Journal of Developments in Sustainable Agriculture 4: 106-117 (2009)

Comparative Study on the Growth and Yield of NERICA Cultivated with Organic and Inorganic Fertilizers: Participatory On-Farm Research at Marakwet District in Kenya

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A participatory field study was conducted in Tunyo division, Marakwet district, Kenya, to investigate whether there would be a significant response of New Rice for Africa (NERICA) cultivars 1 and 4 to farmyard manure and chemical fertilizers. Seeds were directly sown in 2 m × 5 m plots at a depth of 2-3 cm and a spacing of 30 cm × 1.5 cm. The treatments included chemical fertilizer, organic fertilizer (farmyard manure), and control (no fertilizer). In the chemical fertilizer treatment, 2.5 g N m^{-2} was applied as compound fertilizer N: P: K (20: 12: 12) as basal fertilizer at planting, and 2.5 g N m^{-2} using urea (46: 0: 0) as topdressing at panicle initiation stage. In the organic fertilizer treatment, 10.6 g N m^{-2} from farmyard manure (N-0.53%, P-0.62%, K-1.35%) obtained from cattle droppings was applied at planting. The experiment was conducted in two farmers' fields using split plot design with two replicates. Data on days to seed emergence, panicle initiation, heading, flowering and maturity were collected. Plant height and tiller number data were recorded during vegetative growth stage. At harvest, panicle number, panicle length, grain number per panicle, weight of 1,000 grains and paddy yield were measured. Growth pattern, fertilizer response, and post harvest qualities of NEIRCA were evaluated by farmers by means of questionnaires and interviews. Focus group discussions to clarify on farmers' responses were held. Yield increased significantly with fertilizer application, and the yield of NERICA 4 was significantly higher than that of NERICA 1, irrespective of the treatment. Farmers evaluated NERICA 1 as having excellent tillering ability, excellent response to fertilizers, good growth vigor as measured by height and yield, excellent threshability and aroma, very good milling quality, and good eating qualities. Farmers also assessed NERICA 4 as having excellent tillering ability, excellent response to fertilizers, excellent growth vigor, excellent yield, excellent threshability and taste, very good milling properties, and good eating qualities.

NERICA 4 performed as well as or better than NERICA 1 in most attributes evaluated in this research. NERICA 1 was preferred for its aroma, while NERICA 4 earned the overall preference by farmer for cultivation owing to its superior yield. This research showed that the participation of farmers in field research strengthens the research-extension-farmer linkage, which could be expected to lead to faster technology transfer and uptake of new farming practices in Kenya.

Key words: eating quality, farmer participation, farmyard manure, food security, yield

Introduction

NERICA stands for New Rice for Africa and refers to a suite of interspecific cultivars of rice. It is a new high-yielding upland rice variety which has been widely recognized as a promising technology for addressing the food shortage in sub-Saharan Africa (Kijima *et al.*, 2006). NERICA was developed by the West Africa Rice Development Authority (WARDA) through the successful crossing of African rice, *Oryza glaberrima* L, and Asian rice, *Oryza sativa* L, to produce inter-specific progeny which combine the best traits of both parents, of higher yields, superior disease resist-

Received: October 1, 2009, Accepted: November 2, 2009
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ance, earlier maturity, reduced lodging, little or no shattering, good grain quality, adaptability to low soil fertility, higher protein content, and greater tolerance to drought than paddy rice (WARDA, 2001).

Rice in Kenya forms part of the larger diet for urban population and it is the third most important staple food in Kenya after maize and wheat. The consumption of rice in Kenya has increased while the production has fluctuated between 65,000 and 85,000 tonnes and the national demand is about 185,000 tonnes with an annual increase of about 12%. About 95% of the rice in Kenya is grown under irrigation with the remaining 5% of the rice is rain fed. The dominating rice ecosystems in Kenya are irrigated, rain-fed upland and rain fed-lowland. Irrigated rice require heavy investments, and therefore, rains fed ecosystems remain the viable option to small scale farmers who depend on rain fed farming (Kore *et al.,* 2007).

NERICA is a new crop, and was first introduced in Tunyo division (study area) during preliminary adaptive trials by joint initiatives of Japanese International Co-operation Agency (JICA) and African Institute for Capacity Development (AICAD) in 2005, and majority of farmers have inadequate information on its cultivation techniques. After NERICA adaptive trials in the target area, NERICA 1 (WAB 450-IBP-38-HB) and NERICA 4 (WAB 450-IBP-91-HB), were among four cultivars identified as promising, and suitable for cultivation in the study area.

The JICA-backed Community Agricultural Development in Semi-Arid Lands (CADSAL) project has been conducting capacity development in NERICA cultivation for farmers in the study area, mainly through seminars and seed multiplication (Tunyo Agricultural Office, un-published data).

Traditionally, agricultural research in Kenya is performed in research stations, where the facilities for conducting highly controlled experiments are excellent and easily accessible to the researchers, while technology dissemination was top-down, unidirectional process with little or no feedback from the farmers. The down side is that this involves very little or no involvement of the end-user, the farmer. The assumption has often been that the best technology in research stations is also the best for farmers' conditions; as a result, many technologies that could improve farm productivities were not adopted by farmers (Mureithi *et al.,* 2002). Farmers are more than merely the key actors in agricultural research program development; they are the actual owners of the information generated. The use of a methodological process-approach for Participatory Learning and Action Research (PLAR) improved observation skills of farmers to allow improved analysis and decision-making; discovery of agro-ecological principles in a social learning setting; sharing basic knowledge of technologies practices by farmers themselves, are important processes in strengthening, research-farmer linkages (Somado *et al.,* 2008).

Soils in the study area are declining in fertility and other physical qualities owing to inadequate soil conservation systems and diminishing soil organic matter. Farmers in the study area, have limited resources, and cannot sustain farming by use of chemical fertilizers whose prices are unstable and are ever increasing (Republic of Kenya; Ministry of Agriculture, 2007). The key underlying questions are; how sustainable is the use of chemical fertilizer and what is the significance of using farm yard manure from animal droppings which is readily available in most households in Tunyo division in farming?

The objectives of this research were; to asses yield performance and phenotypes of NERICA 1 and 4 under organic and chemical fertilizers in farm conditions, and to enhance the participation and capacity development of farmers through the PLAR approach.

Materials and Methods

Tunyo division (study area) is in the warm and semi-arid Kerio Valley at about 950 m above sea level to the East of Marakwet escarpment. Three landscape-ecological zones are recognized as Upper Mid Land zone 4 and 5 and Inter mid Land zone 6, which are named after topography, 'mosop' and 'keu' or 'highland' and 'lowland' (District Development Office, 2008 unpublished report). A participatory field study was conducted in the study area to investigate the effects of chemical and organic fertilizers to the germination, growth, tillering, heading, flowering and yield in NERICA 1 (WAB 450-IBP-38-HB) and NERICA 4 (WAB 450-IBP-91-HB) cultivars. The research consisted of two

sections, namely; (i) an on-farm participatory experiment to evaluation on NERICA yield performance and phenotypes, and (ii) participatory evaluation of NERICA field performance and eating qualities was done between August and December, 2008. A conceptual model illustrating the outline of this research is provided in Fig. 1. The farmers in this research defined, analyzed and presented their preferences and priorities regarding the crops and methods tested.

1. On-Farm Field Experiment with the Farmers

The sample size of the participating farmers was 25 farmers chosen randomly from the farming community in Tunyo division. The farmers were both females and males of different educational levels with small landholdings and different ages ranging between 26 years and 68 years. (See Fig. 6a, b, c and d).

The participating farmers did land clearance, land tillage, and experimental plot lay out. They also did seeding, weeding and supplementary irrigation. They helped in the harvesting and threshing the crop after harvesting. They also participated in milling and cooking demonstrations, and at many stages of the process collected data. Weeding was done twice by the farmers manually using hand hoes, at 20 and 50 days after seeding. The farmers patrolled the crops in shifts to deter birds attack and minimize their damage on the crop after grain filling stage. No pest or disease control was performed during the experiment. Newly germinated weeds after the first and second weeding were uprooted from the trial plots by use of hands.

The experimental design (Fig. 2) consisted of 6 plots, which were replicated twice using split plot design done in two farmer's farms. In the experimental layout, the uppermost adjacent plots were planted without fertilizer application (control), the middle adjacent plots were treated with manure, while the lower most adjacent plots were treated with chemical fertilizer. Experimental plots measured 5 m×2 m and were separated by 0.5 m wide paths between the treatments, and a 1 m path separating the cultivar plots. The crop spacing was approximately 30 cm×1.5 cm. Dry NERICA seeds were direct-drilled at a depth of 2–3 cm (Fig. 3), giving rise to 17 rows per plot and a plant population of about 222 plants m^{-2}. Chemical fertilizer was applied in two equal splits using 2.5 g N m^{-2} of compound fertilizer (N-20: P-12: K-12) as basal fertilizer at planting, and 2.5 g N m^{-2} using urea (46: 0: 0) as topdressing during panicle initiation stage. In the organic treatment plots, farm yard manure (N-0.53: P-0.62: K-1.35) obtained from

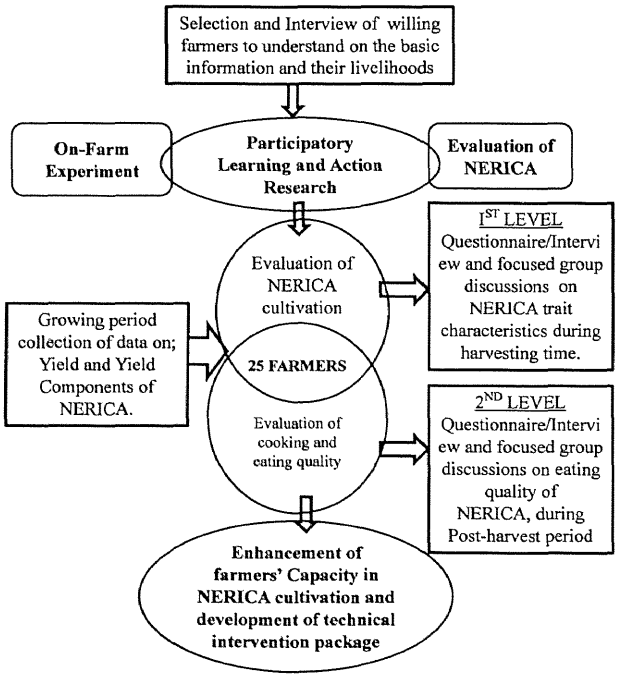
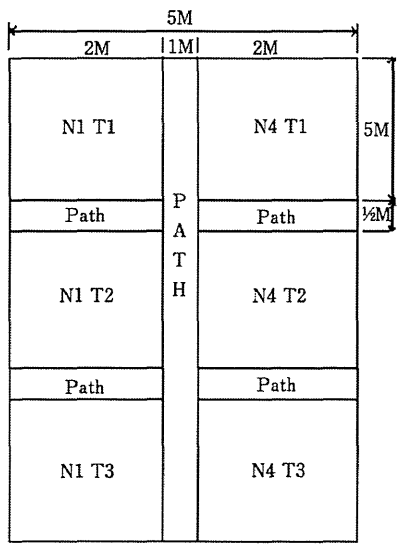


Fig. 1. The conceptual model on which this study was based.



N1=NERICA 1, N4=NERICA 4,
T1=Control, T2=Manure treatment, T3=Fertilizer treatment.

Fig. 2. Experimental layout design.

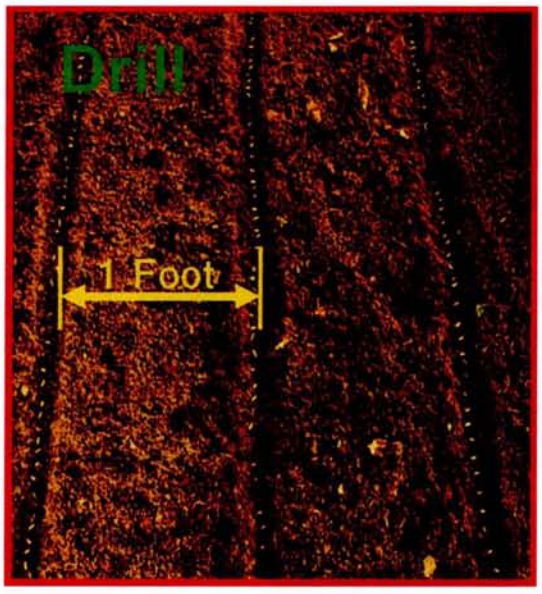


Fig. 3. Photos of drilled NERICA seeds.

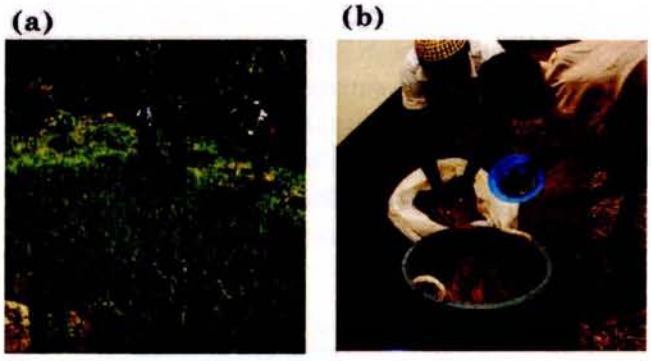


Fig. 4. Photos of farmers (a) participating in NERICA monitoring, (b) checking ripened grains.

the cattle sheds locally referred to as cattle 'bomas', was applied at planting at the rate of 10.6 g N m^{-2}.

Participatory data collection pertaining to date of panicle initiation, heading, flowering, and maturity was done from the two farmer's farms with the farmers' attendance in each day of data collection. Participatory data collection on plant height and tiller number and their response to different treatments at 14, 28, 42, and 56 days after sowing (DAS) was done (Fig. 4a). The same plants were measured each time for both height and tiller number. To determine the percentage ripened grains, 4 panicles were selected from each trial plot and threshed. The total threshed grains from a sample of 48 panicles from each plot were tested for grain ripening percentage as shown in Figure 4b. The farmers then strained the sunken grains, dried and counted them and the percentage of ripened grains calculated. The ripened grains percentage was determined by using the following formula; % $R = (SG/TG) \times 100$. Where; R represents ripened grains, SG represent sunken grains and TG represents total grains.

The procedure for determining the plant panicle initiation with the farmers, was by the selection of the longest growing tiller (main tiller), then splitting it lengthwise from the base to the apical point, using a sharp razor and then open the slit immediately, to see if the panicle had developed. The post harvest activities included the collection of data on yield and yield components such as, weight of paddy yield from each trial plot and the weight of 1,000 grains, number of grains per panicle and the percentage of filled grains per panicle. Farmers used sickles to harvest NERICA, and then selected five panicles per plot for measuring panicle length and number of grains per panicle. Participatory manual threshing and weighing of the paddy yield from all the plots for each cultivar was done.

2. Administration of Questionnaires/Interviews to the Participating Farmers

The questionnaires and interviews were administered to the same 25 farmers who had participated in the on-farm field experiment as mentioned earlier in this report and this was done between December 2008 and January 2009. An integral activity in both components was the administering of questionnaires and interviews with farmers to obtain their views on NERICA phenotypic characteristics at harvesting and the evaluation of its threshing, milling and eating qualities during post harvest field demonstrations. Focus group discussions were also held with the farmers to obtain information that the questionnaires and interviews did not successfully reveal. The volume and type of information collected depended on the questions that were asked during the participatory research and the degree of precision and depth of analysis required. Information collected through the questionnaires and interviews had categorical classifications as, extremely important (4), very important (3), important (2) or not important (1) for the livelihood of farmers' and

excellent (4), very good (3), good (2), or fair (1) for the evaluation of NERICA performance. A milling exercise was carried out by the farmers using a local milling device that one of the farmers had developed (Fig. 5a). Each variety was cooked and evaluated by two groups of farmers (15 households in one group and 10 in the other group, Fig. 5b). The questionnaires were self-administered or researcher-administered depending on the level of education of the farmers and consisted of four sections. The structure of the questionnaire was divided into 4 sections; section 1 obtained data on

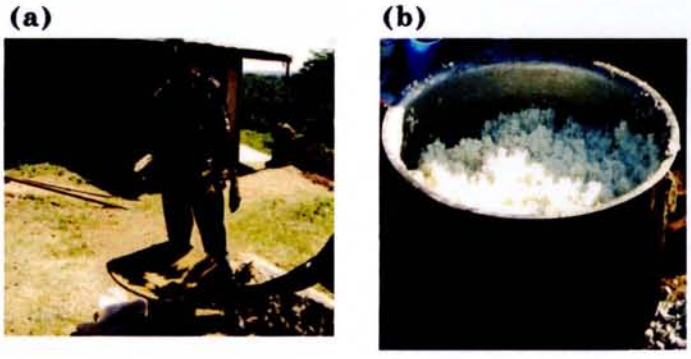


Fig. 5. (a) A locally developed rice milling device and (b) cooking demonstrations.

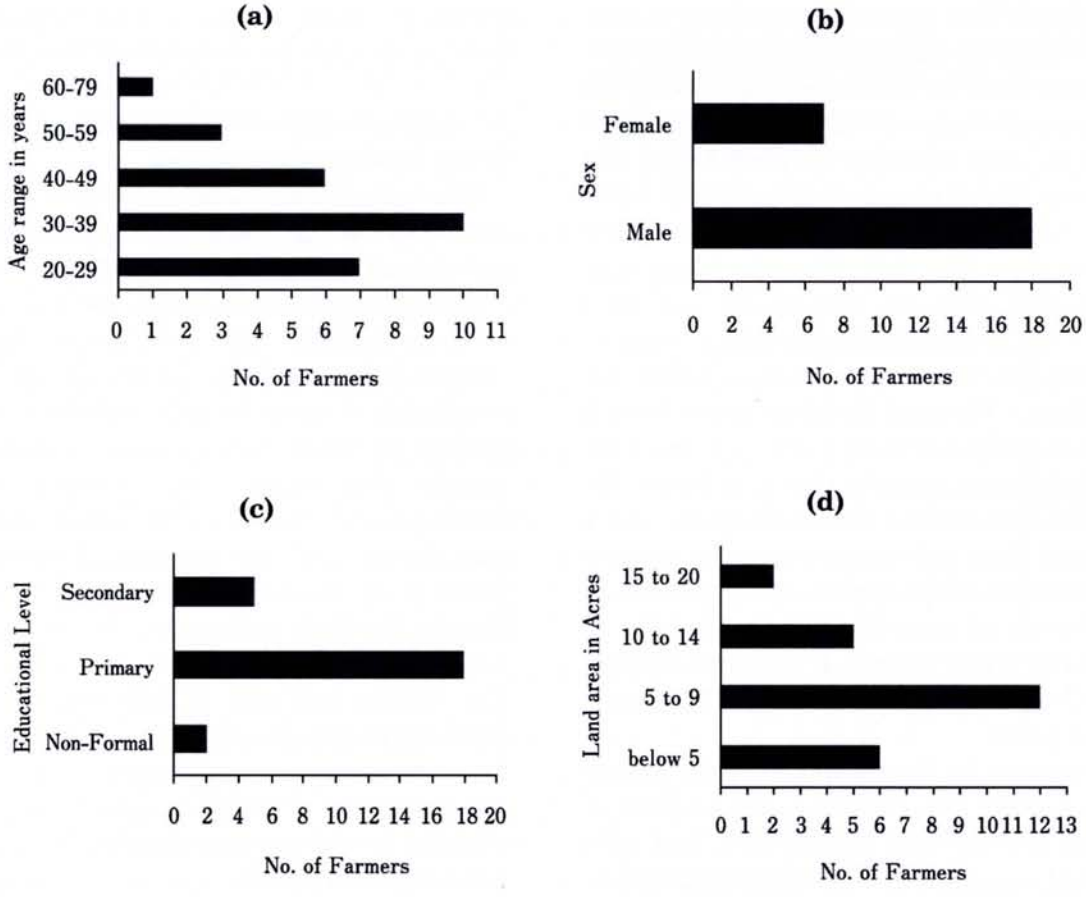


Fig. 6. Frequency histograms of the numbers of participating farmers by (a) age, (b) sex, (c) education level, and (d) size of landholding.

the basic information of the participants, section 2 obtained data on farmer's livelihoods, section 3 obtained data on the results of joint field monitoring and evaluation, and section 4 obtained data on post-harvest evaluation of NERICA 1 and NERICA 4 (See sample questionnaire in Appendix 1).

Data obtained in the two sections of this research were analyzed using Excel (Microsoft®, office 2003) and JMP statistical packages (JMP 7, SAS Institute Inc.) for descriptive statistics such as means, frequency distribution, and P values for significance of differences between means.

Results and Discussion

1. On-Farm Participatory Experiment

a) The growth pattern of NERICA 1 and NERICA 4

Table 1 shows that there is no significant difference in the number of days it takes for the seeds to emerge after seeding between the control, manure and fertilizer treatments in NERICA 1 which are 9, 9 and 9 days after seeding (DAS). NERICA 1 cultivar takes 46, 48 and 46 DAS in the manure, chemical and control treatments to initiate. This implies that the farmers have to wait for about one and half months after seeding before the application of fertilizer topdressing in the chemical treatment. The crop in manure plots in NERICA 1 took slightly more days to mature when compared to that of the control and fertilizer treatments, which is about 114 days after seeding against 112 and 111 DAS for the control and fertilizer plots. On the dissimilarity, NERICA 1 took fewer days to head and flower in the manure treatment, 77 and 79 DAS as compared to 78 and 80 DAS, and 79 and 80 DAS in the fertilizer and control treatments. This research could not establish the source of this difference since it showed different trends. Like NERICA 1, NERICA 4 cultivar did not show significant difference in the number of days the seeds take to emerge after seeding. NERICA 4 showed significant difference in the days it takes to initiate panicle, 47, 45 and 45 DAS for manure treatment, the control and fertilizer treatment, respectively. NERICA 4 cultivar showed significant difference in the heading date, the flowering date and the maturity date after seeding in the chemical treatment at 71, 73 and 102 DAS against those of control and manure treatments at 69, 72 and 100 DAS in the control and at 69, 72 and 101 DAS in the manure treatment. As in the previous conflicting trends this research could not establish the source of these differences. In comparing the two cultivars, NERICA 1 is later at maturing than NERICA 4, by a difference of about 12 days. Although this research did not participate the farmers in evaluating, the preference of each cultivar based on the maturity rate, this is an important aspect that can influence the household food security and especially if the two crops are to be attacked by pests after 100 DAS, the early

Table 1. The effect of fertilizer on the growth patterns of NERICA 1 and NERICA 4 cultivars

Cultivar	Treatment	Emergence	Panicle initiation	Heading	Flowering	Maturity
		(Days After Seeding)				
NERICA 1	No fertilizer	9.0^{a}	48.0^{b}	79.0^{b}	80.0^{b}	112^{a}
	Manure	9.0^{a}	46.0^{a}	77.0^{a}	79.0^{a}	114^{b}
	Chemical	9.0^{a}	46.0^{a}	78.0^{b}	80.0^{a}	111^{a}
	Mean	9.0^{A}	46.7^{A}	78.0^{A}	79.7^{A}	112.3^{A}
NERICA 4	No fertilizer	9.0^{a}	45.0^{a}	69.0^{a}	72.0^{a}	100^{a}
	Manure	9.0^{a}	47.0^{b}	69.0^{a}	72.0^{a}	101^{a}
	Chemical	9.0^{a}	45.0^{a}	71.0^{b}	73.0^{b}	102^{a}
	Mean	9.0^{A}	45.7^{A}	69.7^{A}	72.3^{A}	101^{A}

Values within a treatment with different lower case letters are significantly different, while different capital letters indicate significant difference between cultivars across treatments, by Tukey's HSD Test for Post-ANOVA Pair-Wise Comparisons in Two-Way ANOVA at 5% level.

Table 2. Effect of fertilizer on NERICA 1 and NERICA 4 plant height and tiller number at 56 days after seed emergence

Cultivar	Treatments	Plant height (cm)	Tiller per hill
NERICA 1	No fertilizer	45.0^{a}	10.0^{a}
	Manure	46.4^{b}	11.3^{b}
	Chemical	45.8^{a}	12.0^{b}
	Mean	45.7^{A}	11.1^{B}
NERICA 4	No fertilizer	61.9^{a}	11.0^{a}
	Manure	67.2^{b}	12.0^{b}
	Chemical	67.1^{b}	13.0^{b}
	Mean	65.4^{B}	12.0^{B}

Values within a treatment with different lower case letters are significantly different, while different capital letters indicate significant difference between cultivars across treatments, by Tukey's HSD Test for Post-ANOVA Pair-Wise Comparisons in Two-Way ANOVA at 5% level.

Table 3. The effect of fertilizer on yield and yield components of NERICA 1 and NERICA 4

Cultivar	Treatments	Panicle length (cm)	Grain number per panicle	Filled grains (%)	1000 grains weight (g)	Yield (t ha^{-1})
NERICA 1	No fertilizer	16.8^{a}	120.0^{a}	59.5^{a}	24.3^{b}	2.61^{a}
	Manure	17.3^{b}	124.0^{b}	66.5^{b}	23.6^{a}	2.80^{b}
	Chemical	17.0^{b}	122.0^{b}	66.3^{b}	24.5^{b}	2.91^{b}
	Mean	17.0^{A}	122.0^{A}	64.1^{A}	24.1^{A}	2.77^{A}
NERICA 4	No fertilizer	19.1^{b}	145.0^{a}	67.3^{b}	26.5^{a}	2.81^{a}
	Manure	18.7^{a}	154.0^{b}	68.0^{b}	28.7^{b}	3.40^{b}
	Chemical	19.5^{b}	185.5^{b}	64.0^{a}	26.7^{a}	3.61^{b}
	Mean	19.1^{B}	161.5^{B}	66.4^{B}	27.3^{B}	3.27^{B}

Values within a treatment with different lower case letters are significantly different, while different capital letters indicate significant difference between cultivars across treatments, by Tukey's HSD Test for Post-ANOVA Pair-Wise Comparisons in Two-Way ANOVA at 5% level.

maturing variety may also be preferred in times of hunger, because it would be harvested earlier.

b) Field performance in plant height and tiller number of NERICA 1 and NERICA 4

Table 2 shows the effect of chemical and organic fertilizers on plant height and tiller number of the two NERICA cultivars at 56 days after seed emergence. There was no significant difference in plant height in control and chemical fertilizer treatments in NERICA 1, but that in manure treatment was significantly taller. The tiller number per hill is significantly larger in manure and chemical treatments than in chemical treatment. The plant height of NERICA 4 is significantly taller in the manure and chemical treatments than the control treatments. NERICA 4 showed significantly larger tiller number per hill in the both manure and chemical fertilizer treatments than the control treatment. The results also showed that the plant height and tiller number per hill in NERICA 4 are greater than that of NERICA 1.

Table 4. Farmer's assessment of growth and response to fertilizer by the two NERICA cultivars as numbers of farmers scoring each attribute by each evaluation criteria category

Category	NERICA 1					NERICA 4				
	E	VG	G	F	TS	E	VG	G	F	TS
Growth vigor	10	11	1	0	75	11	10	4	0	82
Tiller Ability	12	10	3	0	84	15	8	2	0	88
Response to fertilizer	13	10	2	0	86	15	10	0	0	90
Response to manure	13	11	1	0	87	14	10	1	0	88
Yield	10	13	2	0	83	14	10	1	0	88

Evaluation criteria: Excellent (E)=4 Points, Very Good (VG)=3 Points, Good (G)=2 Points and Fair (F)=1 Point. TS (Total Score)=sum of the number of farmers x evaluation criteria points.

c) Yield performance in NERICA 1 and NERICA 4

Table 3 shows the effect of chemical and organic fertilizers on yield and yield components of the two NERICA cultivars. Panicle lengths are 17.0 cm and 19.1 cm for NERICA 1 and NERICA 4, respectively. The panicle length in NERICA 4 is significantly longer than that of NERICA 1. There are significant differences among treatments in both varieties. The grain number per panicle in NERICA 4 is significantly higher than that of NERICA 1. The grain numbers per panicle are 122 and 161 for NERICA 1 and NERICA 4, respectively. On overall performance of grain number in both cultivars, there is a tendency for the grain number to be higher in chemical and manure fertilizer treatments than in control in both NERICA 1 and NERICA 4.

The filled grains mean percentages are 64.1% and 66.4% for NERICA 1 and NERICA 4, respectively. Filled grains in NERICA 4 are significantly higher than that of NERICA1. There is a tendency of filled grain percentage to be higher in fertilizer treatments than in control in both varieties. Thousand grain weights are 24.1 g and 27.3 g for NERICA 1 and NERICA 4, respectively. That of NERICA 4 is significantly heavier than that of NERICA1. There is significant difference among treatments in both varieties. As a result of such yield components, grain yields are 2.77 t ha^{-1} and 3.27 t ha^{-1} for NERICA 1 and NERICA 4, respectively. That of NERICA 4 is significantly higher than that of NERICA 1. The difference among treatments is also significant in both varieties. While yields in no fertilizer plots are 2.6 t ha^{-1} and 2.8 t ha^{-1} for NERICA 1 and NERICA 4, respectively, yields in chemical fertilizer treatment are 2.9 t ha^{-1} and 3.6 t ha^{-1} for NERICA 1 and NERICA 4, and yields in manure treatment are 2.8 t ha^{-1} and 3.40 t ha^{-1} for NERICA 1 and NERICA 4, respectively. The highest yield is found in chemical fertilizer treatment in both varieties, but the difference between chemical fertilizer and manure treatments is not significant in each cultivar (Table. 3).

Kijima *et al.* (2006) reported that the average yield of traditional upland rice in Africa is about 1 t ha^{-1}, so yield data from the current study suggest that NERICA can achieve remarkable yield improvements.

2. Participatory Evaluation of NERICA 1 and NERICA 4 Performance by Farmers

a) The response of farmers to NERICA agronomic performance

Table 4 compares the evaluation of NERICA performance, each category is evaluated by the total score (TS); TS indicates the sum of the number of farmers who selected each evaluation criteria multiplied by criteria points, evaluation criteria point; Excellent (E) as 4, Very good (VG) as 3, Good (G) as 2 and Fair (F) as 1. This means that higher TS indicates better evaluation and lower TS indicates lower evaluation by the participating farmers.

TS for growth vigor are 75 and 82, TS for tiller ability are 84 and 88, TS for response to chemical

Table 5. Farmer's assessment of NERICA grain physical and eating qualities as numbers of farmers scoring each attribute by each evaluation criteria category

Category	NERICA 1					NERICA 4				
	E	VG	G	F	TS	E	VG	G	F	TS
Threshability	22	2	1	0	96	19	3	2	0	89
Milling quality	8	15	1	1	80	9	15	1	0	83
Cooking	3	7	15	0	63	2	8	15	0	62
Aroma	24	1	0	0	99	0	2	3	20	32
Taste	19	7	1	0	99	19	8	1	0	92

Evaluation criteria: - Excellent (E)=4 Points, Very Good (VG)=3 Points, Good (G)=2 Points and Fair (F)=1 Point. TS (Total Score)=sum of the number of farmers x evaluation criteria points).

fertilizer are 86 and 90, TS for response to manure are 87 and 88, and TS for yield are 83 and 88 for NERICA 1 and NERICA 4, respectively. These results indicate that farmers perceive that NERICA 4 has better agronomic performance in field experiments (Table 4).

b) Response of farmers to NERICA Post-harvest qualities

Table 5 shows the results of farmers' scores in evaluating the attributes of the two NERICA cultivars' response to chemical and organic fertilizers. TS for threshability are 96 and 89, TS for milling quality are 80 and 83, TS for cooking quality are 63 and 62, TS for aroma are 99 and 32, and TS for taste are 99 and 92 for NERICA 1 and NERICA 4, respectively. On the contrary to the response of agronomic performance, farmers gave better evaluation on cooking and aromatic qualities to NERICA 1 compared to NERICA 4. TS of NERICA 1 in aroma is the highest in all traits. The results for cooking and taste qualities indicate farmers perceive that NERICA has good eating quality.

Farmers displayed a strong preference for NERICA 4 because of its superior yeild performance, which is likely to influence the rate of adoption of the NERICA 4 cultivar in the target area. NERICA 4 for its superior yield performance. The results on the evaluation of post harvest qualities of NERICA by farmers in this study are in agreement with those mentioned by Okech (2007).

Conclusion

Kijima (2006) stated that, the average yield of traditional upland rice in Africa is about 1 t ha^{-1}. This research shows that NERICA can achieve higher yields under farmers' conditions. Both NERICA 1 and 4 produced higher yields with chemical and organic fertilizer application than without fertilizer. Fertilizer is therefore essential for maximizing production. Since the yields of NERICA 1 and 4 were not significantly different between chemical fertilizer and farmyard manure treatments, farmers can use farmyard manure, which is locally available to most households in the study area. NERICA 4 performed better than NERICA 1 in most characteristics measured. The farmers preferred NERICA 1 for its aroma, but NERICA 4 for its superior yield.

The expected long-term impact of this participatory research and the post-research promotion of NERICA cultivation would be capacity development and adoption of rice cultivation by farmers in Tunyo Division and other parts of Kenya, through the implementation of research based action plan. The number of participating farmers that adopt this crop in their future farming practices will be construed as a tangible increase in knowledge within the study area.

This research identified that the participation of farmers in field research may strengthen research-extension-farmer linkages and may be the key in bringing about the "NERICA revolution" in Kenya. However, the main bottleneck to promulgating NERICA cultivation among farmers is

the lack of adequate seed. This constraint needs to be overcome for an effective promotion of NERICA cultivation. Further research should be undertaken with greater replication to clarify the variation in results on other areas of land and different farmer groups. Future participatory research should investigate if the number of days that a NERICA cultivar takes to mature would influence the farmers' choice for that cultivar.

Acknowledgements

I thank my supervisors at the University of Tsukuba for their guidance with the research and helpful suggestions on this manuscript, particularly Prof. Sachiyo Maruyama, Dr. Hisayoshi Hayashi and Dr. Morio Kato of the graduate school of life and environmental sciences, University of Tsukuba. I am indebted to Dr. Morio Kato for his close supervision during Japan based NERICA trials and for his constant assistance, during the revision of my manuscript.

I thank the staff of Tunyo Division Agricultural Office for their support with data collection in the field, particularly Mr. Thomas Chepkonga. I am indebted to all the farmers who participated in this research and especially, Mr Paul Cheserek. I am indebted to the Government of Kenya and the Japan International Cooperation Agency for providing the approval and funds for the research and supporting my studies in Japan. I am grateful to CADSAL project management for nominating me. I appreciate the support and services of JICA and JICE staff in Japan. Lastly, but not least I acknowledge my family for their constant moral support.

References

Kijima Y., Sserunkuuma D. and Otsuka K., 2006. How revolutionary is the "NERICA revolution"? evidence from Uganda. Foundation for Advanced Studies on International Development and National Graduate Institute for Policy Studies, Tokyo, Japan and Makerere University, Kampala, Uganda. Journal Compilation Institute of Developing Economies, 44 (2): 252–267.

Kore W.O., Onyango G. and Omuga G., 2007. NERICA on-farm trials. Proceedings of the 5th Workshop on the Promotion of New Rice for Africa (NERICA) in Kenya' 26th–27th February. African Institute for Capacity Development (AICAD) reports, 8: 13–14.

Mureithi J.G., Murithi F.M., Asiabaka C.C., Wamuongo J. W., Mose L. and Mweri B. Methodology Development for Participatory Monitoring and Evaluation of Farmer Field School Approach for Scaling up the Adoption of Agricultural Technologies. KARI-NARL, P.O. Box 14733, Nairobi, Kenya; (http://www.eseap. cipotato. org / UPWARD / Events / FFS-Workshop-Yogya2002/06-Muriethi.pdf, accessed, October, 2009).

Okech J.N.O., 2007. On the job training on analysis of preconditions for the dissemination of new rice for Africa (NERICA) in Kenya, Proceedings of the 5th Workshop on the Promotion of New Rice for Africa (NERICA) in Kenya' 26th–27th February. African Institute for Capacity Development, AICAD reports, 8: 44–49.

Republic of Kenya, Ministry Agriculture, 2007. National Rice Development Strategy (2008–2018). (http:// www.jica.go.jp/activities/issues/agricul/pdf/NRDS/ NRDS_ken E.pdf , Accessed October, 2009).

Somado E.A., Guei R.G. and Keya S.O., 2008. The New Rice for Africa (NERICA). A Compendium 2008 edition, West Africa Rice Development Centre, 20 pp.

West African Development Association (WARDA), 2001. 'NERICA rice for life'. http://www.warda.org/ publications/NERICA8.pdf, accessed October, 2009.