International Journal of Agricultural Extension and Rural Development ISSN 3254-5428 Vol. 3 (7), pp. 207-213, July, 2016. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

A study on varieties upland rice that meet farmers' criteria using participatory varietal selection method

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Accepted 11 June, 2016

In Senegal, rice plays a critical role for smallholder farmers by providing food security. However, rice production is very low compared to the high needs of the population. This might be explained to some extent by the use of not adapted and low yielding varieties. This study aimed at identifying the best upland rice varieties that meet farmers' criteria using participatory varietal selection method in order to speed up their early adoption and therefore increase upland rice diversity in the Southern and South-Eastern part of the groundnut basin agro-ecological zone. In total, 30 varieties including NERICA 6 as standard check were evaluated at ISRA Nioro research station. At flowering time, 29 farmers including both men and women were invited to participate in the selection process. Farmers classified upland rice varieties' selection criteria according to the order of importance: Earliness, moderate plant height, high yield and termite tolerance respectively. The most chosen varieties by farmers were NERICA 8 and ART16-13-13-2-2-B-1-B-1-B. For all the agronomic traits, the genotypes showed a highly significant variation. The high yielding varieties were CNAX 3031-78-2-1-7 and JOPYEONG which yielded respectively 48 and 44% more than the check. In general, the ranking according to farmers' choice was not in agreement with the method using grain yield. Based on agronomic performances, farmers and breeders selections, few varieties were selected and should be evaluated under multi-location trials in farmer' fields for two seasons, before undergoing for a release process.

Key words: Rice, participatory varietal selection, groundnut basin, Senegal.

INTRODUCTION

Rice is among the major food crops in Africa where it plays a critical role in smallholder farmers' food security. In 2013, the overall paddy rice production was estimated at around 741 million tons, representing more than 26%

of the overall cereals production (FAO, 2014). In sub Saharan Africa countries, rice demand has increased from 1.9 to 5.8 million tons during the past two decades (Ogunbayo et al., 2007, 2005). This high rice demand has resulted in a food crisis observed in 2008. In response to this world crisis, several West African countries have adopted strategies such as the use of improved seeds and better technical assistance to rice farmers (Seck et al., 2012).

In West Africa, Senegal is the seventh most important rice producer and one of the largest rice consumers, with more than 50% of total cereals consumed (FAO, 2014; Gergely and Baris, 2009). In 2011, rice consumption exceeded 1.14 million tons with an average per capita consumption of 92 kg (Demont and Rizzotto, 2012). Despite the importance of this cereal, the level of self-sufficiency is low compared to the overall leading to a huge proportion of the population which cannot meet its food needs. Consequently, a production gap was notices and needed to be supplemented annually by rice importation. This explains why Senegal is the third largest rice importer in Africa, after Nigeria and Ivory Coast (FAO, 2014). In 2013, the imported milled rice was estimated at around 918 897 tons which worth around US$ 250 million (ANSD, 2014). This high dependence is a source of food insecurity and has attracted the attention of governments as well as their partners. To close such a widening gap between supply and demand, the Senegalese government has developed a nationwide rice program for self-sufficiency by 2017. This program has established a contribution for each of the Senegalese agro-ecological zone. The Southern, South-eastern and South central (groundnut basin) parts of the country where rainfed rice is mainly produced should contribute for 40% of the total paddy rice production. In the groundnut basin, this has the largest agricultural land (60%) and total cereal production (40%), agricultural production dependents on climatic and soil conditions. Lands allocated for rice production are in a small portion and grain yield is very low with around 1000 kg ha^{-1} (DAPS, 2014). This low yield might be due to the use of no adapted and low yielding varieties, inappropriate technologies, and environmental constraints (low soil fertility, rainfall variation, etc.). In fact, the national rice breeding program with their different partners has released up to eight upland rice varieties having a mean yield potential of around 4 t ha^{-1} (MAER, 2012). However, these varieties have not been aggressively and widely popularized by farmers in the groundnut agro-ecological zone. This situation might be explained by the fact that these varieties are not well suitable for farmers' needs, preferences and conditions. This has been pointed out as one of the reasons for the low adoption of improved varieties in subsistence and small scale farming systems (Nkongolo et al., 2009; Röling et al., 2004). Thus, farmers' needs and preferences have to be identified and incorporated in the breeding process of any given crop so that they can test the right varieties. This can be done by using participatory varietal selection (PVS) process.

This technique has shown success in identifying farmers' preferred varieties, their wide dissemination and may help breeders to identify farmers' constraints and preferred traits in short time (Ceccarelli et al., 2007; Gyawali et al., 2007; Mulatu and Belete, 2001). It has been also demonstrated that this technique is more effective in terms of cost and transferring the right varieties to farmers. Mangione et al. (2006) have demonstrated that there is no significant difference in overall costs between participatory plant breeding and non-participatory plant breeding of barley. They found also that this technique provided more information compared to non-participatory plant breeding at the same cost.

The Senegalese Agricultural Research Institute (ISRA) was engaged to identify and/or develop farmers' preferred and adapted upland rice varieties which are high yielding and tolerant to biotic and abiotic stresses in the groundnut basin of Senegal and thus contribute to rice self-sufficiency by 2017. To identify these preferred varieties and have a better understand on rice farmers' preferences traits, a participatory varietal selection technique coupled with an agronomical evaluation was conducted.

MATERIALS AND METHODS

The study was conducted at ISRA Nioro Research station (13°45'27" N; 15°47'18" W) in 2015 rainy cropping season using 30 upland rice varieties from different origins including NERICA 6 as a standard check (Table 1). The trial was laid out in a randomized complete block design with three replications. Sowing was done with spacing of 25 cm between rows and 20 cm between plants within a row in plots of six lines of five meters for each evaluated variety. A 15N-15P-15K fertilizer at a rate of 200 kg ha^{-1} was applied before sowing. During the crop development a top dressing using urea (150 kg ha^{-1}) was done twice (100 kg ha^{-1} at 20 days after sowing (DAS) and 50 kg ha^{-1} at 45 DAS). All the recommended cultural practices were applied.

A field day was organized at flowering stage where farmers were invited to evaluate the new rice varieties. Farmers from Fatick, Kaolack and Kaffrine regions, located in the southern and south-eastern part of the groundnut basin agro-ecological zone (Figure 1) were randomly selected and in overall, 29 rice farmers were involved. No ethical issues, as defined in the EU 7th Framework Program guide to applicants were identified for this study. During the participatory varietal selection process , farmers were assisted

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Table 1. List of upland rice entries evaluated at Nioro Research Station.

Entry	Variety name	Origin
1	ART15-21-23-1-3-1-1-B-1-B	AfricaRice
2	ART15-21-32-4-1-1-4-B-1-B	AfricaRice
3	ART15-21-56-2-1-1-1-B-1-B	AfricaRice
4	ART16-9-4-18-3-2-1-B-1-B	AfricaRice
5	ART16-4-13-1-2-1-1-B-1-B	AfricaRice
6	ART16-9-29-12-1-1-2-B-1-B	AfricaRice
7	ART16-12-22-1-3-1-1-B-1-B	AfricaRice
8	ART16-13-13-2-2-B-1-B-1-B	AfricaRice
9	ART16-17-7-18-1-B-1-B-1-B	AfricaRice
10	ART3-7-L3P3-B-B-2	AfricaRice
11	ART3-7-L9P8-1-B-B-1	AfricaRice
12	ART3-11-L1-P1-B-B-2	AfricaRice
13	BRS SORTANEJA	Brasilia
14	BRS PEPITA	Brasilia
15	BRS CARAJAS	Brasilia
16	BRS CONAÏ	Brasilia
17	BRS PRIMAVERA	Brasilia
18	NERICA 4	AfricaRice
19	NERICA 8	AfricaRice
20	NERICA 14	AfricaRice
21	NERICA 11	AfricaRice
22	WAB 609-43-1-1-HB	AfricaRice
23	WAB 775-21-5-2-HB	AfricaRice
24	WAB 804-23-11-2-HB	AfricaRice
25	ART3-9-L6P2-B-B	AfricaRice
26	ART3-7-46-B-B-3	AfricaRice
27	CNAX 3031-78-2-1-7	Unknown
28	JOPYEONG	Korea
29	K1	Korea
30 (Check)	NERICA 6	AfricaRice

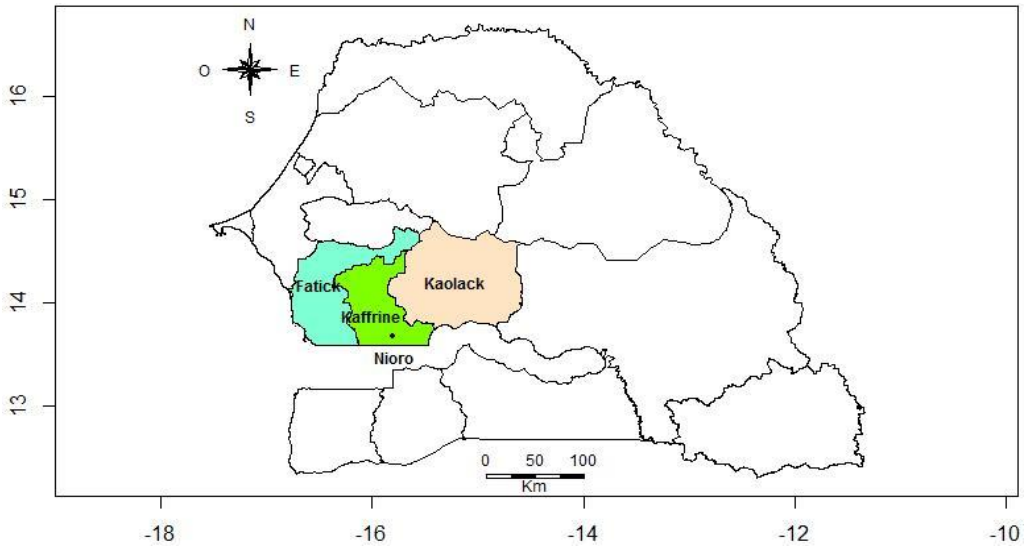

Figure 1. Localization of the regions and experimental site in the south and south-eastern groundnut basin of Senegal.

Table 2. Description of sampled farmers from 3 regions in the south and south-eastern groundnut basin of Senegal (n = 29).

Variable	Region			Total	Percentage
	Fatick	Kaolack	Kaffrine		
Gender					
male	2	5	9	16	55
Female	6	7	0	13	45
Level of education					
illiterate	7	10	6	23	79
Primary	0	2	2	4	14
Secondary	1	0	1	2	7
Age					
<35	3	3	4	10	35
35-50	3	4	3	10	34
>50	2	5	2	9	31

Table 3. Chosen upland rice varieties (n = 29).

Entry	Region			Total	Percentage
	Fatick	Kaolack	Kaffrine		
NERICA 8	7	12	5	24	83
ART16-13-13-2-2-B-1-B-1-B	5	9	8	22	76
JOPYEONG	4	8	4	16	55
ART3-7-L3P3-B-B-2	5	5	6	16	55
NERICA 4	1	0	1	2	7
NERICA 6	0	0	1	1	3
ART3-7-L9P8-1-B-B-1	0	1	1	2	7

by researchers from ISRA and experts from the NGO Symbiose. Before starting the field evaluation, farmers were grouped in order and set principal criteria which they would like to see into a newly bred cultivar. These criteria were termite resistance, plant height, earliness and grain yield. Farmers discussed and all these criteria were ranked in the order from 1 to 4 according to their importance by each farmer for selecting a new variety Characteristic with smallest rank is considered to be the most important while the one with higher rank is perceived to be less important in choosing a new variety. Farmers were also asked to give an overall assessment of tested varieties and select two to three varieties that they would like to grown in their rice field. In addition to farmers' evaluation, an agronomical evaluation was conducted and all agronomic data were collected and subjected for analysis of variance using SAS software, version 9.2.

RESULTS AND DISCUSSION

The description of sampled farmers chosen for the participatory varietal selection (PVS) in the three regions is given in Table 2. The sampled rice producers who assisted to the PVS included 55.5% male farmers. However, the male proportion is relatively lower in Fatick (25%) and in Kaffrine no female has participated to the PVS. In fact, farming activities are perceived to be very tedious in this part of the country and this may explain why crop production is dominated by males. The greater majority of the rice farmers (79%) did not have any form of formal education. Only a small fraction (21%) of them had some form of formal education with 14% educated up to primary level and 7% up to secondary level. Rice production in the study area involves mainly farmers in their middle ages. The majority of them (69%) were less than 50 years. This result is interesting and might boost efforts to improve rice production in this part of the country In fact, these are farmers who are targeted by various projects, NGOs and with their enthusiasm they are more likely to invest in new technologies.

At flowering time, farmers were invited at Nioro research station to evaluate and chose varieties based on their own established criteria. As indicated in Table 3, among the total of 30 tested upland rice entries, seven including the check were chosen by the farmers who participated in the PVS. Out of the seven rice varieties selected, NERICA 8 and ART16-13-13-2-2-B-1-B-1-B originated from AfricaRice were the most preferred by farmers across the project locations, followed by ART3-7-

Table 4. Mean rank of the most important preferred traits of upland rice cultivars.

Characteristics*	Region			Mean	Rank
	Fatick	Kaolack	Kaffrine		
Short duration	1.6	2.3	1.6	1.8	1
Plant height	2.0	1.7	2.5	2.1	2
High yield potential	2.6	2.2	2.8	2.5	3
Termite Resistance	3.8	3.8	3.0	3.5	4

*Characteristic with smallest mean rank within a column is perceived to be the most important.

L3P3-B-B-2 and JOPYEONG. NERICA 8 and ART16-13-13-2-2-B-1-B-1-B were chosen respectively by 83 and 76% of the farmers. The reasons behind farmers' preferences of these varieties are attributed to their high grain yield, early maturity and moderate plant height.

Farmers have shown strong interest in the use of early upland varieties because of the short rainfall season which characterize this part of the country (Table 4). Then, such varieties can escape easily drought. Besides earliness, the semi-tall stature and high yield potential could be found as the putative favorable attributes for preference into a new bred upland rice cultivar. In the study areas, farmers were less concerned about termite resistance and ranked fourth criterion in selected a cultivar. Farmers of this agro-ecological zone wanted intermediate plant height after early maturity and explained that short statured cultivars were more difficult to harvest than an intermediate cultivar. When harvesting an intermediate plant height they reduce the problem of bending down to cut the panicles, activity mainly done by women with a knife. Tallness was not desirable because of the associated problem of lodging. These results on preferred traits of upland rice varieties are in accordance with those of Efisue et al. (2008) and Virk et al. (2003). They reported that farmers in the upland ecology in the eastern part of India and in Sikasso region of Mali adopted rice cultivars that are early maturing, intermediate to tall plant height and high yield potential. It is imperative, therefore, for upland rice breeders to create and select upland rice varieties with early flowering, moderate plant height and having a high yield potential to meet food demand and contribute to rice self-sufficient goal by 2017.

Analysis of the data revealed highly significant variations among the tested upland rice varieties for all the agronomic traits observed and measured (Table 5). The tallest variety was ART15-21-32-4-1-1-4-B-1-Bwith 127 cm whereas the shortest were BRS PEPITA (74 cm) and JOPYEONG (75 cm). NERICA 8 (93 cm) and ART16-13-13-2-2-B-1-B-1-B (108 cm), the two most preferred by farmers, had moderate plant height. These results are in agreement with the rank of most important traits of upland rice cultivars done by farmers in this area where they indicated that the plant height is an important traits and ranked after earliness. The flowering time ranged from 55 to 74 days after sowing (DAS). Indeed, earliness is an important criterion in selecting an upland rice variety and might explain why JOPYEONG which flowered 55 DAS was selected. So, its selection was certainly driven by its early flowering time rather than the plant height. This variety can be improved for plant height in order to meet farmers' needs. All the other selected varieties flowered between 64 and 70 DAS. According to the mean values of grain yield, CNAX 3031-78-2-1-7 and JOPYEONG had the highest yield with 5821 kg ha^{-1} and 5662 kg ha^{-1}, respectively. They were significantly more productive than all the other varieties. This is in agreement with Kim et al. (2014) who reported that JOPYEONG, a multiple resistance variety to stripe virus, bacterial blight and blast, is a highly yielding variety. The grain yield of farmers' selected varieties during the PVS process ranged from 3362 kg ha^{-1} to 5662 kg ha^{-1} with a mean value of 4062 kg ha^{-1}. This average grain yield of 4 t ha^{-1}a is higher than the grain yield potential of some national released upland varieties (MAER, 2012). Only ART16-13-13-2-2-B-1-B-1-B, one of the farmers' selected varieties, was among the top ten high yielding varieties. Hence, the result clearly indicated why high yielding criterion was ranked third in selecting a new upland variety. The consistency of earliness and plant height as the most important criteria for selecting varieties indicated that these criteria should be considered as the major selection criteria in upland rice improvement programme targeting the groundnut basin in order to ensure varietal acceptance and adoption.

Conclusion

This study conducted in the groundnut basin agro-ecological zone in Senegal characterized upland rice varieties from diverse origins and examined farmers' preferences traits into newly bred cultivars. The results show that a number of new genotypes are better than the check NERICA 6 for yield and other characteristics that farmers considered to be important in selecting a cultivar to grow. Farmers prefer to have early maturing varieties with moderate plant height, high yielding and tolerant to termite. Farmers were not very concerned about termite tolerance as it was ranked fourth. Some of these farmers'

Table 5. Mean values and analysis of variance for agronomic traits.

Entry	Flowering (DAS)	Plant Height (cm)	Tiller	Harvest Index	Yield (kg ha^{-1})
ART15-21-23-1-3-1-1-B-1-B	71	110	7	0.2	2631
ART15-21-32-4-1-1-4-B-1-B	74	127	11	0.2	3952
ART15-21-56-2-1-1-1-B-1-B	72	105	8	0.3	3411
ART16-9-4-18-3-2-1-B-1-B	70	100	9	0.3	3784
ART16-4-13-1-2-1-1-B-1-B	66	95	11	0.3	3675
ART16-9-29-12-1-1-2-B-1-B	65	99	13	0.3	4095
ART16-12-22-1-3-1-1-B-1-B	69	119	12	0.3	4463
ART16-13-13-2-2-B-1-B-1-B	65	108	10	0.3	4609
ART16-17-7-18-1-B-1-B-1-B	68	110	12	0.3	4783
ART3-7-L3P3-B-B-2	65	111	9	0.3	3837
ART3-7-L9P8-1-B-B-1	64	94	10	0.3	3927
ART3-11-L1-P1-B-B-2	66	97	9	0.3	3706
BRS SORTANEJA	73	98	12	0.3	4306
BRS PEPITA	74	74	21	0.2	3670
BRS CARAJAS	69	117	14	0.2	3122
BRS CONAÏ	65	90	14	0.3	4401
BRS PRIMAVERA	69	116	9	0.2	1947
NERICA 4	70	103	11	0.3	3362
NERICA 8	67	93	12	0.3	3838
NERICA 14	64	102	14	0.3	4816
NERICA 11	68	106	9	0.3	4118
WAB 609-43-1-1-HB	74	97	13	0.2	3928
WAB 775-21-5-2-HB	71	120	9	0.2	3158
WAB 804-23-11-2-HB	74	78	22	0.1	3094
ART3-9-L6P2-B-B	71	103	10	0.3	4310
ART3-7-46-B-B-3	71	103	8	0.2	3532
CNAX 3031-78-2-1-7	73	116	11	0.4	5821
JOPYEONG	55	75	21	0.3	5662
K1	74	76	18	0.1	2716
NERICA 6	71	116	9	0.3	3926
CV (%)	2.437	10.0	15.0	18.1	22.2
Mean	69	102	12	0.3	3887
Standard error of mean	0.46	1.71	0.43	0.006	113.1
LSD (5%)	2.2	16.6	2.9	0.08	1409.3
Mean square variety	52.4***	567.2***	44.4***	0.009***	2002725***
Mean square error	2.2	103.5	3.23	0.002331	743550

*** = significant difference at the 0.001 probability level.

selected and high yielding varieties will be evaluated under multi-location trials in order to identify which one will be proposed for release.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors would like to thank Benjamin Badji, Bernabe Diatta and Ibrahima Dioum for their assistance in data collection and experts from Symbiose NGO for their assistance in organizing farmers' evaluation. This work was sponsored by the Korea Project on International Agriculture based in Senegal.

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