Phosphorus requirement of onion (*Allium cepa* L.) in the Sudan savanna zone of Nigeria

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SUMMARY

Phosphorus requirement of onion (*Allium cepa* L.) was evaluated on a low P fixing and P deficient sandy loam soil (*Typic ustipsamment*) in a 4 year field experiment in Nigeria. The results showed that the onion cultivar (Borno Local) required available P levels greater than 12.3, 16.7 and 11.7 $mgkg^{-1}$ for the Bray P1, Bray P2 and $NaHCO_3$ extractants, respectively to produce over 75 per cent of the maximum bulb yield on the sandy loam soil. The optimum P rate of 50 kg/ha established in this study corresponded to 0.23 mgl^{-1} in the solution equilibrated with the soil. Three years continuous P fertilization resulted in significant increases in the available P which had a significant residual response in the fourth cropping season. In 2 out of the 3 years of direct P fertilization, banding the fertilizer below the transplants was found most effective. P critical levels and P sorption isotherms are reliable estimates of P requirement of onion on the savanna soil.

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RÉSUMÉ

KWAKYE P. K. & WAPASTDA S. J.: *L' exigence phosphore d' oignon (*Alium cepa *L.) dans la zone Sudano-savane du Nigéria.* L' exigence phosphore d' oignon (*Allium cepa* L.) a été évalué dans un sol sablonneux riche en terreau, (typic ustipsamment) faible en fixation de P et déficient en P dans une expérience terroir de 4 ans au Nigéria. Les résultats indiquaient que la variété d' oignon cultivé (Borno Local) exigeait des niveaux de P disponible plus élevés que 12.3, 16.7 et 11.7 mg kg^{-1} respectivement pour Bray P1, Bray P2 et $NaHCO_3$ extractants afin de produire plus que 75 pour cent du maximum de rendement de bulbe dans le sol sablonneux riche en terreau. La proportion optimum de P de 50 kg/ha établit dans cette étude correspondait à 0.23 mg l^{-1} dans la solution équilibrée avec le sol. Trois années de fécondation continue avec P, avait abouti à un accroissement significatif de P disponible qui avait une réponse résiduaire significative pendant la quatriéme saison de cultivation. Dans 2 sur 3 années de fécondation directe avec P, ceinturage d' engrais au-dessous des transplantations, était considéré le plus efficace. Les niveaux critiques de P et les isothermes sorptions de P sont des estimations sûr de l' exigence de P d' oignon sur le sol de la savane.

Introduction

Large areas of the Sudan savanna zone of Nigeria are covered by soils ranging from sandy loams to sandy soils characterized by low available phosphorus (P) besides nitrogen (N). For example, Kargbo & Adanan (1985) reported the $NaHCO_3$ extractable P in some soils of the zone to be ranging from 6.0 to 11.0 $mgkg^{-1}$.

Onion (*Allium cepa* L.) is extensively grown in the area. Responses of onion to P fertilization have been widely reported elsewhere (Galbiatti & Gastellane, 1980; Laughlin, 1989; Vishnu Shukla & Prabhakar, 1989). The importance of P nutrition of onion in the Nigerian savanna zone was demonstrated by Inyang (1966) and Aman, Ahmed & Fisher (1982) who reported significant bulb yield increases with varying levels of P fertilizer. Because of the low P status of the soils of the Sudan savanna zone where the bulk of the crop is produced, P fertilization is required for maintaining optimum concentration of soil solution P to maximize production. In this zone, however, there is lack of published information on the P requirement of onion.

The effectiveness of phosphate fertilization is influenced by the method of application among other factors. Opinions vary on the response of crops to the methods of P application. Some results (Wit, 1953; Prummel, 1957; Welch *et al.*, 1966) indicate advantages of band over broadcast applications; others (Barber, 1958; Olsen & Sander, 1977) show higher effectiveness when the P fertilizer is banded. While McMurtrey (1963) reported the least effectiveness with banded P under the planting row, Bullen, Soper & Bailey (1983) obtained highest yield with the phosphate fertilizer placed directly below the seed. The method of phosphate application to onion in the Sudan savanna zone of Nigeria has not been studied. The aim of the present study was, therefore, to evaluate the optimum concentration of soil solution P, critical P level, optimum fertilizer P rate, appropriate method of application for onion, and residual effect of the applied phosphate.

Materials and methods

The experiment was conducted at the University of Maiduguri Teaching and Research Farm (11° 30'N and 12° 45'E) during the harmattan periods from 1984/85 to 1987/88. The soil at the experimental site is a sandy loam of slightly acid reaction (*p*H 6.2) and low inherent fertility (organic carbon, 0.59 per cent; total N, 0.047; available P, 8.7 mgkg^{-1}) with a low capacity to sorb P. It is classified as *Typic ustipsamment* (Klinkenberg & Higgins, 1968) equivalent to Haplic Arenosol in the FAO/UNESCO legend.

A split-plot design was used with P rates as main plots and methods of application as sub-plots with five replicates. In 1984/85 cropping season, the P treatments consisted of 0, 11, 22 and 33 kg/ha. Following a linear response of the crop to the selected P rates, the treatments were modified as 0, 25, 50 and 75 kg P/ha in 1985/86 and 1986/87 cropping seasons. These modified rates corresponded to 0.00, 0.06, 0.23 and 0.58 mgl^{-1}, respectively in the solution equilibrated with the soil.

The P sorption isotherm of the soil was determined exactly after the procedure of Fox & Kamprath (1970). However, the P in the supernatant was determined using the molybdate blue colour method (Olsen *et al.*, 1954). P which disappeared was considered to have been sorbed. P sorbed was plotted as a function of P remaining in solution (Fig. 1).

In 1984/85, the broadcast-incorporated and band applications were investigated. In the subsequent years, three additional methods were included. The methods of P application are described below.

(a) Surface broadcast and incorporated at transplanting;
(b) Banded near one side of the transplant 8 cm away from the seedling and about 8 cm deep, 2 weeks after transplanting;
(c) Banded near both sides of the seedling 8 cm away from the seedling and about 8 cm deep, 2 weeks after transplanting;
(d) Banded along the transplanting row at the same

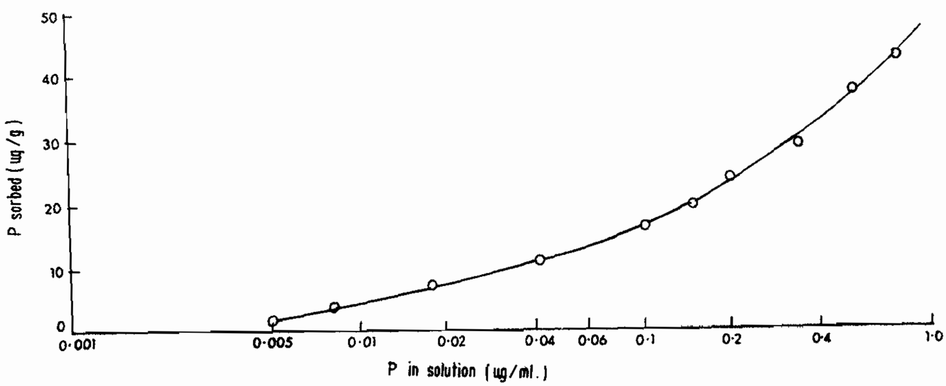

Fig. 1. Phosphorus sorption isotherms of a Typic ustipsamment, north-east Nigeria

distance and depth as in b and c;

(e) Banded in grooves about 8 cm wide and deep, half way covered and seedlings transplanted above the P band.

Urea and muriate of potash were applied at 100 kg N and 50 kg/ha, respectively with 50 per cent of the N and all the K broadcast and incorporated at planting. Six-week old seedlings of an onion variety (cv. Borno Local) were transplanted 25 cm apart on 2 m × 4 m beds between mid-November to mid-January. The remaining N fertilizer was top-dressed 6 weeks after transplanting. The plots were irrigated twice a week but stopped 3 weeks to harvest.

Farmers rarely leave the arable land fallow during the rainy season. Cowpea, an important crop in the zone, was planted during the 1986 season to find out whether a low rate of phosphate (25 kgP/ha) applied to the cowpea crop could benefit the succeeding onion crop which did receive phosphate fertilizer (control plots in 1986/87). The crop failed due to heavy striga infestation. At the end of the rainy season, the cowpea residues were incorporated into the soil. Top soil samples from all plots were analysed for available P (Bray & Kurtz, 1945) just before planting the 1986/87 harmattan crop. Phosphate was applied as in 1985/86 season. The P source was single superphosphate (8.1 per cent P).

In the 1987/88 harmattan period, no further P was applied but the crop was fertilized with N and K. The residual effect of the applied P was thus evaluated.

Before planting in the 1987/88 season, surface samples (0-15cm) were collected from each plot, after working the soil with a hoe, for the determination of residual available P using Bray 1, Bray 2 (Bray & Kurtz, 1945) and Olsen's (1954) methods. Per cent relative yield were plotted against soil test P values to estimate the critical P level for the onion on the soil.

Results and discussion

Phosphorus sorption isotherm

The P sorption isotherm (Fig. 1) shows that the soil has a low capacity to sorb phosphorus. This indicates that relatively large amounts of both native and applied P will be made available for plant use during the cropping season. The slope of the curve represents the buffering capacity (6.6 kgP/ha per 0.1ml) measured at 0.25 - 0.35/mgl^{-1} equilibrium P concentration estimated according to the procedure of Ozanne & Shaw (1968). It has been shown that the critical equilibrium solution level of P for maximum growth varied among different crops (Fox *et al.*, 1973). However, the results obtained in this study shows that the optimum P concentration for optimum onion yield did not deviate from the generally established equilibrium soil solution concentration of 0.2 mgl^{-1} for several arable crops. The optimum concentration of 0.23 mgl^{-1} obtained in the present study corresponds to 50 kgP/ha. The P sorption curve agrees with the response curve (Fig. 3a) because the highest rate of P applied (75 kg/ha) corresponds to more than double the soil solution P concentration, an area of luxury consumption, hence, a decline in yield. It is evident from this study that the P sorption isotherm can be a reliable method for estimating the P requirement of onion on the savanna soil. This technique has been successfully used for determining P require-

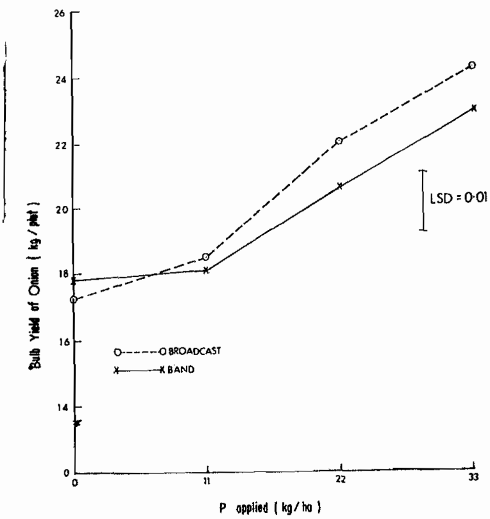

Fig. 2. Effect of rate and method of phosphate fertilization on the bulb yield of onion, 1985

ment of other crops (Ozanne & Shaw, 1968; Mokunye, 1977).

Effect of phosphate fertilizer rate, and relationship between yield and P levels

In 1984/85, a plateau response was not observed (Fig. 2). During 1985/86 season, the mean bulb yield increased by 25.2 per cent over the yield in 1984/85. Early planting and higher rate of P applied might have accounted for the higher yield which was favoured by cooler temperatures during the bulb initiation in late January, and subsequent development in February as against the hotter temperatures experienced in March during the same developmental stages of the crop in 1984/85. Each increment of P added produced a significant bulb yield increase ($P = 0.01$) up to 50 kg/ha but yield declined when the P fertilizer was applied at the rate of 75 kgP/ha (Fig. 3a). The result of soil analysis at the end of 1986 showed high levels of available P on the control plots which did not significantly differ from the levels on the P fertilized plots as a

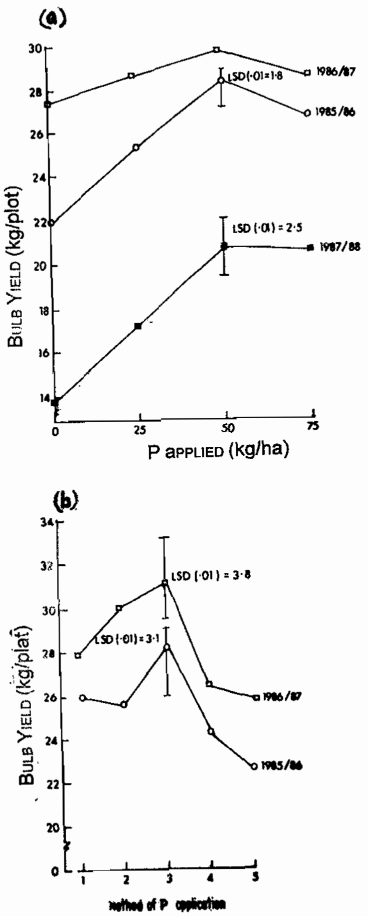

Fig. 3. Effect of rate (a) and method (b) of phosphate fertilization on bulb yield of onion

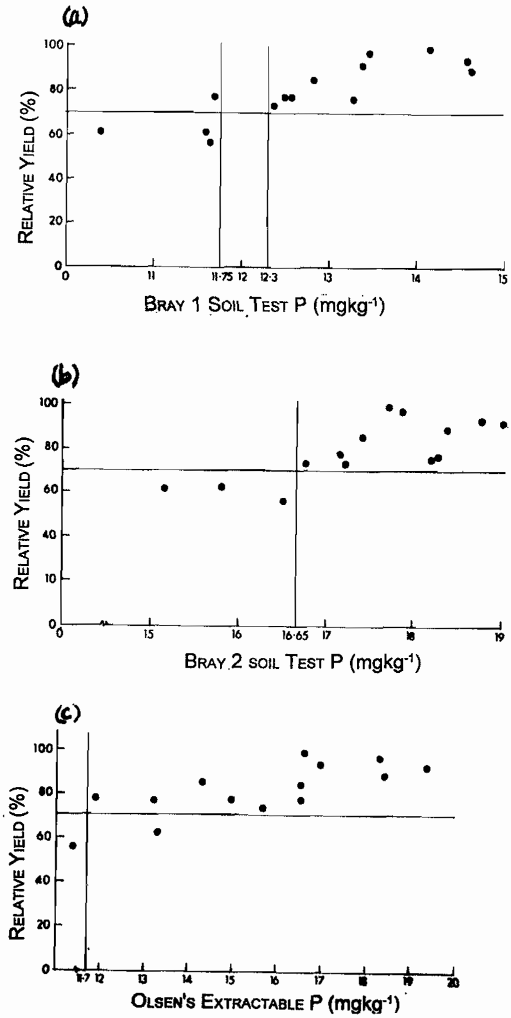

Fig. 4. Relationship between bulb yield of onion and P levels

result of available P released from the decomposed cowpea residues incorporated. Consequently, in 1986/87, there was no significant response of onion to P fertilization.

The relationship between the bulb yield and available P levels was established by plotting percentage relative yields as a function of soil test P values obtained by the three extractants according to Cate & Nelson's method (1965). The results in Fig. 4 show that the onion cultivar used in this experiment requires P fertilization on the sandy loam soil when the available P levels were below the critical levels of 12.3, 16.7 and 11.7 $mgkg^{-1}$ corresponding to 0.18, 042 and 0.20 $mgPl^{-1}$ in the equilibrated solution for the Bray 1, Bray 2 and Olsen's extractants, respectively. The results also indicated that more than 75 per cent of the maximum bulb yield were obtained when the available P levels were greater than the critical levels established in this experiment. Hipp (1986) found that for more efficient use of P and high yield, P should be applied to each crop if the initial $NaHCO_3$ extractable P levels are between 6 and 13 $mgkg^{-1}$. The $NaHCO_3$ extractable P levels of the soil used for this experiment ranged from 8.7 in 1984/85 to 11.57 $mgkg^{-1}$ in 1987/88 and therefore required P fertiliza-

TABLE 1

Effect of Rate and Method of Phosphate Application on Residual P ($mgkg^{-1}$)

Bray P1

Method of application	*Rate of application (kg/ha)* 0	25	50	75	*Means (± 0.26)*
Broadcast	10.40	12.50	13.40	13.80	12.52
Band one side of transplant	11.65	13.28	14.58	15.2	13.66
Band below transplant	11.62	12.55	13.48	14.07	12.93
Band along transplanting row	11.72	12.83	14.15	14.53	13.31
Band both sides of transplanting row	9.05	12.38	14.63	15.94	13.00
Mean (± 0.39)	10.90	12.71	14.05	14.69	

Bray P2

					Means (± 0.13)
Broadcast	15.13	18.26	19.20	20.79	18.34
Band one side of transplant	16.50	18.20	18.76	20.08	18.38
Band below transplant	15.80	17.13	17.83	18.65	17.35
Band along transplanting row	17.19	17.41	17.40	19.27	17.89
Band both sides of transplanting row	13.51	16.76	18.36	18.81	16.86
Mean (± 0.50)	15.62	17.55	18.37	19.52	

$NaHCO_3$

					Means (± 0.74)
Broadcast	10.90	14.93	19.30	21.28	16.60
Band one side of transplant	11.37	13.14	16.96	17.47	14.73
Band below transplant	13.22	16.50	18.29	21.13	17.28
Band along transplanting row	11.81	14.28	16.50	19.52	15.53
Band both sides of transplanting row	10.56	15.61	18.43	19.86	16.12
Mean (± 0.28)	11.57	14.89	17.90	19.87	

tion to significantly increase yield.

Effect of method of phosphate application

In 1984/85 cropping season, yield responses to the method of phosphate application were not significant, but the P banded was slightly superior to the broadcast application. In 1985/86 and 1986/87, the phosphate banded below the seedlings 2 weeks after transplanting, yielded significantly higher than the yields obtained when the phosphate was banded along one side or both sides of the transplanting rows (Fig. 3b). The onion plant does not develop extensive root system and coupled with the low mobility of P in the soil, the crop seems to explore greater amount of P within its immediate vicinity. The absorption of applied P appeared, therefore, to be more efficient in the fertilizer band below the plant where the nutrient's concentration seemed highest. The residual effect of the phosphate fertilizers was not significantly affected by the method of application.

Residual effect of applied P

By the end of the 1987 cropping season, the available P levels in the control plots had significantly declined (Table 1) while the levels on all the P fertilized plots had increased. There was thus significant yield response of onion (Fig. 3a) to the residual P ($P = 0.01$). These results suggest that as fertilizer P is applied in increasing amounts it is necessary to consider the value of the residues. Mokunye (1977) found that in most savanna soils in Nigeria, the accumulation of the residual fertilizer P had contributed to substantial improvement in the levels of plant available P. It has been reported (Georgeville, 1967) that the efficiency with which fertilizer P is absorbed by plant is 15-25 per cent of the added P in the year of application. Wagar, Stewart & Moin (1986) also showed that approximately 50 per cent of the fertilizer P residue remained in plant-available form.

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