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Direct and Residual Effect of Sulphur on Growth, Nutrient Uptake, Yield and its Use Efficiency in Maize and Subsequent Greengram

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Abstract: Field experiments were conducted with maize and green gram in sandy clay loam soils of Thondamuthur block of Coimbatore district to study the direct and residual effect of S application on growth, nutrient uptake, yield and S use efficiency. The main crop treatments constituted application of S at 0, 15, 30 and 45 kg ha^{-1} replicated 5 times in RBD. The residual crop green gram received no S. The results revealed that application of S had no significant influence on plant height and leaf length of maize. However the increased yield attributes and nutrient uptake with S application contributed to the increased grain and stalk yield of maize. The S use efficiency, apparent recovery and value cost ratio are favorably influenced by S application irrespective of the experimental locations. The residual effect of S was more convincing in enhancing the yield attributes and yield of green gram. The nutrient uptake also favorably influenced by the residual effect of S which was evidenced through increased S use efficiency.

Key words: Sulphur, yield attributes, yield of maize, nutrient uptake, S use efficiency, value cost ratio, Residual effect on green gram

INTRODUCTION

Sulphur is considered to be some times forgotten secondary nutrient in crop production. However it is very essential for the synthesis of amino acids and activity of proteolytic enzymes. Sulphur fertilization improves both yield and quality of crops if adequate supply in the field is ensured[5]. The real importance of S has been marked in the recent past due to intensive cultivation with high yielding varieties and the use of complex fertilizers, which led to S deficiency in many farm soils[6]. Hence the importance of S is being increasingly emphasized in the recent past because of its deficiency being widely reported in different parts of the country.

In Tamil Nadu maize is one of the important commercial crops used as an ingredient in poultry and cattle feed. Maize crop responds well to S application and it removes about 30-70 kg S ha^{-1}[17]. Several workers have reported that S also has positive influence on the uptake of major nutrients[2,4]

Generally the S applied to main crop leaves residual effect to succeeding crops. The positive influence of residual effect of S on growth, uptake of nutrients and yield of many crops were reported by many authors in sugarcane ratoon crop, sunflower-greengram and groundnut-rice cropping sequences[10,17,8]. The information available on residual effect of S on pulses is meager. In Tamil Nadu limited research work has been carried out on the effect of S nutrition and its use efficiency on millets and its residual effect on subsequent crops and hence the present investigation was taken up to study the effect of S application on growth and yield of maize and green gram.

MATERIALS AND METHODS

Field experiments were conducted in sandy clay loam soil (Udic Haplustalf) at two locations viz., Nathegoundenpudur (LI) and Mathuvarayapuram (LII) in Thondamuthur block of Coimbatore district with maize varieties Swarna and Gargil. The treatments consisted of 4 levels of S (0, 15, 30 and 45 kg ha^{-1}), which were replicated 5 times in RBD. The N was applied through urea as 50% basal, 25% at vegetative stage and remaining 25% at tasseling stage while P and K were applied as 100% basal through DAP and MOP respectively. The S is complemented through application of SSP as per the treatment schedule. In both the locations the plant height, leaf length, length of cob, 100 grain weight, yield of grain and stalk were recorded treatment wise.

After the harvest of main crop of maize residual crop of Co.6 green gram was grown. Green gram

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received 25 kg N, 50 kg P ha^{-1} with no S application. In both locations the No. of pods $plant^{-1}$, No. of grains pod^{-1}, 1000 grain weight, yield of grain and stover were recorded treatment wise. The plant samples collected at harvest were dried at 70ºC, powdered in Willey mill and digested to analyze the various nutrient compositions. Available S in soil samples was determined by turbidimetric method[19] after extracting with 0.15% $CaCl_2$ extractant.

$$\text{Sulphur Use Efficiency (kg grain / kg S)} = \frac{\text{Grain yield with S-S uptake without S}}{\text{S added}}$$

$$\text{Apparent Sulphur Recovery} = (\%) \frac{\text{S uptake with S-S uptake without S}}{\text{S added}} \times 100$$

$$\text{Value Cost Ratio} = \frac{\text{Increase in grain yield in kg ha}^{-1} \text{ x price of 1 kg grain}}{\text{price of 1 kg SSP x S added (kg ha}^{-1})}$$

RESULTS AND DISCUSSION

Direct Crop: Maize

Yield Attributes: The results of field experiments conducted are presented here under. The beneficial effect of added S influencing the length of cob and 100 seed weight of maize was observed in the present study with S 45 kg ha^{-1} and S 30 kg ha^{-1} recording on par values in both the locations (Table1). The increased seed weight and length of cob in the present experiments might be the cause of increased protein metabolism due to S application [3,9]. Whereas the plant height and leaf length of maize were not significantly influenced by S application in both the locations (Table1).

Yield: Increasing levels of S increased significantly the grain yield of maize from 6471 to 7271 kg ha^{-1} up to 30 kg ha^{-1} in LI and 6426 to 7531 kg ha^{-1} in LII. However there was no significant difference in yield between S 30 kg ha^{-1} and S 45 kg ha^{-1} in both the locations (Table1). The increase in grain yield owing to S addition could be attributed to the increased yield attributes like cob length and 100 seed weight. S fertilization also resulted in an increased uptake of nutrients viz., N,P,K and S, thus resulting in higher yield. The higher magnitude of grain yield response indicates greater contribution of S in grain production. The similar trend of increase in grain yield due to S addition was also established by many authors [13,4,15].

Stalk yield also followed the same trend as that of grain yield where the application of S increased the maize stalk yield from 10419 to11059 kg ha^{-1} up to 30 kg ha^{-1} in LII, whereas the highest stalk yield of 14562 was recorded by S @ 45 kg ha^{-1} in L1(Table1). The increase in stalk yield due to S fertilization was mainly because of the stimulatory effect of applied S in the synthesis of chloroplast and activation of ferridoxin photosynthetic process its involvement in metabolic processes and its role in protein and hormone synthesis[11,13]. S application increased harvest index due to conversion of photosynthates in to grain.

Table 1: Effect of sulphur application on yield parameters and yield of Maize

Treatments	Plant height (cm)	Leaf length (cm)	Length of cob (cm)	100 grain weight (g)	Grain Yield (kg ha^{-1})	% increase	Straw Yield (kg ha^{-1})	Harvest index	SUE %	ASR	VCR
Location I											
S0	2.88	70.6	15.2	31.2	6471	-	14077	31.49	-	-	-
S15	2.88	70.4	15.4	31.8	6779	4.75	14105	32.46	20.5	4.6	17.4
S30	2.90	71.2	16.2	32.1	7271	12.36	14536	33.34	26.6	5.2	22.7
S45	2.80	70.4	16.7	32.4	7247	11.99	14562	33.22	17.2	4.8	14.7
CD (0.5%)	NS	NS	0.938	NS	579		NS				
Location II											
S0	1.82	64.4	13.8	29.8	6426	-	10419	38.15	-	-	-
S15	1.83	64.2	14.2	30.6	6630	3.17	10465	38.78	13.6	3.3	11.6
S30	1.84	64.8	14.9	31.2	7509	16.85	11059	40.44	36.1	4.8	30.7
S45	1.84	65.3	15.1	31.5	7531	17.20	10996	40.64	24.5	4.2	20.9
CD (0.5%)	NS	NS	1.00	NS	769		NS				

Table 2: Effect of sulphur application on N, P and K uptake by maize

	LI (kg ha^{-1})			L II (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total
S uptake						
S0	3.94	9.59	13.53	3.95	6.33	10.28
S15	4.41	9.81	14.22	4.25	6.53	10.78
S30	4.80	10.30	15.10	4.72	6.99	11.71
S45	4.91	10.80	15.71	5.16	7.01	12.16
CD (0.5%)	0.495	0.801	0.798	0.486	NS	0.950
N uptake						
S0	69.4	139.5	208.9	67.7	102.8	170.5
S15	81.3	141.1	222.4	83.6	109.9	193.5
S30	95.1	149.9	245.0	89.7	112.0	201.7
S45	92.6	151.2	244.2	98.5	113.4	211.9
CD (0.5%)	14.04	NS	16.5	21.9	NS	
P uptake						
S0	22.3	32.9	55.2	20.7	23.2	43.9
S15	26.9	34.7	61.6	20.5	21.8	42.3
S30	29.6	36.6	66.2	25.4	22.6	48.0
S45	34.6	36.0	70.6	25.2	24.2	49.4
CD (0.5%)	6.95	NS	8.8	3.4	NS	
K uptake						
S0	43.5	171.3	214.8	57.4	120.7	178.1
S15	61.4	167.9	229.3	72.4	128.5	200.9
S30	66.7	171.6	238.3	76.6	130.8	207.4
S45	74.2	180.3	254.5	85.8	137.1	222.9
CD (0.5%)	12.0	NS	19.2	14.4	NS	

Nutrients Uptake: The uptake of S by maize grain and stalk increased significantly with increasing levels of S. This seems to be associated with increased S availability from applied S with a concomitant increase in S concentration and dry matter production[16,13,12,1] (Table2).

Increasing levels of S progressively enhanced the N uptake by maize from 208.9 to 244.2 kg ha^{-1}(Table3). Increase in N uptake may be attributed to increase in N concentration of plant and dry matter yield due to rising S levels. Such synergistic relationship between N and S has been reported by author[8]. Application of S progressively increased the total P uptake up to 45 kg ha^{-1} in both LI and LII which might be due to the S application induced better root development and beneficial effect on P uptake[4]. Similarly graded level of S significantly enhanced the total K uptake from 214.8 to 254.5 kg ha^{-1} in LI and 178.1 to 222.9 kg ha^{-1} in LII.

Response of S: The data on Sulphur Use Efficiency (SUE), Apparent Sulphur Recovery (ASR), Value Cost Ratio (VCR) are presented in Table1. SUE increased with increasing levels of S application up to 30 kg ha^{-1} and recorded maximum of 26.6 and 36.1 in LI and LII respectively. Crop response in terms of kg grain kg^{-1} S ranged from11.2 to 26.6 and 13.6 to 36.1 in LI and LII respectively. The greater apparent recovery of S (5.2, 4.8) was observed with S application @ 30 kg ha^{-1} there after it declines. Regarding VCR application of S @ 30 kg ha^{-1} gave the highest VCR of 22.7 and 30.7 in LI and LII respectively suggesting that S @ 30 kg ha^{-1} in the form of SSP was found to be optimum dose for recommendation to get increased yield of maize. Available S content in post harvest soil increased with S application and indicate the positive residual effect on subsequent crops.

Residual crop: Greengram: The results of the field experiments conducted with residual crop of green gram are presented here. The initial available S in the residual soil ranged from 8.5 to 24.0 and from 7.2 to 21.0 mg kg^{-1} in L I and L II respectively with concomitant increase with S application at 0, 15, 30 and 45 kg ha^{-1} in main crop of maize.

Table 3: Residual effect of sulphur application on yield parameters and yield of green gram

Treatments	Available S (Mg kg^{-1})	No of pods Plant^{-1}	No of grains pod	1000 grain weight	Grain yield (Kg ha^{-1})	% increase	Stover Yield (Kg ha^{-1})	Harvest index	SUE %	ASR	VCR
Location I											
S0	8.5	9.2	9.0	34.12	1002	-	1817	35.5	-	-	-
S15	17.5	11.2	9.6	35.42	1015	1.2	1811	35.9	0.87	1.3	6.19
S30	19.0	13.4	10.2	36.12	1045	4.3	1853	36.1	1.43	1.2	10.23
S45	24.0	14.2	8.6	36.24	1062	5.9	1865	36.3	1.33	0.7	9.52
CD (0.5%)		0.898	NS	1.56	20.80	-	NS	-	-	-	-
Location II											
S0	7.8	7.0	9.2	33.20	701	-	1542	31.3	-	-	-
S15	10.0	7.6	10.8	34.24	721	2.9	1559	31.6	1.33	0.6	9.52
S30	11.2	10.4	11.2	34.64	755	7.7	1671	31.1	1.80	0.9	12.85
S45	12.5	12.6	11.4	35.01	763	8.8	1672	31.3	1.40	0.7	9.84
CD (0.5%)		1.146	1.30	0.693	52.7	-	NS	-	-	-	-

Table 4: Residual effect of sulphur application on S, N, P and K uptake by green gram

	LI (Kg ha^{-1})			L II (Kg ha^{-1})		
	Grain	Stover	Total	Grain	Stover	Total
S Uptake						
S0	1.55	1.58	3.01	1.02	1.25	2.27
S15	1.61	1.60	3.21	1.05	1.31	2.36
S30	1.69	1.69	3.38	1.13	1.40	2.53
S45	1.71	1.60	3.31	1.14	1.43	2.57
CD (0.5%)	0.04	NS	0.10	0..04	0.14	0.19
N uptake						
S0	11.9	22.9	34.8	8.3	21.8	30.1
S15	12.3	22.9	35.2	8.6	22.5	31.1
S30	13.2	23.8	37.0	9.4	23.4	32.8
S45	13.3	24.1	37.4	9.2	23.7	32.9
CD (0.5%)	0.91	0.70	1.21	0.65	1.24	1.32
P uptake						
S0	2.60	3.70	6.30	2.02	3.90	5.92
S15	2.80	3.80	6.60	2.06	4.00	6.06
S30	2.90	3.90	6.80	2.20	4.10	6.30
S45	3.00	4.00	7.00	2.30	4.10	6.40
CD (0.5%)	NS	NS	NS	NS	NS	NS
K uptake						
S0	15.2	25.1	40.3	9.70	24.5	34.2
S15	15.8	24.8	40.6	9.80	24.5	34.3
S30	17.3	25.8	43.1	10.6	25.0	35.6
S45	17.3	25.9	43.2	10.7	25.2	35.9
CD (0.5%)	1.90	NS	2.14	0.72	NS	NS

The yield parameters viz., No of pods plant^{-1}, No of grains pod^{-1} and 1000 grain weight were favorably influenced by the residual S. This might be due to the important role of S in energy transformation, activation of enzymes and in carbohydrate metabolism[18].The residual effect of S significantly and positively affected the grain yield of green gram (Table 3). The highest grain and stover yield (1062, 1865 kg ha^{-1} (LI) and 763, 1672 kg ha^{-1} (LII)) were recorded in residual S @ 45 kg ha^{-1}. However it was statistically on par with residual S @ 30 kg ha^{-1} (1045, 1853 kg ha^{-1} (LI) and 755, 1671 kg ha^{-1} (LII)) while control recorded the lowest yield in both locations. An increase in grain yield of 1.2, 4.3, 5.9% and 2.9, 7.7, 8.8 % were recorded by 15, 30, 45 kg S ha^{-1} in L1 and LII respectively.

The S applied to the first crop still increased the grain and stover yield significantly in the residual crop of maize-greengram and groundnut-rice cropping sequence[14,8] which was in line with the present findings. Higher seed yield of green gram with residual S may be attributed to cumulative effect of increased yield attributes such as No of pods plant^{-1}, seeds pod^{-1} and 1000 grain weight[7].

As the level of S increased from 0- 45 kg ha^{-1} there was a significant and linear increase in uptake of S and recorded the highest value at S @ 30 kg ha^{-1} in both locations (Table 4). However there was no significant difference between 30 and 45 kg S ha^{-1}. S uptake by stover was higher as compared to that with S uptake by grains. The residual value of S significantly increased the S uptake by grain and stover might be due to increase S availability from applied S with a concomitant increase in crop yield and increased S concentration in plant and dry matter yield[13,15]. There was significant increase in uptake of N and K with increasing levels of residual S effect while the P uptake showed slight increase at non significant level. The highest SUE and VCR were found to be observed high in the treatment which received residual S @ 30 kg ha^{-1} followed by residual S @ 45 kg ha^{-1}.

The highest SUE, ASR and VCR were found to be observed high in the treatment which received residual S @ 30 kg ha^{-1} suggesting that 30 kg S ha^{-1} in the form of SSP is optimum dose for maize and to get better residual effect on green gram.

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