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Phosphorus Response Effects on Macro- and Micronutrient Removal by Sorghum under Rainfed Cropping on a Vertisol

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Abstract: Amounts of N, P, K, Ca, Mg, Na, Fe, Zn, Mn and Cu absorbed by sorghum (cv CSH 6) grown with four P levels (0, 10, 20 and 40 kg P ha^{-1}) were determined in a field experiment at the ICRISAT Centre, Patancheru (Andhra Pradesh) under rainfed conditions for three consecutive years (1987-89). The soil was a calcareous Vertisol, very low in available P. Fertilizer P increased grain and stalk yields in all the three years. The uptake of macro- and micronutrient elements accordingly increased with the increase in yield. Phosphorus application also increased the nutrient harvest index for macro- and micronutrient elements. Ratio of nutrient concentrations in the grain relative to stalk was widest for P (5:1) and narrowest for Ca (0.03:1). (***Key words:*** *Grain and stalk yields, nutrient harvest index, nutrient uptake, P fertilization,* Sorghum bicolor)

Sorghum [*Sorghum bicolor* (L.) Moench] is an important crop of the semi-arid tropics (SAT). The mineral nutrition and fertilizer management of grain sorghum have been extensively reviewed (Myers & Asher 1982; Grundon *et al.* 1987; Katyal & Das 1993). The low nutrient status of most semi-arid tropical soils has been recognized but fertilizer use in rainfed areas across the SAT is low except with irrigation (Tandon & Kanwar 1984; Burford *et al.* 1989). Deficiencies of N, P and Zn are common for crops such as sorghum (Burford *et al.* 1989; Katyal & Das 1993). Little attention has been given to study macro- and micronutrient concentrations in the field grown grain sorghum, especially under rainfed cropping (Myers & Asher 1982; Katyal & Das 1993). The present paper reports the uptake of macro- and micronutrient elements by sorghum in response to fertilizer P.

Materials and Methods

Field experiments were conducted during the rainy season in 1987, 1988 and 1989 at the ICRISAT Centre, Patancheru, Andhra Pradesh (17.5°N, 78.5°E; 545 m altitude). The soil at the experimental site belongs to the Kasireddipalle series, a benchmark Vertisol (Typic Pellustert) at the ICRISAT Centre. Some characteristics of the surface soil (0-15 cm) determined by standard methods (Sahrawat *et al.* 1995) are given in table 1.

Table 1. Characteristics of the soil at the experimental site

Soil characteristics	Value
pH (1:2) water	8.3
Organic C (g kg^{-1})	3.3
Total N (mg kg^{-1})	401.0
Clay (%)	53.0
Sand (%)	21.0
Silt (%)	26.0
CEC [cmol (p^+) kg^{-1}]	49.2
Total P (mg kg^{-1})	150.0
Extractable P, 0.5 *M* $NaHCO_3$ (mg kg^{-1})	0.4
Exchangeable cations 1*N* NH_4OAc (mg kg^{-1})	
Potassium	232.0
Calcium	7575.0
Magnesium	1156.0
Sodium	184.0
Extractable Zn, DTPA (mg kg^{-1})	5.8
$CaCO_3$ (g kg^{-1})	56.0

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The experiment used a split-plot design with four replications in which diammonium phosphate was applied at four rates (0, 10, 20 and 40 kg P ha^{-1}) (Sahrawat *et al.* 1995). All plots received uniform rates of N (120 kg N ha^{-1} in two splits between two applications), K (90 kg K ha^{-1} as KCl) and Zn (10 kg ha^{-1} as zinc sulphate).

Sorghum (cv CSH 6) crop was grown each year in the rainy season from June to September under rainfed conditions. The crop was seeded at a spacing of 50 cm × 16 cm providing a final stand of 1,25,000 plants/ha. At maturity, the crops were harvested from an area of 3 m × 2 m (gross area 4 m × 4 m) of each sub-sub-plot. The harvested crops were separated into grain and stalk, and oven-dried at 60°C. Selected fertilizer treatments dealing with the response of sorghum to fresh P in each of the three years (1987-1989) are used in this paper.

During the growing season from sowing to harvest of the crop, 604 mm of rainfall was received in 1987, 941 mm in 1988 and 583 mm in 1989.

The grain and stalk samples of sorghum were analysed separately. Nitrogen and P were analysed in plant digests by an auto-analyser colorimetric procedure (Technicon Industrial Systems 1972). Potassium, Ca, Mg, Na, Fe, Zn, Mn, and Cu were determined in triacid digests (nitric acid, perchloric acid and sulphuric acid in a ratio of 12.5:2:1 by volume) by atomic absorption spectrophotometer.

Results and Discussion

Sorghum responded spectacularly to fertilizer P application in each of the three years and the highest grain yield in each year was produced at 40 kg P ha^{-1}. Based on the pooled statistical analysis of the three years data, sorghum grain yield increased from 0.23 to 3.17 t ha^{-1} and the stalk yield increased from 1.75 to 5.39 t ha^{-1} with P application at the highest rate of 40 kg P ha^{-1} (Table 2).

The uptake of macro- and micronutrients increased in response to increased yields of grain and stalk (Table 2). The total amounts of different nutrients harvested in the biomass followed the decreasing order: K > N > Ca > Mg > P > Na > Fe > Zn > Mn > Cu. On an average, with the application of 40 kg P ha^{-1}, total N uptake increased 3.6 times,

Table 2. Yield and total nutrients harvested in sorghum at four P levels. Results presented are based on the pooled statistical analysis of the three years (1987-89) data

	P added (kg ha^{-1})				
	0	10	20	40	SE
Grain (t ha^{-1})	0.23	1.49	2.19	3.17	0.177
Stalk (t ha^{-1})	1.75	3.60	4.55	5.39	0.223
Total nutrients harvested					
N (kg ha^{-1})	19.20	42.00	52.10	69.50	3.000
P "	1.48	4.31	5.71	9.50	0.520
K "	25.10	65.40	88.10	102.60	5.310
Ca "	6.22	11.27	14.21	17.59	1.076
Mg "	2.98	6.56	8.92	11.37	0.580
Na "	0.64	1.33	1.66	2.26	0.214
Fe (g ha^{-1})	307.00	662.00	702.00	854.00	83.300
Zn "	121.00	194.00	215.00	213.00	16.100
Mn "	54.00	119.00	161.00	203.00	10.000
Cu "	13.00	30.00	36.00	44.00	2.600

P uptake 6.4 times, K uptake 4.1 times and Zn uptake 1.8 times that of uptake in control plots. The uptake of Zn increased significantly due to P application up to 20 kg P ha^{-1} in the 1987 and 1988 seasons but in 1989, the uptake of Zn significantly increased only with the smallest rate of P application and a further increase in P rates did not significantly increase the amount of Zn harvested in the biomass (results not shown).

Most of the K, Ca, Mg, Na and micronutrients remained in the stalk and only small portions were translocated to the grain. But for N and P, larger amounts were found in the grain than in the stalk. Ratio of nutrient concentrations in the grain relative to stalk varied widely. The ratios of nutrient concentrations in the grain to stalk were 3:1 for N, 5:1 for P, 0.17:1 for K, 0.03:1 for Ca, 0.71:1 for Mg, 0.22:1 for Na, 0.18:1 for Fe, 0.65:1 for Zn, 0.30:1 for Mn and 0.40:1 for Cu.

The results imply that under a farming practice in which the sorghum stalks are returned to the land, they would replenish soil fertility at least partly with regard to nutrients such as K, Ca, Mg and some micronutrient elements. Sorghum stalk application, however, will return small amount of N and the smallest amount of P.

The amounts of major and micronutrients removed in the biomass to produce 1 tonne of sor-

ghum grain, computed from the 1988 season data (results not shown) revealed that K accounted for the highest amount (39 kg) followed by N (19 kg), Ca (6 kg), Mg (4 kg) and P (3 kg). Sodium was taken up in smaller amount (0.4 kg) compared to K, Ca and Mg. It is possible that high level of K, Ca and Mg measured in the present study may not be required for optimum crop production, and represent luxury consumption because the Vertisol is rich in the bases and additionally K was also applied as fertilizer. For the total amounts of micronutrients removed in the biomass to produce 1 tonne sorghum grain, it was highest for Fe (358 g) followed by Mn (87 g), Zn (56 g) and Cu (13 g).

Plant nutrient harvest indices (amount in grain/ amount in grain and stalk) for macro- and micronutrient elements were greatly increased by P fertilization of the crop (Table 3, data are for the 1988 season).

Table 3. Nutrient element harvest index (%) of sorghum as affected by P fertilization in the 1988 cropping season*

Element	P rate (kg P ha^{-1})				
	0	10	20	40	Mean
N	31	47	55	58	48
P	41	61	64	71	59
K	4	6	7	7	6
Ca	0.6	1.0	1.2	2.0	1.2
Mg	9	17	22	23	18
Na	9	19	15	7	13
Fe	4	5	7	8	6
Zn	5	10	19	23	14
Mn	7	8	9	12	9
Cu	10	13	13	17	13

* Nutrieent harvest index = Amount in grain/ amount in grain and stalk

The results indicate that in the Vertisol low in extractable P, fertilizer P response induced removal in sorghum of macro- and micronutrients and thus their requirements increased several-fold with increase in yield and crop biomass.

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