International Scholars Journals

African Journal of Crop Science ISSN 2375-1231 Vol. 3 (9), pp. 230-233, November, 2015. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Influence of nitrogen and phosphorus fertilizer application on grain yield of upland rice in Eastern Uganda

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Accepted 15 July, 2015

Rice (*Oryzasativa*) is increasingly becoming an important food and cash crop in Uganda especially among small-scale holder farmers. Declining soil fertility is thought to be the major production constraint leading to low yields. Nitrogen and phosphorus are the major limiting nutrients to rice production in most rice growing areas in Uganda especially in the Eastern region. A study was conducted to explore the yield benefits associated with nitrogen and phosphorus fertilization. Screen house experiments were conducted at Serere Agricultural and Animal Production Research Institute (SAAPRI). Two upland rice cultivars were grown in soil which had been continuously cultivated. The experimental design was a randomized complete block design arranged in split-split plots with variety as main plots, nitrogen and phosphorus treatments as sub-sub plots. Phosphorus at three rates (0, 25 and 50 kg P_2O_5 ha^{-1}) was applied at planting and Nitrogen at five rates (90, 150, 180 and 240 kg N ha^{-1}) was applied two weeks after planting. Nitrogen and phosphorus application significantly ($P<0.05$) influenced grain yield of upland rice. However, combined application of nitrogen and phosphorus at 150 kg N ha^{-1} and 25kg $P_2O_5ha^{-1}$ respectively, gave highest and significant effect ($P<0.05$) on grain yield.

Key words:*Oryzasativa,* nitrogen, phosphorus, upland rice, Eastern Uganda.

INTRODUCTION

Although rice was traditionally very prominent in Asia, it has gained prominence in the farming systems and diets in Africa, Middle East and Latin America (Cummings, 1982; Ochollah et al., 1997; Audebert et al., 1999). It ranks as Africa's fourth most important grain crop, behind maize, sorghum and millet in providing primary source of carbohydrates for farmers in Africa (WARDA, 2008). It is one of the most important food crops of the developing world and a staple food crop for about 50% of the world's population, accounting for about 20% of the world's calorie consumption (FAO, 1999). In terms of acreage grown, it is second to wheat (FAO, 1998; USAID, 2015). For many African farmers, rice is a secondary crop only relied on as both a source of income, as a niche crop in low-lying areas of small farms. In East Africa it is considered a new crop producing less than 0.4% of the world's total rice output (FAO, 1999; IRC,2015) and in Uganda, rice (*O. sativa*) is one of the

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major cereal crops today, others being maize, millet and sorghum.

Despite the crop being relatively new in Uganda, within a period of only four years between 2001 and 2004, rice production rose from 76,000 tonnes to 93,000 tonnes per year, an average annual increase of 4,250 tons (FAO, 2004, MAAIF, 2004) with upland rice production being on the increase. Currently, annual area under rice production is increasing by 6,500 ha (MAAIF and UBOS, 2005). With the introduction of the early maturing and high yielding NERICA varieties, upland rice production will rise further. Upland rice production has now spread to non-traditional rice districts of Wakiso, Mukono, Luwero, Kitgum, Arua, Lira, Apac and Gulu. Upland rice production has also been highly adopted in the major rice growing districts of Masindi, Hoima, Iganga, Bugiri, Tororo, Pallisa, Kumi and Mbale (Ochollahet al., 1997; MAAIF, 2003).

It evolved from being a dominant pioneer upland crop in the process of expansion of frontier areas in the previous years to becoming a well-established, intensive, highly commercial cash and food crop. In Uganda, rice has increasingly become an important food and cash crop. In the past, it was considered a commercial product rather than a food crop. Many rural farmers relied on it as a source of income and only consumed it on special occasions (WARDA, 2008).

The crop is among the most appreciated of all the crop assets, providing incomes to the rural households and the national economy (Oryokot, 1998; WARDA, 2008). It is also one of the important tradable crops generating high income in the domestic, regional and world markets (Lamo et al., 2004) thus earning revenue to the country. In addition to being a commercial crop, rice has now changed its status and become a common and major food crop even in rural areas. It is now a staple food to over a half of the population (Oryokot, 1998) forming a significant proportion of the diet of urban dwellers and is one of the major foods in institutions like schools, colleges/universities, and hospitals (Imanywoha and Kibwika, 2002). It has become a staple in the diets of consumers of even rural households (FAO, 2004).

The area under cultivation is not sufficient and it seems not possible to increase the area for rice cultivation in Uganda, although some non-traditional areas are being brought under rice cultivation through the shift to upland rice ecology. However, the most important thing is to increase the per hectare yield of rice by applying modern agricultural techniques such as the use of good quality (disease free) and high yielding seeds, weed control, irrigation, use of pesticides, proper fertilization practices and development of integrated approaches towards pest management among others.

Additionally, the land brought under upland rice cultivation in Uganda is generally low in nutrients (Briggs and Twomlow, 2002). As a result the soils cropped annually without any additional inputs are generally low in soil fertility (Wortmann and Kaizzi 1998; Ssendiwanyoet al., 2000). Nitrogen (N) and phosphorus (P) fertilizers play important roles on the yield of cereal crops including rice grown on such soils. Many studies have found positive influences of N and P fertilizations on the yield of cereal crops grown under these soils (Nyende, 2000; Olupotet al., 2004). Generally, Nitrogen and phosphorus deficiencies contribute to low soil fertility in Uganda (Bekunda, et al., 1997). Olupot (2004) also found N and P contents to be very low in Eastern Uganda where cereals are largely grown. Nitrogen and phosphorus are reported to be the most limiting nutrients in Ugandan soils (Bekundaet al., 2002).

MATERIALS AND METHODS

Description of study sites

Greenhouse studies were conducted at Serere Agricultural and Animal Production Research Institute (SAAPRI) under natural daylight conditions. The Institute is located in north eastern Uganda and lies between 1^{o} 32`N, 33 $^{o}$ 27`E at an altitude of 1100m above sea level. The soil was a composite obtained from a field that was cultivated continuously without additional inorganic inputs for several years. Soils used consisted of the following; pH, 5.0; organic matter (OM) 1.98%; N, 0.12%; available P, 4.75mgkg^{-1} and K 0.22me/100g soil. The soil used in pot experiment was sandy clay loam texture with 48, 28 and 24% sand, silt and clay respectively.

Treatments and experimental design

The treatments consisted of nitrogen at five levels, phosphorus at three levels and two up land rice cultivers (NARIC 1 and NARIC 3). Nitrogen was applied at five different rates; 0kg (no N applied), 90 kg N ha^{-1}, 150 kg N ha^{-1}, 180kg N ha^{-1}, and 240 kg N ha^{-1} while phosphorus was applied at three rates of 0, 25 and 50kg ha^{-1} equivalents. Single supper phosphate and urea fertilizers were used as sources of P and N respectively. The treatments were arranged in a spit split plot arrangement of a randomised complete block design with three replications. Four rice seeds were planted for each cultivar at equal spacing in a plastic pot measuring 20cm in diameter and 15 cm height which were filled with 3.5 kg of soil collected at 0-20cm depth. The plants were fertilized with urea 21days after planting. Watering was done as necessary throughout the growth period.

Plant growth parameters

To establish the relationship between fertilization and rice performance, Grain yield and the interaction between the two treatments was determined. Grain yield was determined by counting and weighing the quantity of seeds per panicle per pot. Four panicles per pot were harvested and number of filled grains recorded as a mean number of grains per plant.

Data analysis

All data collected were subjected to analysis of variance (ANOVA) for determination of means of samples and treatments using GenStat, version 14. The Least Significant Differences (LSD) from GenStat at 5% probability level was used to determine differences among significant treatment means.

RESULTS AND DISCUSSION

Influence of Nitrogen and Phosphorus on grain yield

Using two fertilizers in combination (Nitrogen and Phosphorus) was significantly ($P<0.05$) different from the control treatment and where one form of fertilizer was used (Table 1). The highest grain yield obtained with 240 kg N ha^{-1} application might have been due to highest number of tillers which maintained the highest number of productive tillers when applied singly and also in combination with phosphorus. This was reflected in NARIC 1 rice variety. (Peng *et al*., 1994) found grain yield to be dependent on tiller numbers produced per plant. Similar results were also found in this study. Similarly the highest grain yield obtained in NARIC 3 at 180 kg N ha^{-1} could also be as a result of the highest plant height that resulted in this treatment. In previous studies Nyende, (2001) found plant height to be related to grain yield. On the other hand, the higher tiller numbers obtained at high doses of fertilizer did not yield more productive tillers while the few tillers produced at 150-180 kg N ha^{-1} yielded more productive tillers resulting in equal grain weights. This might be that at high doses of nitrogen and phosphorus more tillers were produced and the plants remained short due to over competition for space, air and nutrients, since this treatment had no significant yield advantage over others (Table 1). Grain yield followed a similar trend with grain numbers per panicle. This could be because the more the grains produced the more the weight. It could also be that phosphorus was well utilized for grain formation while nitrogen influenced the many tillers to produce panicles consequently higher yields. Similar findings were reported by Wen and Yang (1991) who obtained higher rice yield, effective panicles, number of grains and panicle per square metre.

Since the same number of plants was maintained in all treatments, therefore, similar conditions merely prevailed among treatments. Srinivasulu *et al*. (1999) obtained higher grain yield when one seedling was planted per hill compared to two or three seedlings per hill due to the higher tillering ability coupled with space and nutrient available to one plant which reduces competition from roots for nutrients, space and air reducing the percentage of productive tillers. These findings are in line with the above findings. Therefore, grain yield can be dependent on morphological components of yield such as plant height, number of panicles per unit area, the number of grains per panicle, or grain weight. These components are influenced greatly by the soil environments (Peng*et al*., 1994).

Interactive effect of N and K on grain yield

The N x P (Fig.1) increased grain yield by 37% and 49 % at the lowest combination and by 63% and 46% at 150 kg Nha^{-1} x 25 kg P_2O_5 ha^{-1} in NARIC 1 and NARIC 3 respectively. The improvements in yield of N x P treatments (Fig.1) compared to control and N applied treatments could be due to better utilisation efficiency of nutrients by rice plants. The consistent increase in yield where N + P was applied implies that both nutrients were deficient in the soils of the study. Overall 150 kg Nha^{-1} x 25 kg P_2O_5 ha^{-1} gave higher yields. The increased yield under fertilised treatments irrespective of rate, confirm that these soils have low fertility for intensive rice production given the fact cereal crops depletes soil resources very fast (Briggs and Twomlow, 2002; Kijima, 2005).

The reduced yields under single applications P and N alone, implies that these nutrients were poorly utilised (P analytical value, was below critical values) and the increasing tillering without enhancing tillers to bear panicles and encourage grain formation is wasteful as nitrogen is essential for increase plant height and production of panicle bearing tillers while phosphorus promotes grain formation consequently increasing gain yield. The increased productivity of rice might also be due to better physical, chemical and biological characteristics of soil due to increased N utilization efficiency that caused a parallel increase in the respective yielding components.

This is explained by the fact that grain yield is a function of interplay of various yield components such as plant height, number of productive tillers and grain numbers per panicle (Hassan et al., 2003). In other studies, Kijima et al., (2005) found lower yields from farmers who had no rice growing experience and had applied larger amounts of fertilizers to NARIC cultivars. Similarly lower yields were observed in plots planted to NARIC rice after cereal crops. This suggests that upland rice yields can be increased through fertilizers replenishment(WARDA 2008). The lowest yield obtained with control treatments and also the decline in yield observed at higher nitrogen and phosphorus doses (240 kg N ha^{-1} and 50 kg $P_2O_5ha^{-1}$)in this study are supported by these findings. Therefore,

Table 1. Effect of N and P fertilization on grain yield (g).

N kgha⁻¹	**P_2O_5, kg ha^{-1}**				
	Vty	**0**	**25**	**50**	**Av**
0	NARIC 1	8.13	9.18	8.48	8.60
	NARIC 3	8.67	8.25	7.45	8.12
90	NARIC 1	9.25	11.15	11.85*	10.51
	NARIC 3	11.03	12.92*	11.85*	11.93
150	NARIC 1	9.58	13.27*	10.60	11.15
	NARIC 3	9.65	12.73*	12.37*	11.58
180	NARIC 1	9.55	13.02*	11.83*	11.47
	NARIC 3	11.70	11.64*	9.43	10.93
240	NARIC 1	11.55*	10.62	15.47*	12.54
	NARIC 3	8.55	11.02	9.87	9.81
Av	NARIC 1	9.61	11.45	11.50	
	NARIC 3	9.92	11.31	10.19	

LSD (0.05)(N-rates): 1.811 (P-rates): 1.403 Nx P: 3.136 Vty: 1.145
* Significant (0.05)
Significant for values within the same column.

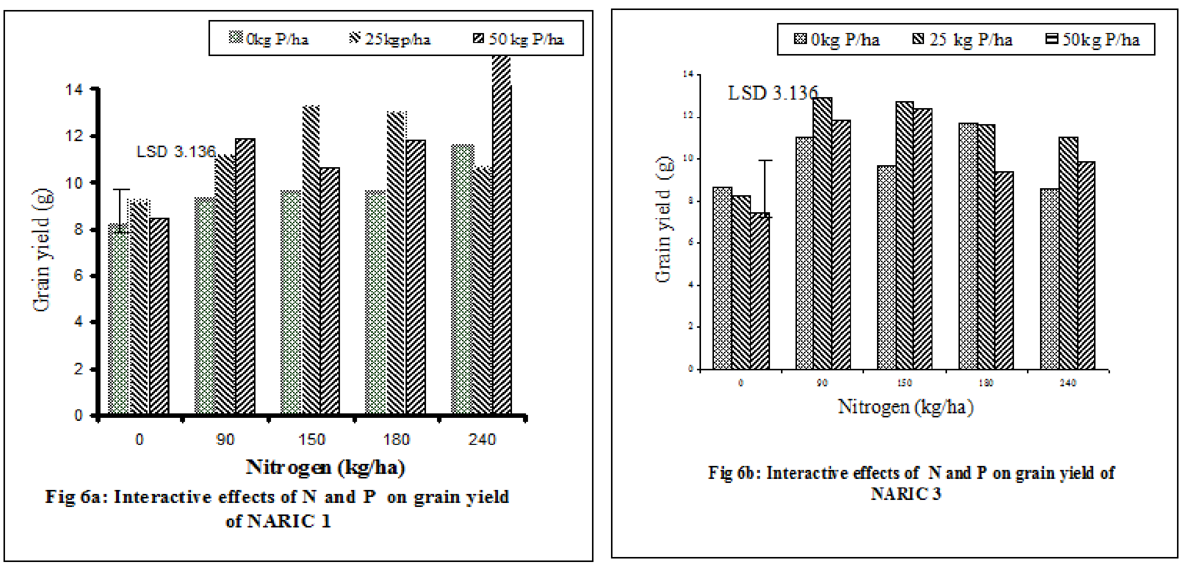

Figure 1. Interactive effects of N and P on grain yield of rice for NARIC 1 and 3.

continuousrice cultivation would require addition inorganic fertilizers. Otherwise soils will be depleted and upland rice yields particularly NARIC yields will remain low.

ACKNOWLEDGEMENT

The authors thank the Regional Universities Forum for Capacity Building in Agriculture [RUFORUM] for financial support, the extension workers in the districts for mobilizing farmers. The members of the various farmers' groups in the districts are appreciated for their participation and co-operation during the trials.

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