Received: 18 December 2023 | Accepted: 14 February 2025

DOI: 10.1111/ajae.12540

ARTICLE

Impact of inputs, information, and financial services on the adoption of a biofortified crop by women farmers in Uganda

Niklas Buehren[1] | Shyamal Chowdhury[2] | Sreelakshmi Papineni[1] | Munshi Sulaiman[3]

[1]Africa Gender Innovation Lab (GIL), World Bank, Washington, DC, USA

[2]The Australian National University, Canberra, Australian Capital Territory, Australia

[3]BRAC Institute of Governance and Development, Dhaka, Bangladesh

Correspondence
Sreelakshmi Papineni, Africa Gender Innovation Lab (GIL), World Bank, 1818 H Street, NW, Washington, DC, USA.
Email: spapineni@worldbank.org

Abstract

Smallholder farmers in low- and middle-income countries face several constraints to technology adoption. We test the relative efficacy of interventions designed to incentivize the production and consumption of a biofortified orange-fleshed sweet potato crop by female farmers in Uganda. Through a clustered randomized controlled trial involving more than 8000 female farmers across 210 communities, we track the impact of the interventions on adoption, consumption, and health outcomes, both in the short term and long term. Our findings suggest that the provision of inputs and agricultural extension is an effective approach to adoption, leading over 60% of households to cultivate and 50% to consume the crop. Nutrition training emphasizing the crop's health benefits has limited impact on cultivation, but it leads 20% of households to consume the biofortified crop. Combining the two approaches with supplementary credit and insurance products has limited marginal effects on adoption. We also observe improvements in dietary diversity resulting from the tested interventions, along with spillover effects through social networks in neighboring communities. We find little evidence of treatment effects on higher-order outcomes such as visual acuity, child health and nutrition, or income.

KEYWORDS

agriculture, biofortification, orange-fleshed sweet potato, technology adoption, Uganda

JEL CLASSIFICATION

O12, O13, Q12, Q16

1 | INTRODUCTION

Increasing the adoption of agricultural technologies is essential for farm productivity, economic growth, and poverty alleviation (Foster & Rosenzweig, 2010; Fuglie et al., 2019; Gollin et al., 2021). Smallholder farmers in low- and middle-income countries face several barriers to adopting agricultural technologies, and programs that eliminate distortions and resolve market failures that constrain adoption are needed (Bridle et al., 2019). In the presence of limited capacity and budgets, policymakers often seek interventions that tackle the most binding constraints first. However, there is little evidence on the relative efficacy of interventions that relax adoption constraints individually versus interventions that relax a suite of constraints simultaneously (Jack, 2013).[1]

In this article, we use a clustered randomized controlled trial (RCT) to test the relative efficacy of providing inputs and agricultural information compared to nutrition- and health-related information designed to overcome constraints to technology adoption. To incentivize agricultural production and consumption of a new biofortified crop variety with greater nutritional benefits, interventions were designed to help smallholder women farmers access free inputs and agricultural extension, and receive health trainings that included information about the nutritional benefits of the new crop. We also test combining the two approaches and the marginal impact of three layered financial products: a credit product with a backloaded repayment schedule designed to alleviate seasonal liquidity and credit constraints to purchase inputs, an advance purchase input voucher to overcome present bias, and a price insurance product to help farmers offset market price risk.

The biofortified crop that we examine is the orange-fleshed sweet potato (OFSP), introduced to women smallholder farmers in southwest Uganda. Biofortification has been at the forefront of nutrition-sensitive agriculture initiatives, addressing challenges related to malnutrition through the introduction of locally adapted staple foods that are bred to be rich in micronutrients. Among the many varieties of sweet potatoes, the OFSP is a special type of biofortified sweet potato containing high levels of beta-carotene, which is considered an excellent source of vitamin A (Hotz et al., 2012; van Jaarsveld et al., 2005).[2]

We experimentally test the relative importance of the different intervention bundles on a number of adoption, nutrition, and health outcomes. The interventions were implemented by the non-governmental organization (NGO) BRAC in Uganda, and our study covers as many as 8000 female farmers across 210 communities. Overall, we find that the most effective intervention tested is the provision of free planting material (vines) and agricultural extension. Households are 67 percentage points (pp) more likely to cultivate the biofortified crop 2 years after the crop was first introduced and 30 pp more likely in the longer run (5 years after input provision), relative to a control group who received no interventions. More than 50% of treated households are found to consume the biofortified crop regularly, both in the short (6 month) and longer run (2 and 5 years after input provision, respectively). In contrast, providing nutrition- and health-related information has no impact on cultivation of OFSP. However, the health trainings led to 21 pp higher OFSP consumption in the short run, an effect that dissipates in the longer run. Bundling the two approaches has similar impacts on production and consumption outcomes as the input and agricultural information intervention alone. Augmenting the interventions with subsidized credit, commitment devices, or price insurance has minimal additional impact on adoption and consumption due in part to low take-up.[3] OFSP appears to be grown primarily for home consumption in our study context, with only 11% of treated households reporting they ever sold the OFSP crop.

[1]In a comprehensive literature review, Jack (2013) highlights seven primary market inefficiencies that may cause low adoption of beneficial agricultural technologies: credit, risk, information, input and output markets, labor and land market inefficiencies, and externalities.

[2]OFSP is one of the most prominent biofortification technologies. In a meta-analysis, Stewart et al. (2015) identify innovation in agricultural inputs (more specifically, OFSP) as one of the most promising areas of research and intervention. In our study areas, only 2% of households had ever cultivated an OFSP crop and 3% had consumed OFSP at baseline.

[3]Only 12% of women farmers accepted credit, 13% purchased vouchers, and 7% signed a written contract for a market price guarantee with BRAC. Although take-up rates of the financial products are similar to other microcredit products studied in similar contexts (Banerjee et al., 2015; Beaman et al., 2014), we likely lack power to detect a reasonable effect size (see Dahal and Fiala 2020).

To adopt biofortified crops such as OFSP, farmers do not necessarily need to make any extensive additional investments if they are already producing an unfortified crop with similar agronomic requirements, such as local (sweet) potato varieties. The cost of obtaining the initial planting material is the main investment needed. In our study area, white and yellow sweet potato varieties are commonly grown, and previous studies report little resistance among consumers to switching to OFSP from traditional white and yellow varieties (Low & Thiele, 2020; Naico & Lusk, 2010). We find that treatment households who received free planting materials and advice substitute away from production of the staple white sweet potato crop in order to cultivate the orange-fleshed variety.

Interestingly, in the longer run, we identify consumption spillover effects to non-beneficiary households in control group communities. Households in control group communities who received no interventions increased their consumption of the biofortified crop from 3% at baseline to more than 18% 5 years later. Increased consumption may arise from sales or gifts from farmers in treatment communities. Using geocoded data of detailed social network data, we show a link between the consumption of OFSP and closer proximity to a direct social network link in a treatment community. We find minimal production spillovers indicating that receiving the free planting material did not immediately lead to sharing of OFSP vines with neighbors and social network connections in other communities.

Much of the recent literature on technology adoption in agriculture has focused on social learning externalities described by Besley and Case (1993). For example, Conley and Udry (2010) study the adoption of fertilizer among small-scale pineapple growers in Ghana. They collect information on farmers' sources of information and find evidence of learning, not only from their own experiences but also within information neighborhoods. We find minimal signs of spillovers on the likelihood of cultivation and little evidence of knowledge spillovers or information diffusion about vitamin A–rich foods driving the increase in consumption of the crop among the control group over time. We show that greater access to treatment social networks encourages consumption among non-beneficiaries in control communities in the longer run.[4]

Our article contributes to the literature in several ways. First, our results on technology adoption and diffusion of a biofortified crop among women farmers can help inform the policy dialogue on promoting beneficial agricultural technologies. A number of constraints to adoption have been explored in the economics literature, including information barriers, financial resource constraints, seasonal liquidity and credit constraints, taste preferences, and a lack of effective commitment devices (e.g., see Duflo et al., 2011; Jack, 2013; Oliva et al., 2020; Suri, 2011); an inability or unwillingness to take risks and other behavioral constraints (e.g., see review by Allan et al., 2014; De Janvry & Sadoulet, 2019); mental barriers such as procrastination or lack of a reference price (e.g., Belay & Ayalew, 2020; Duflo et al., 2011); as well as institutional and cultural barriers (Achandi et al., 2018). We add to this evidence base by testing the effect of relaxing multiple constraints individually and simultaneously.[5]

Second, whereas several studies evaluating the nutritional impact of orange-fleshed sweet potatoes have been conducted across different settings, we examine impacts on additional outcomes not already captured in the literature (see de Brauw et al., 2018).[6] Most of the existing literature on OFSP examines vitamin A intake, with less evidence available on effects on production, consumption, and further downstream outcomes. Orange-fleshed sweet potato, high in vitamin A, is hypothesized to protect eye health and therefore improve vision. We implement a novel eye test to measure impacts on visual acuity.[7] We find no evidence of a treatment effect on the visual acuity of children or adults. We show that beyond treatment effects on dietary diversity of women and children, there are no

[4]A study by BenYishay et al. (2020) in Malawi found that women farmers can play a role in technology diffusion as strong as that of male farmers, and Gilligan et al. (2020) ound that women use greater bargaining power to facilitate diffusion of the OFSP technology in Uganda.

[5]It is worth pointing out that distributing OFSP vines to beneficiaries at no cost can alleviate multiple constraints in itself, such as an availability constraint, a financial resource constraint, and/or an information constraint.

[6]In the context section of the article, we summarize the literature on OFSP adoption further.

[7]We test impact on vision using the Sjogren Hand Test.

impacts on women's empowerment, income, or other maternal- and child health and nutritional outcomes.

Finally, our article examines program impacts in two post-program time periods, 2 and 5 years after implementation. The sustainability of the impact of promoting biofortified crop varieties remains largely unexplored. For example, reviews by Ruel et al. (2018) and Webb and Kennedy (2014) highlight a lack of evidence beyond the immediate post-intervention period.

The remainder of the article is organized as follows: Section 2 describes the study context and interventions. Section 3 outlines the study design and describes the various data sources. Section 4 presents the empirical strategy. Section 5 discusses the results, and Section 6 concludes.

2 | CONTEXT AND DESCRIPTION OF INTERVENTIONS

More than two billion people globally are affected by micronutrient deficiency, also known as *hidden hunger*, primarily caused by insufficient dietary intake of vitamins and minerals (Food and Agriculture Organization [FAO], 2020). Especially among the poor, this often stems from an inadequate quantity of food and calories consumed, but for others, it relates to the quality and diversity of their food.[8] In the case of OFSP, beta-carotene plays a vital role as it is a good source of vitamin A; vitamin A deficiency in early childhood is linked with night blindness and increased risk of other morbidity and mortality (Dowling, 1966).

The intersection of malnutrition and agricultural practices is particularly relevant for self-sufficient smallholder farmers, since the food they consume closely mirrors the crops they grow. Several vehicles for micronutrient delivery—such as shifting diets toward nutrient-rich foods, supplementation, industrial fortification of packaged foods, and biofortification of crops—have been used to great effect over the years (e.g., see Bhutta et al., 2013; Ruel & Alderman, 2013), and nutrition-sensitive agriculture has gained prominence as a promising approach to address the malnutrition challenge. The promotion of biofortified crops has been at the forefront of nutrition-sensitive agriculture initiatives, and OFSP is one of the most prominent biofortification technologies (Ruel et al., 2018).[9]

According to nutritionists, the consumption of as little as 50 grams of OFSP a day is enough to provide a child's recommended dietary allowance of vitamin A (Burri, 2011). Consumption of relatively modest amounts of boiled OFSP by young schoolchildren in South Africa significantly improved their vitamin A status (van Jaarsveld et al., 2005), and similar results were obtained in Mozambique and Uganda (Hotz et al., 2012). Also in Uganda, de Brauw et al. (2018) find that the magnitude of impacts on children's vitamin A intake and dietary diversity increases with the level of farmers' participation in the program, and impacts are mediated through adoption of OFSP rather than through knowledge gain.

Southwest Uganda, where this study takes place, lags behind other regions in sweet potato productivity, with regional yields more than 1 metric ton per hectare (t/ha) below the national average (Uganda Census of Agriculture, 2009). Our baseline data show that less than 2% of households were cultivating OFSP in this area prior to the intervention.

Our focus is on studying the effectiveness of three sets of interventions that were implemented by the NGO BRAC to incentivize OFSP adoption: (a) provision of agricultural inputs and agriculture extension, (b) trainings on health and nutrition, and (c) access to innovative financial products. These interventions were delivered through BRAC's existing agriculture, health, and microfinance

[8]In Uganda, malnutrition is a major development concern that costs lives, diminishes productivity, and causes significant human capital and economic losses (World Health Organization [WHO], 2006).

[9]Other linkages between agriculture and nutrition that are frequently discussed in the literature include increasing access to more nutritious food for one's own production for subsistence farmers, relying on increased income from higher agricultural productivity to be used for better nutritional intake, and improving diet through women's economic empowerment (e.g., see Headey et al., 2012; World Bank, 2007).

program platforms.[10] We briefly describe each intervention below and provide further details in Appendix A.

The *agriculture* intervention involved providing inputs and agricultural extension services to women farmers. This intervention entailed using community agents to train beneficiaries using demonstration plots in the community and the provision of planting material (vines) for OFSP and a few other nutrient-enriched crops, including beans, tomatoes, and groundnuts. In our analysis, we concentrate on the adoption of OFSP, as it was the main focus of the agricultural intervention.[11] Given that it is also the only crop that requires planting vines (instead of seeds), this distinguishes it from other crops since the logistics around obtaining and storing the planting material are more complex. Finally, the seeds and the produce for the other nutrient-enriched crops are more difficult to differentiate from the standard varieties, which increases the likelihood of misreporting. The provision of the free input package, especially the OFSP vines, was thought to be crucial to convince farmers to try out a new crop when there was very little information on the crop either from their own experience or through learning opportunities from observing other farmers. This intervention was primarily aimed at improving the nutritional value of crops grown by targeted farmers and not necessarily at helping farmers to increase the quantity of their agricultural production.

The *health and nutrition* information intervention focused on information dissemination through training. The training sessions were conducted by community health providers (CHPs) during quarterly health and nutrition community forums that targeted female caregivers and their husbands to promote the consumption of nutrient-rich foods.

Credit, risk, and behavioral constraints are likely to play different roles in the adoption decisions of biofortified crops vis-à-vis technologies to increase productivity, such as high-yielding seed varieties or fertilizer. Existing agricultural micro-loan products, with their rigid weekly repayment schedules, may not fit the needs of farmers (in the context of microenterprises, see Field et al., 2013). Therefore, context-specific financial products were designed to address three financial barriers to technology adoption. The *credit* product was customized to alleviate credit constraints for input purchases. The loan was designed to address potential inefficiencies in rural financial markets and, like the one studied by Das et al. (2019), was tailored to alleviate the constraint of seasonal cash flow. An *input voucher* was designed to act as a commitment device for the purchase of inputs to address behavioral constraints such as time inconsistency and present bias. Farmers were offered the opportunity to purchase input packages for OFSP and other nutrient-rich crops (including seeds and fertilizers) immediately after the harvest period when they had cash on hand. These inputs would then be delivered to farmers when they were needed during the subsequent planting season. The *price insurance product* was offered for the first cropping season to cover the potential downside price risk created by unpredictable demand for OFSP in the market.[12] The insurance product is a surplus buyback guarantee at prevailing market prices of similar produce, intended to ensure that, in the event of low demand, farmers would continue to produce an adequate supply of the crop.

The aim of our study is not necessarily to contrast the effectiveness of the two main interventions. Instead, our interest lies in understanding whether either intervention induces smallholders to grow and consume OFSP, or whether a bundle augmented with financial tools can achieve meaningful uptake. In this context, it is worth stressing that the two interventions were not cost equivalent, and, therefore, direct impact comparisons are less meaningful (see Appendix B for information on program cost).

[10]The Ugandan Ministry of Agriculture, Uganda Food and Nutrition Council in the Office of the Prime Minister, civil society representatives, and other stakeholders were involved in the intervention design and delivery.

[11]In Appendix D, Table D2, we show that there was a greater impact on OFSP cultivation than the planting of beans, tomatoes, and groundnuts, which were distributed together with the OFSP vines.

[12]Chowdhury et al. (2010) find evidence of bias against OFSP in Uganda, although nutrition information could potentially counter that.

3 | STUDY DESIGN AND DATA SOURCES

3.1 | Study design

This impact evaluation follows a clustered randomized controlled trial design to allocate 210 villages into the following groups: (a) agriculture intervention only (T1); (b) health and nutrition intervention only (T2); (c) agriculture and health interventions combined (T3); three financial innovations of (d) credit (T3 + Cr), (e) vouchers (T3 + V), and (f) insurance (T3 + I) that are offered in addition to T3; and (g) a control group that does not receive any interventions (C).

First, the implementing partner identified study locations and eligible households through mapping and a census before the rollout of the program. The village mapping was carried out to identify 210 study communities located in the catchment area of four BRAC branches.[13] Using administrative records of villages from the Uganda Bureau of Statistics, a community listing was generated based on distance to the respective BRAC branch office. A household census in 218 villages was conducted between December 2013 and March 2014, covering 23,361 households. Some neighboring villages with smaller populations were merged to form clusters, which were used as the unit of randomization to form 210 community clusters. Clustering helped reduce the threat of contamination and aided more efficient program delivery. The clusters are referred to as communities throughout the article.

Following the mapping and census, eligible smallholder farmer households in all 210 communities were identified following specific targeting criteria: (a) agriculture had to be the main income source for the household, (b) the household cultivated five acres of land or fewer, and (c) the household had to include at least one woman of reproductive age (15–49 years old). The target number of households per village was set at 40. Among the eligible households, those who had (a) a pregnant or lactating woman or (b) a child aged less than 2 years or (c) were headed by a female were automatically included in the program and study. A random sample from the remaining eligible households was drawn to reach the targeted 40 households per village.

The randomization of 210 communities into treatment and control groups was conducted after a baseline survey was completed in June 2014 for approximately 8000 households. BRAC branch was used as a stratification variable during randomization. For each of the six treatment arms and the control group, 30 communities were randomly chosen.

The interventions were initiated in October 2014. A follow-up survey (Follow-up I) was conducted for the full sample 2 years after the intervention had started. A second follow-up survey (Follow-up II) was completed approximately 5 years after the intervention was initiated to examine longer-run impacts. In Appendix A, Figure A1 presents a summary of the impact evaluation design and Figure A2 shows the study timeline.

3.2 | Data

Household survey

Our primary source of data is three rounds of a household survey. The surveys cover a period of 5 years (2014–2019) and comprise a baseline and two follow-up surveys. The interviews were conducted with female respondents who were typically either the wife of the male household head or household heads themselves.

The baseline survey was conducted between April and June 2014, during which a total of 7694 households (out of 8400 sampled from the community census) were surveyed prior to the start of the program. The households interviewed at baseline were reinterviewed between July and

[13]The four BRAC branches were located in Ibanda, Kabwohe, Kyotera, and Lukaya.

September 2016, approximately 2 years later (Follow-up I), and again between July and December 2019, approximately 5 years later (Follow-up II).

In all survey rounds, we collected detailed data on agricultural practices, household welfare, economic outcomes, nutrition, health, and anthropometric measurement of children.[14] At Follow-up II, we administered the Sjogren Hand Test to collect visual acuity measurements. In the agriculture module, we collected data on crop production, market access, and sources of information. Finally, we measured an index of food security, income sources, food consumption, knowledge of vitamin A, dietary diversity, maternal health, child feeding practices, and child health (diarrhea and fever), along with demographic information for each household member.[15]

We collected information on exposure to and take-up of the interventions (agriculture and health). At Follow-up II, the respondent was asked a modified version of the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) module to measure economic empowerment (Alkire et al., 2013). Intra-household decision-making power and time-use data were collected as well. The baseline survey collected additional information on participation in BRAC programs, as well as information on the respondent's risk, time preferences, and financial literacy.

In Uganda, there are two agricultural seasons in the year roughly divided between January–June and July–December. The first round of agriculture interventions coincided with the second agricultural season of the year 2014 (i.e., July–December), followed by training and free input distribution starting in early 2015. Financial products were offered starting in mid-2015 after the harvest. The agriculture module of our survey covers the last two cropping seasons. In the Follow-up I survey, the corresponding agricultural seasons were the second cropping season of 2015 (July–December 2015) and the first cropping season of 2016 (January–June 2016); for the Follow-up II survey, they were the second cropping season of 2018 (July–December 2018) and the first cropping season of 2019 (January–June 2019).

Networks survey

A random subsample of 5080 study participants was interviewed for a networks survey in September 2014 prior to the interventions. Respondents were asked about their main social contacts for health- and agriculture-related advice, capturing the frequency, direction, and intensity of information flows between contacts. Data on information-seeking behavior and social network size, inclumding the number of friends, were collected.[16] More precisely, respondents were asked to identify up to six individuals with whom they speak about agriculture, health/nutrition, financial topics, and borrowing, and with whom they spend most of their free time. Households indicated network connections with other study participants within and outside their community, and unique household identifiers were used to identify direct connections.

Baseline sample balance

In Table 1, we present a balance test across the randomized treatment groups. We find that the treatment groups are, on average, statistically similar to the control group across a number of observable

[14]Height and weight information was collected for all children aged 0–24 months at baseline and aged 0–5 years at Follow-up I and Follow-up II, which was then transformed into z-scores according to WHO child growth standards. Note that z-scores are set to missing if the value is deemed implausible, the gender variable is missing, or the z-score has an absolute value greater than five standard deviations away from the reference. Only 82 observations were set to missing for weight-for-age, 338 for height-for-age, and 524 for weight-for-height. We show z-scores for all measures of malnutrition, and stunting is a dummy variable if the z-score is greater than two or three standard deviations below the reference median. At Follow-up II, we also measure middle and upper arm circumference (MUAC).

[15]Dietary diversity information was collected for the respondent and youngest child at baseline and at Follow-up I, and for the respondent and all children 6–23 months of age at Follow-up II.

[16]Number of close friends, number of people they could borrow money from, frequency of listening to radio, number of times called/texted in the past week, and how often people come to them for advice were examined but are not shown.

TABLE 1 Baseline balance test.

	Mean (std deviation)	Mean differences control–treatment {normalized differences}			Mean differences across treatment groups {normalized differences}				
	Control	T1: Agriculture only	T2: Health only	T3: Agriculture and health	(2)–(4) T1–T3	(3)–(4) T2–T3	T3 − (T3 + credit)	T3 − (T3 + voucher)	T3 − (T3 + insurance)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A: Household characteristics									
Male-headed household (Yes = 1)	0.76	0.01	0.01	−0.00	−0.01	−0.01	0.01	0.05	0.03
	(0.63)	{0.00}	{0.00}	{−0.00}	{−0.00}	{−0.01}	{0.00}	{0.02}	{0.01}
Household members own home (Yes = 1)	0.90	0.03	0.02	0.01	−0.02	−0.01	0.02	−0.01	−0.00
	(0.55)	{0.02}	{0.01}	{0.01}	{−0.01}	{−0.00}	{0.01}	{−0.00}	{−0.00}
Number of rooms in the house	3.89	0.08	0.06	0.07	−0.01	0.01	−0.14	−0.09	−0.05
	(3.06)	{0.01}	{0.01}	{0.01}	{−0.00}	{0.00}	{−0.01}	{−0.01}	{−0.01}
Number of children in household	2.72	−0.01	−0.03	−0.20	−0.19	−0.18	0.19	0.21	0.24
	(4.28)	{−0.00}	{−0.00}	{−0.02}	{−0.01}	{−0.01}	{0.01}	{0.02}	{0.02}
Female sole decision maker on household expenses (Yes = 1)	0.24	−0.02	−0.03	−0.03	−0.01	−0.00	0.01	−0.03	−0.01
	(0.55)	{−0.01}	{−0.01}	{−0.01}	{−0.00}	{−0.00}	{0.00}	{−0.01}	{−0.01}
Monthly household income (UGX)	239,398.39	18,289.91	35,580.40	11,457.01	−6832.90	−24,123.39	−11,994.40	23,538.64	14,985.54
	(570,597.57)	{0.01}	{0.02}	{0.01}	{−0.00}	{−0.01}	{−0.01}	{0.01}	{0.01}
B: Respondent characteristics									
Age of respondent (years)	39.93	0.50	−0.00	−0.69	−1.19	−0.69	−0.79	0.33	0.15
	(17.24)	{0.01}	{−0.00}	{−0.01}	{−0.01}	{−0.01}	{−0.01}	{0.00}	{0.00}
Respondent pregnant at census (Yes = 1)	0.34	−0.03	−0.04	−0.06	−0.03	−0.02	0.06	0.07	0.02
	(1.11)	{−0.01}	{−0.01}	{−0.02}	{−0.01}	{−0.01}	{0.02}	{0.02}	{0.01}
Respondent has secondary education or higher (Yes = 1)	0.24	0.03	0.02	0.03	−0.00	0.01	−0.04	0.01	−0.01
	(0.53)	{0.01}	{0.01}	{0.01}	{−0.00}	{0.00}	{−0.02}	{0.00}	{−0.00}
C: Nutrition									
Respondent: Dietary diversity score (0–9)	4.51	−0.06	0.05	0.00	0.07	−0.04	−0.07	0.16	−0.04
	(3.36)	{−0.01}	{0.01}	{0.00}	{0.01}	{−0.01}	{−0.01}	{0.02}	{−0.00}

TABLE 1 (Continued)

	Mean (std deviation)	Mean differences control–treatment {normalized differences}			Mean differences across treatment groups {normalized differences}				
	Control	T1: Agriculture only	T2: Health only	T3: Agriculture and health	(2)–(4) T1–T3	(3)–(4) T2–T3	T3 − (T3 + credit)	T3 − (T3 + voucher)	T3 − (T3 + insurance)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Youngest child: Dietary diversity score (0–9)	4.41	−0.05	0.01	0.05	0.10	0.05	−0.08	0.13	−0.14
	(3.09)	{−0.01}	{0.00}	{0.01}	{0.01}	{0.01}	{−0.01}	{0.01}	{−0.02}
Household Food Intake Insecurity (Yes = 1)	0.76	−0.06	−0.03	−0.04	0.01	−0.01	0.01	−0.03	0.02
	(0.91)	{−0.02}	{−0.01}	{−0.02}	{0.01}	{−0.00}	{0.00}	{−0.01}	{0.01}
D: Agriculture									
Number of crops cultivated (sum of past two seasons)	9.73	−0.04	−0.01	−0.10	−0.06	−0.09	0.02	−0.02	0.16
	(8.81)	{−0.00}	{−0.00}	{−0.01}	{−0.00}	{−0.01}	{0.00}	{−0.00}	{0.01}
Cultivation area of all plots (sum of past two seasons, acres)	4.15	0.03	−0.10	−0.08	−0.11	0.03	0.16	0.01	−0.03
	(7.06)	{0.00}	{−0.01}	{−0.00}	{−0.01}	{0.00}	{0.01}	{0.00}	{−0.00}
Cultivated OFSP in any of last two cropping seasons (Yes = 1)	0.02	0.00	0.01	0.00	−0.00	−0.01	0.01	0.01	0.01
	(0.41)	{0.00}	{0.01}	{0.00}	{−0.00}	{−0.01}	{0.01}	{0.01}	{0.02}
Number of observations	1086	1111	1082	1068	2179	2150	2038	2022	2019
Joint test p-value		0.56	0.76	0.40	0.94	0.77	0.22	0.27	0.48

Note: (1) Column 1 shows the mean of the control group, with the standard deviation in parentheses. The normalized differences between each treatment arm (T1, T2, and T3) with the control group are presented in columns 2, 3, and 4. We report the mean differences and indicate the normalized differences in curly brackets underneath the mean, which is a scale-invariant measure of the size of the difference. In columns 5 and 6, we present comparisons of T1 with T3, and T2 with T3; in columns 7, 8, and 9, we present comparisons of T3 with the T3 + Cr, T3 + V, and T3 + I (Finnovation) treatment arms. (2) Here, 1 USD was approximately 2500 UGX shillings (exchange rate in 2014). (3) The value displayed for F-tests are p-values. (4) Joint test is an F-test testing the joint significance of the variables in the table on each treatment status run as a linear regression with standard errors adjusted for within-community correlation and including branch dummies. Omnibus test p-value comes from an F-test of joint orthogonality of all variables X in regression individual treat = a + b'X + c'randomization + e. (5) Household monthly income, land area, value of crop production, number of crops, and area cultivated values are winsorized at the 99% level. Note that the age of respondent and youngest child dietary diversity score variables, which are missing for a few households, are not included in the calculation of the joint orthogonality test (F-test) in order to utilize the full study sample size in the comparisons.
*Significant at 10% level;
**Significant at 5% level;
***Significant at 1% level.

characteristics measured at baseline. The *F*-test of joint orthogonality shown at the bottom of Table 1 suggests we cannot reject the null hypothesis that these characteristics are jointly unrelated to treatment status. Normalized differences are also presented, where only one variable out of 26 (between the agriculture intervention only and control group) shows a difference of greater than 0.25, which is the rule-of-thumb threshold proposed by Imbens and Rubin (2015).

Concentrating on the control group only, we can see from the first column of Table 1 that the respondents are, on average, 40 years old, have 2.72 children, and are literate (83% report that they can read and write in any language). Overall, 75% of households report a male household head and an average monthly household income of 240,000 Ugandan shillings (UGX).[17] Farmers have an average of 2.3 acres of agricultural land. Stunting rates are 47% for boys and 35% for girls under 2 years.[18] At baseline, only 2% report that they had ever cultivated OFSP, and 3% had ever consumed OFSP.

Attrition

Overall, 91% of the sample was tracked and surveyed at Follow-up I and 85% at Follow-up II.[19] In Appendix C, Table C1, we detail the sample sizes for each survey round by treatment status. In general, attrition rates are slightly higher in the control group compared to the treatment groups at Follow-up II.

We are also interested in the extent of differential attrition by baseline characteristics in treatment groups vis-à-vis the control group. This is shown more formally in Appendix C, Table C2. We do not find any statistically significant difference in the attrition rates for treatment groups from baseline to Follow-up I. However, there are statistically significant differences in attrition rates by Follow-up II. Being assigned to the agriculture intervention only or in combination with the health intervention, with or without the offer of the financial innovations, lowers the likelihood of attrition of the survey. The F-statistic of joint significance of the interactions of treatment arms with baseline characteristics is not statistically significant.

We run two robustness checks of our results using bounding approaches to show that the main results of the article are robust to attrition. More precisely, the results based on inverse probability weighting (IPW) and Lee bounds (Lee, 2019) are presented for the main outcomes in Appendix C, Tables C3 and C4.

Program take-up and treatment compliance

Table 2 provides details on the take-up of services offered by BRAC, as reported by the respondent, which confirm a high level of compliance with the assigned treatment status.[20] Low take-up (and/or high contamination) is of concern, as it can reduce the intention-to-treat effect sizes. Table 2 shows that the input packages containing free OFSP vines were successfully distributed correctly, with an average take-up rate of 86% among households assigned to any agriculture intervention. Among the households assigned to agriculture only (T1), 66% participated in BRAC agricultural trainings, of which 98% reported that the sessions included information on OFSP cultivation.

Among the health and nutrition information treatment group, the majority of respondents (94%) said they knew their CHP and 80% had met to discuss health and/or nutrition. Often, these interactions were recent. Nearly 47% of households indicated that they had a visit with a health

[17]This is equivalent to approximately USD 95 at the prevailing exchange rate at the time of the baseline survey.

[18]Note that Uganda's national stunting rate was approximately 35% at the time of the baseline (UBOS, 2016).

[19]This is equivalent to an attrition rate of 8.9% from baseline to Follow-up I, and 15.1% by Follow-up II. Only 4.7% of the sample completed only the baseline survey with no follow-up surveys (not shown). At baseline, 7694 households were surveyed. Follow-up I was administered to 7008 households, and Follow-up II to 6534 households that form the panel.

[20]Table 2 shows self-reported take-up. Column 1 gives the average among households in control group communities, and columns 2–7 report the average for the treatment groups.

TABLE 2 Randomization compliance and take-up of BRAC interventions.

					Financial innovations		
	Control (C)	Agriculture only (T1)	Health only (T2)	Agriculture + health (T3)	Agriculture + health + credit (T3 + Cr)	Agriculture + health + voucher (T3 + V)	Agriculture + health + insurance (T3 + I)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Agriculture							
Received free OFSP vines from BRAC	0.8%	86.8%	4.1%	87.3%	82.6%	88.0%	84.7%
Participated in BRAC agricultural trainings	4.0%	66.7%	12.9%	55.9%	67.6%	76.6%	64.5%
Met with a community agriculture promoter to discuss agriculture	1.6%	75.1%	9.3%	72.7%	71.3%	70.8%	75.1%
Health							
Met with community health provider to discuss health or nutrition	5.7%	13.3%	79.9%	81.3%	63.4%	69.3%	73.1%
Community health worker visited your home in past 3 months	11.5%	13.3%	40.0%	38.2%	27.1%	40.4%	34.7%
Participated in BRAC growth monitoring and promotion with youngest child	8.9%	19.4%	35.4%	36.6%	27.1%	35.5%	33.7%
Financial innovations							
Heard of BRAC agricultural credit	2.8%	27.7%	16.7%	27.4%	53.8%	37.7%	12.5%
Offered BRAC agricultural credit	0.1%	1.8%	0.5%	2.5%	21.8%	8.5%	1.1%
Accepted BRAC agricultural credit	0.1%	0.0%	0.2%	0.5%	11.8%	3.2%	0.3%
Heard of BRAC agricultural input voucher cards	1.3%	10.5%	5.3%	11.5%	8.0%	58.0%	9.3%
Offered BRAC agricultural input voucher cards	0.1%	0.3%	0.0%	0.5%	1.2%	27.1%	1.5%
Purchased BRAC agricultural input voucher cards	0.1%	0.2%	0.0%	0.0%	0.3%	13.1%	0.2%

(Continues)

TABLE 2 (Continued)

					Financial innovations		
	Control (C)	Agriculture only (T1)	Health only (T2)	Agriculture + health (T3)	Agriculture + health + credit (T3 + Cr)	Agriculture + health + voucher (T3 + V)	Agriculture + health + insurance (T3 + I)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Heard of BRAC market guarantees for OFSP products	2.8%	57.3%	18.9%	44.5%	61.4%	57.0%	55.8%
Offered a guaranteed market by BRAC for any OFSP products	0.2%	14.4%	4.4%	9.1%	25.8%	17.4%	26.0%
Signed written contract with BRAC that guaranteed a market for OFSP products	0.0%	0.2%	0.3%	3.0%	0.7%	0.5%	6.1%

Note: (1) Columns 1–7 report average percentage of respondents who said yes to receiving the specific BRAC services. (2) All take-up measures were self-reported by the respondent in the Follow-up I survey round after implementation was completed.

worker outside their home and 34% inside their home (not shown) within the 3 months prior to the survey. The average take-up rate of BRAC's growth monitoring and promotion (GMP) sessions was 34%.[21] Average participation in GMP sessions was 52% for households with children under 5.

Table 2, columns 5–7 present the take-up of the three financial products. Among households assigned to receive credit, 54% had heard about agricultural credit, 22% were offered credit by BRAC, and only 12% had accepted credit. There were no established marketing channels or value chains connected to the crop. Therefore, farmers may have been reluctant to make investments financed by debt. Similarly, for the households assigned to receive vouchers, we find 58% had heard about input voucher cards, 27% were offered the BRAC voucher cards, and 13% had purchased them. Again, OFSP lacked market orientation when it was introduced, and this may have served as a barrier to investment. For the price insurance product that offered a buyback guarantee for OFSP produce, 26% of the respondents reported that they were offered the guaranteed market and 6% explicitly signed a written contract with BRAC. There appears to be some contamination in other agriculture treatment households, where 14% of the agriculture-only group report that they were offered a guaranteed market by BRAC as well. We speculate that perhaps, in an effort to encourage cultivation, community agriculture promoters may have communicated informally with the farmers that a buyback guarantee was available. We find no evidence that a formal contract was signed for anyone in these groups.

4 | EMPIRICAL STRATEGY

4.1 | Main econometric specification

We estimate intention-to-treat (ITT) effects by exploiting the random variation in program placement at the community level. For outcomes that were measured at baseline and follow-up surveys,

[21]The GMP sessions were meant to be attended by the respondent and their youngest child in the health treatment.

the regression specification follows the analysis of covariance (ANCOVA) estimator, which has been shown to increase statistical power over a more standard difference-in-differences estimator (McKenzie, 2012). Accordingly, our main specification is

$$\begin{aligned} Y_{ivt} = \beta_0 + \beta_1 \text{AgricOnly}_{\text{iv}} + \beta_2 \text{HealthOnly}_{\text{iv}} + \beta_3 \text{AgricHealth}_{\text{iv}} \\ + \beta_4 \text{Credit}_{\text{iv}} + \beta_5 \text{Voucher}_{\text{iv}} + \beta_6 \text{Insurance}_{\text{iv}} + \beta_7 Y_{iv0} + \delta' X_{iv0} + \varepsilon_{itv}, \end{aligned} \quad (1)$$

where Y_{ivt} is the outcome variable for household i in community v at time t. We present estimates for the two follow-up periods separately, with Follow-up I considered the short run (2 years post-intervention) and Follow-up II the longer run (5 years post-intervention). Y_{iv0} is the baseline value of the outcome variable, if available. X_{iv0} is a vector of control variables that includes number of rooms in the house (proxy for wealth), age, male-headed household, and number of children under 18 years at baseline. ε_{itv} is the error term.

In all regressions, standard errors are clustered by community, which is the level of randomization, and include BRAC branch fixed effects (randomization strata). The equality of the treatment effects is tested, and F-tests are presented at the bottom of the regression tables to examine any complementarity between the agriculture and health interventions.

In Equation (1), the treatment arms are grouped in the following way: AgricOnly is a treatment dummy variable for being randomly assigned to the agriculture-only treatment arm (T1); HealthOnly is a treatment dummy variable for being assigned to the health information–only treatment arm (T2); AgricHealth is a treatment dummy variable for being assigned to the treatment arm that combines the agriculture and health interventions (T3); and Credit, Vouchers, and Insurance are dummy variables that take on a value of 1 in addition to AgricHealth if the respondent is assigned to T3 + Cr, T3 + V, or T3 + I. The coefficients on Credit, Vouchers, and Insurance, therefore, measure the marginal impacts of the financial products over and above T3. That is, coefficients β_1, β_2, and β_3 measure the ITT estimates that give the direct effects of the AgricOnly, HealthOnly, and AgricHealth treatment groups as compared to the control group, respectively, and β_4, β_5, and β_6 measure the marginal effects of the financial treatment arms. For most of the robustness analysis, however, we combine the credit, voucher, and price insurance treatments into a single *Finnovations* treatment arm (T3+) to simplify the presentation of results.

4.2 | Multiple hypothesis testing

We account for multiple inference by adjusting the statistical test for each hypothesis and present sharpened false discovery rate (FDR) q-values, which use a simple method proposed by Benjamini and Hochberg (1995) to calculate the smallest level of significance at which the null hypothesis would be rejected. The Benjamini and Hochberg (1995) sharpened two-stage q-values are presented in our main regression tables in square brackets below the standard errors. The q-values are calculated by aggregating hypotheses across the outcomes and treatments contained in each results table. In addition, we aggregate some outcome measures into indices or composite variables.

4.3 | Expost power calculations

Appendix A, Table A1 presents ex post power calculations to demonstrate that the study is well powered to test the main effects on production, consumption, and sales of OFSP, as well as dietary diversity. However, the study is underpowered for other outcomes, in part due to the relatively small and uncertain dose of additional OFSP consumed relative to other factors affecting overall dietary quality and nutritional status.

5 | RESULTS

5.1 | Impact on OFSP cultivation

Table 3 presents the treatment impacts on the cultivation of OFSP in the two follow-up time periods and the two agricultural seasons separately: July–December in Panel A and January–June in Panel B. Table 3 shows that OFSP is more likely to be cultivated by farmers in the July–December cropping season than in the January–June cropping season.

In Table 3, column 1, we find a large positive impact of the agriculture treatments on the cultivation of OFSP in the short run. We find that being assigned to the agriculture-only treatment leads to a 67 pp increase in the likelihood of cultivating OFSP in the July–December season and a 37 pp increase in the January–June season, relative to the control group. Households that received the agriculture interventions also had a larger area devoted to OFSP cultivation (0.22 acres of land) and produced, on average, 100 kilograms more OFSP in the July–December cropping season than the control group. Only 1.5% of control group households reported cultivating the crop in either cropping season at Follow-up I.

The agriculture treatment impacts are slightly more muted in the longer run. In Follow-up II, we find that being assigned to receive the agriculture intervention leads to a 29 pp higher likelihood of cultivating OFSP in the July–December season and 13 pp higher likelihood in the January–June season. Agriculture treatment households devoted approximately 0.06 acres of land to produce an average of 50 kilograms more OFSP in the July–December cropping season than households in the control group. Over time, households in the control group villages increased the likelihood of cultivating the OFSP crop from 1.5% of households at baseline and Follow-up I to 5.6% in Follow-up II. These impacts may not have resulted in an increase in overall agricultural production, as farmers appear to decrease the production of white sweet potato varieties in response to the agriculture treatment (see Appendix D, Table D1 for more information on this result). In Appendix D, Table D2, we also examine impacts on the planting of beans, tomatoes, and groundnuts, seeds of which were distributed together with the OFSP vines in agricultural input packages. We find a positive impact on growing beans (including iron-rich varieties), tomatoes, and groundnuts. The magnitude of the impacts is smaller compared to OFSP and largely dissipates over time.

We find no evidence of an impact of the health-only treatment on the likelihood of cultivating the OFSP crop or any marginal effect of combining the agriculture with the health interventions or providing supplementary financial products on cultivation.

5.2 | Impact on OFSP consumption and sales

Outcomes in Table 4 include household consumption and sales of the biofortified crop. Table 4, columns 1 and 2 show that at Follow-up I, agriculture treatment households are 50 pp more likely to consume OFSP at least once a month, and 34 pp once a week, than the control group. In the longer run, the agriculture treatment households are 41 pp more likely to consume OFSP once a month and 39 pp once a week. The results suggest that once women farmers are given inputs for the nutrient-rich crop, their households produce and consume the crop. This result holds true even 5 years after inputs were first distributed. The majority of the crop's harvest was consumed by the household rather than sold for income.[22]

We also find positive impacts of the health-only treatment. Households are just over 21 pp more likely to consume OFSP at least once a month, and about 12 pp more likely to consume it at least once a week, relative to the control group. Although the magnitude of the impact for the health information treatment is significantly lower than for the agriculture treatment arms, the result suggests that the messaging around the nutritional benefits of the biofortified crop was effectively taught

[22]More than 50% of study households name OFSP as one of the top six crops grown on agricultural land at follow-up.

TABLE 3 Adoption: Impact on the cultivation of the biofortified crop.

	Follow-up I			**Follow-up II**		
	Cultivated OFSP in the cropping season (yes = 1)	**Area cultivated with OFSP (acres)**	**Quantity of OFSP produced (kg)**	**Cultivated OFSP in the cropping season (yes = 1)**	**Area cultivated with OFSP (acres)**	**Quantity of OFSP produced (kg)**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Panel A	**Cropping season: July–December 2015**			**Cropping season: July–December 2018**		
T1: Agriculture only	0.668***	0.229***	104.090**	0.287***	0.064***	46.542***
	(0.05)	(0.02)	(44.87)	(0.03)	(0.01)	(5.89)
	[0.00]	[0.00]	[0.02]	[0.00]	[0.00]	[0.00]
T2: Health only	0.008	0.004	0.196	0.014	0.003	1.518
	(0.02)	(0.01)	(16.90)	(0.02)	(0.00)	(3.78)
	[1.00]	[1.00]	[1.00]	[0.98]	[0.65]	[1.00]
T3: Agriculture + Health	0.611***	0.197***	115.833**	0.330***	0.071***	58.673***
	(0.04)	(0.02)	(50.47)	(0.04)	(0.01)	(7.27)
	[0.00]	[0.00]	[0.02]	[0.00]	[0.00]	[0.00]
T3 + Credit (marginal)	0.008	−0.007	6.900	0.023	0.012	0.449
	(0.05)	(0.03)	(62.06)	(0.04)	(0.01)	(8.93)
	[1.00]	[1.00]	[1.00]	[1.00]	[0.47]	[1.00]
T3 + Vouchers (marginal)	−0.064	−0.028	104.414	−0.049	−0.013	−10.828
	(0.05)	(0.03)	(76.01)	(0.05)	(0.01)	(9.24)
	[0.31]	[0.42]	[0.21]	[0.50]	[0.46]	[0.32]
T3 + Insurance (marginal)	0.043	0.035	21.858	0.085*	0.006	5.075
	(0.06)	(0.03)	(62.56)	(0.04)	(0.01)	(8.11)
	[0.79]	[0.44]	[1.00]	[0.06]	[1.00]	[1.00]
Observations	7008	7004	7007	6533	6533	6533
Control group mean at follow-up	0.015	0.005	1.545	0.056	0.010	7.133
Panel B	**Cropping season: January–June 2016**			**Cropping season: January–June 2019**		
T1: Agriculture only	0.363***	0.116***	36.699	0.125***	0.022***	15.872***
	(0.04)	(0.02)	(26.74)	(0.02)	(0.00)	(3.48)
	[0.00]	[0.00]	[0.21]	[0.00]	[0.00]	[0.00]
T2: Health only	0.019	0.005	0.092	0.014	0.001	1.675
	(0.02)	(0.01)	(7.11)	(0.02)	(0.00)	(2.46)
	[0.54]	[1.00]	[1.00]	[0.68]	[1.00]	[0.98]
T3: Agriculture + Health	0.378***	0.122***	35.000*	0.144***	0.024***	19.445***
	(0.04)	(0.02)	(18.18)	(0.03)	(0.01)	(4.73)
	[0.00]	[0.00]	[0.06]	[0.00]	[0.00]	[0.00]
T3 + Credit (marginal)	0.009	−0.016	−6.674	0.028	0.011	4.534
	(0.05)	(0.02)	(19.89)	(0.04)	(0.01)	(5.87)
	[1.00]	[0.78]	[1.00]	[0.90]	[0.24]	[0.79]

(Continues)

TABLE 3 (Continued)

Panel B	Cropping season: January–June 2016			Cropping season: January–June 2019		
T3 + Vouchers (marginal)	−0.031	−0.022	34.702	0.014	0.005	2.093
	(0.05)	(0.02)	(31.50)	(0.04)	(0.01)	(5.57)
	[1.00]	[0.33]	[0.37]	[1.00]	[0.94]	[1.00]
T3 + Insurance (marginal)	0.039	0.014	27.489	0.074*	0.010	5.359
	(0.06)	(0.02)	(32.31)	(0.04)	(0.01)	(5.17)
	[0.94]	[1.00]	[0.66]	[0.06]	[0.17]	[0.43]
Observations	7008	7008	7008	6533	6533	6533
Control group mean at follow-up	0.014	0.004	0.791	0.025	0.005	2.831
Panel A: *p*-values						
T1: Agriculture only–T2: Health only	<0.0001	<0.0001	0.0219	<0.0001	<0.0001	<0.0001
T3: Agriculture + Health–T1: Agriculture only	0.3197	0.3286	0.8568	0.3513	0.5289	0.1550
T3: Agriculture + Health–T2: Health only	<0.0001	<0.0001	0.0231	<0.0001	<0.0001	<0.0001
Panel B: *p*-values						
T1: Agriculture only–T2: Health only	<0.0001	<0.0001	0.1744	<0.0001	<0.0001	0.0001
T3: Agriculture + Health–T1: Agriculture only	0.7956	0.7949	0.9587	0.5777	0.7615	0.4997
T3: Agriculture + Health–T2: Health only	<0.0001	<0.0001	0.0551	<0.0001	0.0001	0.0002

Note: (1) ANCOVA regressions include controls measured at baseline level for the level of the outcome variable, BRAC branch dummies, number of rooms in the house, age of respondent, male-headed household dummy, and number of children under 18 years. Standard errors are clustered at the community level. (2) Area and quantity variables are winsorized at the 95th percentile level. (3) At baseline and Follow-up I, details on OFSP quantity for each season are collected if OFSP is one of the six most important crops they cultivated in each of the past two cropping seasons. At Follow-up II, details on OFSP quantity are collected for each season if the respondent stated they cultivated any OFSP. (4) Standard errors are reported under the coefficient in parentheses. Sharpened *q*-values that correct *p*-values for the false discovery rate are in square brackets.
*Significant at 10% level;
**Significant at 5% level;
***Significant at 1% level.

by community health providers and internalized by the training participants. For the health-only treatment, households are only 5 pp more likely to consume OFSP once a week in the longer run than the control group. Intuitively, it makes sense that households in the nutrition information

TABLE 4 Impact on consumption and sales of the biofortified crop.

	Follow-up I				Follow-up II			
	Household consumes OFSP at least once a month (yes = 1)	Household consumes OFSP at least once a week (yes = 1)	Household sold OFSP in either of past two cropping seasons (yes = 1)	Quantity of OFSP sold in past two cropping seasons (kg)	Household consumes OFSP at least once a month (yes = 1)	Household consumes OFSP at least once a week (yes = 1)	Household sold OFSP in either of past two cropping seasons (yes = 1)	Quantity of OFSP sold in past two cropping seasons (kg)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
T1: Agriculture only	0.507***	0.346***	0.077***	1.474***	0.412***	0.393***	0.107***	12.699***
	(0.06)	(0.05)	(0.01)	(0.34)	(0.04)	(0.04)	(0.02)	(2.49)
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
T2: Health only	0.211***	0.123***	0.007	0.119	0.048	0.052*	0.012	0.988
	(0.06)	(0.04)	(0.01)	(0.09)	(0.04)	(0.03)	(0.02)	(2.03)
	[0.00]	[0.00]	[0.53]	[0.21]	[0.25]	[0.11]	[0.79]	[1.00]
T3: Agriculture + Health	0.573***	0.429***	0.044***	0.738***	0.426***	0.379***	0.118***	15.578***
	(0.07)	(0.06)	(0.01)	(0.18)	(0.04)	(0.04)	(0.02)	(4.11)
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
T3 + Credit (marginal)	−0.106	−0.158**	0.015	0.425	−0.012	0.019	0.037	3.389
	(0.08)	(0.07)	(0.01)	(0.32)	(0.04)	(0.05)	(0.03)	(4.97)
	[0.22]	[0.03]	[0.34]	[0.22]	[1.00]	[1.00]	[0.29]	[0.99]
T3 + Vouchers (marginal)	0.093	−0.027	0.034**	0.768**	−0.069	−0.028	0.033	2.687
	(0.08)	(0.09)	(0.01)	(0.32)	(0.05)	(0.05)	(0.03)	(4.94)
	[0.36]	[1.00]	[0.02]	[0.02]	[0.18]	[1.00]	[0.34]	[1.00]
T3 + Insurance (marginal)	0.053	0.072	0.069***	1.527***	0.055	0.131***	0.030	3.103
	(0.08)	(0.08)	(0.02)	(0.43)	(0.05)	(0.05)	(0.03)	(4.60)
	[0.95]	[0.64]	[0.00]	[0.00]	[0.31]	[0.01]	[0.30]	[1.00]
Observations	6819	6819	7008	7004	6533	6533	6533	6530
Control group mean at follow-up	0.029	0.009	0.000	0.000	0.184	0.110	0.013	1.936

(Continues)

TABLE 4 (Continued)

	Follow-up I				Follow-up II			
	Household consumes OFSP at least once a month (yes = 1)	Household consumes OFSP at least once a week (yes = 1)	Household sold OFSP in either of past two cropping seasons (yes = 1)	Quantity of OFSP sold in past two cropping seasons (kg)	Household consumes OFSP at least once a month (yes = 1)	Household consumes OFSP at least once a week (yes = 1)	Household sold OFSP in either of past two cropping seasons (yes = 1)	Quantity of OFSP sold in past two cropping seasons (kg)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
p-values								
T1: Agriculture only–T2: Health only	0.0002	0.0009	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
T3: Agriculture + Health–T1: Agriculture only	0.4003	0.2993	0.0315	0.0535	0.7582	0.7786	0.6396	0.5098
T3: Agriculture + Health–T2: Health only	<0.0001	<0.0001	0.0004	0.0019	<0.0001	<0.0001	<0.0001	0.0005

Note: (1) Standard errors are clustered at the community level. All ordinary least squares (OLS) regressions include controls measured at baseline for the level of the outcome variable, number of rooms in the house, age of respondent, male-headed household dummy, number of children under 18 years, and BRAC branch fixed effects. (2) Quantity variables are winsorized at the 95% level. (3) Standard errors are reported under the coefficient in parentheses. Sharpened q-values that correct p-values for the false discovery rate are in square brackets.

*Significant at 10% level;

**Significant at 5% level;

***Significant at 1% level.

treatment group are more likely to consume than produce OFSP relative to those in the agriculture treatment group receiving inputs.

However, treatment effects on OFSP consumption are potentially being underestimated in the longer run because of potential spillover effects on households in control group communities.[23] The proportion of control group households who consume OFSP increases over time from 3% at baseline and Follow-up I to 18% at Follow-up II. We examine these consumption spillovers in the next subsection.

We find that only a relatively small fraction of households sell OFSP. About 8% and 11% of agriculture treatment households report sales of OFSP in the Follow-up I and Follow-up II survey periods, respectively. Small sale volumes of OFSP could simply reflect the targeting strategy of the program, as only 17% of households report that they ever sold staple sweet potato varieties (yellow and white) in local markets at baseline.[24] It is worth remembering that there were no established value chains or markets for OFSP at the time of the study initiation. Given the muted impacts on OFSP sales, economic outcomes at the individual and household levels are unlikely to be affected. Nevertheless, we show the impacts on women's economic empowerment and decision-making power as well as household income and asset wealth for completeness.

The *p*-values at the bottom of Table 4 test equality between the different treatment arms. Although we cannot reject equality between the agriculture-only and the combined treatment arms for consumption of OFSP, there seems to be a significant difference in the likelihood of sales of OFSP in the short run. Women assigned to the combined treatment arm are 3 pp less likely to sell OFSP in the cropping seasons compared to the agriculture-only treatment. Access to the supplementary financial product erases this difference at Follow-up I.

5.3 | Spillover effects

In the following analysis, we examine potential cross-community spillover effects to control group households in terms of cultivation and consumption of OFSP. To do so, we use data on the geographic location of households and combine this information with data from a preprogram network survey. We restrict the analysis to households in control group communities only. We leverage the exogenous variation in distance between households in control communities and treated communities created by the randomization.

We use the following equation to estimate whether household i in control group community v at time t is more or less likely to cultivate and consume OFSP as the household's distance to the nearest treatment household or network connection increases.

$$Y_{ivt} = \beta_0 + \beta_1 D_{iv} + \beta_2 Y_{iv0} + \delta' X_{iv0} + \varepsilon_{itv} \quad (2)$$

As before, Y_{ivt} is the outcome variable of interest. D_{iv} measures either (a) the distance of control household i to the nearest treated household or (b) having a network connection named from a treatment community.[25] For each of these measures, coefficient β_1 measures the correlation between the explanatory distance and network variables and the outcome. To explore the predictive nature of both networks and distance combined, we also interact a network link in a treatment village with a variable for the distance to a treatment household. X_{iv0} is a vector of baseline control variables that may influence the outcome, and standard errors are clustered at the community level. In the

[23]The percentage of households who consume OFSP among those assigned to the agriculture treatments increased from 3% to 60%, and among the health treatment from 1% to 23% over a 5-year period.

[24]The targeting criteria of the program were intentionally aimed toward the most vitamin A–vulnerable population (pregnant women or women with a child less than 2 years of age).

[25]We winsorize the distance variables at the 99th percentile to correct for possible outlier distances. We use the *geodist* and *geonear* commands in Stata to compute the distance variables.

regressions, we control for the distance of control household i to the nearest study households (the median distance of household i's five nearest neighbors) and whether i named any network connection in the study sample.

Table 5 presents spillover effects on whether the household cultivated OFSP in either of the past two cropping seasons and whether they consumed OFSP in the past month. In Table 5, we present the correlation between a control group household's distance to the nearest treated household and the outcomes of interest. In the short and longer runs, we find that the few households in the control group who cultivated OFSP were more likely to do so if they were in closer proximity to a treatment household. We also find a weak negative correlation between distance to a treatment household and consumption of OFSP. We find no evidence of a correlation between having named a direct network connection within a treatment village and cultivation or consumption of OFSP.[26] In Table 5, columns 3, 6, 9, and 12, we interact having a direct network link in a treatment village with the distance to the nearest treatment household.[27] The interaction helps us to understand whether the closer a control group household is physically and socially determines the likelihood of cultivation or consumption. We find control group households that have a direct network connection in a treatment village that is closer in distance (within approximately 0.5 km) are more likely to consume OFSP in the longer run. Control group households that name a close network connection with someone in a nearby treated village are 12 pp more likely to consume OFSP at least once a month. These results suggest that it is not just the network or proximity that matters, but both are important for consumption spillovers.[28]

In summary, more than one-third of households who received free planting material and agricultural extension continued to cultivate the crop in the longer run. The majority of households (about 60%) in the agriculture treatment arm were still consuming the nutrient-rich crop 5 years later. Consumption benefits spill over to nontreated households in control communities with close social network connections to people in nearby treated communities, implying that our estimates of direct effects are likely to be downward biased. However, the magnitude of the spillover effect is very small compared to the direct treatment effect sizes.[29]

5.4 | Impact on dietary diversity and food security

Table 6 presents the treatment impacts on measures of dietary diversity and household food security following Equation (1). The dietary diversity index is a count of the number of food groups out of nine reported to have been consumed in the past 24 h using the list-based method specified in FAO guidelines.[30] We report results for the respondent and the youngest child. The Household Food Insecurity Access Scale (HFIAS) ranges from 0 to 27; households with a higher score are more food insecure.[31]

[26]Approximately 10% of control group households named a direct link with a treatment household.

[27]Note that the median distance of a control household to a treated household is equivalent to 0.562 km.

[28]In Appendix D, Table D3, we show that there is little evidence of information diffusion about the crop's benefits by examining knowledge spillover effects related to vitamin A–rich foods among control group households.

[29]Note that using the distance from treatment households as a proxy for spillover effects limits us from calculating an average spillover effect size. However, based on regression coefficients from Table 5, column 10, an estimate of the likelihood of control group households consuming OFSP at least once a month is 1.97 pp for those 200 meters from a treatment household. This rate declines to 1.23 and 0.021 pp for distances of 0.5 km and 1 km, respectively. Given an average control–treatment distance of 0.68 km, spillover effects appear notably small to substantially bias the 41 pp treatment effect on consumption of OFSP at Follow-up II.

[30]The nine food groups include starchy staples (grains and cereals, roots and tubers), legumes and nuts, milk and milk products, meat (flesh foods) and fish, organ meat (liver), eggs, vitamin A–rich vegetables and tubers/vitamin A–rich fruits, dark green leafy vegetables, and other fruits and vegetables.

[31]The HFIAS score is the sum of the frequency of occurrence during the past month for nine food insecurity–related conditions based on USAID's measurement guide. The HFIAS occurrence questions relate to anxiety and uncertainty about household food supply, insufficient quality of food, and insufficient food intake.

TABLE 5 Spillover effects of distance and networks links with treatment on adoption.

	Follow-up I						Follow-up II					
	Grow OFSP in either of past two cropping seasons (yes = 1)			Consume OFSP at least once a month (yes = 1)			Grow OFSP in either of past two cropping seasons (yes = 1)			Consume OFSP at least once a month (yes = 1)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Distance to nearest treatment household (km)	−0.025**		−0.025**	−0.015*		−0.016*	−0.033*		−0.029	−0.025		−0.017
	(0.010)		(0.010)	(0.009)		(0.008)	(0.019)		(0.018)	(0.022)		(0.021)
Distance to neighboring study households (km)	0.006		0.007	0.024		0.022	0.121**		0.121**	0.171**		0.170**
	(0.021)		(0.022)	(0.036)		(0.036)	(0.056)		(0.056)	(0.065)		(0.062)
Network link from a treatment village (yes = 1)		−0.010	−0.009		−0.001	−0.008		0.023	0.048		0.058	0.120*
		(0.018)	(0.033)		(0.012)	(0.015)		(0.036)	(0.057)		(0.044)	(0.069)
Network link with any study household (yes = 1)		0.004	0.004		−0.004	−0.004		−0.016	−0.015		−0.038	−0.036
		(0.007)	(0.007)		(0.016)	(0.016)		(0.017)	(0.017)		(0.028)	(0.028)
Network link from treatment × Distance to treatment			−0.009			0.010			−0.053			−0.122**
			(0.031)			(0.027)			(0.044)			(0.054)
Observations	974	974	974	892	892	892	890	890	890	890	890	890
Control group mean at baseline	0.025	0.025	0.025	0.029	0.029	0.029	0.026	0.026	0.026	0.025	0.025	0.025

Note: (1) Distance to nearest treatment household is based on GPS data for each control group household collected at Follow-up I or Follow-up II or census (distance estimated in kilometers using the *geodist* command in Stata). All distances are winsorized at the 99% level. (2) Network link from a treatment village is based on data collected in a networks survey. If the respondent named a direct link with a household in a treatment village, the variable equals 1 and 0 otherwise. (3) Distance to treated above the median is a dummy variable equal to 1 if the distance from the control group to their nearest treatment household is above the median and 0 if below the median. (4) The sample includes only control group households. Standard errors are clustered at the community level. All regressions include controls measured at baseline for the level of the outcome variable, number of rooms in the house, age of respondent, male-headed household dummy, number of children under 18 years of age, and BRAC branch fixed effects. In the regression, we also control for distance with neighboring study households (km) given by the median distance of the five nearest neighboring study households (estimated using the *geonear* command in Stata) and whether they named a direct connection with any household in the study.

*Significant at 10% level;

**Significant at 5% level;

***Significant at 1% level.

TABLE 6 Impact on dietary diversity and household food insecurity.

	Follow-up I			Follow-up II		
	Female respondent dietary diversity score (0–9)	Youngest child (above 6 months) dietary diversity score (0–9)	Household Food Insecurity Access Scale score (0–27)	Female respondent dietary diversity score (0–9)	Youngest child (above 6 months) dietary diversity score (0–9)	Household Food Insecurity Access Scale score (0–27)
	(1)	(2)	(3)	(4)	(5)	(6)
T1: Agriculture only	0.255*	0.522**	−0.650	0.155	0.069	−0.564
	(0.15)	(0.23)	(0.89)	(0.15)	(0.31)	(0.64)
	[0.09]	[0.02]	[0.88]	[0.47]	[1.00]	[0.61]
T2: Health only	0.273*	0.468**	−0.319	−0.131	−0.056	−0.338
	(0.15)	(0.23)	(0.96)	(0.12)	(0.29)	(0.62)
	[0.07]	[0.04]	[1.00]	[0.38]	[1.00]	[1.00]
T3: Agriculture + Health	0.150	0.305	−0.424	−0.003	−0.113	−0.503
	(0.14)	(0.20)	(0.90)	(0.15)	(0.33)	(0.70)
	[0.41]	[0.14]	[1.00]	[1.00]	[1.00]	[0.90]
T3 + Credit (marginal)	0.228	0.035	−0.193	0.094	0.531*	−0.552
	(0.15)	(0.19)	(0.82)	(0.18)	(0.29)	(0.64)
	[0.16]	[1.00]	[1.00]	[1.00]	[0.07]	[0.64]
T3 + Vouchers (marginal)	0.019	−0.021	−0.365	0.153	−0.187	0.695
	(0.15)	(0.20)	(0.76)	(0.15)	(0.34)	(0.63)
	[1.00]	[1.00]	[1.00]	[0.46]	[1.00]	[0.38]
T3 + Insurance (marginal)	0.172	0.206	−0.238	0.171	0.360	−0.050
	(0.14)	(0.18)	(0.83)	(0.16)	(0.30)	(0.61)
	[0.29]	[0.34]	[1.00]	[0.38]	[0.31]	[1.00]
Observations	6783	6233	6960	6506	684	6482
Control group mean at follow-up	3.954	3.335	7.223	4.859	4.404	7.652
p-values						
T1: Agriculture only–T2: Health only	0.9122	0.8104	0.7200	0.0509	0.6529	0.6680
T3: Agriculture + Health–T1: Agriculture only	0.4902	0.2761	0.7905	0.3573	0.5838	0.9210
T3: Agriculture + Health–T2: Health only	0.4244	0.4058	0.9102	0.3601	0.8844	0.7850

Note: (1) Outcome variables on dietary diversity and food insecurity follow the FAO guide. Dietary diversity score counts the consumption of nine food groups by the respondent and the youngest child in the household in the past 24 h (only include data for youngest child above 6 months of age for Follow-up I and children 6–23 months for Follow-up II). Food insecurity is separated into three domains: anxiety and uncertainty about the household food supply, insufficient quality (includes variety and preferences of the type of food), and insufficient food intake. The HFIAS score is the sum of the frequency of occurrence during the past 4 weeks for nine food insecurity–related conditions. (2) Standard errors are clustered at the community level. All regressions include controls measured at baseline for BRAC branch dummies, number of rooms in the house, age of respondent, male-headed household dummy, and number of children under 18 years. Regressions with outcome variables of the respondent's dietary diversity score and HFIAS also include the baseline level of the outcome variable. (3) For Follow-up I, dietary diversity is measured for the youngest child in the household, but analysis is restricted to the youngest child in the household who is above 6 months of age. For Follow-up II, dietary diversity is measured for all children between 6 and 23 months of age, but analysis is restricted to the youngest child between 6 and 23 months of age. (4) Standard errors are reported under the coefficients in parentheses. Sharpened *q*-values that correct *p*-values for the false discovery rate (FDR) are in square brackets.

*Significant at 10% level;

**Significant at 5% level;

***Significant at 1% level.

In Table 6, columns 1 and 2, we find a positive treatment effect of the agriculture-only and health-only treatments on dietary diversity of both the respondent and the youngest child in the household at Follow-up I, which is in line with an increase in OFSP consumption. It is worth noting that the health-only intervention is effective on its own in impacting dietary diversity. Results on diet are not sustained in the longer run, however. At Follow-up II, we find no evidence of a treatment impact on the dietary diversity score for both the respondent and the youngest child (see columns 4 and 5).[32] We also find no evidence of a direct treatment impact on food insecurity scores that measure both the quality and quantity of food consumed. However, it is worth pointing out again that the program was not necessarily designed to improve agricultural production. Instead, the emphasis was on incentivizing farmers to switch to crops with greater nutritional value. This observation is supported by the finding that farmers who received the agriculture treatment substituted away from producing other types of potato varieties (see Appendix D, Table D1).

5.5 | Impact on child health and nutrition outcomes

Table 7 presents the impacts on measures of malnutrition of children less than 5 years, including z-scores for height-for-age, weight-for-age, and weight-for-height.[33] Although the program timeline was expected to be too short to change malnutrition indicators, we show outcomes for completeness.[34] Overall, the results in Table 7 suggest limited impact on indicators of child health and nutrition. The negative coefficient on weight-for-height (column 3) for the health-only treatment and combined intervention suggests a worsening in child nutritional status. Conversely, there is a reduction in the likelihood of a child being severely stunted for the health-only treatment.[35] During Follow-up II, we find that agriculture-only households have lower underweight and wasting z-scores, relative to control households.

The main morbidity measures included in all our survey rounds were diarrhea and fever prevalence of the youngest child in the household. Impacts are estimated on children aged 5 or under, as was shown for anthropometric measures. In columns 7 and 8, we find no effects on the incidence of diarrhea or fever experienced by the youngest child. The incidence of diarrhea was fairly stable over time, with approximately 10% of reports of children under age 5 having had diarrhea in the past 2 weeks at baseline, 6% at Follow-up I, and 11% at Follow-up II.

Note that the health intervention curriculum included lessons on breastfeeding best practices, healthy pregnancy, and sanitation and hygiene. We find no evidence of any treatment impact on various measures of maternal health or use of antenatal care services (not shown).

5.6 | Impact on visual acuity

In Table 8, we present impact results on a vision test (columns 1–4) and self-reported measures of eyesight (columns 5–8). We administered the Sjogren Hand Test at Follow-up II to measure eyesight of the respondent and all children residing in the household aged between 6 and 18 years. The test was devised to gauge the vision of children and illiterate populations.[36] Visual acuity when measured through the Sjogren Hand Test is recorded as a fraction (e.g., 20/25, which means that the line read

[32]Note the sample size in column 5 is smaller because the Follow-up II survey was restricted to the youngest child aged 6–23 months; Follow-up I was unrestricted.

[33]The average stunting rates (low HFA) among the sample at baseline are in line with national Uganda averages, where 39% of under-5 boys are stunted compared to 30% of under-5 girls (UBOS LSMS 2014 data).

[34]For the analysis of stunting, wasting, and underweight outcomes among children under 5 years and visual acuity in the next section, we include enumerator fixed effects to correct for potential enumerator bias (Maio & Fiala, 2020).

[35]We find no evidence of health treatment households switching away from other nutritious food groups, such as milk, in favor of OFSP.

[36]The test is administered for both eyes from two distances: 10 feet and 20 feet away from the test sheet. From each distance, and for each eye, the respondent and children are asked to use hand gestures to copy the position of the hands in a test sheet.

TABLE 7 Impact on child nutrition and health.

	All children aged less than 5 years						In the past 2 weeks, has child had …	
	Height-for-age z-score (HAZ)	Weight-for-age z-score (WAZ)	Weight-for-height z-score (WHZ)	Moderate stunting (HAZ < −2) (yes = 1)	Severe stunting (HAZ < −3) (yes = 1)	Malnourished (MUAC < 125 mm)	Diarrhea (yes = 1)	Fever (yes = 1)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Follow-up I								
T1: Agriculture only	0.138	−0.060	−0.205	−0.006	0.005	-	−0.012	−0.033
	(0.13)	(0.08)	(0.14)	(0.03)	(0.02)	-	(0.02)	(0.05)
	[0.39]	[0.83]	[0.19]	[1.00]	[1.00]		[1.00]	[1.00]
T2: Health only	0.263*	−0.089	−0.345*	−0.033	−0.035*	-	0.003	−0.016
	(0.14)	(0.09)	(0.18)	(0.03)	(0.02)	-	(0.02)	(0.05)
	[0.06]	[0.44]	[0.06]	[0.34]	[0.08]		[1.00]	[1.00]
T3: Agriculture + Health	0.180	−0.112	−0.315**	0.002	−0.026	-	0.006	−0.009
	(0.13)	(0.07)	(0.14)	(0.03)	(0.02)	-	(0.02)	(0.04)
	[0.19]	[0.14]	[0.02]	[1.00]	[0.17]		[1.00]	[1.00]
T3 + Credit (marginal)	0.004	0.120	0.155	−0.044	0.019	-	0.036*	0.010
	(0.11)	(0.10)	(0.15)	(0.03)	(0.02)	-	(0.02)	(0.04)
	[1.00]	[0.29]	[0.44]	[0.13]	[0.68]		[0.07]	[1.00]
T3 + Vouchers (marginal)	−0.144	0.043	0.182	0.014	0.034	-	−0.010	0.011
	(0.12)	(0.11)	(0.15)	(0.03)	(0.02)	-	(0.01)	(0.04)
	[0.29]	[1.00]	[0.27]	[1.00]	[0.12]		[1.00]	[1.00]
T3 + Insurance (marginal)	−0.121	0.091	0.224*	−0.012	0.043**	-	0.009	−0.000
	(0.11)	(0.09)	(0.13)	(0.03)	(0.02)	-	(0.02)	(0.04)
	[0.38]	[0.45]	[0.09]	[1.00]	[0.04]		[1.00]	[1.00]
Observations	3805	3805	3805	3805	3805	-	4707	4708
Control group mean at follow-up	−0.955	−0.506	0.064	0.284	0.120	-	0.063	0.284

TABLE 7 (Continued)

	All children aged less than 5 years						In the past 2 weeks, has child had …	
	Height-for-age z-score (HAZ)	Weight-for-age z-score (WAZ)	Weight-for-height z-score (WHZ)	Moderate stunting (HAZ < −2) (yes = 1)	Severe stunting (HAZ < −3) (yes = 1)	Malnourished (MUAC < 125 mm)	Diarrhea (yes = 1)	Fever (yes = 1)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel B: Follow-up II								
T1: Agriculture only	0.049	−0.282**	−0.459**	0.002	0.013	0.002	0.034	0.018
	(0.19)	(0.13)	(0.21)	(0.04)	(0.04)	(0.01)	(0.03)	(0.04)
	[1.00]	[0.04]	[0.04]	[1.00]	[1.00]	[1.00]	[0.46]	[1.00]
T2: Health only	−0.145	−0.183	−0.160	0.015	0.019	0.009	−0.008	−0.062
	(0.17)	(0.14)	(0.18)	(0.05)	(0.03)	(0.01)	(0.03)	(0.04)
	[0.68]	[0.24]	[0.62]	[1.00]	[1.00]	[0.23]	[1.00]	[0.17]
T3: Agriculture + Health	−0.145	−0.204	−0.179	0.031	0.027	0.007	0.018	−0.019
	(0.17)	(0.14)	(0.19)	(0.05)	(0.04)	(0.01)	(0.03)	(0.05)
	[0.69]	[0.16]	[0.55]	[1.00]	[0.94]	[0.50]	[1.00]	[1.00]
T3 + Credit (marginal)	0.149	−0.005	−0.102	−0.040	−0.025	0.005	−0.004	0.046
	(0.17)	(0.13)	(0.22)	(0.05)	(0.03)	(0.01)	(0.03)	(0.05)
	[0.60]	[1.00]	[1.00]	[0.65]	[0.81]	[1.00]	[1.00]	[0.54]
T3 + Vouchers (marginal)	−0.018	−0.036	−0.010	−0.015	−0.001	0.007	−0.035	−0.058
	(0.17)	(0.13)	(0.20)	(0.05)	(0.03)	(0.01)	(0.03)	(0.05)
	[1.00]	[1.00]	[1.00]	[1.00]	[1.00]	[0.74]	[0.33]	[0.28]
T3 + Insurance (marginal)	−0.089	0.066	0.140	0.006	−0.002	−0.012*	0.018	0.028
	(0.15)	(0.13)	(0.19)	(0.04)	(0.03)	(0.01)	(0.04)	(0.05)
	[1.00]	[1.00]	[0.84]	[1.00]	[1.00]	[0.08]	[1.00]	[1.00]
Observations	2289	2289	2289	2289	2289	2289	2949	2949
Control group mean at follow-up	−1.501	−0.233	0.837	0.390	0.210	0.028	0.107	0.273

(Continues)

TABLE 7 (Continued)

	All children aged less than 5 years						In the past 2 weeks, has child had …	
	Height-for-age z-score (HAZ)	Weight-for-age z-score (WAZ)	Weight-for-height z-score (WHZ)	Moderate stunting (HAZ < −2) (yes = 1)	Severe stunting (HAZ < −3) (yes = 1)	Malnourished (MUAC < 125 mm)	Diarrhea (yes = 1)	Fever (yes = 1)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: *p*-values								
T1: Agriculture only–T2: Health only	0.3174	0.7779	0.4636	0.3646	0.0458	-	0.4697	0.7071
T3: Agriculture + Health–T1: Agriculture only	0.6943	0.5337	0.3822	0.7622	0.0844	-	0.3323	0.5784
T3: Agriculture + Health–T2: Health only	0.5077	0.8164	0.8667	0.2047	0.6738	-	0.8502	0.8341
Panel B: *p*-values								
T1: Agriculture only–T2: Health only	0.3038	0.5181	0.1945	0.7883	0.8601	0.3429	0.2065	0.0474
T3: Agriculture + Health–T1: Agriculture only	0.3018	0.5919	0.2305	0.5096	0.6837	0.3910	0.6719	0.4367
T3: Agriculture + Health–T2: Health only	0.9977	0.8801	0.9205	0.7703	0.8245	0.7840	0.3921	0.3469

Note: (1) The outcome variables for anthropometric measurement are z-scores (HAZ for stunting, WAZ for underweight, and WHZ for wasting). Dummy variables on stunting are defined as the percentage of children, aged 0 to 59 months, whose height for age is below minus two standard deviations (moderate stunting) and below minus three standard deviations (severe stunting) from the median of the WHO Child Growth Standards. Dummy variables indicating prevalence of diarrhea and fever for children in the past 2 weeks are reported by the respondent. (2) Regressions use Follow-up I and Follow-up II data with standard errors clustered by village. The OLS regressions include control variables for the four branches, number of rooms in the house (a proxy for wealth), age of the respondent, number of children, and male-headed household at baseline. OLS regressions for anthropometric analysis (HAZ, WAZ, WHZ, moderate stunting, severe stunting, malnourished) also include enumerator fixed effects. (3) At Follow-up I, prevalence of diarrhea and fever is asked for the youngest child in the household (and analysis is restricted to those below 60 months of age). At Follow-up II, prevalence of diarrhea and fever is asked for all children below 60 months of age in the household. (4) Standard errors are reported under the coefficients in parentheses. Sharpened *q*-values that correct *p*-values for the FDR are in square brackets.

*Significant at 10% level;

**Significant at 5% level;

***Significant at 1% level.

TABLE 8 Impact on visual acuity.

	(Follow-up II)				Follow-up I		Follow-up II	
	Sjogren Hand Test for visual acuity (LogMAR)				Any problems with eyesight? (yes = 1)			
	Adults (> 18 years)	Children (6–18 years)	Girls (6–18 years)	Boys (6–18 years)	Female respondent	Children (≤ 18 years)	Female respondent	Children (≤ 18 years)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
T1: Agriculture only	0.015	0.004	0.004	0.003	0.004	−0.004	0.013	−0.009
	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)	(0.01)	(0.03)	(0.01)
	[0.19]	[1.00]	[1.00]	[1.00]	[1.00]	[1.00]	[1.00]	[0.57]
T2: Health only	0.017*	0.006	0.008	0.003	0.098***	0.003	0.018	0.002
	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)	(0.01)	(0.03)	(0.01)
	[0.09]	[0.84]	[0.35]	[1.00]	[0.01]	[1.00]	[1.00]	[1.00]
T3: Agriculture + Health	0.020	0.007	0.013	−0.001	0.020	−0.016**	−0.002	0.003
	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)	(0.01)	(0.03)	(0.01)
	[0.19]	[0.90]	[0.20]	[1.00]	[1.00]	[0.04]	[1.00]	[1.00]
T3 + Credit (marginal)	−0.005	−0.006	−0.013	0.001	0.026	0.014	0.013	−0.012
	(0.02)	(0.01)	(0.01)	(0.01)	(0.04)	(0.01)	(0.03)	(0.01)
	[1.00]	[1.00]	[0.27]	[1.00]	[0.99]	[0.13]	[1.00]	[0.18]
T3 + Vouchers (marginal)	0.001	−0.000	−0.005	0.005	0.041	0.011	0.017	−0.005
	(0.02)	(0.01)	(0.01)	(0.01)	(0.04)	(0.01)	(0.03)	(0.01)
	[1.00]	[1.00]	[1.00]	[1.00]	[0.43]	[0.14]	[1.00]	[1.00]
T3 + Insurance (marginal)	−0.016	0.011	0.011	0.011	−0.024	0.008	−0.006	−0.006
	(0.02)	(0.01)	(0.01)	(0.01)	(0.04)	(0.01)	(0.03)	(0.01)
	[0.47]	[0.41]	[0.50]	[0.35]	[1.00]	[0.56]	[1.00]	[1.00]
Observations	6475	13,296	6477	6819	6984	18,330	6499	18,166
Control group mean at follow-up	0.165	0.109	0.106	0.113	0.211	0.042	0.266	0.034
p-values								
T1: Agriculture only–T2: Health only	0.9044	0.8280	0.6061	0.9673	0.0165	0.6007	0.8429	0.8429

(Continues)

TABLE 8 (Continued)

	(Follow-up II)				Follow-up I		Follow-up II	
	Sjogren Hand Test for visual acuity (LogMAR)				Any problems with eyesight? (yes = 1)			
	Adults (> 18 years)	Children (6–18 years)	Girls (6–18 years)	Boys (6–18 years)	Female respondent	Children (≤ 18 years)	Female respondent	Children (≤ 18 years)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
T3: Agriculture + Health–T1: Agriculture only	0.7830	0.8088	0.4263	0.7317	0.6821	0.2264	0.6168	0.0882
T3: Agriculture + Health–T2: Health only	0.8462	0.9451	0.6542	0.7530	0.0346	0.06	0.473	0.9813

Note: (1) Sjorgen's Hand Test consists of pictures of hands in four different directions. The logarithm minimum angle of resolution (LogMAR) value is calculated based on the corresponding Snellen fraction of the Sjogren Eye Test. Lower LogMAR values correspond to higher visual acuity. As each hand size changes by 0.1 logMAR units per row and there are five hands on each row, each letter can be assigned a value of 0.02. Thus, the final LogMAR value takes account of every direction of the hand that has been correctly read. (2) Standard errors are clustered at the community level. All OLS regressions include BRAC branch dummies, number of rooms in the house, age of respondent, male-headed household dummy, and number of children under 18 years. All OLS regressions for the Sjogren Eye Test include enumerator fixed effects. (3) Any problems with eyesight were collected in the household roster for all household members. Only outcomes for the female respondent and children are shown. The Sjorgen Hand Test is administered to the respondent and all children between 6 and 18 years. (4) Standard errors are reported under the coefficients in parentheses. Sharpened q-values that correct p-values for the FDR are in square brackets.

*Significant at 10% level;

**Significant at 5% level;

***Significant at 1% level.

TABLE 9 Impact on women's empowerment and decision-making power.

	Empowered (yes = 1 if 4+ A-WEAI indicators adequate)	Empowerment index: Sum of A-WEAI indicators (0–5)	Female made decisions (either alone or jointly with male household head) about … What to cultivate (yes = 1)	Household expenditures and investments (yes = 1)	Childcare and schooling (yes = 1)
	(1)	(2)	(3)	(4)	(5)
T1: Agriculture only	0.015	−0.013	0.026	0.028	0.027
	(0.05)	(0.11)	(0.04)	(0.04)	(0.04)
	[1.00]	[1.00]	[0.87]	[0.76]	[0.88]
T2: Health only	−0.009	−0.037	−0.029	−0.012	−0.004
	(0.05)	(0.11)	(0.04)	(0.04)	(0.04)
	[1.00]	[1.00]	[0.90]	[1.00]	[1.00]
T3: Agriculture + Health	−0.034	−0.121	−0.022	0.040	−0.016
	(0.06)	(0.12)	(0.04)	(0.04)	(0.05)
	[1.00]	[0.48]	[1.00]	[0.52]	[1.00]
T3 + Credit (marginal)	0.107**	0.293***	0.076*	0.010	0.077*
	(0.05)	(0.11)	(0.04)	(0.04)	(0.04)
	[0.04]	[0.01]	[0.06]	[1.00]	[0.08]
T3 + Vouchers (marginal)	0.000	0.062	0.042	−0.005	0.023
	(0.06)	(0.13)	(0.04)	(0.04)	(0.05)
	[1.00]	[1.00]	[0.46]	[1.00]	[1.00]
T3 + Insurance (marginal)	0.053	0.122	0.073*	−0.003	0.073*
	(0.06)	(0.12)	(0.04)	(0.04)	(0.04)
	[0.53]	[0.47]	[0.07]	[1.00]	[0.08]
Observations	5877	5877	5398	5877	5877
Control group mean at follow-up	0.422	3.233	0.838	0.801	0.796
p-values					
T1: Agriculture only–T2: Health only	0.6246	0.8261	0.1655	0.3022	0.4200
T3: Agriculture + Health–T1: Agriculture only	0.3578	0.3723	0.2328	0.7951	0.3087
T3: Agriculture + Health–T2: Health only	0.6628	0.5088	0.8655	0.2431	0.7821

Note: (1) Standard errors are clustered at the community level. All OLS regressions include controls measured at baseline for the level of the outcome variable, BRAC branch dummies, number of rooms in the house, age of respondent, male-headed household dummy, and number of children under 18 years. (2) A-WEAI indicators included in the index: adequate workload (caring for others [children, ill household members], domestic tasks, tasks on non–farm business activities, paid activities outside home, tasks on family farm, shopping or getting services), input in decisions for at least two productive domains (food crop farming, cash crop farming, livestock raising, fishing or fishpond culture), input in at least one domain in income decisions (regarding wage, employment, nonfarm economic activity, and major household expenditures [but not minor household expenditures alone]), comfortable speaking in public in at least one situation (on decisions on infrastructure, on proper payment of wages, and/or to protest misbehavior of elected officials), group membership in at least one group (agricultural group, credit/microfinance group, mutual help or insurance group, trade and business association, civic groups, religious group, etc.). (3) The sample consists of female respondents in all households who completed the WEAI module in the Follow-up II survey. (4) Standard errors are reported under the coefficients in parentheses. Sharpened q-values that correct p-values for the FDR are in square brackets.

*Significant at 10% level;

**Significant at 5% level;

***Significant at 1% level.

TABLE 10 Impact on household income and asset wealth.

	Total sale value of household assets (UGX)	Total monthly household income (UGX)	Household owns agricultural land (yes = 1)	Agricultural land area (acres)	Total value of animals owned (UGX)
	(1)	(2)	(3)	(4)	(5)
T1: Agriculture only	−144676.472	−41661.305	−0.007	0.110	43782.804
	(1081100.74)	(26964.48)	(0.02)	(0.15)	(79893.07)
	[1.00]	[0.14]	[1.00]	[0.90]	[1.00]
T2: Health only	−766170.197	−38677.613	−0.021	0.003	−55634.648
	(1085846.20)	(28227.78)	(0.02)	(0.15)	(71386.32)
	[0.93]	[0.21]	[0.42]	[1.00]	[0.78]
T3: Agriculture + Health	324939.698	−15461.020	−0.012	0.064	7153.922
	(1097409.47)	(33212.86)	(0.02)	(0.14)	(80836.06)
	[1.00]	[1.00]	[1.00]	[1.00]	[1.00]
T3 + Credit (marginal)	2417572.087**	−16643.318	−0.003	0.351*	−85536.204
	(1198712.38)	(31811.27)	(0.02)	(0.20)	(91308.65)
	[0.05]	[1.00]	[1.00]	[0.08]	[0.54]
T3 + Vouchers (marginal)	335527.911	−23059.854	0.004	−0.063	−30992.198
	(1110526.43)	(33222.46)	(0.02)	(0.14)	(79658.99)
	[1.00]	[0.95]	[1.00]	[1.00]	[1.00]
T3 + Insurance (marginal)	227638.002	8483.094	0.008	0.065	19883.799
	(1002865.31)	(34025.99)	(0.02)	(0.13)	(76364.53)
	[1.00]	[1.00]	[1.00]	[1.00]	[1.00]
Observations	6507	6533	6533	5897	6533
Control group mean at Follow-up II	9764252.770	283656.517	0.930	1.952	643066.292
p-values					
T1: Agriculture only–T2: Health only	0.5570	0.9128	0.5015	0.5015	0.2151
T3: Agriculture + Health–T1: Agriculture only	0.6636	0.4227	0.8146	0.7578	0.6814
T3: Agriculture + Health–T2: Health only	0.3116	0.4920	0.7028	0.6717	0.4398

Note: (1) Standard errors are clustered at the community level. ANCOVA regressions include controls measured at baseline for the level of the outcome variable, BRAC branch dummies, number of rooms in the house, age of respondent, male-headed household dummy, and number of children under 18 years. (2) Assets include homestead land, house/other buildings, furniture, household appliances, furnishings, bed nets, clothing, jewelry and watches, mobile phone, television, radio/cassette player, bicycle, motorcycle/boda boda, pangas/slashes/hoes/agricultural tools, and other. Value is recorded by total Ugandan shillings (UGX) amount of all asset types owned by the household. Animals include both poultry and livestock. (3) Total sale value of assets, monthly household income, and agricultural land area are winsorized at the 99th percentile. (4) Standard errors are reported under the coefficients in parentheses. Sharpened q-values that correct p-values for the FDR are in square brackets.

*Significant at 10% level;

**Significant at 5% level;

***Significant at 1% level.

from 20 feet away can be read by someone who has normal vision from 25 feet away) and is converted into a LogMAR scale.[37] Self-reported eyesight for all household members was measured at

[37]LogMAR is the logarithm of the minimum angle of resolution (MAR). Note that a higher LogMAR value indicates lower visual acuity.

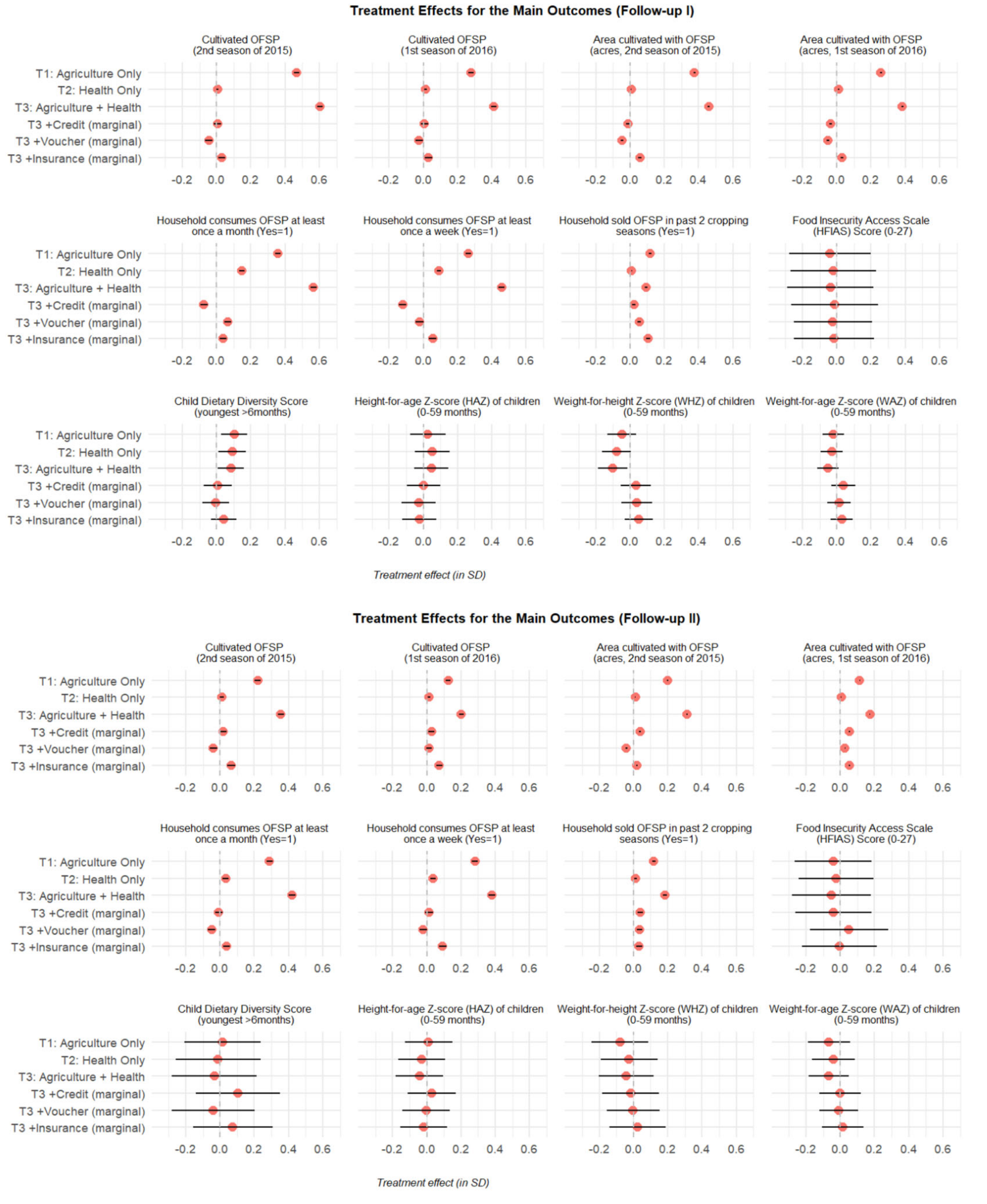

FIGURE 1 Treatment effects: visual summary.

both Follow-up I and Follow-up II, where the respondent was asked to indicate whether each household member had any sight problems.

Columns 1–4 indicate that there is no evidence of a treatment effect on visual acuity for children aged 6–18 in the household.[38] There appears to be a slight worsening of visual acuity among adults in the household as a result of the health information intervention, measured by the LogMAR scale

[38]Reference tables for tests: https://dicom.nema.org/DICOM/2013/output/chtml/part17/sect RR.2.html.

and self-reported eyesight. This result appears to be driven by an increase in the reported eyesight problems among respondents aged 35 years and older (age breakdown not shown in Table 8). We can only speculate that this could be due to increased health-seeking behavior (e.g., if eye tests were more accessible in health clinics).

5.7 | Impact on women's economic empowerment

Table 9, column 1 presents a measure of women's empowerment that is a dummy variable indicating whether the respondent achieved adequacy in at least four indicators in the A-WEAI.[39] In column 2, we present an unweighted sum of five indicators that were coded as 1 if the respective category was considered adequate in the A-WEAI; columns 3–5 are measures of intrahousehold decision making across three domains.

Column 1 shows that, on average, 42% of the control group achieved adequacy in at least four indicators (coded as empowered). We find no evidence of an overall impact on women's economic empowerment or decision-making power. We find some weak evidence that the financial innovations had a positive marginal impact on women's input into the decision of what to cultivate on agricultural land, relative to the control group.

5.8 | Impact on household income and assets

In Table 10, we analyze treatment effects on additional household welfare outcomes, including household income and assets.

Overall, we find no evidence that the interventions had an impact on any asset category or income. Given that most of the OFSP that was produced was consumed by the households rather than sold, the absence of any program impacts on income is to be expected.

In Figure 1, we summarize the treatment effects on the main outcomes of interest.

6 | CONCLUSION

Sub-Saharan Africa shows lower rates of agricultural technology adoption relative to the global trend. Convincing smallholder farmers to adopt a beneficial agricultural technology is complex, since numerous factors may affect the adoption and diffusion process.

In this article, we study the impact of a program designed to increase adoption of biofortified orange-fleshed sweet potato (OFSP) introduced to women farmers in southwest Uganda. OFSP is a relatively new crop in our study area, with limited prior experience in farming OFSP or established output markets. Prior to the intervention, only 3% of households reported having ever consumed an orange sweet potato variety. Public provision of new planting material and possibly other interventions to incentivize adoption may be necessary to successfully introduce such a crop quickly. The article tests a set of stand-alone and combined interventions in health, nutrition, and agriculture to determine which have the greatest impact on adoption of the new nutrient-rich crop variety. Our results show that providing the new planting material together with extension services had a considerable positive impact on adoption of the nutrient-rich crop. Giving female farmers planting material for the nutrient-rich variety and information on how to cultivate it led to persistent adoption (after 5 years), with large increases in production that is both consumed and sold.

[39]The Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) is described in Alkire et al. (2013), and measurements were collected during Follow-up II; adequacy is determined using guidelines from A-WEAI resources.

Our article demonstrates that multiplication and distribution of improved planting material is a binding constraint on adoption of OFSP, with no additional benefit from four other interventions addressing possible market failures (information on OFSP's health benefits and three financial innovations). Farmers in our study area clearly found the OFSP variety attractive and are able and willing to plant it for both home consumption and sale, but without incentives for multiplication and distribution, the planting material remained unavailable to farmers unless it was provided through the intervention. Farmer-to-farmer multiplication and distribution was ineffective in this context. Our study provides a valuable demonstration of how multiplication and distribution of improved planting material can be a public good, with a high value to recipients but insufficient incentives for private delivery.

The availability of OFSP in communities where the crop is cultivated may be sufficient to induce some consumption spillover effects in nearby communities that were excluded from the interventions. We find that the extent of potential spillovers may be driven by geographic proximity and the network connectedness of farmers across communities. Women and children also experienced some benefits to their dietary diversity as a result of the interventions. Yet, despite the large and significant rise in the fraction of households frequently consuming OFSP, there were almost no statistically significant differences in other indicators of diet quality and nutritional status, visual acuity, or measures of women's economic empowerment or income.

The biofortified orange sweet potato variety was a novel crop in our study area that was introduced with the aim to improve household food security and nutrition, targeting the most vitamin A–vulnerable households. Of note is that only 17% of households in the study sample reported that they ever sold the staple white or yellow sweet potatoes in local markets at baseline. If policy aims to increase income or encourage women's economic empowerment, then targeting and supporting women farmers who are already trading staple crops in the market is potentially of greater promise. Programs with an explicit economic empowerment goal may need to find an alternative approach to encourage sales, for example, by introducing outgrower schemes. The low take-up and muted additional impact of the financial products on adoption are somewhat disappointing. However, without a clear link of the technology to market (value chain approach) to generate income, debt financing becomes risky.

Policymakers need to consider input availability as well as farmers' priorities and incentives for technology adoption (e.g., economic returns, increased food security, nutritional benefits, or risk mitigation) when designing programs that are tailored to the recipient farmer and local conditions. Programs that encourage the adoption of agricultural technologies may serve broader nutrition, health, or food security goals, but they may not align with farmers' incentives to maximize profits. Since there were no established value chains or markets for the new OFSP technology at the start of the program, farmers may have been unable to take advantage of market opportunities to obtain planting material from private sources and therefore did not adopt the technology. This study demonstrates how multiplication and distribution of planting material, combined with information about its use, can be a public good with high and persistent uptake by recipients. Control group households remained less likely to plant and consume OFSP even 5 years after its introduction, revealing the lack of incentives for private sector distribution or farmer-to-farmer sharing of planting material. This was in spite of the crop's appeal, as revealed by continued planting and increased consumption of the OFSP crop by those who benefited from public distribution of the planting material for this new crop variety.

ACKNOWLEDGMENTS

We thank Rajdev Brar for excellent research assistance, as well as Jonah Rexer, Gieltje Adriaans, and Pallavi Prabhakar for superb fieldwork management in Uganda. Many thanks to Aletheia Donald, Pushina Kunda Ng'andwe, Joseph Oryokot, and various seminar participants who provided useful comments. We also thank the implementing partner of the project, BRAC Uganda. This work has been funded by the Japan Social Development Fund (JSDF) and the World Bank's Umbrella Facility for Gender Equality (UFGE). The findings, interpretations, and conclusions expressed in this article are entirely those of the authors. They do not necessarily represent the views of the World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent. The randomized controlled trial is registered in the AEA RCT Registry: https://doi.org/10.1257/rct.7076.

REFERENCES

Achandi, E., G. Mujawamariya, R. Agboh-Noameshie, S. Abera, N. Rahalivavololona, and J. Rodenburg. 2018. "Women's Access to Agricultural Technologies in Rice Production and Processing Hubs: A Comparative Analysis of Ethiopia, Madagascar and Tanzania." *Journal of Rural Studies* 60: 188–198.

Alkire, S., R. Meinzen-Dick, A. Peterman, A. Quisumbing, G. Seymour, and A. Vaz. 2013. "The Women's Empowerment in Agriculture Index." *World Development* 52: 71–91.

Allan, C., A. Jaffe, and I. Sin. 2014. "Diffusion of Green Technology: A Survey." *International Review of Environmental and Resource Economics* 7: 1–33.

Banerjee, A., D. Karlan, and J. Zinman. 2015. "Six Randomized Evaluations of Microcredit: Introduction and Further Steps." *American Economic Journal: Applied Economics* 7: 1–21.

Beaman, L., D. Karlan, B. Thuysbaert, and C. Udry. 2014. Selection into Credit Markets: Evidence from Agriculture in Mali. Working Paper No. 20387, National Bureau of Economic Research

Belay, D. G., and H. Ayalew. 2020. "Nudging Farmers in Crop Choice Using Price Information: Evidence from Ethiopian Commodity Exchange." *Agricultural Economics* 51: 793–808.

Benjamini, Y., and Y. Hochberg. 1995. "Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing." *Journal of the Royal Statistical Society: Series B (Methodological)* 57: 289–300.

BenYishay, A., M. Jones, F. Kondylis, and A. M. Mobarak. 2020. "Gender Gaps in Technology Diffusion." *Journal of Development Economics* 143: 102380.

Besley, T., and A. Case. 1993. "Modeling Technology Adoption in Developing Countries." *The American Economic Review* 83: 396–402.

Bhutta, Z., J. Das, A. Rizvi, M. Gaffey, N. Walker, S. Horton, L. A. Webb, and R. Black. 2013. "Evidence-Based Interventions for Improvement of Maternal and Child Nutrition: What Can be Done and at What Cost?" *Lancet* 382: 452–477.

Bridle, L., J. Magruder, C. McIntosh, and T. Suri. 2019. Experimental Insights on the Constraints to Agricultural Technology Adoption. Working Paper, Agricultural Technology Adoption Initiative, J-PAL (MIT) and CEGA (UC Berkeley)

Burri, B. J. 2011. "Evaluating Sweet Potato as an Intervention Food to Prevent Vitamin A Deficiency." *Comprehensive Reviews in Food Science and Food Safety* 10: 118–130.

Chowdhury, S., J. V. Meenakshi, K. Tomlins, and C. Owori. 2010. "Are Consumers in Developing Countries Willing to Pay More for Micronutrient-Dense Biofortified Foods? Evidence from a Field Experiment in Uganda." *American Journal of Agricultural Economics* 93: 83–97.

Conley, T. G., and C. R. Udry. 2010. "Learning about a New Technology: Pineapple in Ghana." *American Economic Review* 100: 35–69.

Dahal, M., and N. Fiala. 2020. "What Do we Know about the Impact of Microfinance? The Problems of Statistical Power and Precision." *World Development* 128: 104773.

Das, N., A. de Janvry, and E. Sadoulet. 2019. "Credit and Land Contracting: A Test of the Theory of Sharecropping." *American Journal of Agricultural Economics* 101: 1098–1114.

de Brauw, A., P. Eozenou, D. Gilligan, C. Hotz, N. Kumar, and J. Meenakshi. 2018. "Biofortification, Crop Adoption and Health Information: Impact Pathways in Mozambique and Uganda." *American Journal of Agricultural Economics* 100: 906–930.

De Janvry, A., and E. Sadoulet. 2019. Transforming deveLoping Country Agriculture: Removing Adoption Constraints and Promoting Inclusive Value Chain Development, Working Paper FERDI 253

Dowling, J. 1966. "Night Blindness." *Scientific American* 215: 78–84.

Duflo, E., M. Kremer, and J. Robinson. 2011. "Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya." *American Economic Review* 101: 2350–90.

Field, E., Papp Pande, and N. Rigol. 2013. "Does the Classic Microfinance Model Discourage Entrepreneurship among the Poor? Experimental Evidence from India." *American Economic Review* 103: 2196–2226.

Food and Agriculture Organization (FAO). 2020. The State of Food Security and Nutrition in the World 2020. Transforming Food Systems for Affordable Healthy Diets

Foster, A. D., and M. R. Rosenzweig. 2010. "Microeconomics of Technology Adoption." *Annual Review of Economics* 2: 395–424.

Fuglie, K., M. Gautam, A. Goyal, and W. F. Maloney. 2019. *Harvesting Prosperity: Technology and Productivity Growth in Agriculture*. The World Bank, Washington, DC.

Gilligan, D. O., N. Kumar, S. McNiven, J. Meenakshi, and A. Quisumbing. 2020. "Bargaining Power, Decision Making, and Biofortification: The Role of Gender in Adoption of Orange Sweet Potato in Uganda." *Food Policy* 95: 101909. https://doi.org/10.1016/j.foodpol.2020.101909.

Gollin, D., C. W. Hansen, and A. M. Wingender. 2021. "Two Blades of Grass: The Impact of the Green Revolution." *Journal of Political Economy* 129: 2344–84.

Headey, D., A. Chiu, and S. Kadiyala. 2012. "Agriculture's Role in the Indian Enigma: Help or Hindrance to the Crisis of Undernutrition?" *Food Security* 4: 87–102.

Hotz, C., C. Loechl, A. de Brauw, P. Eozenou, D. Gilligan, M. Moursi, B. Munhaua, P. van Jaarsveld, A. Carriquiry, and J. Meenakshi. 2012. "A Large-Scale Intervention to Introduce Orange Sweet Potato in Rural Mozambique Increases Vitamin A Intakes among Children and Women." *The British Journal of Nutrition* 108: 163–176.

Imbens, G. W., and D. B. Rubin. 2015. *Causal Inference for Statistics, Social, and Biomedical Sciences: An Introduction*. Cambridge University Press, United Kingdom.

Jack, B. K. 2013. Constraints on the Adoption of Agricultural Technologies in Developing Countries. Literature Review, Agricultural Technology Adoption Initiative. J-PAL (MIT) and CEGA (UC Berkeley)

Lee, D. S. 2009. "Training, Wages, and Sample Selection: Estimating Sharp Bounds on Treatment Effects." *The Review of Economic Studies* 76(3): 1071–1102.

Low, J. W., and G. Thiele. 2020. "Understanding Innovation: The Development and Scaling of Orange-Fleshed Sweetpotato in Major African Food Systems." *Agricultural Systems* 179: 102770.

Maio, M. D., and N. Fiala. 2020. "Be Wary of those Who Ask: A Randomized Experiment on the Size and Determinants of the Enumerator Effect." *The World Bank Economic Review* 34: 654–669.

McKenzie, D. 2012. "Beyond Baseline and Follow-Up: The Case for More T in Experiments." *Journal of Development Economics* 99: 210–221.

Naico, A. T. A., and J. L. Lusk. 2010. "The Value of a Nutritionally Enhanced Staple Crop: Results from a Choice Experiment Conducted with Orange-Fleshed Sweet Potatoes in Mozambique." *Journal of African Economies* 19: 536–558.

Oliva, P., K. Jack, S. Bell, E. Mettetal, and C. Severen. 2020. "Technology Adoption under Uncertainty: Take-Up and Subsequent Investment in Zambia." *The Review of Economics and Statistics* 102: 617–632.

Ruel, M., and H. Alderman. 2013. "Nutrition-Sensitive Interventions and Programmes: How Can they Help to Accelerate Progress in Improving Maternal and Child Nutrition?" *Lancet* 382: 536–551.

Ruel, M., A. R. Quisumbing, and M. Balagamwala. 2018. "Nutrition-Sensitive Agriculture: What Have we Learned So Far?" *Global Food Security* 17: 128–153.

Stewart, R., L. Langer, N. Da Rebelo Silva, E. Muchiri, H. Zaranyika, Y. Erasmus, N. Randall, et al. 2015. "The Effects of Training, Innovation and New Technology on African Smallholder Farmers' Economic Outcomes and Food Security: A Systematic Review." *Campbell Systematic Reviews* 11: 1–224.

Suri, T. 2011. "Selection and Comparative Advantage in Technology Adoption." *Econometrica* 79: 159–209.

Uganda Bureau of Statistics. 2016. *The National Population and Housing Census 2014 – Main Report*. Kampala, Uganda.

Uganda Census of Agriculture. 2009. *Uganda Bureau of Statistics (UBOS)*. Kampala, Uganda. https://www.ubos.org/wp-content/uploads/publications/03_2018UCACrop.pdf.

van Jaarsveld, P., M. Faber, S. Tanumihardjo, P. Nestel, C. Lombard, and A. Benadè. 2005. "Beta-Carotene-Rich Orange-Fleshed Sweet Potato Improves the Vitamin A Status of Primary School Children Assessed with the Modified-Relative-Dose-Response Test." *The American Journal of Clinical Nutrition* 81: 1080–87.

Webb, P., and E. Kennedy. 2014. "Impacts of Agriculture on Nutrition: Nature of the Evidence and Research Gaps." *Food Nutrition Bulletin* 35: 126–132.

World Bank. 2007. *From Agriculture to Nutrition: Pathways, Synergies and Outcomes*.

World Health Organization. 2006. *WHO Child Growth Standards: Methods and Development*. USA: World Health Organization. https://iris.who.int/handle/10665/43413.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Buehren, Niklas, Shyamal Chowdhury, Sreelakshmi Papineni, and Munshi Sulaiman. 2025. "Impact of Inputs, Information, and Financial Services on the Adoption of a Biofortified Crop by Women Farmers in Uganda." *American Journal of Agricultural Economics* 107(4): 1117–51. https://doi.org/10.1111/ajae.12540