at about 5 kg/farmer to plant a half-acre piece of land.

Determinants of adoption of *DroughtTEGO*® hybrid seed

Results of the two models used to investigate factors affecting the adoption of *DroughtTEGO*® hybrid varieties are presented in Table 3. The Chi-square indicates that the parameters included in the model were significantly different from zero at the 1% probability level. The Log Likelihood function of -275 and -282 and the highly significant likelihood ratio statistic shows good model fitness. The adoption of *DroughtTEGO*® hybrid seed was determined by different factors at different levels of significance. The key variables found to be significantly associated with the probability of adoption of *DroughtTEGO*® hybrid varieties include age of the household head, main source of information being farmer-to-farmer interactions and demo sites, record keeping, women's control of household resources, perception on food security, price and location controls.

Adoption increases with age of the household head, although at a decreasing rate as can be seen from the negative coefficient of the age squared. Middle-aged farmers, as opposed to young farmers, tend to have more education and are often hypothesized to be more willing to innovate [33]. Education levels appear to have no effect on adoption of *DroughtTEGO*® seed although, education had a positive and significant impact on the adoption of modern inputs elsewhere [34, 35]. Adoption was higher for the

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DEMOS variable for farmers who had seen the varieties being grown in the demonstration sites.

The results showed that in households where women control resources, there was a high likelihood of adoption of the *DroughtTEGO*® hybrid varieties, suggesting that social relations had no effect on the adoption of the varieties. Previous research in Africa have documented women's lesser access to and control of critical resources, especially land, cash, labour and information [37, 38]. It is also noteworthy that neither gender of the household head nor government extension as a source of information had any significant effect on adoption. Studies elsewhere, suggest that female-headed households face constraints not faced by farmers in male-headed households [36]. The non-significance of government extension could be explained by the existence of other more effective service providers. There was a high likelihood of adoption of the *DroughtTEGO*® hybrid varieties, suggesting that social relations had no effect on the adoption of the varieties in households where women-controlled resources.

The probability of adoption was higher if farmers kept production records, probably because farmers who kept records were more aware and more judicious in their production activities and could be vigilant of new methods of production. With records, a farmer can also have better farm planning and can see how well she/he is managing production operations, which helps to identify the strengths and weaknesses in those activities.

Location control for agro-ecology differences showed that farmers in Vihiga and Kakamega counties were highly likely to adopt while those located in Bomet were less likely to adopt as compared to the ones in Migori (Reference County). This could be attributed to the strong influence of Rural Outreach Program-Africa, a non-governmental organization, that has a high grassroots presence in Vihiga and Kakamega counties compared with the other counties.

Perception on the variety price confirmed our earlier information as these varieties are more expensive than other regular varieties. This could possibly be attributed to the premium attached to the drought-tolerant product by the seed companies. When the model was re-estimated (restricted) by dropping insignificant variables, the estimated coefficients for all explanatory variables remained significant and retained the signs, suggesting that the model is reasonably robust.

CONCLUSIONS

This study represents one-step towards understanding the dynamic nature of the adoption of *DroughtTEGO*® hybrid varieties. Most of the farmers (61%) were aware of at least one *DroughtTEGO*® variety and adoption rate stood at 26% with WE1101 hybrid being widely known and adopted. About 65% of the farmers were likely to adopt in the future, with an accumulated number of about 89% new farmers.

The econometric results reveal substantial and significant differences among the variables that influence the adoption of *DroughtTEGO*® hybrid varieties. The

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significantly different variables that determine adoption include age of the household head, other farmers and demo sites as the main source of information, record keeping, women's control of household resources, perception of food security and price, and location controls. Thus, targeted strategies on these variables could be effective in attracting new adopters. Enhancing adoption of *DroughtTEGO*® hybrid varieties in Kenya requires several strategies including seed pricing which could be revised to compete well with other varieties to allow extensive market penetration. Economic theory suggests that a reduction in price of a normal product or service can result in increased demand. Further, the positive effect of age of the household head on adoption means the promotion messages and extension approach should be appropriate to both the young and the aged. More importantly, the attributes of the hybrids need to be communicated well to the farmers. To enhance adoption, extensive promotion of the varieties through on-farm demonstrations for wider reach was recommended especially targeting specific locations with low probability of adoption.

Fourth, to assess the impact of *DroughtTEGO*® hybrid varieties, detailed impact studies after at least five years when adopters have gained more experience with the technology will be useful. It is likely that adoption intensity will have increased beyond the initial stage of testing and experimentation, providing a solid basis for analyzing the impact on farmer productivity. The farmer-to-farmer mode of communication, which relates to face-to-face interaction with farmers, or one-on-one interaction, conveyed customized information to the farmers, which may be more useful than group discussions and would contribute to the adoption of technologies. For governments to address food insecurity adequately by increasing maize productivity, they may consider strengthening the extension service to promote one-on-one farmer follow-up on the use of new technologies. Extension services should also effectively and efficiently publicize the benefits of the adoption of new technologies like *DroughtTEGO*® hybrid varieties in Kenya.

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Table 1: Regional distribution of survey respondents

Region	Counties	Sampling Sub-Counties	Sample size based on County maize growers)
South Rift	Bomet	Bomet	102
Western Kenya	Vihiga	Sabatia	75
	Kakamega	Kakamega	60
Nyanza	Migori	Rongo	135
Upper Eastern Kenya	Nyeri	Mukurweini	170
Lower Eastern Kenya	Machakos	Kangundo	100

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Table 2: Description of variables used in estimations with expected sign

Variable	Definition
Treatment variable	
ADOPT	1, if household adopted any *DroughtTEGO*® varieties; 0, otherwise
Independent variables *Demographic characteristics*	
AGE	Age of household head (years)
AGESQ	Age of household head squared (years)
EDUCATION0	1, Household head with no formal education; 0, otherwise
EDUCATION1	Household head with primary education; 0, otherwise
EDUCATION2	Household head with secondary education; 0, otherwise
EDUCATION3	Household head with > secondary education; 0, otherwise
GENDER	1, if the household head is male; 0, otherwise
HHSIZE	Number of family members living in the household in adult equivalent (count)
DRATIO	Dependency ratio (proportion over 64 and under 18years of age (%)
Access to information	
EXTENSION	1, if main source of information government extension; 0, otherwise
FARMER	1, if main source of information another farmer; 0, otherwise
DEMOS	1, if main source of information demonstration and field trials; 0, otherwise
Asset endowment	
FARMSIZE	Farm size (ha)
INCOME	Total income (Ksh)
Other variables	
RECORD	1, if the household keeps farm records; 0, otherwise
WOMEN	1, if women control household resources; 0, otherwise
STAPLE	1, if maize is the main staple food; 0, otherwise
OWN	1, if the household grows its own staple food; 0, otherwise
FOODSEC	Rating of food security in the last 2 years
PRICE	1, if farmer perceives the *DroughtTEGO*® seed to be expensive; 0, otherwise
County dummies	
Migori	1, if the farmer is located in Migori; 0, otherwise
Bomet	1, if the farmer is located in Bomet; 0, otherwise
Nyeri	1, if the farmer is located in Nyeri; 0, otherwise
Vihiga	1, if the farmer is located in Vihiga; 0, otherwise
Kakamega	1, if the farmer is located in Kakamega; 0, otherwise

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Table 3: Estimation results of Probit model on determinant of *DroughtTEGO*® hybrid adoption

	Unrestricted		Restricted	
	Estimated coefficients	Std. Err.	Estimated coefficients	Std. Err.
AGE	0.08	0.03**	0.07	0.03**
AGESQ	-0.00	0.00**	-0.00	0.00**
EDUCATION0	0.27	0.32		
EDUCATION1	0.29	0.21		
EDUCATION2	-0.01	0.22		
GENDER	0.24	0.19		
HHSIZE	0.01	0.02		
DRATIO	0.00	0.00		
EXTENSION	0.23	0.21		
FARMER	-0.26	0.15*	-0.30	0.14**
DEMOS	0.52	0.21**	0.49	0.20**
FARMSIZE	-0.02	0.03		
INCOME	0.00	0.00		
RECORD	0.33	0.19*	0.29	0.18*
WOMEN	0.23	0.14*	0.20	0.13
OWN	-0.33	0.28		
STAPLE	0.15	0.39		
FOODSEC	0.43	0.07***	0.42	0.07***
PRICE	-0.72	0.25***	-0.72	0.25***
Migori	0.07	0.20		
Bomet	-0.40	0.24*	-0.47	0.21**
Vihiga	0.89	0.21***	0.83	0.18***
Kakamega	1.35	0.22***	1.29	0.20***
Constant	-3.96	1.00***	-3.50	0.81***
Observations	633		637	
Log likelihood	-274.82		-282.33	

Statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

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