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Original Research Paper

Effect of Phosphorus source, Nitrogen Source and Rates on Yield and yield components of Maize (*Zea mays L.*) in different Soil Types in River Nile State–Sudan

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ABSTRACT

An experiment was carried out during two seasons 2008/09 and 2009/10 Hudeiba Research Station Farm, representing moderate fertile "Karu" middle terrace soil and "matara" site representing high terrace poor soil. The two sites are located in the semi- desert climate in River Nile State, Sudan. The objective was to study the effect of phosphorus source, nitrogen source and rate on yield and yield components of maize plants. Treatments consisted of two sources of phosphorus (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. The design was a split- split- plot Design with three replication P sources as main plots and N sources and rates as split and split- split plots, respectively. The results obtained showed that 1000- kernel weight was significantly affected by P sources in the karu soil type and in the high terrace soil in the second and first season, respectively. Whereas, ear yield was significantly affected by P source in the karu soil type in both seasons and in the high terrace poor soil only in the second season. On the other hand, N source had no significant effect on all measured maize characters except for maize grain yield in the two soil types in 2008 and only in the "Karu" soil in 2009, respectively. The application of nitrogen also resulted in higher number, heavier kernels weight and greater ear yield than the zero N treatments in both soil types. For maize grain yield, the results indicated that ammonium nitrate showed about 9% more grain yield than urea, in the "Karu" soil only during 2009. However, the application of N at the two rates (43 and 86 kg N/ha), irrespective of N source, significantly increased maize grain yields (2255 and 1155 kg/ha) by about 20, 47, 59 and 98 % in both soil types averaged over both seasons than the zero N treatments with significant differences between the two N rates. Generally, the results revealed that significant interaction of P source x N rate and P source x N source in most of the maize characters. In conclusion, the application of N at 43 kg N/ha or 86 kg N/ha, irrespective of N source, resulted in better maize performance and a substantial maize yields increases in both soil types than the zero N treatments with significant differences between N rates in most cases.

Key words: Maize, Phosphorous, Nitrogen, Source, Rate.

INTRODUCTION

Worldwide, maize (*Zea maize L.)* is the third important cereal crop after wheat and rice in total cultivated area and production, but it is the top ranking cereal in grain yield per unit area (FAO, 2007). Moreover, the consumption per capita in many tropical and sub-tropical regions of the world as staple human food exceeded wheat and rice (Fisher and Palmer, 1984). In addition to maize contribution to human dietary total calories, some maize genotypes are processed to produce vegetable oil, fatty acids and alcohol, starch and glucose (Fisher and Palmer, 1984). The fresh stalks of maize are used in silage production, while the dry stalks are valuable fodder for livestock and also for making papers, insulators and cardboard.

In Sudan, though maize is of less importance than sorghum, wheat and millet, it is the main stable human food and greatly contributed to food security for the people who live in South Kordufan (Nuba Mountains), and Blue Nile States. Moreover, the demand for maize as feed and forage crop is greatly increased over the past few years due to the increased export opportunities to Arab countries and the local consumption by the growing poultry and livestock industries. As a result of this, the maize total cultivated area also increased and reached about 250 thousands ha (Kambal, 2008). However, the average grain yield of maize from small- holdings farmers and large scale maize growers (companies) in Sudan (0.6- 1.0 t/ha) is far below that of the world (6 t/ha) (FAO, 2007) and very low as compared with grain yield usually obtained under research conditions (2- 4 t/ha) where maize is grown under improved cultural practices. In fact, the role of different nitrogen and phosphate fertilizers as key improved cultural practices in increasing maize yields was studied by several research workers worldwide, and in Sudan (for example, Anderson, 1970, Panwar and Singh, 1972, Hera *et al.,* 1978, Fan and Mackenzie, 1994, and Sharer *et al*. 2003) and in Sudan (Nour *et al*., 2003; El Faki *et al.,* 2005; Salih *et al.,* 2008; Osman *et al.,* 2009). Research in Sudan showed significant and substantial maize yields increases were obtained by the application of nitrogen regardless of N source; however, for phosphorus fertilizer there were considerable variable findings. For example, Nour *et al.,* (2003) found no response in maize hybrid (PAN 6480) to Phosphorus application (TSP) up to 86 kg P2O5/ha in Gezira clay soil, central Sudan, while El-faki *et al.,* (2005) and Mohammed *et al.,* (2008) found a positive response to phosphorus application and recommended the application of I P (43 kg P2O5/ha for high grain yield of maize at the same location.

Moreover, new sources of nitrogen and phosphorus fertilizers (NPK, ASN, AS, DAP) that were recently tested on maize and other crops in the clay soils of central Sudan, gave similar results compared to the traditional ones (urea and TSP) and in some cases proved to be superior to them (Ali *et al.,* 2006; Mohammed *et al.,* 2008 and Osman *et al.,* 2009).

On the other hand, maize has high yield potential and more adapted particularly to unfavorable growing seasons for wheat in northern Sudan and can be grown in a wide range of planting time (August to December) (Mohammed *et al.,* 2008). Therefore, maize could be an alternative cash crop in northern Sudan along with wheat and sorghum.

Nonetheless, previous research regarding maize fertilization in northern Sudan focused to a greater extend on some nitrogen management practices (for example, N rate, way and time of application) only in the middle terrace "Karu" soils (Ibrahim and El-Agib, 2003 and Mohammed, 2006). In fact, in northern Sudan (River Nile State) the main soil types used for crop production are the high fertile "Gurier" soils, the moderately fertile middle terrace "Karu" soils and the high terrace poor soils. The first two soil types are intensively cultivated by most farmers in the State to produce high value cash crops (grain legumes, vegetables, spices and wheat) often in mono-cropping system. Although, the middle terrace "Karu" soils are more fertile than the high terrace poor soils, yet application of mineral fertilizers especially N and P is very critical for high maize yield. The high terrace poor soil on the other hand, is deficient in N and available P and has high soil pH (> 8.5). Moreover, earlier research in these soils indicated that application of NP fertilizers resulted in high wheat grain yield (Ibrahim, 1995).

In fact, research concerning maize fertilization in the high terrace poor soil in northern Sudan and the effect of different sources of N and P fertilizers in the middle terrace "Karu" soil is lacking.

The present study was, therefore, undertaken to investigate the effect of different sources from phosphorus and nitrogen at different rates on growth and yield of maize grown in different soil types in River Nile State.

MATERIALS AND METHODS

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 m2). The design used was a split- split plot replicated three times with P sources as main plots 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

Table 1. Effects of phosphorous source, nitrogen source and rates on number of kernels\ear and thousand kernels weight (g) of maize grown in two soil types during two seasons.

	Middle terrace"Karu " soil		High terrace (poor fertile) soil	
	2008	2009	2008	2009
Number of Kernels\Ear				
P source				
TSP	271 a	434 a	161 a	264 a
DAP	248 a	463 a	172 a	284 a
N source				
Urea	255 a	456 a	160 a	289 a
AN	259 a	436 a	179 a	269 a
N rate (kg N\ha)				
0.0	230 b	411 b	143 b	201 c
43	254 ab	431 b	165 b	275 b
86	287 a	496 a	202 a	362 a
General mean	257	446	170	279
Thousand kernels weight (g)				
P source				
TSP	202 a	213 b	188 b	177 a
DAP	202 a	229 a	200 a	184 a
N source				
Urea	201 a	226 a	192 a	184 a
AN	196 a	217 a	184 a	179 a
N rate(kg N\ha)				
0.0	188 b	199 c	174 b	164 c
43	198 ab	226 b	185 b	179 b
86	208 a	239 a	205 a	202 a
General mean	198	222	188	182

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.

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 % P2O5 and diammonium phosphate (DAP) which contains about 21 % N and (54 % P2O5) (Cooke, 1975) were assigned at the rate of 43 kg P2 O5/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. The data were on collected

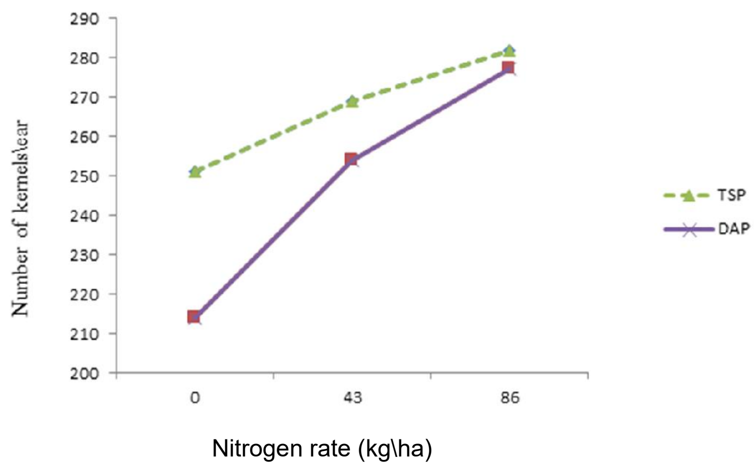
number of kernels \ ear, 1000-kernel weight (g),ear yield (g),and grain yield (kg\h).

RESULTS AND DISCUSSION

Number of kernels\ear and thousand kernels weight (g)

Phosphorous source had significant effects only on thousand kernel weight in the moderate fertile "Karu" soil in 2009 and in the high terrace poor soil in 2008, while nitrogen source had no significant effects on both characters in all cases (Table 1). The phosphorus source, diammonium phosphate (DAP) gave heavier kernels in the two soil types than triple super phosphate. Such a result could be attributed to the fact that diammonium phosphate (DAP) contains about 21 % N and more 23 % P (54 % P2O5) than triple super phosphate (TSP) that contains 20 % P(46- 47 % P2O5). Moreover, the fixation of triple super phosphate might be greater than DAP as a result of the high soil pH in the two soil types and therefore, Phosphorus was not available for uptake by maize plants. On the other hand, nitrogen rate had

(a)Number of kernels\ear



(b)Thousand kernels weight (g)

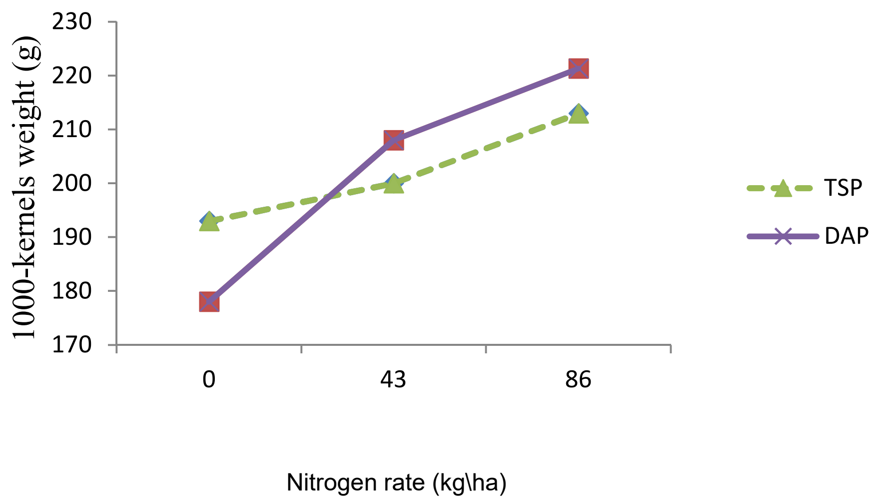


Figure 1. Interaction effect of phosphorous source and nitrogen rate on number of kernels\ear and 1000-kernels weight (g) of maize grown in moderate fertile "Karu " soil in 2008.

significant effects on both maize characters at the two sites and in both seasons (Table 1).

Greater number of kernels\ear and heavier kernels were obtained at the two nitrogen rates than the zero nitrogen treatments, with significant differences between the two nitrogen rates for both maize characters in the "Karu" soil only in the second season and in the poor high terrace soil in both seasons. The application of 43 kg N\ha increased number of kernels\ear by 24, 20, 22, and 74%, while addition of 86 kg N/ha increased number of kernels\ear by 57, 85, 59, and 161% in the moderate fertile "Karu" and the high terrace poor soil, during both seasons, respectively, compared to the zero nitrogen treatments (Table 1).

Greater number per ear and heavier kernels in maize due to nitrogen application regardless of N source was also reported by (Salih *et al.,* 2008). Also, the findings of Sorgio and Andrade (1995) and Mohammed et al., (2008) that nitrogen shortage resulted in lower number of kernels per ear and lighter kernels supported such a result.

Significant interaction effects of phosphorous source by nitrogen rate on number of kernels\ear and thousand kernel weight were only detected only in the moderate fertile "Karu" soil in 2008 (Figures 1 a and b). In both maize characters triple superphosphate resulted in higher number of kernels\ear and heavier kernels than diammonioum phosphate at the two nitrogen rates.

Also, the interaction effects of P source x N source on thousand kernel weight were significant only in the poor high terrace soil in the first season (Figure 2) and in the

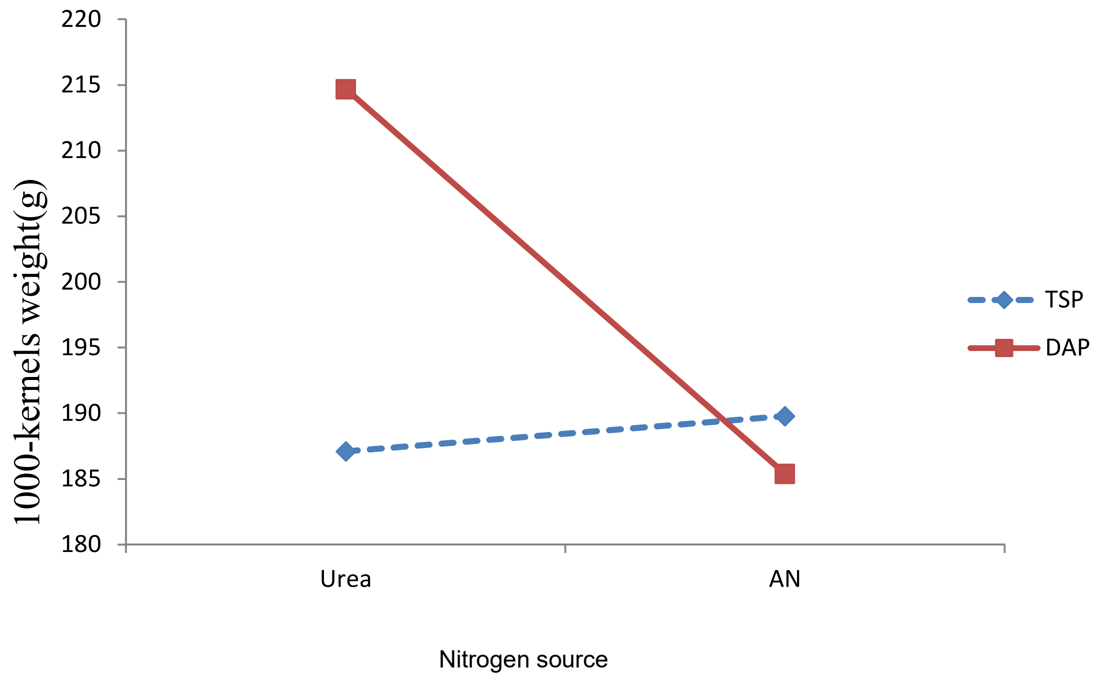


Figure 2. Interaction effect of phosphorous and nitrogen source on 1000-kernels weight (g) of maize grown in a high terrace (poor fertile) soil in 2008.

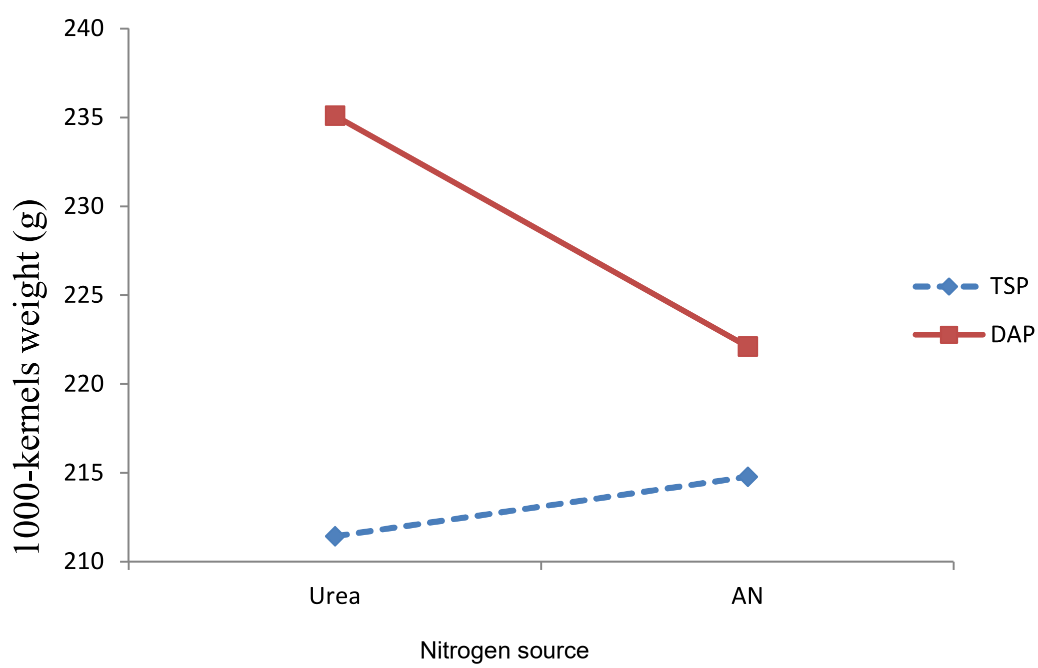


Figure 3. Interaction effect of phosphorous and nitrogen source on 1000-kernels weight (g) of maize grown in moderate fertile "Karu " soil in 2009.

karu moderate fertile soil in the second season (Figure 3). Triple super phosphate gave similar kernel weight at both N sources during the first season in the poor high terrace soil (Figure 2), while differences were significant in the

Table 2. Effects of phosphorous source, nitrogen source and rates on ear yield (g) and grain Yield (kg\ha) of maize grown in two soil types during two seasons.

Treatments	Middle terrace "Karu "soil		High terrace (poor fertile) soil	
	2008/09	2009/10	2008/09	2009/10
Ear yield (g)				
P source				
TSP	52 a	88 b	33 a	45 b
DAP	47 b	99 a	31 a	53 a
N source				
Urea	49 a	94 a	30 a	52 a
AN	49 a	93 a	33 a	49 a
N rate (kg N\ha)				
0.0	41 b	74 c	29 b	33 c
43	48 b	95 b	28 b	49 b
86	567 a	111 a	38 a	70 a
General mean	48.7	93.3	31.3	50.7
Grain yield (kg\ha)				
P source				
TSP	1574 a	2879 a	891 a	1360a
DAP	1337 a	3057 a	916 a	1537a
N source				
Urea	1359 a	2916 b	893 a	1547 a
AN	1534 a	3212 a	822 a	1358 a
N rate (kg N\ha)				
0.0	1114 b	2490 c	643 b	890 c
43	1334 b	2975 b	799 b	1502 b
86	1890 a	3726 a	1129 a	1965 a
General mean	1446	3064	857	1452

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.

"Karu" moderate fertile soil (Figure 3). The interaction effects of the three studied factors on number of kernels/ear and 1000- kernel weight were not significant in all treatments combinations.

Ear yield (g) and grain yield (kg\ha)

Phosphorous source significantly affected ear yield of maize in the moderate fertile karu soil in both seasons and in the poor high terrace soil in the second season (Table 2).While, it had no significant effect on maize grain yield in both seasons and soil types (Table 2).The triple superphosphate gave higher ear yield only in the middle terrace "Karu" soil in the first season than diammonium phosphate; while diammonium phosphate resulted in greater ear yield in the rest of the treatments combination than the triple super phosphate (Table 2).This finding disagreed with that of Mehdi *et al.,* (2001) who reported that TSP revealed significant superiority over other P fertilizers sources. The non- significant effect of phosphorus source on maize grain yield was in accordance with the result of Salih *et al.,* (2008) who found that P source had no significant effect on maize grain yield.

On the other hand, nitrogen source had a significant effect on maize grain yield of maize only in the middle terrace (Karu soil) in 2009 (Table 2). In this treatment, ammonium nitrate exceeded urea in grain yield by about 9 %. Such a result partially agreed with that of Ali (2006) who found urea was inferior to NPK (nirophoska) and ammonium sulfate nitrate (ASN) in wheat grain yield grown at the same location "Karu" soil and disagreed with that of Salih *et al.,* (2008) whereas urea gave significantly higher maize grain yield compared to other ammonium fertilizers in Gezira clay soil.

Nitrogen rate significantly affected ear yield and grain yield of maize at the two sites in both soil types with significant differences between the two nitrogen rates in

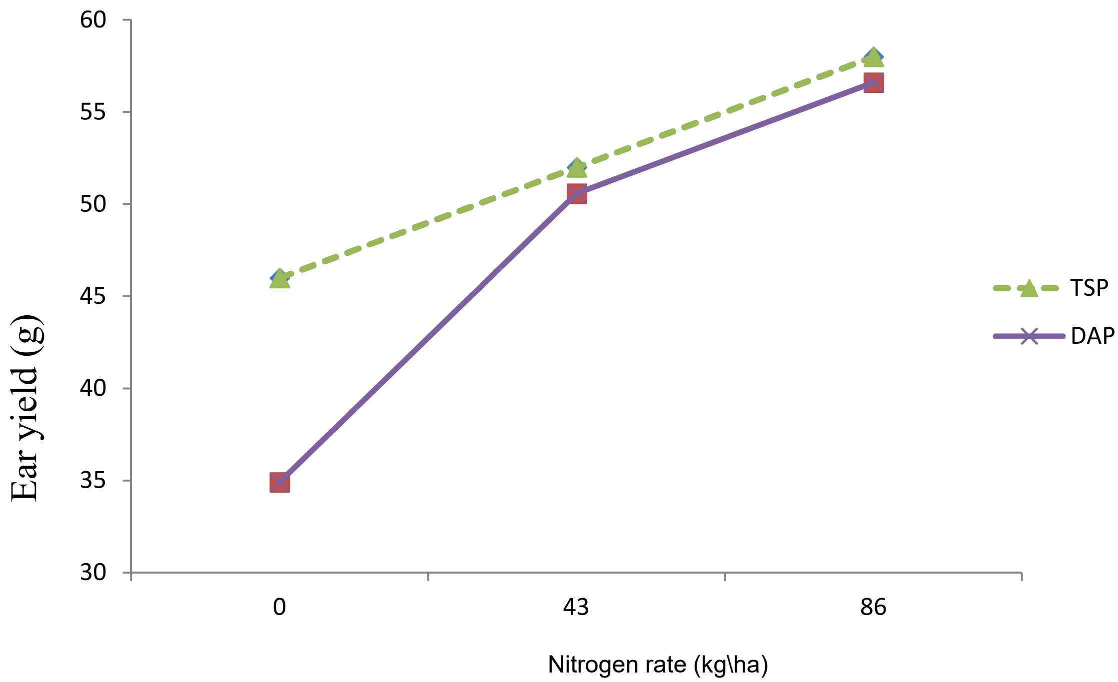


Figure 4. Interaction effects of phosphorous source and nitrogen rate on ear yield (g) of maize grown in a moderate fertile"Karu " soil in 2008.

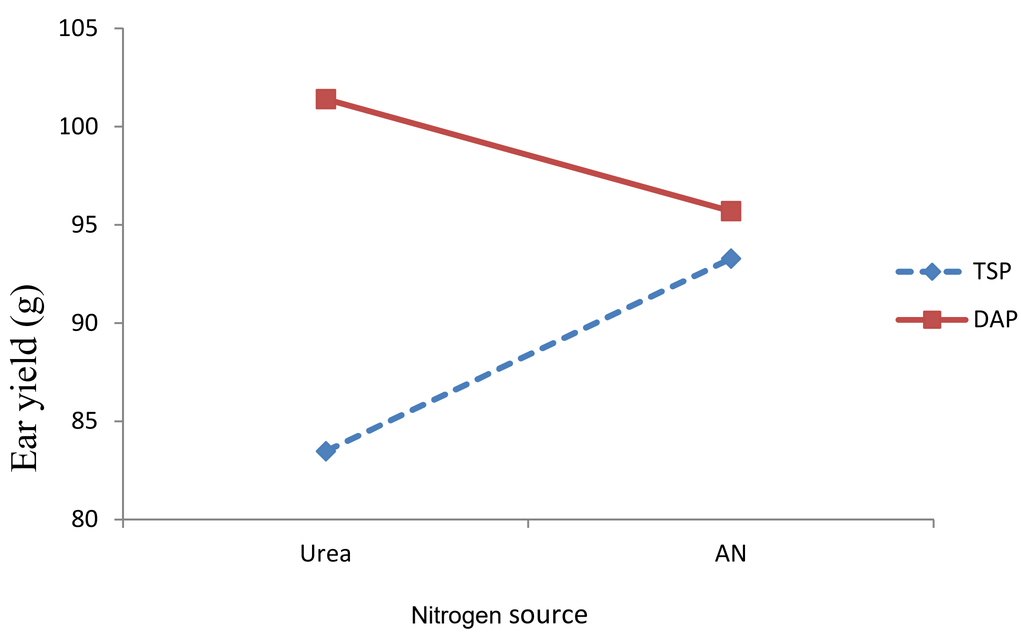


Figure 5. Interaction effects of phosphorous source and nitrogen source on ear yield (g) of maize grown in a high terrace (poor fertile) soil in 2009.

both maize characters (Table 2). The application of nitrogen at both N rates irrespective of N source increased both ear yield and grain yield of maize than the zero N treatments. An interaction significant effects of P source X N rate and P source X N source were detected for ear yield in the moderate fertile "Karu " and the high terrace poor soil in the first and second season, respectively (Figure 4 and Figure 5).

With regard to maize grain yield, the results showed that application of 43 kg N/ha increased maize yield by about 20%, 19%, 24 and 69 % in the moderate fertile and the high terrace poor fertile soil, respectively, during 2008 and 2009 over no nitrogen treatments (Table 2). Increasing nitrogen rate to 86 kg N/ha resulted in maize grain yields increases ranging from 42 %, to 25 %, and from 41 % to 31 % in the moderate fertile "Karu" and the high terrace poor soil, respectively in the two seasons. Grain yield percentage increases were greater especially in the "Karu" moderate fertile soil as N rate were increased from 43 to 86 kg N/ha than that obtained by other research workers at the same site (Mohammed *et al.,* 2008). Increased maize grain yield, irrespective of N source agreed well with the findings of Salih *et al.,* (2008) and Osman *et al.,* (2009) who reported that grain yield of maize was significantly increased by addition of different N sources, regardless of N source used. Moreover, the non- significant differences between the two nitrogen rates in maize grain yield at both sites in the two seasons indicated that optimum N rate was not reached in this study and need further investigation, especially for the high terrace poor soil.

All the interaction effects of the three tested factors on maize grain yield were not significant in both soil types in the two seasons.

On the other hand, grain yield obtained from the "Karu" moderate fertile soil averaged over the two seasons was about 95 % greater than that obtained from the high terrace poor soil (1155 kg\ha) (Table 2). Such result could be mainly attributed to the fact that "Karu" middle terrace soil is more fertile than the high terrace soil. Also, great grain yield was obtained in the second (2255 kg\ha) than in the first season (1155 kg\ha).

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