Sulphur and Micronutrient Impact on Sunflower (*Helianthus annuus*) Yield and Nutrient Uptake

ABSTRACT: Soil composition, fertilizer quality, and fertilizer type are all important factors in the growth and yield of sunflowers. Fertilizers are generally used to replenish the soil with essential nutrients that are necessary for optimal sunflower growth and yield. To assess the impact of elemental Sulphur (S) supplementation on the yield of sunflower crops, a field experiment was conducted in December 2021 in Maharashtra soil. The trial was arranged in a Randomized Block Design with five treatments, each replicated five times.T1 (Control), T2 (100% RDF i.e. Recommended NPK 80:60:40 only), T3 (Recommended NPK with 40kg/ha Elemental S), T4 (Recommended NPK with 40kg/ha along with foliar spray of micronutrients (Cu 1.0%,Zn 3.0%,Mn 1.0%,Fe 2.5%,B 0.5%,Mo 0.1%)],T5 (Recommended NPK with foliar spray of micronutrients(Cu 1.0%,Zn 3.0%,Mn 1.0%,Fe 2.5%,B 0.5%,Mo 0.1%). The application of a recommended dose of fertilizer and 40 kg/ha of elemental sulphur along with a foliar spray of micronutrients (T4)combined had a significant effect on the sunflower seed yield and quality. The utilization of a prescribed dosage of fertilizer and 40 kg/ha of elemental sulphur together had a noteworthy result on the sunflower seed yield and quality. The integration of sulphur amplified the all-inclusive nutrient concentration and their absorption by the sunflower.

Keywords: Soil, sunflower, Elemental sulphur(S), Fertilizer, Inductively Coupled PlasmaSpectrophotometer (ICP-OES).

1. INTRODUCTION

Sunflower *(Helianthus annuus L.)* is an important oilseed crop in India, renowned for its high-quality edible oil with exceptional nutritional qualities. Due to its adaptability to various conditions and soils, it is easy to cultivate [1]. Sunflower oil is especially rich in linoleic acid and has a range of health benefits [2]. Sunflower crops occupy the fourth place among all oil-seed crops in India, with the main states for its cultivation being Karnataka, Andra Pradesh, Maharashtra, and Tamil Nadu [3]. The amount of fertilizer applied should be based on the soil type, the stage of the plant, and the environmental conditions. Applying too much fertilizer can lead to nutrient burn, which can cause stunted growth and poor yields. The pros of using the right fertilizer for sunflowers include increased growth and yield, improved nutrient absorption, and better environmental conditions.

Studies have found that sulphur deficiency is a problem in various states of India, with eighty-eight out of four hundred districts identified as having varying degrees of deficiency [4]. Micronutrients are required in far smaller amounts; they are essential for plant growth and important for cell division and hastening plant maturity. Micronutrient deficiency can be a major issue for soils and food crops, reducing both their yield and the nutritional quality. Plant health is an indicator of the nutrient sufficiency of soil. Sulphur application increases the uptake of macro and micronutrients in oil seed crops [5]. The consequences of not applying sulphur to soil, or soils deficient in sulphur, can be seen through low yields and a negative impact on the agro-based economy [6]. Elemental sulphur, when decomposed by microbes, gets converted to sulphuric acid which reduces soil pH and consequently increases nutrient availability [7].

2. MATERIAL AND METHODS

A field experiment was conducted from November 2021 to March 2022 in Maharashtra to examine the effect of elemental Sulphur (S) application at a rate of 40 kg/ha in combination with the recommended dose of fertilizer (NPK) and foliar spray of micronutrients on the quality and quantity of sunflower crop (*Helianthus annuus L*.). In addition, the physical parameters and chemical properties of the experiment soil were analyzed using the method described by the Food and Agricultural Organization [8]. For the winter season, 5 treatments were arranged in a field with 5 replicates. Each replicate consisted of 20 plants, with a total area of 17.4 meters in length and 13.7 meters in breadth, amounting to 43.84 square meters. As a basal dose, nitrogen (80 kg/ha), phosphorous (60 kg/ha), and potassium (40 kg/ha) were applied at the time of sowing in 4 treatments. Additionally, elemental sulfur (96.25 gm) and compost (47.16 kg) were mixed and applied as a basal dose. For the 5 rows, 1.17 kg Suphala (N15:P15:K15), 0.191 kg Di Ammonium Phosphate, and 38.14 gm urea were required.

Urea and diammonium phosphate were used as sources of N and P, respectively. Suphala was used as a source of NPK, and the treatments were represented by a combination of sulfur and micronutrients. Micronutrients were sprayed after 45 days during the flowering stage. To check the physical and chemical parameters, 10 randomly selected plants from each row were chosen. After 90 days of sowing, the whole plot was harvested and soil and plant samples were collected for analysis. Soil samples were taken from four different corners and analyzed for various nutrients. All the collected plant samples were then divided into roots, stems, and leaves and sun-dried for 8 to 10 days before being crushed into separate parts. The samples were then extracted using the wet acid digestion method and analyzed with an Inductively Coupled Plasma Spectrophotometer to check the nutrient parameters such as P, K, S, Cu, Zn, Mn, Fe, B, and Mo. The N content was then measured using the Kjeldahl procedure.

- **Preparation of stock solutions:**

In accordance with the guidelines from the Maharashtra Gazette, a multi micronutrient fertilizer was prepared with Cu (1.0%), Zn (3.0%), Mn (1.0%), and Fe (2.5%). B (0.5%), Mo (0.1%). The chemicals used were CuSo4.7H2O 4.49gm, ZnSo4.7H2O 15.4 gm, MnSo4 2.71gm, FeSo4.7H2O, Boric Acid 2.86gm, Ammonium Molybdate 0.72gm, which were dissolved in distilled/demineralized water at 65^{0C}-70^{0C} for two hours. The volume was then made up to 100ml and the solution was filtered using Whatman filter paper no.42. This stock solution was diluted to 1ml in 1000ml and used as a foliar spray on the crop.

- **Elemental Analysis:** The roots, stems, and leaves were allowed to dry under the sun for 10 days, before being ground and filtered through a 0.25 mm sieve for further analysis. 0.5 g of each sample was then digested with 10.0 mL of HNO3-HClO4 (v/v: 4:1) and transferred to a 50-mL volumetric flask. The solution was made up to the volume and filtered in order to measure the concentration of mineral elements such as P, K, S, Zn, Fe, Cu, Mn, B and Mo using inductively coupled plasma spectrophotometer (ICP-Optical Emission Spectrophotometer). For the purpose of nitrogen analysis, 0.5 g of each sample

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was digested in Conc. sulfuric acid (H_2SO_4), and the resulting digest was analyzed through the Kjeldahl method.

- **Table 1 Treatment is given as follows:**

Sr.No	**Treatment**
1	Control
2	100% RDF
3	100% RDF + Elemental S
4	100% RDF + Elemental S + Micronutrient
5	100% RDF + Micronutrient

4. STATISTICAL METHOD USED

The statistical analysis of the data of various characteristics studied in the investigation was carried out for each year through analysis of variance technique as described by Panse and Sukhatme (1985) [9]. The statistical design used for this experiment is Randomized block designed (RBD).

3. RESULTS AND DISCUSSION

The application of 40kg/ha of elemental sulphur along with the foliar spray of micronutrients (Cu (1.0%), Zn (3.0%), Mn (1.0%), and Fe (2.5%). B (0.5%), Mo (0.1%) proved to be the most beneficial for the growth of sunflowers, as evident from the height, weight of the flower, stem girth, a diameter of the flower, diagonal length of the leaves, and biomass. This was superior to the 100% RDF, 100% RDF+Elemental Sulphur+100% RDF+ micronutrients, and the control. This could have been due to the interaction effect of sulphur, zinc, and iron, which aids in the metabolism of auxins and the formation of chlorophyll. This is in line with the findings of Jasim et al.,[10] and Kumar et al., [11]who reported similar results in mustard. Singh et al., [12] also reported an increase in the uptake of N, P, and K by mustard when the level of sulphur was increased. The addition of only S (RDF+40kg/ha) did not have

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a significant effect on the seed yields, but the foliar application of micronutrients Cu (1.0%), Zn (3.0%), Mn (1.0%), and Fe (2.5%). B (0.5%), Mo (0.1%) improved the overall growth of the crop, making it better than the (RDF+micronutrients).

Table 2. Changes Occurred in the sunflower plant after given sulphur treatment

Treatment	Plant height (cm)	Weight of Flower (gm)	Diameter of Leaf(cm)	Diagonal length of leaf(cm)	Width of the stem (cm)	Biomass (kg)	Diameter of flower(cm)
Control (T1)	109.86	343.4	16.12	15.39	11.12	9.1	10.72
100% RDF (T2)	129.38	482.816	20.93	19.4	14.95	15	12.66
100% RDF +ElementalS (T3)	159.6	692.05	26.1	25.56	16.54	18.6	14.9
100% RDF +Micronutrient +Elemental S (T4)	175.312	915.96	28.5	26.6	17.74	21.3	16.14
100% RDF +Micronutrient (T5)	150.3	765	22.42	22.87	15.98	19.5	13.98
SEM+	0.98	3.50	0.76	0.63	0.70	0.72	0.57
CD (*P*=0.05)	2.95	10.48	2.28	1.88	2.09	2.15	1.72
CV %	1.52	1.22	7.44	6.37	10.22	9.62	9.37

The results of our experiments shows a great significant effect among all the treatments which indicated that the combination of T4 RDF, 40kg/ha of elemental sulfur plus a foliar spray of micronutrients Cu (1.0%), Zn (3.0%), Mn (1.0%), and Fe (2.5%). B (0.5%), Mo (0.1%) treatments produced the Significantly highest plant height of 175.31cm, weight of flower 915.96gm,diameter of leaf 28.5cm, and biomass 21.3 kg diagonal length of leaf 26.6cm,width of stem 17.7 cm, biomass 21.3kg.

Significantly lowest plant height 109.96cm, weight of flower 343.49gm,diameter of leaf 16.12cm and biomass 9.1kg was found under the control(T1).

The combination of T4 RDF, 40kg/ha of elemental sulfur plus a foliar spray of micronutrients Cu (1.0%), Zn (3.0%), Mn (1.0%), and Fe (2.5%). B (0.5%), Mo (0.1%) treatments produced the Significantly higher diagonal length of leaf (26.6cm), width of stem (16.54cm) and diameter of flower (14.9cm), whereas 100%RDF + elemental sulphur (T3) produced significantly higher diagonal length of leaves (25.56cm), width of stem (16.54cm) and

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diameter of flower (14.9cm) and also shown in (T5) 100% RDF+Elemenal Sulphur produced width of stem (15.95cm) both this treatment were remaining at par with (T4).

Graphical representation of changes that occurred in sunflower plants after being given sulphur treatment:.

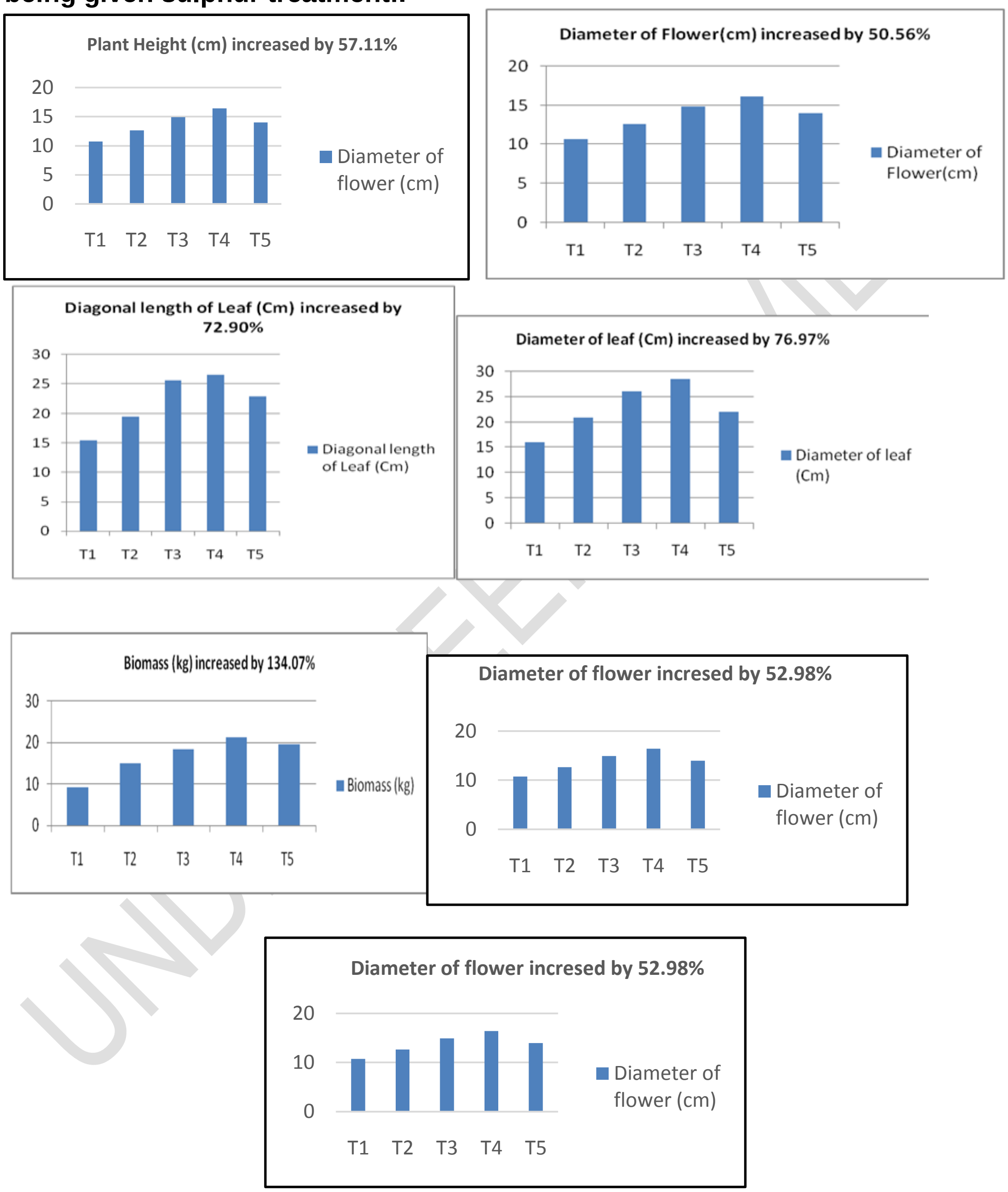

Figure 1. Graphical representation of physical parameter of sunflower plant: Plant height, weight of flower, diameter of leaves, and diagonal length of leaves,width of stem, biomass and diameter of flower as influenced by sulphur effect.

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Research has shown that elemental sulphur can be beneficial for sunflower growth and yield. It is possible that the improved growth characteristics of the sunflowers were a result of the production of amino acids, increased cell division, and enhanced photosynthetic activity, which could explain the increased plant height, stem girth, and flower diameter Raja et al., [13] and Saleem et al.,[14].

Barbara et al.,[15] reported that a higher level of sulphur application resulted in a better yield of grain. Agegn A et al., [16] found that combining Iron, Zinc, and Manganese together is more effective than using them individually in improving grain yield and dry matter. It has been established that sulphur increases nutrient availability in the soil, as evidenced by Dhage et al., [17]. When sulfur is applied to sunflower plants, a number of changes occur. First, the leaves and stems of the plant become more resistant to disease, insect damage, and environmental conditions such as drought. This is because sulfur helps reduce the amount of stress on the plant. In addition, the plant will become bushier and fuller due to the increased availability of sulfur. This is because sulfur helps the plant produce more chlorophyll and other essential molecules, which makes the leaves thicker and greener. Sulphur also helps to improve the overall health of the plant. It increases the concentration of essential minerals in the soil, which helps the plant absorb nutrients more efficiently. This leads to larger and healthier blooms.

Effects of sulphur application along with the foliar spray of micronutrients on total NPK and S uptake and distribution of sunflower crop at physiological maturity in 2022

The data demonstrates the effect of elemental sulfur on the physicochemical characteristics of experimental soil in Maharashtra (India). The pH of the soil decreased from 6.68 to 5.88, which is slightly acidic and thus favorable for oil-seed crops. The addition of 100% RDF (N80:P60:K40) also increased the levels of N, P, K, and S (161.31kg/ha to 375.66kg/ha, 78.91 kg/ha to 166.43kg/ha, 692.69kg/ha to 2316.12 kg/ha, and 107.33kg/ha to 276.32kg/ha). Similarly, the addition of sulfur resulted in a rise in the micronutrients Cu, Zn, Mn, Fe, B, and Mo (1.25 to 5.10 mg/kg, 1.20 to 9.25 mg/kg, 21.81 to 39.22 mg/kg, 12.70 to 25.51 mg/kg, 0.38 to 1.08 mg/kg, and 0.18 to 0.48 mg/kg).

Table 3. Effects of sulphur application along with the foliar spray of micronutrient on total NPK and S content and distribution of sunflower crop at physiological maturity in 2022

Treatment	Nitrogen Content%			Phosphorus Content%			Potassium Content%			Sulphur Content%		
	R%	S%	L%	R%	S%	L%	R%	S%	L%	R%	S%	L%
control (T1)	0.77	0.60	0.5	0.57	0.56	0.88	2.08	2.59	2.68	0.13	0.51	0.55
100% RDF(T2)	0.81	1.21	0.77	0.61	0.57	0.97	2.42	3.53	3.23	0.20	0.65	0.57

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100 % RDF + Elemental S (T3)	0.89	1.23	1.37	0.63	0.63	1.08	2.72	3.7	3.73	0.25	0.74	0.69
100 % RDF + Micronutrient+ Elemental S (T4)	0.98	1.67	1.43	0.70	0.67	1.21	3.63	3.79	3.88	0.39	0.86	0.82
100 % RDF + Micronutrient	0.81	1.06	0.70	0.62	0.64	1.1	3.33	3.57	3.43	0.31	0.58	0.66
SEM+	0.03	0.04	0.05	0.03	0.03	0.07	0.11	0.15	0.13	0.02	0.02	0.03
CD (*P*=0.05)	0.10	0.12	0.15	N.S	N.S	N.S	0.34	0.44	0.38	0.05	0.07	0.08
CV %	8.42	7.67	11.64	11.51	10.48	15.88	8.85	9.55	8.39	14.15	7.95	8.75

Table 4. Effects of sulphur application along with the foliar spray of micronutrient on total Micronutrient content and distribution of sunflower crop at physiological maturity

Treatment	**Copper Content (ppm)**			**Zinc Content (ppm)**			**Manganese Content (ppm)**		
	R	S	L	R	S	L	R	S	L
control (T1)	18.3	40.2	58.2	46.8	33.1	81.7	15.4	97.9	68.4
100% RDF(T2)	19.5	39.7	62	53.8	45.4	81.9	26.9	113.3	98.1
100 % RDF + Elemental S (T3)	20.8	41.8	63	54.3	55.9	87.7	30.1	154.5	154.4
100 % RDF + Micronutrient+ Elemental S (T4)	22.6	47.7	71.4	62.2	64.2	120.1	42.1	185.2	233.7

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100 % RDF + Micronutrient (T5)	21.1	42.8	65.2	59.1	67.4	93.3	29.3	166.4	180.3
SEM+	1.17	1.92	2.97	1.14	1.14	2.91	1.24	3.4	2.19
CD (P=0.05)	N.S	N.S	N.S	3.42	3.42	8.72	3.73	10.21	6.58
CV %	12.7	10.1	10.4	4.61	4.79	7.0	9.67	5.31	3.34

Table 4A Effects of sulphur application along with the foliar spray of micronutrient on total Micronutrient content and distribution of sunflower crop at physiological maturity

Treatment	**Iron Content(ppm)**			**Boron Content(ppm)**			**Molybdenum Content(ppm)**		
	R	S	L	R	S	L	R	S	L
control (T1)	2798.8	1201.6	2439.6	11.8	28.1	39.8	0.11	0.32	2.14
100% RDF(T2)	2954.8	1585.1	2562.4	12.9	29.5	42.4	0.13	0.34	2.22
100 % RDF + Elemental S (T3)	3389.5	1817.6	3109.5	13.7	33.1	42.6	0.13	0.36	2.25
100 % RDF + Micronutrient+ Elemental S (T4)	4087.6	2376.2	3537.2	15.1	35.1	49	0.14	0.4	2.5
100 % RDF + Micronutrient (T5)	2712.8	1606.4	2916.1	14.9	29.9	43.6	0.13	0.35	2.17
SEM+	173.3	86.37	138.4	0.91	1.69	2.1	0.01	0.02	0.09
C.D (*P*=0.05)	519.6	258.92	414.8	N.S	N.S	N.S	N.S	N.S	N.S

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CV%	12.15	11.24	10.62	14.9	12.1	10.8	14.6	12.8	9.31

Nutrient content :

Table no. 3 and 4 indicated the results of our experiments showing a great significant effect among all the treatments which indicated that the combination of T4 RDF, 40kg/ha of elemental sulphur plus a foliar spray of micronutrients Cu (1.0%), Zn (3.0%), Mn (1.0%), and Fe (2.5%). B (0.5%), Mo (0.1%) treatments produced the Significantly highest content of all macro and micronutrients.

The highest and lowest macronutrients and micronutrients contents are as follows:

Highest content in treatment no.4 (T4):

- **Roots**- N(0.98%), P(0.70%), K(3.63%), S(0.39%), Cu(22.6ppm), Zn(62.2ppm), Mn(42.1ppm), Fe(4087.6ppm), B(15.1ppm), Mo(0.14ppm).
- **Stem**- N(1.67%), P(0.67ppm), K(3.79ppm), S(0.86ppm), Cu(47.7ppm), Zn(64.2ppm), Mn(185.2ppm) Fe(2376.2%), B(35.1%), Mo(0.4ppm)
- **Leaves**- N(1.43%), P(1.21%), K(3.88%), S(0.82%), Cu(71.4ppm), Zn(120.1ppm), Mn(233.7ppm), Fe(3537.2ppm), B(49ppm), Mo(2.5ppm)].

Lowest content in treatment no.1 control (T1):

- **Roots-** N(0.77%), P(0.57%), K(2.08%), S(0.13%), Cu(18.3ppm), Zn(46.8ppm), Mn(15.4ppm), Fe(2798.8ppm), B(11.8ppm), Mo(0.11ppm).
- **Stem-** N(0.60%), P(0.56%), K(2.59%), S(0.51%), Cu(40.2ppm), Zn(33.1ppm), Mn(97.9ppm), Fe(1201.6ppm), B(28.1ppm), Mo(0.32ppm).
- **Leaves-** N(0.5%), P(0.88%), K(2.68%), S(0.55%), Cu(58.2ppm), Zn(81.7ppm), Mn(68.4ppm), Fe(2439.6ppm), B(39.8ppm), Mo(2.14ppm).

Tables 3 and 4 both demonstrate that the concentration of phosphorus, copper, boron, and molybdenum in the roots, stems, and leaves did not exhibit any significant variations due to the application of different treatments. However, the content of Zn (59.1ppm) in Treatment 5 (T5),100% RDF+ micronutrients, remained at par with Treatment 4 (T4).

Table 3 reveals that the application of different treatments had a non-significant impact on the concentration of phosphorus in the root, stem, and leaves.

Similarly, Table 4 demonstrates that the concentration of copper, boron, and molybdenum in the root, stem, and leaves remained unaffected by the various treatments, showing no significant differences. Additionally, it is also observed that the majority of both macro and micronutrient levels were found maximum in the leaves, followed by the stem and roots.

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Table 5. Effects of sulphur application along with the foliar spray of micronutrient on total Macronutrient uptake and distribution of sunflower crop at physiological maturity kg/ha

Treatment	Nitrogen uptake kg/ha			Phosphorus uptake kg/ha			Potassium uptake kg/ha			Sulphur uptake kg/ha		
	Rkg/ha	Skg/ha	Lkg/ha	Rkg/ha	Skg/ha	Lkg/ha	Rkg/hat	Skg/ha	Lkg/ha	Rkg/ha	Skg/ha	Lkg/ha
control (T1)	7.02	24.37	9.60	5.19	23.00	17.02	19.04	104.76	51.42	1.23	20.64	10.51
100% RDF(T2)	12.65	84.22	24.85	9.45	39.40	31.42	37.72	244.85	104.67	3.17	45.17	18.52
100 % RDF + Elemental S (T3)	16.72	102.70	53.67	11.92	52.44	42.21	51.10	308.19	146.04	4.70	61.86	26.93
100 % RDF + Micronutrient+ Elemental S (T4)	21.27	160.28	64.57	15.01	64.33	54.51	78.67	364.27	175.36	8.44	82.70	36.71
100 % RDF + Micronutrient	15.96	92.94	29.03	12.22	56.14	45.55	65.81	312.90	141.61	6.05	50.96	27.10
SEM+_	0.87	4.09	1.99	0.69	2.35	2.62	2.36	13.0	4.99	0.39	2.62	0.95
CD (*P*=0.05)	2.62	12.26	5.98	2.08	7.05	7.86	7.09	38.97	14.95	1.17	7.85	2.86
CV %	13.26	9.85	12.27	14.44	11.17	15.36	10.47	10.89	9.01	18.56	11.20	8.9

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Table 6. Effects of sulphur application along with the foliar spray of micronutrient on total Micronutrient uptake and distribution of sunflower crop at physiological maturity gm/ha.

Treatment	**Copper uptake (gm/ha)**			**Zinc uptake (gm/ha)**			**Manganese uptake (gm/ha)**		
	R	S	L	R	S	L	R	S	L
control (T1)	16.59	163.59	111.85	42.80	134.04	156.19	13.99	396.72	130.66
100% RDF(T2)	30.36	272.81	202.08	83.86	313.52	265.63	41.87	783.51	318.58
100 % RDF + Elemental S (T3)	39.16	348.32	246.74	102.09	465.38	343.15	56.42	1287.89	605.68
100 % RDF + Micronutrient+ Elemental S (T4)	48.97	457.37	320.59	134.74	616.31	541.22	91.23	1777.85	1054.99
100 % RDF + Micronutrient (T5)	41.67	375.0	269.06	117.18	591.35	384.86	58.02	1460.99	743.36
SEM+	1.55	13.30	11.69	3.30	137.27	11.18	2.52	38.87	20.40
CD (*P*=0.05)	4.64	39.88	35.04	9.89	411.52	33.51	7.56	116.55	61.16
CV %	9.78	9.20	11.36	7.67	11.67	7.39	10.78	7.62	7.99

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Table 6A. Effects of sulphur application along with the foliar spray of micronutrient on total Micronutrient uptake and distribution of sunflower crop at physiological maturity gm/ha

Treatment	**Iron uptake (gm/ha)**			**Boron uptake(gm/ha)**			**Molybdenum uptake(gm/ha)**		
	R gm/ha	Sgm/ha	Lgm/ha	Rgm/ha	Sgm/ha	Lgm/ha	Rgm/ha	Sgm/ha	Lgm/ha
control (T1)	2553.3	4862.1	4648.0	10.86	115.02	75.55	0.1	1.31	4.09
100% RDF(T2)	4589.8	10910.1	8306.4	20.15	202.84	136.86	0.2	2.33	7.18
100 % RDF + Elemental S (T3)	6371.2	15173.8	12204.2	25.75	275.09	166.75	0.25	2.98	8.81
100 % RDF + Micronutrient+ Elemental S (T4)	8818.6	22876.8	15979.6	32.7	336.29	222.23	0.31	3.83	11.31
100 % RDF + Micronutrient (T5)	5380.7	14064.6	12031.1	29.42	262.61	179.61	0.25	3.04	8.97
SEM+_	296.87	740.88	651.70	1.69	12.47	9.64	0.02	0.19	0.42
CD (*P*=0.05)	890.0	2221.16	1953.79	5.06	37.37	28.9	0.05	0.57	1.27
CV %	11.98	12.20	13.70	15.88	11.69	13.80	15.61	15.79	11.75

Nutrient Uptake :

Table no. 5 and 6 indicated the results of our experiments showing a great significant effect among all the treatments which indicated that the combination of T4 RDF+ 40kg/ha of elemental sulfur plus a foliar spray of micronutrients Cu (1.0%), Zn (3.0%), Mn (1.0%), and Fe (2.5%). B (0.5%), Mo (0.1%) treatments produced the Significantly highest uptake of all macro and micronutrients.

The highest and lowest macronutrients and micronutrients uptakes are as follows

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Highest uptake in treatment no.4 (T4):

- **Roots**- N(21.27kg/ha), P(15.01kg/ha), K(78.67 kg/ha), S(8.44 kg/ha, Cu(48.97 g/ha), Zn(134.74 g/ha), Mn(91.23 g/ha), Fe(8818.6 g/ha), B(32.7 g/ha), Mo(0.31 g/ha)
- **Stem**- N(160.28kg/ha), P(64.33kg/ha), K(364.27kg/ha), S(82.70kg/ha), Cu (457.37g/ha), Zn(616.31 g/ha), Mn(1777.8g/ha), Fe(22876.8g/ha), B(336.29g/ha), Mo(3.83g/ha)
- **Leaves**- N(64.57kg/ha), P(54.51kg/ha), K(175.36kg/ha), S(36.71kg/ha, Cu(320.59 g/ha), Zn(91.23g/ha), Mn(1054.99 g/ha), Fe(15979.6 g/ha), B(222.23g/ha), Mo(11.31g/ha)

Lowest uptake in treatment no.1 control (T1):

- **Roots**- N(7.02kg/ha), P(5.19kg/ha), K(19.04kg/ha), S(1.23kg/ha, Cu(16.59g/ha), Zn(42.80g/ha), Mn(13.99g/ha), Fe(2553.3g/ha), B(10.86g/ha), Mo(0.1g/ha)
- **Stem**- N(24.37kg/ha), P(23kg/ha), K(104.76kg/ha), S(20.64kg/ha), Cu (163.59g/ha), Zn(134.04g/ha), Mn(396.72g/ha), Fe(4862.1g/ha), B(115.02g/ha), Mo(1.39g/ha)
- **Leaves**- N(9.60kg/ha), P(17.02kg/ha), K(51.42kg/ha), S(10.51kg/ha), Cu (111.85g/ha), Zn(156.19 g/ha), Mn(130.66g/ha), Fe(4648g/ha), B(75.55g/ha), Mo(4.09g/ha).

It is also observed that most of the macro and micro nutrients uptakes are found maximum in stem followed by leaves and stem.

The uptake of Zinc in stem (T2) 100% RDF (313.52gm/ha), and (T3)100% RDF+Elemental Sulphur (465.38gm/ha), and T5(100%RDF+micronutrient (591.35gm/ha) these three treatment were remaining at par with (T4). Uptake of Boron in root (T5)100%RDF+micronutrient (29.42gm/ha) was remaining at par with (T4).

Foliar applications of zinc significantly increased the number of leaves and leaf area per plant, leading to higher vegetative growth. AR Chowdhury et al., [18], found that boron assists in increasing the activity of phosphatase enzymes and dehydrogenase, leading to significantly higher seed weight. Similarly, BA Kumar et al., [19] and Crista F., [20] concluded that foliar application of boron improves the head weight of sunflower.

4. CONCLUSION

The results of the experiment suggest that the application of 40kg/ ha of elemental sulphur basally as a soil application, along with RDF and micronutrients such as Cu 1.0%, Zn 3.0%, Mn1.0%, Fe 2.5%, B 0.5%, and Mo 0.1% as a foliar application at bud initiation stage leads to higher growth and yield components and greater uptake of macro and micronutrients from the sunflower plant. On the other hand, the control treatment showed the lowest yield characteristics and nutrient uptake compared to the other treatments. The foliar application of micronutrients enhanced the concentration of macro and micronutrients in the sunflower plant. Furthermore, elemental Sulphur increases soil nutrient mobility by reducing the soil pH, which positively affects nutrient uptake, thereby improving the physical growth of the crops.

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