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Effect of agriculture-nutrition education and extension services on early adoption and diffusion of biofortfied crops: The case of orange-fleshed sweetpotato in Kenya

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Abstract:

Biofortification of crops to combat micronutrient deficiencies is gaining global recognition. Projects promoting biofortified crops use intensive agriculture-nutrition education and extension to increase adoption of such crops. This study used discrete choice regression analysis and data collected from households targeted by a project with one of the most intense agriculture-nutrition education and extension program to test the effect of such program on the adoption and diffusion of biofortfied crops. The study was conducted in western Kenya and involved 537 households with children under 5 years, a pregnant or lactating women. The study finds that intensive agriculture-nutrition education and extension programs adopted by some of the biofortification projects indeed increases the likelihood of adoption and diffusion of biofortified crops. It specifically finds that participation in events that offer practical education on the agronomy and preparation of foods from such crops, participation in mother-to-mother nutrition support platforms and nutrition-focused health talks affect adoption and diffusion of biofortified crops, but with varying degrees of importance. Among control factors, ability to conserve the planting material over dry period and household assets-endowments are important in both adoption and diffusion of biofortified crops. The paper discusses the implications of these findings.

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adoption and diffusion of biofortified crops. The paper discusses the implications of these findings.

Key words: Biofortified crops, adoption and diffusion, agriculture-nutrition education and extension, vulnerable households, Kenya

Introduction

The importance of biofortified crops in combating the widespread incidence of micronutrient deficiency is now widely acknowledged globally (Hotz et al, 2012; Low et al, 2017). This recognition is exemplified by the recent award of the 2016 World Food prize to biofortification, and is a result of efforts in several developing countries to scale up the production and consumption of these crops. This recognition has energized the biofortofication community in its push to reach millions of households affected by problems associated with micronutrient deficiencies globally. In sub-Sahara Africa, for instance, a biofortification platform organized around sweetpotato, known as Sweetpotato for Profit and Health Initiative (SPHI), has the target of reaching 20 million households with improved/nutritious sweetpotato varieties and by 2020. The platform is a response to high incidence of malnutrition in Sub-Sahara Africa (SSA). The World Health Organization (WHO) indicates that 59 million children in Africa suffer from some form of malnutrition (WHO, 2017), and that Africa is the only continent where progress against malnutrition remains stubbornly slow. For instance, stunting, on average, declined in Africa only between 38.3% in 2000 to 31.2% in 2016, thus averaging less than one-half the rate of decline in Asia and Latin America.

Despite the drive to reach many more households with biofortified crops in SSA and globally, questions remain about the uptake of such crops by the targeted vulnerable households. Specifically, i) what influences households' decision to continue planting biofortifed crops after the initial project-level interventions? ii) what factors facilitate, or otherwise, the diffusion of such crops in project communities through farmer-to-farmer sharing of planting materials? This paper examines the effect of a combination of intensive agriculture-nutrition education and extension services provided by projects (and project partners) that promote the cultivation and consumption of biofortified crops influence adoption and diffusion of such crops within the local communities targeted by such projects.

Majority of biofortification projects often use very robust promotion efforts that encompass both intensive nutrition and agriculture education and extension. Under such campaigns, targeted households receive information about the benefits of biofortified crops in tackling micronutrient deficiency, and for food security in general, at the local health facility, during home visits and in

community nutrition-focused clubs. The informational sensitization is, in some of the projects, followed by structured intensive nutrition education focusing on how to incorporate biofortified crops into local diets and in children's weaning foods. At the same time, targeted beneficiaries are linked to sources of planting materials, and provided with agronomic information about the production of biofortified crop and on-farm seed maintenance. They further receive regular extension visits by local health promoters to reinforce information and training received at the local clinics. The agronomic information is provided in the form of handouts or verbal narratives, and is accompanied by demonstration of planting and nursery care of the biofortified the material, usually by agricultural extension agents and community-based seed multipliers. Ultimately, cooking demonstrations are conducted in which incorporation of the biorfortifed crop into local menus is illustrated and recipes shared. In some countries, these activities are conducted by community development nutrition-agriculture promoters.

This study uses data collected a project that had one of the most intensive agriculture-nutrition education and extension programs to tests two hypotheses, namely that intensive agriculture-nutrition education and extension services project by biofortification projects increase: i) sustained adoption of biofortified crops by targeted households, and ii) the diffusion of such crop through farmer-to-farmer sharing of planting materials. The paper analyses early adoption of biofortified crops focusing on drivers of adoption and diffusion of a biofortified crops 1-2 years following the initial project intervention activities.

The study is based on data collected from 537 households that received planting materials of pro-vitamin A-rich orange-fleshed sweetpotato (OFSP), a biofortofied crop with proven efficacy against vitamin A deficiency, combined with intensive agriculture and nutrition education and extension activities. Our study is similar to that of De Groote et al (2016) which examined the effect of nutrition-agriculture extension on adoption of biofortified crops. It, however, differs from their study in several key respects. First, rather than focusing only on extension-related promotion, we study a case where targeted households had structured education on nutrition and agronomic practices followed by a series of extension messages at the source of planting material, in their homes (by extension officers) and during regular field and open days. Second, during open days and cooking demonstration sessions the nutrition/health benefits of OFSP, and

the planting and care for the crop, were discussed. Third, the nutrition and agronomic messages relayed through physical contacts were reinforced by radio programs aired in vernacular via interactive local FM radio.

This paper specifically focuses on households that benefited from a 4-year project designed to tackle vitamin A deficiency in five Countries of western Kenya by scaling up sweetpotato through agriculture and nutrition (hence the name, SUSTAIN). The project targeted households that are vulnerable to vitamin A deficiency, namely, those with children under 5 years of age and/or pregnant and lactating woman. The households were recruited at the local health facilities (which also acted as the first point of nutrition education) and linked to multipliers of OFSP planting materials and field extension staff. The combination of nutrition and agriculture education and extension therefore presents an interesting case to study.

The rest of this paper is organized as follows: Section 2 presents the study context and describes the project education and extension design. Section 3 discusses the study methods and sampling design while Section 4 discusses the findings of the study. Section 5 presents the conclusions and policy implications

2. Study context

This study was conducted in Nyamira, Homa bay, Siaya, Counties of western Kenya where SUSTAIN project had operated since 2014. Western Kenya has high incidence of malnutrition and poverty (Kenya National Bureau of Statistics, 2015). Official government statistics for Homa bay county, for example, indicate that only 22% of children 6-23 months old receive adequate feeding. It is also estimated that only 41% of 0-5 months old children have early breastfeeding initiation, with only 35% of them being exclusively breastfed, and that 50% of the 6-23 months old children receive minimum acceptable diet (Kenya National Bureau of Statistics, 2013).

In each of the study counties the project worked closely with the Ministry of Health and Ministry of Agriculture staff to implement the project activities. The former was responsible for promoting the consumption of OFSP as part of household diet through what is known as the

food-basket approach. The Ministry of Agriculture, on the other hand, provided extension services. We discuss the responsibilities of each of these public-sector collaborators/partners in the roll-out of the SUSTAIN project activities in detail below.

2.1. Role of the Ministry of Health Department in SUSTAIN project implementation

The ministry of health (MoH) played a key role in identifying and recruiting the beneficiaries of the SUSTAIN project. The targeted individuals comprising pregnant and lactating women were recruited at the local health facilitates during their routine antenatal and postnatal visits.

In each health facility, the project involved Community Health Workers (CHWs) who, in turn, worked with a team of Community Health Volunteers (CHVs) under each Community Units[1] (CU). The project team prepared and passed on the education materials (including illustrative charts and handouts) to the CHWs for use during nutrition education sessions. The strategies used by CHWs to train targeted beneficiaries included: i) nutrition messaging in form of health talks at the ante- and post-natal clinics and mother-to-mother (M2M) support clubs, ii) nutrition counselling (i.e., one-to-one education/training on recommended maternal and child nutrition), iii) cooking demonstrations illustrating how to incorporate OFSP products (especially cooked roots and leaves) in weaning and baby foods for children and local foods for the rest of family, iv) health-talks during field days, open days, agricultural fairs and stakeholder meetings. Further, the project conducted radio talk shows, in local vernacular FM stations, that discussed nutrition, vitamin A importance and prevalence of vitamin A deficiency and answered call-in questions from the listeners.

Additional nutrition education was provided during the open day events. Participants of these events learned about child feeding practices using the nutrition counselling cards that were adapted to emphasize incorporation of OFSP into diets to contribute to the fight against vitamin A deficiency, especially among children under the age of 5 years, and pregnant/lactating

[1] A Community Unit is defined as a health service delivery structure within a designated geographic area covering a specified population manned by a community health volunteer who promotes various health services.

mothers. Open day participants also participated in cooking demonstrations that illustrated how OFSP can be incorporated into weaning and adult foods, suitable cooking times for OFSP roots, leaves and OFSP-based local foods. They then sampled some of the pre-cooked OFSP-based foods.

The CHVs reinforced the information received at the clinics, M2M clubs and other events during home visits to the targeted household, thus providing nutrition extension services. The project and MoH adopted a social and behavior change communication (SBCC) campaign strategy in implementing the nutrition education and targeted some of the personal, economic, environmental, and cultural and social factors likely to influence household's decision to grow and consume.

2.2 Role of Ministry of Agriculture Department

The ministry worked closely with project agronomists to backstop multipliers of OFSP planting materials in providing agronomic information and were also in contact with targeted households. The agricultural education/extension contacts were mainly through open days and field days.

During the open day, the participating targeted/project beneficiaries were taken through a structured hands-on/ practical training on sweetpotato agronomy using a module jointly prepared by the project agronomist (specialized in sweetpotato agronomy) and agricultural extension staff. As part of the agronomic training, the participants of the open day typically learn about planting practices including: preparation of planting/seed beds (e.g., ridges and mounds), recommended length of sweetpotato cuttings, spacing of the plants, weeding, timing of harvest and postharvest handling. The participants also learn about sweetpotato pests and diseases and their identification.

Field days were, on the hand, less intense and takes a show-and-tell approach. During field day events, the participants walked through sweetpotato demonstration plot with an agronomist explaining the key agronomic practices, pest and disease identification and management, harvesting regime and post-harvest handling. The agronomist then fielded any questions arising.

They were used by extension staff to educate farmers about suitable practices for growing OFSP to optimize production.

3. Research methods

3.1 Theoretical framework

A household will adopt a new technology if it has relative advantage over the existing technology (Rogers, 1995, Beceril and Abdulai, 2010). More specifically, the decision to adopt a new technology is driven by the benefits and costs of doing so (Ali et al, 2012). The adoption literature further posits that such decision is a function of several farmer and farm level characteristics, capital/asset endowment factors, institutional factors as well as fixed and quasi-fixed factors (Shiferaw et al, 2007; Otieno et al, 2012; Okello et al, 2017).

The decision to adopt a new variety of sweetpotato (i.e., the biofortified OFSP) can be analyzed using binary choice models. This study applied binary logit regression model to assess the factors that influence early adoption OFSP. The logit regression model used is expressed, following Gujarati and Porter (2009), as:

$$P = \frac{e^{z}}{1 + e^{\sigma}} \tag{1}$$

where P is the probability that a household used CSP and δ is a latent variable that takes the value of 1 if the farmer used quality seed, and 0 otherwise. Transformation Equation (1) yields:

$$\sigma = \ln\ (\frac{\mathrm{P}}{1-\mathrm{P}}) \tag{2}$$

where,

$$\sigma = F(X, V, T, K, z) + \epsilon \tag{3}$$

In the above formulation, X usually represents a vector of inputs such as seed (i.e., planting material), fertilizer, manure, and agrochemicals namely, insecticides and fungicides used by the farmer, V is a vector of embodied OFSP varietal traits such as good taste, ease of cooking, higher pest and disease tolerance, early maturity and high-yielding ability; T is the total labor requirement, comprising family labor and hired labor. The vectors, K and z are fixed capital inputs which represent the assets owned, and institutional factors including, membership to farmer organization and access to credit, respectively. Lastly, **ε** is the stochastic term, assumed to

have a normal distribution. Most farmers do not apply fertilizer, manure and agrochemicals on sweetpotato, hence X is expected to comprise planting material only.

The implicit functional form of the empirical logit regression model used to test the first hypothesis, based on Equation 3, can be expressed as:

$$plantofsp = f(lnwomanage, lndistmkt, lndisthealth, M2Mclub; fmradio, openday, fieldday, dvmvines, womanedu, womansal, livestockval, lnassetval, lowland, chvvisit) + \varepsilon \qquad (4)$$

Where *plantofsp* represents household decision to plant OFSP one year after initial project dissemination; *womanedu* is level of education of the women with child under 5 years or age or who is pregnant in the household; *lnwomanage* is the natural logarithm of respondent's age; *lndistmkt* is the natural logarithm of distance to nearest market; *fmradio* is a dummy variable for listening to local FM radio station; *lndisthealth* is the natural logarithm of distance to nearest health center/clinic; *M2Mclub* is a dummy variable for participation in mother-to-mother nutrition support clubs; *openday* is a dummy variable for participating in project-organized open day events; *fieldday* is a dummy variable for participating in project-organized field day events; *dvmvines* is a dummy variable for collecting vines[2] from a decentralized vine multiplier (DVM); *lowdland* is a dummy variable household owning land or plot in the lowlands; *lnassetval* is the natural logarithm of the value of physical assets (excluding livestock); *lnlivestockval* is the natural logarithm of the value of livestock assets; *chvvisit* is a dummy variable for household being visited by a CHV to discuss OFSP; and ε is the stochastic term.

The variables *lndisthealth, M2Mclub; fmradio, openday, fieldday, dvmvines* are included in the model in Equation 4 to capture the agriculture-nutrition education and extension activities of the project, and are henceforth referred to as agriculture-nutrition education and extension variables. They are therefore used in testing the two hypotheses regarding the effect of project education and nutrition extension program on adoption and diffusion of OFSP varieties.

[2] Vines comprise the above-ground stalks and leafy parts of the sweetpotato from which planting materials are extracted. We therefore use sweetpotato vines and planting materials interchangeably in this paper.

The second hypothesis, namely that intensive agriculture-nutrition education activities increases diffusion of OFSP through farmer-to-farmer sharing, was also tested using a logit regression model. The implicit functional form of model use is expressed as:

$$sharevines = f(lnwomanage, lndistmkt, lndisthealth, M2Mclub; fmradio, openday, fieldday\ dvmvines, womanedu, womansal, livestockval, lnassetval, lowland, chvvisit) + \varepsilon \qquad (5)$$

where the dependent variable, *sharevines*, is a dummy variable equal to 1 if a direct project beneficiary gave out vines to another farmer/neighbor, and 0 otherwise, and the rest of the variables (i.e., the independent variables) are as earlier defined.

3.2 Sampling and data

The sampling of the survey respondents proceeded as follows: First counties where SUSTAIN project and its partners distributed vines and conducted agriculture-nutrition education and extension activities since 2014 were purposively selected. The choice of 2014 ensured that direct project beneficiary households had at least one cropping season to plant vines from their own sources, and without the project's intervention, and at least one season of vine sharing. This resulted in the selection of Homa bay, Siaya and Nyamira countries (See Figure 1). Second, within each county, a list of all the health facilities that participated in the project was drawn with the help of the project staff and the County Health Department link persons namely, the CHWs and the senior community health volunteer (SCHV). Third, within each facility, a list of direct project beneficiaries of sweetpotato vines and agriculture-nutrition education and extension activities was obtained from project implementing partners and validated with the help of CHVs. Lastly, respondents were randomly selected from the list of the direct beneficiaries in each health facility using probability proportionate to size sampling technique. That is, a facility with more beneficiaries had more respondents selected from it, and vice versa. This procedure yielded 560 respondents. However, 23 respondents could not be interviewed due to refusals, absences and relocations, resulting in 537 completed interviews and a non-response rate of 4.1%.

Figure1: Maps showing the study counties

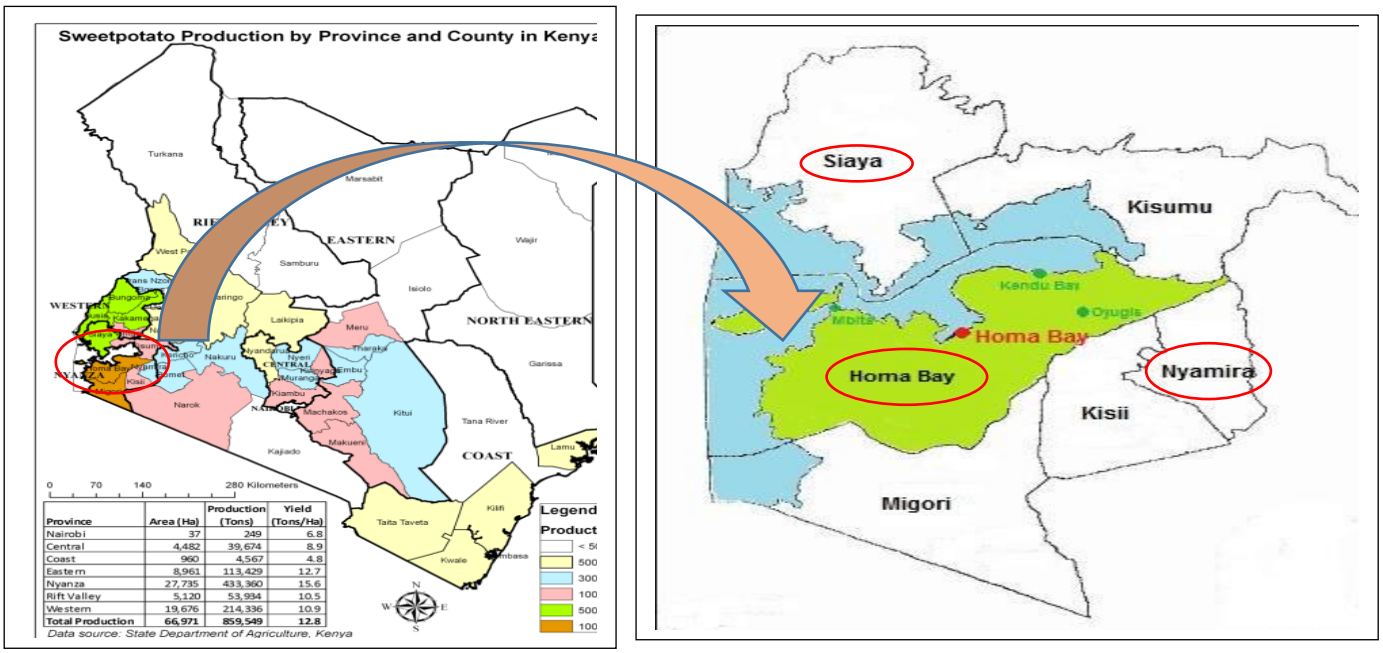


Table 1 below presents the distribution of the respondents by country and CU, and the study locations, respectively. Table 1 shows that the majority of the respondents were from Nyamira county, with Siaya County contributing less than 20%. This is mainly because Nyamira had a higher proportion of households and individual that had interacted with the project compared to the other counties.

Table 1: Distribution of respondents by county and health facility

County	Community unit	Respondents (#)	Percentage
Siaya (N=95)			
	Dienya	49	50.52
	Sirembe	48	49.48
Nyamira (N=224)			
	Cherachani A	67	30.18
	Miruka	95	42.79
	Charachani	60	27.03
Homa Bay(N=218)			
	Kakangutu East	46	21.20
	Kakelo Kamroth	23	10.60
	Kakelo Dudi B	39	17.97
	Kasewe B	1	0.46
	Kakelo Dudi A	73	33.64
	Rongo Pala	8	3.69
	Kakangutu West	20	9.22
	Got Ber	7	3.23

3. Results

3.1 Characterization of study household

The characteristics of the study respondents are presented in Table 2. A large majority (99.1%) of the respondents were females, mostly because the study focused on caregivers of children under 5 years of age and pregnant or lactating women. The average age of respondents was about 31 years, with no statistically significant differences among the study counties. The low average age is likely due to the fact that the project targets households with women of reproductive age. Table 2 also shows that the respondents had, on average about 8 years of schooling, which is equivalent to primary level of education in Kenya, thus indicating that the project's target group had relatively low level of education. The low level of education has implications on the kinds of behavior change communication strategies that are effecting in influencing behavior towards incorporating OFSP into household and children's diets.

The data further show that majority (about 73%, overall) of the respondents undertook farming as the primary occupation. Specifically, 76% of the respondents in Siaya and Nyamira and 79% in Homa bay had farming as the main employment. Only about 8% of the respondents, overall, had salaried employment while about 5% worked off-farm.

The results also show differing levels of participation in agriculture-nutrition education and extension activities. Specifically, results show statistically significant differences in participation in health talks, contact with CHVs, and radio talk shows, among the nutrition education and extension activities. For instance, a higher proportion of respondents in Nyamira and Homa bay participated in health talks than in Siaya. Similar, there were statistically significant difference in participation in open days and field days, and in collecting vines from DVMs, which were sources of both nutrition and agricultural education. A higher proportion of households in Homa bay, for example, participated field days than in Nyamira.

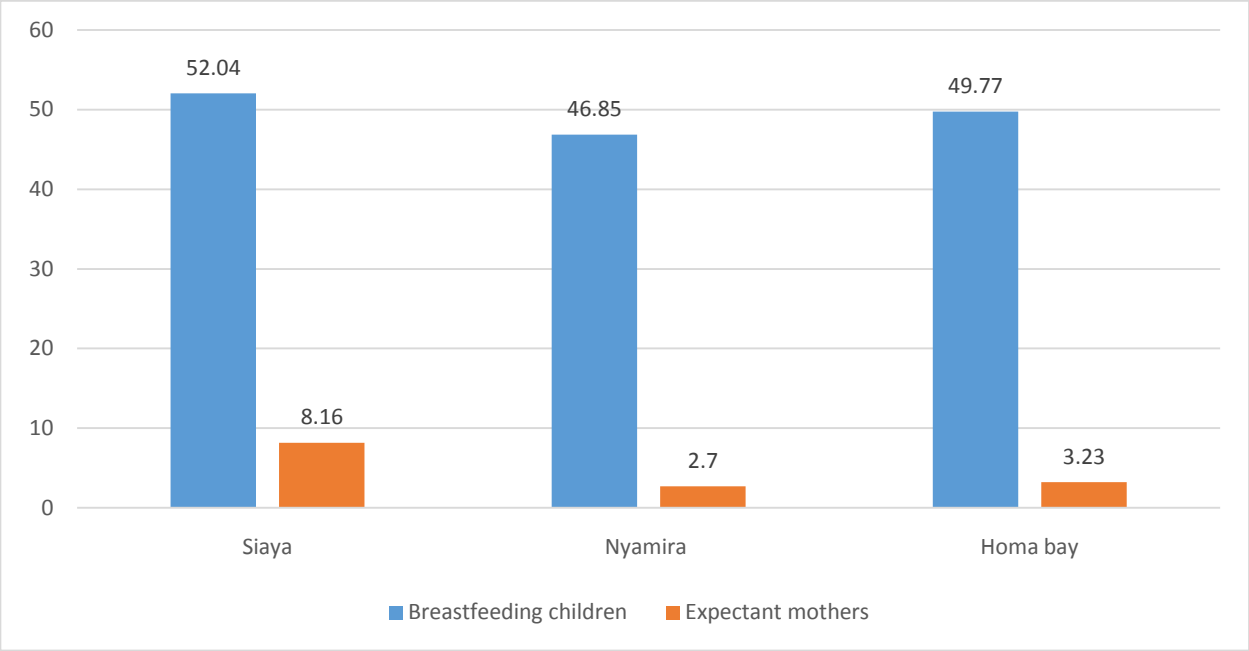
Table 3: Variable definition and characteristics of study respondents, by country

Variable	Variable definition	County			Overall (n=537)	p-values*
		Siaya (n=98)	Nyamira (n=222)	Homabay (n=217)		
womanedu	Number of years of formal education of the woman	8.18[a]	8.66[a]	8.69[a]	8.59	0.287
womansal	Salary (Kshs) earned by the woman in one year	2.04[ab]	4.95[a]	14.29[b]	8.19	0.000
distdvm	Distance (walking minutes) to nearest DVM	43.13[a]	40.94[a]	42.06[a]	41.80	0.839
disthealth	Distance (walking minutes) to nearest health center	36.39[a]	28.96[b]	34.92[a]	32.71	0.000
distmkt	Distance (walking minutes) to nearest market	38.01[a]	36.82[a]	37.69[a]	37.39	0.924
nationalradio	Woman listens to national radio 1=yes;0=otherwise	8.20[a]	18.02[b]	15.28[ab]	15.11	0.076
clinics	woman visits ante/post-natal clinics 1=yes;0=otherwise	69.39[a]	68.47[a]	60.37[a]	65.36	0.133
healthtalks	Woman participates in project organized health talks 1=yes;0=otherwise	19.39[a]	34.23[b]	41.01[b]	34.26	0.001
cookdemos	Woman participates in project-organized cooking demonstrations 1=yes;0=otherwise	58.16[a]	53.15[a]	60.83[a]	57.17	0.262
fieldday	Woman participates in project-organized field days, 1=yes;0=otherwise	28.57[a]	36.49[a]	43.32[ab]	37.80	0.038
M2Mclub	Woman participates in project-organized mother clubs 1=yes;0=otherwise	34.69[a]	42.34[a]	46.54[a]	42.64	0.144
chvvisist	Household was visited by a CHV to discuss OFSP 1=yes; 0=otherwise	74.49[a]	84.68[b]	88.48[b]	84.36	0.007
lowland	Household owns land or plot in the lowlands, 1=yes; 0=otherwise	21.67[a]	25.31[a]	29.37[a]	26.50	0.446
fmradio	Woman listens to local FM radio stations 1=yes; 0=otherwise	73.47[a]	80.18[a]	86.63[a]	81.56	0.175
openday	Woman participates in project-organized open days 1=yes; 0=otherwise	57.14[ab]	52.25[a]	63.59[b]	57.73	0.055
dvmvines	Household received vines from a decentralized vine multiplier (DVM) 1=yes; 0=otherwise	29.59[ab]	22.52[a]	45.16[b]	32.96	0.000
assetvalue	value (Kshs) of physical assets (excluding livestock)	988.78[a]	2265.32[b]	1948.85[b]	1904.45	0.000
stockvalue	Value (Kshs) of livestock assets	85140.97[a]	102844.80[a]	129368.80[a]	110332	0.387

* p-values of Sidak multiple comparison tests of differences in means; Superscripts **ab** indicate statistically significant difference while **aa** and **bb** indicate no difference.

Figure 2 shows the number of respondents that had breastfeeding children or were pregnant at the time of the study. It shows that about 50% of the respondents in all the counties still had breastfeeding child or were lactating or pregnant woman at the time of the study. However, a much lower percentage of respondents (i.e., less than 10% in all the study counties) were pregnant at the time of the study.

Figure 1: Study respondents that met project's eligibility[3] criteria at the time of the study, % of responses



4.2 Factors affecting farmer-to-farmer diffusion of OFSP varieties

The results of a logit regression model estimated to assess the effect of agriculture-nutrition education and extension are presented in Table 3. The model is based on robust standard errors, implying that estimation procedure took into account any form of heteroskedasticity, a statistical problem that renders estimated parameters inefficient/imprecise. Among the agriculture-nutrition education and extension variables, participation in field days and mother-to-mother clubs were

[3] For a household to be eligible to receive SUSTAIN interventions, it needed to have a child under 5 years of age, a pregnant/expectant woman or a lactating woman.

dropped from the final model, along with some other explanatory variables including distance to DVM and distance to health facility, proxies for ease of access to education and extension services, after the Wald joint exclusion restriction test showed that they explain very little of the variability in early adoption of OFSP.

Table 3: Results of the logit regression model estimated to determine the factors affecting the decision to plant vines one year later

Variable	Coefficient	p-value	dy/dx	p-value
lnwomanage	0.31	0.343	0.06	0.334
localfm	0.49	0.081	0.10	0.100
openday	0.61	0.006	0.12	0.008
lnassetval	0.13	0.180	0.02	0.181
lndisthealth	0.25	0.129	0.05	0.136
dvm	3.53	0.000	0.48	0.000
womaneduc	-0.02	0.204	-0.00	0.208
womansal	-0.58	0.039	-0.11	0.040
lnstockvalue	0.17	0.023	0.03	0.027
lowland	1.29	0.000	0.19	0.000
lndistmkt	-0.11	0.409	-0.02	0.412
chvvisit	-0.13	0.676	-0.02	0.668
Contant	-5.27	0.002		
N = 525; Wald chi2(12) =85; p-value =0.000; Pseudo R^2= 0.286				

As shown, two of the variables representing project-related agriculture-nutrition education and extension activities had a positive and statistically significant effect on the decision to plant OFSP. These are information from local FM stations about OFSP (*fmradio*) and participation in open days (*openday*). Specifically, listening to a local vernacular FM radio program about OFSP statistically significantly, albeit weakly, increases the likelihood of early adoption of OFSP. Column 4 of Table 3 presents marginal effects of the variables. It shows that listening to local FM radio program on OFSP increases the likelihood of early adoption by 10%, other things constant. The results further show that participation in open days statistically significantly increases the likelihood of adopting OFSP by 12%, other things constant. Unlike the case of listening to radio, participation in open days has a strong significant effect, being significant at 1% level significance. The above results therefore indicate that listening to radio talk shows about the importance of OFSP and how to grow it, and especially that participation in open day events where practical training on growing and utilizing OFSP as a young-child and family food,

increases the likelihood of continuing to plant OFSP after the initial project dissemination of free orange-fleshed sweetpotato vines.

The results also show that respondents who collected vines from the DVMs, and therefore received some basic education on sweetpotato agronomy and nutrition, were more likely to continue planting OFSP. Collecting vines increases the likelihood of early adoption of OFSP by 48%, other things constant. The magnitude of this effect and the fact that the coefficient is highly significant (p-value = 0.000), indicates that beneficiaries who obtain their planting materials from the DVMs are very likely to continue planting OFSP after the initial dissemination and promotion efforts by the project. This could be due to the fact that DVMs are not only sources of vines and basic agronomic and nutrition information but also are model farmers and a source of inspiration to OFSP farmers. Indeed, one of the criteria used during the selection of the DVMs was being a role model in the community. The study however finds no evidence that extension visits by CHVs to reinforce nutrition education received at M2M clubs and health clinics/facilities affects the likelihood of continuing to plant OFSP after the initial project activities.

Among the conditioning variables, participation in salaried employment by the eligible[4] woman in the household, value of livestock assets owned (one of the proxies for household wealth status), and having a plot in the lowlands all affect the decision to plant sweetpotato vines one year after the initial project dissemination. As shown in the third column of Table 3, an increased in the value of livestock assets by one unit increases the likelihood of planting OFSP one year after by 3%. The results also show that having land in the lowlands (a proxy for ability to conserve planting material over the dry season) increases the likelihood of early adoption of OFSP by 19%, other things constant. On the other hand, women's participation in salaried employment reduces the likelihood of continuing to plant OFSP by 11%, other things constant. The findings that wealth status of the household and ability to conserve vines increases the early adoption of OFSP corroborate those of Okello et al (2015).

[4] As discussed above a woman's eligibility to participate in the SUSTAIN project was being pregnant or mother of a child under the age of 5 years.

4.3 Factors affecting the diffusion of OFSP beyond project households

The results of model estimated to assess the factors driving decision to share vines with other farmers in the community (that is, the diffusion), and to test the effect of nutrition and extension activities on diffusion of OFSP varieties are presented in Table 4. As in the previous model, the standard errors are robust to any form of heteroskedasticity. In addition, following the Wald joint exclusion restriction test, we dropped two of the agriculture-nutrition education and extension variables from the final model after the test showed that they explain very little of the variability in dependent variable (i.e., vine sharing). The variables dropped were cooking demonstrations and field days. They were dropped along with distance to DVM and value of non-livestock/physical assets.

As shown in Table 4, among the agriculture-nutrition education variables, participation in health talks and in M2M clubs are the only variables that positively influence decision to share vines with neighbors (other farmers).

Table 4: Results of the logit regression model estimated to determine the factors affecting the decision to disseminate vines

Variable	Coefficient	p-value	dy/dx	p-value
lnwomanage	0.05	0.855	0.01	0.855
localfm	0.03	0.920	0.01	0.920
openday	0.15	0.533	0.12	0.530
healthtalks	1.007	0.000	0.19	0.000
M2Mclub	0.45	0.054	0.08	0.057
dvmvines	0.28	0.222	0.05	0.232
womaneduc	0.03	0.057	0.01	0.059
womansal	0.32	0.172	0.05	0.179
lnlivestockval	0.16	0.026	0.03	0.026
lowland	0.66	0.011	0.13	0.021
chvvisit	-0.50	0.094	-0.09	0.117
Contant	-5.27	0.010		
N = 526; Wald chi2(12) =48.18; p-value =0.000; Pseudo R^2= 0.0944				

The results (see Column 4) specifically show that participation in M2M clubs increases the likelihood of sharing OFSP with other farmers by 8%, holding other factors constant. At the same time, participation in health talks increases the likelihood of sharing vines with neighbors by 19%, holding other factors constant. The third agriculture-nutrition education and extension variable, that is CHV visit has negative effect on the sharing of vines. This, perhaps, indicates

that extension visits by the CHVs had the effect of dampening the diffusion of OFSP as project's direct beneficiaries held onto their vines to multiply them further in order to produce more OFSP for their households. The project provided only 200 cuttings of the vines, which can only plant a very small plot of land, usually with the expectation that the direct beneficiaries will multiply the vines further. Indeed, the CHVs are expected to emphasize the importance of conserving and multiplying the vines to ensure that sufficient OFSP roots are produced to meet the family requirements. Therefore, this finding is in line with our expectations. Nonetheless, the effect of this variable (i.e., CHV extension visits) on the sharing of vines is very weak, and vanishes when marginal effects are computed.

Given the differential (i.e., one negative and others positive) effects of the agriculture-nutrition education and extension variables on diffusion, we tested the overall effect of these variables on OFSP diffusion using Wald multiple exclusion restriction test. Specifically, we tested if the four variables in the estimated model (i.e., *fmradio*, *openday*, *M2Mclub* and *chvvist*) have joint significant effect on vine-sharing, and the direction of that effect. The test yielded a chi-square statistic of 25.42 and p-value of 0.000, indicating that the four agriculture-nutrition education and extension variables have joint significant and positive effect.

A number of conditioning variables also influenced the decision to share vines with other farmers/households. They include education level of the eligible woman in the household, value of livestock assets owned by the family (a proxy for household wealth status), and having land/plot in lowlands (hence the capability to conserve vines over the dry period). All these control variables have positive and significant effect on the diffusion of OFSP varieties, and are in line with *a prori* expectations and adoption literature (Rogers, 2003; Abdulai and Hufmann, 2005; Alene and Manyong, 2006; van der Boor et al, 2014; Okello et al, 2015).

5. Summary conclusions and implications

This study investigated the effect of an intensive agriculture-nutrition education and extension program offered through a project promoting the cultivation and consumption of orange-fleshed sweetpotato (OFSP), a biofortified crop rich in vitamin A. The study tested two hypotheses, namely, that intensive agriculture-nutrition education and extension activities increase: i) the

adoption of OFSP varieties, and ii) the diffusion of OFSP through farmer-to-farmer sharing of OFSP vines (i.e., planting materials). It used discrete choice regression analysis and data collected from 537 households in three counties of western Kenya. The study focused on households with children under 5 years of age, a pregnant woman or lactating woman, that is, household vulnerable to vitamin A deficiency. The nutrition-agriculture education and extension program was based on a well-structured intensive social and behavior change communication (SBCC) strategies. The SBCC strategies used included open day and field day events, nutrition-focused health talks at the health clinics and mother-to-mother support clubs, home visits by community health volunteers (CHVs) to reinforce training received at health facilities and support clubs, and some basic agronomic and nutrition messaging at the decentralized multipliers of sweetpotato vines (i.e., DVMs).

The study finds that participation in open days, listening to FM radio program on OFSP, and collecting vines from the DVMs significantly increased the likelihood of continuing to grow OFSP. It also finds that participation in health talks and mother-to-mother support clubs significantly increased vine-sharing, while home visits by CHVs reduced the probability that direct beneficiaries will share vines with other farmers. Among the control variables, owning land/plot in the lowlands and household endowment with assets increased the likelihood of both early adoption and vine-sharing.

This study therefore concludes that the intensive agriculture-nutrition education and extension program promoted by the project increased continued cultivation of OFSP after the initial project dissemination and promotion activities. The study also concludes that the intensive agriculture-nutrition education and extension program increased farmer-to-farmer vine-sharing.

The findings of this study have several implications. First, the findings relating to open-day and field-day events clearly highlight the importance of combining both information sensitization efforts (e.g., heath and agronomic talks) with practical demonstrations in the adoption and diffusion of biofortied crops. Second, the strong significance of DVMs in continued cultivation of OFSP demonstrates the importance of social factors (role models) in promoting adoption of biofortified crops. Indeed, a recent study in Malawi also highlighted the significance of social norms in access to extension services in potato production (Mudege et al, 2016). Third, the finding that household's asset-endowment influences OFSP adoption and diffusion is interesting.

It may imply that farmers perceive OFSP production as a costly investment, probably because of the effort needed to conserve vines over the dry season. This finding needs further investigation. Fourth, the study has further highlighted the importance of quasi-fixed assets, namely, access to lowlands, in the production of OFSP. This probably illustrates the challenge farmers face in conserving vines, and implies the need to search for and promote varieties that are tolerant to moisture stress in drought-prone areas.

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