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Effect of Nitrogen and Phosphorus Application on Growth and Yield of Dual-purpose Sorghum (*Sorghum bicolor* (L) Moench), E1291, in the Dry Highlands of Kenya

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Abstract: This study was conducted using a dual-purpose cold tolerant sorghum E1291 to determine the effect of varying rates on nitrogen (N) and phosphorus (P) on its growth and yield at KARI, Beef Research Centre, Nakuru for two seasons. The experiment was laid out in a 5x5 factorial in a Randomized Complete Block Design (RCBD). Phosphorous (P_2O_5) (0, 20, 30, 40 and 50 kg ha^{-1}) was applied at sowing and N (0, 20, 30, 40 and 50 kg ha^{-1}) applied when the seedlings were 50 cm in height. Treatment effects were determined using plant height, 1000-seed weight, Crude Protein (CP) and grain yield. Nitrogen and Phosphorous levels beyond 40 and 30 kg ha^{-1}, respectively did not increase plant height, seed weight, crude protein and grain yield. Crude protein content in grain increased from 9.38 to 11.56%, while grain yield increased from 7 to 9 tons ha^{-1}. The optimum sorghum grain yield was attained at 40 kg ha^{-1} N and 20 kg ha^{-1} P_2O_5, respectively. For crude protein the optimum was obtained at 20 N and 30 P kg ha^{-1}, respectively. Overall, this study showed that fertilizers could enhance the production of grain sorghum (*Sorghum bicolor* (L) Moench) in the dry highlands of Kenya. However, the conventionally recommended rates of 88 kg ha^{-1} of nitrogen (N) and 94 kg ha^{-1} of phosphorous (P_2O_5) proved wasteful and excessive.

Key words: Dual-purpose sorghum, phosphorus, nitrogen, Kenya

INTRODUCTION

Nitrogen, phosphorous and potassium are the essential elements required for plant growth in relatively large amounts. However, deficiencies of nitrogen and phosphorus are common. Soil nutrients become depleted due to leaching of nitrogen, fixation of phosphorous, soil erosion and removal by crops[1-4]. To maintain high crop production level, the nutrient status of the soil has to be maintained through crop rotation, addition of manures or application of inorganic fertilizers[5,6]. Inorganic fertilizers are important inputs in any agricultural production system because they supply the required nutrients in a readily available form for immediate plant use. Nitrogen deficiency can result in reduced Dry Matter (DM), crude protein and grain yields. Sorghum (*sorghum bicolor* (L) Moench) responds to applied fertilizers and can increase yield by over 50%. Recorded yields ranging between 20 to 40 kg of grain per kg of applied nitrogen have been reported by House[7].

However, many researchers[8-11] found little grain yield response to fertilizer in some cold tolerant sorghum varieties. In the cold dry highlands, sorghum farmers seldom apply fertilizers to their sorghum. This is partly because sorghum is often grown under marginal rainfall conditions, resulting in relatively low yields and partly due to the fact that fertilizer prices are unfavorably high in relation to sorghum grain price. Further, low usage of fertilizer is therefore due to the fact that yields are usually not high enough to be seriously limited by nutrient supply. The current recommendation of 88 kg ha^{-1} N and 92 kg ha^{-1} P_2O_5[12] are deemed to be high and similar recommendations were made by the Fertilizer Use Recommendation Project (FURP). A review of this recommendation is essential due to changing economic situation in Kenya.

The objectives of this study were to determine the response of cold tolerant dual purpose sorghum E1291 to Nitrogen and Phosphorous and to evaluate the effect of varying levels of both N and P (P_2O_5) on plant height, seed weight, crude protein and grain yield of sorghum under dry conditions of the Kenyan highlands.

MATERIALS AND METHODS

The study was carried out at the Kenya Agricultural Research Institute, Beef Research Centre, Lanet (0°, 30°S, 36°E) in Nakuru District of Rift Valley Province during the long rainy seasons of 2001, 2002 and 2003. Annual rainfall is often below 800 mm and is unreliable

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both in quantity and distribution. The area experiences bimodal rainfall patterns, the long rains beginning at the end of March up to June and short rains beginning in mid-October to mid-December. Temperatures range between 8 and 30°C. Soils are a deep sandy loam with good water holding capacity and are classified as of marginal agricultural potential in Ecozone IV[13].

Experiments were laid out in a Randomized Complete Block Design (RCBD) with three replicates. Cold tolerant, medium maturity dual-purpose sorghum cultivar E1291 was used and sown at the onset of long rains. Single Super Phosphate (SSP) and Calcium Ammonium Nitrate (CAN) fertilizers were used to supply phosphorous (P_2O_5) and nitrogen, respectively. Furadan 5G was used to control soil borne pests, while Actellic liquid was used to control foliage pests.

The experimental site was ploughed, harrowed and finally hand leveled to ensure a fine tilth. Plot size was 4.2x4.2 m. Furrows were made by manually dragging a stick along a string used to mark rows. Furadan granules were thinly applied in the rows and later thoroughly mixed with the soil. Phosphorous P_2O_5 was thinly applied at varying levels of 0, 20, 30, 40 and 50 kg ha^{-1} in the furrows and mixed with the soil. Sorghum seeds (E1291) were sown in the rows at spacing of 60 cm between rows and 20 cm within rows and thinly covered with soil.

Treatments constituted of a 5x5 factorial arrangement in a Completely Randomized Block Design. Each treatment was replicated three times. Nitrogen (CAN) was applied six weeks after sowing at varying levels of 0, 20, 30, 40 and 50 kg ha^{-1}. Plots were kept weed free by hand weeding and Actellic sprayed to control foliage pests @ 1 L ha^{-1}. Data collected were days to 50% flowering and grain yield. Observations made during crop growth were used to explain the results. Grain and stover were further analyzed for Crude Protein (CP) using proximate and Van Soest methods of analysis.

SYSTAT statistical package was used to analyze the data[4].

RESULTS

Results of this experiment show varied responses of highland sorghum to the different levels of fertilizer application. At all fertilizer levels, there were significant differences in crude protein ($p<0.05$). Grain yield also had significant differences ($p<0.05$) at all N fertilizer levels.

Considering interactions, application of 40 kg ha^{-1} of nitrogen and 20 kg ha^{-1} phosphorus fertilizers produced the highest grain yield, 9.85 tons ha^{-1} (Fig. 1). However, application of 30 kg ha^{-1} of P and 20 N kg ha^{-1} produced the greatest crude protein, 16.41% (Fig. 2).

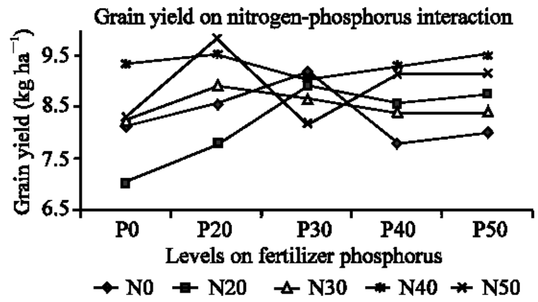

Fig. 1: Grain yield of sorghum, E1291, in nitrogen-phosphorus interaction within the study area

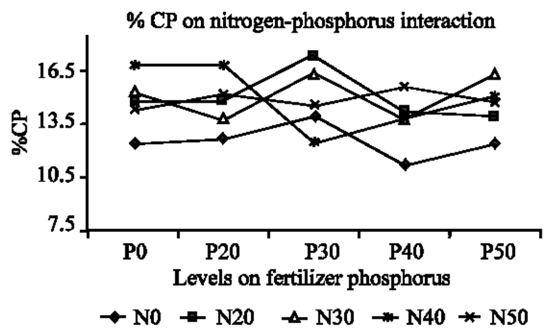

Fig. 2: Crude protein of sorghum, E1291, in a nitrogen-phosphorus interaction within the study area

Table 1: Height (cm) of sorghum, E1291, in a nitrogen-phosphorus fertilizer interaction

N fertilizer (kg ha^{-1})	Phosphorus fertilizer (kg ha^{-1}) 0	20	30	40	50	Mean (N)
0	158.0	165.0	163.0	165.0	160.0	162.0
20	162.0	163.0	156.0	165.0	163.0	162.0
30	163.0	163.0	165.0	165.0	159.0	163.0
40	155.0	163.0	167.0	158.0	167.0	162.0
50	150.0	162.0	153.0	162.0	153.0	156.0
Mean	158.0	163.0	161.0	163.0	161.0	
LSD	10.5					
CV	4%					

Table 2: 1000-seed weight (g) of sorghum, E1291, in a nitrogen-phosphorus fertilizer interaction

N fertilizers (tons ha^{-1})	Phosphorus fertilizer (kg ha^{-1}) 0	20	30	40	50	Mean (N)
0	2.10	2.12	2.0	2.1	2.2	2.1
20	2.20	2.24	2.1	2.1	2.2	2.2
30	2.19	2.23	2.2	2.2	2.2	2.2
40	2.23	2.12	2.1	2.0	2.3	2.1
50	2.25	2.22	2.1	2.2	2.2	2.2
Mean	2.20	2.2	2.1	2.1	2.2	
LSD	0.18					
CV	5.2%					

Plant height was highest (165 cm) at 0 N kg ha^{-1} and 20 P kg ha^{-1}, 30 N kg ha^{-1} and 30 P kg ha^{-1} and 20 N and 40 P kg ha^{-1}, respectively (Table 1). Further, 1000-seed weight was greatest (2.25 g) at 40 N kg ha^{-1} and 50 P kg ha^{-1} (Table 2).

DISCUSSION

For all parameters under study, a positive linear correlation (R^2=0.45) was observed when nitrogen and phosphorous were varied upwards (Fig. 3) suggesting that initially nitrogen played a complementary role in the uptake of phosphorous. This is in agreement with the observation of Roy and Wright[15], Dhliwayo and Whingwiri[16].

Phosphorous acting independently did not increase grain yield at levels beyond 20 kg ha^{-1} indicating the greater relevance of phosphorus mainly in the early stages of sorghum plant development. The increase of P uptake in the interaction between N and P (30 kg ha^{-1}) also indicates complementarities of nitrogen in the uptake of phosphorous. However as the levels of both N and P increases the response starts declining which probably indicates some acidification of the soil resulting in fixation of P[17].

The high yield obtained in control a plot was probably because land used for this experiment had been under grass for one year and the soil was not deficient in nutrients under review. The difference in yield of control plots and that with the highest levels of N and P_2O_5 was not enough to justify high levels of fertilizer application. Roy and Wright[15] showed that nitrogen application increased N uptake and therefore the protein content of the grain. Proximate analysis on grain showed that high levels of both nitrogen and phosphorous increased crude protein content from 9.38 to 11.56% (Fig. 3). Increasing N CP increase then decrease and same trend for grain yield. Height showed this trend because of genetic and environment interaction. As P increased the height of sorghum decreased from 20 to 50 cm. As N increased height increased up to 30 kg ha^{-1} then decreased although these differences were not significant.

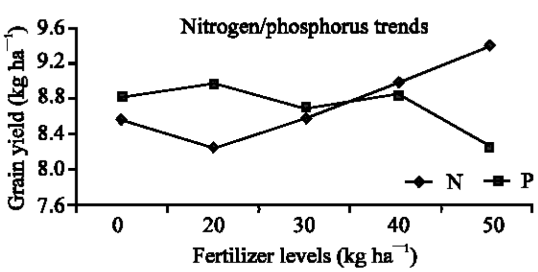

Fig. 3: Grain yield of sorghum E1291, in response to various fertilizer N and P levels in the study area

This study shows that cold tolerant sorghum positively responds to both nitrogen and phosphorous. The study has also shown that high grain and other yield components from highland dual-purpose sorghum can be obtained when optimum levels of nitrogen and phosphates, 40 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} are applied, respectively.

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