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Behavioral interventions in informal seed systems to nudge sustainable demand for quality seed of sweetpotato☆

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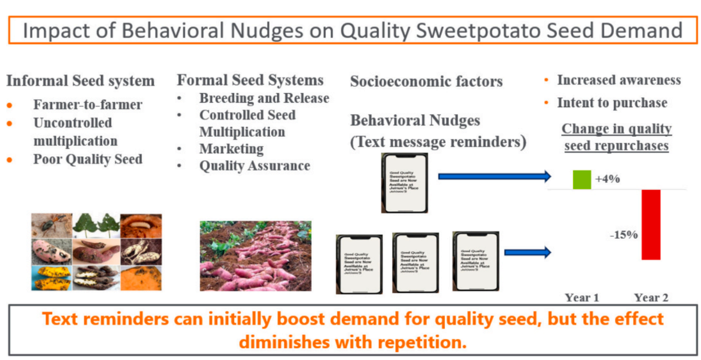
HIGHLIGHTS

- Reliance on informal seed systems reduces yields due to pests and disease buildup.
- Text reminders increased initial quality sweetpotato seed repurchase by 4 % in Uganda.
- Repeated reminders lost effectiveness and gave negative results in the second year.
- Wealth, age, education and land access also affect quality seed repurchase decisions.
- Strategically timed reminders are critical for a sustained quality seed adoption.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: The introduction of quality-certified seed (QCS) in the informal farmer network-based seed systems, which have largely relied on informal signals of quality, represents a promising innovation towards integrated seed sector development, combining formal and informal sector elements. At the same time, behavioral nudges have emerged as potentially powerful ways to encourage the uptake of innovations among smallholder farmers in developing countries.

OBJECTIVE: Here we examine whether nudges may be used to influence adoption rates of QCS in an informal seed system.

METHODS: We focused on the use of text message reminders to increase the repurchase of sweetpotato vines that are certified to be free of pests and diseases. Our study site was a sweetpotato growing district in Uganda where

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yield is severely depressed due to sweetpotato virus disease and sweetpotato weevils. We used a randomized controlled trial involving 120 village clusters to test the effectiveness of text message reminders.
RESULTS AND CONCLUSIONS: We observe some indication that initial text reminders increased the likelihood of repurchase. In subsequent seasons, additional reminders reduced this likelihood. This suggests that simple reminders may be a useful tool to encourage the swifter integration of formal and informal elements in seed systems, but that their repeated use may be counterproductive.
SIGNIFICANCE: This study highlights the potential and limitations of using behavioral nudges to promote sustainable demand for quality seed in informal seed systems. Text reminders can initially encourage adoption of quality seed. However, careful consideration is needed regarding their frequency and implementation to avoid negative effects.

1. Introduction

Access to clean and quality-certified seed is a critical pathway towards agricultural transformation through productivity enhancement. While there have been significant investments in formalizing seed systems to enhance access to quality seed, a large proportion of smallholder farmers in developing countries still rely on informal seed systems for seed acquisition (McGuire and Sperling, 2016). This is especially true for vegetatively propagated crops (VPCs) such as sweetpotato, cassava, bananas, yam, and potato, often referred to as roots, tubers and banana (RTB) crops. The nature of the seed material for these crops (i.e., stems, vines, tubers and suckers) is conducive for farmer-to-farmer exchange of planting material and for farmers to recycle seed, with little incentive for the participation of private seed entrepreneurs. Consequently, seed systems for RTB crops remain largely informal, with cultural norms and social relations playing a big role in governing seed acquisition (Hodgkin et al., 2007; Schöley and Padmanabhan, 2017).

Seed material disseminated using such informal channels is usually uninspected and uncertified. Under this system, farmers plant the progenies of the same material repeatedly over many seasons, and often years. This results in a build-up of pests and diseases, and rapid seed degeneration and associated reduction in crop growth, vigor and yield (Ogero et al., 2023; McGuire and Sperling, 2016). While new improved varieties of RTB crops that are resistant to pest and disease stress have been developed, their diffusion within existing informal seed systems is a challenge given the mentioned nature of the seed that allows for recycling and seed-sharing. This contributes to low variety turnover, with an estimated adoption ceiling of 40 % among RTB crops in sub-Saharan Africa (Gatto et al., 2021; McEwan et al., 2021a).

Beyond the informal seed system structure for RTB crops, other demand and supply factors contribute to seed recycling among RTB crops. With trading within the informal system common, the quality of seed is not clearly observable. Throughout the text we refer to seed that is disease free as *quality seed*. When procuring seed, a farmer is not able to observe whether the seed is quality seed or not, and must rely on external signals of quality. We distinguish between three potential signals of quality, differentiated by the degree of verifiability and reliability. Quality certified seed (QCS) is seed that has been produced in a formal operation that is regularly tested and inspected for diseases as part of a legally required seed certification scheme that ensures seed meet minimum quality standards and has a formal certificate of quality assurance. Quality declared seed (QDS) may be obtained from less formal channels, but has been *visually inspected* for diseases by a trained and formally authorized agriculturalist. Such visual inspection may miss some crop diseases. Though QDS is not afforded any specific assurances through a certificate, a farmer may take the declaration as a signal of quality. Finally, in the absence of QCS or QDS, a farmer may consider the reputation and history of the source in discerning quality—a fully informal signal. The difficulty and cost of obtaining QCS lead to substantial risk of poor performance and yield.

Unfamiliarity with a new technology and the associated perceived risk of poor performance form a strong disincentive for the adoption of new technologies generally, and has been a concern among RTB farmers specifically (Jogo et al., 2021; Almekinders et al., 2019). Thus, unfamiliarity may undermine demand for quality seed. High prices of quality seed, whether real or perceived, also contribute to seed recycling among the farmers (Bayiyana et al., 2024). In addition, lack of quality signals for VPCs seed limits differentiability of certified and uncertified seed, thereby reducing trust. Seed is a credence good whose quality cannot be directly observed (McEwan et al., 2021b; Spielman et al., 2021), and credible signals are strongly incentivized by allowing buyers and sellers to differentiate between seed bundles. For instance, seed for cereal crops is easily packaged and labelled to signal quality. This same effect is challenging to achieve, for instance, with sweetpotato vines and cassava cuttings. A rational farmer may, therefore, be unwilling to spend more to purchase seed that is not clearly and credibly differentiated as being of high quality, compared to other cheaper options. On the supply side, key impediments to farmer replacement of seed from VPCs include unavailability and the high transaction and transportation costs of accessing quality seed (Gibson et al., 2011; McEwan et al., 2021a). Community seed multipliers, the only source of quality seed, tend to be few and hence located too far from the majority of the farmers. The bulkiness and high perishability of the seed, especially sweetpotato vines, increase transaction costs. At the same time, while this study centers on quality seed, farmers' decisions about replanting or accessing quality seed may also depend on the variety preference, as recently documented by Bayiyana et al. (2024, 2025). We however don't pursue this aspect in our current paper because it is outside the scope of this study.

1.1. Context

In Uganda, sweetpotato is grown both as a commercial and as a subsistence/food security crop, with many households having a strong cultural affiliation with the crop as it forms a key part of local food systems in some regions of the country (Echodu et al., 2019). In the Teso sub-region, where the study was conducted, sweetpotato is grown in the first season mainly for fresh root consumption and sale (Bayiyana et al., 2024). In the second season, it is grown for making dried sweetpotato chips and flakes, called *amukeke* and *inginyo*, respectively, popularly used for making a cultural food known as *amukeke* also (Echodu et al., 2019). To make *amukeke* food, farmers peel sweetpotato roots and chip into large chunks which are then sun-dried. The process therefore needs strong sun over several days, conditions which are more prevalent after the second season harvest. The flakes (*inginyo*) are used to make flour for porridge.

Two types of sweetpotato seed systems exist concurrently in Uganda, one based on exchange within a social network and the other on commercial/market purchases (Rachkara et al., 2017; Sperling and Almekinders, 2023). These are however both informal, as seed flowing through these are usually uninspected, uncertified and often composed of unregistered and unreleased varieties.

The dominant seed system is social network-based not just for sweetpotato, but also for other vegetatively propagated crops, and thrives on farmer-to-farmer seed exchange. This system serves family, friends, neighbors and other farmers within the community. Seed is largely exchanged for free, or borrowed, with reciprocation culturally expected. Quality is determined through observation of the crop during the growth stage and/or visual observation of the vines (McEwan et al., 2021a). It is based on farmers' indigenous knowledge of disease and pest manifestations on growing plants and/or leaves and stems. Farmers collect/harvest the seed directly from neighbors' gardens, hence select what they perceive to be satisfactory in quality. The level of keenness in selecting the best in terms of quality depends on availability, with quality disregarded to a greater extent the more scarce the seed is.

The informal commercial/market sweetpotato seed systems are nascent and small, and strongest in the northern region of Uganda where drought desiccates all the sweetpotato planting material (Sperling and Almekinders, 2023). This system serves both local and distant farmers. Seed is produced off-season on wetlands, sold to neighbors, or traded in local roadside markets. A limited amount is traded across the border in Southern Sudan. Non-governmental organizations (NGOs) that supply seed aid play a major role in this system and deliver seed to distant communities. Non-NGO distant trade is facilitated by seed transportation using public bus and minibus services (Rachkara et al., 2017). The seed traded is of unknown quality. Seed quality assurance is "informal" based on trust and/or maintaining a good reputation (Sperling and Almekinders, 2023).

An important component of market/commercial sweetpotato seed systems revolves around community seed production by decentralized vine multipliers (DVMs) mostly piloted by research and development projects as a transitional formal model to bridge access to disease-free planting material of improved varieties. This system gained prominence with the introduction of biofortified crops and is mainly project-based (Gibson, 2013). It combines elements of informal and formal systems. The latter encompass training of seed multipliers on seed production and quality maintenance mechanisms. Starter material is sourced from the National Agricultural Research Organization (NARO) or credible certified private sector sources supervised by the National Seed Certification Service (NSCS).

Multipliers' operation and seed plots are routinely inspected and tested by the NSCS for the dominant diseases, and certificates of quality assurance are issued (Gibson, 2013). Alternatively, seed can be visually inspected usually by agricultural staff and declared relatively clean compared to seed from local seed networks. Seed from this second source is therefore referred to as QDS because it is inspected according to set guidelines to minimize, but not eliminate, pest and disease infestation (Mukasa et al., 2016). Due to the high cost of seed testing and certification, DVMs mainly produce QDS. It is sold predominantly to NGOs at high and sometimes subsidized prices. Some DVMs sell, usually leftovers, to local farmers/neighbors at lower prices than offered by NGOs. With the exception of a few cases, only registered and released varieties pass through this system.

Sweetpotato "seed (vines)" found in most communities will often have circulated in the community, or been recycled by farmers, for many years. Such seed accumulate high loads of diseases and pests that affect their yield. The most devastating of these pests and diseases are the sweetpotato weevils and sweetpotato virus diseases (SPVD), respectively. SPVD-infected seed produce thin, elongated, unmarketable roots used to make non-traded *inginyo* (Okello et al., 2023). Weevil-infected seed produce roots with dark spots and holes in the flesh, making the roots inedible. The use of poor-quality seed, therefore, has a hefty yield penalty (Low et al., 2020). The average yield of sweetpotato in smallholder farms in Uganda is 4 tons/ha, as compared to more than 15 tons/ha obtained from the use of quality seed under the same farming conditions (Namanda et al., 2019). The penalty is in terms of depressed production, which can be a matter of shape, size or number of roots produced. Yield penalties of up to 86 % have been reported for smallholder farmers who use poor-quality sweetpotato seed (Van Vugt and Franke, 2018). Mugisa et al. (2023) estimate that sweetpotato weevil damage to roots can cause 60 % to 100 % losses.

In this paper, we present results of an intervention that combined elements of formal and informal seed systems, to assess the effect of behavioral nudges on sustainable demand for quality seed of VPCs. Nudges have been used in many fields to influence choice decisions, including in agriculture (for the latest applications in the field, see Balew et al., 2022; Okello et al., 2023; Rola-Rubzen et al., 2023). Specifically, the paper examines the impact of mobile phone-based text message reminders on the purchase and repurchase of quality sweetpotato seed (vines), using a large field experiment in Uganda. Digital technologies are rapidly on the rise in the global south for providing useful information to smallholders; see Deichmann et al. (2016) and Gumbi et al. (2023) for reviews. Uganda is an interesting case to study because it is the secondary center of diversity for sweetpotato varieties globally. Yada et al., 2010a, Yada et al., 2010b found more than 1300 sweetpotato varieties in Uganda. The bulk of these varieties are landraces, which are particularly popular among farmers (Mwanga et al., 2021). It is estimated that farmers maintain, on average, four varieties in their gardens, the majority of them landraces (Okello et al., 2022).

2. Study methods

2.1. Ethical approval

This study was conducted in accordance with the ethical research guidelines laid down in the Declaration of Helsinki. It was implemented jointly by the International Potato Center, Cornell University, the National Agricultural Research Organization of Uganda, the Norwich Institute for Sustainable Development, and Uganda's Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) under the Cornell University Institutional Review Board (IRB) ethics approval ID# 2110010648.

2.2. Study site

This study was implemented in the Amuria district of Uganda. The district borders the northern region and has trade links with markets for sweetpotato seed in the northern districts. Farmers in the district used both social networks and market sources of seed. However, purchase of seed was limited, mainly because of availability and cost. At the time of the study, the nearest source of quality seed (primarily QDS) produced by trained DVMs was 70 km away, with no direct public bus service, hence greatly restricting access to quality seed. Indeed, Bayiyana et al. (2024) found that smallholder farmers grew local varieties that were readily available within the community, i.e., obtained seed within their social networks. Their study further found that a liquidity constraint was a major factor contributing to the low use of market sources of seed.

2.3. Experimental treatments

The study interventions covered the whole of the district of Amuria, comprising two counties, fifteen sub-counties and 91 parishes/wards. The district had never had a sweetpotato crop improvement program/project prior to this study. The interventions were implemented in 120 villages randomly selected from the 91 parishes/wards proportional to the size of each parish/ward. The 120 villages were then randomized into treatment ($n = 64$) and control ($n = 56$) groups. Care was taken not to assign any two villages that were less than 5 km apart, one to the treatment group and the other to the control group, to avoid contamination (McCann et al., 2021). This restriction combined with the physical availability of villages led us to a small imbalance in the treatment groups. This was considered as preferred to using a smaller number of villages with even treatments. The spatial distribution of the treatment and control villages is shown in Fig. 1. Lastly, in each of the 120 villages, 10 households were randomly selected from a list of households that had grown sweetpotato in the year preceding the study, and their purchase behavior was tracked over time. Thus, a total of 1200 households, which prior power calculations deemed sufficient to detect purchase behavior due to treatment, participated in the study. The power calculation was based on a 9 % adoption rate – implying a standard deviation of

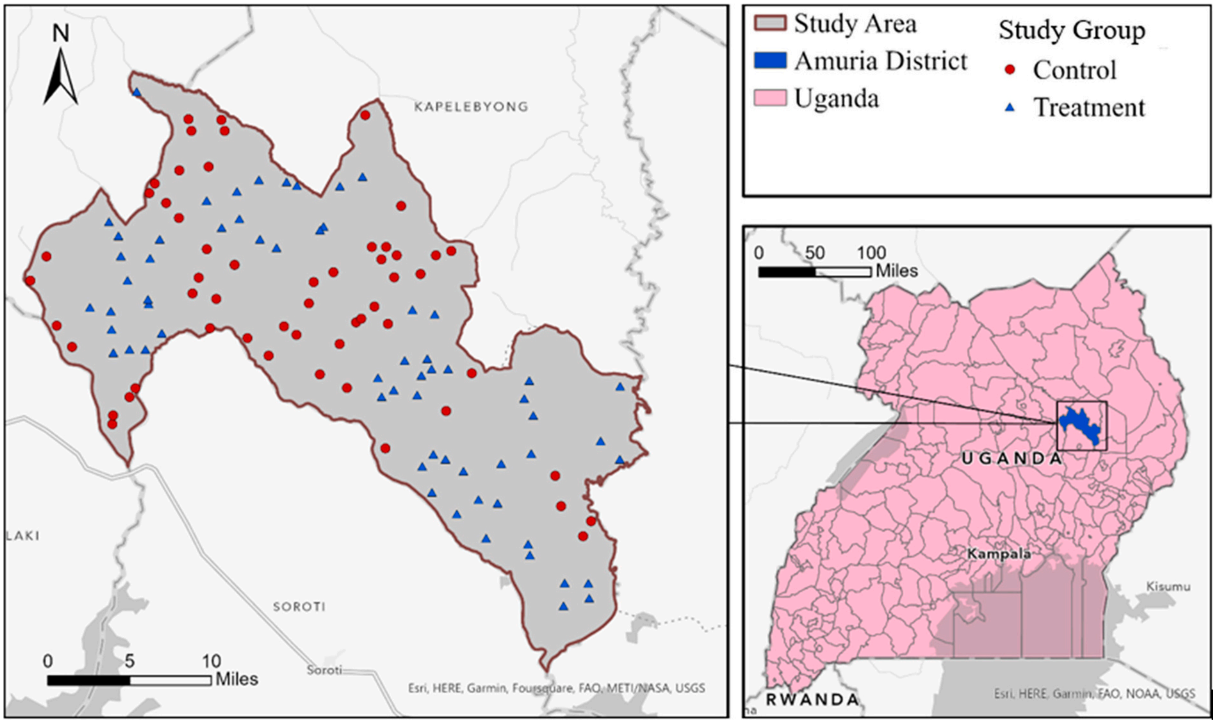

Fig. 1. Layout of the treatment and control villages in the district.

approximately 0.29, a within-village correlation coefficient of 0.10 and a 20–25 % desired increase in adoption. With these assumptions, an $n =$ 1000 (100 villages, 10 households per village) is sufficient to detect an increase in adoption of 20 % with 97 % probability (and 15 % with 80 % probability). Twenty extra villages were added to allow for potential attrition, yielding 120 villages.

To understand how behavioral nudges influenced sustainable demand for quality seed, this study deployed a number of interventions that embodied elements both of formal and informal sweetpotato seed systems. The formal system aspects related to the use of registered/released varieties, seed plot inspection, seed testing, certification, and maintenance of the identity of the variety as it flowed through the system from the lab to the farmer's field. In the absence of the interventions, sweetpotato seed flow to and among farmers was informal, and the material was usually of unknown quality. Thus, the deployed interventions attempted to formalize this informal system and examine how behavioral nudges could sustainably promote demand for QDS.

Salespoints stocked with QDS were established in both treatment and control villages, and sellers provided information about the seed quality, the process by which quality was established, and the benefits of using quality seed. Those in the treated villages were exposed to promotional posters with simple statements about the benefits. The nudge deployed was in the form of text message reminders sent to past seed purchasers. The dispatch of the messages started one week before the delivery of quality seed to salespoints. The reminders were in the two vernacular languages used in the study area. One message was sent at a time each day of the week for seven days, then repeated during the second week, during which the seed was displayed at the salespoints. They reminded past purchasers that the seed was available at the salespoint and of seed quality. The reminder text messages were thus designed to nudge the repurchase of quality seed. Reminders were deployed from the second growing season to the end of the interventions.

2.4. Quality seed

We used QDS of four sweetpotato varieties. The varieties were chosen jointly by breeders and agronomists to represent the most popular varieties in the country, and that are known to perform well under conditions like those in the study district. The selected varieties included two released landraces ("Ejumula" and "Tanzania") and two newly bred and released varieties NASPOT 13 O or "Joweria" and NAROSPOT 1 or 'New Dimbuka'. Fig. 2 summarizes the characteristics of the four varieties used. "Ejumula" and "Tanzania" are both widely grown varieties in the study district. However, due to repeated planting, locally available seed of these varieties is infested with SPVD and sweetpotato weevil, which greatly reduces their yield, therefore reducing (in the second season) the volume of roots available for making *amukeke*. At the time of the study, farmers were not growing "Ejumula" and "Tanzania" as the most preferred variety because of poor yield performance and lack of access to quality seed (Bayiyana et al., 2024).

Quality seed of the four varieties were produced from a starter material sourced from a certified/accredited early generation seed producer. The seed was bulked/multiplied by trained and certified seed multipliers, under strict monitoring. The multipliers had been inspected by a government seed inspector and their operations certified. One week prior to harvest, the seed plot of each variety was inspected for sweetpotato viruses and sweetpotato weevils, and samples tested for virus load. Only plots that tested negative for viruses were harvested for use in the study.

To relax the seed access constraint, seed distribution outlets (also referred to as salespoints) were constructed in each study village. The salespoints were established in easily accessible locations and were hosted by salespersons recruited from among model/progressive farmers in each village with the help of government extension officers. The criteria for recruitment included good reputation, easy to approach, living within the village, and literacy. To avoid contamination, salespoints were not placed in or near locations where they could be easily seen by non-villagers, such as major roads, health centers, religious centers (churches/mosques), and schools. From the first rain season of 2022, and for the next four seasons, 12 bags of seed each with 30-cm-long cuttings, were delivered to the salespoints for sale to co-villagers by the salesperson.

Due to high perishability, seed were delivered in two rounds separated by one week, to reduce losses. Salespersons captured data on

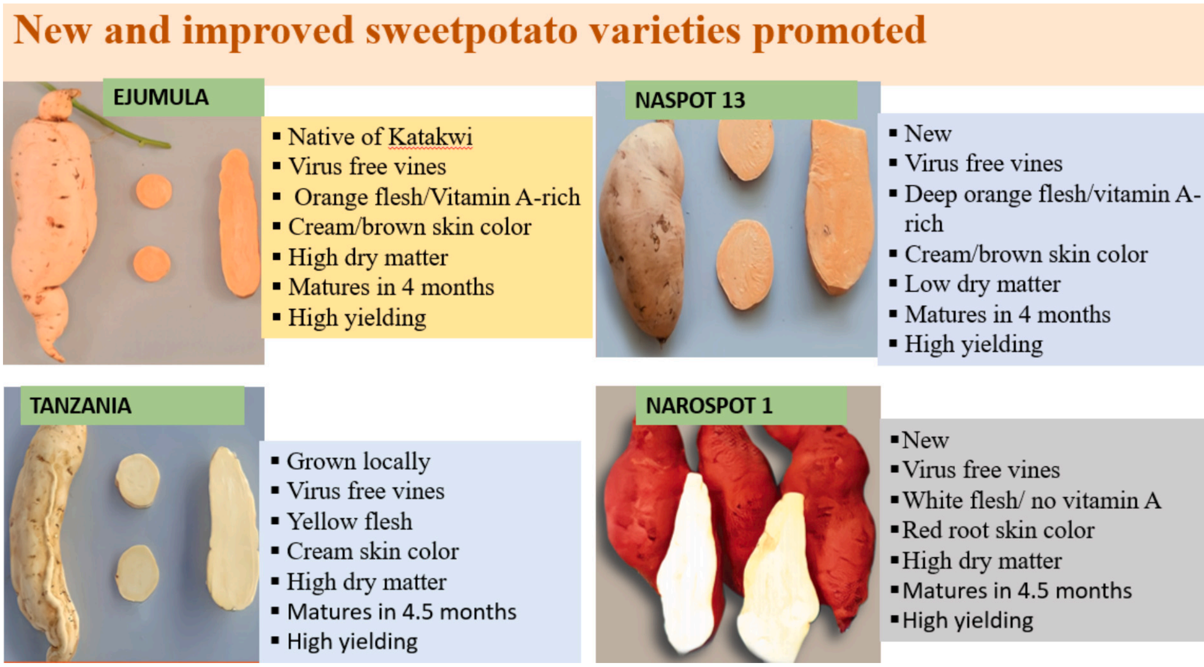

Fig. 2. Varieties of sweetpotato used in the study.

transactions made in each village and season. The transactions were captured by variety. This is because a qualitative conducted in the same study communities revealed that varietal preferences strongly influence smallholder farmers decision about replanting of popular landraces and whether they purchase quality seed of improved varieties (Bayiyana et al., 2025).

2.5. Empirical strategy

We examined the impact of text message reminders on farmers in the treatment group who previously purchased vines, comprising 194 participants in 2022 and 235 in 2023. A linear probability model (LPM) is estimated as follows:

$$Y_{csh} = \beta_0 + \beta_1 Text_{csh} + \gamma' X_{csh} + v_c + \varepsilon_{csh} \tag{1}$$

In this model, Y_{csh} represents the purchase decision of household h in village s, subcounty c during the second season of each year, while $Text_{csh}$ is a binary variable indicating whether text message reminders were sent to the household. The term v_c denotes a vector of subcounty fixed effects, which are included to account for unobservable characteristics at this very level. In certain specifications, the model includes X_{csh}, a vector of household-level controls, such as past vine purchase frequency, gender, age, educational level, household size, and the acreage of land available for cultivation. The error term is given by ε_{csh}. Our primary interest, β_1, captures the effect of the text message intervention. Results are presented with both robust standard errors and standard errors clustered at the village level, with symmetric tests conducted according to standard practice.

To account for potential selection bias in the data, a two-stage Heckman selection model was employed. In the first stage, a probit regression was estimated to model the probability that a household provides a phone number for future contact. The selection equation is specified as:

$$P(PhoneNumberListed_{csh} = 1 \mid X_{csh}') = \Phi(\alpha_0 + \alpha X_{csh}') \tag{2}$$

where $PhoneNumberListed_{csh}$ is a binary variable indicating whether household h in village s subcounty c, provided a phone number. The vector X_{csh}' includes household-level covariates such as respondent sex, age, education level, household size and the acreage of own cultivable land. The term $\Phi(\alpha_0 + \alpha X_{csh}')$ represents the cumulative distribution function of the standard normal distribution. From this probit model, the inverse Mills ratio is calculated, which corrects for selection bias and is subsequently incorporated into the second-stage model. In the second stage, another linear probability model (LPM) is specified to examine the household's purchase decision:

$$Y_{csh} = \beta_0 + \beta_1 Text_{csh} + \beta_2 InverseMillsRatio_{csh} + \gamma' X_{csh} + v_c + \varepsilon_{csh} \tag{3}$$

This equation is structurally identical to the earlier model (1) but includes the inverse Mills ratio to adjust for the selection effect, following the method introduced by Heckman (1979). Our primary focus remains on the coefficient β_1, which estimates the effect of the text message reminders on the purchase decision. Standard errors are adjusted for clustering at the village level, in addition to the use of robust standard errors, to account for correlation and ensure the robustness of the statistical inference.

Another variable in the dataset recorded whether participants could recall the text message reminder. The analysis categorizes participants into four groups: those who received and recalled the text, those who received but did not recall the text, those who did not receive but recalled the text, and those who neither received nor recalled the text. Due to the limited number of households responding to the question of recall for both years, the analysis includes 94 and 158 farmers in 2022 and 2023, respectively. To examine these groups, a similar model is specified:

$$Y_{csh} = \beta_0 + \beta_1 SentRecalled_{csh} + \beta_2 SentNotRecalled_{csh} + \beta_3 NotSentRecalled_{csh} + \gamma' X_{csh} + v_c + \varepsilon_{csh} \tag{4}$$

where $SentRecalled_{csh}$, $SentNotRecalled_{csh}$ and $NotSentRecalled_{csh}$ are indicators for whether household h in village s , subcounty c falls into the respective group. A dummy variable for the group "text not sent and not recalled" is omitted from (4), with this group serving as the reference category. All other variables and the presentation of results remain consistent with the previous model.

To assess whether text message reminders significantly impacted the total sales of the village, two additional linear regressions were estimated as follows:

$$TotalSales_s = \beta_0 + \beta_1 Group_{high} + \beta_2 Group_{low} + \beta_3 Treatment_s + \beta_4 PreviousSales_s + \varepsilon_s \quad (5)$$

$$TotalSales_s = \beta_0 + \beta_1 NumPeopleText + \beta_2 Treatment_s + \beta_3 PreviousSales_s + \varepsilon_s \quad (6)$$

In Eq. (5), $Group_{high}$ indicates whether more than two-thirds of the 10 participants in village s were sent text messages, while $Group_{low}$ shows whether the percentage is less than one-third. Both β_1 and β_2 are of research interest in this model. In Eq. (6), *NumPeopleText* denotes the total number of farmers in village s who were sent text message reminders over the two years. The coefficient β_1 is the main parameter of interest in this model. In both regressions, $TotalSales_s$ refers to the sum of total sales (in thousands Uganda Shillings) in village s starting from the second season in 2022 to the first season in 2024. $PreviousSales_s$ accounts for sales (in thousands) during the first season of 2022, and $Treatment_s$ indicates whether village s is part of the treatment group. The error term is denoted by ε_s, and symmetric statistical tests are also conducted.

3. Results

Table 1 displays summary statistics for the control and treatment groups, respectively, based on surveys. There was little statistical difference between the two groups suggesting effective randomization. Table A1 (see the appendix) provides results of the treatment within the initial season of implementation. While estimates of the treatment effects were of a moderate size, they were quite fragile and noisy. The treatment was only marginally significant within the first season, and only when using robust standard errors. That said, the significance of the treatment effect was unaffected by the inclusion of control variables, supporting the notion of effective randomization.

Table 2a & Table 2b provide an analysis of the impact of text message reminders on the purchase of quality seed by previous buyers in the treatment group, examining data from 2022 and 2023, respectively. In 2022, the likelihood of households purchasing improved vines increased between 3.5 % and 4.9 % in four of the models when text message reminders were sent. However, this result showed some fragility, as models (6), (9), (11) and (12) did not yield statistically significant outcomes. These models incorporated a set of control variables, revealing that socioeconomic factors, particularly age, years of schooling, and the acreage of cultivable land, was associated with the farmer's decision to purchase improved seed. The lack of significance

Table 1
Baseline randomization balance check between treatment group and control group.

	Control		Treatment		Difference	
Variables	N	Mean	N	Mean	Mean	t-value
Purchased	525	0.446	608	0.442	0.003	0.111
Years of Schooling	525	5.977	608	5.855	0.122	0.546
Respondent Sex (1 = Male)	525	0.613	608	0.582	0.031	1.064
Respondent Age (years)	525	41.65	608	41.96	−0.306	−0.316
Household Size (count)	525	7.208	608	7.174	0.033	0.171
Own Cultivable Land (acres)	525	3.303	608	3.341	−0.038	−0.249
Distance to Sales Point (minutes)	379	19.480	459	18.296	1.184	0.826
Frequency of Vine Purchase						
Every Season	525	0.101	608	0.107	−0.006	−0.327
Every Other Season	525	0.109	608	0.138	−0.030	−1.505
Once in a While	525	0.310	608	0.332	−0.022	−0.781
Never	525	0.480	608	0.423	0.057	1.935*

Note: Column 6 is the t-value of the difference between the mean value of the control and treatment groups.
Asterisks indicate the following: *** = $p < 0.01$, ** = $p < 0.05$, and * = $p < 0.1$.

Table 2a
Effect of text message reminders on the purchase of quality vines of improved sweet potato varieties (2022).

2022	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
				Robust SE				Parish-Village Clustered SE				
VARIABLES	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased
Text Sent	0.040***	0.035*	0.038*	0.044*	0.049*	0.027	0.040***	0.035*	0.038	0.044*	0.049	0.027
	(0.015)	(0.019)	(0.022)	(0.024)	(0.027)	(0.024)	(0.015)	(0.020)	(0.024)	(0.026)	(0.031)	(0.028)
Respondent Sex			−0.015	−0.017	−0.022	−0.034			−0.015	−0.017	−0.022	−0.034
			(0.027)	(0.027)	(0.026)	(0.028)			(0.029)	(0.029)	(0.029)	(0.032)
Respondent Age			0.000	0.001	0.001	0.002*			0.000	0.001	0.001	0.002*
			(0.001)	(0.001)	(0.001)	(0.001)			(0.001)	(0.001)	(0.001)	(0.001)
Years of Schooling						0.009*						0.009*
						(0.005)						(0.006)
Household Size			0.002	0.003	0.004	0.004			0.002	0.003	0.004	0.004
			(0.003)	(0.003)	(0.003)	(0.003)			(0.003)	(0.003)	(0.004)	(0.004)
Own Cultivable Land				−0.007*	−0.008*	−0.009**				−0.007	−0.008	−0.009*
				(0.004)	(0.004)	(0.004)				(0.004)	(0.005)	(0.005)
Constant	0.000	0.132	0.109	0.139	0.108	0.097	0.000	0.132	0.109	0.139	0.108	0.097
	(0.000)	(0.155)	(0.173)	(0.180)	(0.165)	(0.164)	(0.000)	(0.184)	(0.202)	(0.214)	(0.203)	(0.202)
Frequency of Vine Purchase	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Observations	194	194	194	194	194	194	194	194	194	194	194	194
Adjusted R-squared	−0.001	0.096	0.086	0.091	0.106	0.123	−0.001	0.096	0.086	0.091	0.106	0.123
Subcounty Fixed Effects	No	No	No	No	Yes	Yes	No	No	No	No	Yes	Yes

Note: * indicates a confidence level of 90 %, ** indicates 95 %, and *** indicates 99 %.

Table 2b
Effect of text message reminders on the purchase of quality vines of improved sweet potato varieties (2023).

2023	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
				Robust SE				Parish-Village Clustered SE				
VARIABLES	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased
Text Sent	−0.114	−0.131	−0.153*	−0.167**	−0.175**	−0.181**	−0.114	−0.131	−0.153*	−0.167**	−0.175*	−0.181**
	(0.083)	(0.081)	(0.079)	(0.078)	(0.083)	(0.084)	(0.086)	(0.084)	(0.083)	(0.082)	(0.089)	(0.090)
Respondent Sex			−0.026	−0.047	−0.052	−0.059			−0.026	−0.047	−0.052	−0.059
			(0.039)	(0.038)	(0.039)	(0.041)			(0.040)	(0.039)	(0.041)	(0.043)
Respondent Age			−0.002	−0.003*	−0.002*	−0.002*			−0.002	−0.003*	−0.002*	−0.002
			(0.001)	(0.001)	(0.001)	(0.001)			(0.001)	(0.001)	(0.001)	(0.001)
Years of Schooling						0.004						0.004
						(0.006)						(0.006)
Household Size			−0.009	−0.012**	−0.013**	−0.013**			−0.009	−0.012**	−0.013**	−0.013**
			(0.005)	(0.005)	(0.006)	(0.006)			(0.005)	(0.006)	(0.006)	(0.006)
Own Cultivable Land				0.015*	0.016*	0.016*				0.015	0.016*	0.016*
				(0.009)	(0.008)	(0.008)				(0.009)	(0.009)	(0.009)
Constant	0.200**	0.114	0.288**	0.314***	0.331**	0.307**	0.200**	0.114	0.288**	0.314**	0.331**	0.307**
	(0.080)	(0.072)	(0.121)	(0.119)	(0.133)	(0.131)	(0.083)	(0.074)	(0.127)	(0.125)	(0.143)	(0.140)
Frequency of Vine Purchase	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Observations	235	235	235	235	235	235	235	235	235	235	235	235
Adjusted R-squared	0.010	0.036	0.045	0.060	0.037	0.035	0.010	0.036	0.045	0.060	0.037	0.035
Subcounty Fixed Effects	No	No	No	No	Yes	Yes	No	No	No	No	Yes	Yes

Note: * indicates a confidence level of 90 %, ** indicates 95 %, and *** indicates 99 %.

when controlling for these factors suggests the potential that the reception of text reminders was affected by wealth, which was also correlated with repurchase. Notably, the inclusion or exclusion of sub-county fixed effects does not have a noticeable impact on estimates, suggesting that spatial concentration of treatments likely did not play a role in the detected effect.

In contrast, the results from 2023 presented in Table 2b told a different story. For 2023, test reminders led to between a 15.3 % and 18.1 % decrease in the repurchase of seed when controlling for demographic factors. This is true after accounting for socioeconomic factors, previous purchase frequency, and whether or not we include subcounty fixed effects. Models for 2023 that did not control for demographic characteristics did not yield statistically significant results (again with or without subcounty fixed effects). This indicated that the effect of text message reminders was either not statistically significant or, in some cases, even negatively significant in 2023. The lack of positive statistical significance suggests that the impact of text messages either diminished over time or could be negatively autocorrelated over seasons. Data limitations prevent us from exploring this aspect further. Future studies should therefore investigate further this difference and how it affects the results.

By the following year, sending more and more reminders were no longer effective in increasing the likelihood of households purchasing quality seed. The findings indicate that text messages might be effective for repurchase, but not for several seasons in a row. Their influence does not sustain over longer periods.

The results are somewhat noisy, and have the potential to be influenced by spatial factors as well as selection. While the invariance with respect to sub-county controls provides us one potential check on spatial factors, we also ran regressions using leave-one-out analysis (in this case leaving out parishes) to see the impact on model estimates (see the graphs in the appendix). While there is some variation in the coefficient of interest, the effects for 2022 remain within approximately 1.5 percentage points of the original estimates for each of the models with significant results, and do not change in significance. For 2023, the results remain negative and significant for all models that include demographic variables, with variation that remains within approximately 8 percentage points of the original estimate. One parish (Kuju) appears to be an outlier creating a negative effect. This area is predominantly control villages in our sample, perhaps suggesting this region saw higher repurchase rates than most control areas. Kuju displayed a similar pattern of purchase in 2022, though the effect on coefficients was much smaller. Figs. 3 and 3b display a heatmap of seed repurchase over the sample region. This reveals that repurchase was much more concentrated in the northwest in 2022, while repurchase was much more widely distributed in 2023. Notably the areas of high repurchase in both years occur in both treatment and control villages.

To correct for potential sample selection bias in the above results, a probit regression was employed as the first stage of the Heckman selection model, providing the inverse Mills ratio for the subsequent stage of analysis. Table A2 presents the results of this probit regression, which estimated the probability of individuals listing their phone numbers for the years 2022 and 2023. The results demonstrate that age and years of schooling were significant determinants of phone number listing in both years. As reflected by the negative coefficients for age, older individuals were less likely to list their phone numbers, while those with more years of education were more likely to provide their contact information. Furthermore, the coefficient of household size showed statistical significance in 2022, and the acreage of own cultivable land was a significant predictor in 2023. However, neither variable demonstrated statistically significant effects consistently across both years.

The second stage of the Heckman selection model, as shown in Table 3a & Table 3b, assessed the effect of text message reminders on households' seed repurchase decisions in the second season while accounting for selection bias through the inclusion of the inverse Mills ratio. Similarly, the analysis covered data from both 2022 and 2023,

(b)

Fig. 3. a: Heatmap of Seed Repurchase, 2022 b: Heatmap of Seed Repurchase, 2023.

focusing on households that previously purchased seed. In 2022, the coefficient for the text message variable was positive, but only reached statistical significance in models (4) and (5) when using clustered standard errors at the parish-village level. In these two models, the probability of repurchasing vines increases by 4.1 % or 3.8 % when the text message reminder was sent. This suggests that sending text message reminders had a small but positive effect on individuals' repurchasing decisions, though this result is somewhat sensitive to model specifications.

Other variables, such as respondent age, years of schooling, and own cultivable land, also showed statistical significance in some models. Notably, younger individuals and those with more land were less likely to repurchase seed, whereas better-educated farmers were more inclined to do so. In contrast, the results for 2023 told a different story. The coefficient for text message reminders was negative and statistically significant in models (3), (5), and (6), indicating that the reminders had a substantially negative effect on repurchase behavior in that year. Households that received text message reminders had a 14.8 % or 19.0 % lower probability of repurchasing quality seed in the year 2023. This suggests that repeated reminders may have become less effective or even counterproductive over time. Additional factors, such as respondent age, household size and own cultivable land also appeared to significantly influence repurchase decisions in 2023. Although the inverse Mills ratio does not achieve statistical significance in either year, its inclusion helps adjust for potential selection bias. The combined results from both 2022 and 2023 reflected a notable shift in the effectiveness of text message reminders, confirming our previous conclusion that their impact could diminish or even reverse over time.

To compare vine purchasing decisions across different groups of farmers, 94 participants were divided into four categories: those who received and recalled a text message, those who received but did not recall the text, those who did not receive but recalled the text message (probably from a neighbor), and those who neither received nor recalled the text message.

Table 4a & Table 4b presents a comparative analysis of seed purchasing behavior among these groups, with a focus on the influence of text message recall and receipt. In 2022, models (1), (2), (4), and (5) showed significant results for the group that received and recalled the text messages. Depending on the specific model, participants in this group were 18.7 % or 15.3 % more likely to purchase quality seed compared to those who did not receive and could not recall the text messages. However, this finding is not entirely robust, as models (3) and (6) did not yield statistically significant results. In these latter models, household size emerged as a significant factor influencing farmers' purchasing decisions, suggesting that particular household characteristics may also play a critical role in this context.

In contrast, the 2023 analysis revealed that there were no statistically significant differences in seed purchasing behavior between those who did receive and could recall the text messages and the base group. This pattern mirrors the findings in Table 2b, indicating that while sending recallable messages could initially increase the likelihood of purchasing seed, this positive effect faded away over time. Table A3 examines the impact of text message reminders on total seed sales at the village level over four seasons from 2022 to 2024, accounting for treatment effects and initial sales in the first season of 2022. In columns (1) and (2), villages were categorized into three groups based on the proportion of households receiving text reminders: more than two-thirds, between one- third and two-thirds, and less than one-third. The results indicate no statistically significant differences in total quality seed sales among these groups, suggesting that the proportion of households receiving reminders did not significantly influence overall sales of a particular village. Columns (3) and (4) shift the analysis to the number of individuals in each village who received text reminders, but similarly, this variable also fails to yield a statistically significant impact on sales.

4. Discussion and conclusions

This study examined the effect of a bundle of interventions including behavioral nudges on sustained use of quality seed of sweetpotato varieties. Seed systems of sweetpotato, a vegetatively propagated crop, are largely informal (McGuire and Sperling, 2016). Farmers typically rely on poor quality seed obtained from their own harvest or from a network of family members, neighbors and friends. Such seed is often infected with pests and diseases, which greatly reduces yield, affecting household food and income security (Okello et al., 2023).

Nudges in the form of mobile phone-based text reminders have been

Table 3a
Summary of Ordinary Least Squares (OLS) regression results - second stage of Heckman selection model (2022).

	(1)	(2)	(3)	(4)	(5)	(6)
	Robust SE			Parish-Village Clustered SE		
VARIABLES	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased
Text Sent	0.041	0.038	0.026	0.041*	0.038**	0.026
	(0.029)	(0.026)	(0.029)	(0.022)	(0.018)	(0.019)
Respondent Sex			−0.032			−0.032
			(0.031)			(0.029)
Respondent Age			0.002*			0.002**
			(0.001)			(0.001)
Years of Schooling			0.009			0.009**
			(0.006)			(0.004)
Household Size			0.004			0.004
			(0.004)			(0.003)
Own Cultivable Land			−0.009*			−0.009**
			(0.005)			(0.004)
Inverse Mills Ratio	−0.388	−0.327	−0.375	−0.388	−0.327	−0.375
	(0.432)	(0.401)	(0.42)	(0.452)	(0.38)	(0.386)
Constant	0.095	0.208	0.207	0.095	0.208	0.207
	(0.138)	(0.224)	(0.248)	(0.144)	(0.199)	(0.227)
Frequency of Vine Purchase	No	Yes	Yes	No	Yes	Yes
Observations	194	194	194	194	194	194
Adjusted R-squared	0.045	0.104	0.123	0.045	0.104	0.123
Sub-county Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Note: * indicates a confidence level of 90 %, ** indicates 95 %, and *** indicates 99 %.

Table 3b
Summary of Ordinary Least Squares regression results - second stage of Heckman selection model (2023).

	(1)	(2)	(3)	(4)	(5)	(6)
	Robust SE			Parish-Village Clustered SE		
VARIABLES	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased
Text Sent	−0.129	−0.148	−0.190**	−0.129	−0.148*	−0.190**
	(0.093)	(0.091)	(0.092)	(0.091)	(0.087)	(0.084)
Respondent Sex			−0.058			−0.058
			(0.043)			(0.042)
Respondent Age			−0.002			−0.002*
			(0.001)			(0.001)
Years of Schooling			0.003			0.003
			(0.006)			(0.006)
Household Size			−0.014**			−0.014**
			(0.006)			(0.006)
Own Cultivable Land			0.017*			0.017*
			(0.009)			(0.009)
Inverse Mills Ratio	0.691	0.612	0.684	0.691	0.612	0.684
	(0.459)	(0.47)	(0.47)	(0.426)	(0.448)	(0.439)
Constant	−0.008	−0.064	0.097	−0.008	−0.064	0.097
	(0.196)	(0.195)	(0.215)	(0.173)	(0.181)	(0.192)
Frequency of Vine Purchase	No	Yes	Yes	No	Yes	Yes
Observations	235	235	235	235	235	235
Adjusted R-squared	−0.006	0.023	0.046	−0.006	0.023	0.046
Sub-county Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Note: * indicates a confidence level of 90 %, ** indicates 95 %, and *** indicates 99 %.

shown to be effective in inducing behavior change among smallholder farmers (Rola-Rubzen et al., 2023). Our study found some evidence that this could indeed be the case for smallholder sweetpotato farmers too. We found that after resolving other key constraints that smallholder farmers faced, namely access to seed and quality assurance, text message reminders increased the likelihood that farmers would repurchase quality seed. In particular, our findings indicate that exposure to text message reminders increased the chances of farmers repurchasing quality seed by 4 %. The results do not appear to be due to spatial correlation. Moreover, zooming into the nature of exposure by examining the recall of text messages received also indicated that nudges increased the likelihood of purchase of quality seed among farmers who both received and could recall the nudges. These findings suggest that nudges in the form of text reminders can influence farmers' behavior towards innovation use in agriculture.

The initial positive effect of reminders suggests that they can be usefully deployed in the promotion of quality seed (vines) of vegetatively propagated crops. However, the results are not robust to all model specifications indicating fragility. For instance, we found a null effect of text reminders for other model specifications and a reduction in the likelihood of purchase of quality seed when reminders are repeated. Some elements of our findings corroborate those of Zachmann et al. (2023). They found that using nudges to promote the use of practices that reduce pesticide applications by grapevine farmers resulted in a null effect.

We also found that the continued deployment of text message reminders either diminished seed purchases over time or could be negatively autocorrelated with the seed purchase over seasons. There are multiple reasons we might see being responsible for such a whiplash effect in this case. First, it could be that the farmers become less attentive

Table 4a
Comparative analysis of vine purchasing behavior among farmers based on text message recall and receipt (2022).

	(1)	(2)	(3)	(4)	(5)	(6)
	Robust SE			Parish-Village Clustered SE		
VARIABLES	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased
Text Sent & Recalled	0.187*	0.153**	0.132	0.187*	0.153**	0.132
	(0.099)	(0.091)	(0.092)	(0.094)	(0.071)	(0.085)
Text Sent & Not Recalled	0.136	0.092	0.098	0.136	0.092	0.098
	(0.090)	(0.078)	(0.099)	(0.090)	(0.075)	(0.091)
Text Not Sent & Recalled	0.122	0.115	0.074	0.122	0.115	0.074
	(0.084)	(0.074)	(0.094)	(0.082)	(0.070)	(0.106)
Respondent Sex			−0.069			−0.069
			(0.061)			(0.063)
Respondent Age			0.003			0.003
			(0.002)			(0.002)
Years of Schooling			0.009			0.009
			(0.010)			(0.006)
Household Size			0.014*			0.014*
			(0.008)			(0.008)
Own Cultivable Land			−0.019			−0.019
			(0.012)			(0.013)
Constant	−0.162*	0.192	0.114	−0.162*	0.192	0.114
	(0.092)	(0.264)	(0.304)	(0.088)	(0.267)	(0.304)
Frequency of Vine Purchase	No	Yes	Yes	No	Yes	Yes
Observations	94	94	94	94	94	94
Adjusted R-squared	0.054	0.092	0.116	0.054	0.092	0.116
Sub-county Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Note: * indicates a confidence level of 90 %, ** indicates 95 %, and *** indicates 99 %.

Table 4b
Comparative analysis of vine purchasing behavior among farmers based on text message recall and receipt (2023).

	(1)	(2)	(3)	(4)	(5)	(6)
	Robust SE			Parish-Village Clustered SE		
VARIABLES	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased	Repurchased
Text Sent & Recalled	−0.039	−0.082	−0.106	−0.039	−0.082	−0.106
	(0.063)	(0.069)	(0.073)	(0.065)	(0.069)	(0.074)
Text Sent & Not Recalled	0.035	−0.026	−0.060	0.035	−0.026	−0.060
	(0.092)	(0.098)	(0.098)	(0.092)	(0.104)	(0.097)
Text Not Sent & Recalled	0.193	0.165	0.150	0.193	0.165	0.150
	(0.127)	(0.129)	(0.128)	(0.138)	(0.143)	(0.136)
Respondent Sex			−0.022			−0.022
			(0.066)			(0.063)
Respondent Age			−0.005**			−0.005***
			(0.002)			(0.002)
Years of Schooling			−0.001			−0.001
			(0.008)			(0.009)
Household Size			−0.008			−0.008
			(0.007)			(0.007)
Own Cultivable Land			0.014			0.014
			(0.014)			(0.015)
Constant	0.214*	0.101	0.296**	0.214	0.101	0.296**
	(0.111)	(0.096)	(0.127)	(0.148)	(0.128)	(0.127)
Frequency of Vine Purchase	No	Yes	Yes	No	Yes	Yes
Observations	158	158	158	158	158	158
Adjusted R-squared	−0.015	0.007	0.012	−0.015	0.007	0.012
Subcounty Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Note: * indicates a confidence level of 90 %, ** indicates 95 %, and *** indicates 99 %.

to the reminders, considering them a hassle or annoyance, or perhaps just not able to sustain their attention. Second, this may reflect some learning by farmers. For example, farmers may determine that recycling the QDS seed they purchased resulted in sufficient yields that it would not be worth it to repurchase every season. Finally, the result could be due to localized spatial factors that happen to target treated villages. While this is possible, it does not appear to be the case from our spatial exploration (and we are unaware of any such candidate factor). The diminishing effect of nudges on behavior has been reported in other fields. Harnischmacher et al. (2023) for instance found a drastic decline in nudges aimed at keeping recommended distances to contain the spread of COVID-19 in retail settings one year after the intervention commenced. Sasaki et al. (2021), on the other hand, reported a negative effect of gain-framed repeated nudges aimed at encouraging contact avoidance to curtail the spread of COVID-19 in Japan, thus corroborating our finding that under certain contexts, repeated exposure to nudges can be counterproductive.

The fragility of the findings needs to be put into context. First, as a vegetatively propagated crop, farmers mostly plant seed harvested from their own gardens (McGuire and Sperling, 2016) and resort to using external sources when their own vines show visible signs of pest/disease infection and a significant reduction in yield (Gibson et al., 2011). Both are unlikely to occur when farmers use quality seed. It is estimated that it takes more than three seasons of repeated planting of sweetpotato seed

Table A3
Effect of text message reminders on total vine sales at the village level.

	(1)	(2)	(3)	(4)
	Total Sales	Total Sales	Total Sales	Total Sales
VARIABLES	(in thousands)	(in thousands)	(in thousands)	(in thousands)
More than 2/3 receiving text	24.947	24.905		
	(41.821)	(41.267)		
Less than 1/3 receiving text	−0.898	−14.834		
	(13.641)	(15.262)		
Number of people receiving text			−2.056	3.231
			(2.755)	(4.307)
Treatment		−24.848*		−28.123
		(12.825)		(17.699)
Previous Sales (in thousands)	0.188	0.151	0.164	0.143
	(0.120)	(0.120)	(0.120)	(0.119)
Constant	23.905	51.496**	29.490**	37.433**
	(14.751)	(20.364)	(13.820)	(14.601)
Observations	106	106	106	106
Adjusted R-squared	−0.002	0.025	0.010	0.024

Note: * indicates a confidence level of 90 %, ** indicates 95 %, and *** indicates 99 %.

for the signs of seed degeneration (disease/pest infection and depressed yield) to be noticeable (Ogero et al., 2023).

Better performance of the quality seed (by being disease-free and high yield) may, therefore, have discouraged farmers from repurchasing quality seed soon after the initial purchase, since no significant reduction in yield will yet have occurred. In other instances, farmers who initially purchased seed in the previous season may have opted to buy less than previously in the second season because they already have good material and are simply supplementing (topping up) what they have. This is because farmers are known to multiply/bulk seed of the variety that find appealing by recycling while purchasing small amounts to top up. This behavior has been documented for several of the vegetatively propagated crops (Jacobsen et al., 2019; Ogero et al., 2019; Navarrete et al., 2022). This study centered on quality seed of improved sweetpotato varieties, but farmers' decisions about replanting or accessing quality seed through purchases may also depend on the variety. Bayiyana et al. (2025), using qualitative techniques, argue that this is indeed the case for a small sample of farmers drawn from the same study communities as ours. They highlight the strong affinity farmers have towards certain varieties, some of which are local landraces, that are perceived to embody the preferred sensory and culinary quality attributes. A detailed exploration of this aspect is however beyond of the scope of our current paper.

A second important contextual factor relates to the typical use of mobile phones and literacy rates of the farmers in the study area. The majority of rural farmers keep their phones turned off at certain times when not in use to preserve battery power. In other instances, phones can be off for extended periods of time during electricity blackouts (Houngbonon et al., 2021). These result in the intermittent use of phones that could have resulted in some farmers not receiving or seeing text messages. Further, some less literate rural farmers use mobile phones for voice (calling and receiving) calls only and do not know how to navigate the text message platforms (Okello, 2013).

Our findings also highlight socio-demographic factors, notably that wealth, education, age, household size and endowment with land drive the likelihood of repurchase of seed. The finding that land ownership and wealth influenced seed repurchase decisions is interesting for two reasons. First, it corroborates the findings of Bayiyana et al. (2024) that liquidity constraints are a major factor influencing demand for quality seed of sweetpotato varieties. Second, this finding has major gender implications. Women tend to dominate sweetpotato seed acquisition and other field operations (Bayiyana et al., 2025). At the same time, women also tend to have less access to land (Mudege et al., 2018) and wealth (Yorke et al., 2023). Hence, the current finding that wealth and access to land influence seed repurchases suggests that women farmers are likely to be excluded in the use of quality seed unless supported.

Notwithstanding the fragility of findings relating to impacts on repurchases, this study finds evidence that nudges in the form of mobile phone-based text message reminders initially positively and next negatively influence the continued purchase of quality seed by smallholder sweetpotato farmers. This suggests that reminders should be judiciously used and, in particular, that their repetition may be counterproductive. It further suggests that nudges can positively influence sustainable use of quality seed in an informal seed system when other key constraints are resolved, provided that they are not overused. In this study, two of these constraints were resolved – namely, seed access and quality assurance. The fragility of the results suggests the need for further studies to better understand the effect of text message reminder nudges on the use of quality seed.

CRediT authorship contribution statement

Julius Juma Okello: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **David R. Just:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Arjan Verschoor:** Writing – review & editing, Methodology. **Chalmers Mulwa:** Writing – review & editing, Methodology, Investigation. **Mingcong Xie:** Writing – review & editing, Formal analysis, Data curation. **Sylvester Ojwang:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Sam Namanda:** Writing – review & editing, Methodology, Investigation. **Benard Yada:** Writing – review & editing, Methodology. **Reuben Ssali:** Writing – review & editing, Methodology. **Moses Bunsen Okim:** Writing – review & editing, Methodology, Investigation. **Janet Mwende Mutiso:** Writing – review & editing, Methodology. **Srinivasulu Rajendran:** Writing – review & editing, Methodology. **Hugo Campos:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Appendix 1: Poster used to activate feelings of nostalgia and loss aversion among treatment farmers

Appendix B. Appendix 2: Text message reminders sent to purchasers of quality vines of ISV at the beginning of Season 2

B.1. English language

1. Did you know that vines from local sources often contain many pests and diseases?
2. Did you know that planting quality vines found at your village sales stand leads to higher yields?
3. Hurry! Get quality sweetpotato vines at your village sales stand.
4. You get more, bigger and better roots when you use quality vines in your village sales stand local vines.
5. Farmers who plant quality vines sold in your village sales stand worry less about sweetpotato pests and diseases.
6. Farmers who are planting quality vines from your village sales stand are getting more, bigger and better roots.
7. Planting quality vines sold at your village sales stand gives you more sweetpotato to cook and sell, and more amukeke.

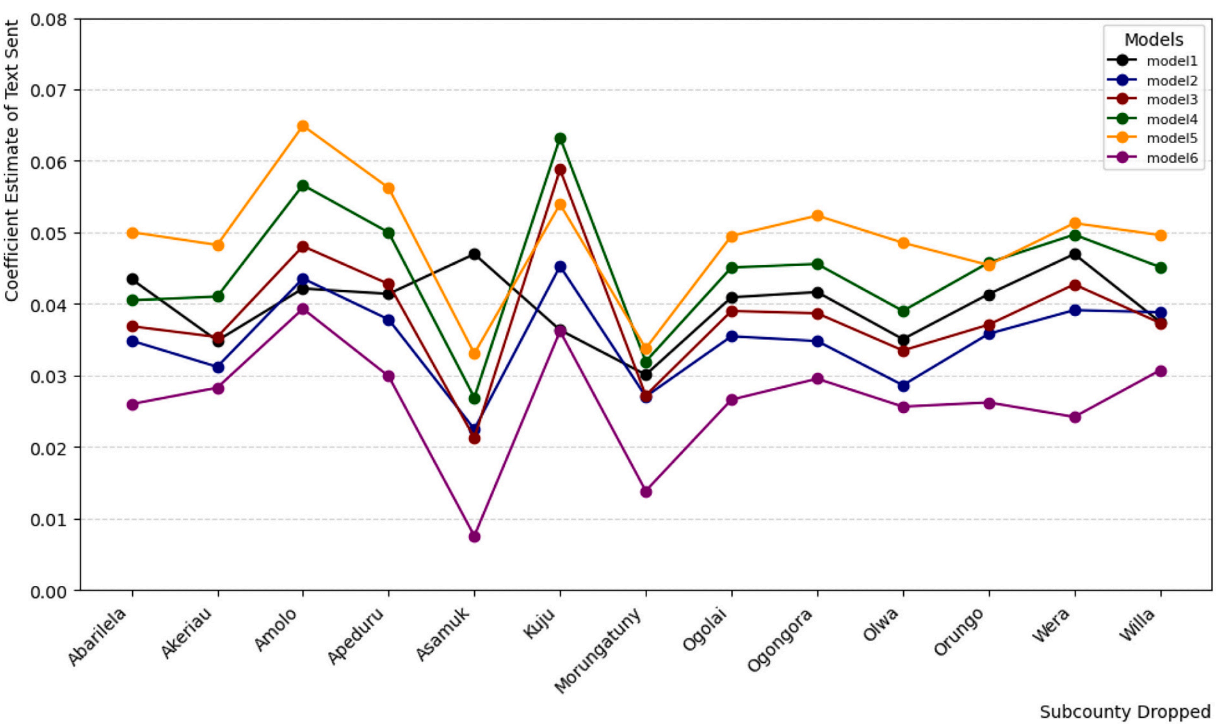
B.2. Ateso language

1. Kijeni lem ijo ebe, akwii nu acok nu itocununete amisirin wok etapit duc ajaut keda ikur ka adekasinei nu acok.
2. Kijeni lem ijo ebe, aira akwii nu itojokaritai nu ejaasi agwelanaret na ocalo kon einakini acok aimini ejok.
3. Kiwonyuni!, kodum akwii nu acok nu itojokaritai kane egwelanarere kocaalo kon.
4. Icoki bino nywal apol, adito kede abeco ka ipito oboke icok akome yot ame otye acato icalo ni.
5. Akoriok luiraete akwii nuitojokaritai nukwana egwelario ocalokus, mam iyalongongoete kanu ikur ka adekasinei nu acok.
6. Akoriok lu iraete akwii nu itojokaritai nu ejaasi agwelanaret na ocalo kon edumunete acok nu ejokuka, koburok ido kominitos ejok.
7. Aira akwii nu itojokaritai nu ejaasi agwelanaret na ocalo kon ijaikini ijo acok nu ipu nu nyaman ka agwelar da. Ka amukeke da na epol.

B.3. Langi language

1. Onwongo ingoe ni oboke icok me kin paco kom gi pe yot; otye kede kudi apol acamo gi kede two pol?
2. Onwongo ingoe ni pito oboke icok akome yot mio icok nyak adwong?
3. Bunye! Nwong oboke icok akome yot ame two pe iye me apita ame otye acato icalo ni.
4. Ikunyu icok apol, adito kede abeco ka ipito oboke icok akome yot ame ber kato pito oboke me kin paco.
   Icoki bino nywal apol, adito kede abeco ka ipito oboke icok akome yot ame otye acato icalo ni.
5. Oput ame pito oboke icok akomgi yot pe paro ni kudi acamo onyo two amako icok gi.
6. Opur ame pito oboke icok akome yot gin kunyu icok apol, adito kede abeco.
7. Pito oboke icok akome yot mii inwongo icok apol ame konyi me ateda kede acata, dang mii otere adwong.

Appendix C. Appendix 3: Results of the leave-one-out analysis at the parish level



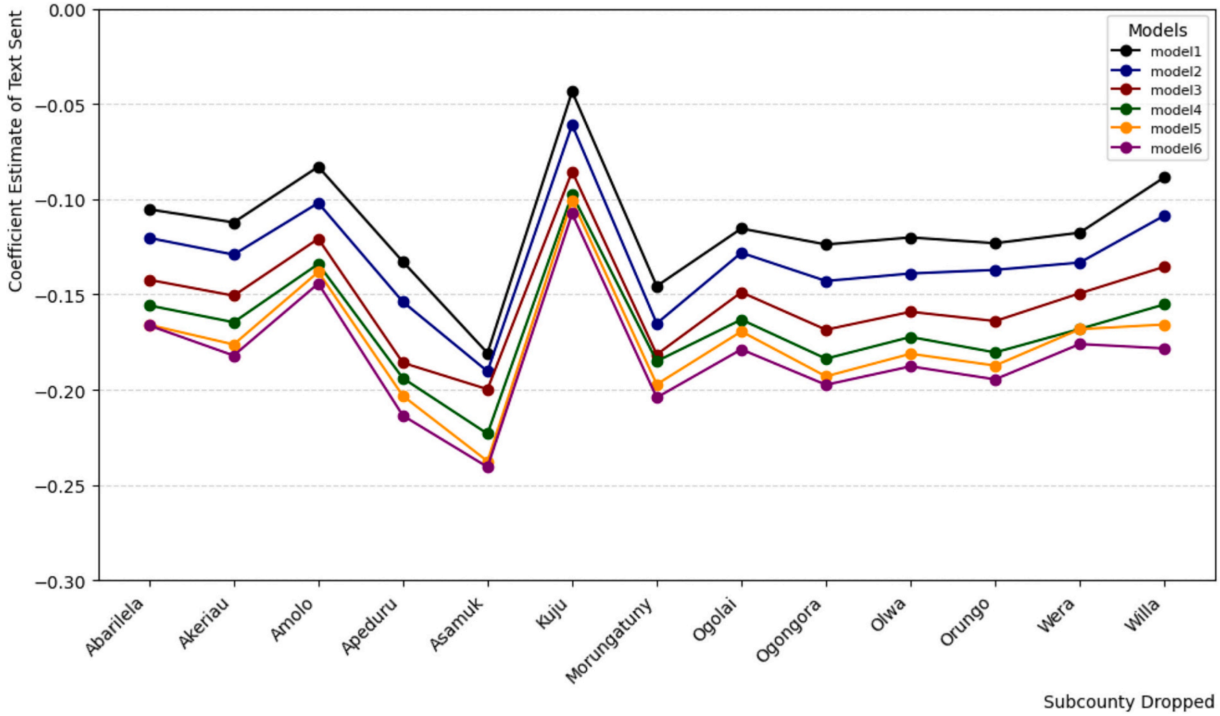


Table A1
Effect of behavioral nudges on the purchase of quality seed of improved sweetpotato varieties.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Purchased	Purchased	Purchased	Purchased	Purchased	Purchased
Treatment	0.065*	0.070*	0.068*	0.065	0.070	0.068
	(1.68)	(1.85)	(1.82)	(1.44)	(1.57)	(1.55)
Respondent Sex		−0.026	−0.030		−0.026	−0.030
		(−0.81)	(−0.95)		(−0.84)	(−0.99)
Respondent Age		−0.000	−0.000		−0.000	−0.000
		(−0.25)	(−0.20)		(−0.22)	(−0.17)
Years of Schooling		0.017***	0.017***		0.017***	0.017***
		(3.83)	(3.78)		(3.62)	(3.57)
Household Size		0.008*	0.007		0.008*	0.007
		(1.82)	(1.61)		(1.69)	(1.51)
Own Cultivable Land		0.016***	0.016***		0.016***	0.016***
		(2.96)	(2.97)		(2.93)	(2.94)
Constant	0.349***	0.166*	0.134	0.349***	0.166	0.134
	(4.94)	(1.87)	(1.50)	(3.79)	(1.49)	(1.19)
Observations	1133	1133	1133	1133	1133	1133
Adjusted R-squared	0.017	0.039	0.039	0.017	0.039	0.039
Number of Counties	15	15	15	15	15	15
Frequency of Vine Purchase	No	No	Yes	No	No	Yes
Sub-county FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Columns (1) to (3) show the results from the initial regression with robust standard errors and columns (4) to (6) are results with village-level clustered standard error. *Treatment*, representing whether the household receives the treatment, is interpreted as the average treatment effect of behavioral nudges. All models include sub-county-level fixed effects. T-statistics are shown in parentheses. Asterisks indicate the following: *** = $p < 0.01$, ** = $p < 0.05$, and * = $p < 0.1$.

Table A2
Summary of probit regression results - first stage of Heckman selection model.

	2022	2023
VARIABLES	Phone Number Listed	Phone Number Listed
Respondent Sex	0.061	0.074
	(0.116)	(0.128)
Respondent Age	−0.015***	−0.017***
	(0.003)	(0.004)
Years of Schooling	0.127***	0.098***

(*continued on next page*)

Table A2 (*continued*)

VARIABLES	2022 Phone Number Listed	2023 Phone Number Listed
	(0.019)	(0.021)
Household Size	0.029*	0.029
	(0.016)	(0.018)
Own Cultivable Land	0.012	0.077***
	(0.021)	(0.027)
Constant	0.744***	0.826***
	(0.232)	(0.263)
Observations	953	857
Pseudo R-squared	0.161	0.153
Log Likelihood	−351.07	−290.93

Note: * indicates a confidence level of 90 %, ** indicates 95 %, and *** indicates 99 %.

Data availability

Data will be made available on request.

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