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Response of new rice for Africa (NERICA) varieties to different levels of nitrogen fertilization in Zimbabwe

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The new rice for Africa (NERICA) varieties were bred and released in West Africa. This rice has high yield, good quality and other agronomic traits that include adaptability to harsh environments found in Africa. Zimbabwe, recently introduced NERICA varieties, however, the best performing NERICA varieties under local conditions were not known and the optimum level of nitrogen fertilization for those varieties was unknown. A study was carried out to evaluate the response of introduced NERICA varieties to different levels of nitrogen fertilization in Zimbabwe during the 2011/2012 summer season. A four by four factorial experiment in a randomized complete block design was used. One factor consisted of four levels of nitrogen (0, 39.5, 64.5, and 89.5 kg / ha) and the other had four varieties (NERICA 1, NERICA 3, NERICA 7 and Mhara 1). Analysis of variance showed that there was no significant interaction between nitrogen fertilization rates and varieties. However, significant nitrogen effects (P < 0.05) were found on plant height, panicle length, filled grains per panicle, unfilled grains per panicle, grains per panicle and grain yield. Grain yield for level 1 (0 kg N / ha) was significantly reduced compared to nitrogen addition, but level 2 (39.5 kg N / ha), level 3 (64.5 kg N / ha) and level 4 (89.5 kg N / ha) were not significantly different. This showed that the optimum level of nitrogen fertilization is 39.5 kg N / ha. Varieties showed significant differences (P < 0.05) for days to 50% heading, plant height, filled grains per panicle, filled grain ratio, grains per panicle, 1000 grain weight and grain yield. All NERICA varieties performed better than the local check variety, Mhara 1 and NERICA 3 had the best yield followed by NERICA 7. Growing of these NERICA varieties using the nitrogen rate of 39.5 kg / ha can boost rice yield in Zimbabwe.

Key words: Upland rice, new rice for Africa, nitrogen fertilization, grain yield.

INTRODUCTION

Rice is the staple food for about half the human race and is the main source of calories world-wide (Khush, 2010). The recent cross between the Asian rice (*Oryza sativa*) which is high yielding and the African rice (*Oryza glaberrima*) which is resilient to adverse production conditions (Jones et al., 1997; Dingkun et al., 1998) gave birth to new rice for Africa (NERICA). The NERICA varieties are high yielding, outcompete weeds, are resistant to pests, diseases and drought, grow in poor soils and mature 30-50 days earlier than traditional varieties (Hideo et al., 1999; Kaneda, 2007; Jones et al., 1997). To date, up to 18 NERICA varieties were adopted

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in most African countries (Diagne, 2006).

Until now, Zimbabwean farmers have been growing local rice varieties (Bluebell and Mhara) that are mainly lowland rainfed in major production areas that include Mutoko, Murehwa, Rusape, Zvimba, Seke and Chivhu. However, the growing of rice in the wetlands is towards being banned in a bid to protect the wetlands. The NERICA varieties (upland rice), have potential to replace the lowland varieties while giving the farmers several benefits (Hideo et al., 1999; Kaneda, 2007). In 2004, the government of Zimbabwe declared rice as a strategic crop. In an attempt to increase rice production hence food security and income, the Ministry of Agriculture, therefore introduced seven upland NERICA varieties from West African Rice Development Association (WARDA). Although NERICA varieties were introduced in Zimbabwe, their agronomic performance under local conditions is unknown since different varieties are known to respond differently to different agro-ecological environments (Cooper et al., 1999; Fukai et al., 1999; Kaneda, 2007). This raised the need to evaluate the agronomic performance of the introduced NERICA varieties under local condition in order to identify best performing NERICA varieties that can be promoted locally.

Nitrogen is the most limiting nutrient for rice yields (Kato et al., 2006; Duangjai et al., 2000; Ragland and Boonpuckdee, 1988). It has a crucial role to play in tillering and plant growth (Yan et al., 2010; Sheehy et al., 2001). Nitrogen must be applied at tillering and / or booting stage (De Batista, 2002). This nutrient, when overproduced in the vegetative stage and between the neck-node differentiation and spikelet differentiation stages, absorbed and metabolized, induces increased levels of protein instead of carbohydrates, resulting in excessive growth of shoots, affecting negatively the root system, degree of lodging, spikelet fertility and lowering the resistance of plants to water deficiency (Marschner, 1986; Matsushima, 1980). However, it is one of the main factors involved in productivity, mainly increasing the panicle length, panicle number per unit area, the number of spikelets per panicle and spikelet fertility (Mingotte et al., 2013; Fageria and Barbosa Filho, 2001) and in improving the nutritional quality of rice grain (Mingotte et al., 2012). For maximum nitrogen efficiency and to minimize lodging (De Batista, 2002), it is best to apply nitrogen in split dose (De Batista, 2002; De Datta et al., 1990). Watanabe et al. (1988) and Wade et al. (1999) reported that a rice crop used an average of 40 to 50 kg N / ha from the soil when fertilizer was applied while Fukai and Ouk (2012) reported nitrogen requirements of up to 67kg / ha.

Cultivars differ widely in their response to nitrogen fertilization (Inthapanya, 2000a; 2000b; Fukai and Ouk, 2012). Studies done in West Africa showed that the yield for NERICA varieties increased with nitrogen fertilizer level from 40 to 100 kg / ha (Kareda, 2007; Jones et al. 1997; Fukai and Ouk, 2012). De-Battista (2002) also reported that nitrogen is by far the most limiting nutrient in rice production. Inthapanya (2000) noted that nitrogen recommendations should be based on the rice variety grown and the location. However, Zimbabwean farmers are applying fertilizers in rice using rates that are close to the recommended rates for maize (300 kg / ha compound D with 7N: 14 P_2O_5: 7 K_2O ratio and 100 kg / ha ammonium nitrate with 34.5% N). This shows a huge wastage of fertilizers and potential diminishing returns. Identification of the optimum rate of the nitrogen fertilizer will help to boost the crop yield since nitrogen is the most limiting nutrient.

If the optimum level of the nitrogen is found for a particular variety, then wastage that results from using high fertilizer rates will be avoided. This will avoid diminishing returns and therefore boost the yield and economic returns for the resource poor farmers. The objectives of this study were to; (i) establish the optimum nitrogen requirements of three NERICA varieties, and (ii) identify the best performing NERICA varieties under local conditions.

MATERIALS AND METHODS

Description of the trial site

The trial was conducted at Gwebi variety testing centre (GVTC), which is located in Natural Region IIa in Zimbabwe. The location is at an elevation of about 1600 m above sea level. The soils are sandy loams and mean annual rainfall ranges 700 to 950 mm. Average summer temperatures are between 24 and 26°C.

Source of germplasm

Three NERICA varieties; NERICA 1, NERICA 3, and NERICA 7 and a local check variety, Mhara 1, were used. The NERICA varieties were introduced by the Crop Breeding Institute, Ministry of Agriculture and Irrigation Development from the West African Rice Development Association (WARDA). The local check variety, Mhara 1, from the Crop Breeding Institute, was chosen because of its highest yield performance amongst the local varieties in Zimbabwe.

Trial establishment and management

The land was disc ploughed and harrowed to a fine soil tilth. The seed was manually drilled in plots at a rate of 60 kg / ha. The plots had 6 rows of 2 m length and an inter-row spacing of 0.25 m. A four by four factorial experiment in a randomized complete block design with three replicates was used. The first factor (variety) had four levels; NERICA 1, NERICA 3, NERICA 7 and Mhara 1. The second factor (nitrogen) had four levels; 0, 39.5, 64.5 and 89.5 kg N / ha. Except for level 1 (0 kg N / ha where no fertilizer was applied), 24.5 kg N / ha came from the basal fertilizer compound D (7%: 14% P_20_5: 7% K_20) that was applied at planting at a recommended rate of 350 kg / ha. The other difference for each level was applied as top dressing twice as split application of ammonium nitrate (34.5% N) at four and eight weeks after crop emergence. The trial was kept weed free by hand hoeing. There was no incidence of diseases so no control was done. Bird scaring began at grain filling stage.

Table 1. Effect of nitrogen level on the agronomic performance of NERICA varieties.

Nitrogen level	Days to 50% heading	Plant height (cm)	Number of tillers	Panicle length (cm)	Maturity period (days)	Filled grains per panicle	Unfilled grains per panicle	Filled grain ratio (%)	Grains per panicle	1000 grain weight (grams)	Yield (grams/m^2)
0 kg/ha	103.42	73.17	4.58	20.75	141.76	37.08	16.75	81.16	53.83	29.66	289.50
39.5 kg/ha	100.75	74.75	4.33	21.25	140.50	50.42	21.83	83.38	72.25	30.09	394.80
64.5 kg/ha	101.42	77.75	4.67	22.17	140.17	45.75	24.17	77.66	69.92	29.46	347.70
89.5 kg/ha	101.08	81.58	4.58	23.50	139.17	51.17	29.05	73.87	80.25	28.95	386.60
P-value	0.080	0.012	0.924	0.005	0.450	0.005	0.005	0.390	0.001	0.607	0.011
5% LSD	-	5.12	-	1.50	-	8.23	6.50	-	10.02	-	66.02
% CV	5.70	7.90	10.50	8.29	20.10	21.40	33.98	17.91	17.41	14.50	22.33

Data collection and analysis

Data collected include days to 50% heading (number of days taken by plants in a plot to reach 50% heading), height of the plants, number of tillers at 28 days after emergence, panicle length at harvest time, maturity period, filled grains per panicle, unfilled grains per panicle, filled grain ratio, total grains per panicle, 1000 grain weight and grain yield. The data were subjected to analysis of variance (ANOVA) using Genstat software version 13 (Genstat, 2010). The 5% least significant difference was used to separate significantly different means.

RESULTS

The interaction between nitrogen fertilizer level and variety was not significant for all traits measured. However, significant nitrogen effects were observed on the average height of the plants (P = 0.012), panicle length at harvest time (P = 0.005), filled grains per panicle (P = 0.005), unfilled grains per panicle (P = 0.005), total grains per panicle (P = 0.001) and grain yield (P = 0.011) (Table 1). Nitrogen level 1 (0 kg N / ha) produced the lowest yield (2.9 t / ha). However, yield from level 2 (39.5 kg N / ha), 3 (64.5 kg N / ha) and 4 (89.5 kg N / ha) were 4.0, 3.5 and 3.9 t / ha, respectively, and were not significantly different from each other.

The grains per panicle were least with level 1 (0 kg / ha) which was significantly different from other levels and were high as the amount of fertilizer was increased. However, the number of grains per panicle produced from 39.5 and 64.5 kg N / ha were not significantly different. The unfilled grains per panicle increased as the level of nitrogen increased.

However, level 2 (39.5 kg N / ha) and level 3 (64.5 kg N / ha) had the same number of unfilled grains per panicle. Filled grains per panicle werelowest at 0 kg N / ha. However, means for filled grains per panicle from level 2 (39.5 kg N / ha), level 3 (64.5 kg N / ha) and level 4 (89.5 kg / ha) were not significantly different from each other. Panicle length increased with an increase in the level of nitrogen fertilizer (Table 1). However, means for panicle length from level 1, 2 and 3 were not significantly different from each other. Increased fertilizer rates also increased the height of the plants. However, heights from level 1, 2 and 3 were not significantly different from each other. Level 4 produced the tallest plants. Irrespective of the level of the fertilizer used, the days to 50% heading, number of tiller at 28 days after emergence, maturity period, filled grain ratio and 1000 grain weight were not significantly different at 5% level of significance (Table 1).

The variety main effects were significant on days to 50% heading (P = 0.001), average height of the plants (P = 0.001), filled grains per panicle (P = 0.001), filled grain ratio (P = 0.013), total grains per panicle (P = 0.001), 1000 grain weight (P = 0.001) and grain yield (P = 0.001). However, the variety main effects were not significant on the number of tillers at 28 days after emergence, panicle length at harvest time, maturity period and unfilled grains per panicle (Table 2).

The type of variety had an effect on the agronomic performance of rice varieties tested. The variety performed in a more or less the same order for most yield components that include 50% heading, average height of the plants, filled grains per panicle, filled grain ratio, grains per panicle, 1000 grain weight and grain yield. NERICA 1 had the least number of days to 50% heading(96 days) that was significantly fewer than the rest,

Table 2. Response of three NERICA varieties to different nitrogen fertilization levels under local environmental conditions.

Variety	Days to 50% heading	Plant height (cm)	Numbers of tillers	Panicle length (cm)	Maturity period (days)	Filled grains per panicle	Unfilled grains per panicle	Filled grain ratio (%)	Grains per panicle	1000 grain weight (grams)	Yield (grams/m^2)
NERICA 1	96.52	65.75	4.58	22.83	140.17	49.92	20.08	79.23	70.00	26.96	359.60
NERICA 3	101.98	76.21	4.04	21.62	139.93	63.79	23.70	83.46	87.48	25.93	444.90
NERICA 7	104.20	81.52	4.79	21.75	140.04	49.23	21.21	85.60	70.45	29.48	388.00
Mhara 1	103.30	82.00	4.50	21.42	141.33	26.33	27.67	67.07	54.00	34.60	245.00
P-value	0.001	0.001	0.640	0.252	0.786	0.001	0.101	0.013	0.001	0.001	0.001
5% LSD	2.20	5.12	-	-	-	8.23	-	11.80	16.00	1.74	66.02
% CV	5.70	8.00	10.5	8.29	20.10	21.40	33.98	17.91	17.41	14.50	22.33

followed by NERICA 3 (101 days). The number of days to 50% heading were not significantly different for NERICA 7 and Mhara 1. The same trend that occurred on days to 50% heading occurred on the plant height. NERICA 1 had the least plant height (65.7 cm) that was significantly different from the rest, followed by NERICA 3, NERICA 7 and then Mhara 1. However, the heights of NERICA 3, NERICA 7 and Mhara 1 varieties were not significantly different from each other. Furthermore, the maturity periods were not significantly different for the varieties tested. The numbers of tillers per variety were not significantly different at 5% level of significance.

Although, the numbers of unfilled grains per panicle were not significantly different, the total number of grains per panicle, filled grains per panicle and the filled grain ratio were significantly different and followed the same trend on all varieties. NERICA 3 had the highest number of grains per panicle, filled grains per panicle and filled grain ratio followed by NERICA 7, then NERICA 1. Mhara 1 had the least number grains per panicle, filled grains per panicle and filled grain ratio (Table 2). Interestingly, the same trend was found on the grain yield. NERICA 3 produced the highest mean yield (4.4 t / ha) followed by NERICA 7 (3.9 t / ha) and then NERICA 1 (3.6 t / ha). The local check variety, Mhara 1, had the least yield (2.5 t / ha) (Table 2).

DISCUSSION

The interaction that was not significant for all traits indicate that the performance of the varieties was not related to the level of nitrogen fertilization. Since level 2 (39.5 kg / ha), 3 (64.5 kg N / ha) and 4 (89.5 kg N / ha) produced statistically similar yield, the optimum level of nitrogen fertilization for these varieties is level 2 (39.5 kg / ha). This optimum level is also confirmed by the number of grains per panicle and filled grains per panicle, which were not significantly different from each other for level 2 and 3. This observation is line with the previous reports that identified 40 to 67 kg / ha of nitrogen as the optimum level (Watanabe et al., 1988; Dingkun et al., 1998; De Batista, 2002; Fukai and Ouk, 2012). Therefore, an increase in the level of nitrogen beyond level 2 (39.5 kg / ha N), would result in diminishing returns.

The addition of nitrogen beyond 39 kg / ha N had a tendency to increase the number of unfilled grain per panicle. This could possibly be accounted for by the increase in the rate of abortion. Marschner (1986) and Matsushima (1980) reported that over-application of nitrogen in the vegetative stage and between the neck-node differentiation and spikelet differentiation stages, induces increased levels of protein instead of carbohydrates, resulting in excessive growth of shoots, affecting negatively the root system, degree of lodgingand spikelet fertility. Thus, nitrogen tends to favor the vegetative phase than the grain filling phase (De Batista, 2002; Yan et al., 2010). Panicle length was not influenced by the addition of nitrogen. The nitrogen fertilizer increased the height of the rice plants. This shows that excess nitrogen application can result in increased height of rice plants and is undesirable because it causes lodging (Kato et al., 2006).

The type of variety has an effect on the agronomic performance of rice varieties tested (Wade et al., 1999; Inthapanya et al., 2000;

Sheehy et al., 2001). In terms of yield and other yield related traits, NERICA 3 is the best variety followed by NERICA 7, and then NERICA 1 while the local check variety, Mhara1, is the poorest. The number of days to 50% heading influences the height of the rice plants. The less the number of days to 50% heading the shorter the plant. This is desirable since shorter plants do not suffer much from lodging (Yan et al., 2010; Jones et al., 1997). Since the maturity period of these varieties were not significantly different from each other, varieties that reached 50% heading earlier would have a prolonged grain filling duration. However, in this study, varieties with longer grain filling duration (as indicated by earlier heading) did not always give high yield. This suggest that yield is not only influenced by grain filling duration, but also the efficiency in partitioning of the photo-assimilates to the respective sinks (Sheehy et al., 2001). Maturity period that was not significant, indicate that these varieties have the same maturity period.

The unfilled grains per panicle could be caused by the location of the grains on the panicle. In most cases, grains at the tip abort because they lack photo-assimilates since they are located far away from the source (Yan et al., 2010; Sheehy et al., 2001). The local check has poor grain filling ratio compared to NERICA varieties that were bred for high yield and hence high grain filling ratio. Yield is a function of the number of filled grains per panicle and 1000 grain weight and the number of grains per panicle contributed more to yield than the 1000 grain weight.

However, since panicle length was not significantly different it shows that the variation in yield and the number of grains per panicle observed could result from bigger diameter than length of the panicle. Nitrogen increases the panicle length, panicle number per unit area, the number of spikelets per panicle and spikelet fertility (Mingotte et al., 2013; Fageria and Barbosa Filho, 2001) and in improving the nutritional quality of rice grain (Mingotte et al., 2012).

Conclusions

The optimum level for nitrogen fertilizer (34.5% N) is 39.5 kg / ha for all varieties. The NERICA 3 variety is the best under local conditions followed by NERICA 7 while NERICA 1 is the poorest. All these introduced NERICA varieties out yielded the local check variety, Mhara 1 and thus can be promoted to boost rice yield under Zimbabwean conditions.

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REFERENCES

Cooper M, Fukai S, Wade L (1999). How can breeding contribute to more productive and sustainable rained lowland rice system? Field Crops Res. 64:199-209.

De Batista JJ (2002). Rice management and fertilization in the Entere Rios Province. Field Crops Res. 16:40-47.

De Datta SK (1990). Sustainable rice production: challenges and opportunities. Paper presented at the 17th Session of the International Rice Commission (IRC). Food and Agriculture Organisation of the United Nations, 4-9 February, 1990. Goiania, Brazil.

Diagne A (2006). Diffusion and adoption of NERICA rice varieties in Côte d'Ivoire. Devel. Econ. 2:208-231.

Dingkun M, Jones MP, Johnson DE (1998). Growth and yield potential of *Oryza sativa* and Oryza glaberrima. Field Crops Res. 57:57-69.

Duangjai SA, Prasert C, Fukai S, Pax B (2000). Identification of nutrients limiting rice growth in soils of Northeast Thailand under water-limiting and non-limiting conditions. Plant Prod. Sci. 3:417-421.

Fageria NK, Barbosa Filho MP (2001). Nitrogen use efficiency in lowland rice genotypes. Commun. Soil Sci. Plant Anal. 32:2079-2089.

Fukai S, Cooper M, Wade L (1999). Adaptation of rain-fed lowland rice. Field Crops Res. 64:198-210.

Genstat (2010). Genstat Release 13.3 (PC/ Windows Vistal). VSN International Ltd.

Hideo W, Koichi F, Jones MP, Teslim I, Sobambo B (1999). Grain Quality of Glaberrima/Sativa Progenies in Relation to Their Parents. Japanese J. Crop Sci. 68(1):204-205.

Inthapanya P, Sihavong P, Sihathep V, Chanphengsay M, Fukai S, Basnayake J (2000a). Genotype differences in nutrient uptake and utilisation for grain yield production of rainfed lowland rice under fertilised and non-fertilised conditions. Field Crops Res. 65:57-68.

Inthapanya P, Sihavong P, Sihathep V, Chanphengsay M, Fukai S, Basnayake J (2000b). Genotypic performance under fertilised and nonfertilised conditions in rainfed lowland rice. Field Crops Res. 65:1-14.

Jones P, Dingkuhn M, Aluko GK, Semon L (1997). Rice improvement through Interspecific hybridization of Oryza sativa and Oryza glaberrima. Euphytica 92:237-246.

Kaneda C (2007). Breeding and dissemination efforts of NERICA varieties. A Review. Field Crops Res. 5:49-77.

Kato Y, Kamoshita A, Yamagishi J, Abe J (2006). Growth of three rice (Oryza sativa L.) cultivars under upland conditions with different levels of water supply. 1. Nitrogen content and dry matter production. Plant Prod. Sci. 9:422-434.

Khush GS (2010). What it will take to feed 5.0 billion rice consumers in 2030. Plant Mol. Bio. 59(1):1-6.

Marschner H (1986). Relationship between mineral nutrition and plant diseases and pests. In: Marschner H. (Ed.). Mineral nutrition of higher plants. London, Academic Press. pp.369-390.

Matsushima S (1980). Pratices of stable and high yielding rice cultivation. In: Rice cultivation for the million. Tokio Japan Sci. Soc. pp.141-144.

Mingotte FLC, Hanashiro RK, Fornasieri Filho D (2012). Physico-chemical parameters of rice cultivars fertilized with nitrogen. Ciências Agrárias 33:2605-2618.

Mingotte FLC, Hanashiro RK, Fornasieri Filho D (2013). Response of rice cultivars to nitrogen in upland conditions. Rev. Ceres. Viçosa. 60(1):86-95.

Ragland J, Boonpuckdee L (1988). Fertilizer responses in Northeast Thailand. 3. Nitrogen use and soil acidity. Thai J. Soils Fert. 10:67-76.

Sheehy JE, Dionora MJA, Mitchell PL (2001). Spikelet numbers, sink size and potential yield in rice. Field Crops Res. 71:77-85.

Fukai S, Ouk M (2012). Increased productivity of rainfed lowland rice cropping systems of the Mekong region. Crop Pasture Sci. 63:944-973.

Wade L, Fukai S, Samson BK, Ali A, Mazid MA (1999). Rainfed lowland rice – physical environment and cultivar requirements. Field Crops Res. 64:3-12.

Watanabe I, Padre BC, Santiago ST (1988). Quantitative study on nitrification. Soil Sci. Plant Nutr. 27:373-382.

Yan J, Yu J, Tao GC, Vos J, Bouman BAM, Xie GH, Meinke H (2010). Yield formation and tillering dynamics of direct-seeded rice in flooded and non-flooded soils in the Nuai River Basin of China. Field Crops Res. 116:252-259.