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Phosphorus and Sulphur Constraints for Soybean, Wheat and-Gram Production on Some Swell-Shrink Soils

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Abstract : *The extent of constraints of phosphorus and sulphur and the magnitude of response of soybean, wheat and gram to the applied P and S in Islamnagar 3, 4 and 5 series were assessed. About 87,72 and 11 per cent samples were deficient in P in Islamnagar 4, 3 and 5, respectively. The corresponding per cent samples deficient in S were 24, 25 and 33. Organic carbon showed significant positive correlation with both available P and S. Addition of 13 to 39 kg P ha^{-1} and 20 to 60 kg S ha^{-1} increased significantly the yield of the test crops at different sites. Soybean, wheat and gram showed an average response (kg grain kg^{-1} nutrient) of 10.8, 22.2 and 10.9 to P; and 4.8, 11.0 and 8.8 to S respectively.* (**Key words :** *Vertisol, available phosphorus and sulphur, crop response).*

Research on phosphorus and sulphur management in Vertisols and associated soils for sustainable agriculture has received much less attention than it deserves. Phosphorus and sulphur deficiencies are wide spread in these soils. Ghosh and Hasan (1979) identified 23 districts of Madhya Pradesh low in phosphorus. A reconnaissance survey of the black soils of Madhya pradesh revealed the deficiency of S to an extent of 20 to 40 per cent (Gupta *et al.* 1986). Deficiencies of P and S, and optimum crop yields on these soils may vary widely, and lack of information on the extent of their constraints in well characterized shrink-swell soils of Islamnagar 3,4 and 5 series necessitated to undertake the studies to find out the extent of constraint of P and S and to establish the relationships between their availability and soil properties, and response to soybean, wheat and gram.

MATERIAL AND METHODS

Fifty surface (0-15 cm) soil samples, from each of three soil series (Islamngar 3,4 and 5) were collected in summer 1990 and 1991 at a grid of 2 ha. Ground samples (2 mm sieved) analysed for various physico-chemical properties (Jackson 1968) and available P by Olsen's method (Olsen *et al.* 1954) and available S by extracting with 0.01 M $CaCl_2$ (Williams & Steinbergs 1959). Important characteristics of the soils are given in Table 1.

TABLE 1. Characteristics of the soils of the experimental sites

Soil series	pH	OC (%)	$CaCO_3$ (%)	Available P	Available S
				(mg kg^{-1})	
Islamnagar 3	8.2	0.46	2.2	3.70	7.1
Islamnagar 3	8.0	0.46	1.4	1.38	14.0
Islamnagar 3	8.3	0.32	2.2	1.51	11.6
Islamnagar 4	8.4	0.47	0.2	1.87	11.2
Islamnagar 4	8.4	0.65	2.4	0.91	10.9

Field Experiments

Soybean: Nine field experiments five in 1990 and four in 1991 during kharif season were conducted to study the response of soybean (Punjab-1) to applied P. P (0, 13, 26 and 39 kg P ha^{-1}). A uniform basal dose of N @20kg ha^{-1} was applied through urea. The experiment was conducted in randomised block design. The response of soybean to applied S (0,20,40 and 60 kg S ha^{-1}) were tested. The uniform application of P@ 26 kg ha^{-1} was given as basal dose.Gypsum was the source of S. The initial soil samples were analysed for available P and S.

Wheat: In rabi 1991 the response of wheat (WH-147) was tested to P (13,26 and 39 kg P ha^{-1}) over 60, 120 and 180 kg N ha^{-1} and to S (20,40 and 60 kg S ha^{-1}) over 13, 26 and 39 kg P ha^{-1}, 120 kg N ha^{-1} was applied in each plots of the three field experiments.

Gram : The response of gram (Ujjain-1) was tested to P (13,26 and 39 kg P ha^{-1}) over 20, 40 and 60 kg N ha^{-1}. Sulphur (20,40 and 60 kg S ha^{-1}) was tested over 13, 26 and 39 kg P ha^{-1} . A uniform dose of 40 kg N ha^{-1} was applied basaly in three field experiments.

Soil Description

The soil series were identified by NBSS&LUP (1983). An extract of the description of these series under investigation, is given below.

Islamnagar - 3 series (Vertic Ustochrepts) : It occupies an area of 301.7 ha on piedmont plain having 1-5 per cent slope. The soils are very deep, dominantly clayey in the control section (25-100 cm). They are slightly to moderately eroded. The internal drainage is not free. They are mostly cultivated to soybean, wheat, and gram. The limitations of these soils are workability and susceptibility to erosion.

Islamnagar-4 series (Vertic Ustochrepts) : It occupies an area of

272.2 ha on piedmont plain having 1 to 5 per cent slope. The soils are silty clay to clay with dark brown to grayish brown colours in control section (25-100 cm). They are moderately well drained and non-calcareous having high water holding capacity and fertility status. They are more suited to intensive cultivation soybean, wheat and horticultural and vegetable crops.

Islamnagar-5 series (Udic Ustochrepts): It covers an area of 89.7 ha on very gentle sloping land. The soils are silty clay to clay, moderately well drained, very deep and non-calcareous. They are best suited to paddy and wheat cultivation.

RESULTS AND DISCUSION

Available P : Available phosphorus ranged from 0.5 to 12 mg kg^{-1} in Islamnagar 4 series, 0.3 to 17.8 kg^{-1} in Islamnagar 3, and 3.9 to14.9 mg kg^{-1} in Islamnagar 5. The average available P content was 2.63, 4.61 and 9.17 mg kg^{-1} in Islamnagar 4, 3, and 5 series respectively (Table 2). The higher available P content in Islamnagar 5 series may be due to irrigation of these soils with sewage water. About 87 per cent samples in Islamngar 4 series, 72 per cent in Islamnagar 3 and 11 per cent in Islamngar 5 were deficient in P. Bansal and Sekhon (1994) reported a range of 3.9 to 82.5 $kgPha^{-1}$ in Sarol series and 6.5 to 51 $kgPha^{-1}$ in Kamliakheri series of Madhya Pradesh. There was a significant positive relationship ($r = 0.42$) between available phosphorus and soil organic carbon. Subba Rao and Ganeshamurthy (1994) also reported similar finding in Islamnagar soils.

Available S: The available S content ranged from 5.4 to 18.2 mg kg^{-1} in Islamnagar 3, 7.0 to 15.5 in Islamnagar 4 and 6.4 to 15.4 mg kg^{-1} in Islamnagar 5 series. Considering 10 mg kg^{-1} S as the critical level (Table 2) about 24 per cent soils in Islamnagar 3, 25 per cent in Islamnagar 4, and 33 per cent in Islamnagar 5 series were deficient in available S. There was a significant positive relationship only between available S (Table 2) and soil organic carbon ($r = 0.214$).

Crop Responses to P and S

Soybean: Response of soybean (Punjab-1) to P was assessed in field experiments covering Islamnagar 3 and 4 series. All the fields were deficient in P. The response of soyabean to fertilizer P was between 26 and 39 kg

TABLE 2. Frequency distribution of available phosphorus and sulphur in three soil series

Parameters	Islamnagar 3	Islamnagar 4	Islamnagar 5
Available P			
Range	0.30-17.8	0.50-12.0	3.90-14.9
Mean	4.61	2.63	9.17
(%) samples			
Low	72	87	11
Medium	24	7	39
High	4	6	50
Available S			
Range	5.4-18.2	7.0-15.3	6.4-15.4
Mean	11.6	10.9	11.3
(%) samples			
Deficient	24	25	33
Sufficient	76	75	67

P ha^{-1} (Table 3). The response function of phosphorus in Islamnagar 3 series are,

Site 1: $Y = 16.53 + 0.059\text{-}0.00043x^2$

Site 2: $Y = 20.13 + 0.138\text{-}0.00081x^2$

At site 1, soybean responded significantly upto 30 kg P ha^{-1} with a mean response of 2.95 kg grain kg^{-1} P, while at site 2 the response was observed upto 38 kg P ha^{-1} with a mean response responded upto 17.6 kg P ha^{-1} in a P deficient black soil of north

TABLE 3. Effect of phosphorus on grain yield of soybean (t ha^{-1}) on Islamnagar 3 and 4 soil series

P (kg ha^{-1})	Islamnagar 3						Islamnagar 4		
	Site 1		Site 2		Site 3		Site 4		Site 5
	1990	1991	1990	1991	1990	1991	1990	1991	1990
0	1.65	0.98	2.04	1.40	1.65	1.35	1.21	1.00	1.43
13	1.77	0.98	2.27	1.38	1.87	1.49	1.33	1.10	1.51
26	1.87	1.06	2.63	1.55	2.23	1.64	1.61	1.16	1.73
39	1.83	1.05	2.57	1.55	-	1.73	-	1.18	-
C.D.(0.05)	0.22	0.84	0.23	0.14	0.14	0 .21	0.20	0.12	0.14

TABLE 4. Effect of Sulphur on grain yield of soybean (t ha^{-1}) on Islamnagar 3 and 4 soil series

Sulphur (kg ha^{-1})	Islamnagar 3						Islamnagar 4		
	Site 1		Site 2		Site 3		Site 4		Site 5
	1990	1991	1990	1991	1990	1991	1990	1991	1991
0	1.87	1.06	2.63	1.55	2.23	1.64	1.61	1.16	1.73
20	1.95	1.08	2.35	1.63	2.07	1.74	1.76	1.28	1.55
40	2.32	1.18	2.54	1.65	2.36	1.78	1.99	1.43	1.80
60	2.25	1.21	2.55	1.66	2.34	1.74	1.97	1.50	1.80
C.D.(0.05)	0.22	0.10	NS	0.10	0.14	0.11	0.20	0.28	NS

western Madhya Pradesh and upto 53.2 kg P ha^{-1} on alluvial soils (Abbas 1993; Chatterjee *et al* 1972). In a green house experiment response of soybean to 35 kg P ha was also observed on medium black soil of M.P. (Dwivedi *et al.* 1985).

Out of the five fields where response of soybean to applied S was studied, four soils tested low in available S (7.1 to 11.6 mg kg^{-1}) and one tested medium in available S status (Table 1). In 1990, the application of 40 kg S ha significantly increased the grain yield at site 1,3 and 4 only (Table 4). In 1991 there was significant increase in grain yield of soybean upto 40 kg S ha^{-1} in all the four sites. Earlier Shinde *et al.* (1979) reported higher yield of soybean is a pot experiment with medium black soil having 75 mg S kg^{-1}, and 69 mg P kg^{-1}.

Wheat : The response of wheat to applied P was significant upto 26 kg P ha^{-1} at site 1, 2 and 3 (Table 5). Experiments conducted on farmers fields in Diara land of Bihar, indicated that the most profitable production of wheat was obtained at 144 kg N with 36 kg P ha^{-1} in 1984-85 and 135 kg N with 38 kg P ha^{-1} in subsequent year.

The response of wheat to applied S was significant upto 20 kg S ha^{-1} at site 1, and upto 60 kg S ha^{-1} at site 2 and 3 (Table 6). Several experiments conducted on black soils earlier have shown the positive effect of sulphur application on increasing wheat yield by 32.4 per cent with application of 20 kg S ha^{-1} (Bapat 1989). In sulphur deficient Vertisols of Central India, 56 kg S ha^{-1} was found optimum for wheat (Tandon 1988).

TABLE 5. Effect of phosphorus on wheat and gram on Islamnagar 3 and 4 soil series

Treatment (Kg ha^{-1})		Grain yield (t ha^{-1})		
N	P	Site 1	Site 2	Site 3
Wheat				
60	0	2.20	3.55	2.43
120	0	2.65	4.12	2.92
180	0	2.83	4.47	3.07
60	13	2.93	4.52	2.76
120	26	3.57	4.63	3.22
180	39	3.72	4.70	3.28
CD(0.05)		0.24	0.26	0.27
Gram				
10	0	1.37	1.52	1.04
20	0	1.48	1.65	1.19
40	0	1.46	1.63	1.24
10	13	1.53	1.73	1.26
20	26	1.72	1.97	1.48
40	39	1.75	2.05	1.53
CD(0.05)		0.10	0.13	0.23

TABLE 6. Effect of sulphur on wheat and gram on Islamnagar 3 and 4 soil series

Treatment (Kg ha^{-1})		Grain yield (t ha^{-1})		
P	S	Site 1	Site 2	Site 3
Wheat				
13	0	2.93	4.52	2.76
26	0	3.57	4.63	3.22
39	0	3.72	4.70	3.28
13	20	3.93	4.87	3.24
26	40	3.73	4.13	3.88
39	60	3.86	5.15	3.92
CD(0.05)		0.24	0.26	0.27
Gram				
13	0	1.53	1.73	1.26
26	0	1.72	1.97	1.48
39	0	1.75	2.05	1.53
13	20	1.77	2.17	1.45
26	40	2.01	2.39	1.82
39	60	2.05	2.44	1.88
CD(0.05)		0.10	0.12	0.32

Gram: In Islamnagar series 3 and 4 soils testing low in available P, optimum grain yield was obtained with 26 kg P ha^{-1} at site 1 and 2; and with 39 kg P ha^{-1} at site 3 (Table 5). Under field conditions, application of 18 kg N + 20 kg P ha^{-1} significantly increased the gram grain yield over 9 kg N + 10 kg P ha^{-1} in deep black soil (Nimje 1991).

Gram yield response was also significant to applied S upto 40 kg S ha at site 1, and 60 kg S ha^{-1} at site 2 and 3 (Table 6). Similar response was also reported by Aulakh & Pasricha (1979).

In response data further indicated that there was potential benefits from the use of P and S fertilizers on soybean, wheat and gram on Vertic Ustochrepts (Table 7). The responses were dramatic upto 26 kg P and 40 kg S ha^{-1}.

TABLE 7. Average response of soybean, wheat and gram to added P and S

Treatment (kg ha^{-1})	Response, kg grain kg^{-1} nutrient			
	Soybean		Wheat	Gram
	1990	1991	1990-91	1990-91
Phosphorus				
13	11.84	4.23	52.05	15.13
26	15.00	6.54	22.18	10.90
39	9.11	5.00	11.37	8.56
Sulphur				
20	-	4.00	30.50	14.50
40	5.60	3.95	11.00	8.75
60	3.40	2.95	6.80	5.78

The wide spread deficiencies of P and S and spectacular responses of soybean, wheat and gram to the applied P and S fertilizers brings forth the urgent need for popularizing the P and S use among the farmers of Vertisols region. However, the evaluation of the efficacy of single super phosphate and gypsum as sources of P and S of soybean, wheat and gram needs to be confirmed.

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