International Journal of Agricultural Sustainability

ISSN: 1473-5903 (Print) 1747-762X (Online) Journal homepage: https://www.tandfonline.com/loi/tags20

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To cite this article: Tomonori Yokouchi & Kazuki Saito (2017) Why did farmers stop cultivating NERICA upland rice varieties in central Benin?, International Journal of Agricultural Sustainability, 15:6, 724-734, DOI: 10.1080/14735903.2017.1400712

To link to this article: https://doi.org/10.1080/14735903.2017.1400712

INTERNATIONAL JOURNAL OF AGRICULTURAL SUSTAINABILITY, 2017
VOL. 15, NO. 6, 724–734
https://doi.org/10.1080/14735903.2017.1400712

Why did farmers stop cultivating NERICA upland rice varieties in central Benin?

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ABSTRACT

New Rice for Africa (NERICA) was developed by the Africa Rice Center by crossing high-yielding Asian rice (*Oryza sativa* L.) with locally adapted African rice (*Oryza glaberrima* Steud.). Community-based seed production of NERICA varieties was introduced in a village in central Benin in 2006 through seed dissemination projects. It was reported that high-adoption rates of these varieties were mainly due to high demand by development projects for seed dissemination, and to incentives (i.e. selling the rice seed at a higher than local market price to a local extension service) for farmers to grow NERICA varieties. A follow-up survey was undertaken after the seed dissemination projects ended to examine the change in the cultivation of NERICA varieties. About half of the farmers had ceased cultivation of NERICA varieties in 2011. The reasons for abandonment were the combined effects of reduced seed demand and low yields, which were attributed to a lack of access to credit and training on NERICA cultivation practices. The majority of the farmers did not abandon rice cultivation, but grew other high-yielding varieties, including one aromatic variety for which there was market demand. We conclude that to avoid immediate reductions in the adoption of new varieties after projects are terminated and to enhance agricultural sustainability, the varieties should be introduced in conjunction with appropriate group training on their cultivation, and the project should target farmers who do not have off-farm businesses. Furthermore, access to credit should also be enhanced, and the marketability of the varieties should be assessed.

KEYWORDS

Sub-Saharan Africa; technology transfer; farmer-based seed system; NERICA

1. Introduction

In 2012, the self-sufficiency ratio for rice production in sub-Saharan Africa (SSA) was about 60%, and SSA imported approximately 12 million tonnes, which accounted for one-third of traded rice in the global market (Saito, Dieng, Touré, Somado, & Wopereis, 2015; Seck, Diagne, Mohanty, & Wopereis, 2012). Such dependency on imports can pose a serious risk not only to food security but also to social and political stability if global food prices increase dramatically, as occurred during the food crisis of 2008 (Berazneva & Lee, 2013; Food and Agriculture Organization of the United Nations [FAO], 2008; Kumar & Quisumbing, 2013). Rice consumption in SSA is expected to continue to grow in the foreseeable future because of high-population growth rates and changes in food consumption habits, especially in urban situations. Thus, to ensure food security, increasing domestic rice production has become a top priority for SSA governments.

The role of improved crop varieties in enhancing crop productivity in SSA has been well documented (Dalton & Guei, 2003; Lanteri & Quagliotti, 1997). In the development of the rice sector in SSA, New Rice for Africa (NERICA) varieties have contributed to improved rice production. These varieties were developed by the Africa Rice Center (AfricaRice) by crossing high-yielding Asian rice (*Oryza sativa* L.) with African rice (*Oryza glaberrima* Steud.), which was adapted to the harsh environments of SSA (Somado, Guei, & Keya, 2008). Previous field studies showed that

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upland NERICA varieties could escape terminal drought due to their short crop duration, and that they were well adapted to highly fertile soils (Saito & Futakuchi, 2009; Saito, Fukuta, Yanagihara, Ahouanton, & Sokei, 2014; Saito, Sokei, & Wopereis, 2012). Many studies have documented that the adoption of NERICA varieties enhanced rice productivity and farmers' incomes (Adekambi, Diagne, Simtowe, & Biaou, 2009; Dibba, Fialor, Diagne, & Nimoh, 2012; Kijima, Otsuka, & Sserunkuuma, 2008; Kijima, Sserunkuuma, & Otsuka, 2006; Kinkingninhoun-Mêdagbé, Diagne, & Adegbola, 2014; Wiredu, Asante, Martey, Diagne, & Dogbe, 2014).

However, in agricultural development, the seed production and dissemination systems of the public-sector model are often a bottleneck for out-scaling and large impact of new varieties (Bam et al., 2007; David, Mukandala, & Mafuru, 2002; Lanteri & Quagliotti, 1997). In most West African countries since the 1990s, seed production and dissemination have mainly relied on national extension services (Anyonge, Holding, Kareko, & Kimani, 2001; Okry, Van Mele, Nuijten, Struik, & Mongbo, 2011). Due to limited budgets, formal public-sector seed production and dissemination systems often do not produce seed to distribute to farmers (Ndjeunga, 2002; Seboka & Deressa, 1999; van Mele, Bentley, & Guéi, 2011). Although private-sector seed businesses in SSA are emerging, business opportunities are still limited (van Mele et al., 2011). In the late 1990s and early 2000s, various agricultural development projects proposed farmer-based (or community-based) seed systems as an alternative to the public-sector model. In farmer-based systems, seed of 'acceptable quality' is produced and sold by farmers who receive training in seed production from extension services (Bèye & Wopereis, 2014). In central Benin, Yokouchi and Saito (2016) found that the promotion of farmer-based systems by development projects resulted in high-adoption rates of improved rice varieties. However, the high adoption rate in their study was partly due to high demand by the development projects for seed and to incentives for farmers to grow NERICA varieties (i.e. selling the seed at a higher than local market price to the local extension service that implemented the project and distributed the seed purchased from the project to other farmers). However, these types of rural development interventions are not sustainable (Chambers, 1994; Fujisaka, 1994). Several studies have demonstrated that although improved technologies have conferred benefits in terms of crop productivity and income shortly after their introduction, farmers later abandoned them (Kijima, Otsuka, & Sserunkuuma, 2011; Sterk, Christian, Gogan, Sakyi-Dawson, & Kossou, 2013; Yamano, Baruah, Sharma, & Kumar, 2013). Various reasons have been reported for such abandonment. For example, in Uganda, farmers abandoned new rice varieties because of a range of factors, including severe water stress, limited access to millers and poor seed quality (Fujiie, Maruyama, Fujiie, Takagaki, & Kikuchi, 2010; Kijima et al., 2011). Sterk et al. (2013) reported from seven case studies that farmers in Benin and Ghana abandoned varieties introduced within five years of the development projects ending. In the study by Yokouchi and Saito (2016) in central Benin, unless the farmer-produced seed of NERICA varieties had been purchased directly by other farmers, the NERICA varieties would not have been widely disseminated after the development projects ended in 2010. Furthermore, the farmers might have abandoned the NERICA varieties if they were unable to sell their seed at a higher price than alternative varieties.

To the best of our knowledge, little has been published on the early adoption and continued use by farmers of seed varieties introduced as part of farmer-based seed systems. Assessing the adoption by farmers of varieties introduced in farmer-based seed systems and identifying factors linked to their adoption after the projects have terminated could provide insights for future research and development efforts on improved varieties and their up-scaling in a sustainable manner in SSA.

The objectives of this study were to: (i) describe farmers' cultivation practices and their sales of NERICA varieties introduced via farmer-based seed systems in development projects after the termination of the projects; (ii) compare farmers' adoption of NERICA before and after the projects and (iii) identify reasons for farmers' adoption or abandonment of the NERICA varieties after the end of the project and socio-demographic factors associated with these reasons.

2. Materials and methods

2.1. Survey

This was a follow-up survey of an earlier study in 2009 reported by Yokouchi and Saito (2016). Those authors describe the farmer-based seed systems introduced in the area, so those details are not repeated in this paper. The survey was conducted in Sowé village, Kpakpasa Arrondissement, Glazoué commune,

Zou-Collines department in central Benin in September–October 2011. The village is located approximately 169 km north-west of Porto-Novo (the capital of Benin), and had a reported population of 3351 in 2004 (Ministère Chargé du plan de la prospective et du Développement [MCPPD], 2004).

In this follow-up survey, interviews were conducted with 895 randomly selected farmers. A structured questionnaire was used to gather socio-demographic data, and a semi-structured questionnaire was used to identify reasons why farmers continued or abandoned cultivation of the NERICA varieties after the projects had ended (Table 1). Within households in Benin, husbands and wives have separate budgets, and they tend not to share information about their incomes with their spouses (LeMay-Boucher, 2007). Thus, in the present study, the men and women were interviewed separately and individually.

In Sowé village, there were 14 farmer groups in 2009, and these groups generally cooperated for land preparation, sowing, weeding, harvesting and/or threshing in rice cultivation. In 2011, two of the groups were no longer in operation but had been replaced by new ones. About 39% ($n = 347$) of the farmers surveyed belonged to at least one group (Table 1). Among the 14 groups, there were 2 large groups: Adjo-AKETE ($n = 144$) and KASSOWOKPO ($n = 124$). Members of these two groups accounted for 77% of the total group members surveyed in this study. They were also the oldest farmer groups in the village, having been established in 1991.

2.2. Statistical analysis

Student's *t*-test and Fisher's exact test were used to compare the cultivation by farmers of NERICA and other rice varieties between 2009 and 2011 (Fisher, 1922; Hotelling, 1951).

A logistic regression was conducted to characterize farmers who continued growing NERICA varieties because of their high yield, continued growing NERICA varieties because of a high sale price, or stopped NERICA cultivation due to low yield (Glonek & McCullagh, 1995; Hocking, 1976). To select the model that best explained the observed variation, six models for each objective were tested, and the best-fitting model was selected on the basis of Akaike's information criterion (AIC) (Akaike, 1974; Gongotchame et al., 2014; Yokouchi & Saito, 2016). As shown in Table 2, each of the models contained six variables. For each objective, the six models had four predictors in common. The choice of predictors in all the tested

Table 1. Socio-demographic parameters of farmers ($n = 895$) in Sowe village, central Benin collected via a structured questionnaire.

Description	Parameter (%)
Discrete variables	
Gender	Female (47%), male (53%)
Member of farmer group	Non-member (61%), Adjo-AKETE (16%), KASSOWOKPO (14%), other groups (9%)
Experience of rice cultivation	No (6%), yes (94%)
Experience of NERICA cultivation among farmers who had cultivated rice at least once	No (45%), yes (55%)
Access to NERICA seeds	Free (40%), purchased (55%), exchanged (5%)
Source of NERICA seeds	CeCPA (5%), others (e.g. family and relatives, group member, other) (95%)
Training in rice cultivation practices among farmers who had cultivated rice at least once	No (54%), yes (46%)
Use of credit for agricultural activities by farmers who had cultivated rice at least once	No (51%), yes (49%)
Off-farm business among farmers who had cultivated rice at least once	No (50%), yes (50%)
NERICA sales outlets in 2010	Local markets (31%), other farmers (4%), CeCPA (19%), millers (45%), others (e.g. NGO) (1%)
Continuous variables	Range (mean ± standard deviation)
Age (years)	18–80 (37 ± 13)
Years of experience in rice cultivation	1–41 (11 ± 6)
Year that farmers started NERICA cultivation	1995–2011 (2007 ± 2)
Final year of NERICA cultivation	2006–2010 (2009 ± 1)
Total rice sales volume per capita in 2010 (kg)	0–12,000 (533 ± 728)
NERICA sales volume per capita in 2010 (kg)	0–5280 (279 ± 412)
Value of NERICA sales in 2010 (US$)[i]	0.10–01.35 (0.29 ± 0.16)

[i]US$ = 480 FCFA (9 September 2011).

Table 2. Models used in the logistical regression analyses.

Model no.	Parameter used[i]	AIC score[ii]
Farmers (n = 237) who cited high yields as a reason for continuing growing NERICA varieties in 2011		
Model 1	GENDER, GROUP, NERICASALES, SHARENERICA, CREDIT and OFF-FARM	286
Model 2	GENDER, GROUP, NERICASALES, SHARENERICA, CREDIT and TRAINING	288
Model 3	GENDER, GROUP, NERICASALES, SHARENERICA, CREDIT and YEAR	286
Model 4	GENDER, GROUP, NERICASALES, SHARENERICA, OFF-FARM and TRAINING	283
Model 5	GENDER, GROUP, NERICASALES, SHARENERICA, OFF-FARM and YEAR	281
Model 6	GENDER, GROUP, NERICASALES, SHARENERICA, TRAINING and YEAR	286
Farmers (n = 237) who cited high sale prices as a reason for continuing growing NERICA varieties in 2011		
Model 7	AGE, GENDER, GROUP, NERICASALES, CREDIT and NERICAVOLUME	183
Model 8	AGE, GENDER, GROUP, NERICASALES, CREDIT and OFF-FARM	183
Model 9	AGE, GENDER, GROUP, NERICASALES, CREDIT and TRAINING	185
Model 10	AGE, GENDER, GROUP, NERICASALES, NERICAVOLUME and OFF-FARM	182
Model 11	AGE, GENDER, GROUP, NERICASALES, NERICAVOLUME and TRAINING	185
Model 12	AGE, GENDER, GROUP, NERICASALES, OFF-FARM and TRAINING	183
Farmers (n = 119) who cited low yields as a reason for discontinuing NERICA cultivation in 2011		
Model 13	AGE, GENDER, GROUP, NERICAVOLUME, CREDIT and OFF-FARM	160
Model 14	AGE, GENDER, GROUP, NERICAVOLUME, CREDIT and START	162
Model 15	AGE, GENDER, GROUP, NERICAVOLUME, CREDIT and TRAINING	159
Model 16	AGE, GENDER, GROUP, NERICAVOLUME, OFF-FARM and START	165
Model 17	AGE, GENDER, GROUP, NERICAVOLUME, OFF-FARM and TRAINING	164
Model 18	AGE, GENDER, GROUP, NERICAVOLUME, START and TRAINING	166

[i]GROUP: membership of farmer group (Adjo-AKETE, KASSOWOKPO, other groups or non-member); NERICASALES: sales outlets for NERICA in 2010 (sale to CeCPA, sale to non-CeCPA or self-consumption); SHARENERICA: share of NERICA in total sales volume of rice; CREDIT: use of credit for agricultural activities or not; OFF-FARM: off-farm business or not; TRAINING: received training in rice cultivation or not; YEAR: number of years of experience in rice cultivation; NERICAVOLUME: NERICA sales volume per capita in 2010; START: year when the farmer started NERICA cultivation (before, in or after 2008).
[ii]AIC (Akaike's information criterion): lower = better fit.

models was based on findings from previous studies (Kijima et al., 2011; Yokouchi & Saito, 2016). R version 3.0.2 was used for all statistical analyses (R Core Team, 2016).

3. Results

3.1. Description of the cultivation of NERICA and other varieties in central Benin and trends between 2009 and 2011

The history of the introduction of NERICA varieties to the village has been described previously (Yokouchi & Saito, 2016). Two national programmes were established in Benin in the 2000s: the five-year 'Programme de diffusion du riz NERICA (PDRN)' in 2006 and the three-year 'Programme d'urgence d'appui poor la securité alimentaire (PUASA)' in 2008. PDRN involved the distribution of seed and farmer-based seed production, and PUASA involved the distribution of seed, mechanization and credit for the purchase of fertilizer. These two national programmes terminated in 2010, and there was no other project for NERICA dissemination when the present follow-up survey was conducted in 2011. In these two national programmes, the extension service (CeCPA) in Glazoué played a critical role in the dissemination of NERICA varieties among farmers. From 2010, the amount of NERICA seed that CeCPA was purchasing from farmers had fallen, compared with 2009 (Mr Gildas, CeCPA staff, personal communication, 14 May 2010).

Comparison of the data on the cultivation of NERICA and other rice varieties by farmers in 2009 (see Yokouchi & Saito, 2016) with data from 2011, taking into account differences in the sample size between the two years, revealed that the proportions of farmers in 2009 (94%) and 2011 (94%) who cultivated rice among the farmers surveyed in 2009 (n = 1390) and 2011 (n = 895) were not significantly different. Similarly, there was no difference between the proportions of farmers in 2009 (61%) and 2011 (61%) who had experience of cultivating NERICA varieties among rice-growing farmers. However, the proportion of farmers who cultivated NERICA varieties among rice-growing farmers was significantly lower in 2011 than in 2009 (Table 3). Some 46% of farmers had abandoned NERICA cultivation. In contrast, compared with 2009, in 2011, more farmers cultivated WAB32 (upland variety developed by AfricaRice in Côte d'Ivore), IR841 (an aromatic variety known locally as IR) and other varieties that had been introduced prior to the introduction of NERICA varieties

Table 3. Cultivation of NERICA and other rice varieties by farmers in Sowe village, central Benin in 2009 and 2011.

	2009 ($n = 1241$)	2011 ($n = 768$)
Number of farmers who grew the given rice varieties		
WAB32	940a[i] (76[ii])	657b (86)
IR	14a (1)	210b (27)
NERICA varieties	598a (48)	253b (33)
Other varieties	122a (10)	123b (16)
Area planted with the rice variety (ha per farmer)		
WAB32	0.20a[iii]	0.17b
IR	0.15a	0.18a
NERICA varieties	0.19a	0.14b
Other varieties	0.28a	0.13b

Note: Data are from rice-growing farmers.
[i]Within a row, the same letter indicates no significant difference between means for 2009 and 2011 according to a Fisher's exact test at the 5% level. This test took account of the difference in total number of famers surveyed in the two years.
[ii]Percentage of farmers.
[iii]Within a row, the same letter indicates no significant difference between means for 2009 and 2011 according to a *t*-test at the 5% level.

to this village. Except for IR, the average plot size per farmer for planting each rice variety in 2011 tended to be smaller than in 2009.

3.2. Difference in NERICA sales between 2008 and 2010

When NERICA sales outlets were compared between 2008 (Yokouchi & Saito, 2016) and 2010 when the projects ended, more farmers sold NERICA seeds to extension services, such as CeCPA and INRAB (Institut National des Recherches du Bénin), other farmers and non-governmental organizations (NGOs) in 2008 than in 2010 (Table 4). In contrast, more farmers sold NERICA to non-seed outlets (direct to local market, merchants or millers) in 2010 than in 2008. Similar trends were observed in sales volumes of NERICA varieties. Volumes of NERICA sales to CeCPA, other farmers or NGOs as seed, per farmer, increased from 133 kg in 2008 to 288 kg in 2010. However, when the total number of farmers who cultivated NERICA varieties was considered, the average NERICA sales volume per farmer across farmers was reduced in 2010 by 25% in comparison with that in 2008.

The sales price of NERICA varieties to both types of sales outlet fell (sales as seed vs. sales as grain), but the price still differed between the two in 2010.

3.3. Reasons underlying farmers' adoption or abandonment of NERICA in 2011

Reasons for farmers' adoption or abandonment of NERICA varieties were examined, targeting farmers

Table 4. Buyers, sales volume and price of paddy for NERICA in 2008 ($n = 587$) and 2010 ($n = 356$).

	No. farmers who sold to NERICA sales outlets[i]		NERICA total sales volume[ii]		Average NERICA sales volume of farmers who sold to the given outlet		Average NERICA sales volume of farmers who grew NERICA		Average price for NERICA paddy (US$[vii]/kg)	
	2008	2010	2008	2010	2008	2010	2008	2010	2008	2010
Sale as seed (CeCPA, INRAB, other farmers and NGOs)	359a[iii](58 [iv])	77b (21)	47,757a (42[v])	22,209b (22)	133a[vi]	288b	81a	62b	0.70a	0.49b
Sales as grain (local markets, merchants and millers)	231a (38)	244b (68)	65,520a (58)	77,200b (78)	284a	316a	112a	217b	0.39a	0.23b
Self-consumption	25a (4)	39b (11)	–	–	–	–	–	–	–	–

[i]Sum > farmers who cultivated NERICA because some respondents sold to more than one type of buyer.
[ii]The total sales volume of 587 farmers in 2008 was 113,277 kg, and that of 356 farmers was 99,409 kg in 2010.
[iii]Within a row, the same letter indicates no significant difference between means for 2008 and 2010 according to a Fisher's exact test at the 5% level.
[iv]Percentage of farmers.
[v]Percentage of sales volume.
[vi]Within a row, the same letter indicates no significant difference between means for 2008 and 2010 according to a *t*-test at the 5% level.
[vii]US$ = 450 FCFA (9 September 2009), 480 FCFA (9 September 2011).

Table 5. Reasons for adoption or abandonment of NERICA varieties by farmers who had cultivated NERICA varieties in 2010 ($n = 356$).

Reason	Percentage
Reasons for adoption of NERICA varieties ($n = 237$)	
High yield	71
Desirable taste	71
Short duration	47
High sales price	18
Reasons for abandonment of NERICA varieties ($n = 119$)	
Low yield	61
Difficult to thresh	51
Damage by birds, rats and insects	23

who cultivated NERICA varieties in 2010 ($n = 356$), those who grew NERICA in 2011 ($n = 237$) and those who ceased NERICA cultivation in 2011 ($n = 119$) (Table 5).

The major reasons reported by farmers growing NERICA in 2011 for continuing to cultivate NERICA varieties were high yields and desirable taste, each indicated by around 71% of farmers. Some 47% of the farmers reported the short duration as a reason for continued cultivation, and 18% cited high sales prices as the deciding factor.

Among farmers who ceased cultivating NERICA in 2011 ($n = 119$), 61% reported low yields as a causative factor. Other major reasons given by farmers were that NERICA is difficult to thresh (51%) and damage by birds, rats and insects (23%). Of those who ceased cultivating NERICA in 2011, some 107 farmers (98%) replaced NERICA varieties with existing varieties, such as WAB32 (51%) and IR (37%). High yields were cited by 84% and 58% of farmers as the main reason for growing WAB32 and IR varieties, respectively, rather than NERICA varieties.

3.4. Logistic regression analysis

With an AIC score of 281, model 5 gave the best fit to the results of the logistic regression analysis of the characteristics of farmers who indicated high yield as the major reason for continuing to cultivate NERICA varieties in 2011 identified (Tables 2–6). In this model, three predictors were statistically significant: membership of the Adjo-AKETE group, a higher share of NERICA in total sales volume of rice in 2010, and no off-farm business.

Model 10 (AIC = 182) was the best-fitting model of the factors affecting farmers who indicated high sales price as a reason for continuing to grow NERICA varieties. Among the model parameters, only one predictor was statistically significant: sale of NERICA to CeCPA in 2010.

As shown by the logistic regression analysis of the characteristics of farmers who reported a low yield of NERICA varieties as their reason for terminating cultivation of these varieties, model 15 (AIC = 159) gave the best fit. Three predictors were statistically significant: member of the KASSOWOKPO group, no training in NERICA cultivation, and use of credit for agricultural activities.

4. Discussion

Many previous studies in SSA countries, such as Uganda (Kijima et al., 2006, 2008, 2011), Benin (Adekambi et al., 2009; Kinkingninhoun-Mêdagbé et al., 2014; Yokouchi & Saito, 2016), the Gambia (Dibba et al., 2012; Dibba, Zeller, Diagne, & Nielsen, 2015) and Ghana (Asante, Wiredu, Martey, Sarpong, & Mensah-Bonsu, 2014; Wiredu et al., 2014), have reported high-adoption rates of NERICA varieties. Some studies have also indicated that the introduction of these varieties contributed to increased productivity (Kijima et al., 2006; Kinkingninhoun-Mêdagbé et al., 2014) and income (Dibba et al., 2012; Kijima et al., 2008; Wiredu et al., 2014) in SSA. In a case study in Benin, the adoption rate of NERICA varieties was enhanced via a public-sector seed distribution system, training in rice cultivation targeting group members, and a farmer-based seed production system, which allowed farmers to sell NERICA varieties at a higher than market price to development projects (Yokouchi & Saito, 2016).

The main objective of the follow-up survey in central Benin reported here was to assess the adoption by farmers of varieties introduced in farmer-based seed systems after the seed dissemination projects ended and to identify factors linked to this adoption. This study showed that the farmer-based seed production system had been changed after the projects, as fewer farmers sold NERICA as seed and average sales volume per farmer who grew NERICA was reduced (Table 4). In contrast, average sales volume per farmer who sold as seed was increased. These indicate that fewer farmers benefited from seed business. From this study, we cannot judge whether this change will affect the continuation of farmer-based seed production. Further study is needed to assess the sustainability of the farmer-based seed production system. However, the result from this study clearly showed that around half the farmers who had cultivated NERICA had abandoned its cultivation by 2011, while the other half continued

Table 6. Socio-demographic parameters of farmers and reasons for continuing or abandoning the cultivation of NERICA varieties in 2011.

Parameter[i,ii]	Coefficient	Std. error	Wald X^2	*P*-value[iii]	Odds ratio[iv]	95% CI[v]
Farmers who evaluated that NERICA is high yield as reasons to continue growing the NERICA (n = 237)						
GENDER	−0.17	0.34	0.25	.61	0.84	0.43–1.64
GROUP (Adjo-AKETE, *n* = 51)	0.96	0.48	4.00	<.05*	2.60	1.05–6.91
GROUP (KASSOWOKPO, *n* = 49)	−0.06	0.41	0.02	.89	0.94	0.42–2.14
GROUP (Others, *n* = 28)	0.15	0.50	0.09	.76	1.16	0.44–3.21
NERICASALS (Sale to not-CeCPA, *n* = 178)	−0.56	0.45	1.55	.21	0.57	0.23–1.33
NERICASALS (Self-consumption, *n* = 16)	0.42	0.75	0.31	.58	1.52	0.35–6.80
OFF-FARM	−0.74	0.32	5.34	<.05*	0.48	0.25–0.89
SHARENERICA	0.02	0.01	9.32	<.01**	1.02	1.01–1.03
YEAR	−0.05	0.03	2.65	.10	0.96	0.90–1.01
Farmers who evaluated that advantage of NERICA is high price for sale as reasons to continue growing the NERICA (n = 237)						
AGE	−0.03	0.02	2.20	.14	0.969	0.926–1.01
GENDER	0.63	0.47	1.79	.18	1.88	0.755–4.83
GROUP (Adjo-AKETE, *n* = 51)	−0.55	0.62	0.77	.38	0.578	0.160–1.89
GROUP (KASSOWOKPO, *n* = 49)	0.22	0.56	0.15	.70	1.25	0.398–3.71
GROUP (Others, *n* = 28)	0.64	0.66	0.92	.34	1.89	0.492–6.83
NERICASALES (sales to non-CeCPA, *n* = 178)	−1.88	0.45	17.20	<.01***	0.153	0.0613–0.367
NERICASALES (self-consumption, *n* = 16)	−17.74	956.38	0.0003	.99	1.98×10^{-8}	(7.67×10^{-133})–(2.05×10^{12})
NERICAVOLUME	−0.001	0.001	1.10	.30	0.999	0.996–1.00
OFF-FARM	0.78	0.43	3.26	.07	2.17	0.954–5.21
Farmers who referred to low yield of NERICA as reason to abandon growing the NERICA (n = 119)						
AGE	−0.02	0.02	1.31	.25	0.98	0.94–1.02
CREDIT	−1.27	0.46	7.58	<.01**	0.28	0.11–0.68
GENDER	−0.53	0.46	1.34	.25	0.59	0.23–1.43
GROUP (Adjo-AKETE, *n* = 22)	0.70	0.59	1.42	.23	2.02	0.65–6.67
GROUP (KASSOWOKPO, *n* = 16)	2.18	0.78	7.88	<.01**	8.81	2.09–45.54
GROUP (Others, *n* = 18)	0.62	0.66	0.90	.34	1.87	0.51–6.95
NERICAVOLUME	−0.0004	0.0009	0.19	.67	1.00	1.00–1.00
TRAINING	−1.05	0.51	4.28	<.05*	0.35	0.13–0.92

[i]For definitions of parameters, see note i of Table 2.
[ii]For categorical variables, the reference for each predictor was 'no', except for the predictors GENDER, GROUP and NERICASALE, the references for which were 'female', 'non-member' and 'sales to CeCPA', respectively.
[iii]*, ** and *** indicate significance at $P < .05$, $P < .01$ and $P < .001$, respectively.
[iv]Odds ratio estimate of <1 indicates that farmers with the reference characteristic tended to have characteristic with response variable (e.g. farmers who evaluated that NERICA's high yield as reason to contribute growing the NERICA). For example, for GROUP (Adjo-AKETE), farmers who evaluated that NERICA has high yield as reasons to contribute growing the NERICA, members of Adjo-AKETE tended to continue growing NERICA and evaluate that NERICA is high yielding.
[v]95% confidence interval.

growing NERICA varieties. The variation in the motivations of farmers in the same village to continue or discontinue NERICA cultivation in this study could be attributed to various factors. These include (1) the way in which the NERICA varieties were promoted in the projects (offering a higher price for seed rice); (2) characteristics of NERICA varieties and their adaptation and (3) farmers' socio-demographic characteristics. These issues are discussed in more detail below.

The seed business was a major incentive for farmers to grow NERICA varieties in the study area in 2009 (Yokouchi & Saito, 2016). However, this follow-up study indicates that the initial success of the NERICA promotion programme in the study area was not sustainable. In 2011, only 18% of NERICA-cultivating farmers indicated high price as a reason to grow NERICA varieties due to shrinking demand for NERICA seeds by the public sector within this short time. Previous studies of NERICA cultivation in Uganda also reported a dramatic reduction in adoption rates after initial success in dissemination of this technology (Fujiie et al., 2010; Kijima et al., 2011) and other technologies (e.g. Djagba, Rodenburg, Zwart, Houndagba, & Kiepe, 2014; Sterk et al., 2013; Yamano et al., 2013). Sterk et al. (2013) indicated that agricultural development projects often evaluated their results immediately after the projects finished and that they conducted no follow-up evaluations to examine how the projects' interventions affected adoption of the varieties by farmers and their livelihoods in the longer term. The absence of follow-up studies is partly due to the fact that donors and governments often tend to look at short-term impacts within a limited number of years. Consequently, an impact-assessment study is often

only done immediately after a project has ended (Douthwaite & Gummert, 2010).

Apart from the price incentive, in this follow-up study, NERICA-cultivating farmers cited high yield, desirable taste and short duration as reasons for continued cultivation of NERICA varieties. This finding is in accordance with those of previous studies (Jones, Mandè, & Aluko, 1997; Rodenburg et al., 2006; Somado et al., 2008). On the other hand, farmers who ceased cultivation of NERICA reported low yield, difficulty of threshing, and damage by birds, rats and insects as the main reasons for their abandonment of NERICA varieties. Most of these farmers cultivated existing varieties rather than NERICA varieties because of their higher yields compared with NERICA varieties. The contradictory results in yield levels reported by the farmers in the study area have been discussed elsewhere (Yokouchi & Saito, 2016). The damage by rats and birds can be explained by the fact that the NERICA varieties mature earlier than other varieties and it is well known that short-duration varieties are at risk of such damage. In the present study, the farmers also mentioned that it was difficult to thresh NERICA varieties, something that has been supported by previous research (e.g. Bello, Salau, & Ezra, 2012; Kimani, Tongoona, Derera, & Nyende, 2011). There is no scientific evidence that yields of NERICA varieties are inferior to those of existing varieties, such as WAB32 and IR. However, NERICA varieties might incur a yield penalty due to their short duration, when they are compared with existing longer duration varieties, although the aforementioned characteristic allows them to escape terminal drought (Saito et al., 2012, 2015; Saito, Azoma, & Sokei, 2010). Another reason for the abandonment of NERICA varieties might be the increased popularity of the aromatic IR variety among farmers in the study area, as there is much demand for this variety in the Benin market. Thus, it is not surprising that shrinking opportunities for NERICA seed business resulted in a shift away from NERICA varieties to existing varieties. In Uganda, more than half of NERICA adopters in 2004 had ceased cultivation by 2006 due to a low income from NERICA cultivation (Kijima et al., 2011).

Concerning the farmers who indicated a high yield as their reason for continued cultivation of NERICA, these farmers were members of the Adjo-AKETE group. NERICA varieties also accounted for a high share of their total rice sales volumes, and they had limited revenue from off-farm businesses. In terms of the farmers who indicated a low yield as the reason for abandoning NERICA in 2011, these farmers tended not to have experience or training in NERICA cultivation practices and to use credit for agricultural activities. Yokouchi and Saito (2016) discussed the importance of training in the continuation of NERICA cultivation. Kijima et al. (2011) also pointed out the importance of training in farmer-based seed systems, as the quality of farmer-produced seed can affect productivity in farmers' fields. In cases of farmers with off-farm businesses, rice farming may not be their sole source of income (i.e. rice farming may be considered a side business). In contrast, farmers without off-farm businesses might put more effort into obtaining a greater income from the rice business. In the study area, farmers use credit mainly for purchasing fertilizer, which is applied to the rice fields. If farmers in the study have insufficient credit and limited access to funds to purchase fertilizer, they will be unable to apply fertilizer to rice and therefore achieve lower yields (authors' unpublished data).

To enhance the sustainability of farmer-based seed systems, the findings suggest that seed development projects related to seed distribution and seed businesses based on informal seed systems should adopt a range of comprehensive measures. These include (1) targeting farmers who do not have off-farm businesses and are keen to invest their resources in rice farming; (2) enhancing farmers' access to credit for purchasing inputs; (3) providing group training on the cultivation of new varieties and seed production and (4) sharing information on cultivation across different groups to enable discussion of problems and opportunities.

5. Conclusions

The dissemination using a farmer-based seed system was effective for the rapid adoption of NERICA varieties in a seed-producing village in SSA, where farmers are not well served by a formal public-sector seed system (Yokouchi & Saito, 2016). However, the high-adoption rate of NERICA varieties was not sustained after the termination of the NERICA dissemination projects. To avoid immediate reductions in the adoption of new varieties after projects are terminated and to enhance agricultural sustainability, the varieties should be introduced in conjunction with appropriate group training on their cultivation, and the project should target farmers who do not have off-farm businesses. Access to credit should also be enhanced, and the marketability of the varieties should be

assessed. To avoid heavy reliance on inorganic fertilizer application for rice (for which credit is used), sustainable intensification options in rice-based farming systems should be developed and introduced. These could include crop rotation with leguminous crops and use of organic inputs (Partey, Saito, Preziosi, & Robson, 2016). Introduction of small-scale machinery could also help reduce labour inputs for rice cultivation (Gongotchame et al., 2014; Nimoh, Tham-Agyekum, & Nyarko, 2012). Market information including seed should be shared among farmers to improve access to market (Bèye & Wopereis, 2014).

Although the introduction of NERICA varieties has been successful in some SSA countries, this study indicates that there is scope for improving upland NERICA varieties. Future breeding efforts need to address the shortcomings identified in the present study, such as yield and threshing difficulties. Grain quality should also be addressed (Kijima et al., 2011).

Acknowledgements

We are grateful to E. Fassounde and K. Azoma who supported our surveys in this village. We would like to thank anonymous reviewers and editors for their valuable comments.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The research was funded by The Ministry of Foreign Affairs of Japan and the Ministry of Agriculture, Forestry and Fisheries of Japan (Japan-CGIAR Fellowship Program 2009-2010, 2013-2014). We express our gratitude to the farmers in Sowe village who contributed to this study and the staff of Africa Rice Center.

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