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Effect of Different Sources and Levels of Sulphur under Irrigated Condition in Maize

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Authors' contributions

This work was carried out in collaboration between all authors. Author RKS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BNAK and MPP managed the analyses of the study. Author AMP managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Maize has a greater significance in irrigated condition and is used as human food and animal feed. In recent years, it is being realised that apart from the major nutrients, the role of secondary nutrients in general and sulphur in particular in increasing yield and quality of maize is of paramount importance. A field experiment was conducted during *rabi* season of 2011 at Saidapur farm, University of Agricultural Sciences, Dharwad, India to evaluate the response of maize to different sources and levels of sulphur in sandy clay loam soil. The results revealed that grain yield differed significantly due to different sources and levels of sulphur applied. Among the sources, application of sulphur through Bentonite recorded significantly higher grain yield (42.35 q ha^{-1}) as against gypsum (38.98 q ha^{-1}). This increase in grain yield was 31.60 and 21.3% with the application of bentonite and gypsum, respectively compared to control. With respect to levels, increasing levels of sulphur significantly increased the grain yield of maize from 33.02 to 48.56 q ha^{-1} with rise in sulphur level of 10 to 50 kg ha^{-1}. Among the treatment combinations 50 kg S ha^{-1} through Bentonite recorded significantly higher grain yield of 48.56 q ha^{-1} compared to other treatment combinations

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but was on par with treatment receiving 40 kg S ha^{-1} through Bentonite (45.64 q ha^{-1}). The lowest yield was recorded under control (32.18 q ha^{-1}). A similar trend was followed for growth and yield parameters.

Keywords: Maize; sulphur; bentonite; gypsum; growth and yield parameters.

1. INTRODUCTION

Maize is known as "Queen of cereals" because of its high production potential and is one of the important food grains extensively grown worldwide and also as a source of raw material for manufacturing of several products such as corn sugar, cornflakes, corn oil and corn protein [1]. Among several factors responsible for crop production, nutrients play an important role. In recent years it is being realised that apart from the major nutrients, the role of secondary nutrients in general and sulphur in particular in increasing cereal production is well established [2,3]. The newly evolved high yielding hybrids and varieties of maize are more fertiliser responsive, accelerated the depletion of sulphur reserves in the soil, even from lower soil depths. In one of the study conducted by Saalbach [4] reported yield loss in maize to an extent of 10 to 30% due to sulphur deficiency. Several factors contributing to sulphur deficiencies were reported by many researchers include, the increased use of sulphur free high analysis fertilisers [5,6] and less use of sulphur containing pesticides along with multiple and high intensive cropping [7], leaching and erosion [8], restricted use of organic manures [9] and removal of crop residues for feed and fuel.

Sulphur plays a vital role in the primary metabolism of higher plants and involved in synthesis of secondary metabolic products in certain group of plants. It ranks along with nitrogen and phosphorus in importance in the formation of proteins. It not only influences yield but also improves crop quality owing to its influence on protein metabolism and oil synthesis [10]. It is involved in the synthesis of the essential amino acids like cysteine, cystine and methionine [11]. Sulphur application at 20 kg per hectare with sulphur oxidising biofertiliser proved beneficial for improving quality parameters in sunflower [12]. It improves crop management through its favorable effect on environmental stress, resistance against pest and diseases [13]. Apart from increasing the crude protein content of fodders, Sulphur reduces the nitrate levels in forages and improves their quality. The critical challenge ahead for agricultural scientists in the country is to optimise the sulphur availability in cropping systems, synchronising plant demand for sulphur in the required form and quantity. Hence, this study was undertaken to evaluate the response of maize to different sources and levels of sulphur under irrigated condition.

2. MATERIALS AND METHODS

A field experiment was conducted during *rabi* season of 2011 at Saidapur farm, University of Agricultural Sciences, Dharwad, India. The experiment was laid out in a randomised complete block design (RCBD) with factorial concept in three replications (Plate 1). Treatments comprised two sources of sulphur (i) Gypsum (ii) Bentonite pastilles and their five levels (10, 20, 30, 40 and 50 kg S ha^{-1}) and a control treatment without sulphur. Prior to conducting an experiment, sandy clay loam soil with deficient in available sulphur (<10 ppm) was chosen to assess the true response of maize to sulphur application. All treatments included the

Plate 1. General view of experimental unit

recommended dose of fertiliser at the rate of 150:75:37.5 kg N, P_2O_5 and K_2O ha^{-1}, respectively. The genotype Arjun (EH-434042) a three way cross hybrid was used for experiment. Package of practices recommended for crop management for Dharwad region were followed. Available sulphur content in soil was determined by extracting with 0.15% CaCl2 and the released SO4 ion in solution was estimated by turbidometric method using spectrophotometer outlined by (Chesnin and Yien, 1950). The data collected from the experiment were subjected to statistical analysis as prescribed by Gomez and Gomez (1984). The level of significance used in 'F' and 't' tests was P = 0.05, critical difference (CD) values were calculated wherever the 'F' test was significant.

3. RESULTS AND DISCUSSION

The data on effect of different sources and levels of sulphur on yield attributes, grain and stover yield along with economics of maize in *rabi* 2011 are presented in the Tables 1 and 2. Among the sources, application of Bentonite recorded significantly higher grain yield of maize (42.35 q ha^{-1}) over Gypsum (38.98 q ha^{-1}). This increase in grain yield was 31.60 and 21.13% with Bentonite and Gypsum application, respectively over control (32.18 q ha^{-1}). The increase in grain yield of maize with application of sulphur through Bentonite has also been reported by Bhagyalaxmi et al. [14]. In one of the study, Jena and Kabi [15] noticed increase in rice yield with Bentonite application. The increase in grain yield owing to sulphur application through Bentonite might be due to its higher concentration, minimum leaching loss and slow release of sulphur into soil solution to match the required absorption pattern of maize [15]. Further, the available sulphur status of the experimental field was low (6.4 ppm), application of sulphur might have improved the nutritional environment of rhizophere as well as plant system. Application of graded levels of sulphur had significant influence on grain yield of maize. Increasing levels of sulphur significantly increased the grain yield of maize from 33.02 to 48.56 q ha^{-1} with rise in sulphur level of 10 to 50 kg ha^{-1}. Significantly higher grain yield of 48.56 q ha^{-1} was recorded with application of sulphur at 50 kg ha^{-1} followed by 40 kg ha^{-1} (45.64 q ha^{-1}). The lowest grain yield was recorded under control (32.18 q ha^{-1}). Application of higher dose of sulphur (50 kg ha^{-1}) might have reduced the latent sulphur deficiency by enhanced availability of sulphur which in turn increases the uptake of nitrogen, phosphorous and potassium and ultimately yield. Similar results have also been reported previously by Dhananjaya [16], Singh and Singh [17], Mehta et al. [18], Maurya et al. [19] in maize. Among interaction effects, application of 50 kg S ha^{-1} through Bentonite pastilles recorded significantly higher grain yield (51.98 q ha^{-1}) over other treatments but was on par with application of 40 kg S ha^{-1} through Bentonite (49.57 q ha^{-1}). Stover yield followed the similar trend.

Table 1. Effect of sources and levels of sulphur on growth and yield parameters of maize

Treatment	Leaf area (cm^2)	LAI	DM production (g plant^{-1})	Cob length (cm)	No. of grains cob^{-1}	100 grain weight (g)	Grain weight cob^{-1}
			Sources of sulphur				
S_1 (G)	3244.64	2.70	251.34	15.54	384.33	29.29	123.87
S_2 (B)	3443.19	2.87	259.24	16.51	413.03	30.38	128.15
S.Em.±	16.65	0.01	0.75	0.07	2.73	0.10	0.25
C.D. (0.05)	49.46	0.04	2.22	0.22	8.12	0.30	0.75
			Levels of sulphur (kg ha^{-1})				
L_1(10)	2564.13	2.14	244.47	15.12	359.72	26.69	118.46
L_2(20)	2870.08	2.39	249.32	15.62	377.57	28.59	121.59
L_3(30)	3327.59	2.77	255.39	16.05	387.62	30.17	124.21
L_4(40)	3496.79	2.91	260.30	16.48	427.87	31.03	130.41
L_5(50)	4460.81	3.72	266.99	16.86	440.62	32.69	135.38
S.Em.±	41.62	0.03	1.87	0.18	6.83	0.25	0.63
C.D. (0.05)	123.66	0.10	5.55	0.55	20.29	0.74	1.86
			Interaction effect				
S_1L_1	2488.35	2.07	241.80	14.74	346.90	27.18	118.23
S_1L_2	2815.09	2.35	245.99	15.28	369.87	28.55	121.77
S_1L_3	3226.20	2.69	251.94	15.76	382.20	28.79	123.98
S_1L_4	3471.19	2.89	255.65	15.69	404.10	29.10	127.04
S_1L_5	4222.39	3.52	261.33	16.22	418.57	32.84	128.31
S_2L_1	2639.90	2.20	247.13	15.50	372.53	26.20	118.69
S_2L_2	2925.08	2.44	252.65	15.96	385.27	28.63	121.41

Treatment	Leaf area (cm^2)	LAI	DM production (g $plant^{-1}$)	Cob length (cm)	No. of grains cob^{-1}	100 grain weight (g)	Grain weight cob^{-1}
S_2L_3	3428.98	2.86	258.84	16.34	393.03	31.56	124.44
S_2L_4	3522.79	2.94	264.96	17.27	451.63	32.97	133.78
S_2L_5	4699.22	3.92	272.65	17.50	462.67	32.53	142.44
S.Em.±	83.24	0.07	3.74	0.36	13.66	0.50	1.26
C.D. (0.05)	NS	NS	NS	NS	NS	1.48	3.73
Treatment X control							
Treatment	3343.19	2.79	255.29	16.06	398.68	29.83	126.01
Control	2140.30	1.78	218.19	13.33	263.27	24.65	113.4
S.Em.±	277.19	0.23	12.45	1.21	45.48	1.65	4.18
C.D. (0.05)	823.59	0.69	36.99	3.67	135.13	4.92	12.42

Note: Control: Without sulphur; S1(G): Gypsum; S2(B):Bentonite; L – Levels of sulphur

Table 2. Effect of sources and levels of sulphur on yield and economics of maize

Treatment	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
Sources of sulphur				
S_1 (G)	38.98	44.39	19515	1.83
S_2 (B)	42.35	48.11	22802	1.95
SEm±	0.17	0.28	185	0.01
CD (0.05)	0.50	0.83	550	0.02
Levels of sulphur (kg ha^{-1})				
L_1(10)	33.02	36.49	13307	1.58
L_2(20)	35.93	41.21	16222	1.70
L_3(30)	40.19	46.36	20631	1.87
L_4(40)	45.64	51.81	26351	2.10
L_5(50)	48.56	55.39	29281	2.21
SEm±	0.42	0.69	463	0.02
CD (0.05)	1.25	2.06	1376	0.06
Interaction effect				
S_1L_1	33.13	35.25	13515	1.59
S_1L_2	35.62	39.73	16032	1.69
S_1L_3	39.13	44.55	19680	1.84
S_1L_4	41.71	49.19	22294	1.95
S_1L_5	45.33	53.25	26056	2.09
S_2L_1	32.91	37.74	13099	1.57
S_2L_2	36.24	42.69	16412	1.70
S_2L_3	41.25	48.18	21583	1.91
S_2L_4	49.57	54.44	30408	2.26
S_2L_5	51.78	57.53	32506	2.33
SEm±	0.84	1.39	926	0.04
CD (0.05)	2.50	NS	2752	0.10
Treatment X control				
Treatment	40.67	46.25	21158	1.89
Control	32.18	32.45	12596	1.55
SEm±	2.80	4.63	2997	0.13
CD (0.05)	8.33	13.74	8332	0.29

Note: Control: Without sulphur; S1(G): Gypsum; S2(B):Bentonite; L – Levels of sulphur

Further, the differences in yield can be attributed to variation in yield components (Fig. 2 and Plate 2). Application of sulphur through Bentonite might have promoted the uptake and translocation of food assimilated from source to sink effectively, resulting in higher yield attributes *viz*., cob length (16.51 cm), number of grains cob^{-1} (413.03), 100 grain weight (30.38 g) and grain weight cob^{-1} (128.15 g) leading to higher grain yield (Table 1). Among sulphur levels, 50 kg S ha^{-1} recorded significantly higher number of grains cob^{-1} (440.62), 100 grain weight (32.69 g) and grain weight cob^{-1} (135.38 g) compared to preceding levels. These results are in conformity with the findings of Shrinivasrao et al. Sinha et al. [20,21] who reported an increase in cob length and 100 grain weight with the application of higher level of sulphur. Yield attributes and yield also indirectly depends on growth attributes. In present investigation, significantly higher leaf area (3443.19 cm^2), leaf area index (2.87), dry matter production (259.24 g $plant^{-1}$) at harvest was observed with application of Bentonite compared to Gypsum. Among sulphur levels, significantly higher leaf area (4460.81 cm^2), leaf area index (3.72), dry matter production (266.99 g $plant^{-1}$) at harvest was observed with 50 kg S ha^{-1} compared to preceding levels.

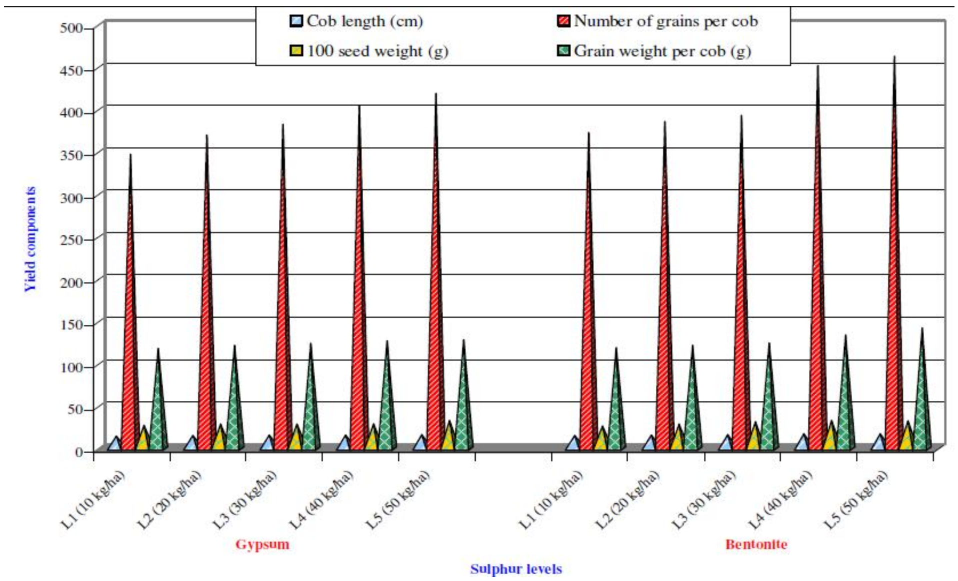

Fig. 2. Effect of different sources and graded levels of sulphur on yield components of maize

Plant height at 90 DAS

Cob length of maize

Plate 2. Effect of different sources and levels of sulphur on plant height at 90 DAS and cob length of maize

Significantly higher net return and B:C ratio (Rs. 32,506 ha^{-1} and 2.33) was realised with application of 50 kg S ha^{-1} through Bentonite compared to other treatment combinations but was on par with treatment receiving 40 kg S ha^{-1} through Bentonite (Rs. 30,408 ha^{-1} and 2.26). Lower net returns Rs.12596 ha^{-1} and B: C ratio of 1.55 was realised under control.

4. CONCLUSION

The critical challenge ahead for agricultural scientists in the country is to optimise the sulphur availability in cropping systems, synchronising plant demand for sulphur in the required form and quantity. It could be concluded that application of 40 kg S ha^{-1} through Bentonite was found to be economical dose for maize under irrigated condition to achieve higher grain yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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