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Effect of different sources and levels of sulphur on growth parameters of sunflower (*Helianthus annus* L.)

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Abstract
A field experiment conducted on sunflower during *kharif* of 2016 in vertisol under rainfed condition at Main Agriculture Research Station, Raichur revealed that Among the different sources of sulphur, significantly higher plant height (184.10 and 185.66 cm) and number of leaves (22.37 and 17.68) was observed with ammonium sulphate as a source of sulphur at 60 DAS and at harvest over other sources of sulphur. Among different levels of sulphur significantly higher plant height and number of leaves were recorded with 45 kg S ha^{-1} (L_3) at 30, 60 DAS and at harvest. At 60 DAS, among various sources of sulphur, application of ammonium sulphate (102.97 g) recorded significantly higher dry matter compared to gypsum (95.17g) and elemental sulphur (89.73 g) but statistically on par with SSP (99.78 g). At harvest, similar trend was observed as followed at 60 DAS.

Keywords: Sunflower, plant height, number of leaves, dry matter

Introduction

Oil seed crops play a vital role in Indian agriculture as food for human and animals. Sunflower being one of the important edible oil crop in the world next to soybean, holds great promise because of its short duration (90-100 days), high seed multiplication ratio, wider adaptability, photo-insensitive, higher water use efficiency and drought tolerance. Presently in India, sunflower is cultivated in an area of 0.69 m. ha with a production of 0.55 m. t with an average productivity of 791 kg ha^{-1}. In India, sunflower cultivation is progressively picking up especially in *rabi* and summer seasons. In recent times, the yield potential of the crop is reduced due to little amounts of organic manures used, poor recycling of crop residues, wide spread secondary and micronutrient deficiencies and insufficient use of sulphur containing fertilizers. Sulphur is considered as quality nutrient as its application not only influences crop yield but also improves crop quality owing to its influence on protein metabolism, oil synthesis and formation of amino acids (Krishnamoorthy, 1989) [1]. It is a constituent of three amino acids *viz.* Methionin (21% S), Cysteine (26% S) and Cystine (27% S), which are the building blocks of protein. About 90% of plant sulphur is present in these amino acids. Sulphur is also involved in the formation of chlorophyll, glucosides and glucosinolates (mustard oils), activation of enzymes and sulphydryl (SH-) linkages that are the sources of pungency in onion, oils, *etc*. (Ghosh, 2002) [2]. Sulphur is a mobile element which is easily lost from the soil through leaching. The level of available sulphur reaches below the critical limit and sunflower is bound to suffer sulphur deficiency.

Material and Methods

The experiment was conducted at Main Agriculture Research Station, Raichur during *kharif* 2016-17.The field experiment was laid out in factorial RBD design and replicated thrice with twelve treatments comprised of 3 sulphur levels, *i.e*. 15, 30 and 45 kg S ha^{-1} supplied through 4 sources, *i.e*. elemental sulphur, gypsum, ammonium sulphate and SSP was tested on sunflower hybrid ‘KBSH-44’.

Five plants were selected randomly from net plot and tagged for recording growth attributes throughout crop growth period. Plant height was measured from the ground level up to the base of node which the first fully opened leaf from the top was borne at flowering and at harvest and expressed in centimetres. Total number of fully opened trifoliate leaves was counted in the five plants and average was taken as number of leaves per plant. Plant samples for dry matter studies were collected at 30 DAS, 60 DAS and at harvest of crop. At each sampling, five plants were uprooted at random in each treatment and partitioned into leaf, stem and reproductive parts. These samples were oven dried at 70º C in a hot air oven for 72 hours till a constant weight. The dry weight of different plant parts was recorded; the dry matter production per plant was obtained with the summation of dry weight of all plant parts and was expressed in g plant^{-1}.

Results and Discussion

Plant height (cm)

Experimental data on effect of different sources and levels of sulphur on plant height of sunflower was analysed statistically and presented in the Table 1.

Among different sources of sulphur, significantly higher plant height (184.10 and 185.66 cm) was observed with ammonium sulphate (S_1) as a source of sulphur at 60 DAS and at harvest over other sources of sulphur *viz*., SSP (S_4), gypsum (S_2) and elemental sulphur (S_1). However, sulphur sources did not show significant influence on plant height at 30 DAS.

Increase in plant height due to ammonium sulphate might be attributed to the supply of sulphur is more readily available form than the other sources like SSP, gypsum and elemental sulphur. This would have increased the metabolic processes in the plants and promoted the meristamatic activities causing apical growth and resulted in increased plant height (Intodia and Tomar, 1997) [3]. Improvement in plant growth could partly be attributed to the beneficial effect of sulphur fertilization as nutrient (Tandon, 1989) [4]. Superiority of ammonium sulphate over the other sources such as gypsum and SSP in respect to plant height was observed in in sunflower (Sreemannarayana *et al*., 1994) [5].

Different levels of sulphur showed significant influence on plant height of sunflower at all the growth stages. Among different levels of sulphur significantly higher plant height (68.09, 188.07 and 187.04 cm) was recorded with 45 kg S ha^{-1} (L_3) at 30, 60 DAS and at harvest and significantly superior to 30 kg S ha^{-1} (L_2) and 15 kg S ha^{-1} (L_1). The plant height increased with increasing sulphur level from 15 kg S ha^{-1} (L_1) to 45 kg S ha^{-1} (L_3).The interaction effect of different sources and levels of sulphur was found to be non significant with respect to plant height of sunflower at all the growth stages.

Better growth and development of sunflower plants due to higher levels of sulphur dose would have been due to multiple role of sulphur in protein and carbohydrate metabolism of plants by activating a number of enzymes which participate in dark reaction of photosynthesis and hence increases the plant height by higher dose of sulphur application. The crop receiving higher dose of sulphur might have been helped in terms of vigorous root growth, formation of chlorophyll, resulting in higher photosynthesis (Ravi *et al*., 2010) [6]. Increase in plant height may be due to better nutritional environment for plant growth at active vegetative stages as a result of improvement in root growth, cell multiplication, elongation and cell expression in the plant body (Steffenson, 1954) [7], which ultimately increased the plant height.

Number of leaves

Experimental data on number of leaves per plant influenced by sulphur sources and levels was analyzed statistically and presented in the Table 2.

Experimental data on sulphur sources showed significant influence on number of leaves per plant at all the growth stages except at 30 DAS. Significantly higher number of leaves were recorded at 60 DAS and thereafter declined at harvest stage. Among the different sources of sulphur significantly higher number of leaves plant^{-1} (22.37 and 17.68) was recorded with application of sulphur through ammonium sulphate (S_3) at 60 DAS and at harvest compared to SSP (S_4), gypsum (S_2) and elemental sulphur (S_1) and however, it was statistically on par with SSP and gypsum.

Differences in number of leaves per plant at all the stages of growth were significant due to different levels of sulphur. Number of leaves plant^{-1} increased with increasing levels of sulphur up to 45 kg S ha^{-1} at all the stages of growth. However significantly higher number of leaves plant^{-1} (19.59, 23.89 and 18.66) was recorded with 45 kg S ha^{-1} (L_3) at all the growth stages of crop. There was no significant difference noticed with the interaction effect between different sources and levels of sulphur on number of leaves plant^{-1} at all the growth stages.

The increased number of leaves due to ammonium sulphate might be attributed to the supply of sulphur which enhances cell division, cell elongation or expansion and chlorophyll synthesis. It is also important in the activity of meristematic tissues and development of shoots. Thus in adequate supply of sulphur, it will be expected that plants grow taller with more number of leaves having bigger size and higher chlorophyll content.

Differences in number of leaves per plant at all the stages of growth were significant due to different levels of sulphur. Leaf number increased up to 60 days and declined progressively later because of senescence and leaf fall. Application of 45 kg S ha^{-1} (L_3) recorded significantly higher number of leaves per plant. Number of leaves per plant increased with increasing levels of sulphur up to 45 kg S ha^{-1} at all the stages of growth possibly due to better growth environment leading to increased number of leaves. Also, higher leaf number indicates high mobilizable protein at the beginning of reproductive stage which helps the crop to put forth higher production as indicated by Boote *et al*. (1985) [8].

Dry matter production (g plant^{-1})

Data pertaining to sulphur sources and levels on dry matter production in different parts of plant at different growth stages was analysed statistically and presented in Table 3, 4 and 5.

The data on dry matter production in different parts of the plant of sunflower indicated significant variations due to sources of sulphur at all the growth stages except at 30 DAS. At 60 DAS, among various sources of sulphur, application of ammonium sulphate (102.97 g) recorded significantly higher dry matter compared to gypsum (95.17 g) and elemental sulphur (89.73 g) but statistically on par with SSP (99.78 g). At harvest, similar trend was observed as followed at 60 DAS. Ammonium sulphate recorded significantly higher dry matter plant^{-1} (138.93 g) compared to other sources of sulphur (130.85 and 123.38 g for gypsum and elemental sulphur) and however it was on par with SSP (135.15 g). At 30 DAS higher dry matter was accumulated in stem compared to leaves. Whereas at 60 DAS and at harvest, more dry matter was accumulated in stem followed by head as compared to leaves.

The data on dry matter production plant^{-1} of sunflower indicated significant variations due to different levels of sulphur at all the growth stages. At 30 DAS, significantly higher total dry matter production was recorded with 45 kg S ha^{-1} (30.84 g) compared to 30 kg S ha^{-1} (27.38 g) and 15 kg S ha^{-1} (24.81 g). At 60 DAS irrespective of sources, application of 45 kg S ha^{-1} produced significantly higher dry matter plant^{-1} (110.68 g) and however, there was no significant differences with the application of 15 and 30 kg S ha^{-1} (81.43 and 98.63 g plant^{-1}, respectively). At harvest among the levels of sulphur, significantly higher dry matter production plant^{-1} was observed in the treatment receiving 45 kg S ha^{-1}(146.61 g) followed by 30 kg S ha^{-1} (134.87 g) and 15 kg S ha^{-1} (114.74 g). Interaction effect between different sources and levels of sulphur failed to reach the level of significance with respect to dry matter production plant^{-1} of sunflower at all the growth stages.

The significant improvement in dry matter production might have resulted from better sulphur nutrition of crop. Ammonium sulphate proved the most efficient source of sulphur for correcting sulphur deficiency in a standing crop as reported by Arora *et al*. (1983) [9]. The dry matter production increased continuously up to maturity. The process of dry matter accumulation in sunflower was continuous due to its genetic ability to absorb inorganic materials for synthesizing carbohydrates until it matures (Sarkar *et al*., 1998) [10]. Application of sulphur significantly affected the dry matter accumulation in plants. At all the growth stages irrespective of sources, application of 45 kg S ha^{-1} produced significantly higher dry matter plant^{-1} and however, there were no significant differences with the application of 15 and 30 kg S ha^{-1}. Application of sulphur significantly increased the N uptake, stimulated the photosynthetic activity and synthesis of chloroplast protein which might have resulted in higher dry matter production (Reddy and Reddy, 2001) [11]. The increase in total dry matter with application of sulphur could be due to the release of sulphate ions immediately into the soil solution resulting in better availability and absorption of sulphur and resulted in vigorous crop growth and production of higher dry matter by the plant (Vishwanath *et al*., 2006) [12].

Table 1: Effect of different sources and levels of sulphur on plant height (cm) of sunflower at different growth stages

Treatments	30 DAS	60 DAS	Harvest
Sulphur sources			
S_1 – Elemental sulphur	63.49	175.75	177.20
S_2 – Gypsum	64.66	176.99	178.48
S_3 – Ammonium sulphate	66.13	184.10	185.66
S_4 – Single super phosphate	64.82	181.57	182.96
S.Em±	0.83	2.20	2.23
CD (P=0.05)	NS	6.46	6.54
Sulphur levels (kg S ha^{-1})			
L_1 – 15 kg ha^{-1}	61.20	172.75	175.86
L_2 – 30 kg ha^{-1}	65.03	177.99	180.32
L_3 – 45 kg ha^{-1}	68.09	188.07	187.04
S.Em ±	0.72	1.90	1.93
CD (P=0.05)	2.11	5.60	5.66
Interaction (S x L)			
S.Em ±	1.44	3.81	3.86
CD (P=0.05)	NS	NS	NS

DAS - Days after sowing, NS - Non significant

Table 2: Effect of different sources and levels of sulphur on number of leaves of sunflower at different growth stages

Treatments	30 DAS	60 DAS	Harvest
Sulphur sources			
S_1 – Elemental sulphur	17.49	20.28	16.49
S_2 – Gypsum	17.94	21.14	17.14
S_3 – Ammonium sulphate	18.37	22.37	17.68
S_4 – Single super phosphate	18.14	21.74	17.36
S.Em±	0.37	0.50	0.28
CD (P=0.05)	NS	1.47	0.83
Sulphur levels (kg S ha^{-1})			
L_1 – 15 kg ha^{-1}	15.73	19.16	15.34
L_2 – 30 kg ha^{-1}	18.64	21.10	17.50
L_3 – 45 kg ha^{-1}	19.59	23.89	18.66
S.Em ±	0.32	0.43	0.24
CD (P=0.05)	0.94	1.27	0.72
Interaction (S x L)			
S.Em ±	1.44	0.86	0.49
CD (P=0.05)	NS	NS	NS

DAS - Days after sowing, NS - Non significant

Table 3: Effect of different sources and levels of sulphur on dry matter production (g $plant^{-1}$) in different parts of sunflower at 30 DAS

Treatments	Leaf weight	Stem weight	Total weight
Sulphur sources			
S_1 – Elemental sulphur	10.81	16.07	26.88
S_2 – Gypsum	11.02	16.39	27.41
S_3 – Ammonium sulphate	11.63	16.76	28.39
S_4 – Single super phosphate	11.38	16.64	28.02
S.Em±	0.23	0.35	0.4
CD (P=0.05)	NS	NS	NS
Sulphur levels (kg S ha^{-1})			
L_1 – 15 kg ha^{-1}	9.68	15.13	24.81
L_2 – 30 kg ha^{-1}	11.16	16.22	27.38
L_3 – 45 kg ha^{-1}	12.80	18.04	30.84
S.Em ±	0.2	0.30	0.34
CD (P=0.05)	0.58	0.9	1.01
Interaction (S x L)			
S.Em ±	0.4	0.60	0.7
CD (P=0.05)	NS	NS	NS

DAS - Days after sowing, NS - Non significant

Table 4: Effect of different sources and levels of sulphur on dry matter production (g $plant^{-1}$) in different parts of sunflower at 60 DAS

Treatments	Leaf weight	Stem weight	Head weight	Total weight
Sulphur sources				
S_1 – Elemental sulphur	15.50	44.67	29.57	89.73
S_2 – Gypsum	15.77	48.07	31.34	95.17
S_3 – Ammonium sulphate	16.56	51.21	35.21	102.97
S_4 – Single super phosphate	16.24	50.00	33.54	99.78
S.Em±	0.15	0.95	0.86	1.7
CD (P=0.05)	0.43	2.80	2.52	4.96
Sulphur levels (kg S ha^{-1})				
L_1 – 15 kg ha^{-1}	14.86	41.76	24.82	81.43
L_2 – 30 kg ha^{-1}	15.90	49.17	33.55	98.63
L_3 – 45 kg ha^{-1}	17.29	54.53	38.86	110.68
S.Em ±	0.13	0.82	0.74	1.46
CD (P=0.05)	0.38	2.42	2.18	4.30
Interaction (S x L)				
S.Em ±	0.25	1.65	1.5	2.93
CD (P=0.05)	NS	NS	NS	NS

DAS - Days after sowing, NS - Non significant

Table 5: Effect of different sources and levels of sulphur on dry matter production (g $plant^{-1}$) in different parts of sunflower after harvest

Treatments	Leaf weight	Stem weight	Head weight	Total weight
Sulphur sources				
S_1 – Elemental sulphur	15.33	55.03	53.01	123.38
S_2 – Gypsum	15.52	58.99	56.34	130.85
S_3 – Ammonium sulphate	16.31	62.41	60.21	138.93
S_4 – Single super phosphate	15.97	60.65	58.54	135.15
S.Em±	0.14	1.13	1.20	2.31
CD (P=0.05)	0.42	3.31	3.53	6.80
Sulphur levels (kg S ha^{-1})				
L_1 – 15 kg ha^{-1}	14.61	51.48	48.65	114.74
L_2 – 30 kg ha^{-1}	15.68	60.64	58.55	134.87
L_3 – 45 kg ha^{-1}	17.07	65.69	63.86	146.61
S.Em ±	0.12	0.98	1.04	2.0
CD (P=0.05)	0.36	2.87	3.06	5.9
Interaction (S x L)				
S.Em ±	0.25	1.95	2.08	4.01
CD (P=0.05)	NS	NS	NS	NS

DAS - Days after sowing, NS - Non significant

Conclusion

From the results of the present study, it can be concluded that there was significant response of sulphur fertilization on sunflower crop. Application of S through ammonium sulphate at the level of 45 kg ha^{-1} could be the best source of sulphur as compared to SSP, gypsum and elemental sulphur for enhancing the growth.

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