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Original Research Article

Effect of Phosphorus Source, Nitrogen Source and Rate on Growth and Forage Yield of Maize (*Zea mays* L.) in Two Soil Types in the River Nile State, Sudan

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Abstract

Field experiments were carried out from 2008/09 to 2009/10 growing seasons at two locations, namely, Hudeiba Research Station Farm (moderately fertile "Karu" soil) and Matara site (high terrace "poor fertile" soil) in River Nile State. The objective was to investigate the effect of phosphorus fertilizer source, nitrogen source and rate on growth and yields of maize. Two sources of phosphorus, namely, triple super phosphate (TSP) and diammonium phosphate (DAP), two nitrogen sources (urea and ammonium nitrate) and three N rates, namely, 0.0, 43 and 86 kg N/ha were used in the study. The design used was a split- split- plot with three replicates where phosphorus sources were allotted to the main plots and nitrogen sources and rates were assigned to the split- and split- splits plots, respectively. The results showed to phosphorus source had significant effects on plant height in both soil types only in the first season fresh and dry forage yields, the results indicated that P source had a significant effect only on fresh forage yield in the moderately fertile "Karu" soil in 2009, while N source did not significantly affect both maize characters in all cases. Addition of N significantly affected fresh and dry forage yields in three out of the four cases. In the three cases, application of 43 kg N/ha and 86 kg N/ha increased fresh forage yield by about 27 %, 19%, 50% and 36% over zero N treatments and by 38% and 75% over zero treatments in the Karu moderate fertile and the high terrace poor soil, respectively. The application of nitrogen at 43 kg N/ha to the "Karu" moderate fertile soil increased dry forage yield by about 17 % and13 in the first and second season, respectively over no treatments. While, the application of 86 kg N/ha increased dry forage yield by about 29% and 30% in the first and second season, respectively. In the high terrace poor soil the addition of both N rates (43 and 86 kg N/ha) resulted in 25% dry forage yield only in the second season over no nitrogen treatments. In conclusion, the results of this study showed that P source significantly affected maize performance than N source in the two soil types. Application of N at 43 kg N/ha or 86 kg N/ha, irrespective of N source significantly improved maize performance in the two soil types than the zero N treatments with significant differences between N rates in most cases.

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Introduction

Maize (*Zea maize* L.) is the world's third cereal crop after wheat and rice in consumption and production. However, the crop has a wide range of uses than all cultivated cereals as primary staple food in many tropical and sub tropical countries and feed and forage crop in USA and temperate regions. Moreover, maize is used in many industrial products such as glucose, starch, papers, insulators and vegetable oil for human consumption. The green parts are made into silage, while the dry parts are used as livestock feed (Fisher and Palmer, 1984). In Sudan, maize ranks fourth sorghum, wheat and millet (Hassan, 2004).

In Sudan, maize is grown as a subsistent rain-fed crop around villages in Nuba Mountains, southern Sudan and the Blue Nile State. The crop is also grown under irrigation in central, eastern and northern Sudan. Recently, maize gained more importance as a forage and food crop in the last two decades especially in River Nile State where the crop is successfully grown by irrigation in late summer and winter seasons (Mohammed, 2006). In fact, three soil types-gurier (high fertile), karu (moderately fertile) and high terrace (poor soils) are used to produce different crops. These soils greatly vary in their fertility and other soil characters, and the farmers in the State usually prefer to grow high value crops in gurier and karu soils. As maize cannot compete with these high value crops, therefore, any expansion in maize production will be in the high terrace poor soils. Very little or no research work had been done regarding maize fertilization in the high terrace poor soils. The objective of this study, therefore was to investigate the effects of phosphorus and nitrogen sources and rate on growth and yield of maize grown in two soil types in northern Sudan.

Materials and methods

Characteristics of the two sites

The experiment was conducted at two sites, namely, Hudeiba Research Station Farm (HRSF) moderately fertile "Karu" soil and about 3 km north east from the research station farm at Matara site (high terrace "poor fertile" soil) which is used for conducting different experiments in the high terrace (poor fertile) soil. The two sites are located between 17° 34´ N and longitude 33° 56´ E., 355 m above sea level in the semi desert region of northern Sudan. The first site is characterized by cracking clay soil, moderately fertile and belongs to the so- called middle terrace or karu soils. The total nitrogen ranging from 460 to 514 ppm and the available phosphorus is about 1.3 mg/kg soil, pH is 8.5, Ec (ds/m) is 0.4 and ESP % is 5.5 at 0 – 60 cm soil depth. While the second site (matara) is a non cracking and has poor soil fertility and low clay percentage and belongs to the high terrace soils. Total nitrogen at the second site is about 173 ppm and the available phosphorus is 1.2 mg/kg soil, pH is about 8.7, Ec(ds/m) is 2.7 and ESP % is about 7.6 at 0 – 60 cm soil depth.

Cultural practices and treatments

The experiment was conducted during 2008/09 and 2009/10 growing seasons in the two sites. The land at the experimental sites was prepared by disc plowing, harrowing, leveling and ridging to 60 cm apart. The plot size was 5 ridges, 3 m wide and 6 m long (18 m^2). The design used was a split- split plot replicated three times with P sources as main plot and N sources and rates as split and split- split plots, respectively. Seeds of the open- pollinated maize cultivar Hudeiba-2 that has yellow seed color and released by the Agricultural Research Corporation of Sudan in 1998 were manually sown in holes at 25 and 60 cm intra- row plant spacing. More than three to five seeds from this cultivar were sown in each hole and thinned after ten days from emergence to one plant/hole, to give a theoretical plant population of about 66000 plants/ha. Planting date was the third week of October at the two sites in the two seasons. Treatments consisted of two sources of phosphorus fertilizers, namely, triple superphosphate (TSP) that contains about 46-47% P_2O_5 and diammonium phosphate (DAP) which contains about 21% N and (54% P_2O_5) (Cooke, 1975) were assigned at the rate of 43 kg P_2O_5/ha each to the main plots, while two nitrogen sources, urea (46% N) and ammonium nitrate (AN) that contains 35% N at three rates, namely, 0.0, 43 and 86 kg N/ha were allotted to the split and split- plots, respectively.

The phosphorus sources were applied before sowing, whereas nitrogen was applied in two equal split doses. The first dose of N was applied before the second irrigation, while the second dose was applied before the fourth irrigation at both experimental sites.

Collection of data

Plant height (cm): Plant height was measured from the soil surface to the collar of the most upper leaf recorded as the average plant height of five plants selected at random in each plot.

Ear height (cm): Ear height was also measured from the soil surface to the node bearing the first ear expressed as in centimeter.

Fresh forage yield (t/ha): This character was taken as the fresh weight of the total number of plants harvested 80 days after sowing from a net area of 9.0 m^2 in each plot expressed in kg/plot area and converted to t/ha.

Dry forage yield (t/ha): The fresh forage yield was left to dry in the air and then weighed again to give the dry forage yield expressed in kg/plot and then converted to t/ha.

Data analysis

The data collected for the different characters were subjected to analysis of variance (ANOVA) using the standard procedure of the split- split- plot design and means separation was done by Duncan Multiple Range Test (DMRT) for the main and interaction effects.

Results and discussion

Plant and ear heights (cm)

Both phosphorus and nitrogen sources had significant effects only on plant height in the two soil types in the first season (Table 1). Regarding phosphorus source, triple super phosphate (TSP) showed taller plants in the moderate fertile "Karu" soil than diammonium phosphate (DAP), while diammonium phosphate (DAP) resulted in taller plants in the high terrace soil than triple super phosphate (Table 1). With regard to nitrogen source, ammonium nitrate gave taller plants than urea in the moderate fertile "Karu" soil, while the reverse was true in the high terrace poor soil. Osman et al. (2009) reported a significant difference in plant height of maize between urea and other nitrogen ammonium fertilizers. However, this result disagreed with Mohammed et al. (2008) who reported that urea gave taller plants in the moderate fertile "Karu" soil.

Table 1. Effects of phosphorus source, nitrogen source and rate on plant height (cm) and ear height (cm) of maize grown in two soil types during two seasons.

Treatments	Plant Height (cm)			
	Middle terrace"Karu" soil		High terrace (poor fertile) soil	
	2008/09	2009/10	2008/09	2009/10
P source				
TSP	148 a	166 a	128 b	132 a
DAP	141 b	168 a	134 a	132 a
N source				
Urea	141 b	166 a	131 a	131 a
AN	147 a	168 a	125 b	129 a
N rate (kg N\ha)				
0.0	133 c	157 c	125 b	117 c
43	144 b	166 b	126 b	130 b
86	155 a	177 a	133 a	143 a
General mean	144	167	128	130
Treatments	**Ear height (cm)**			
P source				
TSP	60 a	72 a	49 a	41 a
DAP	60 a	77 a	49 a	43 a
N source				
Urea	57 a	74 a	48 a	43 a
AN	60 a	76 a	46 a	42 a
N rate (kg N\ha)				
0.0	52 b	70 b	45 b	35 c
43	56 b	75 a	44 b	41 b
86	66 a	80 a	51 a	51 a
General mean	58	75	47	42

Means with the same letter(s) within each column are not significantly different according to Duncan Multiple Range Test (DMRT) at the 0.05 level.

On the other hand, nitrogen rate significantly affected plant and ear heights in the four cases (Table 1). The application of nitrogen at the two N rates resulted in taller plants and higher ears placement with significant differences between the two nitrogen rates in both maize characters than the control treatments, except for ear height in the high terrace soil in 2009 (Table 1). Taller plants in maize due to nitrogen application irrespective of nitrogen source were reported by Osman et.al. (2009). The interaction effects of phosphorus source and nitrogen rate on plant and ear heights were significant in the middle terrace soil in 2008 (Figs. 1 a and 1 b). The application of 43 kg N/ha resulted in similar plant and ear heights for both phosphorus sources, while at 86 kg N/ha diammonium phosphate resulted in taller plants than triple superphosphate. The interaction effects of phosphorus source × nitrogen source × nitrogen rate on plant and ear heights were not significant.

Generally, plants grown in the moderate fertile "Karu" soil were taller and have higher ear position than that in the high terrace poor soil (Table 1). This could be attributed to the fact that, the "Karu" soil was more fertile than the high terrace poor soil.

Fresh and dry forage yields (t/ha)

Phosphorus source had a significant effect on fresh forage yield in the moderately fertile "Karu" soil in 2009, while nitrogen source did not significantly affect both characters in the two soil types and seasons (Table 2). Diammonium phosphate gave about 8% greater fresh forage yield than triple super phosphate. Such a result could be attributed to the fact that diammonium phosphate contains about 21% N and 23% P than TSP (Cooke, 1975). However, such a result disagreed with Mehdi et al. (2001) who reported that TSP revealed significant superiority over other P fertilizer sources (SSP, NP and DAP). The non- significant effects of N sources on the two maize characters disagreed with Mohammed et al. (2008) on the maize and agreed with Elasha (2007) on pearl millet.

Table 2. Effects of phosphorus source, nitrogen source and rate on fresh and dry forage yields (t\ha) of maize grown in two soil types during two seasons.

Treatments	Fresh forage yield (t/ha)			
	Middle terrace"Karu" soil		High terrace (poor fertile) soil	
	2008/09	2009/10	2008/09	2009/10
P source				
TSP	14 a	24 b	8 a	11 a
DAP	13 a	26 a	9 a	12 a
N source				
Urea	13 a	25 a	9 a	11 a
AN	13 a	25 a	8 a	11 a
N rate (kg N\ha)				
0.0	11 b	21 c	8 a	8 c
43	14 a	25 b	8 a	12 b
86	15 a	29 a	9 a	14 a
General mean	13	25	8	11
Treatments	**Dry forage yield (t/ha)**			
P source				
TSP	6 a	8 a	3 a	3 a
DAP	6 a	8 a	3 a	4 a
N source				
Urea	6 a	8 a	3 a	4 a
AN	6 a	8 a	3 a	3 a
N rate (kg N\ha)				
0.0	5 c	7 c	3 a	3 b
43	6 b	8 b	3 a	4 a
86	7 a	10 a	3 a	4 a
General mean	6	8	3	3

Means with the same letter(s) within each column are not significantly different according to Duncan Multiple Range Test (DMRT) at 0.05 level.

On the other hand, nitrogen rate significantly affected both maize characters in three out of the total treatments with significant differences between the two nitrogen rates in both soil types only in the second season for fresh forage yield and in the moderate fertile "Karu" soil in the two seasons for dry forage yield (Table 2).

Addition of nitrogen at 43 kg N/ha and 86 kg N/ha increased fresh forage yields by about 27 %, 19 %, 50 % and by 36 %, over zero N treatments and by 38 % and 75 % over zero N treatments in the "Karu" moderate fertile and the high terrace poor soil, respectively (Table 2). The application of nitrogen at 43 kg N/ha to the "Karu" moderate fertile soil increased dry forage yield by about 17 % and13 in the first and second season, respectively over no treatments (Table 2). While, the application of 86 kg N/ha increased dry forage yield by about 29% and 30% in the first and second season, respectively (Table 2). In the high terrace poor soil the addition of both N rates (43 and 86 kg N/ha) resulted in 25% dry forage yield only in the second season over no nitrogen treatments (Table 2). Similar results were reported by Reddy et al. (1985) and Patel et al. (1967).

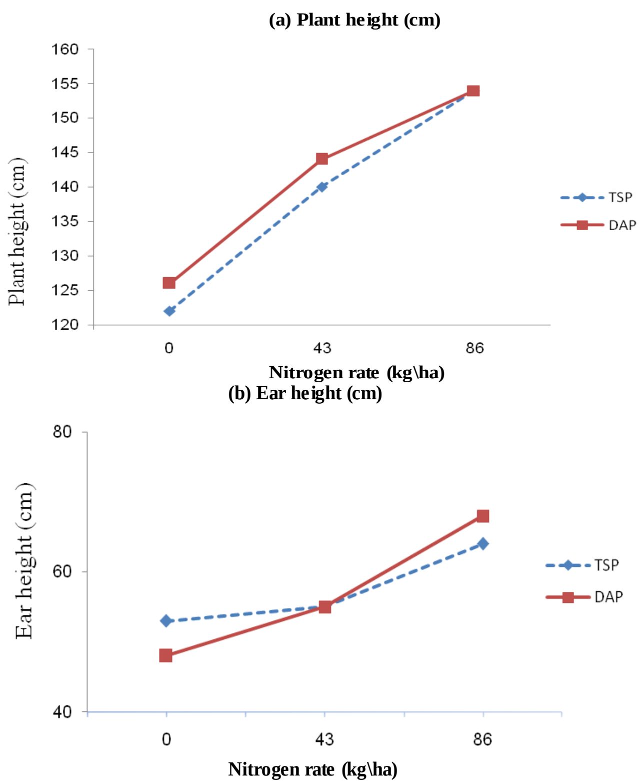

Fig. 1: Interaction effect of phosphorus source and nitrogen rate on plant and ear height (cm) of maize grown in middle fertile "Karu" soil in 2008.

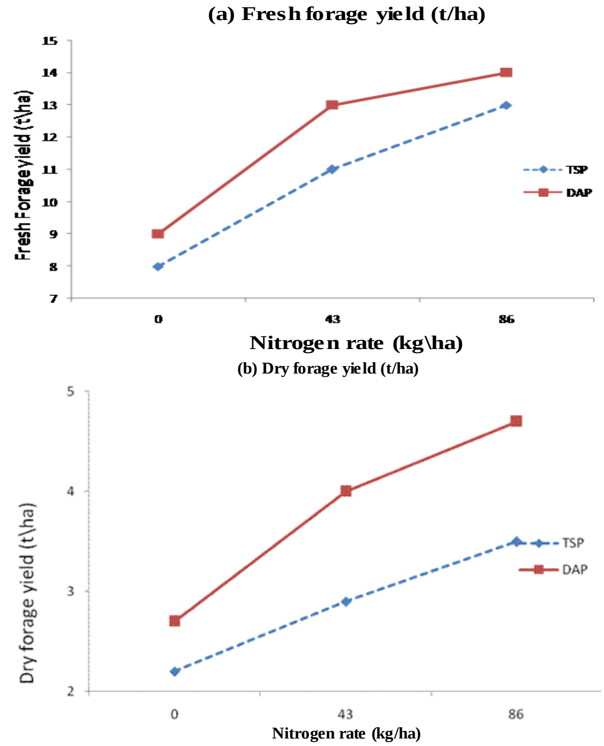

Fig. 2: Interaction effect of phosphorous source and nitrogen rates on fresh forage and dry forage yield (ton/ha) of maize grown in a high terrace soil 2009.

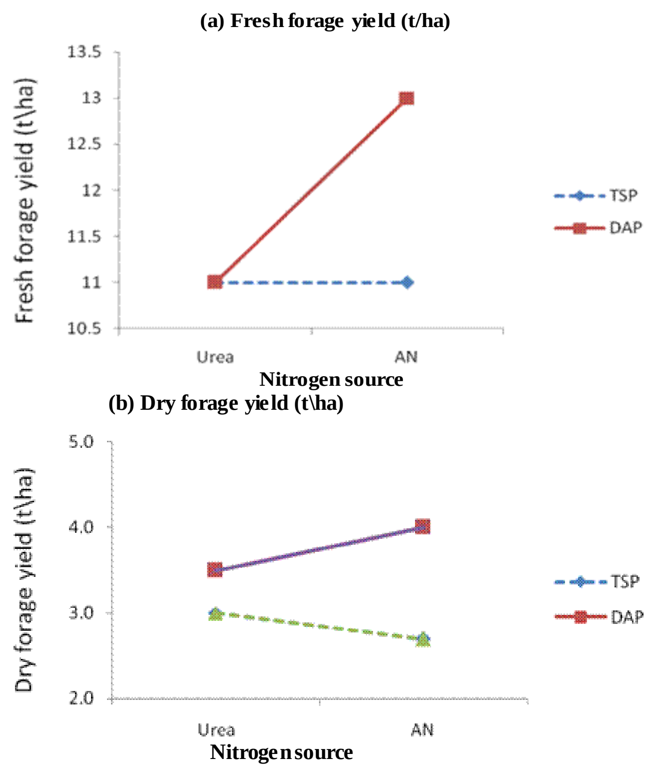

Fig. 3: Interaction effect of phosphorus source and nitrogen source on fresh forage and dry forage yield (ton/ha) of maize grown in a high terrace (poor fertile) soil in 2009.

Table 3. Interaction effect of phosphorus source × nitrogen source × N rate on fresh and dry forage yields of maize grown in the high terrace (poor fertile) soil in 2009.

N rate (kg N/ha)	P source			
	TSP		**DAP**	
	N source			
	Urea	**NH_4NO_3**	**Urea**	**NH_4NO_3**
	Fresh forage yield (t/ha)			
0.0	7.97f	7.97f	8.63ef	8.63ef
43	10.37de	10.70cde	11.50cd	14.00ab
86	13.07bc	13.23bc	13.03bc	15.77a
	Dry forage yield (t/ha)			
0.0	2.2f	2.2f	2.7def	2.7def
43	3.4cd	2.4ef	3.5c	4.4ab
86	3.6c	3.4cd	4.3ab	5.0a

Means with the same letter(s) within each column are not significantly different according to Duncan Multiple Range Test (DMRT) at the 0.05 level.

The interaction effects of phosphorus source and nitrogen rates were significant for both maize characters only in the high terrace soil in 2009 (Figs. 2a and 2b). Differences between the two P sources for fresh forage yield was significant at 43 kg N/ha, but not at 86 kg N/ha. Also, the interaction effect of P source by N source on fresh and dry forage yields were only significant in the high terrace soil in 2009 (Figs. 3 a and 3 b). The interaction effect of the three factors on fresh and dry forage yield was only significant in the high terrace poor soil in 2009 (Table 3).

Conflict of interest statement

Authors declare that they have no conflict of interest.

Acknowledgement

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