Fertilizer Research 44: 23–26, 1996.
© 1996 *Kluwer Academic Publishers. Printed in the Netherlands.*

Relationship between extracted phosphorus and sorghum yield in a Vertisol and an Alfisol under rainfed cropping

K.L. Sahrawat*, G. Pardhasaradhi, T.J. Rego & M.H. Rahman
*International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502324, India; *Present address: West Africa Rice Development Association (WARDA), 01 B.P. 2551 Bouake 01, Ivory Coast*

Received 7 February 1995; accepted in revised form 12 June 1995

Key words: critical limit, Olsen-extractable P, P buffering capacity, relative yield, sandy soil, *Sorghum bicolor*, Vertisols

Abstract

Little attention has been devoted to calibrating the soil tests for P in the field for crops grown under rainfed conditions in different soil types. Field experiments were conducted during the 1990 rainy season (June-September) at the ICRISAT Center, Patancheru (near Hyderabad), India on nearby Vertisol and Alfisol sites having a range in extractable P, for establishing relationships between extractable P and sorghum yield.

In the Vertisol, 90% relative grain yield of sorghum was obtained at 2.8 mg kg^{-1} Olsen extractable P while in the Alfisol, 90% relative grain yield was achieved at 5.0 mg P kg^{-1} soil. These results suggest that a single critical limit of available P does not hold true for grain sorghum in the two soil types under similar agroclimatic conditions and that the critical limit is lower for the clayey Vertisol than the sandy Alfisol.

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is an important crop of the semi-arid tropics (SAT). Over 55 % of the global sorghum production is in the SAT and of the total SAT production, Asia and Africa contribute about 65 % of which 34 % is harvested in India (ICRISAT, 1982). Nutrient inputs are one of the important components of improved farming systems within the assured rainfall area (> 800 mm annual rainfall) of the Indian SAT. Deficiencies of N and P are common for crops such as sorghum (Katyal and Das, 1993).

Under rainfed cropping in India, it is generally understood that in a soil if the 0.5 *M* $NaHCO_3$ extractable P (Olsen P) is less than 5 mg kg^{-1} soil, a response to applied P is likely (El-Swaify *et al.*, 1985). However, recent research at the ICRISAT Center showed that this critical limit is unlikely to hold for grain sorghum grown in Vertisols. The sorghum crop responded little to applied P unless the extractable P by Olsen was less than 2.5 mg kg^{-1} soil. In contrast, substantial responses to fertilizer P were obtained in nearby Alfisols when the Olsen P was greater than 2.5 but less than 5 mg kg^{-1} soil (Sahrawat, 1988).

Little attention has been devoted to calibrating the soil tests for P in the field for crops such as sorghum under rainfed conditions (Katyal and Das, 1993 Tandon, 1987).

The objective of this paper is to report the results of field experiments conducted on nearby Vertisol and Alfisol field sites, having a range in extractable P, for establishing relationships between extractable P and yield of grain sorghum grown in the two soil types in the same season.

Materials and methods

Experimental sites

The Vertisol and Alfisol field sites at the ICRISAT Center, Patancheru (near Hyderabad), India (17.5 ° N, 78.5 ° E; 545 m altitude) previously used for conducting experiments for evaluating P response of sorghum,

were utilized for establishing extractable P-sorghum yield relationships. The plots had a range in extracable P levels.

The Vertisol field site had 256 plots, consisting of 64 fertilizer P treatments with four replications. The different treatment plots at this site had received fertilizer P as diammonium phosphate ranging from 0 to 120 kg P ha^{-1} during the last three years.

The Alfisol field site had 64 plots, consisting of 16 fertilizer P treatments with four replications. The plots at this site had received fertilizer P a single superphosphate (SSP) and partially acidulated phosphate rock PAPR ranging from 0 to 60 kg P ha^{-1} during the last two years.

Soils

The Vertisol at the experimental site belongs to the Kasireddipalle series and is a Typic Pellusterts, developed on basaltic alluvium. The Alfisol is a mixed isohyperthermic Rhodustalf and belongs to the Patancheru series.

Surface (0–15 cm) soil samples were taken before seeding the sorghum crop, air-dried, ground and sieved through a 2-mm screen before analysis. For organic C, total N and total P analyses the soil samples were ground to pass a 0.25-mm sieve. Some characteristics of the soils at the two experimental sites are given in Table 1. For the analysis reported in Table 1, pH was measured by a glass electrode using a soil to water ratio of 1:2. Organic C was determined as described by Walkley & Black (1934) and total N as described by Dalal *et al.* (1984). The total P content in the soil samples was determined by digestion with perchloric acid (Olsen & Sommers, 1982) and extractable P was determined by extracting the samples with 0.5 *M* $NaHCO_3$ (Olsen & Sommers, 1982). Carbonate (expressed as $CaCO_3$) content was determined as described by Allison & Moodie (1965) and particle size was done by the hydrometer method (Gee & Bauder, 1986). Cation exchange capacity (Chapman, 1965), exchangeable K (Jackson, 1967) and extractable Zn (Lindsay & Norvell 1978) were also determined in the soil samples.

The extractable P levels in plots at the Vertisol site ranged froim 0.5 to 4.6 mg P kg^{-1} soil and in plots at the Alfisol site it ranged from 2.8 to 7.1 mg P kg^{-1}.

Field experiments

A sorghum crop (cv CSH6) was grown at the two sites during the rainy season of, 1990. The sorghum crop in the Vertisol was seeded on 8 June 1990 at a spacing of 50 × 16 cm giving a plant population of 125 000 plants ha^{-1}. The area of each plot was 4 × 4 m^2 and there were 256 plots arranged in four blocks. All plots received uniform application of N (120 kg N ha^{-1} as urea, in two splits), K (90 kg K ha^{-1} as KCl) and Zn (10 kg Zn ha^{-1} as $ZnSO_4$). The sorghum crop at the Alfisol site was seeded on 25 June 1990 in plots each measuring 4.5 × 4 m^2. All other cultural and fertilization practices undertaken during the growing season were similar at two sites. The sorghum crop was hand-weeded twice during the growing season. The crop was also protected from shootfly (*Atherigone soccata*) by spraying 0.2% metasystox.

The crop was harvested at maturity (harvested area 3 × 2 m^2). Grain and stalk yields were recorded after drying them in the driers at 60 °C.

During the growing season from seeding to harvest of the crop, 583 mm of rainfall was received at the Vertisol site and 545 mm of rainfall was received at the Alfisol site.

The Cate & Nelson (1971) method of graphic presentation of relationships between extractable P and relative sorghum grain yield was used to arrive at a critical limit of extractable P in each soil. Relative grain yield was calculated relative to maximum yield.

Table 1. Characteristics of the soils at the experimental sites

Soil Characteristics	Vertisol	Alfisol
pH (1:2 water)	8.3	4.9
Organic C (%)	0.33	0.16
Total N (mg kg^{-1})	401	198
Total P (mg kg^{-1})	150	186
$CaCO_3$ (%)	5.6	0.0
CEC (cmol kg^{-1})	49.3	2.6
Clay (%)	53	11
Sand (%)	21	87
Silt (%)	26	2

Results and discussion

Sorghum grain yields at the Alfisol site ranged from 0.9 to 3.7 t ha^{-1} and they ranged from 0.4 to 3.4 t ha^{-1} in the Vertisol.

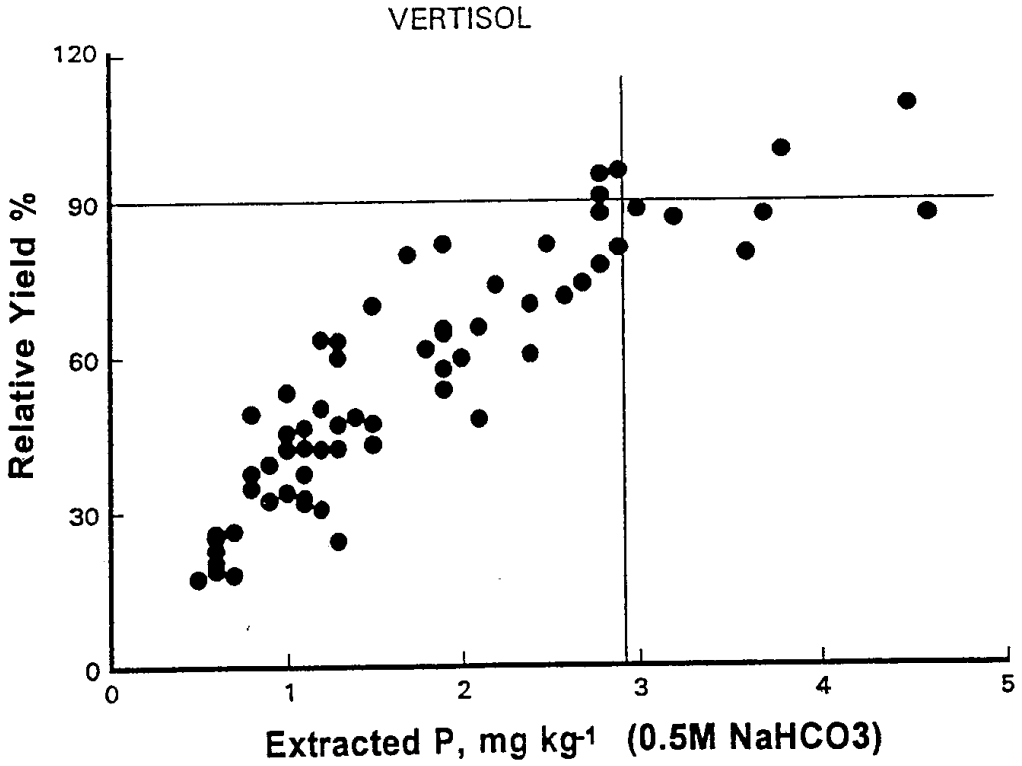

Fig. 1. Relationship between extracted P and relative sorghum grain yield in the Vertisol.

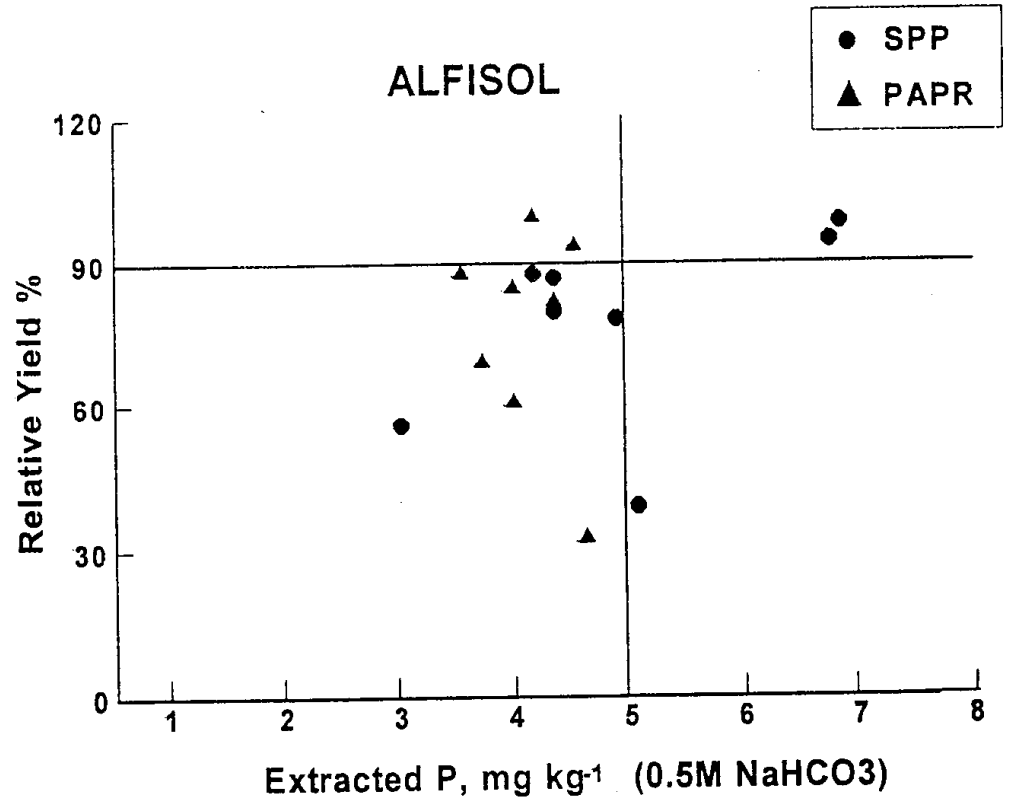

Fig. 2. Relationship between extracted P and relative sorghum grain yield in the Alfisol.

The relationships between relative sorghum grain yield and available P at the Vertisol and the Alfisol sites are shown in Figures 1 and 2. The data indicate that in the Vertisol, 90% relative grain yield was obtained when the Olsen P was around 2.8 mg P kg^{-1} soil and in the Alfisol, 90% relative grain yield was obtained at 5 mg kg^{-1} available P. The results from Vertisol support earlier results which showed that sorghum crop did not

respond to fertilizer P unless the extracted P by Olsen was less than 2.5 mg kg^{-1} soil (Sahrawat, 1988). The results; from Alfisol showed that the amounts of P extracted by Olsen were lower when PAPR than SSP was used as the source of P (Fig. 2).

These results also indicate that one single critical limit of 5 mg kg^{-1} soil of extracted P does not hold true for the two soil types occurring in proximity for the sorghum crop under similar agroclimatic conditions. The critical limit of available P for the sorghum crop (cv CHS6) in the Vertisol was around 2.8 mg kg^{-1} soil and for the Alfisol around 5 mg kg^{-1} soil. These results support the view that the critical limit of extractable P in a clayey soil is lower than in a light-textured soil (Cox, 1991; Kamprath, 1991).

The ideal soil test should not only extract less P from a high buffering soil but just the right amount of less P. This is an unobtainable ideal because the effect of buffering on P requirement differs between plant. The P buffer capacity for the Vertisol was more than twice that of the Alfisol (Sahrawat & Warren, 1989). The Olsen method does not seem to give sufficient discount for buffering for sorghum under these conditions.

Conclusion

Our results suggest that a single critical limit (5 mg kg^{-1}) of available P does not hold true for grain sorghum in the two soil types and that the critical limit is lower for the clay Vertisol than the sandy Alfisol (2.8 vs 5.0 mg kg^{-1} soil).

References

Allison LE & Moodie CD (1965) Carbonate. In : Black CA *et al.* (eds) Methods of Soil Analysis, part 2, Agronomy 9: 1379–1400. American Society of Madison, WI, USA

Cate RB Jr & Nelson LA (1971) A simple statistical procedure for partioning soil test correlation data into classes. Soil Sci Soc Am Proc 35: 658–660

Chapman HD (1965) Cation exchange capacity. In: Black CA *et al.* (eds) Methods of Soil Analysis, part 2 Agronomy 9: 891–901. American Society of Agronomy, Madison, WI, USA

Cox FR (1991) Interpretive summary of part 1: Factors affecting the availability of phosphorus in soils of the semi-arid tropics. In: Johansen C, Lee KK and Sahrawat KL (eds) Phosphorus Nutrition of Grain Legumes in the Semi-Arid Tropics, pp 43–46. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, AP 502324, India

Dalal RC, Sahrawat KL & Myers RJK (1984) Inclusion of nitrate and nitrite in the Kjeldahl nitrogen determination of soils and plant materials using sodium thiosulphate. Commun Soil Sci Plant Anal 15. 1453–1461

El-Swaify SA, Pathak P, Rego TJ & Singh S (1985) Soil management for optimized productivity under rainfed conditions in the semi-arid tropics. Adv soil Sci 1: 1–64

Gee GW & Bauder JW (1986) Particle size analysis. In: Klute A (ed) Methods of Soil Analysis, part 1, Agronomy 9: 383–409. American Society of Agronomy, Madison, WI, USA

ICRISAT (1982) Foreword. In: Sorghum in the Eighties: Proceedings of the Intern Symposium on Sorghum, pp Vii. 2–7 November 1981, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, AP 502324, India

Jackson ML (1967) Soil Chemical Analysis. Prentice-Hall, New Delhi, India. 498p

Kamprath EJ (1991) Appropriate measurement of phosphorus availability in soils of the semi-arid tropics. In: Johansen C, Lee KK and Sahrawat KL (eds) Phosphorus Nutrition of Grain Legumes in the Semi-Arid Tropics, pp 23–31. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, AP 502324, India

Katyal JC & Das SK (1993) Fertilizer management in grain sorghum. In: Tandon HLS (ed) Fertilizer Management in Food Crops, pp 61–78. Fertiliser Development and Consultation Organisation, New Delhi, India

Lindsay WL & Norvell WA (1978) Developement of DTPA soil test for zinc iron, manganese and copper. Soil Sci Soc Am J 42: 421–428

Olsen SR & Sommers LE (1982) Phosphorus. In: Methods of Soil Analysis Part 2, Agronomy 9: 403–430. American Society of Agronomy, Madison, WI, USA

Sahrawat KL (1988) Overview of research on phosphorus in Vertisols. In: Phosphorus in Indian Vertisols. Summary Proceedings of a Workshop, pp 4–8. 23–26 Aug 1988, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, AP 502324, India

Sahrawat KL & Warren GP (1989) Sorption of labelled phosphate by a Vertisol and and Alfisol of the semi-arid zone of India. Fert Res 20: 17–25

Tandon HLS (1987) Phosphorus Research and Agricultural Production in India. Fertiliser Development and Consultation Organisation, New Delhi, India. 160 p

Walkley A & Black IA (1934) An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid method. Soil Sci 29. 29–38