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Priya Sharma
Ph.D. Scholar, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

AS Karle
Chief Agronomist & I/C, AICRP on IFS, VNMKV, Parbhani, Maharashtra, India

AT Jadhav
M.Sc. Scholar, Department of Agronomy, College of Agriculture, Latur, VNMKV, Parbhani, Maharashtra, India

Rajkumar C
M.Sc. Scholar, Department of Agronomy, College of Agriculture, Latur, VNMKV, Parbhani, Maharashtra, India

BK Choudhari
M.Sc. Scholar, Department of Agronomy, College of Agriculture, Latur, VNMKV, Parbhani, Maharashtra, India

Corresponding Author:
Priya Sharma
Ph.D. Scholar, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Influence of micronutrients on growth and productivity of *kharif* sunflower (*Helianthus annuus* L.)

Priya Sharma, AS Karle, AT Jadhav, Rajkumar C and BK Choudhari

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Abstract
A field experiment was carried out during *kharif* season of 2022 at Experimental Farm, Agronomy Section, Oilseeds Research Station, Latur to investigate the effect of different micronutrients on growth and yield of sunflower (*Helianthus annuus* L.). The experiment consisted of nine treatments laid out in randomized block design replicated thrice. The treatments were T_1 - Control, T_2 - RDF (90:45:45 kg N:P:K ha^{-1}), T_3 - RDF + $ZnSO_4$ @ 20 kg ha^{-1}, T_4 - RDF + $FeSO_4$ @ 20 kg ha^{-1}, T_5 - RDF + Borax @ 2 kg ha^{-1}, T_6 - RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}, T_7 - RDF + Multimicronutrient Grade-1 @ 25 kg ha^{-1}, T_8 - RDF + Multimicronutrient Grade-2 @ 0.2% at 20 DAS, T_9 - RDF + Multimicronutrient Grade-1 @ 25 kg ha^{-1} + Multimicronutrient Grade- 2 @ 0.2% at 20 DAS. Application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1} (T_6) recorded significantly highest growth attributes *viz.* plant height (195.53 cm), number of functional leaves plant^{-1} (38.43), leaf area plant^{-1} (84.84 dm^2), stem girth (7.38 cm), head diameter plant^{-1} (19.10 cm), dry matter accumulation plant^{-1} (205.33 g), yield attributes viz. number of filled seeds plant^{-1} (905), weight of head plot^{-1} (6.47 kg), seed yield (1791 kg ha^{-1}) and straw yield (3579 kg ha^{-1}) being at par with RDF + Borax @ 2 kg ha^{-1} (T_5) and RDF + $ZnSO_4$ @ 20 kg ha^{-1} (T_3) over rest of the treatments.

Keywords: Borax, $FeSO_4$, multimicronutrient grade, sunflower, $ZnSO_4$

Introduction
Sunflower being an important oilseed crop grown in *kharif* and *rabi* seasons across the country and holds fourth position after soybean, rapeseed and groundnut. The area under sunflower cultivation in India is 0.22 M ha, with the production of 0.23 MT and productivity of 1023 kg ha^{-1} in 2020-21 (GOI, 2021) [1]. In Maharashtra, sunflower is grown on 26,000 ha area with a production of 12,200 tonnes and productivity of 467.8 kg ha^{-1} (Krishi Vibhag, 2021) [2]. Sunflower is introduced in India from North America in 1969 to curtail the deficiency of country's edible oil production (Shankergoud *et al.*, 2006) [3].

The kernel oil content ranges from 48 to 53% and for seed it ranges from 28 to 35%. The protein content ranges from 14 to 19%. The crude fibre and ash contents vary from 16 to 27% and 2.4 to 3.0%, respectively. High proportion of essential fatty acid – linoleic acid (18:2) which ranges between 40-67% considered to reduce blood cholesterol level and hence sunflower has a considerable significance. The oleic acid content of oil is 22-50% due to which it has greater oxidative stability and is useful as a frying oil in preparation of snack foods. Sunflower oil has light hue, bland flavour, high smoke point (252 – 255 °C) and good nutritional value because of this it is considered as premium oil. Sunflower's protein score is 63 (Soluski and Sarware, 1973) [4] and essential amino acid index is 68 as against 79 for soybean and 100 for egg. Sunflower is also a good source of water-soluble B complex vitamins, namely nicotinic acid (318.7 mg kg^{-1}), thiamine (37.8), pantothenic acid (44.8) and riboflavin (3.6). Its seeds also contain some antinutritional constituents such as chlorogenic acid (1.4 to 4.0%) and phenolic compounds (2.6 to 3.8%).

Indian soils are generally deficient in nutrient status, particularly with respect to micronutrients. During 1960s, green revolution led to increase in food grain production to feed nation's rapidly increasing population but reduced soil fertility by depleting micronutrient reserves of soil. Later on, intensification of agriculture led to further depletion of micronutrient reserves causing the deficiency of other micronutrients besides aggravating the existing ones (Takkar and Shukla, 2015) [5]. Farmers are indiscriminately using micronutrient fertilizers which is also leading towards the depletion of soil fertility. In order to tackle the above challenges, the present investigation was formulated to improve growth and productivity of sunflower.

Materials and Methods

The experiment was conducted at Experimental Farm, Agronomy Section, Oilseeds Research Station, Latur to study the effect of different micronutrients on growth and yield of sunflower (*Helianthus annuus* L.) during *kharif*, 2022. The soil of experimental plot was clayey in texture, neutral in reaction having pH (7.02), low in available nitrogen (231 kg ha^{-1}), very low in available phosphorus (8.57 kg ha^{-1}), very high in available potassium (579.80 kg ha^{-1}) and deficient in micronutrients. Soil was well-drained which was favourable for optimum growth of the crop. The experiment was laid out in randomized block design with 9 treatments replicated thrice. The truthful seed of sunflower var. LSFH-171 was used for sowing with a seed rate of 5 kg ha^{-1}. Sowing was done by dibbling on 17 July, 2022 and the recommended dose of fertilizer used was 90:45:45 kg N:P:K ha^{-1}. Nitrogen, phosphorus and potash (90:45:45 kg ha^{-1}) was applied through urea (46% N), single super phosphate (16% P_2O_5, 48% N) and muriate of potash (60% KCl), respectively. Half dose of nitrogen and full dose of phosphorus and potash were applied in furrow at the time of sowing and remaining half dose of nitrogen was top dressed 30 DAS. Zinc sulphate (21% Zn), ferrous sulphate (19% Fe), borax (11% B) and multimicronutrient grade-1 (2% Fe, 1% Mn, 5% Zn, 0.5% Cu, 1% B) were applied as soil application at sowing while multimicronutrient grade-2 (2.5% Fe, 1% Mn, 3% Zn, 1% Cu, 0.5% B, 0.1% Mo) was foliar sprayed 20 DAS as per the treatments. In control treatment, fertilizers were not applied. The treatments were T_1 - Control, T_2 - RDF (90:45:45 kg N:P:K ha^{-1}), T_3 - RDF + $ZnSO_4$ @ 20 kg ha^{-1}, T_4 - RDF + $FeSO_4$ @ 20 kg ha^{-1}, T_5 - RDF + Borax @ 2 kg ha^{-1}, T_6 - RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}, T_7 - RDF + Multimicronutrient Grade-1 @ 25 kg ha^{-1}, T_8 - RDF + Multimicronutrient Grade-2 @ 0.2% at 20 DAS, T_9 - RDF + Multimicronutrient Grade-1 @ 25 kg ha^{-1} + Multimicronutrient Grade- 2 @ 0.2% at 20 DAS. The recommended cultural practices and plant protection measures were undertaken as per recommendation. The crop was harvested on 12 October, 2022. Data on various variables were analyzed by analysis of variance at P = 0.05 level of probability (Panse and Sukhatme, 1967) [6].

Results and Discussion

Growth attributes

Results presented in Table 1 reveal that growth attributes of sunflower *viz.* plant height, leaf area plant^{-1}, stem girth, head diameter and dry matter accumulation plant^{-1} of sunflower were influenced significantly due to different treatments.

Table 1: Plant height, number of functional leaves plant^{-1}, leaf area plant^{-1}, stem girth, head diameter plant^{-1} and dry matter accumulation plant^{-1} of sunflower as influenced by different treatments

Treatments	Plant height (cm)	Number of functional leaves plant^{-1}	Leaf area plant^{-1} (dm^2)	Stem girth (cm)	Head diameter plant^{-1} (cm)	Dry matter accumulation plant^{-1} (g)
	At harvest	60 DAS	60 DAS	75 DAS	At harvest	At harvest
T_1: Control	137.89	17.53	57.14	5.12	11.98	115.33
T_2: RDF (90:45:45 kg N:P:K ha^{-1})	165.27	23.13	65.98	6.36	15.28	132.33
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	183.53	35.33	75.75	6.91	17.90	191.33
T_4: RDF + $FeSO_4$ @ 20 kg ha^{-1}	175.70	33.30	72.79	6.46	16.67	182.33
T_5: RDF + Borax @ 2 kg ha^{-1}	190.11	36.60	80.30	7.14	18.60	194.33
T_6: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	195.53	38.43	84.84	7.38	19.10	205.33
T_7: RDF + Multimicronutrient Grade-1 @ 25 kg ha^{-1}	168.72	25.07	68.53	6.46	15.69	157.00
T_8: RDF + Multimicronutrient Grade-2 @ 0.2% at 20 DAS	166.93	24.47	66.35	6.42	15.68	145.00
T_9: RDF + Multimicronutrient Grade-1 @ 25 kg ha^{-1} + Multimicronutrient Grade-2 @ 0.2% at 20 DAS	171.62	27.33	69.93	6.53	16.44	176.67
SE(m)±	8.17	1.72	4.03	0.30	0.78	7.45
C.D. (P = 0.05)	23.74	5.00	11.73	0.87	2.25	21.66

Plant height (cm)

Application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1} (T_6) recorded highest plant height (195.53 cm) which was at par with the application of RDF + Borax @ 2 kg ha^{-1} (T_5), RDF + $ZnSO_4$ @ 20 kg ha^{-1} (T_3) and RDF + $FeSO_4$ @ 20 kg ha^{-1} (T_4).

This might be due to involvement of zinc in biosynthesis of plant hormone – auxin, protein synthesis and activates over 300 enzymes in plants. Zinc, iron and boron help in better utilization of nitrogen and phosphorus in plant which in turn maintains a synergistic relationship among nutrients and leads to vigorous growth. The results obtained are in accordance with the findings of Chowdhary *et al*. (2010) [7].

Number of functional leaves plant^{-1} and leaf area plant^{-1} (dm^2)

The maximum number of functional leaves plant^{-1} (38.43) and leaf area plant^{-1} (84.84 dm^2) were obtained with the application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1} (T_6) which was at par with RDF + Borax @ 2 kg ha^{-1} (T_5) and RDF + $ZnSO_4$ @ 20 kg ha^{-1} (T_3) and found significantly superior over rest of the treatments.

Higher number of functional leaves plant^{-1} and leaf area plant^{-1} might be due to better growth of meristem and sufficient supply of micronutrients in an adequate proportion to the plant. The results are confirmative with the findings of Pattanayak *et al.* (2016) [8] and Indu and Singh (2020) [9].

Stem girth (cm) and head diameter plant^{-1} (cm)

Significantly higher stem girth at 75 DAS (7.38 cm) and head diameter plant^{-1} (19.10 cm) were recorded with the combined application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1} (T_6) over rest of the treatments and found to be at par with RDF + Borax @ 2 kg ha^{-1} (T_5) and RDF + $ZnSO_4$

@ 20 kg ha^{-1} (T_3).

Increase in stem girth and head diameter $plant^{-1}$ might be attributed to the influence of boron and zinc responsible for boosting the borate-sugar complex formation and its translocation through the plant from source to sink and assimilation in the sink (head). These results are in accordance with findings of Kawade *et al.* (2018) [10] and Elayaraja *et al.* (2019) [11].

Dry matter accumulation $plant^{-1}$ (g)

Significantly highest dry matter accumulation $plant^{-1}$ (205.33 g) was recorded with the combined application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1} (T_6) over rest of the treatments and found to be at par with RDF + Borax @ 2 kg ha^{-1} (T_5) and RDF + $ZnSO_4$ @ 20 kg ha^{-1} (T_3).

Higher dry matter accumulation $plant^{-1}$ might be due to the effect of micronutrients *i.e.*, zinc, iron and boron in combination leads to the better vegetative and reproductive growth of plant by synthesizing plant growth promoting hormones and enhancing photosynthetic potential of the plants. Similar results were reported in the findings of Rahul *et al.* (2011) [12] and Rex Immanuel *et al.* (2019) [13].

Yield and yield attributes

Results showed in Table 2 reveal that number of filled seeds $plant^{-1}$, number of unfilled seeds $plant^{-1}$, weight of head $plot^{-1}$, seed yield and straw yield were influenced significantly due to different treatments.

Table 2: Number of filled seeds $plant^{-1}$, number of unfilled seeds $plant^{-1}$, weight of head $plot^{-1}$, seed yield and straw yield of sunflower as influenced by different treatments

Treatments	Number of filled seeds $plant^{-1}$	Number of unfilled seeds $plant^{-1}$	Weight of head $plot^{-1}$ (kg)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1: Control	431.33	296.00	2.67	771	1828
T_2: RDF (90:45:45 kg N:P:K ha^{-1})	601.33	284.67	4.00	1179	2611
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	830.67	161.33	5.67	1565	3297
T_4: RDF + $FeSO_4$ @ 20 kg ha^{-1}	747.67	172.00	5.23	1461	3069
T_5: RDF + Borax @ 2 kg ha^{-1}	844.00	162.33	6.33	1612	3394
T_6: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	905.00	133.67	6.47	1791	3579
T_7: RDF + Multimicronutrient Grade-1 @ 25 kg ha^{-1}	638.33	268.67	4.83	1267	2744
T_8: RDF + Multimicronutrient Grade-2 @ 0.2% at 20 DAS	618.33	283.67	4.77	1236	2723
T_9: RDF + Multimicronutrient Grade-1 @ 25 kg ha^{-1} + Multimicronutrient Grade-2 @ 0.2% at 20 DAS	725.00	182.67	5.10	1415	3001
SE(m)±	32.93	11.27	0.33	79	144
C.D. (P = 0.05)	95.73	32.78	0.95	230	419

Number of filled seeds $plant^{-1}$

Maximum number of filled seeds $plant^{-1}$ (905) were obtained by the application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1} (T_6) which was at par with RDF + Borax @ 2 kg ha^{-1} (T_5) (844) and RDF + $ZnSO_4$ @ 20 kg ha^{-1} (T_3) (830.67) and found significantly superior over rest of the treatments.

This might be due to the efficient translocation and assimilation of photosynthates to the sink from source, pollen germination and pollen viability due to the application of boron. In addition to boron, zinc also contributes to flowering and fruit set and hence number of filled seeds $plant^{-1}$ increased. The inferences are confirmative with the findings of Elayaraja *et al.* (2019) [11] and Waghmare *et al.* (2022) [14].

Number of unfilled seeds $plant^{-1}$

Minimum number of unfilled seeds $plant^{-1}$ (133.67) were obtained by the application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1} (T_6) which was at par with RDF + $ZnSO_4$ @ 20 kg ha^{-1} (T_3) (161.33) and RDF + Borax @ 2 kg ha^{-1} (T_5) (162.33) and found significantly superior over rest of the treatments.

Unfilled seeds are the effect of numerous factors including Zn, Fe and B deficiency in the center of the capitulum. Lower the number of chaffy seeds, higher will be the production of crop. The findings were supported by Chowdhary *et al.* (2010) [7] and Gawande *et al*. (2022) [15].

Weight of head $plot^{-1}$ (kg)

Application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1} (T_6) was found to record maximum weight of head $plot^{-1}$ (6.47 kg) which was at par with RDF + Borax @ 2 kg ha^{-1} (T_5) (6.33 kg) and RDF + $ZnSO_4$ @ 20 kg ha^{-1} (T_3) (5.67 kg) and found significantly superior over rest of the treatments.

Seed yield (kg ha^{-1})

Significantly maximum seed yield (1791 kg ha^{-1}) was obtained with the application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1} (T_6) over rest of the treatments and found to be at par with RDF + Borax @ 2 kg ha^{-1} (T_5) (1612 kg ha^{-1}) and RDF + $ZnSO_4$ @ 20 kg ha^{-1} (T_3) (1565 kg ha^{-1})

The increased seed yield caused by the application of boron may most likely owing to a healthy balance of photosynthesis and respiration. Along with boron, zinc and iron also plays a pivotal role in increasing seed yield by better partitioning of assimilates to the sink. These micronutrients increase the uptake of macronutrients which enhances the vegetative and reproductive growth of the crop and hence productivity of the crop is increased. These findings are confirmative with those of Ramulu *et al.* (2011) [16] and Rex Immanuel (2019) [17].

Straw yield (kg ha^{-1})

Application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1} (T_6) was found to record maximum straw yield (3579 kg ha^{-1}) which was at par with RDF + Borax @ 2 kg ha^{-1} (T_5) (3394 kg ha^{-1}) and RDF + $ZnSO_4$ @ 20 kg ha^{-1} (T_3) (3297 kg ha^{-1}) and found significantly superior over rest of the treatments.

Higher straw yield might be attributed to the better growth and development of crop because of application of micronutrients. These findings are in confirmative with the findings of Kumbhar (2017) [18] and Rahul *et al.* (2021) [12].

Conclusion

From the above study it can be concluded that application of RDF along with combined application of $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1} (T_6) performed better in terms of growth and productivity of sunflower.

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