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Does nutrition education influence retention of Vitamin A bio-fortified orange-fleshed sweet potato in farms? Evidence from Kenya

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Abstract

Vitamin A deficiency (VAD) still remains a major nutritional concern in Sub-Saharan Africa. Orange-Fleshed Sweet potato (OFSP) is bio-fortified with Vitamin A and has been globally recognized as the best food-based approach to combat the VAD menace. However, sustainability of its adoption is in question as many farmers still depend on free vines dissemination programs. This paper assessed the immediate effects of providing integrated nutrition education interventions, through different entry points, on the households' retention of the crop on their farms. Primary data were collected from three randomized nutrition education approaches in a controlled experiment with 360 preschooler-caregiver pairs in 15 villages in Homa Bay County, Kenya. A binary logit and special regressor model were employed to estimate the treatment effects. The results show that channeling nutrition education through single entry points do not have significant immediate effects on replanting of OFSP. Conversely, providing nutrition education to both preschool children and their caregivers substantially increases the households' likelihood to retain OFSP after phase-out of the free-vines dissemination programs. Integrating nutrition education approaches simultaneously through multiple entry points may be more effective in ensuring that the households conserve the vines and grow OFSP all year round for nutrition and food security.

Keywords: nutrition education; bio-fortified sweet potato; technology retention.

1. Introduction

Despite the concerted efforts made to reduce hunger and undernutrition, the undernourished global population went up by 2.1 percent to 821 million in 2017 from 804 million in 2016. Sub-Saharan Africa (SSA) and Eastern Africa, in particular, are leading with 23.2 and 31.4 percent of their population being undernourished, respectively (FAO *et al*. 2018). As part of the initiatives to reverse this trend, identification of testable, reliable and evidence-based accelerators for reducing malnutrition have received considerable interest in the literature (Ruel *et al*. 2018)[1].

Vitamin A deficiency is one of the leading components of undernutrition and the world has adopted bio-fortification of food staples as the best food-based approach to combat the menace (Ecker *et al.* 2010: Hotz *et al*. 2012; Domonko *et al.* 2018; Bouis *et al.* 2018). Orange-fleshed sweetpotato (OFSP) is bio-fortified with Vitamin A and has a higher Beta-carotene content than many common vitamin-A-rich foods (Hotz *et al*. 2012). Among other comparative advantages, OFSP matures faster, has a high yielding potential, and can be easily integrated into kitchen gardens. Only 125 grams of the roots is needed to supply the recommended daily vitamin A requirements of under-five-year-old children. It is, therefore, a better source of micronutrients in human diets than the traditional white-fleshed and yellow-fleshed sweet potatoes (WFSP and YFSP).

Unlike fortification and supplementation approaches, bio-fortification is more sustainable since its potential scale-up is not exclusively dependent on continued financial injections by the government (FAO et *al.* 2018; Bouis *et al.* 2018). Given the vegetative propagative characteristics of the crop and the culture of vine sharing among the rural small-scale farmers, the up-scaling of

[1] In the context of ending hunger and malnutrition, accelerators are defined by FAO *et al*. (2018) as "policies, innovations, or interventions- or a combination- that bypass, reduce, or eliminate barriers to advance the end of hunger and malnutrition, amplifying impact through synergies, integration, and partnerships among sectors."

the technology ought to be easier and provide vivid results for every single vine multiplication and dissemination project that has been executed by governments and development agencies. Thus, since it is vegetatively propagated, we would expect that with a one-time investment in multiplication and dissemination of the vines to the farming households, OFSP should be continuously available in the farms of beneficiary households and, by extension, in the entire communities (Bouis *et al.* 2018). However, there is weak evidence, both on the ground and in the literature that this is the case, that is, that OFSP is readily and sustainably available in farming communities (Ruel *et al.* 2018). Therefore, despite the substantial potential of OFSP to contribute to nutrition and food security status of the society, there is a dearth of empirical knowledge of the sustainability of the technology.

Regardless of the many initiatives by governments and development partners in promoting OFSP, farmers still have great challenges with conservation of vines; pest and disease management; storage and processing of the roots; and reliable market development (Bouis *et al.* 2018). Another impediment to successful adoption of OFSP by farmers is their continued dependence on vine handouts. Indeed, Jenkins *et al.* (2018) observed that without the efforts of the decentralized vine multipliers (DVMs) to preserve and distribute vines, persistence of the vines among farming households would be very unlikely. Moreover, even as they preserve the vines, the DVMs are rationally motivated by the expected economic benefits of sales to those who fail to preserve. Increasingly, access to vines from the DVMs depend on the farmers' willingness to pay for the product, which in most cases has faced the challenge of the free vine sharing tradition among rural households. Thus, farmers who depend on shared vines from colleagues are more disadvantaged since they only get the vines after their colleagues have planted their own fields.

Farmers have continuously called for repeated rounds of free vines dissemination programs from government and development institutions (Mazuze 2007). However, in efforts to reach out to the critical mass, re-issuance of free vines in the different planting seasons to the same farmers is usually of little consideration to projects and their implementing partners. Recent studies have, thus, recommended encouragement of the communities to make efforts to conserve the vines for future growth (Jenkins *et al*. 2018). On the other hand, while assessing the effects of nutrition education on sharing of OFSP among farmers, Okello *et al*. (2018) cautiously (due to weak statistically significant estimates) reported that farmers who had been advised by the community health volunteers to conserve and multiply the vines were less likely to have shared their vines with colleagues. In essence, there is weak empirical evidence that points to the factors that influence farmers' decisions to retain OFSP on their farms.

In this study, we assess the immediate effects of integrated nutrition education targeting multiple channels (i.e., entry points) on the retention of OFSP among farming households after the lapse of the free vines dissemination projects. It is imperative to assess the relative differences in the effects of nutrition education initiatives designed to engage and deliver the messages to the households through different entry points in order to manage the prevalent malnutrition problem in many rural households in the SSA region. The rest of the paper is organized as follows: section 2 provides a detailed description of the materials and methods applied; the key results are discussed in section 3, while the main conclusions and implications to policy are offered in section 4.

2. Materials and methods

2.1 Sampling

The study was conducted in Homa Bay County, one of the leading producers of sweet potato and an area where several projects have tried to scale up the adoption of OFSP. Homa Bay County has continuously recorded high cases of undernutrition; less than half the population of under 2-years-old children is fed on minimum acceptable diets (Republic of Kenya 2014). Also, 4.2 percent, 15 percent and 26.3 percent of children under five years old in the County exhibit symptoms of wasting, underweight and stunting, respectively (Republic of Kenya 2014). A majority of the population in Ndhiwa and Rangwe sub-counties produce sweet potato on small-scale mainly for subsistence. In the County, sweet potato is planted in the months of April to June and September to mid-November in the long rains and short rains seasons, respectively (Low 2004; Luedeling 2011).

The study was conducted in 15 villages (see Figure 1), identified by the reference public Early Childhood Development (ECD) Centers in Rangwe and Ndhiwa sub-counties, between January and October 2018. This relatively long duration enabled observation of farm-household behavior on OFSP retention in farms, following exposure to nutrition education.

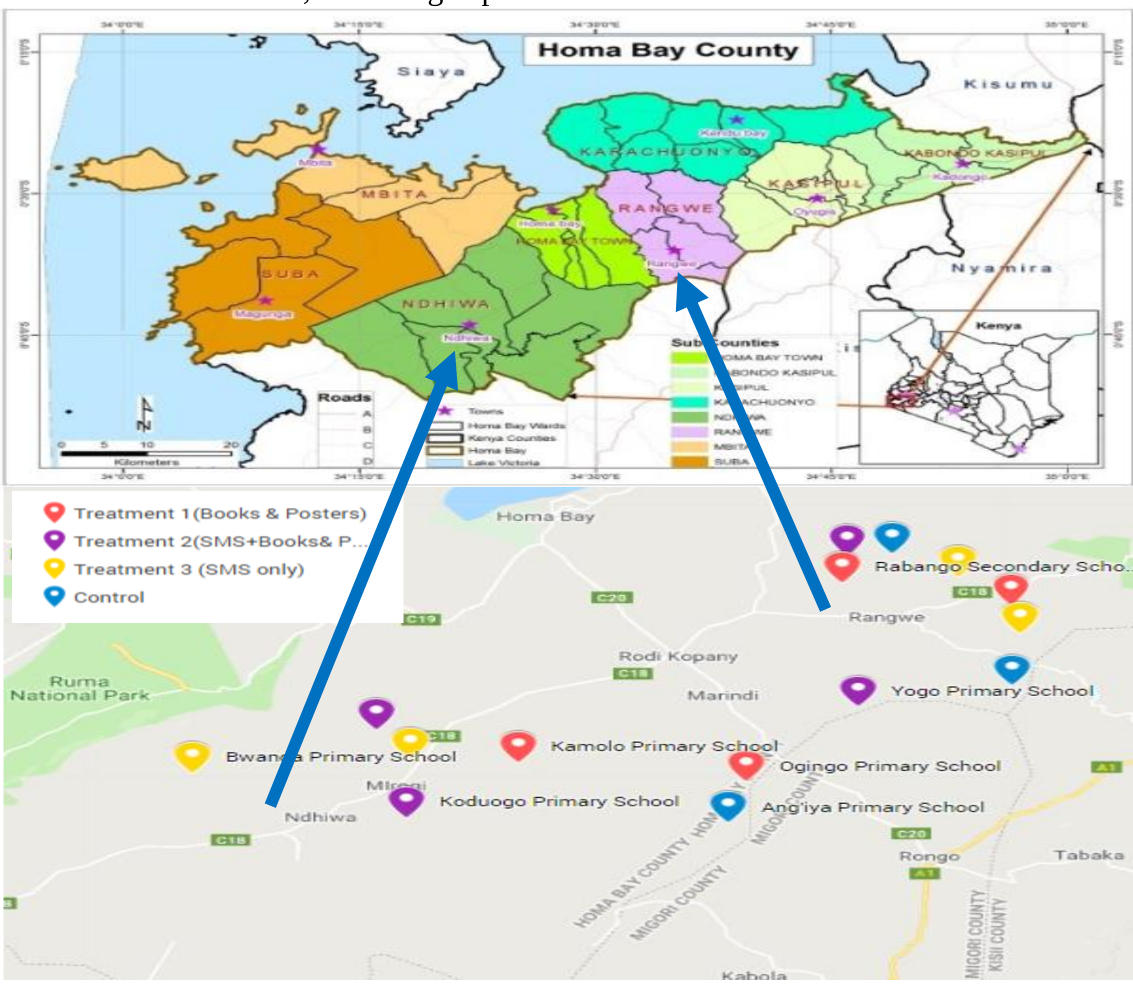

Figure 1: Map of study reference centers in Ndhiwa and Rangwe Sub-counties, Homa Bay County, Kenya

Source: Adapted from Google Maps and IEBC (2018).

The reference villages were purposively selected on the basis that the International Potato Center (CIP) and related organizations had not introduced OFSP to the households in these areas. Thus, there were no reasons to believe that the targeted children and their caregivers would have had an active interaction with OFSP before the study. From the 15 villages, all the participants in the CIP-led routine intervention activities including community-level cooking demonstration workshops, and free vines dissemination programs constituted the sampling frame for the study. A total of 723 households with preschool children who had attended the cooking demonstration workshops and registered to have received the vines from the centers formed the sampling frame. A random sample of 431 caregiver-preschooler pairs was drawn from the 723 households using probability proportionate to size sampling technique[2].

2.2 Study design and study factors

Guided by Duflo *et al.* (2007), the study employed a randomized control trial design that involved random assignment of the reference ECD centers to one control and three intervention groups. All the preschooler-caregiver pairs that formed the sample in each cluster (ECD center) were considered for the respective treatments. The three treatment groups entailed issuing nutrition education interventions to the preschool children alone, both children and their caregivers, and the caregivers alone. In the context of this study, a caregiver is defined as the person who is responsible for preparing the food on behalf of the pre-school child in the household. The treatments were designed as follows:

2. 2. 1 Preschooler-oriented treatment (PT)

Ruel *et al.* (2018) and Murimi *et al.* (2018) observed that interventions in studies with children perform better if designed with a multi-component approach. Thus, the preschooler treatment (PT) intervention involved issuance of OFSP-branded exercise books and posters to the children. The objective was to make children, as change agents, develop a sound and influential knowledge and attitude about OFSP, nutrition, and health. The design involved pictorial illustrations of the messages augmented by the written texts which presented the OFSP as "food that makes us strong, healthy, and intelligent." The concept is frequently used by parents to illustrate healthy food to young children. (Tatlow-Golden *et al*. 2013). The back page of the exercise books had a picture of a group of children holding pieces of cooked OFSP roots and a poem about OFSP and its nutritional benefits (see Appendix A for a sample cover). The message on the front cover of the books and a section of the posters was written in the local language, *Dholuo*, while the poem was written in the English language. All children in the ECD centers assigned to the PT group received an exercise book, and 10 posters of 5 different designs were handed to each of the class teachers. The preschoolers were advised and reminded continuously by their class teachers to read at home the messages on their exercise books and keep reciting the poem that they were taught by their class teachers. Random and impromptu spot check visits were done on a weekly basis to monitor the class teachers on appropriate execution of their duties across all the preschools.

2. 2. 2 Caregiver-oriented treatment (CT)

The second intervention targeted the caregivers and involved dissemination of the OFSP and nutrition-oriented text messages to the caregivers on their mobile phones. It entailed a set of seven tested, moderated and standardized messages that were sent to the caregivers through a commercial bulk mobile phone-mediated text messaging platform. All legal and ethical protocols were observed in the issuance of the messages as each of the messages was verified and approved by the Communication Authority of Kenya (CAK) before they were delivered to the targeted persons. These messages were also conveyed in the local language, *Dholuo*, a language that the rural community was well conversant with. This was necessary to ensure uniformity of the expected understanding of the nutrition education information passed and essentially limit the effects of the language barrier. Seven different messages were repeatedly sent to the caregivers in the 30 days

[2] A center that had recorded a larger number of participants in the sampling frame secured a relatively larger size in the final sample.

of intervention- one uniform message per day to all and seven different messages in seven consecutive days.

2.2.3 Integrated Treatment (IT)

The integrated nutrition education approach involved channeling both the previously discussed interventions to individual households. That is, giving books, posters to preschool children and the mobile phone-mediated text messages to the caregivers concurrently with the aim of increasing chances of the nutritional information delivery and recognition.

2.2.4 Control group

The control group received none of the nutrition education interventions. However, all the study groups attended cooking demonstrations and received free vines delivered by the project team at their centers. The study groups are thus referred to by the notations PT, IT, CT, and "control" to refer to preschooler-oriented treatment, integrated (both caregivers and preschool children oriented) treatment, caregiver-oriented treatment, and control groups, respectively. The intervention period ran for 30 days with the daily recital of the OFSP poems in the classroom from the exercise books and the posters led by the teacher, and daily delivery of text messages to the caregivers.

2.3 Data collection

Three months after the project issued free vines to the caregivers (200 cuttings to each[3]), a household level baseline survey was administered to the caregivers at their homes, and 390 complete questionnaires were collected against a target of 431. Ten percent of the target was missed due to denials, refusals, and absenteeism cases among targeted caregivers. There were also errors in the list of sampling frame as some individuals gave wrong identification information to have a share of the free vines. Thus, some would not be traced while others failed to pass the inclusion criteria of the survey. The baseline survey collected data on socio-demographics of the household; their engagement with OFSP if any; institutional factors around OFSP production and consumption; and their knowledge, attitude, and practices around the same. It helped to obtain the baseline condition of the caregivers before the introduction of nutrition education interventions.

Six months later, a follow-up household survey was conducted with the same caregivers, covered in the baseline survey, immediately after the lapse of the intervention period, in October. This was six months after the issuance of the vines in the previous planting season and almost two months after the baseline survey. A total of 360 respondents managed to complete the end-line survey recording a 7.7 attrition rate. Among other variables, the follow-up survey collected data on perception of the caregivers of OFSP as a food crop; whether the farmers replanted; and the size of the new plots on OFSP. Both the baseline and the follow-up household survey data were collected using the Open Data Kit (ODK) Collect platform version 1.17.2.

2.4 Data analysis

2.4.1 Theoretical framework

Following conventional technology adoption behavior literature, the study borrows the random utility framework to model the farmers' decision to replant OFSP. A farmer is assumed rational and will decide to replant the OFSP if their expected utility (borne from the associated costs and benefits) exceeds that of not replanting (Greene 2003). That is an individual, i, making decision notated by j (1-0) earns a utility function:

$$U_{ij} = X'\beta_{ij} - \varepsilon_{ij} \tag{1}$$

[3] The cuttings were measured in numbers rather than weights because the aim was to provide the farmers with a basic seed and expect them to expand later by getting more vines from their planted farms.

The decision is influenced by the latent variable U^* following the assessment that the expected utility from replanting U_{i1} is greater than from not replanting U_{i0}.

$$U^* = U_{i1} - U_{i0} \quad (2)$$

Suppose the utility function is linear in parameters, we can have the latent variable function as:

$$U^* = U_1 - U_0 = X'(\beta_1 - \beta_0) + \varepsilon_1 - \varepsilon_0 \quad (3)$$

where X is the vector of explanatory variables, and ε the error term. Thus, we would be able to compute the derived utility from such decisions. However, we cannot observe the latent variable U^*, but the decision to replant or otherwise (D). Thus, we can estimate the model as:

$$D = I(X'\beta + \varepsilon \geq 0) \quad (4)$$

Given the binary nature of the dependent variable, the logit specification in equation 5 can be used to estimate the outcomes of nutrition education interventions.

$$Pr(D_{iv}) = expit\big(\beta_0 + \beta_1 PT_{iv} + \beta_2 IT_{iv} + \beta_3 CT_{iv} + \beta_4 Y_{v(t-1)b} + X_{iv}\beta_5 + \lambda_b + \epsilon_{iv}\big) \quad (5)$$

where D is the dependent variable (retention of the OFSP); and PT, IT, and CT are the indicators for assignment of treatments with the control group having been taken as the reference group. The parameter estimates of the regressors are given by $\beta_{1 \ldots}\ \beta_5$. The random error term, ϵ_{iv} is adjusted at the ECD center cluster levels.

In this case, ($Yv(t$-1)b) refers to the area of the OFSP garden planted in the first season at baseline; $Xivb$ is a vector of the child, caregiver, household and village characteristics; and λb is a set of sub-county fixed effects since the randomization was stratified on sub-county basis. Further, the study estimates the average marginal effects of treatment between the treatment groups and the control group.

2.4.2 Empirical model estimation

It is rarely certain that all interventions end up reaching the intended recipients as assigned by the development projects. Assessments of the effects of the interventions can be done with the entire targeted sample or the fraction who attest to having received them (Hernan & Hernandez 2012). It is imperative to assess the effects of the interventions in both tiers to elicit the gap and the importance of compliance enhancement measures in ensuring the effectiveness of development projects. Thus, the study estimated the intention-to-treat and the treatment-on-treated effects as follows.

2.4.2.1 Intent-to-treat (ITT) effects

When a treatment variable is defined as being a member of a group as per the randomization of the clusters, the resulting treatment effect does not account for possible non-delivery of the messages to the intended persons. Thus, the estimated effects at this stage would be referred to as intention-to-treat (ITT) effects. The study used the logit model specified in equation 5 above to estimate the effects of delivering nutrition education through the different approaches on OFSP retention on the farms.

2.4.2.2 Treatment-on-the-treated (TOT) effects

When the definition of the treatment variables is narrowed to refer to only those who acknowledged having received the interventions, the resulting estimates are referred to as the treatment-on-the-treated effects. These refer to the actual effects of receiving nutrition education information, from the different intervention designs, on the dependent variable. The study measured reception of each of the assigned treatments as a dummy variable - *RPT*, *RIT*, and *RCT* - coded as '1' if the caregivers acknowledged having received a nutrition education information and '0' if otherwise, for preschool-oriented treatment, integrated treatment, and the caregiver-oriented treatment, respectively. However, the reception of the assigned interventions is preconditioned by whether the caregiver falls in the assigned group or not. Therefore, the RPT, RIT, and RCT are not only binary but also endogenous. The study, had to look for binary choice models with categorical endogenous regressors. This called for consideration of instrumental variable models. Such control function (CF) methods as instrumental variable probit (IVprobit) and Tobit models would have been used to help with the endogeneity case but would lead to inconsistent estimates if applied with categorical endogenous regressors (Lewbel *et al.* 2012).

2.4.2.3 The Special Regressor Method

This study chose the Lewbel's (2000) Special Regressor Method (SRM) - a simple method designed for binary dependent variable models with one or more discrete endogenous explanatory variables (EEVs) - at the expense of the CF and ML methods following the critical comparisons in literature (Lewbel *et al*. 2012; Baum 2012; Bontemps & Nauges 2015). As an advantage over the alternatives, the SRM not only allows for discrete EEVs but also provides a single estimation method irrespective of the nature of the endogenous regressors and permits unknown heteroscedasticity in the model errors. The SRM Model is specified as:

$$D = I(X'\beta + V + \varepsilon \ \geq 0) \qquad (6)$$

$$D = I(X^e\beta_e + X^0\beta_o + V + \varepsilon \ \geq 0) \qquad (7)$$

In equation (6), D is the binary dependent variable; β is a vector of unknown parameters corresponding to X'-the vector of the regressors, and $\varepsilon$is the unobserved error (Lewbel 2000). X' combines a vector of the exogenous regressors, X^e, and endogenous X^o regressors, as in equation (7). The V is the special regressor, which is set aside from the other regressors and must satisfy a set of 3 conditions to ensure the coefficient is normalized to one (Lewbel, 2000).

Further, as in other standard instrumental variable model cases, the instrument (s), Z, must not be correlated with the error term, $E(Z'\varepsilon) = 0$, and $E(Z'X)$ be fully ranked (Baum *et al*. 2012). Finally, the model is set such that the special regressor, V, affects only the dependent variable of interest, D, but not the endogenous variable(s) X^e. As such, V is not included in Z.

We identified our special regressor as "household size" which was normalized through log transformation and demeaning- a harmless form of normalization. The transformed variable, *speclnHHSIZE,* made a good special regressor in the SRM model as demanded by the assumptions and preconditions of the model (Lewbel et al. 2012; Baum 2012; Dong & Lewbel, 2015).

The randomization variables, PT, IT and CT were considered as instruments based on logical consideration of the following conditions as considered in randomized controlled trial literature (Carter *et al*. 2013): a) Assignment into the treatment groups was randomized using a web-based "research randomizer;" b) There is a high correlation between treatment assignment and caregiver's acknowledgement to have received an intervention of the assigned designs (Spearman's rho= 0.6536, p<0.000); c) Assignment of the treatments is not correlated with replanting of OFSP (the dependent variable) except through the actual reception of the interventions by the targeted respondents. Satisfaction of these theoretical considerations, as guided by Carter *et al.* (2013), makes the estimated TOT parameters unbiased.

Other exogenous variables, X^o, included in the model are: a) Distance to the nearest CHV in walking minutes (*DST_CHV)* controlled for access to agri-nutrition extension services. b) A dummy on whether the farmer managed to harvest the OFSP planted in the first season (*HARVESTED_OFSP*). c) A dummy on whether a farmer is aware of a decentralized vine multiplier around (*DVM_AWARE*). d) A dummy on whether the farmer also grew the white and yellow-fleshed sweet potato (*GREW_WYFSP*). e) A dummy on the marital status of the caregiver (*MARRIED*). f) The size of the farm on OFSP at baseline measured in square meters (*LSIZE*). g) Level of general knowledge of the caregiver on OFSP production, content, and utilization (*KNWP*) measured as a scale 0 – 1 (higher values imply higher knowledge levels). h) The general attitude of the caregiver on OFSP agronomic and nutritional attributes (*ATTP*) measured as a scale 0 – 1 (values close to 1 imply a better or more positive attitude). i) The age of the child (*CHILD_AGE)* measured in years.

The dependent variable of interest, *RETAIN*, was measured once - only in the end-line survey. Thus, the data were analyzed as cross-sectional data for the effects of the treatments relative to control, on the replanting of OFSP. The treatment assignment variables (APT, AIT, and ACT) were used to estimate the ITT effects in an adjusted logit model, while the treatment reception or acknowledgment variables (RPT, RIT, and RCT) were used to estimate the TOT effects in the SRM model. The SRM model was executed with the guidance of Baum's (2012) "*sspecialreg* module" in Stata version 14.

3. Results and discussion

3.1 Sample characteristics

Table 1 below shows the distribution of variables between the study groups. Generally, there was no statistical difference in most of the socio-economic variables except for caregiver's age, household monthly expenditure and accessibility of a community health volunteer (CHV). The average age of the indexed children who participated in the study was 6 years in all the study groups. This is against the curriculum recommendation that children should attend pre-school at between 3 and 5 years old. However, it confirms the finding by Uwezo (2015) that 32.9 percent of children in lower education levels in the entire Western Kenya region are in grades lower than is expected for their age.

The average size of the households also averaged at seven persons across the study groups. Overall, a majority (76 percent) of the whole sample had under-5-year-old children in their households, and there were no statistically significant differences in the proportion of households with under 5-year-olds between the study groups. Therefore, it means that using the ECD centers as a platform for reaching Vitamin A vulnerable population is very appropriate as a majority of the households have at least a child under five years old.

Also, a bigger majority of the households in the control group planted the OFSP to maturity and harvested the roots relative to the treatment groups. However, the difference in the proportion of those who planted and harvested the roots in the treatment groups is not consistent between the treatment groups. Nevertheless, in the second season, fewer farmers retained the crop in the control group relative to those in the treatment groups. Especially the IT group had higher (78 percent) cases of retention than the rest with the CT group recording the least rate (50 percent). Further, the average sizes of the OFSP plots also differed significantly across the study groups in both seasons.

The data present an interesting scenario of how the households interacted with the OFSP on their farms in the first and second planting season, during the study period (see Figure 2). For the whole sample (360 observations) only 53 percent of the interviewed caregivers stated that they grew the OFSP to maturity with the control group leading at 81 percent while the IT and CT groups performed at less than 50 percent. This is probably a proof of the trend of low adoption scenario experienced by free vines dissemination programs during first season (Jenkins 2018). For instance 40 and 60 percent of the One Acre-Fund farmers planted OFSP during first and the second season of the Scaling Orange Fleshed Sweet potato program in Rwanda, respectively (One Acre Fund 2016).

Table 1: Description and Distribution of Study Variables across Study Groups.

Variables	PT (n=68)	IT (n=77)	CT (n=121)	Control (n=94)	Total Sample (n=360)	p-values*
	Books +Posters	Books +Posters + SMS	SMS only			
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Child's Age (years)	5.69^{a} (1.11)	5.73^{a} (1.12)	5.6^{a} (1.14)	5.94^{a} (1.02)	5.74(1.10)	0.226
Caregiver's Age(years)	35.66^{b}(11.27)	31.47^{ab}(9.17)	37.10^{a}(13.02)	38.56^{a} (12.76)	36.01(12.12)	**0.001**
Caregiver's Education level (years)	7.01^{a} (2.49)	7.64^{a} (1.94)	7.36^{a} (2.75)	6.77^{a} (3.34)	7.20 (2.73)	0.202
Household Size (scale)	6.63^{a} (2.08)	6.12^{a} (1.82)	6.17^{a} (1.95)	6.64^{a} (2.51)	6.37 (2.11)	0.188
HH's Monthly Expenditure (USD)	68.98^{b} (59.70)	51.24^{b}(35.21)	67.91^{b}(75.41)	94.12^{a}(102.25)	71.39(75.92)	**0.003**
Distance to CHV (walking minutes)	9.56^{a} (12.27)	13.81^{b}(11.51)	18.53^{a}(17.03)	16.17^{a} (18.12)	15.21(15.77)	**0.002**
OFSP farm size in 1st Season (m^2)	44.89^{ab}(55.61)	37.48^{b}(54.45)	35.94^{a}(41.51)	44.25^{a} (61.17)	41.53(52.19)	0.056
Caregiver's Sex (% female)	93^{a}	91^{a}	88^{a}	86^{a}	89	0.534
Households with under-5-year olds (%)	74^{a}	79^{a}	78^{a}	73^{a}	76	0.605
Household head's Sex (% female)	16^{a}	12^{a}	19^{a}	17^{a}	17	0.926
Married (yes/otherwise) % married	82^{a}	87^{a}	80^{a}	84^{a}	83	0.646
Member of a Farmer Group (0/1) %	29^{a}	35^{a}	29^{a}	36^{a}	32	0.615
HH grew white/ yellow SP (%)	60^{a}	65^{a}	69^{a}	72^{a}	67	0.411
Knowledge on OFSP (0 - 1)	0.72^{a} (0.14)	0.72^{a} (0.14)	0.73^{a} (0.14)	0.75^{a} (0.13)	0.73 (0.14)	0.405
Attitude on OFSP (0 - 1)	0.57^{a} (0.21)	0.50^{a} (0.24)	0.51^{a} (0.24)	0.54^{a} (0.22)	0.52 (0.23)	0.133
Grew OFSP in 1st Season (%)	57^{a}	47^{ab}	31^{b}	81^{c}	53	**0.000**
Harvested OFSP in 1stSeason (%)	69^{a}	72^{a}	84^{b}	80^{c}	77	**0.000**
Retained/replanted OFSP (%)	67^{a}	78^{a}	63^{b}	63^{a}	67	**0.011**

Note: Standard errors are in parentheses.
* p-values of Bonferroni adjusted multiple pairwise comparison tests of differences in means. Same letter superscripts-**aa**, **bb** or **cc**-indicate no significant statistical difference, while unmatched superscripts **ab**, **bc**, and **ac** imply presence of significant statistical difference on the variable between the study groups.
Source: Survey Data (2018).

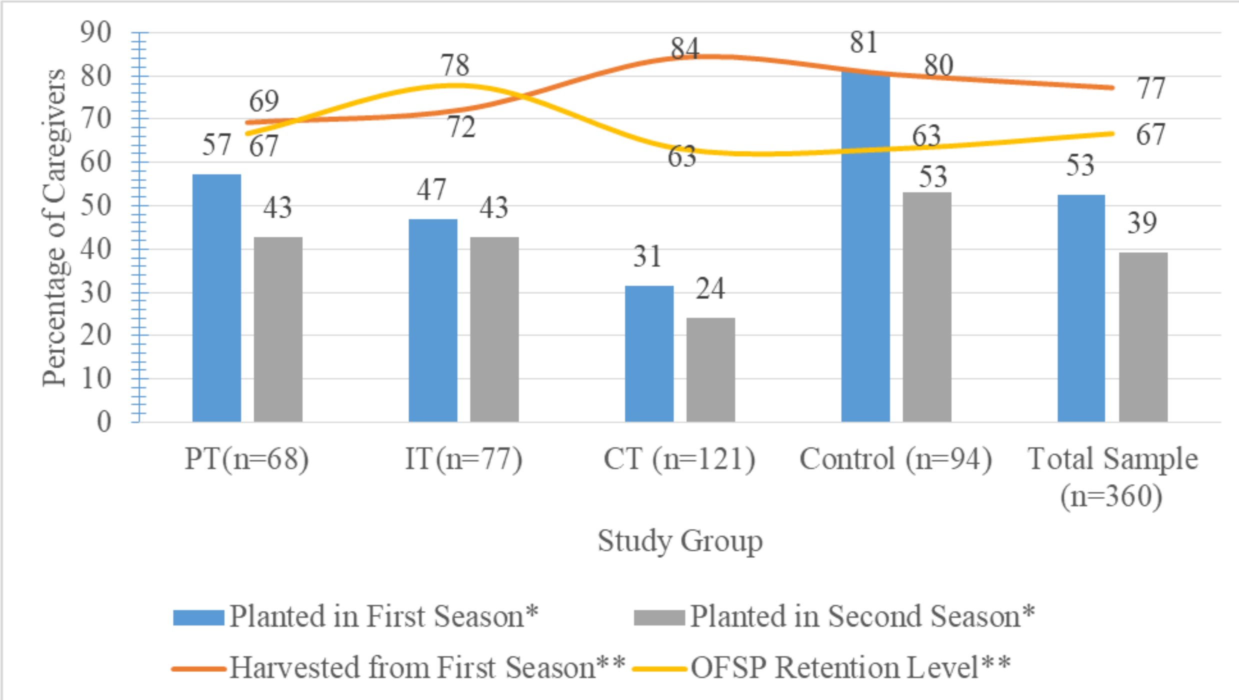

Figure 2: Caregivers' engagement with OFSP across the study groups.

Note: *n= total sample size of the study group as in the parentheses. ** n= total number of those who planted OFSP in the 1st season.

Source: Authors' computation from survey data (2018).

Among those who planted the crop in the first season, 62 percent managed to retain the crop. However, the IT group significantly replanted more (78 percent) OFSP than the rest of the study groups. Interestingly, about 6 percent of those who, for various reasons, failed to harvest their OFSP crops in the first seasons had planted the crop in the second season and only in the IT group. The low rate of diffusion of the technology was expected given the fact that the vines were distributed in small numbers- each farmer was to receive 200 pieces of standard quality vines.

3.2 Acknowledgement of interventions

Figure 3 presents the level of the caregiver's acknowledgment of receipt of nutrition education information as per the assignments and executions to the respective groups. It is imperative to note that the enumerators depended on verbal responses from the caregivers as to whether they received nutrition education messages from any source during the intervention period. Therefore, the 7 percent who reported to have received the messages in the control group are cautiously reported as spillovers, given the possibility of respondent bias. We expected that the caregivers would receive the nutrition education messages from their children or from their (children's) exercise books for the PT group, or from their mobile phones. Overall, the assignment of an individual to a given intervention significantly influenced their exposure to the assigned interventions in comparison to other groups (Pearson chi2 (9) = 446.25; *P* <0.000).

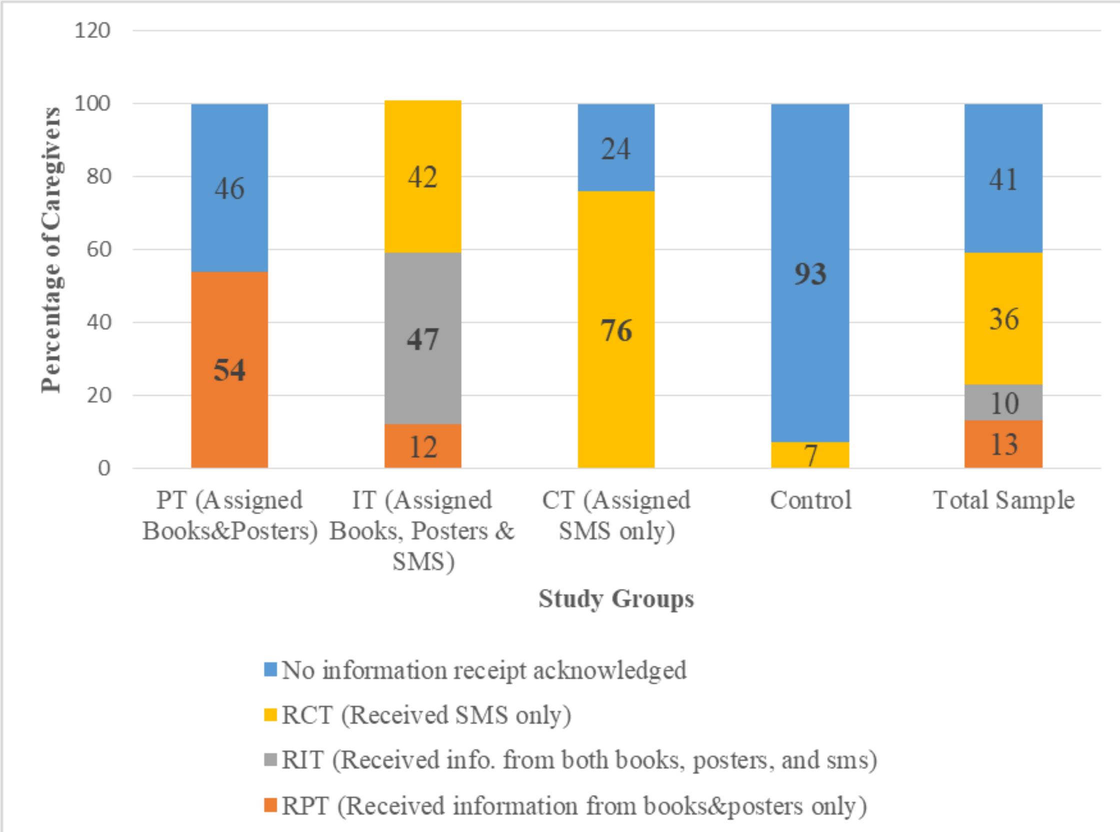

Figure 3: Assignment and acknowledgment of the interventions among caregivers
Source: Authors' computation from survey data (2018)

The acknowledgment of interventions by respondents is expected to be heterogeneous in normal circumstances. However, the level of the acknowledgment of the interventions between different treatment groups is intended to have some trickle-down effects on the usability of the information packaged in every intervention. From the results, it is observed that the caregivers acknowledged the nutrition education information relayed through the preschool materials less than they acknowledge the nutrition information sent through the mobile-phone mediated messages. However, at least every household which was targeted by both approaches attested to have received the nutrition education information from either of the sources. Comparatively, it can be observed that targeting both entry points with the integrated approaches ensured that all the households acknowledged the nutrition education messages within the study period unlike in single entry point approaches. Acknowledgment of information is imperative for assessment of the level of treatment compliance among the targets to assure the project organizers and implementors of the effectiveness intervention designs. This implies that the PT approach was relatively less successful in involving the families, especially the caregivers, in the nutrition education process. Probably this is due to the existing situation with the preschool curriculum as executed in the study area.

On the other hand, the CT seems to have resulted in nutrition education information acknowledgment by a relatively greater proportion (76 percent) of the targeted group. Comparatively, mobile phone-mediated text conveys the information more directly to the caregiver, than when the messages are conveyed through the child and their learning materials as in the PT group. Although every member of the CT and IT groups confirmed to be in possession of a mobile phone, still a good percentage (12 and 24 percent, respectively) failed to acknowledge receiving the mobile phone-mediated nutrition education information.

3.3 Treatment effects

3.3.1 Intention-to-treat effects

The estimation results of the logit regression of the treatment assignment variables and the control covariates on *RETAIN* (an individual's decision to replant OFSP in the second season) are provided in Table 2 below. The results show that positive and significant effects only exist for assignment into the integrated treatment group. The estimates for single entry point interventions, PT and CT, are not significant. In addition, CT estimate gives a surprising negative sign.

The positive estimate in IT implies that a household that gets nutrition education information from both the books and posters given to the preschooler and through SMS sent to the caregiver's cellphone is more likely to replant OFSP in the second season than if they did not get such combinations. The marginal effects estimates for IT assignment imply that a household that is assigned both pre-school and caregiver directed nutrition education increased their likelihood of planting OFSP by 16.7 percent than if they did not receive the intervention, other factors constant. However, collectively a Wald test for joint restriction for the three treatments gives significant statistics, *P*-value of 0.016. This confirms that collectively the nutrition education approaches have a significant effect on the likelihood of farmers to replant OFSP in the second season after phase-out of the free vines dissemination programs, other factors constant.

Table 2: Logit results - average marginal effects estimates of nutrition education interventions and other covariates on retention of OFSP

			Average Marginal Effects	
Dependent variable- RETAIN OFSP	Coefficients	P-value	dy/dx	P-value
APT	0.321	0.591	0.064	0.586
AIT	0.841	**0.001**	0.167	**0.001**
ACT	0.128	0.635	0.026	0.634
Household Size (*log*)	0.921	**0.057**	0.183	**0.052**
Grew White and Yellow-Fleshed SP	0.944	**0.008**	0.188	**0.004**
Caregiver's Knowledge level on OFSP (*squared*)	1.669	**0.092**	0.332	**0.080**
Caregiver's Attitude level on OFSP (*squared*)	-0.546	0.463	-0.109	0.458
Member of a farmer group	0.403	0.246	0.080	0.241
Constant	-1.129	0.125		
Test 1: H_0: APT=AIT		0.384		
Test 2: H_0: APT=ACT		0.752		
Test 3. H_0: AIT=ACT		**0.013**		
Test 4: H_0: APT= AIT=ACT=0		**0.043**		
Number of observations (*who planted OFSP in the first season*)	189			
Wald chi2(8)	33.890			
Prob > chi2	0.000			
Pseudo R2	0.083			

Note: Sample contains only those who planted OFSP in the first season. Standard errors (not presented) were adjusted to clusters at ECD center levels.

APT= Assigned Preschooler-oriented Treatments; **AIT**= Assigned Integrated Treatment; **ACT**= Assigned Caregiver-oriented Treatment.

Source: Survey Data (2018).

3.3.2 Treatment-on-the-treated effects

The average treatment-on-the-treated effects were estimated using the SRM having disqualified the ivprobit, binary probit, and 2SLS for inconsistent estimators and the multiple binary endogenous variables. The endogenous variables were exactly identified; *Z* and X^e have three parameters on both sides of the "first-stage equation". Further, Durbin Wu- Hausman test for endogeneity with the null hypothesis that the instruments are exogenous proves (Durbin Chi^2 (3) = -36.1199; p = 1.0000) that all the instruments are indeed exogenous. Education level, income level, and child's age were tested as instrumental variables that determine whether or not a caregiver acknowledges reception of the assigned treatment. However, these turned out invalid upon execution of the Sargan-Hansen test of over-identification (Sargan chi2= 98.6623; p<0.000) under the null hypothesis that the over-identifying variables are valid. The standard errors were also adjusted to account for possible heteroscedasticity in the clusters. The results of the SRM regression are provided in Table 3.

Only receiving integrated treatment (RIT) gave out positive and significant effects on the caregivers' potential to retain the OFSP on their farms. Receiving treatment channeled through the preschooler alone (RPT) or the caregivers alone (RCT) did not give any significant effects. The average marginal effect estimates for RIT imply that other factors held constant, households, where both the caregiver and the preschooler received the nutrition education were 24.3 percent more likely to replant the OFSP in the second season than if they did not receive the interventions. Just as the case with the ITT estimates, a Wald joint exclusion restriction test (p = 0.065) shows that overall, other things held constant, reception of nutrition education through the three approaches have significant statistical effects on the households' likelihood to replant OFSP in the second season after lapse of the free vines program.

Table 3: SRM results - marginal effect estimates of nutrition education interventions and other covariates on retention of OFSP

Dependent Variable- **Retain OFSP**			Marginal Effects at means[a]	
	Coefficients	P-value	dy/dx	P-value
RPT	0.269	0.341	0.088	0.341
RIT	0.744***	0.007	0.243***	0.007
RCT	-0.093	0.642	-0.030	0.642
Distance to CHV (*square-root*)	0.061**	0.040	0.020**	0.040
Size of OFSP plot (*square-root*)	0.045***	0.008	0.015***	0.008
Harvested OFSP in last season	0.274**	0.028	0.089**	0.028
Caregiver is Married	-0.174	0.287	-0.057	0.287
DVM is nearby	-0.405*	0.054	-0.132*	0.054
Caregiver's Knowledge level on OFSP (*squared*)	0.315	0.325	0.103	0.325
Caregiver's Attitude level on OFSP (*squared*)	-0.116	0.620	-0.038	0.620
Household Monthly Expenditure (USD) (*logged*)	-0.104*	0.080	-0.034*	0.080
Inverse of the square of a child's age (*Years*)	-1.594	0.662	-0.521	0.662
Household Size (*log*)			0.327	
Constant	0.343	0.552	0.112	0.552
Test 1. H_0: RPT=RIT		0.200		
Test 2. H_0: RPT=RCT		0.198		

Test 3. H_0: RIT=RCT		0.022		
Test 4. H_0: RPT=RIT=RCT		0.065		
Observations (180 trimmed)	180			
Wald Chi2	23.84			
P>X^2	0.021			
Root MSE	0.693			

Note: 1). The sample contains only those who planted OFSP in the first season. 2). Standard errors (not presented) were adjusted to clusters at ECD center levels. 3). [a]Marginal effects estimated using Average Index Function (AIF) (Baum 2012). **RPT**= Received Preschooler-oriented Treatment; **RIT**= Received Integrated Treatment; **RCT**= Received Caregiver-oriented Treatment.
*p<0.10, **p<0.05, ***p<0.01
Source: Survey Data (2018).

Focusing on integrated nutrition education intervention results, comparing the ITT and TOT effects estimates of the two gives interesting insights into the study. The ITT and TOT effects are different, implying the effects of the difference between targeting a population with intervention and ensuring that the population receives and acknowledges the intervention. That is, there is a significant difference in results achieved by the issuance of nutrition education initiatives and ensuring the targeted population receives the issued messages. There have been a similar finding by Ogutu et al. (2018) that the TOT estimates of effects of interventions on technology adoption are relatively higher than the ITT estimates. Further, the TOT effects are considered the actual measure of intervention effects.

The TOT effects are higher than the ITT effects by almost an 8 percent margin. This is interesting given that less than half (47 percent) of those in IT acknowledged receiving information from both the preschoolers and the caregivers' mobile phone, while the remaining half received from either of the approaches. Given this scenario, it is plausible to interpret the ITT and the TOT effects of the integrated treatment category as follows. The average marginal probability of households - where the preschooler and caregiver are simultaneously targeted with nutrition education information- to replant OFSP in the subsequent season after the lapse of a free vines distribution is 16.7 percent, other factors constant. Nonetheless, households that receive both the nutrition education approaches have a relatively higher (24.3 percent) chance of retaining OFSP than those who do not receive both treatments, other factors held constant.

4. Conclusion and implications

In this study, we assessed the immediate effects of the nutrition education interventions on continued planting of a bio-fortified crop in the consecutive seasons after a free vines season. We regressed the intervention variables on replanting decisions of the caregivers after a randomized controlled experiment. Our results imply that the success of the interventions relies on: 1) whether or not it is an integrated approach that targets more than one entry point; and 2) the extent to which the targeted population acknowledges the interventions. Collectively issuance of nutrition education activities improves the potential of the caregivers' recognition of the nutrition education information and thus increase their potential to replant the OFSP on the farms. Targeting both preschool children and their caregivers (predominantly their mothers) with nutrition education information has a potential that demands further exploration. Although a majority acknowledged having received the interventions, bridging the gap (ensuring that all the targeted respondents acknowledge the message in the interventions) is worth considering when scaling up such interventions.

Further, designing and executing integrated nutrition education approaches, by targeting both preschool children and their caregivers simultaneously with the nutrition education messages, stands a better chance of eradicating malnutrition when bio-fortified crops are the center of the interventions. The study argues that, collectively, integrating nutrition education with the ECD platform through OFSP-branded exercises books and class posters, and using the bulk mobile phone-mediated text services, may be an effective way to promote the sustainable practice of food-based approaches to combat malnutrition. However, they are more effective when both approaches are channeled to particular households concurrently. In addition, nutrition education intervention planners and implementers from research and development organizations should focus on ensure that a multicomponent and multi-entry approach take the center stage of the intervention designs.

Educators (specifically the ministry of ECDE) should develop more inclusive ways of ensuring active learning that enhance the involvement of the pre-schoolers' families, in particular, in the curriculum. Further, the curriculum should integrate nutrition education activities beyond the practical examples of the OFSP-branded exercise books and posters, as demonstrated in this study, to ensure that interventions channeled through preschool and preschooler entry points reach and are recognized appropriately by the family. It is essential that the curriculum adjustments be guided by the aim of enhancing the households' potential to acknowledge the direct and indirect communication that are channeled through the child and their learning materials.

Limitations and suggestions for further research

First, given the context-specific nature of the study, the study area is of a relatively homogenous agro-ecological condition of the Western Kenya sweet potato producing areas. Therefore, the external validity of our results beyond this boundary is less assured. Future studies should focus on how integrated nutrition education interventions should be carried in different sweet potato growing agro-ecological zones to ensure sustainable production of OFSP among households.

Second, time constraints also affected the scheduling of the study and the duration of the experiment. The interventions were executed in the shortest term of the year as per the fixed basic education calendar in the country. Nonetheless, we also had to make use of the sweet potato harvesting and planting periods. Thus, the treatment period (30 days) was shorter relative to a recommendation of at least three months from a meta-analysis of nutrition education experiments with children or adults (Murimi *et al*. 2017; Murimi *et al*. 2018). Based on these limitations, the results ought to be interpreted carefully. Future studies may expand the intervention period to cover the entire sweet potato life cycle; both the sweet potato growing, harvesting and replanting periods, unlike just the harvesting period as was in this study. Nevertheless, careful planning of future related studies is paramount to ensure every entry point is fully engaged in the projects.

Further, communication to the caregivers through cell phones requires no other party except authorization by the national communication authority. It is, therefore, a relatively cheaper initiative than the deployment of nutrition education officers such as the community health volunteers (CHVs) and the community health extension workers (CHEWs) to physically reach out to the individual households. Future studies can pursue this hypothesis to advise on the relative cost-effectiveness of the integrated nutrition education approach against other approaches that enhance household's potential to retain the OFSP on their farms.

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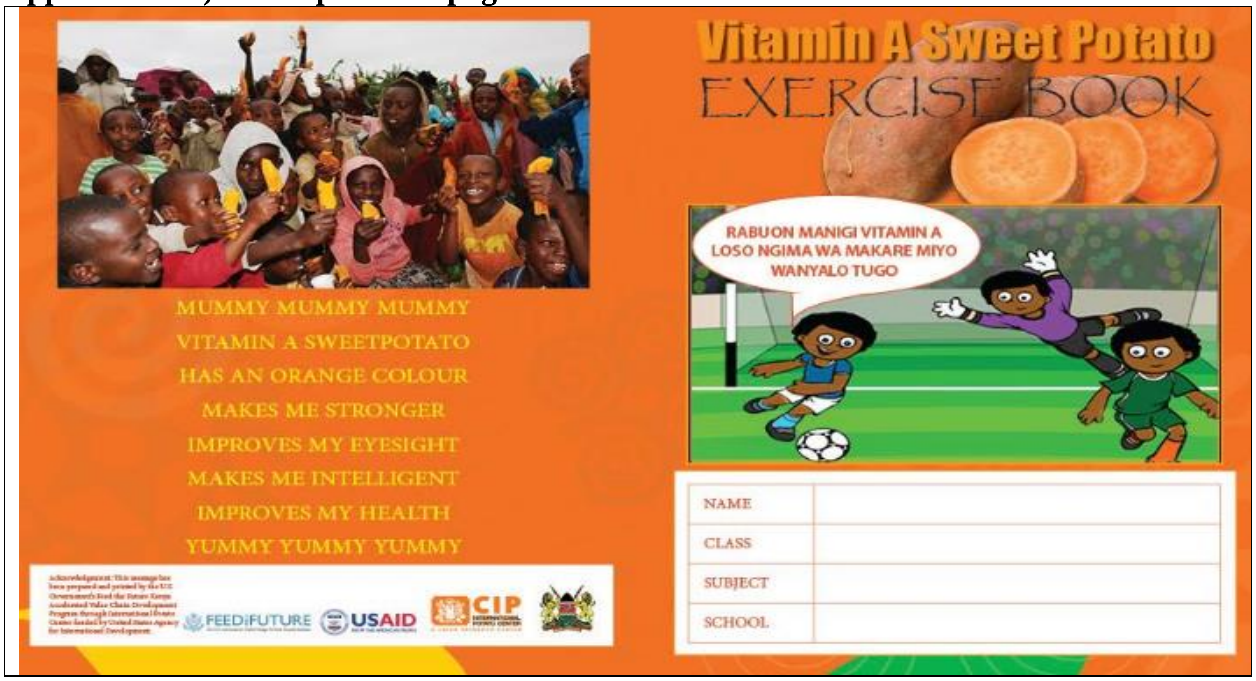
Appendices

Appendix A: a). A sample cover page of OFSP-branded exercise books



b). OFSP-branded class posters