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Effect of organic and inorganic sources of sulphur on growth and yield of sunflower

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Abstract
Field investigations were carried out during March 2012 and August 2012 at Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar, to study the effect of integrated sulphur management practices on the growth, yield, quality, nutrient uptake and nutrient availability of hybrid sunflower cv. sunbred. The experiments were laid out in randomized block design and replicated thrice. The experiment consisted of eleven treatments viz., T_1 – No sulphur / RDF alone (control), T_2 – 45 kg S ha^{-1} through gypsum, T_3 - 45 kg S ha^{-1} through vermicompost, T_4 - 45 kg S ha^{-1} through poultry manure, T_5 - 45 kg S ha^{-1} through lignite flyash, T_6 - 75% S ha^{-1} through gypsum + 25% S ha^{-1} through vermicompost, T_7 - 75% S ha^{-1} through gypsum + 25% S ha^{-1} through poultry manure, T_8 - 75% S ha^{-1} through gypsum + 25% S ha^{-1} through lignite flyash, T_9 – 50% S ha^{-1} through gypsum + 50% S ha^{-1} through vermicompost, T_{10} – 50% S ha^{-1} through gypsum + 50% S ha^{-1} through poultry manure and T_{11}- 50% S ha^{-1} through gypsum + 50% S ha^{-1} through lignite flyash. The results of the experiments revealed that application of 75% S ha^{-1} through gypsum + 25% S ha^{-1} through vermicompost (T_6) significantly influenced the growth, yield, quality, nutrient uptake and nutrient availability in sunflower. This treatment recorded maximum values for growth attributes *viz.*,plant height (152.37 and 154.38 cm), LAI (6.90 and 6.97 cm at flowering stage), DMP (4225.72 and 4328.81 kg ha^{-1}) at harvest stage, chlorophyll content (2.28 and 2.31 mg g^{-1})at flowering during first and second croop, respectively. This treatment also recorded higher values for yield attributes *viz*., total number of seeds head^{-1} (778.06 and 815.26), number of filled deeds head^{-1}(634.45 and 672.28), seed filling percent (83.04 and 84.26%), seed yield (1825.46 and 1927.39 kg ha^{-1}) and stalk yield (3800.63 and 3898.59 kg ha^{-1}) in both the crops. This treatment recorded maximum N,P,K and S uptake, maximum oil content, oil yield and crude protein content in both the crops. This was followed by T_7 (75% S ha^{-1} through gypsum + 25% S ha^{-1} through poultry manure) in both the crops. The lowest values for growth, yield, quality, nutrient uptake and nutrient availability were recorded in T_1-No sulphur / RDF alone (control) in both the crops. T_1 recorded Maximum N,P,K and S availability in both the crops.

Keywords: Sulphur, sunflower, growth, yield

Introduction
The oilseeds form essential part of human diet, besides it produces basic raw materials for agro-based industries. Sunflower has large acreage under various oilseeds in different agro-climatic zones of this country. The average Indian consumer uses relatively lesser quantities of edible oil, no doubt influenced by this modest level of income. Sunflower (*Helianthus annus* L.) holds great promise as an oilseed crop because of its short duration, photo- in – sensitivity and wide adaptability to different agro-climatic regions and soil types. Sunflower seed contains about 48-53 percent edible oil, sunflower oil is a rich source of linoleic acid (64%) which is good for heart patients. The oil is also used for manufacturing hydrogenated oil. It can be grown at any time of year and can serve as an ideal catch crop during period when the land is otherwise fallow. The existing yield is very low, mainly because of the suboptimal soil fertility. After N,P and K, S is the fourth nutrient, whose deficiency is widespread in India (Yadav *et al*., 2000; Sakal *et al*., 2001). Sulphur application has many advantages for sunflower regarding growth parameters and yield and quality. Each unit of fertilizer sulphur generates 3-5 units of edible oil, a commodity needed by every family. Sulphur can be rightly called as fourth major element of the plant because it is a constituent of three amino acids *viz.*, Cysteine, Cystine and Methionine which are the building blocks of protein and helps in the formation of chlorophyll and synthesis of oils. Sulphur improves protein and oil percentage in seeds. Sing (1999) [15] reported that application of sulphur increased the uptake of various macro and micro nutrients in groundnut. Sulphur is required to attain high yield, biological yield, harvesting index and oil content, as affected by biofertilizers and sulphur application. Application of 2 kg S ha^{-1} increased seed yield by 38%.

Ever since the role of soil fertility in crop production has been recognized, the use of organic manures has become an imperative need for successful farming. It is a known fact that organic matter provides considerable amount of both macro and micronutrients. It improves soil structure through increased aggregation, which favorably influences the tilth, water infiltration, moisture retention, drainage, aeration, temperature and root penetration besides prevention of crusting. Utilization of all possible sources of organic matter such as vermicompost, FYM, poultry manure helps in improving the soil fertility status and also enhances the yield of oilseed crops. In addition, integration of organics with inorganic improves the physiological system of crop growth, provides adequate growth regulating substances, modifies physic-chemical properties of soil and thus augmenting crop yields. With this background the investigation was carried to increase sunflower yield and quality through integrated sulphur management.

Material and Methods

Field investigations were carried out during March 2012 and August 2012 at Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar. The soil of experimental field was clay loam in texture. The soil was low in available Nitrogen, medium in available Phosphorous, high in available Potassium and low inavailable Sulphur. The sunflower cv. Sunbredwaschosen for the study. The experiment was laid out in Randomized block design with three replications. The experiment consisted of eleven treatments *viz.*, T_1 – No sulphur / RDF alone (control), T_2 – 45 kg S ha^{-1} through gypsum, T_3 - 45 kg S ha^{-1} through vermicompost, T_4 - 45 kg S ha^{-1} through poultry manure, T_5 - 45 kg S ha^{-1} through lignite flyash, T_6 - 75% S ha-1 through gypsum + 25% S ha^{-1} through vermicompost, T_7 - 75% S ha^{-1} through gypsum + 25% S ha^{-1} through poultry manure, T_8 - 75% S ha^{-1} through gypsum + 25% S ha^{-1} through lignite flyash, T_9 – 50% S ha^{-1} through gypsum + 50% S ha^{-1}through vermicompost, T_{10} – 50% S ha^{-1} through gypsum + 50% S ha^{-1} through poultry manure and T_{11}- 50% S ha^{-1} through gypsum + 50% S ha^{-1} through lignite flyash. The recommended dose of 60:90:60 kgs of NPK $ha^{-1}$was applied in the form of urea, DAP and muriate of potash. Sulphur @ 20 kg ha^{-1} was applied through Gypsum as per the treatments.

Results and Discussion

Growth attributes (Table 1)

The integrated sulphur management practices significantly influenced the growth attributes viz., plant height, LAI, DMP and chlorophyll content. All the sources of sulphur *viz.*, gypsum, poultry manure, lignite fly ash alone and in integration with gypsum had marked influence on the growth attributes of hybrid sunflower over no S application.

Among the integrated sulphur management practices tried, application of 75% S through gypsum + 25% S ha^{-1} through vermicompost(T_6) resulted in tallest sunflower plants, increased LAI, DMP and chlorophyll content at all the stages of crop growth. This was evidenced through the studies of Intodia and Tomar (1997) [3] and Raja *et al*. (2007) [11]. Presence of higher amount of readily available N in vermicompost and numerous active substances like enzymes and vitamins secreted by microbes in vermicompost (Jeyabal, 1996) [5] might have exerted a positive effect on metabolism of sunflower crop at early growth stage leading to higher growth components. Increased plant height, LAI, DMP due to integrated application of sulphur are in concordance with the reports of Vetrimurugan (2002) [19] and Menaka (2004) [8]. This is due to sulphur applied through gypsum along with RDF increased the availability of other nutrients and enhanced the growth attributes of sunflower in both the crops (Vaiyapuri *et al*., 2004) [18] This was followed by application of 75% S ha^{-1} through gypsum + 25% S ha^{-1} through poultry manure and 75% S ha^{-1} through gypsum + 25% S ha^{-1} through lignite flyash, the lowest growth attributes was observed under T_1 (Nosulphur) in both the crops. This is due to less of availability of sulphur which reduced the availability of other nutrients and finally resulted in lesser values for growth attributing characters.

Table 1: Effect of integrated sulphur management on growth attributes of sunflower

Treatments	Plant height (cm)		LAI at flowering stage		DMP (Kg ha^{-1}) (at harvest)		Total Chlorophyll (mg g^{-1})	
	I crop	II Crop	I crop	II Crop	I crop	II Crop	I crop	II Crop
T_1	117.32	123.17	4.49	4.52	2816	3447	1.23	1.25
T_2	135.27	136.59	4.96	5.00	3737	3829	1.90	1.94
T_3	132.23	133.47	4.84	4.89	3659	3752	1.88	1.91
T_4	129.22	129.98	4.73	4.79	3579	3665	1.87	1.90
T_5	126.20	126.78	4.64	4.68	3512	3588	1.85	1.88
T_6	152.37	154.38	6.90	6.97	4226	4329	2.28	2.31
T_7	148.39	150.12	6.44	6.51	4103	4206	2.12	2.15
T_8	141.93	143.13	5.87	5.90	3878	3977	2.06	2.10
T_9	145.12	146.48	6.15	6.20	3980	4087	2.09	2.12
T_{10}	139.58	141.52	5.26	5.32	3871	3968	1.97	2.00
T_{11}	138.55	139.27	5.14	5.20	3810	3906	1.93	1.96
S.Ed	1.40	1.46	0.125	0.14	33.61	37.15	0.05	0.07
CD (P = 0.05)	2.80	2.92	0.25	0.28	67.23	74.31	0.11	0.15

Yield attributes (Table 2)

The integrated sulphur management practices significantly influenced the yield attributes viz., head diameter, total number of seeds $head^{-1}$, number of filled seeds $head^{-1}$, seed filling percent and 100 seed weight in both the crops.

Application of 75% S through gypsum + 25% S ha^{-1} through vermicompost (T_6) significantly increased the head diameter, total number of seeds $head^{-1}$, number of filled seeds $head^{-1}$, seed filling percent and 100 seed weight and seed and stalk yield over the other treatments. Sulphur is known to play a vital role in the formation of aminoacids. It had favourable effect on yield attributes due to proper partitioning of photosynthates from source to sink. These findings were earlier reported by Syed Shajat Hussain *et al.* (2011) [17]. The least values for yield attributes were recorded under T_1 (No sulphur – RDF alone), could be due to poor availability of

Sand other nutrients. These findings were earlier reported by Poonkodi and Poomurugesan (2005) [10]. The increase in yield under this treatment might be due to significant increase in yield attributes leads to seed and stalk yield. This might be due to the influential role played by sulphur in increasing both growth yield attributes. Supply of S in addition to N,P and K might bethe lifting factor behind the increased seed and stalk yield (Kapilashekahwat and Shivay, 2008) [7]. T_1 (Control) recorded lesser seed and stalk yield in both the crops. This might be due to absence of sulphur resulted in reduced growth and yield attributing characters timely seed and stalk yield. These finding are in line with Ravikumar (2001) [12].

Yield (Table 2)

All the integrated sulphur management practices significantly influenced the seed and stalk yield of sunflower in both the crops over sulphur without integration of organics. Among the treatments tried, T_6(75% S through gypsum + 25% S ha^{-1} through vermicompost) significantly recorded higher seed yield of 1825.67 and 1927.39 kg ha-1 and stalk yield of 3800.63 and 3898.59 kg ha^{-1} in first and second crop respectively. This treatment registered higher seed yield over no sulphurapplication (T_1) and the yield increase being 44.18 and 48.01 per cent respectively in first and second crop respectively. Sulphur application increased the chlorphyll content in leaf and gave a significant positive correlation between chlorophyll content in leaf and crop yield (Sinha *et al*., 1995) [16] control treatment T_1 (No sulphur – RDF alone) recorded lesser seed and stalk yield in both the crops. These findings are in line with Ravikumar *et al*. (2001) [12].

Table 2: Effect of integrated sulphur management on yield attributes and yield of sunflower

Treatments	Head Diameter		Total No. of Seeds head^{-1}		No. of filled seeds head^{-1}		Seed filling%		100 seed at (g)		Seed yield (Kg ha^{-1})		Stalk Yield (kg ha^{-1})	
	I Crop	II Crop	I Crop	II Crop	I Crop	II Crop	I Crop	II Crop	I Crop	II Crop	I Crop	II Crop	I Crop	II Crop
T_1	12.60	13.42	489.47	534.35	310.35	337.28	63.40	63.86	3.83	3.90	1266	1302	2872	2957
T_2	14.50	15.32	608.39	628.31	442.17	460.11	72.67	73.22	4.85	4.92	1514	1560	3489	3564
T_3	14.27	15.11	579.27	585.25	405.15	421.13	69.94	71.95	4.68	4.68	1467	1511	3431	3499
T_4	13.98	14.81	545.14	550.16	371.12	390.07	68.07	70.90	4.45	4.43	1399	1435	3385	3435
T_5	13.50	14.45	515.12	523.08	342.07	361.03	66.40	69.02	4.20	4.21	1371	1403	3327	3371
T_6	18.67	19.72	860.58	934.37	714.68	787.35	83.04	84.26	6.20	6.42	1825	1927	3800	3898
T_7	17.45	18.53	778.06	815.26	634.45	67.2.28	81.54	82.15	5.74	5.87	1765	1850	3735	3805
T_8	15.50	16.58	677.38	705.23	520.19	548.12	76.79	77.72	5.33	5.36	1656	1721	3602	3683
T_9	16.37	17.44	725.16	757.21	568.27	601.21	78.36	79.39	5.52	5.60	1702	1780	3668	3746
T_{10}	14.85	15.77	658.47	687.25	500.47	525.29	76.00	76.43	5.28	5.32	1601	1654	3590	3662
T_{11}	14.68	15.56	642.99	673.19	486.25	512.18	75.62	76.08	5.16	5.14	1555	1613	3540	3595
S.Ed	0.30	0.36	7.75	7.92	7.59	8.42	0.20	0.22	0.08	0.09	24	35	27	31
CD (P = 0.05)	0.61	0.73	15.50	15.84	15.18	16.85	0.41	0.45	0.16	0.19	48	25	55	62

Quality characters (Table 3)

The integrated sulphur management practices significantly increased the oil content, oil yield and crude protein content. The maximum oil content of 38.42 and 38.65 percent was recorded with 75% S through gypsum + 25% S ha^{-1} through vermicompost (T_6) and least value was recorded under no S applied plot (T_1). Increase in oil content by sulphur application might be attributed to involvement of sulphur in the biosynthesis of oil (Mudd, 1967) [9]. Lowest values of oil and protein content in sunflower seeds was observed in the treatment T_1 (Nosulphur) in both the crops. This might be due to lesser availability and uptake of nutrients for the oil and protein synthesis in the crop. Similar view was expressed by Renugadevi and Balamurugan (2002) [13].

Nutrient uptake (Table 3)

In both the crops, N,P,K and S uptake were significantly influenced by integrated sulphur management practices. Among the treatments tried, T_6registered the higher amount of N,P,K and S uptake in both the crops respectively. This might be due to optimum rate of 'S' application through gypsum along with vermicompost increased the uptake of N,P,K & S and ultimately more utilization of these nutrients, which in turn enhanced their concentration and uptake (Bhagat *et al.*, 2003) [1]. Increase in the uptake of N,P and K, S by sunflower with gypsum application was due to the combined effect of increase in yield and nutrient content in plants. Similar results were earlier reported by Devakumar and Gajendra Giri (1990) [2]. T_1 recorded minimum values for N,P, K & S uptake due to lesser availability of nutrients in both the crops.

Table 3: Effect of integratedsulphur management of Quality parameters and Nutrient uptake of sunflower

Treatments	Oil Content (%)		Crude Protein Content (%)		Nutrient uptake (kg ha^{-1})							
					N		P		K		S	
	I Crop	II Crop	I Crop	II Crop	I Crop	II Crop	I Crop	II Crop	I Crop	II Crop	I Crop	II Crop
T_1	37.15	37.21	20.48	21.37	67.52	68.43	14.33	15.42	61.48	62.27	6.71	7.38
T_2	37.63	37.69	22.58	23.44	71.34	72.23	15.89	16.79	64.77	65.46	7.93	8.61
T_3	37.50	37.55	22.25	22.86	70.88	71.66	15.67	16.49	64.29	65.25	7.63	8.36
T_4	37.38	37.41	21.39	22.47	70.29	71.36	15.39	16.21	63.86	64.75	7.33	8.16
T_5	37.22	37.27	21.67	21.99	69.86	70.92	15.12	15.94	63.37	64.22	7.12	7.95
T_6	38.42	38.65	27.53	28.39	77.62	78.32	19.42	20.21	70.45	71.27	11.47	12.25
T_7	38.27	38.32	26.21	27.29	76.35	77.23	18.37	19.20	69.31	70.19	10.38	11.21
T_8	38.07	38.21	24.19	25.22	74.16	75.20	16.50	17.30	67.18	68.17	8.73	9.28

T_9	38.16	38.15	25.18	26.23	75.25	76.13	17.42	18.25	68.29	69.18	9.54	10.18
T_{10}	37.35	37.78	23.68	24.55	72.68	73.36	16.41	17.22	65.78	66.47	8.58	9.10
T_{11}	37.76	37.67	23.52	24.41	71.87	72.63	16.14	17.05	65.26	66.16	8.22	8.87
SEd	0.05	0.06	0.07	0.08	0.43	0.43	0.17	0.18	0.38	0.39	0.20	0.21
CD (P = 0.05)	0.10	0.13	0.15	0.17	0.86	0.86	0.35	0.36	0.76	0.78	0.41	0.42

Post-harvest soil available nutrient status (Table 4)

The integrated sulphur management practices influenced the post-harvest nutrient status viz., N, P, K & S over the treatments received sulphur without organics. Among the various practices tried, T_1 recorded higher values for soil available N,P, K & S in both the crops. This might be due to poor uptake of nutrients by the crop as result of lesser foraging capacity. Similar results were also reported by Kalaiyarasan (2000) [6]. N,P, K & S were low in T_6due to more uptake of nutrients by the crop (Gandhi, 2011) [4].

Table 4: Effect on integrated sulphur management of nutrient availability on sunflower

Treatments	Nutrient availability (Kg ha^{-1})							
	N		P		K		S	
	I Crop	II Crop	I Crop	II Crop	I Crop	II Crop	I Crop	II Crop
T_1	237.20	241.22	22.45	27.61	343.64	349.70	22.60	29.15
T_2	224.26	227.29	20.49	24.31	338.31	335.41	19.40	25.30
T_3	226.15	230.42	2021	25.21	339.25	338.22	20.35	26.27
T_4	229.21	233.31	21.45	26.32	340.42	342.19	21.41	27.10
T_5	230.13	239.28	21.20	27.15	342.27	345.23	22.27	28.23
T_6	191.50	201.20	15.28	20.40	305.11	310.23	13.08	17.22
T_7	197.37	207.31	16.19	21.37	315.21	313.32	14.20	19.31
T_8	205.29	213.39	17.21	22.30	320.29	319.29	15.31	21.20
T_9	213.19	219.28	18.32	21.42	329.27	322.30	16.42	22.19
T_{10}	222.69	221.19	19.46	22.37	334.35	325.41	17.29	23.31
T_{11}	223.48	225.31	20.29	23.25	335.22	330.28	18.37	24.28
SEd	0.53	0.49	0.55	0.30	0.53	0.48	0.78	0.78
CD (P = 0.05)	1.12	1.03	1.15	0.64	1.10	1.01	1.64	1.64

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