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Response of Chickpea to Phosphorus Fertilization in Four Soil Types of the Sudan Savanna of Nigeria

*S. M. SHEHU, L. M YUSUF, Y. I. AUJARA AND A. A .MAIGATARI

¹School of Agriculture, Binyaminu Usman Polytechnic, Hadejia P.M.B 013 Jigawa State, Nigeria

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ABSTRACT

Most soils in tropical Africa have low available phosphorus and so, require external inputs of P to achieve moderate yields. Soil characteristic is a major factor that determines crops' response to P application. In this pot trial, the potential yield of Chickpea achievable in four soil types without P application and with different levels of P addition was assessed. The four soil types; Yamidi, Jahun, Kazaure and Zakirai soils and four P sources: no P (control), 15, 30 and 60 kg P₂O₅ ha⁻¹, applied as single super phosphate (SSP) were factorially combine. The treatments were replicated three times and arranged in completely randomized design. Plant available P was lower than the threshold level of 10mg kg⁻¹ in both Yamidi and Kazaure soils. Conversely, clay content was higher in Yamidi soil while sand content was higher in Kazaure soil. The soil types had significant effects on shoot biomass, grain weight and P uptake. Jahun soil (with highest plant available P) was superior to other soil types. Generally, increasing P rates improved shoot biomass, grain weight and P uptake but the effect was less pronounced for Jahun and Yamidi soils. Chickpea grain yield also exhibited variability in response to P levels in the different soil types. For Kazaure and Jahun soils, application of 30 kg P₂O₅ ha⁻¹ and for Zakirai and Yamidi soils, application of 60 kg P₂O₅ ha⁻¹ may suffice for optimum grain weight production under the condition of this experiment. To achieve optimum production of Chickpea in these soils, external source of P will be necessary.

Keywords: Grain weight; P- fertilizer; Soil types; Chickpea; Sudan savanna.

Introduction

Phosphorus is crucial to crop growth and yield because of its multiple effects on plant nutrition. Most tropical soils have low available P as a result of low activity clay, Iron and Aluminium oxides and hydroxides as a result of high degree of weathering (Agbenin, 2003). There is therefore the need for external input of P to achieve optimum yield. However, in the traditional farming systems, inadequate amount of P is used due to poor accessibility and high cost of soluble P fertilizers for a large population of disadvantaged farmers.

Phosphorus deficiency is so acute that plant growth ceases as soon as the phosphorus stored in the seed is exhausted in some soils of the savanna zone of Western Africa (Mokwunye *et al.*, 1986). Numerous studies have shown that P fertilizers can significantly increase crop yields (Batiano *et al.*, 1995; Kolawole *et al.*, 2000). Soils vary greatly in the amount of P requirement to provide an adequate supply of available P for plants and plants also vary in their P requirements for optimal growth. P deficiency in Chickpea affects nodule development and function which directly affect nitrogen fixation process (Shehu, 2012).

Crop response to P depends on soil characteristics among many other factors because its mobility in the soil is controlled by its interaction with the soil matrix, nutrients and amendment (Shaheen *et al.*, 2009). A large portion of phosphate added to tropical soils reacts with the soil in such a way that the phosphate is made less soluble and less available for plant use (Konrad, 1997). The understanding of the soil characteristics will help to do away with the conventional blanket fertilizer application which could load the soil with much higher phosphate concentration than required for optimum crop production thus preventing the hazard of phosphate loss by wind and water erosion and even leaching (Konrad, 1997). The need to determine the threshold level of inherent soil P in different soil types for chickpea production therefore becomes imperative. The present study reports on the performance of chickpea and on how chickpea responded to application of different levels of P fertilizer in four soil types.

MATERIALS AND METHODS

Experimental site – The study was conducted in 2016 dry season in a screen house of Teaching and Research Farm of Binyaminu Usman College of Agriculture Hadejia, (Latitude of 12° 22'N and 12° 24' N and longitude of 7° 46' E and 10° E) in the Sudan savannah ecological zone of Nigeria, with annual rainfall in the range of 800 to 1000 mm and mean annual temperature of 27 to 42°C (Shehu, 2012).

Soil sampling and laboratory analysis: Soil samples at 0-15cm depth of four soil types Yamidi, Zakirai, Jahun and Kazaure soils were collected from four study sites in Kano and Jigawa states, Nigeria. The soils were air-dried, sieved through a 2 mm sieve and sub samples were taken for laboratory analysis. The physico-chemical characteristics of the soils are presented in Table 1. Smyth and Montgomery (1962) described in details the characteristics of these soils.

Experimental Design:

The four soil types formed the main plot treatments and four P sources: no P (control), 15 (0.29 g/3kg soil), 30 (0.58 g/3kg soil) and 60 (1.16g/3kg soil) in kg P₂O₅ ha⁻¹, applied as Single superphosphate (SSP) were the sub treatments. The treatments were

replicated three times and arranged in Split plot design. Three kilogram soil each was weighed into 12 pots for each of the four soil types. This makes a total of 48 pots used for the experiment. The soil was watered to field capacity and left to equilibrate for 48hours before planting. Three seeds each of Chickpea ICCV 97105 were sown in each pot and the seedlings thinned to one per pot at two weeks after emergence. The fertilizers were applied in a ring form about 5 cm away from the Chickpea plant at the time of thinning. Nitrogen fertilizer (90 kg N ha⁻¹) in the form of urea and potassium (60 kg K₂O ha⁻¹) in the form of muriate of potash were applied to all the pots as basal dressing. The plants were watered as regularly as was necessary. Weeds were hand pulled as they emerged and left in the pots to decompose. At physiological maturity, the number of pods was counted, the pods were harvested and the grains removed. The plant shoot was cut at ground level with a sharp knife. Leaf litter was collected as part of the shoot biomass. All plant parts were placed in separate paper bags and oven dried at 65°C for 72 hours to determine their dry weights. The grains were ground to pass through a 2 mm mesh sized sieve and analyzed for P concentrations. For determination of P, samples were wet-digested with a mixture of HClO₄- HNO₃. Phosphorus was measured calorimetrically by auto-analyzer (IITA, 1982).

All data were subjected to analysis of variance (ANOVA). Where F-values were significant, the treatment means were separated with LSD test at 5% probability level.

RESULTS

Soil properties

Generally, the soils showed variation in both the physical and chemical properties investigated. Plant available P was less than the threshold value of 10mg kg⁻¹ in both Yamidi and Kazaure soils. Plant available P was highest in Jahun soil (Table 1). Organic carbon was low in both Kazaure and Jahun soils. Yamidi soil had the highest clay content and Kazaure the lowest. Conversely, sand content was highest in Kazaure soil and lowest in Yamidi soil. All the soils were slightly alkaline.

Grain yield

Performance of Chickpea varied among the soil types. Jahun soil supported significantly higher grain weight compared with the other soils. Kazaure had significantly lowest grain weight (Table 2). On the average, grain weight increased with increasing P application rates. However, only the application of 60 kg P₂O₅ ha⁻¹ gave significantly higher grain weight than the control (no P) and 15 kg P₂O₅ ha⁻¹.

Interaction effect between soil types and P rates on grain weight was significant ($P \leq 0.05$). Response to P was less pronounced under Yamidi and Jahun soils compared with Kazaure and Zakirai soils.

Application of 60 kg P₂O₅ ha⁻¹ resulted in more than 100 percent increase in grain weight compared with the control for Zakirai soil but for Kazaure soil, application of 15 kg P₂O₅ ha⁻¹ caused more than 300 percent increase (Table 2).

Table 1: Physiochemical properties of the research soil types

Properties	Yamidi	Jahun	Kazaure	Zakirai
Sand (g kg ⁻¹)	590	690	810	690
Silt (g kg ⁻¹)	150	190	90	130
Clay (g kg ⁻¹)	260	120	100	180
Soil pH-H ₂ O	8.5	9.3	8.9	9.3
Ex. Ca (cmol kg ⁻¹)	2.05	2.12	0.96	5.33
Ex. Mg (cmol kg ⁻¹)	0.66	0.49	0.36	0.53
Ex. K (cmol kg ⁻¹)	0.14	0.12	0.16	0.29
Ex. Na (cmol kg ⁻¹)	0.31	0.31	0.37	0.36
Fe (ppm)	149.78	156.46	138.67	184.89
Available P (µg g ⁻¹)	6.84	41.88	9.64	32.18
Total N (g kg ⁻¹)	1.11	0.52	0.37	1.16
Organic C (g kg ⁻¹)	10.84	5.39	3.41	12.46

Table 2: Effect of soil types and P fertilizer rates on Chickpea grain yield

Phosphorus rates (kg P ₂ O ₅ /ha)					
		0	15	30	60
Soil types	Grain yield (g/pot)				Soil type means
Yamidi	20.5	18.5	22.1	28.4	22.4
Kazaure	5.8	12.7	19.0	12.0	12.4
Jahun	34.2	38.0	42.4	44.1	40.0
Zakirai	21.8	10.8	15.8	49.6	19.5
P rate means	20.6	20.0	24.8	28.5	

LSD for soil type = 6.59; LSD for SSP rate = 5.32

Table 3: Effect of soil types and P fertilizer rates on shoot biomass of Chickpea

Phosphorus rates (kg P ₂ O ₅ /ha)					
		0	15	30	60
Soil types	Shoot biomass (g/pot)				Soil type means
Yamidi	27.3	22.0	29.0	30.1	27.1
Kazaure	5.9	12.7	24.1	17.0	14.9
Jahun	46.6	43.0	27.7	58.5	51.5
Zakirai	28.5	18.4	20.5	32.7	25.0
P rate means	27.0	24.2	32.8	34.6	

LSD for soil type = 10.22; LSD for SSP rate = 8.39

Shoot biomass

The effects of soil types and P fertilizer application on shoot biomass were similar to those observed for grain weight (Table 3).

Phosphorus content and uptake in grain

Phosphorus content in grain was similar for all the soil types. However, P content increased with increasing P rates (Table 4). Phosphorus uptake was significantly higher in the plant under Jahun soil than under the other soils. Generally, P uptake increased with increasing P rates up to the application of 30 kg P₂O₅ ha⁻¹ (Table 5). Further increase in P application rate did not give any advantage in P uptake.

Table 4: Effect of soil types and P fertilizer rates on Chickpea P content in Chickpea grain

Soil types	Phosphorus rates (kg P ₂ O ₅ /ha)				Soil type means
	0	15	30	60	
	P content in grain (%)				
Yamidi	0.3	0.4	0.5	0.6	0.5
Kazaure	0.3	0.3	0.5	0.5	0.4
Jahun	0.4	0.4	0.4	0.6	0.5
Zakirai	0.2	0.3	0.4	0.5	0.4
P rate means	0.3	0.4	0.5	0.6	

LSD for soil type = 0.12; LSD for SSP rate = 0.05

Table 5: Effect of soil types and P fertilizer rates on P uptake in Chickpea grain

Soil types	Phosphorus rates (kg P ₂ O ₅ /ha)				Soil type means
	0	15	30	60	
	P uptake (g/pot)				
Yamidi	6.6	7.8	10.9	16.8	10.5
Kazaure	1.5	3.3	6.5	6.5	5.1
Jahun	13.5	17.5	25.3	25.3	18.7
Zakirai	4.4	2.8	14.5	14.5	7.0
P rate means	6.5	7.9	15.8	15.8	

LSD for soil type = 5.89; LSD for SSP rate = 2.83

DISCUSSION

The available data indicated that the soil types used in this study varied in soil available P. Whereas soil available P was low in Yamidi and Kazaure soils, Jahun and Zakirai soils had high soil available P. This probably influenced the performance of Chickpea in the different soils without external P application. Variability in plant available P in savanna soils of West Africa had been reported by previous workers (Nwoke *et al.* 2003). Response of Chickpea to applied P fertilizer also varied in the different soils. This was less pronounced in Jahun soil with high inherent plant available P. McKenzie *et al.* (2003) reported that soil types affected P fertilizer response by different crops in Canada.

Sanchez and Uehara (1980) stated that the soil solution P concentration required for maximum plant growth differs with soil properties related to the diffusion of P to plant roots. In this study, Zakirai soil which had high soil available P also required the highest P rate to obtain optimum Chickpea grain. This may be due to its highest Ca and Fe contents which may make applied P unavailable for plant use through fixation (Table 1). Availability of soil P is a complex phenomenon which is affected by both soil and plant properties (Barber, 1995). The initial high concentration of available P in Jahun soil might be responsible for the best performance of Chickpea in this soil (Duffera and Robarge, 1999). The poor performance of Chickpea in Yamidi soil might possibly be due to P – fixation process as a result of

the high clay content (Loganathan *et al.*, 1987; Bennoah and Acquaye, 1989). Generally, Chickpea performance increased with increasing external P application rates. As the shoot dry matter yield, grain weight and P uptake followed a similar trend the capacity of these soils to supply P to growing crops was extremely low, and thus Chickpea production may be severely reduced if P fertilization is ignored. Li *et al.* (2009) reported that application of P to Chickpea resulted in about 89% improvement in its performance in India.

CONCLUSION

The actualization of the potential yield of Chickpea in these soils is possible only with adequate P fertilization since available P in 50% of the soils of Yamidi and Kazaure was below the threshold level. Also, the rates of external P required for the soils differ. Farmers should, therefore, be encouraged to use adequate amounts of P fertilizer for chickpea cultivation in these soils; the rate which is dependent on soil properties.

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