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Modest Ag-Extension and Access to Seeds of Aromatic Rice Can Boost Returns of Smallholder Farmers in Uganda, A Case Study

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Abstract: Limited farmer access to quality seeds of improved varieties and knowledge gaps in good agronomic practices are the major factors limiting rice productivity among smallholder farmers in Uganda. Promoting high yielding aromatic rice varieties alongside good agronomic practices can unlock commercial opportunities for smallholder farmers in rice cultivation, given that 80% of rice consumers in Uganda prefer aromatic rice, which is in short supply. This case study highlights a project's achievements to accelerate the adoption of improved aromatic rice varieties among smallholder farmers in Uganda. This project supported a few selected farmers with the seed of a new aromatic rice variety, NARORICE-1, and equipped them with agronomic skills to raise their yields from an average of 3.1 to 4.1 t/ha. Line transplanting was identified as a crucial technology to increase rice yields among smallholders. Costly and inaccessible crop-enhancing inputs such as seeds and fertilizers, and an unfair distribution of irrigation water were the two main obstacles farmers face in rice production. Farmers valued NARORICE-1 for its aroma, high yield, and early maturity. The project's training of a community seed producer improved farmers' access to NARORICE-1 seeds, increasing its adoption by 20% in two years. NARORICE-1 is much more in demand than any other variety and attracts a better price, making it an ideal innovation for increasing productivity and farmer's incomes. An effective seed system and continuous farmer training are vital for accelerating impact.

Keywords: fragrant rice; NARORICE-1; PR-107; Doho rice scheme

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1. Introduction

Rice is a non-traditional crop in Uganda, albeit increasing in importance both as a staple food and a source of income for farmers, especially the smallholders who are the majority and produce more than 90% of the country's rice output. Unlike other traditional staples such as millet, sorghum, and cassava [1], grown mainly for consumption at the farm household level, rice is considered a cash crop destined for consumption in urban markets [2]. In contrast, rice in Asia is mainly grown for home consumption. Uganda's projected domestic milled-rice production of 228,000 MT is inadequate to feed the growing appetite of Ugandans for rice [3]. The country's imports grew from 59,988 MT in 2008 to 210,102 MT in 2017 to make up for the national deficit [4]. Thus, the government needs to ramp up production to become self-sufficient in rice. Production can be increased by cultivating more land or raising productivity. However, with an ever-growing population exerting more pressure on the available land, the only feasible and sustainable solution for increasing the country's rice production is to boost the on-farm productivity, especially among the smallholder farmers, who are many.

The current national productivity level between 2.5 and 3 tons/ha [2,5] is unfortunate, given that some improved rice varieties in the country can yield up to 6 t/ha [6]. A recent study by Senthilkumar et al. (2020) reported lowland-rice yields of 3.1 t/ha and a corresponding yield gap of 3.3 t/ha in Doho, Butaleja, in eastern Uganda. Given that Doho is a highly productive area with adequate irrigation and fertile volcanic soils, the general yields in eastern Uganda might even be much lower with more significant yield gaps. Many small-scale farmers hardly use agro-inputs such as improved seed, fertilizers, and herbicides [1,7] and have limited extension support [8]. A recent case study of rice growers in eastern Uganda highlighted limited farmer access to improved seed [9] and knowledge gaps in good agronomic practices as the major factors limiting rice productivity among smallholder farmers in Uganda [10]. The near absence of a commercial rice-seed industry hampers farmers' access to quality seeds of improved varieties. Moreover, the cultivation practices are far from optimal due to gaps in awareness/knowledge and limited resources. Hence, investing in quality inputs [7] and modest improvements in skills can give farmers much better returns [8]. This study surmises that rice productivity among smallholder farmers in Uganda can be enhanced by using improved seeds and observing good agronomic practices [11]. In addition, other farmers are more receptive and willing to adopt new technologies (varieties and farming methods) once the benefits of greater returns of yield and income become visible.

This case study describes the methodologies used and the success of implementing a project to accelerate the adoption of improved aromatic and high-yielding rice varieties among smallholder farmers in eastern Uganda. The project funded by the Government of Korea through the Korea Program on International Agriculture (KOPIA) in Uganda adopted a strategy focused on maximizing technology adoption by initially working with a few carefully selected progressive farmers spread out within the rice farming communities [12]. These farmers were provided with the seed of a new, improved aromatic rice variety, NARORICE-1, and given practical season-long agricultural extension support to enhance their yields. Before that, the project used farmer-managed on-farm trials to locally validate and demonstrate the effects of simple agronomic concepts such as line planting on the productivity of irrigated lowland rice. Most importantly, the on-farm trial was meant to compare and demonstrate the performance of the new variety NARORICE-1 against the popular farmer's variety WITA-9. On-farm trials are known to encourage participatory learning and the adoption of new practices and technologies that increase productivity and improve the economic well-being of farmers and the sustainable development of local communities [13]

The information generated by this study may be used by:

(a) the general public, to promote similar approaches among stakeholders wishing to increase crop productivity among smallholder farmers;
(b) the government to formulate, reform, and implement adopted policies and legislation necessary to support strategies for increasing on-farm crop productivity; and
(c) potential donors interested in supporting strategies to increase on-farm crop productivity.

Project Background

Uganda is still a net importer of rice, yet local consumption continues to grow fast. According to the FAO, rice consumption in Uganda increased from 8 to 11 kg pa capita per year between 2013 and 2015. This increase in local rice consumption is an incentive for smallholder farmers to increase their production and earn more income, given that rice is mainly grown as a cash crop and has significantly higher gross margins than other cereals. Smallholder farmers consume only about 25% of their rice harvest at the household level and market the rest [14]. Increasing domestic rice production will stabilize rice supply and thus prices, making rice more affordable for consumers. However, although the enormous economic opportunities for smallholder farmers in rice farming, rice production in Uganda is still characterized by low productivity, currently at an average of 2.5 MT/ha compared to a potential of 8 MT/ha. This low productivity is mainly due to the limited knowledge among farmers on good rice agronomic practices, low-yielding rice varieties, and unreliable seed supply systems [15].

This project, therefore, set out to operationalize an innovative technology upscaling model for upscaling rice production in Uganda with a particular focus on aromatic rice. This objective is premised on the fact that 80% of rice consumers in Uganda (mainly urban dwellers) prefer aromatic rice [16]. However, the supply of aromatic rice is still minimal. Hence, commercial opportunities for smallholder rice farmers in Uganda can be unlocked by breeding and promoting high-yielding rice varieties with the aroma trait that consumers prefer. Recently, the focus of the National Agricultural Research Organization (NARO) in Uganda has been to develop aromatic rice varieties, and aromatic rice varieties yielding up to 7 tons/ha were developed by crossing Korean Rice with 23 aromatic rice lines in Uganda.

2. Materials and Methods

2.1. Description of the Study Area

We conducted the study in the Doho rice scheme found in Butaleja District in eastern Uganda. The Doho rice scheme lies at an altitude of 1100–1220 m with the following central coordinates: 0° 52′ 59″ N (0.88°) 34° 0′ 0″ E (34.00°). Formerly a seasonal wetland on the river Manafwa floodplain, the Doho rice scheme is now an intensive irrigated rice cultivation area [16], covering approximately 2500 ha. It sustains more than 10,000 farmers, both outgrowers and part of the scheme's growers [17]. The Doho rice Scheme Farmers' Cooperative Society (DIFACOS) is the umbrella body managing the scheme.

It lies at an altitude of 1100 m above sea level and the average annual temperature in the region is 22.7 °C and ranges from 15.4 °C to 30.7 °C. The precipitation pattern is bimodal, with peaks in March, May, August, and October, and mean annual precipitation of 1186 mm [18]. Soils here are plinthosols, reddish brown in color, sandy loam and loam textured [19], with a pH range of 5.6 to 6.6, and soil organic matter content range of 2.2 to 3.7% [20]. Because the Manafwa River, which supplies irrigation water to the study area, flows through the fertile slopes of Mt. Elgon and carries some nutrients and sediments [10], the soils in the study area are quite fertile, with all major micro- and macronutrients above critical levels that cause deficiencies in rice except for nitrogen, boron, and copper [21].

2.2. Design of the Study

2.2.1. On-Farm Trial

We set up farmer-managed on-farm trials to demonstrate and locally validate the effects of simple agronomic concepts on the yield of irrigated lowland rice. The on-farm trials were conducted in the farmers' fields on hired land to ensure that the experimental conditions were identical to those of the farmer's field and allow the farmers unlimited opportunities for observation during the whole cropping season.

The technologies evaluated included four varieties (WITA-9, NARORICE-1, KAFACI-287, and KAFACI-167) and three seedling rates (3, 5, and 7 seedlings/hill). NARORICE-1, also known as PR-107, is among Uganda's most recently released high-yielding aromatic rice varieties. It is adapted to the irrigated and rainfed lowland rice ecosystems and matures in 95 days. WITA-9, on the other hand, is a commonly grown rice variety in the Doho rice scheme because it is high yielding and resistant to Rice Yellow Mottle Virus (RYMV) disease and other common diseases of lowland rice. WITA-9 matures in 120 days. In this trial, WITA-9 was used as a local check. KAFACI-167 and KAFACI-287 are newly bred and in the advanced variety testing stages. Some of the unique attributes of KAFACI-167 and KAFACI-287 include aroma, large grain size, and tolerance to the significant diseases of lowland rice in Uganda. While the growth duration for KAFACI-167 is 95 days, KAFACI-287 takes 105 days to mature. Hence, the trial was set up as a two-factor (variety × seedling rate) randomized complete block design with four replications. The experimental plot size was 36 m^2, i.e., 6 m by 6 m.

2.2.2. Field and Crop Management of the On-Farm Trial

Before commencing land preparation, the fields were bundled all-round to enable them to hold adequate water for land preparation and sustain rice growth after transplanting.

The fields were then ploughed twice and puddled using hand hoes before leveling using heavy and flat wooden planks drawn on the wet soil surface using ropes. Furadan 5G was then applied to the fields before transplanting rice to control apple snails known to eat up young, freshly transplanted rice seedlings. Three-week-old rice seedlings were then transplanted into the fields at a spacing of 30 cm by 14 cm to give an average plant stand of 24 hills per square meter. The seedlings were raised by the host farmer in a wet-bed nursery in his field, using seeds provided by the project. After transplanting, the fields were kept wet without flooding for ten days to keep out snails and enable the rice seedlings to establish without being washed away. Controlled flooding of the fields was then implemented from 11 days after transplanting (DAT) onwards, maintaining the water level at 10–15 cm above the ground to control weeds but not submerge the rice seedlings. The rice was hand-weeded using hand hoes at 3 and 6 weeks after transplanting. We applied fertilizer to the fields at 60:30:30 kg NPK ha^{-1}. We applied 30:30:30 kg NPK ha^{-1} using NPK 17:17:17 fertilizer at the time of transplanting and then later 30 kg N ha^{-1} at two months after transplanting. In both cases, we hand broadcasted the fertilizer, making sure that it is uniformly spread in the trial area. Three weeks before harvest, the fields were drained to allow for uniform maturity of the varieties.

2.2.3. Collection and Analysis of On-Farm Trial Data

Data on growth, yield, and components were collected at the appropriate crop stage. Tiller numbers were determined at the active and maximum tillering growth stages. Plant height was measured at the active and maximum tillering growth stages and at harvest. Yield and yield components measurements were done at the time of harvest. For yield determination, rice panicles were harvested from 5 m^2, sun-dried, and then threshed. The threshed grains were then floated in plain tap water to separate the filled and unfilled grains. The unfilled grains were discarded, while the filled grains were dried and weighed for yield assessment. The moisture content of the grains was measured using a Wheat and Rice Flour Moisture Tester—PRg-93 [22] and the moisture content values used to correct the yield, which was reported as the weight of filled grains at 14% moisture content.

The data were summarized in Microsoft Excel and subjected to analysis of variance in a randomized complete block design using the statistical tool for agricultural research [23]. Fisher's least significant difference (LSD) test method was used to separate the treatment means.

2.2.4. Seed and Technical Support to Smallholder Farmers

Using 150 farmers provided by the Doho rice Scheme Farmers' Cooperative Society (DIFACOS), a sample of 40 progressive farmers was purposively selected [24] from the different blocks of the Doho rice scheme based on the willingness to participate in the project activities and a recommendation from the local leadership. Because the Doho rice scheme is divided into 11 blocks of 100 to 200 acres [25], at least three farmers were selected from each block to ensure coverage of the entire scheme The selected farmers were each provided with 10 kg of the NARORICE-1 seed (enough to plant half an acre) (Figure 1). The farmers were provided with technical support and engaged in season-long learning-by-doing exercises in their fields, working together with rice researchers and local extension agents throughout the entire season (Figure 2). Practical field exercises included nursery bed preparation, land preparation, transplanting, weed control, soil fertility management, water management, harvesting, threshing, and drying. At the end of the cropping season, the participating farmers were interviewed using a simple structured questionnaire with open-ended questions to gain useful insights into the different aspects of rice cultivation and the season's yield outcomes. The questionnaires were administered to the individual respondents by enumerators. The interview was conducted off-season (during the dry season) and only focused on the farmers that received seed and technical support from the project and were accessible for the interviews. Many farmers normally engage in other off-farm activities to forge a living, and cannot, therefore, be easily found. As a result, 22 farmers were interviewed, representing 55% of the originally selected farmers. Responses were first grouped into general categories and then into sub-groups of similar or recurring themes for analysis. Their responses were summarized and analyzed in Microsoft Excel.

Figure 1. The Director KOPIA Uganda and his team distributing NARORICE-1 seed and fertilizer to project beneficiaries in the Doho rice scheme. The picture on the left is for the distribution of starter seeds to members of Namunasa Mixed farmers' association who are engaged in community seed production, while the picture on the right shows the distribution of fertilizers to farmers.

Figure 2. Demonstration and training of farmers on how to transplant rice in lines using a transplanting line adapted from Korea.

3. Results

3.1. Results of On-Farm Trial

Varying the seedling number per hill or transplanting spot did not significantly affect rice growth and yield parameters for all tested rice varieties. However, we found apparent differences between the rice varieties in height, tillering, length, and number of panicles (Table 1).

Table 1. Comparison of growth parameters of selected aromatic rice varieties in the Doho rice scheme. Within columns, means values with the same letter are not significantly different.

Variety	Plant Height 60 DAT (cm)	Plant Height at Harvest (cm)	Tiller/Hill 60 DAT	Panicles/Hill	Panicle Length (cm)	Paddy Yield (t/ha)
KAFACI-167	72.3 b	86.5 b	7.6 c	18.8 b	21.0 c	4.5 b
KAFACI-287	84.1 a	112.9 a	8.6 c	13.3 c	25.5 a	5.2 b
NARORICE-1	66.3 b	78.1 c	11.8 b	21.8 b	22.8 b	6.7 a
WITA-9	51.6 c	73.4 c	17.8 a	36.8 a	18.9 d	8.0 a
Mean	68.6	87.8	11.5	2.3	22.0	6.1
CV	7.0	4.3	10.4	18.8	5.0	19.8
p value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (5%)	6.1	4.8	1.5	5.4	1.4	1.5

3.2. Case Study Findings

3.2.1. Socio-Economic Status of the Respondents

Out of the 40 smallholder farmers that received seed and technical support from the project in Doho, Butaleja District in 2021, we interviewed 22, representing 55%. Of those interviewed, 82% were male, while 18% were female; 41% of the respondents were young adults (aged 16–35 years). Similarly, 41% of the respondents were middle-aged adults (senior 36–55 years), while the older adults (aged older than 55 years) comprised 23% of the respondents. Still going by the age categories above, we found that middle-aged adults owned more land on average when compared to the other age categories (Figure 3). Similarly, middle-aged adults allocated more land to rice cultivation than the different age groupings.

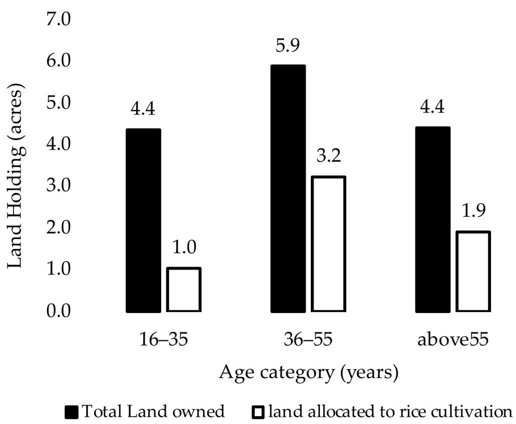

Figure 3. Average land allocation to rice as a proportion of the total arable land owned by the household.

The respondents in this study ranked rice as the number one crop commodity grown for household consumption and sale. Maize, beans, and cassava ranked 2nd, 3rd, and 4th, in that order (Figure 4).

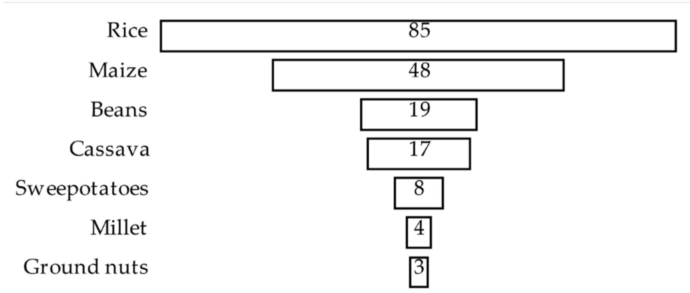

Figure 4. Drop-down scale ranking (by the number of responses) of crops grown by smallholder farmers in the Doho rice scheme, Butaleja District ranked according to importance to the households.

3.2.2. Outcome of Project Interventions on Farmers' Rice Yields

The respondents in this study were farmers provided with the seed of a new, improved aromatic rice variety, NARORICE-1, and given practical season-long agricultural extension training to enhance their yields. Each respondent was given 10 kg of the NARORICE-1 seed and monitored throughout the season until harvest. Our findings show that the farmers could transplant 0.5 acres on average with the 10 kg of seed provided and obtained an average paddy yield of 883 kg, equivalent to 4098 kg/ha or 4.1 tons/ha (Figure 5). Of the respondents, 63% transplanted their rice in lines using the Korean transplanting line at the recommended spacing of 30 cm × 14 cm, giving an average plant stand of 24 hills/m^2. However, some farmers who did not access the Korean transplanting lines opted to experiment with other spacings, such as 20 cm × 15 cm (33 hills/m^2) and 25 cm × 15 cm, with no apparent effects on yield. There was a weak negative correlation between planting density and yield (r = –0.26) with the yield decreasing when the farmers increased their planting density beyond 26 hills/m^2.

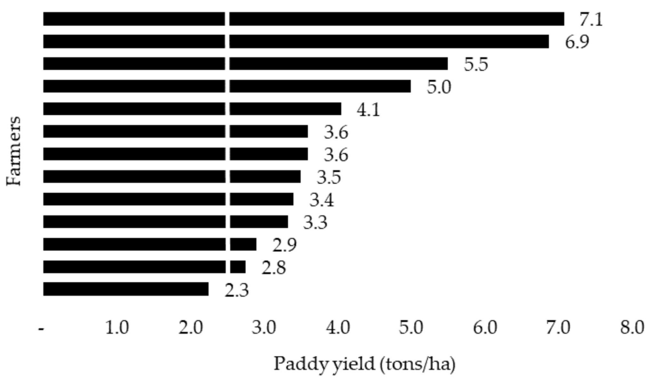

Figure 5. Yield of NARORICE-1 on fields of 22 of the 40 farmers who received seed and technical support throughout the season. The white vertical line represents the current national productivity average of 2.5 MT/ha.

3.2.3. Farmers' Perceptions about Line vs. Random Transplanting

This project set out to promote technologies that enhance the productivity of rice and hence saleable volumes for smallholder farmers in Uganda. Line transplanting was identified as one of the technologies that would increase rice yields in farmers' fields. However, line transplanting is mainly unpopular, so we sought to find why. Some of the respondents' perceptions about the unpopularity of line transplanting are presented in Figure 6 below and explained further in the following bullet points.

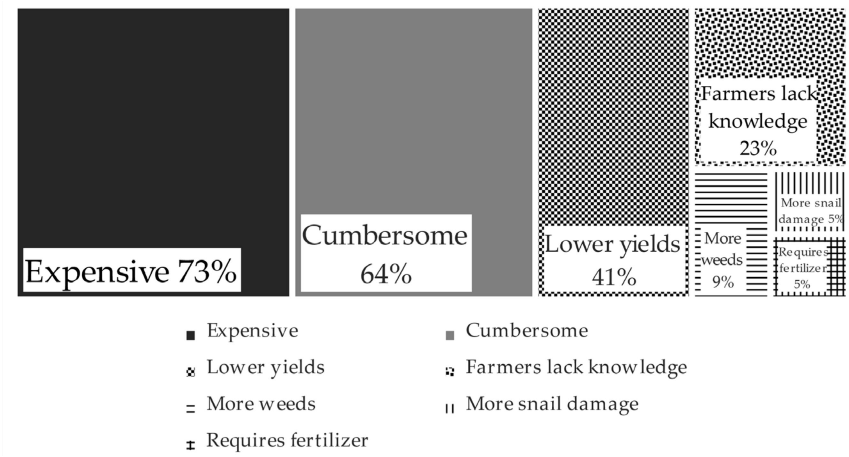

Figure 6. Farmer's ranking of the perceptions on why line transplanting of rice is not practiced by many farmers in the Doho rice scheme.

1. Line transplanting is expensive, requiring extra labor and a well-puddled and levelled field.
2. Line transplanting is cumbersome (it takes a lot of time and effort, it is difficult to measure the spaces between lines, and tiresome to change ropes).
3. Line transplanted rice yields less than random transplanted rice because of a lower plant population resulting from seemingly wide spaces between the lines.
4. Most farmers do not know how to transplant rice in lines and are unaware of its benefits.
5. The wide spaces in line transplanted rice encourage weed growth.
6. Line transplanted rice seedlings are eaten more by apple snails (*Pomacea* spp.), which find it easier to follow and feed along the rows of rice.
7. Fertilizers must be applied to line transplanted rice to enhance yields.

Interestingly, although many smallholder farmers do not transplant rice in lines, they are aware of the benefits of line transplanting. For example, 95% of the respondents indicated that it is easier to weed line-transplanted rice, while 73% noted that the yield of line-transplanted rice is higher than that of randomly transplanted rice (Figure 7). Therefore, the respondents were tasked further to suggest how line transplanting can be popularized in the Doho rice scheme, and 86% of them suggested continuous training of more farmers about line transplanting and its benefits. They suggested farmer field schools, demonstrations, and farmer exchange learning visits as the ideal training methods that would encourage widespread adoption of line transplanting. Another 32% of the respondents suggested that providing farmers incentives such as transplanting lines (like the Korean transplanting line), improved seeds, mechanized push weeders, fertilizers, and financial support might encourage many more farmers to transplant rice in lines. Similarly, 14% of the respondents proposed the introduction of small-scale mechanized transplanters. Lastly, 5% of the respondents recommended the introduction of by-laws that penalize farmers who do not transplant rice in lines. One of the by-laws suggested was withdrawing the farmland of non-abiding farmers and reallocating it to those willing to cooperate.

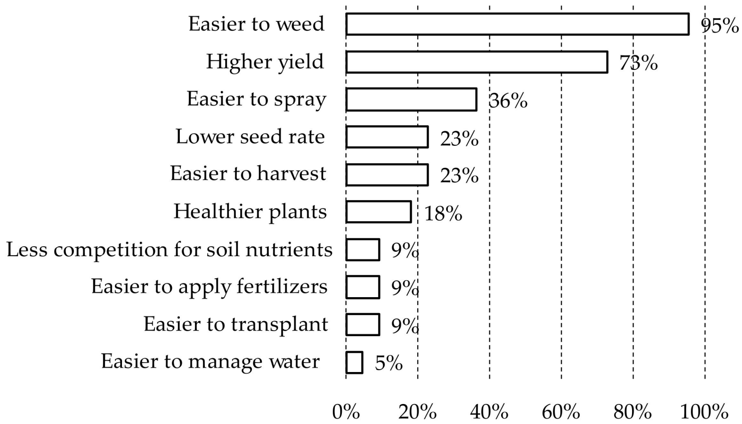

Figure 7. Farmer perceived advantages of transplanting rice in lines when compared to random transplanting.

3.2.4. Farmers' Appreciation of NARORICE-1

Of the respondents, 55% appreciated NARORICE-1 for its favorable farm-gate price and high/ready demand. At the time of this case study, the farm-gate price of NARORICE-1 paddy was UGX 2500 (USD 0.7), while that of the other non-aromatic varieties (Kaiso) was UGX 1800 (USD 0.5). In the same way, 1 kg of the milled NARORICE-1 was sold at UGX 3600 (USD 1.0), while the other varieties were sold at UGX 2500 (USD 0.7). However, despite the favorable farm-gate prices of NARORICE-1, the quantities produced were inadequate to meet the consumer requirements. For example, there was hardly any NARORICE-1 in the local shops during the case study. Buyers stationed at the mill would buy off all the NARORICE-1 immediately after the milling.

Secondly, NARORICE-1 was appreciated for its excellent aroma and eating qualities (45% of the respondents). According to the respondents, the aroma and taste of NARORICE-1 were comparable to Supa, the most preferred (in terms of aroma) locally grown aromatic rice variety. One of the largest local rice processors in the Doho rice scheme is branding and marketing NARORICE-1 as Supa (Figure 8), much to the consumers' appreciation.

Figure 8. NARORICE-1 branded and marketed as Supa by Manafwa Basin Farmers' Cooperative Society in Doho, Butaleja District.

Thirdly, NARORICE-1 was appreciated for its high yield and early maturity (by 41% of the respondents). According to the National Agricultural Research Organization (NARO), NARORICE-1 is a very early (95 days), moderately aromatic, and long-grain rice variety that displays excellent yield potential of up to 5.8 t ha^{-1} [26]. The yield of NARORICE-1, as reported by the farmer's respondents, is presented in Figure 5.

In the fourth place (by 18% of the respondents) was the respondents' appreciation of NARORICE-1 for having high milling percentage and head rice recovery. Some respondents reported a milling recovery of up to 70%.

Finally, NARORICE-1 was lauded for its large grain size and tolerance to pests and diseases. The 1000-grain weight of NARORICE-1 is 34 g, which compares to that of Supa. NARORICE-1 has improved resistance to the RYMV disease, Bacterial Leaf Blight (BLB), Bacterial Leaf Streak (BLS), Rice Blast, and Narrow Leaf Spot when compared to some of the local varieties of rice such as K-85, K-98, and K-5.

However, there were also suggestions on how NARORICE-1 may be improved further to meet the needs of the farmers: 32% of respondents observed that NARORICE-1 was low tillering compared to the common lowland rice varieties (such as WITA-9, K-85/Benenego, K-96 and K-5) and should therefore be improved to tiller more. Another 14% of the respondents observed that the tolerance of NARORICE-1 to RYMV disease should be enhanced.

Given their appreciation for NARORICE-1, the respondents were tasked to estimate the percentage of farmers currently growing NARORICE-1 in the Doho Rice Scheme. Because the Doho Rice Program consists of 11 farming blocks and respondents were selected from each of the 11 blocks, each respondent was asked to estimate the proportion of farmers in their individual blocks growing NARORICE-1. These individual estimates were then averaged to give an indication of the adoption rate of NARORICE-1, which was 20%.

To foster the adoption of NARORICE-1, 40 farmers were selected from the different blocks of the scheme and supplied with 10 kg of seed each. Each beneficiary was obliged to give part of their harvest as seed to three other farmers. Accordingly, 64% (14) of the respondents in this study who received NARORICE-1 seed re-distributed 513 kg of the harvested grain to another 49 farmers, crediting this model.

3.2.5. Challenges Experienced by Farmers in Rice Cultivation

The respondents highlighted six challenges encountered by farmers in rice cultivation in the Doho rice scheme. These are presented in Table 2 in order of their importance.

Table 2. Farmers' ranking of the challenges that they face in rice cultivation in the Doho rice scheme. The responses were drawn from 22 respondents using open-ended questions.

Rank	Challenge	Responses	% Responses
1	High cost and shortage of inputs	16	73%
2	Inadequate irrigation water	12	55%
3	Pests and diseases	9	41%
4	Limited mechanization of rice farming	7	32%
5	Limited farmer access to finance	6	27%
6	Inadequate farmer's knowledge of GAPs	4	18%
7	Limited farmer access to quality inputs	2	9%

4. Discussion

Limited farmer access to improved seed and knowledge gaps in good agronomic practices are significant factors limiting rice productivity among smallholder farmers in Uganda. The near absence of a commercial rice-seed industry hampers farmer access to quality seeds of improved varieties, while the cultivation practices are far from optimal due to gaps in awareness/knowledge and limited resources. This study aimed to document the methodologies used and the achievements during implementing a project to accelerate the adoption of improved aromatic and high-yielding rice varieties and the associated good agronomic practices among smallholder farmers in eastern Uganda. The study also used a farmer-managed on-farm trial to compare and demonstrate the performance of the new variety against the local farmers' variety WITA-9 to locally validate and demonstrate the effects of simple agronomic concepts such as line planting on the productivity of irrigated lowland rice. Most importantly, the second objective was meant to compare and demonstrate the performance of the new variety NARORICE-1 against the popular farmers variety WITA-9. The project was implemented in Butaleja and Lira districts in eastern and northern Uganda, but this study only focused on the Doho rice scheme. The results of this study are discussed in three subsections: on-farm trial findings, case study findings, and other interventions inspired by the project.

4.1. On-Farm Trial Findings

The main objective of the on-farm trial was to demonstrate and compare the performance of the new variety NARORICE-1 and candidate rice varieties against the popular farmer's variety WITA-9. NARORICE-1 and WITA-9 produced the highest paddy yields of 6.7 and 8.0 t/ha, respectively, which were statistically similar. The two candidate varieties KAFACI-267 and KAFACI-287 produced paddy yields of 4.5 and 5.2 t/ha, which were statistically lower than those of NARORICE-1 and WITA-9. The yield differences between varieties were strongly associated with differences in tillering, with WITA-9 producing the highest number of effective tillers (same as panicle number) at 37, which was significantly higher than that of NARORICE-1, KAFACI-287, and KAFACI-167 at 22, 13, and 19 panicles per hill. Rice varieties vary significantly in their tillering ability, with high-tiller varieties typically having higher panicle counts, which contributes to higher yields than low-tiller varieties [27]. High grain yield and early maturity are often the most preferred variety attributes by farmers [28–31]. Therefore, the high yield of NARORICE-1 due to high tillering and its early maturity may positively influence its adoption.

4.2. Case Study Findings

As perceived by the surveyed farmers, rice was ranked as the most crucial cash and food security crop for the households in the study area, followed closely by maize, beans, and cassava, in that order (Figure 4). This is similar to the observations of Kijima [32], whose results showed that rice is grown by all age categories of farmers, i.e., the young adults (16–35 years), middle-aged adults (36–55 years), and the older adults (>55 years). The middle-aged adults were the most active in rice cultivation. They owned the most arable land and allocated a more significant proportion (54%) of their land to rice cultivation (Figure 3). In contrast, the young and older adults only apportioned 23% and 43% of their arable land to rice cultivation. Overall, the study found that households in this community own about 4 acres of arable land on average, which corroborates the findings of Kijima [32].

One of the significant findings from this study is that providing farmers with the improved seed of NARORICE-1 and hands-on lessons in simple proven agronomic techniques can enable them to enhance their yields. For example, when this project's recipients of NARORICE-1 transplanted it in lines, using 2–3 weeks old seedlings (as opposed to the overgrown >4-week-old seedlings that farmers often use), they harvested up to 4.1 tons/ha on average (Figure 5). This represents a significant increase from the yield estimates reported in earlier studies, i.e., 2.5 [1,21], 3.1 [6], and 3.6 t/ha [9]. This finding is consistent with another study which showed that farmers increased their paddy yield by 23% from 3.2 to 4.0 t/ha by improving crop management practices, such as weeding time [33]. In the same study, a high proportion (77%) of their highest-yielding fields (top 10-percentile) were transplanted in lines while only 23% were randomly transplanted. This finding also accords with observations of another study, which showed the paddy yield of line transplanted rice at 4.9 t/ha was 44% higher than the yield of random transplanted rice at 3.4 [34]. Yet another study found that when farmers in the Doho rice scheme applied best practices in rice production, they obtained yields of 4.3 MT/Ha, as opposed to only 2 MT/Ha when they did not use the best practices [1]. This combination of findings, therefore, provides support for the conceptual premise that good agronomic practices are critical for increasing crop productivity [35].

Hence, with the two interventions above, this project increased the adoption of NARORICE-1 in the Doho rice scheme, currently estimated at 20% by this study. The total number of registered rice farmers in Doho-1 is 3868, farming 1000 ha, while Doho-2 has 1700 farmers cultivating 700 ha [6]. This study estimates that NARORICE-1 is now grown by nearly 1000 farmers on approximately 540 ha in the Doho rice scheme alone.

In addition to the improved seed, this project also identified line transplanting as a critical technology for increasing rice yields among smallholder farmers in Uganda. However, the study found that line transplanting is practiced only by about 30% of the farmers in the Doho rice scheme, and therefore, sought to find out why many farmers do not transplant rice in lines. The three main reasons farmers did not transplant rice in lines were that it is more expensive, cumbersome, and yields less than random transplanted rice. Up to 73% of the respondents in this study noted that transplanting was expensive, requiring additional labor and land preparation compared to random transplanting. The study established that the cost of random transplanting was UGX 80,000 or USD 23/acre. Line transplanting, on the other hand, costs UGX 100,000 or USD 29/acre, representing a 25% increment in the cost of transplanting. A similar study by Ponnusamy et al. (2013) showed that line transplanting was 20% more expensive than random transplanting, albeit with a 20% savings in weeding, a 25% yield increment, and a cost–benefit ratio of 1:48 against 1:33 for random transplanting [36]. Hence, line transplanting may appear costly initially, but the costs are offset during weeding, and the resulting yield advantage boosts the farmer's profits.

The study further sought to find out from the respondents what they thought could be done to increase the adoption of line transplanting. One in every three respondents indicated that providing farmers incentives such as transplanting lines (like the Korean transplanting line), improved seeds, mechanized push weeders, fertilizers, and financial support might encourage them to transplant rice in lines. A tenth of the participants proposed the introduction of small-scale mechanized transplanters. At the same time, 5% advocated introducing and enforcing by-laws that temporarily exclude non-compliant farmers from the scheme. A similar by-law requiring farmers in the Doho rice scheme to pay an irrigation user fee of UGX 12,350/ha/season was passed in 1994, and farmers who did not comply would have their fields withdrawn from them for the season and rented out to willing farmers [37].

Nevertheless, many respondents pointed to the introduction of mechanization (push weeders and transplanting machines) to promote line transplanting. Introduction and promotion of scale-appropriate mechanization and labor-saving technologies can buffer the smallholder rice farmers against the increasing labor costs, thereby enhancing rice production efficiency. These technologies are especially relevant for women farmers who perform most backbreaking farm operations. They may also appeal to the youth, who are increasingly reluctant to take on manual, low-return farming jobs.

NARORICE-1 was highly valued by respondents for many reasons, but the most important was its good price and ready market due to its aromatic nature compared to the non-aromatic varieties. The price of NARORICE-1 at UGX 2500 (USD 0.7) for paddy and UGX 3600 (USD 1.0) was higher than the regular market price of the non-aromatic varieties at UGX 1800 (USD 0.5). and UGX 2500 (USD 0.7). The high demand and high prices of NARORICE-1 may be driven by Ugandans' love of aromatic rice, with 80% of consumers preferring aromatic rice [16,38,39]. In fact, the most popular local rice variety among Ugandans is Supa, which is very fragrant [17] and fetches a premium price in the local market [38]. NARORICE-1 compares well to Supa in terms of aroma and is now being marketed as Supa by some millers and farmers (Figure 8). High paddy yield was the second reason why many farmers appreciate NARORICE-1 as highlighted by the respondent. The average yield of NARORICE-1 among respondents was 4.1 t/h, which is higher than the reported mean yield in the Doho rice scheme of 3.1 t/ha [6]. However, NARORICE-1 can potentially yield much more, as shown by a yield of 6.7 t/ha in the agricultural study and demonstration that is part of this study (Table 1). The third attribute that the respondents liked about NARORICE-1 was its early maturity. While WITA-9, a popular rice variety in the Doho, takes 120 days from transplanting to maturity, NARORICE-1 needs only 95 days and is therefore harvested almost 1 month earlier. According to the respondents, NARORICE-1 comes onto the market earlier than the other longer-lasting varieties and is therefore sold out more quickly at a higher price when rice is generally in short supply. Crops harvested outside the regular harvesting season when supply is low and prices are high can give farmers better profits and consumers more choice [40]. Cultivating early-maturing varieties also conserves water by reducing irrigation duration, and the yield reduction that often occurs when rice is subjected to water stress, particularly during the flowering phase, is less likely with early-maturing varieties. It is no wonder therefore that high grain yield and early maturity are often the most preferred variety attributes by farmers [28–31].

This study identified and ranked the most pressing challenges that farmers in the Doho rice scheme experience in growing rice, including the high cost and shortage of critical agro-inputs, inadequate irrigation water, pests and diseases, and limited mechanization of rice farming accordingly. Number one on the list of challenges was the limited access to yield-enhancing agro-inputs such as seed, fertilizer, and pesticides. Seed and fertilizers were highlighted by the respondents as the most critical inputs for enhancing yields. Farmers' limited access to rice seed is not surprising as many seed companies are reluctant to get involved in rice seed production due to poor demand forecasts, as many farmers rely on homegrown seeds which they replant many times as rice is a self-pollinated crop [9]. Because of this, some seed companies either produce when they get a large order (usually from the government) or produce very limited quantities that can be sold in one season. Rice seed is therefore the most inaccessible agricultural input (compared to all other inputs) for farmers in the Doho Rice scheme, as they sometimes have to travel a long distance to the nearest neighboring district of Mbale to obtain it [1]. Most of the agro-input dealers in the Butaleja District do not deal in seed, and farmers must therefore rely on the government, NARO, and NGOs for good quality improved seed. The development of community rice seed systems is therefore crucial to improve farmers' access to quality seeds and increase yields.

Many of the respondents in this study also noted that fertilizer and pesticides are expensive and not readily available locally. Farmers, therefore, have to travel about 50 km away to Mbale to secure fertilizers and pesticides. Again, this reinforces the observations by Barungi and Odokonyero [1]. While fertilizer use remains a difficult option for farmers to improve productivity due to its high cost, significant yield advantages of fertilizer application have been demonstrated. For example, when farmers under the Doho Rice Program applied 100:50:50 kg NPK and implemented recommended agronomic practices (transplanting 25–33-day-old seedlings, transplanting in lines at a spacing of 20 cm by 20 cm, and timely weeding between 15–22 days after transplanting), they were able to increase paddy yields from 3.6 to 4.8 t/ha [33]. A similar study in Doho showed that rice yield increased from 5.5–6.8 and 4.6–9.2 t/ha when 80:40:40 and 100:50:50 kg NPK were applied, respectively. This shows that farmers can benefit from yield increases by adopting fertilizers.

According to respondents, the second most important challenge faced by rice growers in Doho is inadequate irrigation water. The shortage of irrigation water at the tail reaches of the Doho rice Scheme, especially in the dry season, reduces rice paddy yields [5,25,41]. The even water distribution between the fields has a positive effect on the rice yield as it reduces the risk of yield losses due to water scarcity. For example, the rice yield at the lower end of Doho is consistently lower than that at the upper end (Lwoba). The average rice yield for the first season at the lower end of the irrigation scheme is 2.4 t/ha compared to 2.7 t/ha at the high end. Likewise, the average rice yield at the low end of the irrigation system at 2.5 t/ha is lower than at the high end at 2.7 t/ha during the second season [5]. Water scarcity is most problematic during the flowering phase, where it reduces rice yield the most [5,42]. Therefore, aware of the critical growth stages when water shortages must be avoided in rice, and to ensure equitable water distribution, a water allocation model was developed that allows two days of irrigation per week during land preparation, early crop development, and before harvest and three days per week during the late vegetative and reproductive growth stages [25].

4.3. Other Project-Inspired Interventions

To accelerate the uptake of improved aromatic rice, the project focused on improving farmers' access to high-quality rice seeds of the aromatic rice varieties by enabling seed producers in the community to produce and maintain high-quality rice seeds. Community-based seed systems serve as a rapid approach to scaling new varieties that can help improve farmers' yields and livelihoods. Therefore, the project identified a progressive farmers group, the Namunasa Mixed Farmers Association, which consists of 30 members, and is engaged in season-long hands-on training in all aspects of rice seed production, including site selection, starter seed sourcing, nursery bed making, line transplanting, the identification and removal of off-types, harvesting, storage, and marketing. The project then provided the group with 1000 kg of NARORICE-1 stater seeds, which they distributed among their group members. Each member received 20 kg of seed (Figure 1), which they individually grew in their fields. However, the group also maintained a large seed field, where they worked together as a group, and which served to train all group members in seed production throughout the season. From March 2020 to December 2021, the Namunasa Mixed Farmers Association produced up to 80 tons of quality declared NARORICE-1 seed, which they sold locally to farmers in their community.

To encourage line transplanting in the Doho rice scheme, the project intervened by identifying youth aged 13 to 20 and teaching them how to transplant rice in lines using a transplanting line adapted from Korea. The project then provided them with locally made transplanting lines. At the time of this case study, these youth, referred to herein as the transplant squad, were providing a transplant service to the other farmers at negotiated rates ranging from UGX 80,000 or USD 23/acre to UGX 120,000 or USD 34/acre. Each squad could transplant up to 2 acres of rice in one day, earning money while providing a service to the community.

5. Conclusions

Smallholder farmers are more receptive and willing to adopt new technologies (varieties and farming methods) once the benefits of greater returns of yield and income become visible. This project supported a few selected farmers with the seed of a new aromatic rice variety, NARORICE-1, and equipped them with agronomic skills that enabled them to raise their mean yields from 3.1 to 4.1 t/ha. Therefore, providing the improved seeds of NARORICE-1 and hands-on lessons in simple, proven agronomic techniques can enable them to increase their yields. Line transplanting has been identified as a crucial technology to increase rice yields among smallholders. Therefore, continuing to educate farmers about line transplanting and its benefits, and providing incentives such as mechanized planters, push weeders, transplanting lines, and the improved seed will encourage the widespread adoption of line transplanting. High costs and limited access to yield-enhancing inputs such as seeds and fertilizers, and inadequate and inequitable distribution of irrigation water were identified as the two most pressing challenges facing farmers in rice production. Nonetheless, the new rice variety NARORICE-1 has been appreciated by farmers for its aroma and a high percentage of milling and head rice recovery, driving up demand and farm-gate prices. However, an effective seed system and continuous farmer training are vital for accelerating adoption and impact.

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