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Response of spring-planted sugarcane (*Saccharum officinarum*) to phosphorus and sulphur application

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ABSTRACT

An experiment was conducted during the spring season of 2003-04 and 2004-05 on sandy loam soil at Pusa, Bihar to study the effect of four levels each of phosphorus (0, 17.5, 35.0 and 52.5 kg/ha) and sulphur (0, 40, 80 and 120 kg/ha) on growth and yield of sugarcane (*Saccharum officinarum* L.). Application of 35.0 kg P/ha to sugarcane recorded significantly higher mean growth (tillers, 175,000/ha; cane length, 221.0 cm; leaf area index, 4.04), yield attributes (millable canes, 131,100/ha; single-cane weight, 570 g; cane diameter, 2.02 cm) and cane yield (73.54 t/ha) over no P. The mean increase in cane yield with application of 52.5, 35.0 and 17.5 kg P/ha over the control was 20.77, 18.83 and 9.97% respectively. Application of 35.0 kg P/ha registered an increase of 4.4% in sucrose content in juice, 31.8% in P uptake and 22.1% in S uptake over the control. The use efficiency of P decreased with corresponding increase in its level. However, S-use efficiency was maximum at higher level of P application. Apparent P recovery was the highest at 35.0 kg P/ha (8.07 and 8.68%), whereas apparent S recovery progressively increased with increase in P levels from 0 to 52.5 kg/ha. The response of sulphur was also pronounced at 80 kg/ha as evident from significant increase in mean cane length (219 cm), leaf area index (4.02), number of millable canes (131,000/ha), single cane weight (566.0 g), cane yield (73.17 t/ha) and sucrose content in juice (17.3%). Sulphur levels significantly improved the uptake of P and S up to 80 kg S/ha and the increase was 21.4 and 22.2% over the control respectively. Application of 120 kg S/ha recorded maximum P-use efficiency (361.6 kg cane/kg S applied) and apparent P recovery (8.75%), but it recorded S-use efficiency (121.6 kg cane/kg S applied) up to 80 kg/ha level only. There was decrease in apparent S recovery with successive increase in S level from 40 to 120 kg S/ha.

Key words: Cane yield, Phosphorus, Sulphur, Sugarcane, Sucrose content, Uptake

In spite of the use of high-yielding varieties, potential productivity of sugarcane (*Saccharum officinarum* L.) has not been exploited due to inadequate or imbalanced supply of nutrients. Besides changes in soil and fertilizer management practices have altered the P and S status of the soil and its availability. Sugarcane is a long-duration and exhaustive crop that takes an year or more, in which the available P status of the soil may change during the crop-growing season (Bowen and Anderson, 1992). Phosphorus is one of the most important major nutrients and is closely concerned with vital growth process of sugarcane plant. The requirement of sugarcane plant for P is the highest during the early stages of its development. Therefore, it is affected by phosphorus nutrition and long-term available P reserves in the soil (Korndorfer *et al.*, 1995). Sulphur has emerged as the fourth essential element after NPK, which is absorbed in amount comparable to that of P for the healthy growth and optimum cane yield. Intensive cropping, prolonged use of S-free fertilizers and lack of inadvertent addition of organic manure have depleted the soils of their sulphur reserves, leading to an adverse effect on cane yield. The extent of sulphur deficiency varies from 23 to 31% in alluvial soils of Bihar, and higher magnitude of deficiency was recorded in young alluvium, non-calcareous soil followed by recent alluvium, non-calcareous, non-saline and young alluvium calcareous (Biswas *et al.*, 2004). Sulphur fertilization improved both cane yield and sucrose content in the juice (Shukla and Lal, 2003). Keeping these points in view, the present investigation was undertaken to study the response of the levels of P and S on growth, yield and quality parameters of sugarcane.

MATERIALS AND METHODS

A field experiment was conducted during spring season of 2003-04 and 2004-05 at Sugarcane Research Institute farm, Pusa, Bihar. The soil was sandy loam (calciorthents), having 8.4 pH, 0.44% organic C, 29.8% free $CaCO_3$, 10.9

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ppm available S; and 199, 19.8 and 100 kg/ha available N, P and K respectively. The treatments consisted of combinations of four levels of P, viz. 0, 17.5, 35.0 and 52.5 kg/ha; and four levels of S, viz. 0, 40, 80 and 120 kg/ha. Each treatment was replicated thrice in randomized block design. The crop received recommended dose of N (150 kg N/ha) and K (50 kg K/ha) through urea and muriate of potash respectively. Phosphorus and S as per treatment were applied in the form of diammonium phosphate and phosphogypsum, respectively. Half of the N after adjusting the N applied through diammonium phosphate and full dose of P, K and S were applied at planting, and the remaining N was top-dressed in two equal splits after the first irrigation and at the time of earthing-up (early July). An early-maturing variety of sugarcane 'CoP 9301' was planted on 22 February 2003 and 20 February 2004, and harvested on 23 January 2004 and 25 January 2005 respectively. The total rainfall during the crop season was 1435.5 mm in 2003-04 and 912.3 mm in 2004-05. Whole cane samples were taken at the time of harvest and analysed for sucrose content in juice and separately for P and S content following Vanado-molybdate-yellow colour method for determining the P-content and turbidimetric method for the S content in plant, and its uptake was computed.

RESULTS AND DISCUSSION

Growth and yield attributes

Application of P had positive and significant influence on the growth and yield attributes of cane (Table 1). Higher cane growth and yield components, viz. tillers and millable cane production, leaf area index, cane length, cane diameter and single cane weight were obtained with increase P level; however, the response was significant up to 35.0 kg P/ha only. Moreover, increasing doses of P also reduced the tiller mortality, though the effects were significant during 2004-05 only. This indicated that besides tiller production, P nutrition also helped in maintaining the retention of tillers. Phosphorus, being integral participant of photosynthetic activities and constituent of the sugar phosphates and adenosine di- and triphosphates (which act as energy currency within the plants and play a key role in donation or transfer of the energy-rich phosphate molecules from ATP to energy requiring substances in the plants) recorded significant increase in tillers production. It eventually resulted in higher number of mature stalks, probably through production of new meristems and improvement in overall metabolic activities in the plants. Kumar and Verma (1999) also reported significant influence of P fertilization on tillers and millable canes. Application of P registered significant increase in cane length, i.e. 52.5 kg P/ha increased it by 16.1 and 14.1% during

Table 1. Effect of phosphorus and sulphur levels on growth, yield attributes and yield of sugarcane

Treatment	Tillers at 125 DAP ($x\ 10^3$/ha)		Cane length at 270 DAP (cm)		Leaf area index at 270 DAP		Cane diameter at 270 DAP (cm)		Millable canes ($x\ 10^3$/ha)		Tiller mortality (%)		Single cane weight (g)		Cane yield (t/ha)		
	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	Pooled
P level (kg/ha)																	
0	162.0	164.0	191.0	195.0	3.63	3.70	1.84	1.85	119.8	119.5	26.19	27.22	517	524	61.46	62.30	61.88
17.5	168.0	171.0	213.0	215.0	3.89	3.90	1.95	1.97	126.4	127.1	24.90	25.53	545	551	67.74	68.36	68.05
35.0	173.0	176.0	220.0	221.0	4.03	4.04	2.01	2.02	130.4	131.8	24.59	25.00	568	571	73.11	73.96	73.54
52.5	174.0	176.0	221.0	223.0	4.10	4.11	2.03	2.04	131.6	134.4	24.22	23.85	570	572	73.77	75.69	74.73
SEm±	3.5	5.1	4.7	4.6	0.08	0.08	0.04	0.04	2.7	2.8	0.75	0.80	12	12	2.25	2.33	2.23
CD (P=0.05)	10.0	11.0	14.0	13.0	0.24	0.24	0.11	0.11	7.6	8.1	NS	2.30	33	34	5.37	5.57	6.45
S level (kg/ha)																	
0	163.0	166.0	195.0	199.0	3.69	3.75	1.88	1.89	120.6	120.3	26.22	27.68	525	533	63.04	63.83	63.44
40	168.0	171.0	213.0	215.0	3.89	3.90	1.94	1.96	127.0	127.4	24.55	25.35	548	550	67.32	68.41	67.87
80	173.0	175.0	218.0	220.0	4.01	4.02	2.00	2.01	130.2	132.2	24.55	24.32	564	568	72.54	73.80	73.17
120	173.0	175.0	219.0	221.0	4.06	4.08	2.01	2.02	130.5	132.9	24.59	24.25	562	567	73.18	74.27	73.73
SEm±	3.5	5.1	4.7	4.6	0.08	0.08	0.04	0.04	2.7	2.8	0.75	0.80	12	12	2.25	2.33	2.23
CD (P=0.05)	NS	NS	14.0	13.0	0.24	0.24	NS	NS	7.6	8.1	NS	2.30	33	33	5.37	5.57	6.45

DAP, days after planting

2003-04 and 2004-05 respectively compared with control. Significant increase in cane diameter in the P-fertilized plots might have helped the plant attain full capacity of sink size, which manifested into bolder and thicker canes.

Sulphur application from 0 to 80 kg S/ha significantly increased the leaf area index, cane length, millable canes and single cane weight (Table 1). However, 80 and 120 kg S/ha were statistically similar in influencing most of the growth and yield attributes, except tiller count and diameter of cane during both the years. Application of 80 kg S/ha increased the millable canes by 10,750/ha and single cane weight by 37 g over control. Sulphur-mediated N metabolism might have increased the nitrate-reductase and sulphate-reductase activities, improving the chlorophyll formation, which contributed greatly to increased number of millable canes. The increase in cane weight was owing to functional relationship with length and its diameter. Our finding on the increase in millable canes due to S fertilization is in agreement with that of Bokhtiar *et al.* (2001) and Shukla and Lal (2003). Application of sulphur had positive influence on mortality percentage during 2004-05, though it failed to reach the level of significance during 2003-04. The significant decrease in mortality percentage owing to higher dose of S might helped in greater availability of nutrients, which helped the production of tillers and millable canes.

Yield and sucrose content

Application of P significantly improved the cane yield during both the years of experimentation, and the response to P in terms of cane yield was 0.15, 0.14 and 0.03 t/kg P at 17.5, 35.0 and 52.5 kg P/ha respectively (Table 1). High P content in the plant tissues due to P nutrition enabled the plant to maintain high rate of metabolic and physiological activities, increase the sink size and utilize the photosynthate at a faster rate, which laid down the foundation of higher yield. These findings support those of Kumar *et al.* (2004). Application of 35.0 and 52.5 kg P/ha was at par but significantly superior to that of 17.5 kg P/ha and the control in production of sucrose in juice (Table 2).

Application of 40, 80 and 120 kg S/ha increased the cane yield by 9.57, 18.83 and 20.77% over the control respectively, and the response was 0.11, 0.13 and 0.014 t/kg S between 0-40, 40-80 and 80-120 kg S/ha (Table 1). Sulphur application beyond 80 kg/ha did not show any marked response. Improvement in growth and yield attributes owing to positive influence of sulphur and its efficiency and greater partioning of metabolites as well as adequate translocation of nutrients to the developing reproductive structures led to higher yield. Shukla and Lal (2003) also reported similar results. An increase in S level from 0 to 120 kg/ha gave 0.51 and 0.77 unit increase in sucrose content in juice during 2003-04 and 2004-05 respectively, though 80 and 120 kg S/ha behaved statistically alike in this regard and both of them were superior to 40 kg S/ha and the control (Table 2). Our results are in close conformity with those of Choudhary and Sinha (2001).

Nutrient uptake

Uptake of P indicated a significant and progressive increase up to 35 kg/ha (Table 2). The highest P uptake of 16.90 and 17.91 kg P/ha was recorded at 52.5 kg P/ha and minimum of 12.47 and 13.10 kg/ha under the control during 2003-04 and 2004-05 respectively. Improved and pro-

Table 2. Effect of P and S levels on sucrose content in juice, phosphorus and sulphur uptake, its use-efficiency and recovery by sugarcane

Treatment	Sucrose content in juice (%)		P uptake (kg/ha)		S uptake (kg/ha)		P-use efficiency (kg cane/kg P applied)		S-use efficiency (kg cane/kg P applied)		Apparent P recovery (%)		Apparent S recovery (%)	
	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
P level (kg/ha)														
0	16.46	16.72	12.47	13.10	24.30	25.08			92.0	62.8			5.33	4.28
17.5	16.98	17.20	14.76	15.41	27.03	27.79	358.7	346.1	101.5	96.7	6.61	7.27	5.89	5.79
35.0	17.28	17.36	16.48	17.23	29.72	30.57	332.9	333.1	109.5	128.6	8.07	8.68	6.46	7.69
52.5	17.35	17.41	16.90	17.91	30.27	31.63	234.5	255.1	110.5	146.6	6.17	6.51	6.55	8.17
SEm±	0.10	0.12	0.22	0.24	0.42	0.43								
CD (P=0.05)	0.29	0.35	0.64	0.69	1.20	1.25								
S level (kg/ha)														
0	16.72	16.74	13.35	13.98	24.38	25.09	281.8	202.8			5.84	4.63		
40	16.96	16.96	14.50	15.25	27.04	28.00	300.9	265.2	106.9	114.4	6.76	6.76	6.67	7.26
80	17.16	17.47	16.17	17.02	29.68	30.75	324.5	382.0	118.7	124.6	7.54	8.73	6.64	7.08
120	17.23	17.51	16.59	17.40	30.22	31.23	327.5	395.7	84.5	86.9	7.67	9.82	4.87	5.12
SEm±	0.10	0.12	0.22	0.24	0.42	0.43								
CD (P=0.05)	0.29	0.35	0.64	0.69	1.20	1.25								

longed availability of nutrients resulted in higher P concentration in the plants, which markedly increased the P-uptake. Sulphur application significant improved the P uptake. There was an increasing trend of P uptake up to 120 kg S/ha, though it was statistically at par with that of 80 kg S/ha. The maximum P uptake of 16.59 and 17.40 kg P/ha was recorded with 120 kg S/ha, and the minimum of 13.35 and 13.98 kg P/ha under the control during the first and second year, respectively. This was attributable to increase in cane yield with simultaneous increase in P concentration in the plants, which increased the P uptake.

The increase in P level significantly increased the S uptake in each year. Mean values of S uptake were 31.0, 30.1, 27.4 and 24.7 kg/ha at 52.5, 35.0, 17.5 and 0 kg/ha respectively. This might be substantiated by the fact that P nutrition, apart from improving soil properties, mobilized the native soil S. Application of S at 120 kg/ha resulted in higher S uptake, viz. 30.22 and 31.23 kg/ha compared with its minimum uptake, viz. 24.38 and 25.09 kg/ha under no application during 2003-04 and 2004-05 respectively. Choudhary and Sinha (2001) also reported increase in S concentration and its uptake by S-fertilization.

Nutrient-use efficiency

An increase in P level by 35.0 and 52.5 kg/ha led to corresponding decrease in P-use efficiency (Table 2), probably because the cane yield did not increase proportionately. However, P application improved the S-use efficiency by 66.01, 53.76 and 27.95% respectively at 52.5, 35.0 and 17.5 kg P/ha over the control. This was mainly due to higher cane production per unit of P applied. The maximum apparent P recovery of 8.07 and 8.68% was obtained with 35.0 kg P/ha during the first and second years respectively. In our study the increase in P recovery with 35.0 kg P/ha compared with lower and higher levels of P indicates that the applied P was nearly sufficient up to 35.0 kg P/ha, beyond which the absorbed P was less effective in increasing cane yield.

The maximum P-use efficiency (kg cane/kg S applied) was recorded with 120 kg S/ha, which was 49.21% more than that of the control. However, the maximum S-use efficiency of 118.69 and 124.57 kg cane/kg S applied was recorded with 80 kg S/ha during the two years respectively. The apparent P recovery of cane increased with the higher level of S application, thought the apparent S recovery showed reverse trends.

Response function

The relationship between cane yield and levels of P and S was fitted to quadratic response curve, whose coefficient of determination (R^2) was highly significant.

The estimated equations for P and S were:

$$Y = 61.70 + 0.47\,X - 0.004\,X^2 \quad (R^2 = 0.99^{**})$$

$$Y_1 = 61.16 + 0.16\,X - 0.000605\,X^2 \quad (R^2 = 0.93^{**})$$

where, 'Y' is the expected cane yield (t/ha) and 'X' the P and S dose (kg/ha). The optimum P and S doses worked out from quadratic equation were 58.75 kg P and 132.23 kg S/ha with a mean cane yield of 75.50 t and 73.74 t/ha respectively. The economic P and S doses were 22.50 kg P/ha and 57.85 kg S/ha with a corresponding cane yield of 70.26 t/ha and 70.39 t/ha. The increases in cane yield at economic P dose (22.50 kg P/ha) and S dose (57.85 kg S/ha) were 8.38 t/ha and 6.95 t/ha, which realized net returns of Rs 6,568 (cane price Rs 783.80/t, P cost Rs 50.77/kg) and Rs 5,447 (cane price Rs 783.80/t, S cost Rs 17.86/kg) compared with 0 kg P and S respectively. However, the net returns per Re investment on P and S were Rs 5.85 and Rs 5.27, respectively.

It was concluded that sugarcane variety 'CoP 9301' can be grown and fertilized with 35 kg P and 80 kg S/ha along with 150 kg N and 50 kg K/ha, so as to achieve higher cane yield and quality under these agro-climatic conditions.

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