Chapter 2

A Study of Household Food security and Adoption of Biofortified Crop Varieties in Tanzania: The Case of Orange-Fleshed Sweetpotato

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Additional information is available at the end of the chapter

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Abstract

Food insecurity has become a key issue in the field of development in recent years with major inadequate intake of vitamin A-rich foods. Specifically, vitamin A deficiency (VAD) remains a major health problem among poor developing-country households, especially in Africa. Efforts to combat VAD currently focuses on food-based approach that entails breeding for crops that are rich in beta carotene, a precursor for Vitamin A. Success has been registered in sweetpotato, cassava and maize. Among these crops, the greatest effort has gone into promoting the production and consumption of orange-fleshed sweetpotato (OFSP). These efforts include sensitization of farmers on the nutritional benefits of OFSP and the provision of clean sweetpotato planting materials. This study used a rich dataset collected from 732 farm households in Tanzania to assess of effect of household food insecurity and benefit awareness on the adoption of OFSP varieties. The study found that the household food security and awareness of the benefit of OFSP affect the decision to adopt OFSP varieties. It also found evidence that agroecology and farmer endowment with financial and physical assets affect the decision to grow OFSP varieties. It discusses lessons and policy implications of the findings for other countries.

Keywords: food insecurity, benefit awareness, biofortified sweetpotato, farmer adoption, Tanzania

1. Introduction

Hidden hunger has become a major development issue, especially in developing countries. The concept refers to a situation where households and individuals may have access to food in sufficient amounts but fail to attain the required quantities of micronutrients. These micronutrients include zinc, iron, and vitamin A. Hidden hunger is especially a major problem among poor rural households who cannot afford purchased supplements. The problem of hidden hunger, first coined in the 1990s, led to greater emphasis on defining food security to include the nutritional content of the food.

The inability of households to afford purchased food supplements required to meet micronutrient needs has led to the rethinking of the strategies to improve access to essential micronutrients. One approach that has gained importance is the biofortification of crops most frequently used by poor/rural households [1]. Hence, the last one decade has witnessed concerted efforts to breed for crops that have enhanced quantities of essential micronutrients. Some of the essential nutrients targeted by these efforts are zinc, iron, and vitamin A. The crops targeted by these efforts include sweetpotato, maize, sorghum, beans, and cassava. These staple crops are consumed by a large number of rural households in developing countries and are often labeled as the food security crops [2].

Sub-Saharan Africa (SSA) has one of the largest number of food insecure households. Global hunger index (For details, see http://www.ifpri.org/pressrelease/global-hunger-index-calls-greater-resilience-building-efforts-boost-food-and-nutrition-) developed by the International Food Policy Research Institute ranked this region among those with highest levels of hunger. The high incidence of hunger results from inadequate intakes of both micro and macronutrients needed by the body to function adequately. Foremost among the micronutrients that are contributing to micronutrient-based food insecurity in SSA is vitamin A [3–5]. Prevalence of vitamin A deficiency (VAD) is high among the East African countries, including Ethiopia, Uganda, Rwanda, Kenya, and Tanzania [6]. High incidence of VAD is also reported in Southern African countries such as Zambia, Malawi, and Mozambique. For instance, vitamin D deficiency in Uganda is estimated to be about one-third of the population. In Kenya, about 70% of pre-school children suffer from VAD [7, 8].

To combat VAD among these countries, the consultative group for International Agricultural Research (CGIAR) has focused biofortification efforts on maize, sweetpotato, and cassava. Among these, the greatest investment, and success, has been in the development of vitamin A rich orange-fleshed sweetpotato (OFSP). These efforts have been recognized by the award of the 2016 World Food Price to biofortification of sweetpotato. At the same time, past studies have found increased intakes among rural women and children [4, 5] and evidence of reduced incidence of VAD among these vulnerable groups [9]. These studies further suggest regular consumption of OFSP can reduce VAD among vulnerable groups by 13–15%.

Theoretically, the increased intake of OFSP should, in turn, result in higher adoption of OFSP varieties. To date, however, evidence regarding early adoption of OFSP varieties in SSA remains mixed, with experts (i.e., scientists) predicting much higher adoption than what empirical studies suggest [10]. At the same time, there is still rather limited presence of OFSP in the local markets even where extensive campaigns have occurred. This chapter draws from a rich dataset collected from 732 households and the multivariate regression technique to assess the factors that influence a farmer's decision to grow/adopt OFSP varieties. To date, evidence on the factors that drive adoption of OFSP remains very limited. At the same time, no study has systematically examined the effect of awareness of the nutritional benefits of OFSP and household food security status on early adoption OFSP varieties in the presence of the more popular white-fleshed varieties. This chapter uses the multivariate probit regression technique to control for the effects of competing interests in the planting of different varieties of sweetpotato by including the more popular local (white-fleshed) varieties. The chapter then tests two hypotheses. The null hypothesis tested in the two cases state that participation in the project (a proxy for awareness of benefits of OFSP) and food insecurity (a proxy for poor households) have no effect on the decision to plant the sweetpotato varieties examined in this study.

That is, it first tests the hypothesis that the likelihood of adopting OFSP is affected by food insecurity status of the households. Second, the chapter tests the hypothesis that awareness of the nutritional benefits of the OFSP increases the likelihood of planting OFSP.

The chapter focuses on smallholder farm households in the four regions of Tanzania, namely, Mara, Mwanza, Shinyanga, and Kagera. The households are stratified by participation in a project known as Marando Bora, which, among other things, sensitized farmers on nutritional benefits of consuming OFSP varieties. The Tanzania project provides an interesting case study because of the high incidence of poverty in the study regions and activities of the project that created awareness about the importance of growing OFSP and of consuming diets rich in vitamin A to combat vitamin A deficiency.

The rest of this chapter is organized as follows: Section 2 provides the study background and describes the Marando project. Section 3 outlines the study methods while Section 4 presents and discusses the results. Lastly, Section 5 concludes and highlights key policy implications.

2. Study background

2.1. The concept of food insecurity and food-based approach to fighting micronutrient deficiency

Food security has been defined variously in the literature. However, the most widely used definition of food security is that of [11]. It states that food security is "a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life." Among the pillars emphasized by this definition is the fact that food needs to meet nutritional requirements of the people. The failure to access food that meets the nutritional needs of the household, also known as hidden hunger, is, therefore, one of the subtle yet equally dangerous forms of food insecurity. It specifically arises when households do not have access to a diverse diet that supplies their micronutrient needs.

A new strategy being used to combat hidden hunger among poor rural households is the promotion of production and consumption of biofortified crops that are bred to supply the essential micronutrients. This strategy, often referred to as the food-based approach to enhancing household nutrition, particularly aims at tapping into the local food production system to tackle the problem of poor or inadequate consumption of foods that supply essential nutrients. The strategy uses the locally produced staple foods to introduce essential micronutrients into the locally available and preferred foods.

One of the micronutrients targeted by this strategy is vitamin A. Vitamin A deficiency (VAD) is widespread in many rural communities of Africa. It is especially prevalent among pregnant or lactating women and children who are less than five years of age. Young children need vitamin A to fight common childhood diseases (e.g., diarrhea) and for healthy growth. Pregnant women, on the other hand, are in greatest need for vitamin A during the third trimester when they and the unborn child have the highest demand for vitamin A. Thus inadequate consumption of vitamin A–rich foods by these vulnerable household members can significantly compromise the development of the child and health of the mother. Thus growing and consuming vitamin A–rich crops can act as a vehicle for tackling VAD. Indeed, proof-concept studies and efficacy trials have demonstrated that consumption of modest amounts (125g a day) of orange-fleshed sweetpotato (OFSP), a biofortified crop, can supply the daily needs of vitamin A [1, 12, 13].

Following the findings of past studies, several countries have intensified efforts to promote the growing and consumption of biofortified sweetpotato varieties (i.e., orange-fleshed varieties that are rich in vitamin A). The countries include Ethiopia, Kenya, Uganda, Tanzania, Zambia, and Mozambique. Promotion of the varieties usually includes provision of clean planting material to farmers at subsidized rates along with information about the nutritional benefits of growing and consuming orange-fleshed sweetpotato (OFSP). These efforts usually target the farming households and enable them to grow vitamin A–rich foods.

2.2. The case for sweetpotato production in Tanzania and benefit awareness

Sweetpotato is an important food security crop in many districts of Tanzania, including the Lake Victoria region. Throughout these districts, it helps bridge the hunger gap often characterized by acute shortage of staple foods. There are several reasons why sweetpotato plays a significant role in bridging the hunger gap among sweetpotato producing communities. First, sweetpotato can stay in the soil for an extended period making it easy for farmers to "store" it in the field and harvest piecemeal or as needed. Second, it can withstand moisture stress caused by lack or insufficient rains hence it fills in the food gap during inclement weather. Third, sweet potato does not require much use of external inputs and is often grown without fertilizers and pesticides.

Until recently, farmers planted mainly the white and yellow-fleshed varieties of sweetpotato. These varieties contribute to household food security by providing starch (sugars) needed to supply body energy. They, however, lack (for the case of white-fleshed varieties) or contain inadequate amounts of the beta-carotene, the precursor for vitamin A. Nonetheless, the majority of households grow these non-OFSP varieties to meet household food/subsistence needs. Varieties that are richer in vitamin A, popularly known as the orange-fleshed sweetpotato, due to the deep orange color of the flesh, have been bred for the dual purpose of supplying household energy (starch) and micronutrient needs.

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The study targeted Tanzania because of the high incidence of poverty among the rural farm households [14] leading to poor nutritional intake hence inability to access purchased food supplements needed to remedy the vitamin A deficiency. Tanzania also has one of the world's highest rates of undernutrition [1]. It is estimated that around 2.4 million children in Tanzania are malnourished and that 42% of children suffer from stunting. The authors [1] further indicate that about one-third of children in Tanzania are deficient vitamin A. The Tanzania Food and Nutrition Center (2012) estimated that vitamin A deficiency would contribute to one out of 10 child deaths between 2006 and 2015.

The intervention in Tanzania through a project known as Marando Bora, a Swahili phrase for better quality vines, was launched in 2009. The Marando Bora project specifically focused on promoting the use of clean/quality sweetpotato planting materials. It was aimed at resolving the clean seed bottleneck by developing and testing effective strategies for multiplication, dissemination, and exchange of disease-free (i.e., clean/quality) vines from which new plants can be propagated. The project was implemented in several districts of the Lake Victoria region of Tanzania. The project used two strategies to reach out to farmers namely decentralized vine multipliers (DVM) and mass distribution (MD). Under the DVM model, 88 trained vine multipliers were provided with quality planting materials to bulk. Farmers were then informed about these multipliers and given information about where to find them. The MD model used open-air meetings, conducted by partner nongovernmental organizations and government extension personnel, to create awareness among farmers about quality vines.

The Marando Bora project expanded to cover four regions of Tanzania. An estimated 110,000 households were reached through the project between 1999 and 2012. The regions the project has covered are Mara, Mwanza, Shinyanga, and Kagera (**Figure 1**). These regions fall the drier

Figure 1. A map of the southern region of Tanzania showing the study areas. *Source*: http://www.mapsofworld.com/tanzania/tanzania-political-map.htm.

agroecological zones namely zone P4, zone P5, zone P8, zone W3, and zone N10. The sensitization on the use of quality planting materials focused on the sweetpotato agronomy, pest and disease diagnosis, and protection and methods for conserving vines for future planting.

3. Methodology

3.1. Empirical analysis of adoption

Adoption of a different technology (i.e., improved variety of sweetpotato) from the existing one usually entails both costs and benefits. In the case of OFSP, these costs could include conventional (such as having to purchase new planting materials from neighbors) and transaction costs related to search and transportation of planting materials to the firm.

The decision to adopt of improved technology is often modeled using a logit or probit regression model. In the case where OFSP varieties coexist with other improved local varieties, it is also expected that farmers make the decision to adopt OFSP fully knowing of the existence of the other varieties. Thus the adoption decisions relating to OFSP and improved local varieties are interdependent [15, 16]. More formally, this means that the decision to adopt variety j by farmer i is correlated to the decision to adopt variety k. The correlation in decision to adopt multiple varieties of sweetpotato, in turn, suggests the likelihood of correlation of the error terms across the different equations. This correlation renders the use of probit or logit regressions models inappropriate because the estimates coefficients will be biased [16].

To overcome the above problem, a multivariate probit regression was used to model the choice of sweetpotato varieties to plant. The multivariate probit regression technique has been used in several past studies [17–19]. It is an extension of bivariate probit model [20] and uses Monte Carlo simulation techniques to jointly estimate the multivariate probit regression equation system [21].

The implicit form along with the variables included in the estimation of the model is given by

$$\begin{aligned} \text{variety} \;=\; & \text{f}(\mathit{intervened}, \mathit{foodsec}, \mathit{gender}, \mathit{lneduc}, \mathit{lnage}, \mathit{credit}, \mathit{lnusedfarm}, \\ & \mathit{valley\_bottom}\ \mathit{lndistmkt}, \mathit{lncrpinc}1, \mathit{grpmember}, \mathit{assetindex}, \mathit{moreyield}, \\ & \mathit{sugary},\ \mathit{aezP}4\mathit{N}10, \mathit{aezP}8\,) + \text{error term} \end{aligned}$$

The dependent variable in the equation above is a dummy variable equal 1 if a farmer *i* decided to plant variety *j* and 0 otherwise. That is, the dependent variable takes the value of 1 if $variety = j$, for j = Kabode, Ejumala, Jewel, or New Polista, Ukerewe is planted, and 0 otherwise.

The explanatory variables used in the estimation of the model are: *intervened* is a dummy equal 1 if a farmer participated in the Marando Bora project, 0 otherwise; *gender* is a dummy equal 1 if the respondent is a male, zero if otherwise; *lneduc* is natural log of education in years; *foodsec* is an index of food security computed as discussed above; *valley* is a dummy equal 1 if farmer has access to valley bottom, 0 if otherwise; *lndistmkt* is natural log of distance to market in walking minutes; *lnfamsize* is natural log of size of farm in acres ; *grpmember* is a dummy equal 1 if the farmer belongs to a farmer organization, 0 if otherwise; *credit* is a dummy equal 1 if a farmer received credit in 2012; *lncropinc* is natural log crop income in Tanzania Shillings; *assetindex* is wealth index computed from physical (household and farm) assets. The index was computed following [22]; *moreyield* is a dummy equal 1 if a higher root yield is important in decision to conserve vines, 0 if otherwise; *sugary* is a dummy equal to 1 if the sweetness (high sugar content) is important to the farmer, 0 if otherwise; *aezP5N10* is a dummy equal to 1 if a farmer is in the more wet area, 0 if otherwise; *aezP8* is a dummy equal to 1 if a farmer is in moderately wet area, 0 if otherwise; *eazP4W3* is a dummy equal 1 if a farmer is in drier area, 0 if otherwise.

In this study, other variables that should be included in the model, based on a priori expectations, but are highly correlated with participation in the Marando Bora project were dropped. This is because their inclusion along with intervention (i.e., participation in Marando Bora) could result in "double counting" (For example, see [23] for similar treatment but in an unrelated study). The variables dropped are voucher, dummy equal to 1 if a farmer received a voucher that allowed him/her to get sweetpotato vines at discounted rate, 0 otherwise and know_DVM is a dummy equal 1 if a farmer knew where to find a DVM, and 0 otherwise. In addition, the Wald joint-exclusion restriction test is used to assess and drop variables that do not explain much of the variability in the decision to adopt OFSP.

3.2. Computation of household food insecurity index

Food insecure households engage in several activities/actions in efforts to obtain food. Food insecurity status of the household can thus be deduced from a set of actions that it engages in to get food in situations of food shortage. Typically, the more the number of such actions undertaken by a household, the more food-insecure that household is likely to be. In this study, we use these "set of actions" undertaken by the households in the sample, and the Rasch model, to measure the food insecurity status of the household. Under the Rasch model, a farmer's behavior can be expressed as a matrix X containing the response xij of i=1,…,n farmer to j=1,…,m food insecurity statements. The actions typically correspond to a set of binary statements that capture what the farmer did in response to food insecurity situation in his/her household. An index of food insecurity was therefore computed for each of the 732 households by subjecting the collected statements to the Rasch analysis in RUMM2030. The more the actions a household undertook in response to food scarcity, the higher the food insecurity index. Households with a higher index are more food-insecure than the rest of the households in the sample. Moreover, it means that most of the statements they engaged in were extreme/severe.

3.3. Data

This study uses the data collected from 732 households in January and February 2013 as part of the Marando Bora endline household survey. The map of the study areas covered is presented in **Figure 1**. A multi-stage sampling technique was used. First, four regions (Mara, Mwanza, Shinyanga, and Kagera) were purposively selected. Within each region, farmers were categorized into those that participated in the decentralized vine multiplier scheme, the mass distribution scheme and those who did not participate in any of the two schemes. For the purposes of this study, the first two groups of farmers comprise the "intervened" group (i.e., participants) and the last group constitutes the nonintervention group (i.e., non-participants). The list of farmers in each category (i.e., intervened and nonintervention) was then compiled at the village levels in each of the project wards and districts. A random sample of farmers was selected from each category of farmers for personal interviews. In total 481 project participants and 251 nonparticipants were interviewed. The sample contained 221 and 511 male and female farmers, respectively. The high number of female farmers reflects the fact that women mostly grow sweetpotato and that the project also targeted female household members. Data collected included farmer and farm characteristics, asset endowments, institutional characteristics, and varietal traits.

4. Findings

Table 1 summarizes the data used in estimating the regression models. The results are presented for farmers that participated in the project (and hence were sensitized about the benefits

Variable	Participant (*N*=481)		Nonparticipant (*N*=251)		Test of diff. in means	
	Mean	Std Dev	Mean	Std Dev	t-stat	*p*-value
Farmer/household specific variables						
gender	0.31	0.03	0.02	0.47	−0.81	0.4182
lneduc	0.58	3.13	0.27	3.41	−1.23	0.2175
lnage	3.79	0.27	3.84	0.28	1.97	0.0246
Farm specific variables						
valley	0.68	0.47	0.64	0.48	−1.32	0.0939
lndistmkt	1.26	1.61	1.24	1.58	−0.14	0.8878
lnfmsize	1.08	0.81	1.02	0.98	−0.89	0.1966
Capital endowment factors						
lncropinc	6.84	8.59	5.63	8.6	−1.79	0.0363
group	0.64	0.48	0.39	0.49	−6.59	0
assetindex	3.56	2.15	3.4	2.02	−1.01	0.1549
Varietal trait variables						
moreyield	0.93	0.25	0.9	0.29	−1.41	0.0808
sugary	0.75	0.43	0.78	0.41	0.91	0.819
Agroecological factors						
aezP8	0.34	0.47	0.5	0.5	4.09	0
aezP5N10	0.17	0.38	0.02	0.15	−5.97	0
aezP4W3	0.48	0.5	0.47	0.5	0.15	0.4373

Table 1. Summary statistics and t-test of differences in means by project participation.

of OFSP) and those that did not. Growers of orange-fleshed sweetpotato were participants of the project. As results indicate, project participants differed from the nonparticipating ones in terms of age, many of the asset endowment variables, agroecology, and varietal traits, as shown by the very low *p*-values of tests of differences in means. Specifically, participating farmers differed in terms of income and membership to farmer groups. There is also weak evidence that farmers significantly differed with regard to access to land on valley bottoms.

Figure 2 presents the proportion of farmers growing different varieties of orange-fleshed sweetpotato as well as the cleaned-up local white-fleshed variety, New Polista. New Polista and Kabode were planted by nearly one-half of the farmers interviewed while only about one-quarter of the farmers planted Ejumula and Jewel. The high percentage of farmers planting New Polista is due to its popular traits such as high dry matter content and relatively high sugar content making it tastier than orange-fleshed varieties. New Polista is also more tolerant to the sweetpotato pests, especially the sweetpotato weevil, and to sweetpotato virus disease (SPVD). Among the orange fleshed varieties, Kabode is most widely grown by the farmers owing to its resistance to SPVD, good taste, and the fact that it is rich in vitamin A. However, compared to New Polista, Kabode has a lower dry matter content and is less tolerant to moisture stress caused by droughts.

The low adoption of Ejumula and Jewel is mainly attributed to their susceptibility to SPVD, hence requiring higher disease management, and low dry matter content (for the case of Jewel), despite the latter being more tolerant to moisture stress than Kabode.

This study estimated a multivariate regression model to understand the factors that drive the choice of variety of sweetpotato to grow, and to test the null hypothesis that choice of sweetpotato variety planted is not affected by awareness of nutritional benefits of OSFP. The sweetpotato varieties included in the estimated regression model were Jewel, Ejumula, Kabode (for orange-fleshed varieties), and New Polista (for improved local varieties, also promoted by the project but quite popular among the consumers).

Table 2 presents the tests of interdependence/correlation in the decision to plant different varieties promoted by the Marando Bora project, i.e., the atrho and rho. As expected, the

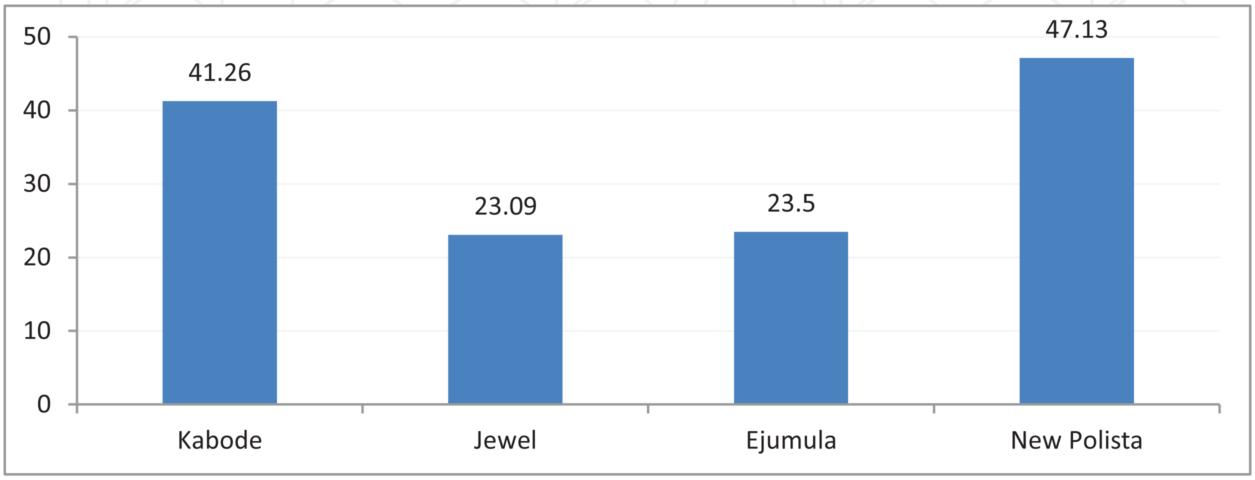

Figure 2. Proportion of farmers growing different varieties of sweetpotato: % (N = 732).

	Coeff.	*p*-value		Coeff.	*p*-value
atrho ejumula-kabode	0.444	0.000	rho ejumula-kabode	0.417	0.000
atrho jewel-kabode	0.313	0.000	rho jewel-kabode	0.303	0.000
atrho newpolista-kabode	0.278	0.000	rho newpolista-kabode	0.271	0.000
atrho jewel-ejumula	0.599	0.000	rho jewel-ejumula	0.537	0.000
atrho newpolista-ejumula	0.270	0.001	rho newpolista-ejumula	0.264	0.000
atrho newpolista-jewel	0.183	0.013	rho newpolista-jewel	0.181	0.011

Note: Likelihood ratio test of rhoejumula-kabode = rhojewel-kabode = rhonewpolista-kabode = rhojewel-ejumula = rhonewpolista-ejumula = rhonewpolista-jewel: Chi^2 (21) = 118.42; *p*-value = 0.000.

Table 2. Tests of correlations in decision to use different sweetpotato varieties.

results indicate that there is statistically significant and positive interdependence/correlation in the decision to choose among the orange-fleshed varieties and also between the orange-fleshed varieties and the white-fleshed New Polista. This finding indicates that estimating separate Probit or Logit regression models to assess the determinants of the decision to plant OFSP varieties would result in biased estimates and justifies the use of multivariate regression technique.

The results of the estimated multivariate probit model are presented in **Table 3**, by variety. We discuss the results by variety below.

4.1. Factors affecting the decision to grow Kabode

As hypothesized, results show that awareness of the nutritional benefits of OFSP and household food security status significantly affect farmer's decision to plant Kabode, an OFSP variety. The *p*-values for the two variables are both 0.0000 indicating that there is very strong evidence from the data to suggest that participation in the Marando Bora project (hence being aware of benefits of eating OFSP) and being food insecure affects the decision to plant Kabode.

Results also indicate that age and agroecology of the area affect the choice of variety planted. Specifically, age is negative and statistically significant indicating that older farmers are less likely to choose to grow Kabode. This finding is probably because older farmers are more used to the local varieties, thus find it difficult to switch to the orange-fleshed varieties. At the same time, aezP8, one of the variables included to capture the effect of agroecology on the choice of variety to plant, is both positive and strongly significant. Specifically, results indicate that farmers in areas falling within zone P8, which is less dry, are more likely to plant Kabode than those falling in the regions covered by zone W3 and P4 (i.e., aezP4W3, the base).

Variable	Kabode		Jewel		Ejumula		New Polista	
	Coeff.	***p*-value**	**Coeff.**	***p*-value**	**Coeff.**	***p*-value**	**Coeff.**	***p*-value**
Farmer specific variables								
intervened	6.949	0.000***	5.910	0.000***	5.893	0.000***	3.380	0.000***
foodsec	0.055	0.000***	0.048	0.000***	0.028	0.015**	0.013	0.300
gender	0.194	0.153	−0.087	0.516	0.214	0.113	0.047	0.728
lneduc	0.010	0.599	0.043	0.042**	0.253	0.209	−0.002	0.914
lnage	−0.486	0.040**	−0.330	0.163	−0.638	0.007***	−0.322	0.156
Farm specific variables								
valley	0.022	0.866	0.160	0.251	0.052	0.712	0.270	0.052*
lndistmkt	−0.023	0.603	−0.076	0.100*	−0.121	0.007***	0.049	0.750
lnusedfarm	0.001	0.998	−0.182	0.080*	−0.116	0.083*	−0.116	0.090*
Asset endowment variables								
lncropinc	0.006	0.491	0.018	0.028	0.019	0.026**	0.015	0.074*
credit	−0.083	0.514	0.003	0.979	0.179	0.127	0.021	0.849
group	0.208	0.110	0.249	0.066*	0.300	0.026**	0.057	0.658
Varietal trait variables								
moreyield	0.303	0.242	0.415	0.131	0.080	0.767	−0.302	0.214
sugary	−0.056	0.704	−0.064	0.660	0.193	0.216	0.331	0.031**
Agroecology variables								
aezP5N10	−0.128	0.455	−0.646	0.002***	−1.026	0.000***	0.248	0.158
aezP8	−0.520	0.000***	−0.068	0.614	−0.558	0.679	0.489	0.001***
_cons	−6.370	0.000	−8.780	0.000	−5.563	0.000	−1.956	0.039

Notes: *N*=732; Log pseudo likelihood = −1104.31; Wald chi^2 (64) = 6408.80; *p*-value=0.0000. Also ***, **, * indicate significance at 1, 5, and 10%, respectively.

Table 3. Factors influencing the use of sweet potato varieties: multivariate probit regression.

4.2. Factors affecting the decision to grow Jewel

The factors driving the decision to plant Jewel are presented in columns 4 and 5 of **Table 3**. As in the case of Kabode, we find, as hypothesized, a strong evidence that both participation in the project (a proxy for awareness of benefits of OFSP) and household food security status affect the decision to plant Jewel. Both variables have *p*-values of 0.0000 indicating that there is firm evidence from the data against the null hypothesis that awareness of the nutritional benefits of OFSP and food insecurity in the household have no effect on the decision to plant Jewel. The results also indicate that education increases the likelihood that a farmer adopts Jewel. This finding is in line with our priori expectations: more educated farmers are more likely to adopt an OFSP variety because education is associated with the demand for quality attributes (in this case the vitamin A content) of food [23, 24].

Results further show that farm-specific, asset endowment, and agroecological variables also affect the decision to plant Jewel. In particular, distance to the market (a proxy for transaction costs) and farm size both reduce the likelihood that a farmer chooses to plant Jewel. The finding that high transaction costs reduce adoption of OFSP variety is in line with the adoption literature which suggests that high transaction costs reduce the price farmers earn and hence dampen the incentives to invest in agricultural technology [25]. At the same time, the results indicate that being in areas under zone aezP5N10 and being a member of a farmer group increase the likelihood that a farmer will decide to plant Jewel. These results are as expected: moving from the less dry zone (i.e., aezP4W3) to the less dry (i.e., aezP5N10) provides more of the moisture needed to grow the less drought tolerant OFSP varieties such as Jewel. The finding that membership to a farmer group increases the likelihood of planting Jewel may be because such groups provide technical and social support to members as well as some value-addition activities [18, 26–28].

4.3. Factors affecting the decision to plant Ejumula

The factors affecting the decision to plant Ejumula, the final OFSP variety we examined in this study, are presented in columns 6 and 7 of **Table 3**. As in the two previous cases, the results indicate that benefit awareness and household food insecurity increase the likelihood that a farmer will grow Ejumula. The null hypothesis that knowledge of the benefits of OFSP and the household food insecurity have no effect on farmer's decision to plant Ejumula is rejected. Results also show that age affects the likelihood that a farmer plants Ejumula. Specifically, as in the case Kabode, the results indicate that older farmers are less likely to adopt Ejumula than younger ones.

Among the farm-specific variables, distance to market and size of farm are both negative and statistically significant suggesting that farmers that face higher transaction costs in the marketing of sweetpotato and those with large farms are less likely to adopt Ejumula. The finding relating the distance to the market (a proxy for transaction) supports our argument above that high transaction costs dampen incentives to grow OFSP. Asset endowment variables, income from crop sales and membership in a farmer group, also affect the decision to plant Ejumula. An increase in crop income and being a member of a group both increase the likelihood of planting Ejumula. The effect on crop income on the adoption of Ejumula is likely to be related to the financial requirements for labor use in the production of sweetpotato. Hired labor is one of the most expensive external inputs in the commercial production of vegetatively propagated crops [29]. Results also show that, among the agroecology variables, farmers in the less dry zone aezP5N10 are more likely adopt Ejumula compared to their counterparts in the drier zone aezP4W3 indicating that agroecology is important in the decision to adopt Ejumula.

4.4. Drivers of decision to adopt New Polista

The results of the factors affecting the decision to use the white-fleshed New Polista variety are presented in the last two columns of **Table 3**. Among, the farmer-specific variables, participation in the project (i.e., intervene) is the only variable that affects the decision to grow New Polista. Specifically, the results indicate that participation in the project increases the likelihood of planting New Polista. While this finding may appear to be contrary to expectations, it actually captures the way the project was designed. While the Marando Bora promoted awareness of the benefits of OFSP, it also promoted the growing of other popular local varieties such as New Polista for the food security purposes and as a source of income. Indeed, this is the reason why the project cleaned up the Polista variety, to remove viruses and to increase its yield potential. The results however do not find food insecurity a significant factor in the decision to grow New Polista.

Two farm-specific variables affect the decision to grow New Polista, namely having access to a valley bottom and size of land. The former increases while the latter decreases the likelihood of planting New Polista. The finding that access to valley bottom influences the decision to grow New Polista likely relates to the fact that access to land in such areas enables farmers to conserve planting materials (i.e., vines) during the dry periods. Results also show that crop income, taste (i.e., sugary), and being in less dry agroecological zone (aezP8) all increase the likelihood of growing New Polista. Notably, the results indicate that farmers who perceive New Polista to be sweeter (i.e., sugary) are more likely to grow it.

The results above have shown that agroecology and asset endowment play a major role in the decision to grow the various improved and cleaned up sweetpotato varieties, including the OFSP. To examine whether these variables jointly affect the decision to plant the four sweetpotato variables analyzed in this study, we conducted appropriate hypothesis tests for each. Following [18, 19], we also examined if the varietal traits affect the likelihood that a farmer will plant these improved varieties. Specifically, a Wald joint-exclusion test of the agroecology variables (proxied aezP5N10, aezP8) and access to the valley bottom, all of which are associated with moisture availability, yielded a Chi-square and *p*-value of 60.88 and 0.0000, respectively. This result indicates these variables jointly affect farmer's decision about the choice of sweetpotato varieties to plant. Thus, the null hypothesis that agroecology of the area has no effect on the choice of sweetpotato variety planted by the farmer is therefore rejected. On the other hand, a Wald test of nonsignificance of asset endowment variables (represented by asset-index, crop income, and size of land) yielded a Chi-square and *p*-value of 24.81 and 0.0158, respectively. This finding indicates that there is firm evidence from the data to suggest that farmers' endowment with physical assets (proxied by asset-index and farm size) and financial capital (proxied by income from previous crop) affect the decision about the sweetpotato variety grown. A Wald test of joint exclusion of the varietal attributes (proxied by moreyield and sugary) however finds no evidence that these variables jointly affect the choice of variety planted. The test yields a Chi-square and *p*-value of 10.68 and 0.2203.

5. Conclusions and lessons

This study examined the effect of awareness of the nutritional benefits of OFSP and food insecurity in the household on the decision to grow OFSP. The study used multivariate probit regression technique, which controls for interdependence/correlation in varietal adoption decisions, to test the effect of participation in the project (a proxy for awareness of nutritional benefits of OFSP) and food insecurity in the household on the decision to plant the three most important OFSP varieties.

The study finds a strong evidence that awareness of the nutritional benefits of OFSP increased the likelihood of a farmer deciding to plant OFSP varieties. It also finds that household food security status increased the probability that a farmer grows OFSP. Some other conditioning variables also affect the decision to plant improved sweetpotato varieties, including the OFSP varieties. In particular, access to agroecology of the area and endowment with financial and physical assets significantly increased the decision to plant improved sweetpotato varieties. This study therefore concludes that household food insecurity has a significant effect on the likelihood of farm households deciding to grow the OFSP varieties.

The findings of this study have several lessons for Sub-Sahara Africa (SSA) countries. First, they imply that interventions aimed at sensitizing farmers on the importance of OFSP need to be coupled with providing access to clean planting materials. In the Marando Bora project, these activities were coupled to ensure not only that farmers have access to better performing (i.e., higher yielding) clean planting material but also were aware of this as well as the nutritional benefits of the growing and consuming OFSP. Indeed, the finding shows that awareness of these benefits is instrumental in the decision to adoption OFSP.

Second, the study demonstrates that sweetpotato farmers are concerned about moisture availability when making the decision to produce OFSP. This finding is not new. Similar findings are presented in [30]. It, however, emphasizes one major challenge farmers' experience, namely, how to conserve planting material over the dry period for next season planting. Thus, efforts to promote the growing and consumption of OFSP need to train farmers on conservation of the planting material. Some of the strategies that can be used in this endeavor are discussed in Refs. [30, 31].

Another major lesson from this study relates to the finding on distance to market, a proxy for transaction costs, reduces the decision to grow OFSP. While this finding is expected, it implies the need to reduce the distances farmers have to access the market since it has implications on the commercialization of OFSP. Since distance to market was measured in terms of time taken to reach produce market, the lesson here is that local governments need to invest

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in improving the time farmers take to reach the market with their produce. Doing so may require simple improvement the state of the road rather than creating new physical markets in local communities.

The finding that food security status of the households affects the decision to grow OFSP also has implications for policy. In particular, this finding confirms the importance of sweetpotato as source of macronutrients (i.e., starch) and micronutrients (i.e., vitamin A). It therefore implies the need to continue the efforts to upscale the growing of sweetpotato by poor rural households who face the dual food security problem of access and nutrition and also do not have the means to afford food supplements.

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