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Full Length Research Paper

Field evaluation of selected NERICA rice cultivars in Western Kenya

E. A. Atera[1,2]*, J. C. Onyango[3], T. Azuma[1], S. Asanuma[4] and K. Itoh[1]

[1]Graduate School of Agricultural Science, Kobe University, 1-1 Rokkodai-cho, Nada-ku, Kobe, 657-8501 Japan.
[2]Department of Engineering and Technical Services, Lake Basin Development Authority, 1516 - 40100, Kisumu, Kenya.
[3]Faculty of Science, Maseno University, Kenya.
[4]International Cooperation Center for Agricultural Education, Nagoya University, Japan.

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Food shortage is a major problem in sub-Saharan Africa as population increases. NERICA (New Rice for Africa), the high yielding rice cultivars with short growth cycle were developed to solve the food crisis. The progeny has shown high potential to revolutionize rice farming, producing high yield with minimum inputs in stress-afflicted ecologies. However, information on their performance in Kenya has not been documented. A study was conducted in a field located at Alupe farm of Lake Basin Development Authority (LBDA), in Western Kenya for a period of three years (2005 - 2007). Four NERICA rice cultivars (NERICA 1, NERICA 4, NERICA 10, and NERICA 11) and a local landrace "Dourado precoce" were planted in a completely randomized block design. Result showed that NERICA 10 attained physiological maturity most quickly [97 days after seeding (DAS)] followed by NERICA 1 (102 DAS). Dourado precoce took a much longer time to mature (116 DAS) than the other cultivars. On grain yield, NERICA 1 (4.1 ton ha^{-1}) produced the highest while Dourado precoce (2.5 ton ha^{-1}) gave the least in 2006. NERICA 10 (2.7 ton ha^{-1}) however, produced the lowest grain yield in the same period among the NERICAs. NERICA 1, the most outstanding cultivar gave the highest yield (4.3 ton ha^{-1}) in 2005 and yielded more than 4.0 ton ha^{-1} in the other seasons.

Key words: NERICA, upland rice, yield, moisture stress, Kenya.

INTRODUCTION

Rice is the staple food for more than half of the world's population. Sub-Saharan Africa produced about 21.6 million tons of rice in 2006 and accounted for 32% of rice import in the global international market to meet its demand (Africa Rice Center, 2008; FAO, 2007). This was as result of population growth (of about 4% per annum) and the increased consumer preference in favor of rice in urban areas (Africa Rice Centre, 2008; Balasubramanian et al., 2007; Kijima et al., 2006). In recent years (2003 – 2006), rice consumption in Kenya increased by 47% while production increased slightly at the rate of 6% per annum (FAO, 2007; Onyango, 2006). In addition, Kaneda (2007b) reported that nearly 73% of rice consumed in Kenya is imported. In order to narrow the gap between import and production of rice, NERICA, the inter-specific hybridization between *Oryza sativa* (Asian rice) and *Oryza glaberrima* (African rice) was introduced. The progeny was developed by West Africa Rice Development Association (WARDA), combining traits from the hardy African rice resistant to pests, weeds and problematic soils with the high yielding, good response to mineral fertilization and non-shattering characteristics of the Asian rice (Dzomeku et al., 2007; Kijima et al., 2006; WARDA, 2001a). The cultivar has carved a special niche as it perfectly adapts to upland conditions where smallholders lack means of irrigation, creating new opportunities of providing farmers with a potential cash crop.

The Green Revolution technological breakthrough

*Corresponding author. E-mail: eatera@yahoo.com. Tel: 254-57-2027227.

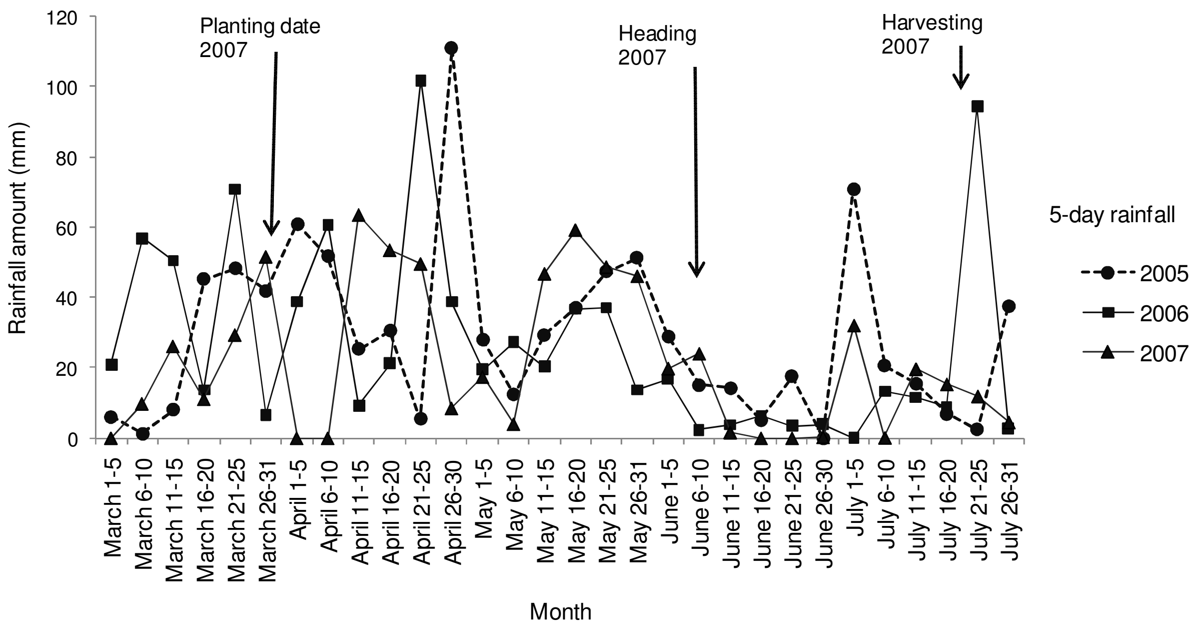

Figure 1. Rainfall distribution during the crop growing period in 2005 to 2007 at LBDA Alupe, Kenya.

increased potential yield of rice to 5 - 7 ton ha^{-1} and later to 10 - 11 ton ha^{-1} in the Asian region in early 1990s (FAO, 2004). Rice yield in upland systems of Africa is about 1 ton ha^{-1} (Africa Rice Center, 2008; Kijima et al., 2006). Inclusion of NERICA cultivars in the cropping system has brought about significant increase in the potential yield of rice within the region. Kijima et al. (2006) stated that NERICA's yield in Uganda was twice as much compared to traditional upland rice varieties in the sub-Saharan Africa. According to Africa Rice Center (2008), NERICA responds better to inputs than the traditional varieties producing enhanced yield. Results in West Africa showed that NERICA yields about 2.5 ton ha^{-1} with low use of inputs and under prudent fertilizer use, yield of 5 ton ha^{-1} or more is achievable (Kijima et al., 2006; WARDA, 2001b). The average yield in the farmers' fields in Uganda is 2.2 ton ha^{-1} (Kijima et al., 2006) while in Guinea, 3.5 ton ha^{-1} has been recorded (JICA, 2006). Preliminary evaluations from WARDA showed that NERICA has surpassed the local landraces in yield with a potential to revolutionize the rice industry.

Weed competition, the most important yield-reducing factor is followed by drought, blast and soil infertility (Johnson et al., 1998). Weeds interfere with growth of upland rice by competing for nutrients, water, light and also harboring pests. In addition, weed roots produce exudates that suppress crops (Dzomeku et al., 2007). Johnson (1996) reported that 20 - 100% of yield loss in rice fields depend on farmers' control of weeds. However, NERICA varieties have desirable agronomic traits that are potentially useful for weed competitiveness including:- good vigor at seedling and vegetative stages for weed suppression, intermediate to tall stature and moderate tillering ability making them more superior to local landraces (Kaneda, 2007a). In addition, they have characteristic wide, droopy leaves that could suppress weeds (Dzomeku et al., 2007). It has been recorded that the first generations of NERICA cultivars were effective to smother out weeds due to their vigorous growth at their early stages of development (Kaneda, 2007a; Johnson et al., 1998). Dzomeku et al. (2007) observes that NERICAs require at least 6 weeks of weed free for the formation of good canopy cover that can suppress weeds.

Owing to NERICA physiological traits and yield performance in West Africa, WARDA released eighteen (18) NERICA cultivars in 2003 to be tested in Kenya. A preliminary evaluation of these cultivars was carried out for two seasons to indentify the best performers. Four (4) NERICA cultivars were identified for further testing and assessment. Growth parameters and yield potential of the four NERICAs were compared with the local landrace under natural conditions for three years (2005 to 2007). The objective was to identify high yielding cultivars that can resist the harsh climatic conditions of Western Kenya.

MATERIALS AND METHODS

Study site and experimental design

The study site (latitude 0° 29´ N, longitude 34° 07´ E and altitude 1189 m) was located at Alupe farm of Lake Basin Development Authority (LBDA) in Western Kenya. Precipitation ranged between 848 - 653.5 mm during the growing period (Figure 1). Rice cultivars namely NERICA 1, NERICA 4, NERICA 10, NERICA 11 and Dourado precoce were planted in completely randomized block design replicated three times in plot sizes of 2.5 × 5 m. The field

Table 1. Significance levels of effects of year and genotype and their interactions on growth and yield parameters of rice cultivars.

Source of variation	df	Significance level						
		PH	MT	MD	TN	SNP	1000 GW	GY
Year (Y)	2	**	ns	*	**	ns	ns	**
Genotype (G)	2	*	ns	**	*	***	*	*
Y × G	4	*	ns	ns	*	**	ns	*

*, **, *** denote effects significant at 5, 1 and 0.1 percent probability level respectively: ns denotes effect not significant.
PH= Plant height, MT= Maximum tillering, MD= Maturity days, PN= Tiller number m^{-2}, SNP= Spikelets number $panicle^{-1}$, 1000GW= 1000 grain weight, GY= Grain yield.

trials were established on March 26, 2005, March 10, 2006 and March 28, 2007 on a fairly drained upland loam soils. Planting dates coincided with onset of the long rainy season. Basal fertilizers were applied at the rate of 25-25-25 kg ha^{-1} of NPK and top dressing 25 kg ha^{-1} of N at 55 days after seeding (DAS). Planting depth, spacing and seed rate of 3 cm, 30 × 12.5 cm and 60 kg ha^{-1} were used respectively. Standard cultural practices were followed in crop management in all seasons.

Sampling and statistical analysis

Data were collected from ten sampled plants for plant height and tiller number on each plot every 14 DAS till harvest to ascertain plant growth patterns. Grain yield were harvested and weighed on plot basis. Yield was adjusted to grain moisture content of 14% and yield components were determined by sampling 20 hills from each plot. Data were subjected to analysis of variance (ANOVA). Whenever significant differences were detected (α = 0.05), the means were compared using the Tukey's HSD test at 5% levels of significance.

RESULTS AND DISCUSSION

Weather conditions

Climatic data showed that wet regimes at LBDA Alupe have generally low rainfall in the month of June (Figure 1). Rainfall amount was highest in 2005 while the lowest was received in 2007 during the growing period (Figure 1). There was uneven distribution of rainfall in 2006 in comparison to 2005. In June 2006, rainfall amount was 36.4 mm which was about one-half the amount in the same period in the previous year. Subsequently, 45.7 mm of rainfall was received with 96% coming within the first 10 days in June 2007. According to Africa Rice Center (2008), NERICA rice responds well to low rainfall, a minimum of 20 mm per week is required which should be well distributed throughout the growing period. Result showed that the month of June received 19.5 mm (2005), 9.7 mm (2006) and 11.4 mm (2007) of rainfall which might have affected yield as it is not within the recommended range. This is critical as heading and ripening stages are likely to be affected since the planting season is in March.

Growth parameters and physiological traits

There were significant differences among the cultivars in growth parameters for the three years of experimentation. The variation among the genotypes for growth parameters over years suggests the presence of Genotype × Environment (G × E) interaction (Table 1). Maximum tillering stage was achieved between 40 - 50 DAS. Among the varieties, the average number of tillers in 2005 was 364 m^{-2} and the corresponding value in 2007 was 373 m^{-2} (Table 2). The number of tillers per unit area in 2005 was translated to yield as compared to 2007 averaged at 3.8 and 3.6 ton ha^{-1} respectively. NERICA 10 and NERICA 4 produced the highest number of tillers while NERICA 11 produced the least in 2007 (Table 2). Comparatively, NERICA 4 had the highest tiller number followed by NERICA 10 and NERICA 1 in 2005. Tiller numbers differed significantly ($P < 0.01$) over years. Result showed that the efficiency and production of tillers depended on environmental factors as evidenced in 2005 season. However, Ntanos and Koutroubas (2002) showed that in addition to the environmental factors, nutrients absorbed and carbohydrates metabolized play a role in tiller development.

Climatic conditions favored the tillering of NERICAs during the early stages of growth in 2007. Tillers that developed in the early stage grew profusely producing panicles at the tips of the stem and contributed to yield as productive tillers in NERICA 1 and NERICA 10 in 2007. Nuruzzaman et al. (1997) reported that the number of panicles in a yield component largely depend on the number of productive tillers. Previous studies have also shown that rice plants with adaptive response of deep roots development are greatly affected when experiencing drought. Kamoshita et al. (2004) observed that moisture stressed plants adjust to osmotic pressure and reduce biomass. Genotypes with larger biomass easily exhaust soil water and can be damaged more severely when experiencing drought. Thus NERICAs tend to cope with drought by adopting dry matter (biomass) reduction mechanism. However, further research is still required to validate this observation.

Effect of water stress on physiological attributes that is,

Table 2. Tiller number, plant height and maturity days in 2005, 2006 and 2007 growing season.

Cultivars	Tiller number per m-2			Plant height at harvest (cm)			Maturity
	2005	2006	2007	2005	2006	2007	days†
Dourado precoce	354.7±8.60b	296.9±12.9a	362.7±17.7a	127.3±2.2a	100.7±5.7a	102.8±4.3a	116a
NERICA 1	365.4±10.3a	245.4±6.2b	375.6±14.0a	98.2±4.5c	79.1±3.2b	75.8±5.6c	102b
NERICA 4	383.3±13.5a	272.9±10.2a	390.3±6.70a	101.1±3.8c	82.4±4.5b	84.6±2.1b	105b
NERICA 10	368.0±16.1a	255.4±9.8b	393.8±22.5a	104.9±3.2c	80.8±2.2b	83.9±3.3b	97c
NERICA 11	347.5±14.7b	231.5±7.3b	343.2±14.7b	112.8±2.7b	87.4±5.1b	89.9±4,2b	109a

Different letters within columns indicate significant differences (P≤0.005) by Tukeys's test. Values are mean ± SE. † Cultivars mean maturity days over the three years.

days to flowering and maturity differed significantly among genotypes. NERICA 10 and NERICA 1 were the early maturing varieties while Dourado precoce and NERICA 4 were late maturing (Table 2). Varieties affected by moisture stress during grain filling stage such as NERICA 4 delayed physiological maturity period in 2006 as compared to WARDA passport data. When plants are exposed to drought their carbohydrates metabolism is affected. In turn the disorder slows down growth rate and delays development stages in stressed plants thus affecting maturity period. Notable among the cultivars was the non uniformity in plant height (Table 2). The plants were taller in 2005 compared to other seasons. This may be attributed the genetic makeup of the genotypes, their behavior and interaction with the environment.

Yield and yield components of the NERICAs

It is generally recognized that the number of spikelets per panicle or number of panicles per unit area determines rice yield depending on the cultivar. Grain yield increased in most cultivars with increased number of spikelets per panicle (Table 3). Kato et al. (2008) made similar observations that in upland conditions where drought occurs sporadically, spikelets number per unit area contributes immensely to yield. NERICA 1 (4.1 ton ha^{-1}) recorded the highest number of spikelet per panicle and a larger sink size in 2006. Average grain yield in 2007 was 18.1% higher than 2006 cropping season. The low yield in 2006 as compared to the other seasons may be due to pre-flowering abortions attributed to moisture stress. Kato et al. (2008) reported that under moisture stress conditions there is a considerable reduction of rachis branches which initiate spikelets (limiting the number of spikelets per panicle) in early reproductive stages. Result showed more spikelets number per panicle in 2005 as compared to 2006 growing season (Table 3). Averaged spikelets number in 2006 was 32% lower than in 2005. NERICA 10 recorded the highest number of spikelets per unit area in 2005 which was not translated into yield. The low yield might have been as a result of decreased filled grains per panicle caused by inhibition of sufficient translocation of assimilates to the grains as the plants competed for moisture.

Grain weight is an important yield component in rice production. Result showed that NERICA 1 recorded the highest 1000 grain weight in 2006 while Dourado precoce gave the highest in 2005 (Table 3). The 1000 grain weight of NERICA 1 and NERICA 11 were higher compared with the WARDA passport data results. Ripening ratio and 1000 grain weight averages in 2006 were lower in 2005 by 10.2 and 1.4% respectively. Grain weight is determined by the supply of assimilates during the ripening period and the capacity of the developing grain to accumulate the translocated assimilates (Ntanos and Koutroubas, 2002). In addition, grain weight is a variable proportion of spikelets sterility regulated by moisture. Therefore, the reasons which may be behind grain yield loss with moisture stress may be as result of decrease in the number of filled grain per panicle and 1000 grain weight.

Several researchers have recognized the importance of sink size in enhancing rice grain yield. Yao et al. (2000) defined yield sink as the product of the number of panicles per unit area and the number of spikelets per panicle. Result showed that the number of spikelets per panicle was correlated to yield sink (Figure 2). Correlation coefficient between yield sink and the number of spikelets per panicle (r = 0.823) was higher than between yield sink and number of panicles per m^2 (r = 0.191). The result of this study based on the description of plant types, therefore, classified NERICA 1 as a more panicle

Table 3. Yield components of NERICAs in 2005 and 2006 cropping seasons.

Cultivars	Number of of panicles m-2	Number of spikelets (%) panicle-1	Grain ripening ratio	1000 grain weight (g)
2005				
DOURADO PRECOCE	304.1±6.7b	58.1±2.1c	86.7±2.4a	30.3±0.31a
NERICA 1	358.7±3.4a	97.6±1.4a	84.6±0.8a	29.4±0.75a
NERICA 4	314.0±9.8b	74.5±4.8b	89.7±1.7a	26.6±0.66b
NERICA 10	332.7±8.6a	101.6±3.9a	82.2±1.9a	27.5±0.43b
NERICA 11	341.4±13.3a	75.0±5.3b	83.8±3.1a	29.9±0.57a
2006				
DOURADO PRECOCE	236.9±15.6a	42.2±4.7d	83.3±0.6b	30.3±0.11a
NERICA 1	220.2±18.3b	72.2±3.1a	89.8±1.8b	32.4±0.51a
NERICA 4	202.2±7.60c	65.6±4.3b	86.5±1.8b	28.6±0.44b
NERICA 10	205.4±8.90c	52.7±1.8c	92.6±0.9a	26.4±0.62b
NERICA 11	227.5±8.70a	43.9±4.2d	81.1±2.7c	32.1±0.98a

Different letters within columns indicate significant differences (P≤0.05) by Tukey's test. Values are mean ± SE.

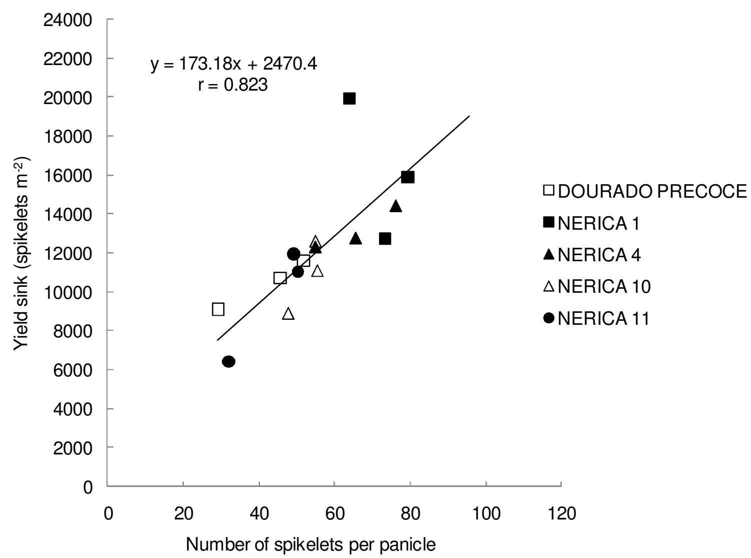

Figure 2. Relationship between yield sink and number of spikelets per panicle in 2006. Each data point is the mean of three replicants for each cultivar significant at P ≤ 0.05.

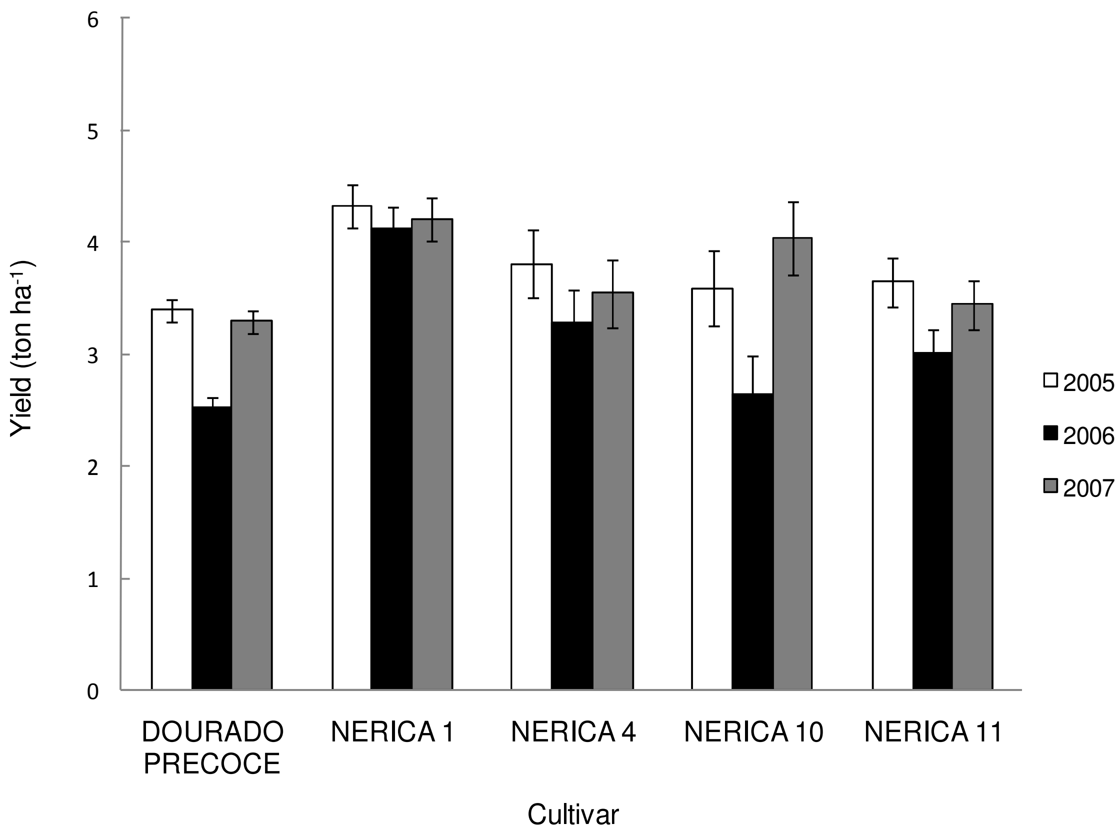

Figure 3. Grain yield of NERICA cultivars in 2005, 2006 and 2007 cropping seasons. Error bars indicate standard error of treatments over the years.

weight cultivar compared to NERICA 11 and Dourado precoce in line with findings of Yao et al. (2000).

Earlier maturing genotypes performed better in 2007 despite the low rainfall compared to the previous years. This is partly because the plants might have evaded moisture stress during flowering period. Banoc et al. (2000) observed that dry matter production is inhibited when plants experience drought and our result support this view. The plants tended to reduce their vegetative cover in 2007 and productive tillers were more distinct. In 2005 NERICA 1 yielded 4.3 and 4.1 ton ha^{-1} in 2006 (Figure 3). Generally the cultivars yielded higher in 2005 than in 2006 due to availability of moisture during flowering and part of ripening period. However, NERICA 11 and NERICA 10 yielded lower in 2006 than in 2007 as a result of prolonged dry spell during ripening stage. Despite the fluctuating and erratic rainfall amount per week, NERICA 1 yielded more than 4.0 ton ha^{-1} in all seasons. Thus NERICAs are generally sensitive to moisture stress except NERICA 1. Tsunematsu (2003) reported that among the 109 NERICA lines evaluated as possible donors for drought tolerance trait, none was selected which is contrary to previous observations at WARDA. However, selection of improved cultivars has been limited because of the difficulty in making field determination of drought avoidance characteristics of numerous entries. Therefore, to improve on selection and accommodate the effects of G × E interactions, genotypes may be evaluated in many experiments over several years and locations with different drought intensities.

Conclusion

Rice is highly sensitive to moisture stress especially during the reproductive stages (Kato et al., 2008). But it appears that moisture stress during the vegetative phase of the NERICAs affects the production of effective tillers, resulting in grain yield reduction. While stress during the reproductive phase tends to interfere with pollination, fertilization and grain filling thereby reducing grain yield. Among the NERICAs evaluated, NERICA 1 in addition to its early maturity, has the greatest potential to tolerate the harsh climatic conditions and thus can be suitable for farmers in Western Kenya. Despite, the yield obtained in Kenya being lower than the yield potential at WARDA, the cultivar has proved to have the potential to enhance rice production. With increasing population and increase in dependence on rice, the search for high yielding cultivars must be a priority in addition to breeding cultivars that are tolerant to biotic and abiotic stress to improve on economic losses.

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