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Nirmala Patel
Department of Agronomy, School of Agriculture, GIET University, Gunupur, Odisha, India

Debasmita Das
Department of Agronomy, School of Agriculture, GIET University, Gunupur, Odisha, India

Priyatam Sidharth
Department of Agronomy, School of Agriculture, GIET University, Gunupur, Odisha, India

SP Rani
Department of Agronomy, School of Agriculture, GIET University, Gunupur, Odisha, India

S Tripathy
Department of Agronomy, School of Agriculture, GIET University, Gunupur, Odisha, India

B Lodh
Department of Agronomy, School of Agriculture, GIET University, Gunupur, Odisha, India

Sumana Balo
Department Soil Science and Agricultural Chemistry, School of Agriculture, GIET University, Gunupur, Odisha, India

Corresponding Author:
Debasmita Das
Department of Agronomy, School of Agriculture, GIET University, Gunupur, Odisha, India

Response of various sources of sulphur on growth and yield of sunflower (*Helianthus annuus* L.)

Nirmala Patel, Debasmita Das, Priyatam Sidharth, SP Rani, S Tripathy, B Lodh and Sumana Balo

Abstract
A field experimentation was conducted during rabi season, 2020-21 at Instructional farm, School of Agriculture, GIET University, Gunupur, Odisha, to analyze the impact of various sources of sulphur on growth parameters and yield of sunflower under red and lateritic soils of Odisha. The experiment design was Randomized Block Design (RDB) and replicated thrice with seven treatments *i.e.* T_1 - Control, T_2 - 20 kg sulphur/ha through ammonium sulphate, T_3 -20 kg sulphur/ha through elemental sulphur, T_4 - 20 kg sulphur/ha through gypsum, T_5 -20 kg sulphur/ha through ammonium sulphate +20 kg sulphur/ha through elemental sulphur, T_6 -20 kg sulphur/ha through elemental sulphur + 20 kg sulphur/ha through gypsum, T_7 -20 kg sulphur/ha through gypsum + 20 kg sulphur/ha through ammonium sulphate. The outcome revealed that combined application of 20 kg sulphur/ha through gypsum and 20 kg sulphur/ha through ammonium sulphate (T_7) recorded higher growth attributes and yield of sunflower over other treatments.

Keywords: Sulphur, oil yield, growth, sunflower, ammonium sulphate

Introduction
Oilseeds have become a vital component of human nutrition and a source of valuable raw resources for agricultural enterprises. Sunflower (*Helianthus annuus* L.) is a short duration, ideal catch crop, photo-insensitive, drought and saline tolerant crop, so it is widely adapted in different agro-climatic regions. It is an important source of vegetable oil from the family Asteraceae (Darqui *et al*., 2021) [5]. It is the fourth largest oilseed crop across the world (Ahmad *et al*., 2020) [1]. In world, the area of cultivation and production of sunflower is 22.81 Mha and 60.5 million tones respectively (FAO, 2019) [6]. In India the area of cultivation of sunflower is 0.28 Mha with a production of 0.25 Mt and productivity of 0.91 t/ha (Annonymous. 2022) [2].
Among different edible oil, sunflower oil is considered best for heart patients as it contains high value of linoleic acid and it reduces cholesterol deposition in the coronary arteries of the heart. As sunflower is a day neutral crop, it can be grown in any season of the year. Due to sub optimal soil fertility, the yields obtained is very low. To fulfill the current needs of increasing population, it is essential to increase the productivity of sunflower. This can be achieved by proper nutrient management (Maitra *et al*., 2020) [10].
Sulphur ranked as fourth important nutrient for oilseed crops after N, P and K (Jamal *et al*., 2011) [8]. Outcomes from 12 Indian states co-operative study showed that out of total arable soil 30 to 35 percent were deficient in Sulphur (Morris, 2006) [11]. Its deficiency is spotted due to higher rate of removal of sulphur by crops, and limited use of fertilizers that contained sulphur. Application of sulphur helps in increasing protein content and oil percentage in seeds. Its application also improves soil properties and enhance the availability of other macro and micro nutrients in soil due to synergistic effect (Roy *et al*. 2020) [15]. It also improves nitrogen use efficiency and phosphorus use efficiency. ‘Sulphur deficiency have been reported in most of the countries. Considering the above points, a field experimentation was planned to observe its effects on growth parameters and yield of sunflower crop.

Materials and Methods
A field experimentation, “Response of various sulphur sources on growth parameters and yield of Sunflower (*Helianthus annuus* L.) " was conducted in Research plot (Agronomy) of the IF-1(Instructional Farm), School of Agriculture, GIETU, Gunupur during *rabi* season of 2020-21 to study the effect of sulphur on growth and yield of *rabi* sunflower.

The design of experiment was RBD with seven treatments and three replications. The net plot size was 5 m x 4 m. The fertilizers were applied considering 80:40:40 kg of N: P_2O_5: K_2O per ha as recommended dose as urea, SSP and MOP, respectively. The experimental site was sandy to clay loam in texture and having pH 6.1 which is medium acidic in nature. Sunflower seed were sown by following 60cm X 20 cm spacing on16th October 2020. The sunflower variety used was MSFH-17. The treatments considered of T_1 = Control, T2 = 20 kg sulphur/ha through ammonium sulphate, T_3 = 20 kg sulphur/ha through elemental sulphur , T_4 = 20 kg sulphur/ha through gypsum, T_5 = 20 kg sulphur/ha through ammonium sulphate + 20 kg sulphur /ha through elemental sulphur, T_6 = 20 kg sulphur/ha through elemental sulphur + 20 kg sulphur/ha through gypsum, T_7 = 20 kg sulphur ha^{-1} through gypsum + 20 kg ha^{-1} sulphur through ammonium sulphate.

Table 1: Effect of different source of sulphur on plant height (cm)

Treatments	Plant height (cm)		
	30 DAS	60 DAS	Harvest
T_1(Control)	37.86	104.67	108.20
T_2 (20 kg S through Ammonium Sulphate)	41.55	119.41	121.32
T_3 (20 kg S through Elemental sulphur)	36.50	114.71	120.31
T_4 (20 kg S through Gypsum)	39.67	118.00	109.96
T_5 (20 kg S through Ammonium Sulphate + 20 kg S through Elemental sulphur)	40.55	122.33	122.18
T_6 (20 kg S through Elemental sulphur + 20 kg S through Gypsum	39.67	123.67	124.02
T_7 (20 kg S through Gypsum + 20 kg S through Ammonium Sulphate	44.66	123.67	125.15
S.Em (±)	2.16	1.43	0.13
CD at 5%	6.65	4.39	0.41
CV (%)	9.33	2.09	0.20

Table-1 revealed the data pertaining plant height of sunflower at 30 DAS, 60 DAS and at harvest. Treatment containing 20 kg S through gypsum+ 20 kg S through ammonium sulphate (T_7) resulted in highest plant heights *i.e*., 44.66 cm, 123.67cm and 125.15 cm over control in respective days. T_1 (control) recorded significantly lowest over others during 60 DAS and at harvest. Among sole application of different sources of sulphur, application of ammonium sulphate recorded higher plant height that might be due to the supply of sulphur in a more readily available form than the other sources like gypsum and elemental sulphur. This would have enhanced the metabolic processes in the plants and increased the meristematic activities which resulted increased in height of plant (Intodia and Tomar, 1997) [7].

Table 2: Effect of different source of sulphur on number of leaves per plant

Treatments	Number of leaves per plant		
	30 DAS	60 DAS	Harvest
T_1 (Control)	9.84	11.32	9.94
T_2 (20 kg S through Ammonium Sulphate)	10.98	17.13	12.99
T_3 (20 kg S through Elemental sulphur)	9.49	15.63	11.22
T_4 (20 kg S through Gypsum)	10.68	16.07	12.17
T_5 (20 kg S through Ammonium Sulphate + 20 kg S through Elemental sulphur)	12.62	17.00	13.04
T_6 (20 kg S through Elemental sulphur + 20 kg S through Gypsum	13.15	17.30	13.94
T_7 (20 kg S through Gypsum + 20 kg S through Ammonium Sulphate	14.74	18.26	14.29
S.Em(±)	0.25	0.23	0.09
CD at 5%	0.76	0.70	0.29
CV (%)	3.67	2.44	1.31

From Table-2 it was recorded that different source of sulphur significantly influence on the average no of leaves $plant^{-1}$ of sunflower at 30 DAS, 60 DAS and at harvest. It has been observed that application of 20 kg S through gypsum + 20 kg S through ammonium sulphate (T_7) was resulted highest leaves count i.e., 14.74, 18.26, 14.29 on respective days over control (T_1). This might be due to the supply of sulphur which improves cell division, cell elongation and chlorophyll synthesis. Number of leaves per plant gradually increasing up to 60 DAS and thereafter declined at harvest stage.

Among sole application of various sources of sulphur significantly higher number of leaves plant-1 (17.13 and 12.99) was recorded with application of sulphur through ammonium sulphate (T_2) at 60 DAS and at harvest compared to elemental sulphur (T_3) and gypsum (T_4).

The observation on dry matter accumulation was recorded at 30, 60 DAS and at harvesting (Table 3). The findings indicated that different source of sulphur exerted a significant effect on the plant dry matter accumulation. It was found that application of 20 kg S through gypsum + 20 kg S through ammonium sulphate (T_7) recorded significantly higher dry matter accumulation *i.e*. 25.22 g, 94.08 g, 153.79 g in respective days over control (T_1). Among sole application of different sources of sulphur, soil application of ammonium sulphate observed significantly higher dry matter (126.42 g) compared to gypsum (110.75 g) and elemental sulphur (119.19 g) at harvest. This might be due to better sulphur nutrition to crop. Arora *et al*. (1983) [3] reported that application of ammonium sulphate resulted the most efficient sulphur source for correcting sulphur deficiency in a standing crop. Similar observations were recorded by Venkatesh *et al*. (2002) [18] in safflower and Reddy and Reddy (2001) [13] in soybean.

Table 3: Effect of different source of sulphur on dry matter production (g plant^{-1})

Treatments	Dry matter production (g plant^{-1})		
	30 DAS	60 DAS	Harvest
T_1 (Control)	20.29	80.00	106.29
T_2 (20 kg S through Ammonium Sulphate)	24.07	89.01	126.42
T_3 (20 kg S through Elemental sulphur)	21.39	84.77	119.19
T_4 (20 kg S through Gypsum)	23.69	87.05	110.75
T_5 (20 kg S through Ammonium Sulphate + 20 kg S through Elemental sulphur)	24.15	89.42	149.08
T_6 (20 kg S through Elemental sulphur + 20 kg S through Gypsum	24.40	90.08	149.90
T_7 (20 kg S through Gypsum + 20 kg S through Ammonium Sulphate	25.22	94.08	153.79
S.Em(±)	0.18	0.13	1.01
CD at 5%	0.55	0.41	3.12
CV (%)	1.32	0.26	1.34

Table 4: Effect of various source of sulphur on seed yield (kg ha^{-1}), stalk yield (kg ha^{-1}) and harvest index (%) of sunflower

Treatments	Yield (kg ha^{-1})		Harvest Index (%)
	Seed Yield	Stalk Yield	
T_1 (Control)	1310.33	2177.33	37.57
T_2 (20 kg S through Ammonium Sulphate)	1629.33	2505.33	39.41
T_3 (20 kg S through Elemental sulphur)	1530.67	2353.00	39.41
T_4 (20 kg S through Gypsum)	1580.67	2376.33	39.95
T_5 (20 kg S through Ammonium Sulphate + 20 kg S through Elemental sulphur)	1603.00	2468.33	39.37
T_6 (20 kg S through Elemental sulphur + 20 kg S through Gypsum)	1613.67	2499.00	39.24
T_7 (20 kg S through Gypsum + 20 kg S through Ammonium Sulphate)	1695.67	2667.67	38.86
S.Em (±)	6.10	10.69	-
CD at 5%	18.80	10.69	-
CV (%)	0.67	0.25	-

Seed yield and stalk Yield

Seed and stalk yield of sunflower was influenced by various sources of sulphur. Significantly higher seed and stalk yield was found under T_7 (20 kg S through Gypsum + 20 kg S through Ammonium Sulphate) over T_3 (20 kg S through elemental sulphur). This might be due to its synergistics effect with other macro and micro nutrient in soil which influenced the crop growth and ultimately increased seed and stalk yield. A significant positive relation exits between chlorophyll content in leaf and crop yield. Higher biological yield might be due to increased chlorophyll content in leaf under sulphur application (Sinha *et al*., 1995, Kumar *et al*., 2011) [17, 9]. T_1 (control) showed lower seed yield *i.e.*, 1310.33 kg ha$^{-1.}$ Absence of sulphur might cause reduction in final yield. Similar result was observed by Chitkala and Reddy (1991) [4], Ravi Kumar *et al*., (2001) [12]; Renugadevi and Balamurugan (2002) [14]. Availability of sulpur was varies significantly with various sulphur sources including combined and sole application. Among the sole application of different sulphur sources, significant increase in grain yield (1629.33 kg ha^{-1}) was observed under application of 20 kg S through Ammonium Sulphate (T_2) compared to T_3(1530.67 kg/ha) and T_4 (1580.67 kg/ha).

Conclusion

Application of sulphur and different sources of sulphur found to be greatly influenced the growth, development and seed yield of sunflower crop. Among different sulphur sources, combined application of 20 kg S through gypsum and 20 kg S through ammonium sulphate recorded significantly higher growth parameters and yield over other given sources of sulphur.

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