Awareness exposure and technology adoption: the case of Orange-fleshed Sweetpotato in West Africa.

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Abstract

Commonly used innovation adoption models indirectly assume homogenous information flow across farmers, which is often not the case. For new and or not well known technologies such as Orange-fleshed sweetpotato (OFSP) varieties, awareness exposure plays an important role in farmers' decision to adopt. OFSP varieties have been shown to be highly effective means of combating it at the community level because of its high pro-vitamin A content and its cost effectiveness as compared with fortification and supplementation. Significant efforts, including the implementation of the Jumpstarting Orange-fleshed Sweetpotato project, have been deployed over the last decade in West Africa to promote the production and consumption of OFSP. Observations in the project countries indicating that the usage rate of OFSP among the beneficiaries was extremely high, suggesting a significant link between awareness activities and adoption behavior. Using the counterfactual outcome framework from the modern evaluation approach on 345 and 381 sweetpotato farmers from Ghana and Nigeria respectively, we found that the OFSP adoption rates could have been up to 61 percent in Ghana and 42 percent in Nigeria in 2016 instead of the observed sample adoption rate of 51 and 33 percent if the whole population was exposed to the OFSP varieties. This suggests that there is potential for increasing dissemination rate among population. Our study has showed that the OFSP adoption is influenced by a number of factors, which vary between the study countries. This implies that actions to increase the adoption rate shouldn't be "one size fits all solution" approach.

Key words: Awareness; Orange-fleshed sweetpotato (OFSP); adoption; West-Africa

1. INTRODUCTION

Vitamin A deficiency (VAD) is one of the major public health problems. It is estimated that globally 190 million preschool children and 19 million pregnant women are deficient in vitamin A (World Health Organization (WHO), 2009; 2011). In Africa, 6% of the child death under the age of 60 months is due to VAD (WHO, 2011). Sub-Saharan Africa (SSA) is the most affected region, constituting more than 40% of children under the age of 60 months suffering from VAD (Black et al., 2013). Vitamin A deficiency is central to preventable child blindness and increases the probability of contracting and dying from infections like measles, and diarrhoeal illnesses (Stevens et al., 2015). For instance, it is estimated that about 250,000 to 500,000 vitamin A-deficient children become blind every year, half of them dying within 12 months of losing their sight (WHO, 2016). In pregnant women VAD is the major cause of night blindness and contributes to the risk of maternal mortality.

To combat VAD, different strategies have been proposed and implemented, of which a food based approach through consumption of locally available foods rich in provitamin A aiming at increasing the dietary intake of particularly β-carotene (precursor of Vitamin A). Orange-fleshed sweetpotato (OFSP) is one of these well-known biofortified crops that are rich in provitamin A and can contribute significantly to vitamin A nutrition in humans. For instance, it has been shown that regular consumption of 100–125 g of OFSP roots provides about 100 percent of the recommended daily amount of vitamin A for children under the age of 60 months (Hortz, et al.,2012; Low et al., 2009) and contributes to the fight against night blindness among women (Black et al.,2013; Nutrition Study Group, 2013). An ex-ante impact assessment showed that the promotion of OFSP will benefit more than 50 million children under the age of 60 months in sub-Saharan Africa (Kapinga et al., 2005).

Since 2014, efforts to promote the production and consumption of OFSP in West Africa, have included market sensitization and demand creation campaigns, and nutrition education trainings in sweetpotato growing areas. For instance, the Jumpstarting Orange-fleshed Sweetpotato in West Africa project conducted sensitization and media campaigns to create awareness of the benefits of consuming OFSP and distributed planting materials to farmer groups coupled with systematic training on good agronomic practices. Further, in order to improve access to planting materials,

decentralized vine multiplication enterprises were created in the communities where sweetpotato is predominantly grown. In addition, teaching about how to better manage the OFSP crops was provided to farmers. These efforts aim at creating awareness and improving farm household members' knowledge about OFSP and ultimately their behavior towards its adoption. Observations in the project countries indicating that the usage rate of OFSP among the beneficiaries of the project was extremely high, suggesting a significant link between awareness activities and usage (i.e., adoption) behavior. The utilization of mass media campaigns aimed at exposing high proportions of large populations of sweetpotato producers to the newly released varieties, OFSP, and thus facilitating their successful dissemination both within and beyond project areas in order to stimulate their adoption.

The literature on adoption of innovations is vast and are concerned mainly with farmers' socioeconomic and institutional factors influencing adoption (see Feder and Umali, 1993 for an overview). Recently, there is a growing interest among researchers in the effect of technology multiple attributes on adoption decisions (Adesina, and Baidu-Forson, 1995; Edmeades, & Smale 2006). The importance of awareness is generally omitted or taking for granted while explaining innovation adoption behavior. These studies seem to implicitly assume that innovation awareness universal. This is not however the case for new technologies. Indeed, Diagne and Demont (2007) has theoretically and empirically shown that newly released technology faces non-universal of its awareness and therefore is likely to lead to selection problems since every individual in the population will not have an equal chance to be exposed and consequently adopt. As OFSP varieties are relatively new in West Africa, awareness of their existence by the population (here sweetpotato producers) is not universal. To date, however, focus remains on farmers' characteristics and OFSP-related attributes while the diffusion and its effects received much less attention in assessing adoption behavior among farm households.

The objective of this study is to understand the rate at which the population of sweetpotato producers is being made aware of OFSP and assess the potential for adoption (actual and potential adoption rates) of OFSP and their determinants in West-Africa using data from a sample of 345 and 381 sweetpotato producers in Ghana and Nigeria respectively

2. SWEETPOTATO PRODUCTION IN WEST AFRICA: THE CONTEXT AND DATA

2.1. The context

Sweetpotato (Ipomoea batatas) is an important crop grown in almost all the agro-ecological zones in West Africa, covering about 1.82 million hectares ha with an estimated production of 5.48 million tons of roots in 2016. Sweetpotato production is mainly dominated by smallholders and mostly for home consumption as a snack or breakfast food. The roots are mainly consumed though the leaves also provide essential minerals, vitamins and protein (Bovell-Benjamin, 2010). Production mainly remains rain-fed, can be planted as a sole crop or intercropped with maize or cassava, and harvest piecemeal or as needed. In some areas, sweetpotato is produced as a cash crop (Peters, 2015). Yield is still generally low. The average yield in the region is between 5 and 25 tons per hectare as compared to 50-60 tons/hectare in South Africa's modern agriculture sector (Low et al., 2017). Mixed cropping, use of low quality vines (planting material), little to no fertilizer use, inappropriate planting density and ineffective weeding regimes are among other the factors that prevent farmers from improving their yields (Fawole, 2007).

The most cultivated sweetpotato varieties in the region are white- and yellow-fleshed. Their roots are an important source of vitamin C, B6, K, and E, and provide other nutrient elements such as Riboflavin, Copper, Pantothenic acid and Folic acid (Woolfe, 1992). These white- and yellow-fleshed, however, contain no or low levels of beta-carotene, the precursor for vitamin A. The orange-fleshed sweetpotato (OFSP) varieties containing β-carotene, therefore a good source of vitamin A which is useful to prevent vision problems and is recommended for especially children under five years and lactating and pregnant women who are the most vulnerable to vitamin A deficiency have been bred (Ofori et al., 2009). For instance, it has demonstrated that just 100 g (1/2 cup) supplies the daily vitamin A needs of young children under 5 years of age and vulnerable women, the group most at risk of VAD (Hotz et al, 2011).

Due to the limited food uses of OFSP and the quest to promote it because of its nutritional value several efforts are underway to promote the production of these varieties in poor sweetpotato growing regions of West Africa. One of such efforts is the '*Jumpstarting orange-fleshed*

sweetpotato in West Africa through diversified markets' project under which efforts have focused on creating awareness among farmers and their families through several market sensitization campaigns in several markets and distributed planting materials to farmers in farmer groups coupled with systematic training the essential agronomic practices. Several OFSP products and recipes have been developed and transferred to families and commercial actors. A training of trainers' module for OFSP utilization and processing has been developed and relevant stakeholders have been trained to use it. The recipes were developed through extensive research and product development and testing. Focus was also made on promoting the use of quality sweetpotato planting materials through the creation of several decentralized vine multiplication in the communities where sweetpotato is predominantly grown. The market opportunities created under the project would provide farmers with a strong incentive to grow the crop. Ghana, Nigeria and Burkina Faso were target by these promotional efforts because of their high incidence of VAD (Ghana PROFILES 2011). Given the training and promotional activities of the project, this study hypothesized that farmers' actual OFSP adoption would significant depend on heterogeneous information flow within the sweetpotato producers' population, and that actual OFSP adoption rates would significantly appear low if awareness asymmetry is not controlled for.

2.2. Data

Data were collected from smallholder farm households in two out of the three project countries namely, Ghana and Nigeria. Selected respondents for the study in Ghana and Nigeria were categorized into three groups i.e. participants from communities targeted by the project representing Treatment, non-participants residing within the intervention community as Treatment1 and non-participants residing outside the intervention community (non-intervention community) as the control group. Using Optimal Design software[1], we determined that a minimum sample size of 350 (125 in treatment and 225 in control) conferred 80% power, with an α of 0.05, and explained variation by covariates (R2) of 0.20, to detect a difference of 0.10 standard deviations in sweetpotato utilization rates between participants and the control groups. To maximize statistical power for detecting the effect size, 345 farmers (127 participants, 123 non-

[1] Optimal Design Software for Multi-level and Longitudinal Research (Version 3.01). 2011. www.wtgrantfoundation.org

participant households within the intervention communities, and 95 non-participant households outside the intervention communities) were interviewed in Ghana and 381 (77 participants, 194 non-participant households within the intervention communities, and 110 non-participant households outside the intervention communities) were surveyed in Nigeria. A purposive sampling technique was adopted to identify the survey areas using the interaction with project partners and production and marketing of sweetpotato as the selecting criteria. The latter applied to targeted by the project only. The intervention communities were those regions where the project team and partners performed promotion activities about orange-fleshed sweetpotato while in control areas no promotion was carried. The non-intervention communities were selected by simple random sampling from a list of communities situated at, at least, 6 km from the nearest intervention community, and where no promotion on OFSP was carried by the project. In total, eight communities outside the intervention zones were selected in Ghana, while seven communities were randomly selected in Nigeria.

In both Ghana and Nigeria, respondents were approached, introduced to the study and consent to voluntarily participate in the study sought. Interviews were only started after consent was obtained. Data was collected by trained enumerators using direct/personal interviews. The data collected included demographic information, seed systems (especially the sources of vines planted), agronomic and pest management practices.

Adoption of OFSP varieties in this study is defined as the use of OFSP varieties during the 2015/2016 production campaign. The farmers were first of all asked whether they knew OFSP varieties, and then were asked whether he or she had cultivated the variety in the last 2015/2016 production campaign if the answer to the awareness question was yes. These farmers were also questioned about their sweetpotato (and OSFP) production, household livestock ownership and control, savings and credit access, access to extension services and other information, and income activities. The interviews were conducted between February and April 2017.

3. ANALYTICAL FRAMEWORK

In the literature (e.g., Diagne and Demont, 2007), modern treatment effect estimation framework abound (e.g. Angrist et al., 1996; Wooldridge, 2002). In this study, a "counterfactual outcome" framework where every farmer in the population has two "potential" outcomes was used. The

potential outcomes are those with and without exposure to a technology (OFSP in our case). There is the need to control for both non-exposure and selection biases and the application of treatment framework allows us to achieve this (Diagne and Demont, 2007). It also helps in estimating true population adoption rates and the determinants of adoption. In this study, the treatment variable is "exposure" or "awareness" of at least one variety of OFSP such that those exposed to the OFSP are considered as "treated", while those unaware are considered "untreated"[2]. For the purpose of clarity, we summarize the procedures for the estimation of the different adoption parameters used on the data from the survey.

The procedure employed in this study follows from Diagne and Demont (2007). The parametric estimation of the average treatment effect (ATE) is based on the following equation that identifies $ATE(x)$ and which holds under the conditional independence (CI) assumption (Diagne and Demont 2007):

$$ATE(x) = E(y_1 \mid x) = E(y \mid x, w = 1) \qquad (1)$$

The parametric estimation procedure proceeds by first specifying a parametric model for the conditional expectation in the right hand side of the equality of equation (1) which involves the observed variables y, x and w:

$$E(y \mid x, w = 1) = g(x, \beta) \qquad (2)$$

where g is a known (possibly nonlinear) function of the vector of covariates x and the unknown parameter vector β which is to be estimated using standard Least Squares (LS) or Maximum Likelihood Estimation (MLE) procedures using observations (y_i, x_i) from the subsample of exposed farmers only with y as the dependent variable and x as the vector of explanatory variables. With an estimated parameter $\hat{\beta}$, the predicted values $g(x, \hat{\beta})$ are computed for all the observations i in the sample (including the observations in the non-exposed subsample) and the ATE, ATE1 and ATE0 are estimated by taking the average of the predicted $g(x, \hat{\beta})$ $i = l, ..., n$ across the full sample (for ATE) and respective subsamples (for ATE1 and ATE0):

[2] We considered exposure to at least one variety of improved Orange-Fleshed Sweetpotto since the type of OFSP disseminated to farmers varies between countries, and sometimes within countries (for instance, Mother's Delight and King J were two OFSP varieties disseminated in Nigeria)

$$\hat{ATE} = \frac{1}{n}\sum_{i=1}^{n} g\left(x_i, \hat{\beta}\right) \quad (3)$$

$$\hat{ATE}1 = \frac{1}{n_e}\sum_{i=1}^{n} wg\left(x_i, \hat{\beta}\right) \quad (4)$$

$$\hat{ATE}0 = \frac{1}{n-n_e}\sum_{i=1}^{n} (1-w_i) g\left(x_i, \hat{\beta}\right) \quad (5)$$

As further expressed by Diagne and Demont (2007), the effects of the determinants of adoption as measured by the *K*-dimensional vector of covariates x at a given point $\bar{x}$ are estimated as:

$$\frac{\partial E\left(y_i \mid \bar{x}\right)}{\partial x_k} = \frac{\partial g\left(\bar{x}, \hat{\beta}\right)}{\partial x_k} \quad k= 1, \ldots\ldots, k \quad (6)$$

Where x_k is the k^{th} component of x.

In this study, we also estimated the determinants of exposure which is important for its own sake as it can provide valuable information regarding the factors influencing farmers' exposure to a new technology.

4. RESULTS AND DISCUSSIONS

4.1. Farmers knowledge of OFSP variety awareness and utilization

The frequency distribution of the three categories of farmers in Ghana and Nigeria on the awareness and adoption of OFSP variety is presented in Table 1. In Ghana, the majority of the respondents participated in the intervention programme that is, 36.8% unlike Nigeria where participants have the lowest representation of the in the intervention program (20.2%).

All the intervention participants claim to be aware of and had grown OFSP at least once. In Ghana, about 50% of the respondents belonging to the non-participating households within the intervention communities (Treatment 1) had grown OFSP at least once, while in Nigeria this accounted for just 26 percent. It is worthy to note that none of the interviewed farmers belonging to the non-participating households outside the intervention communities (Control) planted OFSP in Nigeria in the last two years (2015) and in Ghana in the last three years (2014). All in all, the utilization of OFSP has steadily increased over the past three years, not only among the

intervention participants, but also among neighbors. In Ghana, the OFSP utilization rate among Treatment 1 categories of respondents increased by 651 percent between 2014 and 2016 (6.5 percent in 2014 against 49 percent in 2016) while in it has increased by 315 percent (5.2 percent in 2014 against 25 percent in 2016).

Central to the adoption decisions is the awareness of the technology. As Feder et al. (1984) stated, technology adoption is a multistage process where the decision maker undergoes from the time they get exposed to the technology through to the time that they decide to start using the technology. Therefore, these sample utilization rates presented above are likely to be biased downwards as they include sweetpotato farmers who were not yet aware of OFSP varieties and, therefore, they cannot adopt unless exposed. The awareness rate for OFSP in both Ghana and Nigeria is 67 and 56 percent respectively. Knowledge of OFSP varieties is more prevalent among neighbors, i.e. Treatment 1 categories of respondents (70 and 57 percent in Ghana and Nigeria, respectively) than among control categories of respondents, i.e. the non-participating households outside the intervention communities (18 and 24 percent in Ghana and Nigeria, respectively).

Twenty-three and 38 percent of the participating farmers in Ghana sourced information about OFSP from IDE- Ghana and ACDEP respectively, while most of the Treatment 1 category of respondents claimed they heard about it from other farmers (52 percent). Majority of the Control category (76.5%) testified they were aware about OFSP through radio broadcast. Among the Nigerian farmers, 55 percent of the participating farmers and the Treatment 1 category of farmers received the information about OFSP from the agricultural development project of the state (ADP) and through other farmers respectively. On the other hand, 54 percent of the control category in Nigeria caught wind of the information from radio broadcast. The high awareness rate of OFSP can be then attributed, not only, to intensive awareness campaigns done by the Jumpstarting Orange-Fleshed Sweetpotato project, and its partners in the two countries, but also to (informal) information sharing among peers.

So taking into account the awareness of OFSP varieties, the utilization rate among the sub-sample of farmers that were aware of OFSP is much higher than the utilization rates reported earlier for the whole sample. The overall utilization rate for growing OFSP at least once among the sub-sample of exposed farmers in Ghana is 83 percent (all participants, 71 percent of the Treatment 1 category of farmers, and 18 percent of the Control category of farmers) while it is 61 percent in Nigeria (all participants, 46 percent of the Treatment 1 category of farmers, and 8 percent of the

Control category of farmers). In 2016 season, the overall utilization rate for OFSP among the sub-sample of exposed farmers in is 93 and 97 percent in Ghana and Nigeria, respectively (compared to a lower utilization rates of 51 and 33 percent for the whole sample). The two utilizations rates are significantly different because of differences in awareness of OFSP varieties among the sampled households. The finding is consistent with prior expectation that exposure to OFSP varieties is crucial to their adoption.

***Table 1*. Distribution of farmers based on OFSP Knowledge and adoption**

	Ghana					Nigeria				
	Non-participant households within the intervention communities (N=123) 35.7%	**Participant households (N=127) 36.8%**	**Non-participant households (Control) outside the intervention communities (N=95) 27.5%**	**Overall (N=345) 100%**	**Sig.**	**Non-participant households within the intervention communities (N=194) 50.9%**	**Participant households (N=77) 20.2%**	**Non-participant households (Control) outside the intervention communities (N=110) 28.9%**	**Overall (N=381) 100%**	**Sig.**
Without considering whether or not they are aware of OFSP										
Have grown OFSP at least once	49.60%	100.00%	3.20%	55.40%	***	26.30%	100.00%	1.80%	34.10%	***
Grown OFSP last producing season (2016)	48.80%	89.00%	2.10%	50.70%	***	24.70%	100.00%	0.90%	33.10%	***
Grown OFSP two years ago (2015)	21.10%	94.50%	1.10%	42.60%	***	13.90%	63.60%	0.00%	19.90%	***
Grown OFSP three years ago (2014)	6.50%	33.90%	0.00%	14.80%	***	5.20%	33.80%	0.90%	9.70%	***
Heard of Orange-Fleshed Sweetpotato (OFSP)	***69.90%***	***100.00%***	***17.90%***	***66.70%***	***	***56.70%***	***100.00%***	***23.60%***	***55.90%***	***
First learn about OFSP from:										
iDE-Ghana	0.00%	23.00%	0.00%	12.70%	***					***
ACDEP	0.00%	38.10%	0.00%	21.00%						
Radio	47.70%	5.60%	76.50%	26.60%		28.20%	3.90%	53.80%	22.50%	
Jumpstarting/CIP	0.00%	30.20%	0.00%	16.60%		0.00%	9.10%	0.00%	3.30%	
Other farmers	52.30%	3.20%	23.50%	23.10%		54.50%	15.60%	38.50%	38.50%	
ADP	-	-	-	-		6.40%	54.50%	7.70%	23.90%	
RUDEP (Rural Development Program)	-	-	-	-		10.90%	16.90%	0.00%	11.70%	
Taking into account knowledge of OFSP										
Have grown OFSP at least once	70.90%	100.00%	17.60%	83.00%	***	46.40%	100.00%	7.70%	61.00%	***
Grown OFSP last producing season (**2016**)	98.40%	90.40%	66.70%	92.60%	**	94.10%	100.00%	50.00%	96.90%	***
Grown OFSP two years ago (**2015**)	42.60%	96.00%	33.30%	77.80%	**	52.90%	63.60%	0.00%	58.50%	***
Grown OFSP three years ago (**2014**)	13.10%	34.40%	0.00%	27.00%	***	19.60%	33.80%	50.00%	28.50%	***

Sig. = Significance level ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively

Source: Field survey 2016

4.2 Summary statistics for adopters and non-adopters of OFSP varieties in Ghana and Nigeria

The adoption is defined as the growing (utilization) of one or more OFSP varieties by a farmer. The details of adopters and non-adopters of OFSP varieties in Ghana and Nigeria are as presented in Tables 2 and 3. In Ghana the average age of the farmers participating in the OFSP intervention programme is 53 years relative to the non-participants with mean age of about 51 years. This is an indication that both categories of farmers have passed their active age as observed in the overall mean age of 52 years. It is also noteworthy that both adopters and non-adopters have an average of about 1 year of formal education which is very low relatively. On the proximity to main road which facilitates the movement of produce from the farm gate to point of distribution, both categories of farmers spent less than 30 minutes to access the major roads in their locality. This is expected to minimize challenges encountered in transporting farm products, consequently avoiding wastage.

The average farm size owned by the adopters of OFSP farmers in Ghana is 2.19 hectares which is relatively lower than those of the non-adopters having an average of 2.67 hectares of farmland. The overall farm size used by Ghanaian farmers is 2.43 hectares. The proximity of farmers (both categories) to the nearest agricultural field office where detailed information about OFSP production can be sourced is about three hours to the farmers home. This distance can be a source of discouragement to farmers when issues arise on the farm that needs urgent attention. The adopters of OFSP testify that they interacted with extension officers in last production season for about 3.5 times while non-adopters were only privileged to interact with them only one time during the production season. The interaction will go a long way in assisting the farmers on the necessities of OFSP production.

On the other hand as revealed by Table 3, the Nigerian counterpart, the average age of the adopters and non-adopters of OFSP variety are about 50 years and 48 years respectively. The overall mean value of 48 years is an indication that OFSP farmers in Nigeria are very close to end of their active years. Contrary to the Ghanaian farmers, the adopters and non-adopters of OFSP in Nigeria have about 11years and 8 years of formal education respectively. The overall mean of 9 years indicates that farmers in Nigeria complete their basic education requirements under the national education policy. The proximity of adopters to major roads is less than one hour (41 minutes) while those of their non-adopters counterpart is more than an hour (72 minutes).

Unlike the Ghanaian farmers, the adopters category in Nigeria had a fairly large average farm size of about 3.2 hectares compared to the non-adopters with 2.3 hectares farmland for OFSP production. The overall farm land owned accounted for 2.6 hectares which is a little more than their Ghanaian counterpart. The distance to the nearest agricultural field office for adopters is about 2 hours (126.5 minutes) compared to the non-adopters having about 2 ½ hour to cover before access to extension. The overall mean proximity is 140 minutes. Adopters were also privileged to have interaction with extension officers about 5 times in the last production season while the non-adopters had only one opportunity of interaction.

***Table 2*. Summary statistics for adopters and non-adopters of OFSP varieties in Ghana**

	OFSP adopters		OFSP non-adopters		All respondents		Sig t test
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	
Number of farmers	175		170		345		
Knowledge of OFSP	1.00	0.00	0.32	0.47	0.67	0.45	***
Intervention community (1=yes; 0=otherwise)	0.99	0.11	0.45	0.50	0.72		***
Farmer characteristics							
Age of farmer (years)	53.17	1.11	50.74	13.39	51.97	14.07	*
Gender of the farmer (1=male; 0=otherwise)	0.71	0.46	0.79	0.41	0.75	0.43	*
Farmers' years of formal education	1.21	3.13	1.32	3.43	1.26	3.28	ns
Distance to the nearest main road (minutes)	28.24	49.74	25.20	41.37	26.74	45.77	ns
Presence of reference child in the household	0.91	0.29	0.79	0.41	0.85	0.36	***
Farm assets/resources							
Average farm size owned (hectares)	2.19	1.64	2.67	2.67	2.43	2.22	**
Institutional factors							
Being trained on sweetpotato production and management (1=yes, 0=N0)	0.71	0.46	0.07	0.26	0.39	0.49	***
Farmer belongs to a group/association (1=yes; 0=otherwise)	0.69	0.46	0.22	0.41	0.46	0.50	***
Distance to the nearest agricultural field office (minutes)	165.63	104.13	156.69	116.61	161.23	110.38	ns
Number of times respondent interacted with extension in 2016	3.49	13.58	1.24	1.84	2.38	9.81	**
Variety attribute variables							
Variety high yielding	0.79	0.41	0.07	0.26	0.44	0.50	***
Early maturity	0.75	0.44	0.12	0.33	0.44	0.50	***
Cooks quickly/Faster or Ease of cooking	0.75	0.44	0.13	0.34	0.44	0.50	***
Very Sugary/Sweet	0.50	0.50	0.04	0.20	0.27	0.45	***
Resists Diseases	0.27	0.45	0.11	0.32	0.19	0.40	***
Any man in the household had salaried job during the past year (1=yes, 0=N0)	0.09	0.28	0.11	0.31	0.10	0.29	ns
Any woman in the household had salaried job during the past year (1=yes, 0=no)	0.01	0.11	0.04	0.20	0.03	0.16	*

***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively. ns represents not statistical significance

Source: Field survey 2016

***Table 3*. Summary statistics for adopters and non-adopters of OFSP varieties in Nigeria**

	OFSP adopters		OFSP non-adopters		All respondents		Sig t test
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	
Number of farmers	126		255		381		
Knowledge of OFSP	1.00	0.00	0.34	0.47	0.55	0.49	***
Intervention community (1=yes; 0=otherwise)	0.99	0.08	0.57	0.50	0.71	0.45	***
Farmer characteristics							
Age of farmer (years)	49.87	12.04	47.81	13.05	48.49	12.74	
Gender of the farmer (1=male; 0=otherwise)	0.80	0.39	0.73	0.44	0.76	0.42	
Farmers' years of formal education	10.97	4.09	8.34	4.82	9.21	4.75	***
Distance to the nearest main road (minutes)	41.34	76.72	72.15	92.89	61.96	88.96	***
Presence of reference child in the household	0.35	0.48	0.34	0.48	0.34	0.47	
Farm assets/resources							
Average farm size owned (hectares)	3.16	8.72	2.29	5.92	2.58	6.97	
Institutional factors							
Being trained on sweetpotato production and management (1=yes, 0=N0)	0.51	0.50	0.07	0.25	0.21	0.41	***
Farmer belongs to a group/association (1=yes; 0=otherwise)	0.75	0.44	0.47	0.49	0.55	0.50	***
Distance to the nearest agricultural field office (minutes)	126.50	149.74	147.42	176.87	140.50	168.48	
Number of times respondent interacted with extension in 2016	5.41	10.48	1.42	2.52	2.74	6.63	***
Variety attribute variables							
Variety high yielding	0.48	0.50	0.02	0.14	0.17	0.38	***
Early maturity	0.60	0.49	0.03	0.17	0.21	0.41	***
Cooks quickly/Faster or Ease of cooking	0.57	0.49	0.03	0.16	0.21	0.41	***
Very Sugary/Sweet	0.10	0.30	0.004	0.06	0.04	0.19	***
Resists Diseases	0.07	0.26	0.01	0.09	0.03	0.16	***
Any man in the household had salaried job during the past year (1=yes, 0=N0)	0.29	0.45	0.17	0.38	0.21	0.41	***
Any woman in the household had salaried job during the past year (1=yes, 0=no)	0.30	0.46	0.14	0.35	0.19	0.39	***

***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively. ns represents not statistical significance

Source: Field survey 2016

4.3 Determinants of Farmers' exposure to the OFSP varieties

In this study, about only 67 and 56 percent of the sample households were exposed to at least one of the OFSP varieties in Ghana and in Nigeria, respectively. Based on that, we estimate a probit regression of factors that affect the propensity of awareness of OFSP varieties. Table 4 presents the results of probit estimates which are the determinants of the probability of exposure to the OFSP varieties. The coefficients of about 57% of the hypothesized variables showed statistical significance at 1% and 5% levels for the Ghana sample (residence in the intervention community, farmer belonging to a group or association, number of years of formal education attained by farmer and presence of reference child in the household). Farmers in the intervention communities are more likely to know or be aware of OFSP varieties than those living outside the intervention communities. Farmers who belong to a group or association are significantly more likely to know the OFSP varieties than those who do not belong to any group or association. Further results for the Ghana sample of respondents show that farmers with formal education and with the presence of child under 5 years of age in household are significantly more likely to be aware of the OFSP varieties than their counterparts without these attributes. For the Nigerian sample, only about 29% of the coefficients of the hypothesized variables showed statistical significance at 1% and 5% levels (residence in the intervention community and membership of a group or association). Farmers who are resident in the intervention community and who are members of group or association are more likely to know the OFSP varieties. The significant role of farmers' groups in providing information is consistent with the project's expectation that using farmers' organizations as an entry point to technology dissemination among members.

***Table 4*: Results of Estimation of the Determinants of the Probability of Exposure to the OFSP varieties**

	Ghana		**Nigeria**	
	Coefficient	**Std. Err.**	**Coefficient**	**Std. Err.**
Intervention community	2.14***	0.23	1.11***	0.16
Farmer belongs to a group/association (1=yes; 0=otherwise)	1.45***	0.23	0.32**	0.15
Age of farmer (years)	0.16	0.38	0.03	0.28
Gender of the farmer (1=male; 0=otherwise)	-0.16	0.24	0.24	0.16

	Ghana		Nigeria	
	Coefficient	**Std. Err.**	**Coefficient**	**Std. Err.**
Farmers' years of formal education	0.29**	0.14	0.10	0.08
Presence of reference child in the household	1.04***	0.26	0.15	0.16
Distance to the nearest agricultural field office (minutes)	-0.12	0.13	0.00	0.03
Constant	-2.38	1.72	-1.38	1.16
N	345		381	
Pseudo R2	0.4942		0.1518	
LR chi2(7)	217.06***		79.38***	

Dependent variable: Dummy variable indicating knowledge of OFSP varieties

***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively

4.4 ATE estimate of OFSP adoption rates

Table 5 presents the results of the estimation of the OFSP adoption rates. The desirable parameter in adoption studies is the full population adoption rate (ATE) which provides an estimate of the potential demand of the OFSP varieties by the target population. The full population adoption rate for OFSP is estimated to be 61 and 42 percent in Ghana and Nigeria, respectively. This implies that the OFSP adoption rate in Ghana and Nigeria could have been 61 and 42 percent in 2016 if the whole population had been exposed to OFSP varieties, instead of the sample adoption rates of 51 and 33 percent, respectively. Thus, when compared to the current sample adoption rates, there is a substantial population adoption gap of 10 percent due to the population's incomplete exposure to the OFSP varieties. These results indicate that the OFSP adoption rates could have been increased by 10 percent in 2016 if all farmers were aware of these varieties.

The adoption rate within a sub-population of farmers that are exposed to OFSP varieties (ATE1) is estimated to be 76 percent for Ghana farmers and 59 percent for Nigeria farmers, while the estimated potential adoption rate within the sub-population not yet exposed to OFSP varieties (ATE0) is 31 and 21 percent in Ghana and Nigeria respectively. These estimates are significant at different levels of 5% and 10%. A comparative analysis show that the Ghana farmers recorded better and higher adoption rates than their Nigerian counterparts. The adoption rate among the Ghana farmers exposed to OFSP is up to 76% (for ATE1) higher than the rate recorded for Nigerian farmers (59% of the Nigerian farmers exposed to OFSP).

***Table 5*: Estimates OFSP adoption rates (probability of adoption of OFSP variety)**

	Ghana (N=345)			Nigeria (N=381)		
	Parameter	**Std. Err.**	**P>z**	**Parameter**	**Std. Err.**	**P>z**
In the full population (ATE)	0.61	0.03	0.00	0.42	0.03	0.00
Within the OFSP-exposed subpopulation (ATE1)	0.76	0.02	0.00	0.59	0.02	0.00
Within the non OFSP-exposed subpopulation (ATE0)	0.31	0.06	0.00	0.21	0.04	0.00
Expected non-exposure bias (population adoption gap)	-0.10	0.02	0.00	-0.9	0.02	0.00
Expected population selection bias (PSB)	0.15	0.02	0.00	0.16	0.01	0.00
Observed: Sample estimate						
Ne/N	0.67	0.03	0.00	0.56	0.03	0.00
Na/N	0.51	0.03	0.00	0.33	0.02	0.00
Na/Ne	0.76	0.04	0.00	0.59	0.04	0.00

N: Number of observations

Na: Number of adopters

Ne: Number of respondents who have heard of OFSP

4.5 Determinants of Farmers' adoption of the OFSP varieties

Results of the probit model (for the restricted sub-sample of the exposed) on the factors affecting adoption of OFSP varieties are presented on Table 6. Results show that factors such as age, presence of reference child in the household, number of times respondent interacted with extension in 2016, high yielding, early maturity and very sugary/sweet varieties of OFSP contribute positively to the probability of adoption of OFSP varieties in Ghana. This implies that the more these variables becomes, the more likely the farmers will adopt the OFSP varieties in Ghana. Other factors such as "any man having a salaried job during the past year" and distance to the nearest main road contribute negatively to the probability of adopting the OFSP varieties in Ghana. This indicate that having more women with salaried job and having to cover longer distance to the main road renders the farmers less likely to adopt the OFSP varieties. In Nigeria, results indicate that being trained on sweetpotato production management, number of times respondent interacted with extension in 2016 and early maturity variety of OFSP contributed positively to the

probability of adoption of OFSP varieties. On the other hand, age of farmer and household having goats, sheep and/or pigs contributed negatively to the probability of adoption of OFSP varieties in Nigeria. For the Nigerian farming households, the results indicate that the more the farmers receive training on sweetpotato production management, the more the farmers interact with extension and the more the access to early maturity varieties, the more the likelihood of adopting the OFSP varieties. On the contrary, the more aged the farmer is and the more the number of goats, sheep and or pig in the household, the less likely the Nigerian farmer will adopt the OFSP.

***Table 6*: Results of Estimation of the factors affecting the adoption of OFSP varieties**

	Ghana		Nigeria	
	Coefficient	**Std. Err.**	**Coefficient**	**Std. Err.**
Farmer characteristics				
Age of farmer (years)	1.10**	0.47	-0.26*	0.15
Gender of the farmer (1=male; 0=otherwise)	-0.19	0.31	0.001	0.32
Farmers' years of formal education	0.04	0.12	0.10	0.14
Presence of reference child in the household	0.65*	0.35	0.23	0.26
Farm assets/resources				
Average farm size owned (hectares)	0.10	0.28	-0.05	0.16
Any man in the household had salaried job during the past year (1=yes; 0=otherwise)	-0.78*	0.43	0.23	0.28
Any woman in the household had salaried job during the past year (1=yes; 0=otherwise)	-0.91	0.58	0.22	0.30
Household has cattle and/or donkeys (1=yes; 0=otherwise)	0.16	0.32	0.88	0.63
Household has goats, sheeps and/or pigs (1=yes; 0=otherwise)	0.18	0.39	-0.52**	0.25
Household has chicken, rabbits and/or ducks or doves (1=yes; 0=otherwise)	0.87	0.82	0.33	0.29
Institutional factors				
Being trained on sweetpotato production and management (1=yes, 0=otherwise)	0.59	0.37	1.01***	0.32
Farmer belongs to a group/association (1=yes; 0=otherwise)	-0.48	0.33	0.06	0.29
Distance to the nearest main road (minutes)	-0.22**	0.11	-0.10	0.10

Number of times respondent interacted with extension in 2016	0.31***	0.10	0.07*	0.03
Variety attribute variables				
Variety high yielding	0.91***	0.34	0.61	0.58
Early maturity	1.53***	0.30	1.59**	0.48
Cooks quickly/Faster or Ease of cooking	0.56	0.40	0.55	0.48
Very Sugary/Sweet	1.20***	0.39	-	-
Resists Diseases	-0.32	0.41	-	-
Constant	-6.64***	2.19	-1.66	2.14
N (number of observations)	230		193.00	
Pseudo R2	0.624		0.4649	
Wald chi2(19)	117.69***		76.98***	

Dependent variable: Dummy variable indicating the cultivation of OFSP varieties in 2016

***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively

5. CONCLUSIONS AND RECOMMENDATIONS

Building on the modern evaluation technique and the theoretical approach of Diagne and Demond (2007), this paper examined how heterogenous information flow within farmers' population affects their decision to adopt OFSP in West-Africa. We found that There is potential for increasing dissemination rate among population. The awareness rate about OFSP varieties in the populations in both countries is still relatively low (not yet completed). These findings point to the importance of improving sweetpotato farmers' access to knowledge about OFSP varieties and their benefits that would play significant role in their adoption. We found that the OFSP adoption rates could have been up to 61 percent in Ghana and 42 percent in Nigeria in 2016 instead of the observed sample adoption rate of 51 and 33 percent if the whole population was exposed to the OFSP varieties. Our study has showed that the OFSP adoption is influenced by a number of factors, which vary between the study countries. This implies that actions to increase the adoption rate shouldn't be "one size fits all solution" approach. Instead, actions should be country specifics.

Another important constraint to the adoption of OFSP has to be foreseen, once the dissemination one sorts out: the availability of OFSP planting material. Our findings showed that most of the interviewed sweetpotato farmers in both countries source their planting materials from

own farms, including the actual OFSP adopters. The observations in the fields are that even the OFSP producers just buy part of OFSP vines they need and produce the remaining by themselves. The implications for policy makers and development support partners is that further institutional supports are still needed to significantly increase OFSP awareness and adoption rates among communities, and therefore to spillover the positive and significant impacts of these actions on households' nutritional status.

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