Food Sec. (2016) 8:197–209
DOI 10.1007/s12571-015-0545-7

ORIGINAL PAPER

Factors affecting farmers' adoption of NERICA upland rice varieties: the case of a seed producing village in central Benin

Tomonori Yokouchi[1] · **Kazuki Saito**[2]

Received: 20 March 2015 / Accepted: 1 December 2015 / Published online: 5 January 2016

Abstract We investigated dissemination processes of New Rice for Africa (NERICA) varieties in central Benin in 2009 through structured interviews with 1,390 farmers and semi-structured interviews with 203 farmers. By 2009, 74 % of farmers belonging to a farmer group had experience of growing NERICA varieties, while only 29 % of farmers who did not belong to the group had such experience. This difference was attributed to approaches used by the public extension service, which has mainly worked with farmer groups as an entry point for NERICA dissemination. As women accounted for 70 % of farmers in farmer groups, this approach achieved gender equality on the adoption of NERICA varieties. The seed production business has become an incentive for farmers to grow NERICA varieties, as their seed may be purchased at higher than local market price by the public sector for further dissemination. Male farmers tended to sell greater amounts of NERICA varieties, as female farmers have limited land for their cultivation. Around 20 % of farmers had stopped growing NERICA varieties, because they did not receive proper information on their characteristics and the cultivation methods required. They therefore could not be involved in the seed business. Farmers who had never grown NERICA varieties reported that they had limited access to seed. Thus, opportunities to access technologies and business opportunities should be made equal for farmers, especially when they are introduced. In particular, farmer-to-farmer seed exchange needs to be enhanced.

Keywords Farmer groups · Sub-Saharan Africa · Technology transfer · Upland NERICA · Rice

✉ Tomonori Yokouchi
tomonoriyokouchi@gmail.com

Kazuki Saito
K.Saito@cgiar.org

[1] Graduate School of Agricultural and Life Sciences, The University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-8657, Japan

[2] Africa Rice Center (AfricaRice), 01 BP 2031, Cotonou, Benin

Introduction

A criticism has been made that agricultural development specialists often do not understand the actual conditions on the ground of their projects (Chambers 1983). In particular, resource-poor farmers who need support are often not considered as they tend to stay out of sight. Consequently, a development might result in uneven spread of technologies and increased gap between the rich and poor. Previous studies in Sub-Saharan Africa (SSA) have found that adoption of new technologies strongly depends on access to the market, new technologies, credit, secure land tenure and literacy (Tripp 2001; Doss 2006; Minten and Barrett 2008). In other words, resource-poor farmers who often have limited access to the market, credit and land, and are illiterate, would not benefit from new technologies. Furthermore, gender inequality also affects the adoption of new technologies (Doss 2001; Aterido et al. 2013). Thus, it is critical to develop and disseminate technologies that are gender-neutral and especially targeted to resource-poor farmers, and to develop a pathway or technology-transfer approach that can alleviate the above-mentioned obstacles to poverty reduction.

Although rice consumption in SSA has been increasing at about 5.5 % per year (2000–2010 average), only 40 % of this consumption is satisfied by domestic production (Saito et al. 2015). SSA countries spend huge budgets annually on about 10 million tonnes of imported rice (Seck et al. 2010). Therefore, governments in SSA countries, international

agencies and donors give high priority to developing the rice sector as a vital component of food security, national economic growth and poverty alleviation (World Bank 2007; Kijima et al. 2012; De Graft-Johnson et al. 2014). Upland New Rice for Africa (NERICA) varieties were developed by Africa Rice Center (AfricaRice) through crossing high-yielding Asian rice (*Oryza sativa* L.) with African rice (*O. glaberrima* Steud.) adapted to harsh environments in SSA (Somado et al. 2008). Previous field studies showed upland NERICA varieties matured early, allowing them to escape terminal drought, and were high yielding, especially on fertile soil (Saito and Futakuchi 2009; Saito et al. 2012, 2014). Therefore, as has been frequently documented, NERICA has great potential for improving rice production and reducing the poverty of rice farmers in SSA (Otsuka and Kalirajan 2006; Sakurai 2006; Diao et al. 2008; Otsuka and Kijima 2010) and has already improved farmers' livelihoods in some SSA countries (Kijima et al. 2006; Adekambi et al. 2009; Dibba et al. 2012). Although nearly all of the case studies regarding NERICA introduction report farmers' adoption of NERICA varieties and their impact on livelihoods, there is limited information on how NERICA varieties are disseminated.

To promote agricultural sector development and increase rice production in SSA, improved varieties can play a significant role as indicated by upland NERICA varieties (Lanteri and Quagliotti 1997; Dalton and Guei 2003). However, poor availability and quality of seed of have been constraints to farmer adoption (Lanteri and Quagliotti 1997; David et al. 2002; Bam et al. 2007). In most West African countries since the 1990s, seed dissemination has mainly relied on national extension systems (Anyonge et al. 2001; Okry et al. 2011). However, such public, formal seed systems often do not serve farmers well because of limited budgets for seed production and dissemination (Seboka and Deressa 1999; Ndjeunga 2002; van Mele et al. 2011). Furthermore, the private sector has shown little interest in the seed business (van Mele et al. 2011). As an alternative approach to fill the gap in seed systems, much attention has been paid to farmer-to-farmer exchange within farmers' social informal networks (Seboka and Deressa 1999; Ndjeunga 2002; Kiptot et al. 2006). Participatory farmer-based seed production systems in SSA have also been proposed to promote such farmer-to-farmer exchange (e.g. community-based seed system; Bèye and Wopereis 2014). In these systems, seed of 'acceptable quality' is produced by large numbers of farmers and sold to other farmers. However, the reality is that such seed has mainly been purchased by agricultural development projects for distribution to farmers. Such projects often only provide information on the amount of seed disseminated and budget (LSB project 2009; FAO 2010; Caritas International Belgium 2011) and there is limited information on how seed has been produced or collected for dissemination. This was the case for the study site in central Benin, reported in this paper, where upland NERICA seed was produced by farmers in an informal way for further dissemination. Consequently, it is possible that, owing to variability of seed distribution at the village level, benefit from new varieties might not reach resource-poor farmers (Sperling and Loevinsohn 1993; Tripp 2001).

The objectives of this study were to: (i) describe NERICA dissemination among farmers and the seed production system in a village in central Benin; (ii) describe farmers' reasons for cultivating NERICA varieties; (iii) identify factors affecting adoption of NERICA varieties and their seed production and sale; and (iv) examine how the NERICA seed production system affects adoption of NERICA cultivation.

Materials and methods

Description of the study area

This study was conducted at Sowe village, Kpakpasa Arrondissement, Glazoué commune, Zou-Collines department in central Benin from September to November 2009. This village was selected because many actors have been involved in NERICA dissemination activities. The regional extension service (Centre communal pour la promotion agricole, CeCPA), NGOs, Institut National des Recherches Agricole du Bénin (INRAB), and AfricaRice have implemented research and development activities related to NERICA varieties in this village. Sowe is approximately 169 km northwest of Porto-Novo (the capital of Benin); its population was 3,351 inhabitants in 2004 (MCPPD 2004). Ethnicity of the inhabitants is mainly Idaatcha, Fon and Mahi. The rainy season starts in March or April and ends in November. Farmers generally cultivate cassava (*Manihot esculenta* Crantz), maize (*Zea mays* L.), yam (*Dioscorea* spp.), cowpea (*Vigna unguiculata* (L.) Walp.), soybean (*Glycine max* (L.) Merr.), rice, peanut (*Arachis hypogaea* L.) and vegetables (Table 1). The cropping calendar of different crops is similar among farmers in the village. At the onset of the rainy season, cassava, maize and cowpea are planted. Rice is generally planted in June and July, but some farmers plant in August mainly due to labor shortage and delayed planting of other crops. Delayed rice planting runs the risk of terminal drought at the end of the wet season (Mr. Takemura, personal communication). Rice is generally grown in relatively low-lying areas, so-called 'bas-fond'. Rice is generally grown as a commercial crop, for self-consumption or both, without standing water, except for a few days after heavy rains. Both upland and lowland rice varieties are grown in this area. Popular varieties are Gambiaka, WAB32, NERICA 1, NERICA 2 and NERICA 4. Average rice yield in Glazoué commune (2002–2008) was around 2 t/ha (CeCPA, personal communication, 2009).

In the village, there were 14 farmer groups, which mainly aim to cooperate on rice cultivation (land preparation, sowing,

Table 1 Cropping calendar of major crops and vegetables at Sowe village, central Benin.

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Comment
Cassava					P[a]	P	P	P							Harvesting will be after one year from planting
Yam	P	P	P							H[a]	H	H	H	H	
Maize						P	P		H	H					
Rice								P	P	P		H	H	H	
Cowpea (early planting)						P				H	H				
Cowpea (late planting)										P			H	H	
Soybean								P	P		H	H	H		
Peanut										P			H	H	
Okra							P	P		H	H	H			
Tomato							P	P		H	H	H			

[a] P and H indicate planting and harvesting, respectively.

Source Mr. Takemura (personal communication).

weeding, harvesting and/or threshing). Overall the average number of members per group was 52 farmers, ranging from 15 to 300. Five of the farmer groups included processing and sale of their products. Furthermore, two and 13 groups had micro-credit systems for members and safety-net systems, respectively. The oldest farmer group was established in 1991, and the most recent in 2008.

Survey

We conducted interviews with staff of CeCPA, INRAB and AfricaRice to gather information on projects related to NERICA varieties in the study area and on the history and approaches to NERICA dissemination. In the target village, interviews were conducted with 1,390 randomly selected farmers, using a structured questionnaire to gather information on socio-demographic data (Table 2). Within households, husbands and wives have separate budgets and sometimes cultivate crops separately (LeMay-Boucher 2007). To take this into account, we interviewed men and women separately. We also conducted a survey using semi-structured questionnaires with 203 purposely selected farmers in four groups identified from the first survey. The groups consisted of: (i) farmers who benefited from the current seed production system introduced by CeCPA through selling more than 200 kg of seed of NERICA varieties to CeCPA in 2008 ($n=30$ interviewed out of 33 found in the first survey); (ii) farmers who sold more than 400 kg of NERICA varieties on the local market without selling to CeCPA ($n=28$ out of 35); (iii) farmers who had already stopped growing NERICA varieties ($n=83$ out of 153); and (iv) farmers who never cultivated NERICA varieties ($n=120$ out of 550). In this study, farmers who had experience of NERICA cultivation at least once are referred to as 'NERICA-experienced farmers' ($n=751$), farmers who had already stopped NERICA cultivation are referred to as 'dropout farmers' ($n=153$), farmers who had never cultivated NERICA are referred to as 'non-NERICA farmers' ($n=550$), farmers who belonged to a farmer group are referred to as 'group members', and farmers who did not belong to a farmer group are referred to as 'non-members'.

Statistical analysis

To select the best-fitting regression model for explaining variation in experience of cultivating NERICA at least once (yes or no), NERICA cultivation area in 2009 (ha), NERICA sale as seed to CeCPA in 2008 (yes or no), NERICA sale on the local market in 2008 (yes or no), and NERICA sales volume to CeCPA and local market in 2008 (kg), we used six different models in each analysis using multivariate logistic regression or multiple regression analysis with socio-demographic predictors (Hocking 1976; Glonek and McCullagh 1995). All tested models are shown in Table 3; selection of predictors was based on results of descriptive analysis using data from the two surveys and findings from previous studies (Kijima et al. 2006, 2011; Kijima and Sserunkuuma 2013; Kinkingninhoun-Mêdagbé et al. 2014). Numbers of samples differed among objectives of the analyses (Table 3). For example, for identifying factors affecting NERICA cultivation at least once, we used data from farmers who had grown rice (farmers who do not grow rice are not included in this analysis) (Table 3). Except for Models 7 to 12, all models used six predictors: four predictors were common for each objective of analysis; for each model, two predictors were selected from the remaining four. Models 7 to 12 used seven predictors with five common ones. The best-fitting model was selected based on the lowest Akaike's information criterion (AIC) among the six models (Akaike 1974; Gongotchame et al. 2014). Student's *t*-test and chi-square test were applied to compare socio-demographic characteristics and answers to questions

Table 2 Socio-demographic parameters collected via structured questionnaire at Sowe village, central Benin.

No.	Description	Parameter or range (mean ± standard deviation)
Discrete variables		
1	Gender	Female, male
2	Member of farmer group	No, yes
3	Education	No education, received primary education or more
4	Use of casual labor in agricultural activities	No, yes
5	Experience of NERICA cultivation	No, yes
6	How NERICA seed was obtained	Free, purchased
7	Source of NERICA seed	Family, extension service, member of affiliated group, and others
8	Training on rice cultivation practice	No, yes
9	Use of credit for agricultural activities	No, yes
10	Off-farm business	No, yes
13	Bought rice in 2008	Local market, other farmers, CeCPA, and others
14	Used fertilizer on rice cultivation in 2009	No, yes
15	Used herbicide on rice cultivation in 2009	No, yes
Continuous variables		
16	Age	From 14 to 95 years old (mean = 34.5 ± 13.7)
17	Years of experience in rice cultivation	From 1 to 40 years (8.7 ± 5.0)
18	Year that farmer started NERICA cultivation	From 2000 to 2009 (2006 ± 1.5)
19	Volume of NERICA sales in 2008	From 0 to 4,870 kg (193.0 ± 382.4)
20	Price of NERICA sales in 2008	From 0.19 to 1.67 US$[a] per kg (0.58 ± 0.20)
21	Area planted to rice in 2009	From 0.04 to 16 ha (0.38 ± 0.65)

[a] 1 US$ = 450.37 FCFA (9 September 2009).

regarding NERICA cultivation between group members and non-members (Mann and Wald 1942; Hotelling 1951). R version 3.0.2 was used for all analyses (R Core Team 2013).

Results

Description of rice cultivation, process of NERICA dissemination and its adoption by farmers

In Benin, NERICA varieties were introduced in 1998 (Adekambi et al. 2009). In Sowe village, NGOs (Veco and Rabema) introduced NERICA varieties in 2002. Since then, INRAB has also provided farmers in this village with NERICA seed. During the survey period, two national programs of NERICA dissemination were under way in this area. CeCPA implemented all the activities of these two programs in Glazoué. Programme de diffusion du riz NERICA (PDRN) was established in 2006 as a national agricultural development project. Activities of PDRN included participatory varietal selection (PVS), dissemination of NERICA varieties and farmer-based seed production. The Arrondissement (borough) of Kpakpasa consists of four villages (Kpakpasa, Yawa, Atogbo and Sowe). In 2009, CeCPA contracted seven farmers (two each in Yawa and Atogbo, and three in Sowe) to produce certificated NERICA seed for further dissemination within this program. Programme d'urgence d'appui pour la securité alimentaire (PUASA) was developed in 2008 to ensure food security after the food crisis of 2007–2008. PUASA aimed to increase the amount of cereal production, including NERICA varieties, through distribution of seed, mechanization and credit for purchase of fertilizer. It was noted that NERICA dissemination mainly focused on farmer groups, and CeCPA preferentially disseminated to farmer groups through enhancing access to seed and credit, and provided training.

Only 6 % of respondents indicated that they had never grown rice. Farmers' experience of rice cultivation ranged from 1 to 40 years. In 2009, rice cultivation area ranged from 0.04 to 16 ha, with an average of 0.4 ha per capita (Table 2). Some 58 % of all those farmers surveyed who had ever cultivated rice for at least one season had experienced NERICA cultivation for at least one season. NERICA-experienced farmers dramatically increased in 2006 when PDRN started to be implemented in this village (Fig. 1). The fact that group members tended to have higher NERICA adoption in this study reflected the approaches to NERICA dissemination. Table 4 compares adoption rate of NERICA varieties and socio-demographic parameters between group members and non-members. In 2009, around 75 % of group members had cultivated NERICA for at least one season (Fig. 1). In contrast, only 29 % of non-members had grown NERICA

Table 3 Models used in multivariate logistical and multiple regression analyses.

Model #	Parameter used
Farmers who had cultivated NERICA at least once (sample number: 1,301)	
Model 1	AGE, EDUCATION[a], GENDER, TRAINING[a], CREDIT[a] and GROUP[a]
Model 2	AGE, EDUCATION, GENDER, TRAINING, CREDIT and LABOR[a]
Model 3	AGE, EDUCATION, GENDER, TRAINING, CREDIT and OFF-FARM[a]
Model 4	AGE, EDUCATION, GENDER, TRAINING, GROUP and LABOR
Model 5	AGE, EDUCATION, GENDER, TRAINING, GROUP and OFF-FARM
Model 6	AGE, EDUCATION, GENDER, TRAINING, LABOR and OFF-FARM
NERICA cultivation area in 2009 (sample number: 751)	
Model 7	CECPA[a], FERTILIZER[a], GROUP, HERBICIDE[a], MARKET[a], AGE and GENDER
Model 8	CECPA, FERTILIZER, GROUP, HERBICIDE, MARKET, AGE and SOURCE[a]
Model 9	CECPA, FERTILIZER, GROUP, HERBICIDE, MARKET, AGE and YEAR[a]
Model 10	CECPA, FERTILIZER, GROUP, HERBICIDE, MARKET, GENDER and SOURCE
Model 11	CECPA, FERTILIZER, GROUP, HERBICIDE, MARKET, GENDER and YEAR
Model 12	CECPA, FERTILIZER, GROUP, HERBICIDE, MARKET, SOURCE and YEAR
NERICA sale as seed to CeCPA in 2008 (sample number: 587)	
Model 13	EDUCATION, GENDER, GROUP, TRAINING, AGE and CREDIT
Model 14	EDUCATION, GENDER, GROUP, TRAINING, AGE and METHOD[a]
Model 15	EDUCATION, GENDER, GROUP, TRAINING, AGE and YEAR
Model 16	EDUCATION, GENDER, GROUP, TRAINING, CREDIT and METHOD
Model 17	EDUCATION, GENDER, GROUP, TRAINING, CREDIT and YEAR
Model 18	EDUCATION, GENDER, GROUP, TRAINING, METHOD and YEAR
Sale on local market in 2008 (sample number: 587)	
Model 19	GROUP, OFF-FARM, SALE CECPA[a], TRAINING, AGE and CREDIT
Model 20	GROUP, OFF-FARM, SALE CECPA, TRAINING, AGE and GENDER
Model 21	GROUP, OFF-FARM, SALE CECPA, TRAINING, AGE and METHOD
Model 22	GROUP, OFF-FARM, SALE CECPA, TRAINING, CREDIT and GENDER
Model 23	GROUP, OFF-FARM, SALE CECPA, TRAINING, CREDIT and METHOD
Model 24	GROUP, OFF-FARM, SALE CECPA, TRAINING, GENDER and METHOD
Sales volume to CeCPA and local market in 2008 (sample number: 304 and 201, respectively)	
Model 25	EDUCATION, GROUP, METHOD, SOURCE, CREDIT and GENDER
Model 26	EDUCATION, GROUP, METHOD, SOURCE, CREDIT and TRAINING
Model 27	EDUCATION, GROUP, METHOD, SOURCE, CREDIT and YEAR
Model 28	EDUCATION, GROUP, METHOD, SOURCE, GENDER and TRAINING
Model 29	EDUCATION, GROUP, METHOD, SOURCE, GENDER and YEAR
Model 30	EDUCATION, GROUP, METHOD, SOURCE, TRAINING and YEAR

[a] EDUCATION: received primary education, TRAINING: received training on rice cultivation, CREDIT: use of credit for agricultural activities, GROUP: farmer group membership, LABOR: use of casual labor in agricultural activities, OFF-FARM: have an off-farm business, CECPA: NERICA sales volume to CeCPA in 2008, FERTILIZER: use of fertilizer in rice cultivation in 2009, HERBICIDE: use of herbicide in rice cultivation in 2009, MARKET: NERICA sales volume to local market in 2008, SOURCE: obtaining NERICA seed from CeCPA, YEAR: years of experience in rice cultivation, METHOD: purchasing NERICA seed for beginning cultivation, SALE CECPA: selling NERICA to CeCPA in 2008.

varieties at least one season. Around 19 and 25 % of NERICA-experienced group members and non-members, respectively, had stopped NERICA cultivation by 2009. NERICA cultivation area in 2009 was larger in group members' fields than in non-members' fields (0.21 ha cf. 0.15 ha, on average), whereas total rice area in 2009 was not different between the two groups.

Farmer group membership was characterized by a high proportion of female farmers, farmers with more family members, and farmers who tended to employ casual laborers, have off-farm business, use credit for agricultural activities and have training in rice cultivation. The dominant sources of NERICA seed were other members for group members (42 %) and family or relatives for non-members (52 %)

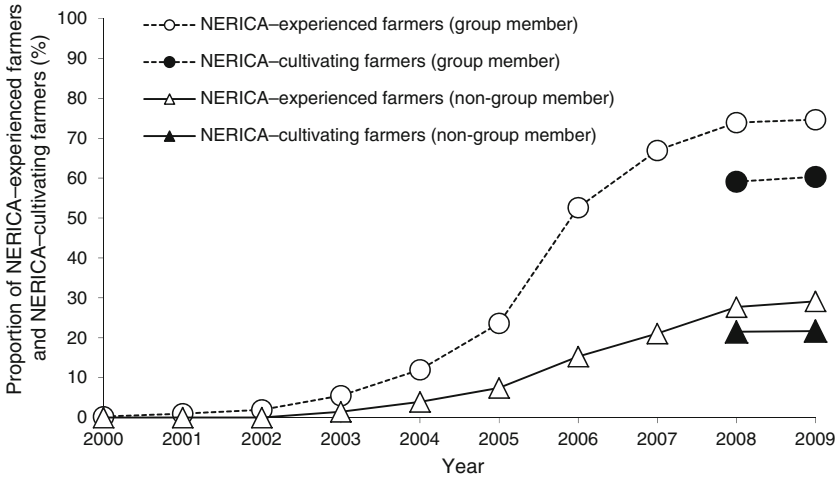

Fig. 1 Change in proportion of farmers who have experience in NERICA, and proportion of NERICA-cultivating farmers in 2008 and 2009 at Sowe village, central Benin ($n = 1301$)

Table 4 Comparison of socio-demographic characteristics and status of rice cultivation in 2009 between farmers who belong to a farmer group and those who do not at Sowe village, central Benin (total $n = 1,390$).

	Group member ($n = 817$)	Non-member ($n = 573$)
No. farmers who grow rice in this survey (rice farmers)	817a[a]	484b
Females among total rice farmers (%)	70a[a]	44b
Age (average)	35a[b]	34a
Average no. years of rice cultivation experience	9a[b]	8b
Farmers without education among total rice farmers (%)	77a[a]	66b
Famers with more than 9 dependents among total rice-experienced farmers (%)	55a[a]	47b
Farmers who employ casual laborers for agricultural activities among total rice farmers (%)	75a[a]	68b
Farmers who have off-farm business among total rice farmers (%)	39a[a]	32b
Farmers who use credit for agricultural activities among total rice farmers (%)	63a[a]	51b
Famers who received training on rice cultivation among total rice farmers (%)	68a[a]	23b
Farmers who cultivated NERICA at least once among total rice farmers (%)	75a[a]	29b
Farmers who abandoned NERICA cultivation among farmers who cultivated NERICA at least once (%)	19a[a]	25a
Status of rice cultivation in 2009		
Farmers who cultivated rice in 2009 among total rice farmers (%)	98a[a]	91b
Rice area in 2009 (average) (ha per farmer)	0.48a[b]	0.41a
Farmers who cultivated NERICA in 2009 among farmers who cultivated NERICA at least once (%)	81a[a]	75a
Farmers who cultivated only NERICA in 2009 among total farmers who cultivated rice in 2009 (%)	31a[a]	22b
Farmers who used fertilizer on NERICA cultivation in 2009 among farmers who cultivated NERICA in 2009 (%)	100a[a]	100a
Farmers who used credit for purchasing fertilizer to cultivate NERICA among farmers who cultivated NERICA in 2009 (%)	72a[a]	56b
Farmers who used herbicide on NERICA cultivation in 2009 among farmers who cultivated NERICA in 2009 (%)	4a[a]	9a
Plot size for NERICA (ha per farmer who grew NERICA in 2009)	0.21a[b]	0.15b

[a] Within a row, the same letter indicates no significant difference between means for group members and non-members according to χ^2-test at the 5 % level.

[b] Within a row, the same letter indicates no significant difference between means for group members and non-members according to t-test at the 5 % level.

Table 5 Source of NERICA seed, how NERICA seed was obtained, and cost of NERICA seed at Sowe village, central Benin ($n = 751$).

Source	Source of NERICA seed (% of farmers among total farmers who cultivated NERICA at least once)[b]		% of farmers who bought NERICA seed among total farmers who obtained the seed from each source[b]		Average cost of NERICA seed (US$[a]/kg)[c]	
	Group member[d]	Non-member	Group member	Non-member	Group member	Non-member
Family or relatives	22a	52b	51a	58a	0.81a	0.76a
CeCPA	9a	10a	62a	93b	0.83a	0.90a
Other member in the farmer group	42		65		0.79	
Others	27a	38b	67a	75a	0.85a	0.77b

[a] 1 US$ = 450.37 FCFA (9 September 2009).

[b] Within a pairing, the same letter indicates that there is no significant difference at 5 % level between means for group members and non-members according to χ^2 test.

[c] Within a pairing, the same letter indicates that there is no significant difference at 5 % level between means for farmer group and non-group members according to *t*-test.

[d] As there were significant differences in all three parameters between two groups, data are shown separately for group members and non-members.

(Table 5). Although non-members were more likely to buy seed than group members, more than half of group members and non-members who bought seed paid double the local market price of rice paddy.

More than half of all farmers who sold NERICA seed in 2008 ($n = 562$) sold it to CeCPA at double the local market price for rice paddy (Table 6). Some 36 % of total farmers who sold NERICA in 2008 (37 and 29 % of group members and non-members, respectively), sold NERICA on the local market.

Factors affecting farmers' experience of NERICA varieties, cultivation area and sales

Multivariate logistic regression analysis for identifying factors affecting experience of cultivating NERICA at least once identified Model 1 as the best-fitting one based on AIC score (AIC = 1,422) (Table 7). Among the six predictors, five were statistically significant. Group members, younger and educated farmers tended to cultivate NERICA varieties at least once. NERICA-experienced farmers tended to have received training on rice cultivation from CeCPA and use credit for agricultural activities.

To explain the variation in area planted to NERICA varieties in 2009, Model 7 was selected as the best fit (AIC = 7.66) (Table 8). All seven predictors in this model were statistically significant. Male farmers, older farmers and group members tended to cultivate NERICA varieties on larger areas. Farmers who took credit and used fertilizer and herbicide on NERICA in 2009 tended to plant NERICA varieties over a larger area than other farmers. Farmers who planted NERICA varieties on a large area in 2009 tended to have sold a great deal of NERICA on the local market or to CeCPA in 2008.

Multivariate logistic regression analysis for identifying factors affecting NERICA sale as seed to CeCPA in 2008 identified Model 14 as the best fit (AIC = 818) (Table 7). In this model, only one predictor was statistically significant. Farmers who did not have training on rice cultivation tended to sell NERICA varieties. For identifying factors affecting NERICA sale on the local market, Model 20 was identified as the best fit (AIC = 441) (Table 7). Apart from TRAINING, five out of six predictors in the model were significant. Group member, male and younger farmers tended to sell NERICA on the local market. Farmers who sold NERICA to CeCPA and did not have off-farm business tended to sell NERICA on the local market.

Table 6 Percentage of farmers who sold to buyers, average paddy price and average sales among farmers who sold NERICA in 2008 at Sowe village, central Benin ($n = 562$).

NERICA sold to	Sales (% of farmers)[b]	Average paddy price (US$[a]/Kg)	Average sales (Kg/capita)
CeCPA	54	0.71	131
Local market	36	0.39	295
Other farmers	6	0.57	159
Others (NGOs, intermediaries)	10	0.53	168

[a] 1 US$ = 450.37 FCFA (9 September 2009).

[b] Sum > 100 % because some respondents sold to more than one buyer.

Model 25 (AIC = 4,305) and Model 29 (AIC = 2,930) were identified as best-fitting models for identifying predictors affecting variation in sales volume to CeCPA and on the local market in 2008 (Table 8). Male and educated farmers, who received credit for agricultural activities and NERICA seed from CeCPA tended to sell a larger amount of NERICA to CeCPA in 2008. Farmers who sold a large amount of NERICA on the local market in 2008 tended to be male and have more experience in rice cultivation.

Reasons why farmers had different adoption behavior of NERICA varieties

Farmers who sold more than 200 kg NERICA varieties as seed to CeCPA in 2008

CeCPA purchased NERICA as seed at twice the local market price (of paddy) for further dissemination as part of the farmer-based seed production system. Farmers who sold seed to CeCPA were deemed to benefit from this system. These farmers clearly recognized that sale of NERICA seed to CeCPA at high price was an incentive to growing NERICA varieties (Table 9). Other major reasons why these farmers grow NERICA varieties are the varieties' short duration and desirable taste.

Farmers who sold more than 400 kg of NERICA varieties as non-seed on the local market in 2008

Some 17 % of all farmers (total = 201) who sold NERICA as non-seed on the local market in 2008, sold more than 400 kg NERICA on the local market (Table 6). Most of these farmers recognized the benefit of selling NERICA seed to CeCPA (Table 9). It is possible that they have recognized the benefit through selling in previous years or heard of it from other farmers. They also indicated that high yield, desirable taste and short duration were major reasons for growing NERICA varieties. On the other hand, none of the farmers reported drought tolerance. This result differed from farmers who sold

Table 7 Socio-demographic parameters of farmers who had cultivated NERICA at least once (n = 1,301), and parameters affecting NERICA sale as seed to CeCPA and local market (n = 587), which were identified via multivariate logistic analysis.

Parameter	Coefficient	Std error	Waldχ^2	P value	Odds ratio[a]	95%CI[b]
Farmers who had cultivated NERICA at least once						
AGE	−0.01	0.01	6.68	<0.01***	0.99	0.98–1.00
CREDIT	0.29	0.13	4.54	<0.05*	1.33	1.02–1.73
EDUCATION	0.65	0.16	15.86	<0.01***	1.92	1.40–2.66
GENDER	0.28	0.15	3.40	0.07	1.32	0.98–1.77
GROUP	1.74	0.15	139.85	<0.01***	5.70	4.29–7.64
TRAINING	1.17	0.14	66.23	<0.01***	3.21	2.43–4.26
NERICA sale as seed to CeCPA						
AGE	0.01	0.01	1.58	0.21	1.01	1.00–1.02
EDUCATION	0.02	0.20	0.01	0.94	1.02	0.68–1.51
GENDER	−0.04	0.19	0.06	0.81	0.96	0.66–1.38
GROUP	0.10	0.23	0.17	0.68	1.10	0.70–1.74
METHOD	−0.26	0.18	2.11	0.15	0.77	0.55–1.09
TRAINING	−0.45	0.19	5.43	0.02*	0.64	0.44–0.93
NERICA sale on local market						
AGE	−0.04	0.01	13.42	<0.01***	0.96	0.94–0.98
GENDER	0.97	0.27	12.94	<0.01***	2.63	1.57–4.50
GROUP	0.93	0.35	7.13	<0.01**	2.54	1.29–5.10
OFF-FARM	−1.36	0.26	26.90	<0.01***	0.26	0.15–0.43
SALE CECPA	4.01	0.33	150.23	<0.01***	0.02	0.01–0.03
TRAINING	0.10	0.29	0.12	0.73	1.10	0.63–1.94

[a] Odds ratio estimate of < 1 indicates that farmers with the reference characteristic tended to have characteristic with response variable (e.g. farmers who had cultivated NERICA at least once). For example, for EDUCATION in farmers who had cultivated NERICA at least once, farmers who had education tended to have experience in NERICA cultivation.

[b] 95 % confidence interval for the estimated odds ratio.

For categorical variables, the reference of each predictor is 'no' except for GENDER, which we consider 'female'.

*, ** and *** indicate significance at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively.

Table 8 Socio-demographic parameters affecting NERICA cultivation area in 2009, and affecting NERICA sales volume to CeCPA and local market in 2008 (identified via multiple regression analysis) and their coefficients.

Parameter	NERICA cultivation area in 2009 ($n = 751$)	Sales volume to CeCPA ($n = 304$)	Sales volume to local market ($n = 201$)
AGE	2.2×10^{-3}**	N/A	N/A
CECPA	3.4×10^{-4}***	N/A	N/A
CREDIT	N/A	9.3×10**	N/A
EDUCATION	N/A	1.1×10^{2}**	7.0×10
FERTILIZER	8.7×10^{-2}***	N/A	N/A
GENDER	5.9×10^{-2}**	1.0×10^{2}**	1.6×10^{2}**
GROUP	5.0×10^{-2}*	7.0×10	3.4×10
HERBICIDE	1.6×10^{-1}***	N/A	N/A
MARKET	2.1×10^{-4}***	N/A	N/A
METHOD	N/A	-7.8×10*	-9.6×10
SOURCE	N/A	1.6×10^{2}**	3.1×10
YEAR	N/A	N/A	2.1×10***
R^2	0.23	0.13	0.16
Adjusted R^2	0.23	0.11	0.13
F-value	32.19	7.2	6.03
P-value	<0.01***	<0.01***	<0.01***

For categorical variables, the reference of each predictor is 'no' except for GENDER, which we consider 'female'.

*, ** and *** indicate significance at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively.

more than 200 kg NERICA varieties as seed to CeCPA in 2008, 10 of whom who indicated drought tolerance of NERICA varieties was a reason. Why this is so is not known as sampling size was limited and information regarding drought stress in this village was not collected. Thus, further investigation would be needed.

Farmers who did not sell NERICA seed to CeCPA in 2008 did not do so mainly for financial reasons: 86, 57 and 46 % of these farmers indicated that they needed cash to solve family problems (health, school expenses), had to pay back debt or credit, or needed cash for living costs (sum >100 % because some respondents gave more than one reasons). A further 39 % reported that, based on their previous experience, they were worried that CeCPA would delay payment and that they could not risk this eventuality. In addition, some farmers also indicated no opportunity to sell to CeCPA due to lack of information.

Table 9 Reasons why NERICA-experienced farmers continue NERICA cultivation ($n = 58$).

	Farmers who sold more than 200 kg NERICA as seed to CeCPA (%, $n = 30$)[a]	Farmers who sold more than 400 kg NERICA as non-seed on local market (%, $n = 28$)[a]
High price paid by CeCPA	100	82
Short duration	77	68
Desirable taste	47	86
Drought tolerance	33	0
High yield	13	93

[a] Sum >100 % because some respondents gave more than one reasons.

Farmers who had already stopped growing NERICA varieties

Farmers who had stopped growing NERICA ($n = 83$) had done so for multiple reasons: 53 % of the farmers indicated low yield. Financial reasons related to cultivation or purchasing of fertilizer was indicated by 33 and 27 %, respectively. A further 20 % indicated seed unavailability and failure of cultivation due to a lack of information on NERICA varieties and their cultivation. Difficulty in selling NERICA as seed was indicated by 19 %. A further 17 % said that NERICA cultivation was too labor-intensive and that NERICA varieties were often damaged by birds and rats.

Farmers who never cultivated NERICA varieties

Farmers who had never cultivated NERICA ($n = 120$) reported the following major reasons for this: unavailability of seed (39 %); reputation for low yield (29 %); financial difficulty in buying seed (27 %); difficulty in cultivating NERICA varieties (24 %); preference for other varieties (18 %); lack of fertilizer (18 %); unavailability of land (15 %); lack of information about NERICA varieties (13 %).

Discussion

This study found relatively high adoption rate of NERICA varieties by farmers, especially those who were members of a group. Apart from a study in Uganda (Kijima et al. 2011), the adoption rate in this study is similar to or higher than previous studies in SSA, which showed that 4, 19, 20, 40 and 45 % adoption rates for Côté d'Ivore, Nigeria, Guinea, The Gambia and Benin, respectively (Diagne 2006; Diagne et al. 2009; Dibba et al. 2012; Nguezet et al. 2013; Kinkingninhoun-Mêdagbé et al. 2014). The reason for the relatively high adoption rate in our study was the fact that CeCPA had preferentially disseminated NERICA to farmer groups through enhancing access to seed and credit, and provided training. Moreover, in this study, we considered only one village where NERICA had been intensively introduced, while other studies considered villages where NERICA varieties were not officially introduced. Furthermore, this village is one of the major seed-producing villages in the area. An approach using farmer groups as an entry point for technology dissemination has been supported by numerous reports, which indicate the effectiveness of dissemination through groups, rather than individuals, for sharing experience, information and materials, including seed (Franzel et al. 2001; Haggar et al. 2001; Ndjeunga 2002).

The approach used for NERICA dissemination in this village was effective for achieving gender equality in adoption of NERICA varieties, as gender did not affect the adoption rate. This was due to the fact that CeCPA had preferentially disseminated NERICA seed to farmer groups, membership of which was around 70 % female. This is inconsistent with previous studies, which found large gender gaps in adoption of agricultural technologies (Doss 2001; Doss and Morris 2001; Kinkingninhoun-Mêdagbé et al. 2010; Aterido et al. 2013). On the other hand, we confirmed that male farmers tended to sell greater volumes of NERICA seed to CeCPA and local markets and this is likely to be attributable to social structure linked with the fact that female farmers have limited access to land. Apart from farmer group and gender, we found that age, education, training and credit use were also associated with adoption of NERICA varieties. This result agrees with previous studies (Asuming-Brempong et al. 2011; Ojehomon et al. 2012; Asante et al. 2014; Dibba et al. 2015).

It is expected that farmers will share seed if supply is increased at the farmer level through farmer-based seed production, and that consequently the difference in NERICA adoption between group members and non-members would decrease through farmer-to-farmer exchange of seed and information. However, non-NERICA-experienced farmers reported that lack of access to NERICA seed was one of the major reasons why they never grew NERICA varieties. As NERICA grains were sold to CeCPA as seed or to other farmers, the seed should not have been limited in general for seed exchange among farmers in this village. In farmer groups, seed was generally shared among group members. In contrast, for non-members, seed-sharing was mainly through family members and other relatives. Also, most farmers needed to buy seed and there was limited farmer-to-farmer exchange of seed at this study site. Similar results have been observed in various locations in SSA, showing that small-scale farmers tend to miss out on the benefits in farmer-to-farmer exchange approaches (Sperling and Loevinsohn 1993; Tripp 2001; Almekinders et al. 2007). Sperling and Loevinsohn (1993) reported that, in Rwanda, exchange is performed among a narrow set of contacts, such as best friends, close family and neighbors. Kiptot et al. (2006) reported that seed and knowledge were mostly shared along kinship ties in Kenya. In South American countries, Almekinders et al. (2007) point out that farmer-to-farmer exchange depends on networks within each social class. In agreement with these studies, our results suggest that there is a need to strengthen farmer-to-farmer exchange in order to reduce the bias in dissemination of new varieties. Seed pool systems and seed loan systems may be applied as described by Witcombe et al. (1999) who reported that a rice dissemination project in India did not purchase seed for further distribution, but had a project-organized seed pool system which enabled seed supply to other villages. In seed loan systems, farmers who have received new seed send some back after harvest to the seed pool. In these systems, there is a risk that seed quality might not be maintained.

Although there were only three farmers contracted to produce NERICA certified seed under the direction of CeCPA in this study village before harvest, CeCPA purchased NERICA as seed from 304 farmers in 2008. This is because CeCPA needed more seed for further dissemination. Consequently, farmers could easily become seed producers without certification. CeCPA bought NERICA seed from farmers at a higher price than the local market. The amount of seed needed by CeCPA determined how many farmers could sell how much seed. There would be a large difference in income between farmers who sold to CeCPA and others who sold the same amount of NERICA on the local market. It was therefore not surprising that farmers indicated selling to CeCPA was one of their motivations for growing NERICA. Male farmers grew NERICA varieties on significantly larger areas in 2009 and sold larger amounts of NERICA to CeCPA in 2008 rather than female farmers. Furthermore male farmers who used fertilizer and herbicide tended to plant NERICA varieties on larger areas. Results from the semi-structured interviews showed that resource-poor farmers tended to sell NERICA on the local market because of an urgent need for cash (caused by, e.g., family problems, cost of living and repayment of credit). This result agrees with the quantitative analysis in this study, showing that farmers who did not have off-farm businesses tended to sell NERICA on the local market. Consequently, these results indicate that there is a possibility that female farmers and resource-poor farmers do not benefit from seed business opportunities, and that there has been an increase in the gap between rich and poor, and between male and female. This is consistent with previous studies, which show that farmers' access to market, inputs and land are hindered by various factors such as poverty and gender (Goetz 1992; Fafchamps

and Vargas-Hill 2005; Alene et al. 2008). Fafchamps and Vargas-Hill (2005) report that small-scale farmers often sell their production to itinerant traders at a lower than market price at the farm gate because they don't have money to carry the crops to market. Although there was no bias on adoption, we confirmed that there was a bias on benefit from NERICA cultivation, in particular seed business, between men and women due to existing gender inequality in the village such as access to cultivation area, labor and inputs.

Although we did find some key socio-demographic characters of farmers who sold rice to CeCPA, we did not ask CeCPA staff how they selected farmers to buy seed from, so further investigation is needed to examine how connection with CeCPA, farmers' resource ability, and/or technical knowledge and skill in rice cultivation affect selling to CeCPA. The community-based seed production observed in this study area does not seem to be a sustainable way of using farmers' expertise, as until and unless there is an assured seed market, seed-producing farmers are always at risk. Proper planning for determining seed needs for the next season and strengthening contractual arrangement for seed business and controlling seed quality should be considered in order to establish a sustainable seed production system.

Farmers, who grew NERICA varieties, reported that they had higher yield. This may be related to their drought tolerance and escape from terminal drought due to their short duration (Saito et al. 2012, 2015). In contrast, farmers who abandoned NERICA cultivation reported that they were low-yielding and they had not been informed of appropriate cultivation practices. The reasons why some farmers identified NERICA varieties as high yielding, but others not are probably due to differences in cultivation practices including agricultural inputs, soil fertility, water conditions, and pests. If NERICA varieties are grown with long-duration varieties, they are damaged by rats or birds due to their short duration (early maturity); consequently farmers would have reported that NERICA varieties had low yield with problem from rats or birds. Farmers who grew NERICA varieties on a large area and/or together with other group members would have reduced damage from birds or rats. Also, farmers who planted NERICA varieties later might have seen the benefit because of their short duration allowing them to escape terminal drought and consequent high yield in comparison with long-duration varieties. Saito and Futakuchi (2009) found that NERICA 1 had high yields in fertile soils, but poor yields in soils of low fertility. A similar tendency was observed with other NERICA varieties in other studies (Saito et al. 2012, 2015). This is supported by the present study. NERICA varieties had low yields when farmers grew them on soils of low soil fertility or with low fertilizer inputs due to lack of resources. In fact, some farmers who stopped NERICA cultivation indicated that they had financial difficulty in growing NERICA varieties as they needed to buy fertilizer and other inputs. Further studies are needed to quantify on-farm yield variation and understand the causes of this variation. It is essential to disseminate information on characteristics of new varieties and their cultivation methods when they are about to be released.

Conclusion

Our study confirmed that a dissemination approach focusing on farmer groups is effective in terms of enhancing technology transfer and achieving gender equality in the adoption of NERICA varieties of rice. However, this approach aggravated the bias in adoption of NERICA varieties between the target group and non-target group in Sowe village. Furthermore, lack of information on characteristics of NERICA varieties and their cultivation practices caused poor adoption by the non-target group. Thus, farmer-to-farmer seed and information exchange should be enhanced beyond target groups.

Seed production business has become an incentive for farmers to grow NERICA varieties, as their seed is purchased at more than the local market price by the public sector. It is not surprising that farmers who already benefitted from selling seed would not share such information or seed with others. Furthermore, smallholders would not purchase seed of new varieties such as NERICA as there is a risk that they would not know how to grow them properly. Therefore, opportunities to access technologies and business opportunities should be made equal for farmer groups and smallholders, especially when new varieties are introduced.

NERICA varieties have been considered as a technology for contributing to poverty reduction in SSA. Numerous studies have reported that NERICA adoption contributed to improving rice farmers' livelihoods. However, the present study shows that it is possible that NERICA introduction can enhance the biases between rich and poor, and between male and female. Thus, consideration is required not only for what type of technologies should be introduced, but also how they should be disseminated.

Acknowledgments 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). We express gratitude to farmers in Sowe village who contributed to this study and the staff of the Africa Rice Center. 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.

References

Adekambi, S. A., Diagne, A., Simtowe, F. P., & Biaou, G. (2009). *The impact of agricultural technology adoption on poverty: the case of NERICA rice varieties in Benin*. International Association of Agricultural Economists 2009 Conference, Beijing, China, 16 August.

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transaction Automatic Control, 19*(6), 716–723.

Alene, A. D., Manyong, V. M., Omanya, G., Mignouna, H. D., Bokanga, M., & Odhiambo, G. (2008). Smallholder market participation under transactions costs: maize supply and fertilizer demand in Kenya. *Food Policy, 33*(4), 318–328.

Almekinders, C. J. M., Thiele, G., & Danial, D. L. (2007). Can cultivars from participatory plant breeding improve seed provision to small-scale farmers? *Euphytica, 153*(3), 363–372.

Anyonge, T. M., Holding, C., Kareko, K. K., & Kimani, J. W. (2001). Scaling up participatory agroforestry extension in Kenya: from pilot projects to extension policy. *Development in Practice, 11*(4), 449–459.

Asante, B. O., Wiredu, A. N., Martey, E., Sarpong, D. B., & Mensah-Bonsu, A. (2014). NERICA adoption and impacts on technical efficiency of rice producing households in Ghana: implications for research and development. *American Journal of Experimental Agriculture, 4*(3), 244–262.

Asuming-Brempong, S., Gyasi, K. O., Marfo, K. A., Diagne, A., Wiredu, A. N., Boakye, A. A., et al. (2011). The exposure and adoption of New Rice for Africa (NERICAs) among Ghanaian rice farmers: what is the evidence? *African Journal of Agricultural Research, 6*(27), 5911–5917.

Aterido, R., Beck, T., & Iacovone, L. (2013). Access to finance in Sub-Saharan Africa: is there a gender gap? *World Development, 47*, 102–120.

Bam, R. K., Craufurd, P. Q., Dorward, P. T., Asiedu, E. A., Kumaga, F. K., & Ofori, K. (2007). Introducing improved cultivars: understanding farmers' seed drying and storage practices in central Ghana. *Experimental Agriculture, 43*(3), 301–317.

Bèye, A. M., & Wopereis, M. C. S. (2014). Cultivating knowledge on seed systems and seed strategies: case of the rice crop. *Net Journal of Agricultural Science, 2*(1), 11–29.

Caritas International Belgium (2011). *Annual implementation report, including 4th quarter achievement (ANNPRS)*. http://www.caritas-int.be/sites/www.caritas-int.be/files/uploads/pd2.pdf. Accessed 16 Nov 2015.

Chambers, R. (1983). *Rural development: Putting the last first*. London: Pearson.

Dalton, T. J., & Guei, R. G. (2003). Productivity gains from rice genetic enhancements in West Africa: countries and ecologies. *World Development, 31*(2), 359–374.

David, S., Mukandala, L., & Mafuru, J. (2002). Seed availability, an ignored factor in crop varietal adoption studies: a case study of beans in Tanzania. *Journal of Sustainable Agriculture, 21*(2), 5–20.

De Graft-Johnson, M., Suzuki, A., Sakurai, T., & Otsuka, K. (2014). On the transferability of the Asian rice green revolution to rainfed areas in Sub-Saharan Africa: an assessment of technology intervention in northern Ghana. *Agricultural Economics, 45*(5), 555–570.

Diagne, A. (2006). Diffusion and adaption of NERICA rice varieties in Côte d'Ivoire. *The Developing Economies, 44*(2), 208–231.

Diagne, A., Sogbossi, M. J., Simtowe, F., Diawara, S., Diallo, A. S., & Barry, A. B. (2009). Estimation of actual and potential adoption rates and determinants of a new technology not universally known in the population: the case of NERICA rice varieties in Guinea. International Association of Agricultural Economists 2009 Conference, Beijing, China, 16–22 August.

Diao, X., Headey, D., & Johnson, M. (2008). Toward a green revolution in Africa: what would it achieve, and what would it require? *Agricultural Economics, 39*(s1), 539–550.

Dibba, L., Simon, C., Diagne, A., & Nimoh, F. (2012). The impact of NERICA adoption on productivity and poverty of the small-scale rice farmers in The Gambia. *Food Security, 4*(2), 253–265.

Dibba, L., Zeller, M., Diagne, A., & Nielsen, T. (2015). How accessibility to seeds affects the potential adoption of an improved rice variety: the case of the new rice for Africa (NERICA) in The Gambia. *Quarterly Journal of International Agriculture, 54*(1), 33–58.

Doss, C. R. (2001). Designing agricultural technology for African women farmers: lessons from 25 years of experience. *World Development, 29*(12), 2075–2092.

Doss, C. R. (2006). Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. *Agricultural Economics, 34*(3), 207–219.

Doss, C. R., & Morris, M. L. (2001). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. *Agricultural Economics, 25*(1), 27–39.

Fafchamps, A., & Vargas-Hill, R. (2005). Selling at the farmgate or traveling to market. *American Journal of Agricultural Economics, 87*(3), 717–734.

FAO (2010). *Rapport de la synthese regionale de la satisfaction des beneficiaires et d'evaluation d'impact pour les projects ISFP TCP*. Accra: Bureau sous-régional de la FAO pour l'Afrique de l'Ouest. http://www.fao.org/fileadmin/user_upload/ISFP/SFW_Synthesis_ISFP_TCP_Assessments_FINALwAnnex.pdf. Accessed 16 Nov 2015.

Franzel, S., Copper, P., & Denning, G. L. (2001). Scaling up the benefits of agroforestry research: lessons learned and research challenges. *Development in Practice, 11*(4), 524–534.

Glonek, G. F. V., & McCullagh, P. (1995). Multivariate logistic models. *Journal of the Royal Statistical Society, 57*(3), 533–546.

Goetz, S. J. (1992). A selectivity model of household food marketing behavior in Sub-Saharan Africa. *American Journal of Agricultural Economics, 74*(2), 444–452.

Gongotchame, S., Dieng, I., Ahouanton, K., Johnson, J. M., Alognon, A. D., Tanaka, A., et al. (2014). Participatory evaluation of mechanical weeders in lowland rice production systems in Benin. *Crop Protection, 61*, 32–37.

Haggar, J., Ayala, A., Diaz, B., & Reyes, C. U. (2001). Participatory design of agroforestry systems: developing farmer participatory research methods in Mexico. *Development in Practice, 11*(4), 417–424.

Hocking, R. R. (1976). The analysis and selection of variables in linear regression. *Biometrics, 32*(1), 1–49.

Hotelling, H. (1951). A generalized *t* test and measure of multivariate dispersion. In J. Neyman (Ed.), *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability* (pp. 23–41). Berkeley: University of California.

Kijima, Y., & Sserunkuuma, D. (2013). The adoption of NERICA rice varieties at the initial stage of diffusion process in Uganda. *African Journal of Agricultural Resource Economics, 8*(1), 45–56.

Kijima, Y., Sserunkuuma, D., & Otsuka, K. (2006). How revolutionary is the 'NERICA revolution'? Evidence from Uganda. *The Developing Economies, 44*(2), 252–267.

Kijima, Y., Otsuka, K., & Sserunkuuma, D. (2011). An inquiry into constraints on a green revolution in Sub-Saharan Africa: the case of NERICA rice in Uganda. *World Development, 39*(1), 77–86.

Kijima, Y., Ito, Y., & Otsuka, K. (2012). Assessing the impact of training on lowland rice productivity in an African setting: evidence from Uganda. *World Development, 40*(8), 1610–1618.

Kinkingninhoun-Mêdagbé, F. M., Diagne, A., Simtowe, F., Agboh-Noameshie, A. R., & Adégbola, P. Y. (2010). Gender discrimination and its impact on income, productivity, and technical efficiency: evidence from Benin. *Agriculture and Human Values, 27*(1), 57–69.

Kinkingninhoun-Mêdagbé, F. M., Diagne, A., & Adegbola, P. Y. (2014). *Impact of NERICA adoption on productivity and income in Benin: Is there gender difference?* Seminar presentation at The Theoretical and Applied Economic Association, Cotonou, Benin, 11 November.

Kiptot, E., Franzel, S., Hebinck, P., & Richards, P. (2006). Sharing seed and knowledge: farmer to farmer dissemination of agroforestry technologies in western Kenya. *Agroforestry Systems, 68*, 167–179.

Lanteri, S., & Quagliotti, L. (1997). Problems related to seed production in the African region. *Euphytica, 96*(1), 173–183.

LeMay-Boucher, P. (2007). Inside Beninese households: how spouses manage their personal income. Edinburgh: Centre for Economic Reform and Transformation, Heriot Watt University. http://www.sml.hw.ac.uk/downloads/cert/wpa/2007/dp0705.pdf. Accessed 16 Nov 2015.

Local Seed Business Project (LSB project) (2009). *Local seed business newsletter* 2. Wageningen: Wageningen UR. https://www.wageningenur.nl/web/file?uuid=7d6797ef-eea8-40f8-bd91-e0a8dbdfa2e9&owner=d8407ff5-f145-43fc-97b0-e50a0b148bad. Accessed 16 Nov 2015.

Mann, H. B., & Wald, A. (1942). On the choice of the number of class intervals in the application of the chi square test. *The Annals of Mathematical Statistics, 13*(3), 306–317.

MCPPD. (2004). *Chaier des villages et quaritiers de ville Département des Collines*. Cotonou: Ministère Chargé du plan de la prospective et du Développement.

Minten, B., & Barrett, C. B. (2008). Agricultural technology, productivity, and poverty in Madagascar. *World Development, 36*(5), 797–822.

Ndjeunga, J. (2002). Local village seed systems and pearl millet seed quality in Niger. *Experimental Agriculture, 38*, 149–162.

Nguezet, P. M. D., Diagne, A., Okoruwa, O. V., Ojehomon, V., & Manyong, V. (2013). Estimating the actual and potential adoption rates and determinants of NERICA rice varieties in Nigeria. *Journal of Crop Improvement, 27*, 561–585.

Ojehomon, V. E. T., Adewumi, M. O., Omotesho, O. A., Ayinde, K., & Diagne, A. (2012). Adoption and economics of new rice for Africa (NERICA) among rice farmers in Ekiti State, Nigeria. *Journal of American Science, 8*(2), 423–429.

Okry, F., Van Mele, P., Nuijten, E., Struik, P. C., & Mongbo, R. L. (2011). Organizational analysis of the seed sector of rice in Guinea: stakeholders, perception and institutional linkages. *Experimental Agriculture, 47*(1), 137–157.

Otsuka, K., & Kalirajan, K. P. (2006). Rice green revolution in Asia and its transferability to Africa: an introduction. *The Developing Economies, 44*(2), 107–122.

Otsuka, K., & Kijima, Y. (2010). Technology policies for a green revolution and agricultural transformation in Africa. *Journal of African Economies, 19*(s2), 60–79.

R Core Team (2013). R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing. http://www.R-project.org/. Accessed 6 July 2015.

Saito, K., & Futakuchi, K. (2009). Performance of diverse upland rice cultivars in low and high soil fertility conditions in West Africa. *Field Crops Research, 111*, 243–250.

Saito, K., Sokei, Y., & Wopereis, M. C. S. (2012). Enhancing rice productivity in West Africa through genetic improvement. *Crop Science, 52*(2), 484–493.

Saito, K., Fukuta, Y., Yanagihara, S., Ahouanton, K., & Sokei, Y. (2014). Beyond NERICA: identifying high-yielding rice varieties adapted to rainfed upland conditions in Benin and their plant characteristics. *Tropical Agriculture and Development, 58*(2), 51–57.

Saito, K., Dieng, I., Touré, A. A., Somado, E. A., & Wopereis, M. C. S. (2015). Rice yield growth analysis for 24 African countries over 1960–2012. *Global Food Security, 5*, 62–69.

Sakurai, T. (2006). Intensification of rainfed lowland rice production in West Africa: present status and potential green revolution. *The Developing Economies, 44*(2), 232–251.

Seboka, B., & Deressa, A. (1999). Validating farmers' indigenous social networks for local seed supply in central Rift Valley of Ethiopia. *The Journal of Agricultural Education and Extension, 6*(4), 245–254.

Seck, P. A., Tollens, E., Wopereis, M. C. S., Diagne, A., & Bamba, I. (2010). Rising trends and variability of rice prices: threats and opportunities for Sub-Saharan Africa. *Food Policy, 35*, 403–411.

Somado, E. A., Guei, R. G., & Keya, S. O. (2008). *NERICA: The new rice for Africa: A compendium*. Cotonou: Africa Rice Center (WARDA).

Sperling, L., & Loevinsohn, M. E. (1993). The dynamics of adoption: distribution and mortality of bean varieties among small farmers in Rwanda. *Agricultural Systems, 41*(4), 441–453.

Tripp, R. (2001). Can biotechnology reach the poor? The adequacy of information and seed delivery. *Food Policy, 26*(3), 249–264.

van Mele, P. V., Bentley, J. W., & Guéi, G. (eds.) (2011). *African seed enterprises: sowing the seeds of food security*. Cotonou: Africa Rice Center; Rome: Food and Agriculture Organization of the United Nations; Wallingford: CAB international.

Witcombe, J. R., Petre, R., Jones, S., & Joshi, A. (1999). Farmer participatory crop improvement. IV. The spread and impact of a rice variety identified by participatory varietal selection. *Experimental Agriculture, 35*, 471–487.

World Bank. (2007). *World development report 2008: Agriculture for development*. Washington: The International Bank for Reconstruction and Development/The World Bank.

Tomonori Yokouchi is a Ph.D. candidate in Agriculture at The University of Tokyo, Japan. He has worked on activities that contribute to improving rice farmers' livelihoods for 2 years as a JOCV (Japan Oversea Cooperation Volunteer). In 2009, he participated in a training program "Description of farmers' cropping practices in relation to upland NERICA in Central Benin" at Africa Rice Center (AfricaRice) through the Japan CGIAR Fellowship Program 2009–2010.

Kazuki Saito is a principal scientist at Africa Rice Center (AfricaRice). He is an agronomist and agro-physiologist with over 10 years experience of working in Asia and Sub-Saharan Africa. Currently, he is leading the Africa-wide Rice Agronomy Task Force involving 21 member countries. He has authored and co-authored more than 50 scientific papers in peer-reviewed journals/book chapters. He received his PhD in Agriculture from Kyoto University, Japan, in 2005 with research on description, constraints and improvement of slash-and-burn upland rice production systems in northern Laos.