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The adoption of NERICA rice varieties at the initial stage of the diffusion process in Uganda

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Abstract

A new high-yielding upland rice variety known as New Rice for Africa (NERICA) has been recognised widely as a promising technology for addressing the food shortage and poverty problems in sub-Saharan Africa. This, however, is no guarantee for NERICA's widespread adoption. This study attempts to assess the major determinants of the adoption of NERICA in the early stages of its diffusion in Uganda. Contrary to common belief, we found that asset endowment did not affect farmers' adoption of NERICA. This is likely because of government intervention under a programme that promoted domestic rice production through the free distribution of seed or as in-kind credit, coupled with an absence of farmers' investment in complementary inputs such as fertilizer and irrigation. However, as expected, membership of farmers' groups increased the probability of adopting NERICA. The government programme promoting NERICA significantly increased its adoption rate, although the lack of extension services, training in post-harvest treatment and better management practices for rice cultivation limited the yield of and income from NERICA.

Keywords: technology adoption, NERICA, Uganda

1. Introduction

Rapid urbanisation and population growth in many African countries have caused the demand for rice to grow at a higher rate than domestic rice production (Africa Rice Center, 2008), with a resultant increase in rice imports and foreign exchange outflow. .The New Rice for Africa (NERICA) was introduced in Uganda in 2002 as one of the government's strategies to achieve its overarching development goals of reducing poverty and improving food security. NERICA is a new, high-yielding variety of upland rice developed to suit the African environment by combining resistance to African rice pests, diseases and water stress with the high yield potential of the Asian species (WARDA 2001a).

Monty Jones, a breeder of NERICA, argues that NERICA's yield is as high as 2.5 tons per hectare under low inputs, and 5 tons or more with prudent fertilizer use under research station conditions

(WARDA 2001b). Kijima *et al.* (2006) found the average on-farm yield of NERICA in 10 NERICA-growing areas of Uganda to be 2.6 tons per hectare under low input rain-fed conditions. Given that the average yield of traditional upland rice in Africa is 1 ton per hectare, these yield data suggest that, if widely adopted, NERICA could achieve remarkable yield improvements and contribute significantly to Uganda's development goals of poverty reduction and food security improvement.

This high-yielding attribute of NERICA, however, does not guarantee high adoption rates. A NERICA adoption study conducted in Cote d'Ivoire in 2000 found the adoption rate to be only 4% (Diagne 2006), suggesting that its high-yielding attribute may not be enough to spur a high adoption rate. This paper presents evidence on the adoption of NERICA and its determinants in rural Uganda, three years after it was introduced, largely because of its high-yielding attribute and potential to increase farm income and reduce poverty. Contrary to the common belief that poverty (lack of assets) deters farmers from adopting new technologies (Feder *et al*. 1985), this paper shows that, in the early stages of NERICA's diffusion in Uganda, poor households were not at a disadvantage compared to their non-poor cohorts as far as NERICA adoption was concerned.

The rest of the paper is organised as follows. The remaining part of the introduction section discusses the history of rice production in Uganda and the national adoption rate for rice (NERICA and non-NERICA) in 2005. The methodology section describes the sampling procedure, data used, and sources and analysis of the data; followed by the results section. The paper ends with a discussion of policy implications and draws conclusions.

1.1 The history of rice production in Uganda

In1970, the government of Uganda recognised the need to promote rice production by establishing large commercial farms at Kibimba (Bugiri district), and smallholder farmer-managed schemes at Doho (Tororo district) and Olweny (Lira district), where paddy (lowland) rice is cultivated. Since then, the acreage under rice in Uganda has increased steadily, especially in the densely populated districts of Eastern Uganda, where a shortage of land has forced people to cultivate and degrade wetlands. Among other factors, the steady rise in food prices in both urban and rural areas has contributed to the increases in rice acreage. The planted area has nearly doubled, from 39 000 hectares in 1990 to an estimated 72 000 hectares in 2000 (Uganda Bureau of Statistics 2002), and is currently estimated at 90 000 hectares (Uganda Bureau of Statistics 2012).Although government support for rice production was limited to paddy rice until the early 2000s, farmers in Northern and Eastern Uganda were keen on upland rice production using traditional varieties. In 2000, half of the total estimated area of 46 300 hectares under upland rice in Uganda was found in Gulu district in Northern Uganda (Agribusiness Development Center 2001). However, following the introduction of NERICA in Uganda in 2002, little was known about its adoption relative to existing, traditional upland varieties. This paper fills the information gap on NERICA adoption and the determinants of its adoption in the early stages of its diffusion process in Uganda.

1.2 Adoption rate of rice in Uganda based on the REPEAT 2005 Survey

The adoption rate of rice in Uganda was estimated using data gathered through a nationally representative household survey, in which the surveyed households were drawn randomly from six agro-climatic zones with different market access and population density (Pender *et al*. 2004;

Yamano *et al*. 2004).This survey was conducted for the first time in 2003, and repeated in 2005,by the Foundation for Advanced Studies on International Development (FASID) and Makerere University under the project, Research on Poverty, Environment, and Agricultural Technology Project (REPEAT).The survey covered 29 districts and 94 local council ones (LC1s – the lowest administrative unit in Uganda).From each LC1, ten households were selected randomly to give a total of sample 940 households. However, only 894 of these households participated in the REPEAT survey of 2005, and it is on these that the results presented in Table 1 are based.

Table 1: Adoption of rice production in Uganda

	Total	**Western Region**	**Central Region**	**Eastern Region**
Number of observations	894	213	278	403
Adoption rate (all rice)	6.26	0.47	2.16	12.16
Number of households growing:				
Lowland rice	41	0	0	41
Upland rice	15	1	6	8
Number of households with rice-growing experience (in years):				
≤ 1 year	16	1	3	12
> 1& ≤ 3 years	17	0	3	14
> 3 & ≤ 10 years	12	0	0	12
> 10 years	9	0	0	9

Source: REPEAT Survey Data (2005)

Table 1shows that, in 2005, the adoption rate for rice (NERICA and non-NERICA) in Uganda was very low, estimated at 6.3%.The rate was highest in the Eastern region (12.2%) and lowest in the Western region (0.5%). In the Eastern region, the production of lowland rice was more common than upland rice. At the time of the REPEAT survey in 2005, 30% of the rice growers (N = 54) had started growing rice less than one year earlier, which suggests that the adoption of rice production, although very low at that time, was increasing.

The REPEAT survey of 2005 asked farmers how much they knew about NERICA. The findings show that: (1) 64% of sampled households (574 out of the 894 households) had heard about an upland rice variety that matures in a short period (approximately three months – one of the characteristics of NERICA); (2) among those who had heard about it, however, only 2.6% (15 households) knew the variety name;(3) only 10 of these 15 households knew where to acquire NERICA seeds; and (4) only six households had grown NERICA. Thus, based on the REPEAT survey sample, the national adoption rate of NERICA rice was 0.67% in 2005. These findings suggest very limited awareness of NERICA rice in Uganda in 2005, which explains its low adoption rate.

2. Methodology

2.1 Sampling procedure, data and sources

Building on the REPEAT survey results, which showed a very low adoption rate for NERICA at the national level (0.67%), a NERICA-specific survey was conducted in 2005. This survey intentionally focused on the NERICA-growing areas in order to select a relatively large number of NERICA

adopters on which to conduct more rigorous statistical analysis of the adoption of NERICA, and the determinants of such adoption.

A stratified random sampling scheme was used to enable the capturing of a large number of NERICA-growing households. After identifying districts and areas with NERICA dissemination programmes, 10 areas covering Central and Western Uganda were selected[1].Information was then collected on the names and number of households that grew NERICA during the second cropping season of 2004 (referred to as "NERICA households" hereafter) from the LC1 and NERICA seed distribution offices. From each of the selected 10 areas, a random sample was drawn of 25 NERICA households and 15 households that did not grow NERICA in the second cropping season of 2004 ("non-NERICA households" hereafter), to make a total sample size of 400 households (250 NERICA and 150 non-NERICA). It is from these that primary data was gathered using a structured questionnaire on household demographic characteristics, asset endowment, production of NERICA, non-NERICA rice and other crops and livestock, use of labour and other inputs, income from rice and other sources, access to markets, agricultural extension and training, etc.

To control for over-sampling of NERICA households, sampling weights were used to compute descriptive statistics and conduct regression analysis, where the sampling weight for NERICA households of area *i* was calculated as the ratio of the total number of NERICA households in area *i* over the number of sampled NERICA households in that area. Similarly, the sampling weight for non-NERICA households of area *I* was calculated as the ratio of the total number of non-NERICA households in area *i* over the number of sampled non-NERICA households in that area. In the sample areas, the adoption rate for NERICA was 16.5%, which, although much higher than the national adoption rate, is still low, suggesting that even in the areas where NERICA was disseminated, the majority of households had not yet adopted it at the time of the survey in 2005. The question is why? Answering this question is the main objective of this paper.

The paper undertakes to explain the low rate of NERICA adoption soon after it was introduced in Uganda, recognising that it is not NERICA adoption per se that is of most concern to rural people and policy makers, but rather its ultimate impact on livelihood goals (such as household income and food security). The impact of NERICA on income and poverty in Uganda is explained in another paper (Kijima *et al*. 2008).

2.2 Data analysis

Conceptually, data analysis and hypothesis testing in this paper are guided by:
(1) The theory of behaviour of agricultural households under imperfect market conditions, which make production and consumption decisions inseparable and lead to variations across households in resource allocation and outcomes (De Janvry *et al*. 1991). (2) The literature on social learning and technology diffusion, which argues that the process of learning about a new technology is social,

[1] The selection of areas was made so as to achieve a broader geographical cover and to capture areas with different rice-growing experience. Districts in Northern Uganda were avoided because of insecurity. Because the major rainy season is different between Eastern Uganda (February to June) and the other regions (August to November), eastern districts were not included in the sample. The selected districts were Masindi, Kibaale, Kamwenge, Hoima, Mabarara, Wakiso, Mpigi, Mubende, Kiboga and Luwero. Half of these districts started growing NERICA in 2004.

with farmers accessing information and learning about new technologies through social networks whose constituent links are not based solely on geographic proximity (Conley &Udry 2001).

Because of imperfect markets, household endowment of capital or assets (physical, natural, financial, human and social) and labour availability affect the household's incentives and capacity to adopt new technologies that require out-of-pocket expenditure and high labour input (Reardon *et al*, 1995). Feder *et al*. (1985) observed that asset endowment has a strong impact on the adoption of new technologies, because a lack of cash and other assets (poverty) reduces the ability to pay for new technologies. Also, because of imperfect labour markets and the heavier labour requirement in rice production compared to other food crops (e.g. maize and beans),it is likely that the availability of family labour also affects the adoption of NERICA.

Beside asset endowment, Feder *et al*. (1985) identified access to information and attitude towards risk as key factors affecting the decision to adopt new technologies. This is because inability to access full information about a new technology makes its adoption more risky than the use of existing technologies, and may deter poor farmers (who tend to be more risk averse) from adopting new technologies. Social networks such as farmers' groups and organisations tend to facilitate the flow of information needed for technology adoption.

Following from the adoption literature discussed above, the following hypotheses are tested in this paper:

(i) Accessibility to information through social networks increases the probability of adopting NERICA rice.
(ii) Asset endowment significantly increases the probability of adopting NERICA rice.
(iii) Family labour endowment significantly increases the probability of adopting NERICA rice.

To test these hypotheses, the survey data were analysed to generate summary statistics of the factors hypothesised to affect NERICA adoption and to fit a probit model to determine the effect of these factors on the probability of adopting NERICA rice. Student T-tests were conducted on the summary statistics to determine which variables have significantly different means.

3. Results

Table 2 summarises the characteristics of the sampled NERICA and non-NERICA households. First, we look at the differences in rice-growing experience, since rice is a relatively new crop in Uganda. On average, NERICA households had more rice (non-NERICA rice) growing experience than non-NERICA households. This suggests that familiarity with rice growing likely decreases the risk of growing NERICA and increases its adoption.

There are other notable differences between NERICA and non-NERICA households. First, NERICA households were more likely to be members of farmers' organisations than non-NERICA households. This suggests that, in the absence of sufficient knowledge about NERICA, local organisations play a critical role in enabling their members to share information about their experiences in growing NERICA and about its availability, which likely enhances adoption. The relationship between membership of farmers' organisations (a proxy for accessibility to information on NERICA) and NERICA adoption is tested further using regression analysis.

Second, the heads of NERICA households were more educated than non-NERICA households, suggesting that education enhances the ability to access, process and use information related to NERICA. Furthermore, during the NERICA survey we found that NERICA dissemination projects in Uganda were using hand-outs and brochures written in English, which could have deterred the less educated from adopting NERICA. The relationship between formal education of the household head and NERICA adoption is tested further using regression analysis.

Third, female-headed households were more likely to be among non-NERICA than NERICA households, probably because women in Africa tend to be disadvantaged in terms of access to information and the inputs needed to adopt new technologies.

Fourth, NERICA households had larger families than non-NERICA households, and the total land size was greater for NERICA than non-NERICA households. However, there was no significant difference in the total land size per household member, or the land-labour ratio, between NERICA and non-NERICA households. Since land size per household member was found to be positively correlated with household income in the study sample (Kijima *et al*. 2008), this finding may suggest that, with regard to NERICA adoption, poorer households (with lower land per capita endowment) may not be as disadvantaged as one would expect. There was also no significant difference in household and livestock assets between NERICA and non-NERICA households, contrary to the common belief (Feder *et al*. 1985) that asset endowment has a strong impact on the adoption of new technologies. The insignificant difference is likely because NERICA was produced without chemical fertilizer and capital investment such as irrigation facilities, which would otherwise make it dependent on asset endowment. Besides, many new NERICA farmers did not have to purchase the initial seed because it was given free or as in-kind credit under the Vice President's Initiative (VPI) – a programme promoting domestic rice production through the free distribution of seed or as in-kind credit.

Fifth, market access, measured by distance to the nearest input supplier, also did not differ significantly between NERICA and non-NERICA households. This is also likely because many farmers obtained their NERICA seed not from input suppliers, but rather through the VPI programme mentioned above.

Table 2: Descriptive statistics of NERICA and non-NERICA households

	Non-NERICA households	NERICA households		NERICA households in RED	NERICA households in NRED	
	-1	-2	-3	-4	-5	-6
Years of experience of growing non-NERICA rice before 2nd season in 2004	0.063 (0.198)	0.467 (0.901)	**	0.553 (0.977)	0.207 -0.607	**
Years of experience growing NERICA	0	2.194 (3.810)	--	2.864 -4.116	0.454 -2.058	**
Proportion of households with a member in an organisation (non-rice)	0.395 (0.490)	0.872 -0.334	**	0.867 -0.341	0.887 -0.318	
Age of household head	45.7 (15.8)	42.9 (13.5)		40.2 (12.4)	50.1 (13.8)	**
Years of formal education of HH head	4.47 (3.11)	7.15 (4.04)	**	7.21 (4.14)	7.00 (3.80)	
Female-headed household = 1	0.351 (0.478)	0.079 (0.27)	**	0.05 (0.22)	0.150 (0.36)	*
Number of household members	5.82 (3.11)	7.69 (3.53)	**	7.48 (3.76)	8.25 (2.81)	
Proportion of male adults aged 15 – 59	0.229 (0.221)	0.243 (0.164)		0.258 -0.169	0.204 -0.146	
Proportion of female adults aged 15 – 59	0.250 (0.228)	0.213 (0.147)		0.210 (0.154)	0.222 -0.125	
Value of livestock (‘000 Uganda Shs)	374.3 (1104.6)	472.9 (805.6)		432.1 -790.2	578.8 -840.8	
Household assets (‘000 Uganda Shs)	236.6 (1533.8)	238.3 (595.7)		208.8 (404.6)	314.9	

					-920.8	
Total land accessed (ha)	2.39 (2.15)	4.15 (4.01)	**	4.39 (3.97)	3.55 (3.99)	
Total land per household member	0.516	0.566 (0.479)		0.61	0.452	*
	-0.553			-0.481	-0.46	
Distance to nearest input supplier (km)	6.76 (7.29)	8.10 (8.81)		8.33 (7.83)	7.49 (11.00)	
Number of observations (households)	150	250		120	130	

Note: ** and * in columns (3) and (6) indicate statistical significance of the differences in means of columns (1) and (2) and columns (4) and (5) respectively, at the 1% and 5% levels. Household assets include means of transport (bicycle, car, motorbike), cell phone, radio, TV and water tanks. Livestock include cows, bulls, goats, pigs and chickens.RED (rice-experienced districts) indicates areas where NERICA was introduced earlier than 2004 (Kibaale, Kamwenge, Hoima, Luwero districts), while NRED (non-rice-experienced districts) indicates areas where NERICA was introduced in 2004.

The results of the regression analysis on the determinants of NERICA adoption[2] are presented in Table 3. The coefficients represent the marginal effects of the explanatory variables on the probability of NERICA adoption.

Table 3: Determinants of adoption of NERICA (probit model)

	All(1)	RED(2)	NRED(3)
Membership in non-rice group = 1	0.173 (4.88)**	0.239 (2.87)**	0.126 (3.89)**
HH head's characteristics			
Formal education (years)	0.010 (2.54)*	0.034 (2.72)**	0.002 (1.56)
Female = 1	-0.061 (1.72)	-0.122 (1.02)	-0.021 (1.56)
Age (years)	0.058 (0.61)	-0.032 (0.11)	0.035 (0.81)
Number of household members	0.012 (2.59)**	0.021 (1.58)	0.004 (2.12)*
Proportion of male members aged 15 – 59	0.099 (0.98)	0.269 (0.86)	0.016 (0.35)
Proportion of female members aged 15 – 59	-0.084 (0.95)	-0.422 (1.63)	0.022 (0.46)
Land per household member (ha)	0.011 (0.44)	0.010 (0.14)	0.001 (0.06)
Value of livestock assets (hundred million shillings)	0.236 (0.15)	-0.744 (0.13)	-0.299 (0.58)
Household assets (hundred million shillings)	-1.589 (0.62)	-14.276 (1.65)	0.081 (0.29)
Distance to nearest input supplier (km)	-0.002 (0.96)	-0.010 (2.10)*	0.001 (0.92)
District dummies	Yes	Yes	Yes
Observations	410	181	229
R-squared or pseudo R-squared	0.38	0.27	0.47

Note: ** and * indicate statistical significance at the 1% and 5% levels. Coefficients are marginal probability (dF/dX). RED (rice-experienced districts) indicates the areas where NERICA was introduced earlier than 2004, while NRED (non-rice-experienced districts) includes the areas where NERICA was introduced in 2004.

Column (1) uses all the sample households, while the specifications of columns (2) and (3) use the sub-sample of the households in areas where NERICA was introduced earlier than 2004 and in 2004 respectively. The reason for estimating the adoption function using these sub-samples is that NERICA promotion efforts, particularly under the VPI in areas where it was introduced in 2004,were meant to target poorer households, which implies that the determinants of NERICA adoption could be different between these sub-samples.

As shown earlier in the summary statistics, membership in farmers' groups and formal education increased the probability of adopting NERICA, which suggests that, at the initial stage of the diffusion process, access to information is critical for enhancing adoption. In other words, the low adoption rate for NERICA at the national level could be attributed to limited information and a weak extension network.

[2]The information from the NERICA survey indicates that 70% of non-NERICA households had heard about NERICA, but a lower proportion (51%) of non-NERICA households knew where to acquire seeds. It therefore is possible that some non-NERICA households could have adopted if they had the information about NERICA and where to acquire seed. Thus, we cannot rule out the possibility of un-exposure bias when estimating the sample adoption rate (Diagne 2006).

The number of household members significantly increased the probability of adopting NERICA, most likely because rice is a labour-intensive crop. The regression results also corroborate what was observed earlier in the discussion of summary statistics, that total land per household member, livestock and household assets did not have a significant effect on the probability of adopting NERICA.

4. Conclusions and Policy Implications

The adoption of a new technology is a central feature of the transformation of farming systems during the process of economic development (Conley &Udry 2001), and is credited with bringing about the Asian Green Revolution. Because poverty in Uganda is predominantly rural, widespread adoption of the high-yielding NERICA rice varieties would likely increase incomes (and reduce poverty) among rural households, thereby spurring rural development. However, evidence from Cote d'Ivoire (Diagne 2006) suggests that the high-yielding attribute of NERICA may not be sufficient for its widespread adoption.

This paper analysed the determinants of adoption of NERICA soon after its introduction in Uganda to draw lessons on how to enhance its adoption rate. The results suggest that assets were not a serious constraint to the adoption of NERICA at the onset of its diffusion. This finding contradicts existing knowledge about the importance of assets in the adoption of new technologies. It is partly because NERICA production in Uganda did not require capital at that time (i.e. there was no use of purchased inputs such as fertilizer) and partly because of government efforts to popularise NERICA through the distribution of seed on credit or free of charge. Assets were unimportant even in the rice-experienced districts (RED), where government efforts did not necessarily target the poor. This suggests that the reasonable performance of NERICA under low input conditions makes it a pro-poor crop, at least in the initial stages of the diffusion process. It was also found that, in the initial stage of the diffusion process, access to information was critical for the adoption of NERICA. Households with membership in farmers' groups that facilitate social learning through information sharing were more likely to adopt NERICA.

The VPI emphasised the promotion of NERICA through free distribution of seed or as in-kind credit. At the national level, however, NERICA awareness in 2005 was limited. Even among those with some knowledge of NERICA, many farmers did not have enough information on how to grow, harvest and dry it, which negatively affected the harvested yield and milling rate (Kijima *et al*. 2006), and thus the income realised from NERICA production. Thus, despite the great opportunity offered by NERICA, Uganda ran a big risk of not only failing to achieve higher rice yields, but also to translate these into reduced household poverty and food insecurity, if the problems of a weak extension system and lack of rice specialists to provide technical advice were not addressed.

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