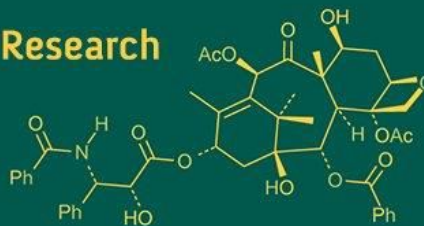


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(8): 865-869
www.biochemjournal.com
Received: 22-05-2025
Accepted: 26-06-2025

Sweta Kumari
M.Sc. Scholar, Department of
Agronomy, Naini Agricultural
Institute, SHUATS,
Prayagraj, Uttar Pradesh,
India

Joy Dawson
Professor and Head,
Department of Agronomy,
Naini Agricultural Institute,
SHUATS, Prayagraj Uttar
Pradesh, India.

Atul Kumar Sharma
M.Sc. Scholar, Department of
Agronomy, Naini Agricultural
Institute, SHUATS,
Prayagraj, Uttar Pradesh,
India

Subhadeep Panda
M.Sc. Scholar, Department of
Agronomy, Naini Agricultural
Institute, SHUATS,
Prayagraj, Uttar Pradesh,
India

Shrutika Mukherjee
M.Sc. Scholar, Department of
Agronomy, Naini Agricultural
Institute, SHUATS,
Prayagraj, Uttar Pradesh,
India

Corresponding Author:
Sweta Kumari
M.Sc. Scholar, Department of
Agronomy, Naini Agricultural
Institute, SHUATS,
Prayagraj, Uttar Pradesh,
India

Influence of foliar application of iron and zinc on growth and yield of Chia seed. (*Salvia hispanica* L.)

Sweta Kumari, Joy Dawson, Atul Kumar Sharma, Subhadeep Panda and Shrutika Mukherjee

DOI: <https://www.doi.org/10.33545/26174693.2025.v9.i8Sm.5266>

Abstract

A field experiment was conducted during *Rabi* season of 2024 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, (U.P) to determine "Influence of Foliar application of Iron and Zinc on growth & yield of Chia seed (*Salvia hispanica* L.)". The treatments included Iron at (100 ppm and 200 ppm) and Zinc at (100 ppm and 200 ppm) and absolute control. The experiment was layout in Randomized Block Design (RBD) with 9 treatments and replicated thrice. The results revealed that Plant height (77.92 cm) was recorded in Treatment 5 (Iron 100 ppm + Zinc 100 ppm), dry weight (15.53 g) was recorded in Treatment 8 (Iron 200 ppm + Zinc 200 ppm), Post harvest Number of spikes/Plant (13.87) was recorded in Treatment 9 (Control plot), Number of seeds/spike (292) was recorded in Treatment 5 (Iron 100 ppm + Zinc 100 ppm), Test weight (1.93 g) was recorded in Treatment 3 (Zinc 100 ppm), Seed yield (6.52 q/ha) and Haulm yield (22.32 q/ha) was recorded in Treatment 5 (Iron 100 ppm + Zinc 100 ppm) compared to other treatments. Maximum gross return (82584.20 INR/ha), Net return (INR 56811.20) and B:C ratio (2.20) was recorded in Treatment 5 (Iron 100 ppm + Zinc 100 ppm).

Keywords: Chia, economics, growth, iron, yield, zinc

Introduction

Chia seed (*Salvia hispanica* L.) is native to Mexico and Guatemala belongsto the family *Lamiaceae*, sub-family *Nepetoideae* and genus *Salvia*. The seeds of this annual herbaceous plant were already eaten thousands of years ago. According to Ixtaina *et al.* (2008), the species' natural habitats were mountainous regions that stretched from northern Guatemala to west central Mexico. It has oppositely oriented leaves and small, purple or white flowers (3 to 4 mm) with a merged flower portion and a smaller corolla. It can reach a height of one meter. Chia seeds have an oval form and range in size from 1-2 mm. They can be gray, black, or white with a black point (Bresson *et al.*, 2009) [3]. The Spanish word "Chian," which meaning greasy, is the source of the English term "chia." It is an oilseed that is rich in omega-3 and omega-6 fatty acids, high-quality protein, dietary fiber, vitamins, minerals, and a variety of polyphenolic antioxidants that protect the seeds against microbial and chemical deterioration. Because of its health benefits, the chia crop is becoming more and more popular worldwide. As a result, it is considered a super food crop because of its exceptional nutritional worth. It can be used as a dietary supplement and is eaten as seeds. The fact that chia contains several chemicals that have antioxidant properties adds to the seed's appeal. The flavanols, caffeic acid, and chlorogenic acid are among the most significant; myricetin, quercetin, and kaempferol are also present. Protein (15-25 percent), lipids (30-33 percent), carbs (26-41 percent), high dietary fiber (18-30 percent), ash (4-5 percent), minerals, vitamins, and dry matter (90-93 percent) make up chia seeds. It has a significant antioxidant content as well. According to heavy metal analysis, chia seeds are devoid of mycotoxins and contain safe amounts of these metals that do not surpass the maximum limits required for food safety. The absence of gluten is another important characteristic of chia seeds (Mohd Ali *et al.*, 2012) [11]. It contains Calcium (536 mg), magnesium (350 mg), potassium (564 mg), phosphorus (751 mg), iron (6.3 mg), copper (1.4 mg), and zinc (4.4 mg) are among the minerals found in 100 g of chia seeds. Reduced enzyme activity caused by mineral deficiencies affects the human body and causes immune system and organ dysfunction,

which frequently results in depression (Kon *et al.* 2013) [7]. Chia plants have a moderate tolerance for salt and acid and may thrive in a variety of sandy and well-drained clay soil types. Chia seeds are widely grown for a variety of applications in Mexico, America, Canada, Chile, Australia, New Zealand, and Southeast Asia, with commercial field production estimated at 550-600 kg/ha. Cultivars and growth environments have an impact on yield. There have also been reports of a yield of 2500 kg/acre under suitable agronomic circumstances. It is grown on 126 thousand hectares of land worldwide, yielding 103 thousand tons of product. With 38% of global chia production, Bolivia is the largest producer in South America (Peperkamp, 2015) [14], followed by Peru with 32 per cent and United States of America with 6.3 per cent. Chia seeds were initially grown in Uttar Pradesh (Amseruva and Siddhaur), while they were previously mostly grown in Mandsaur and Neemuch, India. Harishchandra Singh, the Sultanpur District Military Welfare Officer, has initiated the growing of Chia seeds. Growing chia crops successfully in India will boost the country's economy and raise living standards and health. In order to meet the enormous demand in both the Indian and international markets, chia is rapidly growing in popularity as a superfood worldwide. As a result, it may be grown as a lucrative commercial crop in India. One of the several studies being conducted to make agriculture, food, and nutritional security drought-proof is the cultivation of chia (Singh and Verma 2022) [18].

According to Senthilkumar (2018) [16], micronutrients are crucial for boosting crop output. Plants need essential nutrients, both macro and micro, to function and develop properly. It is commonly known that micronutrients are important for plant nutrition. Micronutrients are essential for the growth of most plants and make up less than 1% of their dry weight. For plants to complete their life cycle, they need certain micronutrients, such as boron, chlorine, copper, iron, manganese, molybdenum, nickel, and zinc. Additionally, they are necessary to keep proteins and cellular structures stable. Even though micronutrients were supplied in very modest levels, their presence improved plant productivity and quality, and their absence was associated with poor plant development and yield (Kobrae *et al.*, 2013) [6]. Crop nutrient uptake is increased by foliar spraying of micronutrients because it is a more affordable, accessible, and efficient method that also lowers environmental pollution and encourages root growth (Aziz *et al.*, 2021) [1]. Micronutrients like boron, iron, and zinc are necessary for plants to complete their life cycles. They also play a significant role in maintaining the stability and biosynthesis of proteins, cellular structures, molecules, enzymes, carbohydrates, and metabolism. They also help plants become more resilient to environmental stressors and maintain chlorophyll, electron transport, and antioxidative systems. They might also affect photosynthesis, respiration, cell division, plant maturity, and meristematic tissue growth. Additionally, micronutrients support seed formation, reproduction, and oil synthesis. For the best crop nutrition and development, micronutrients must be applied topically (Prusty *et al.*, 2022) [15].

The cofactor iron (Fe) is necessary for many different enzymes that catalyze a wide range of biological reactions. Therefore, iron is required at many stages of the biosynthetic pathways and is essential for the production of chlorophyll and chloroplasts, among other plant growth

processes (Boghdady, 2017) [2]. The generation of reactive oxygen species (ROS), which can bind to thiol, carboxyl, and imidazole groups in proteins and alter their structures and functions, makes excess iron extremely dangerous even though it is essential for plant growth. Metal imbalance can result from an excess of iron supply since iron and other essential metals have an antagonistic relationship (Singh *et al.*, 2016) [19].

An essential element, Zinc is linked to a number of enzymatic processes in all photosynthetic plants. Essential growth regulators and enzymes require zinc. Another essential element for increasing plant production and growth is zinc (Zn). It functions as an activator of certain enzymes, such as alcohol dehydrogenase, hexose kinase, and carbonic anhydrase. In addition to aiding in cell division and protein metabolism, zinc is required for the manufacture of auxin, indole-3-acetic acid, and chlorophylls (Singh *et al.*, 2018) [17].

Materials and Methods

During *Rabi* season 2024, a field experiment was carried out at the Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P). The experimental plot's soil had a sandy loam texture, practically neutral soil reaction (pH 6.9), electrical conductivity (0.296 dsm-1), available N (278.93 kg/ha), available P (10.8 kg/ha), and available K (206.4 kg/ha). With nine treatments and three replications, the experiment was set up using a Randomized Block Design. On October 17, 2024, chia seeds were planted directly in hills with a 45-cm gap between hills and a 15-cm intro-row spacing. The seeds were mixed with fine sand (1:2) at a rate of 5 kg per hectare and put into the furrow no deeper than 2 cm. continually and with earth on top. To maintain the ideal plant population, gaps created by mortality were filled by resowing 12 days after the initial sowing. The recommended chia fertilizer dosage of 60:40:40 kg/ha was used. Urea was used to apply nitrogen, single super phosphate was used to apply phosphorus, and muriate of potash was used to apply potassium. The following treatments were applied to plants at varying doses 45 DAS. The treatment combination are as follows, T₁ (Iron 100 ppm), T₂ (Iron 200 ppm), T₃ (Zinc 100 ppm), T₄ (Zinc 200 ppm), T₅ (Iron 100 ppm × Zinc 100 ppm), T₆ (Iron 100 ppm × Zinc 200 ppm), T₇ (Iron 200 ppm × Zinc 100 ppm), T₈ (Iron 200 ppm × Zinc 200 ppm), T₉ (Control Plot 60:40:40 Kg NPK/ha).

The Observations on several growth parameters were documented. In order to determine their significance, plant height, dry weight, number of spikes/plant, number of seeds/plant, test weight, seed yield, and haulm yield were statistically analyzed. The results of the experiment were then compiled using scientific reasoning and covered under the following heading:

Results and Discussion

Growth Attributes

The data on growth-attributing traits are summarized in Table 1. During the course of the study, it was observed that plant height increased progressively following germination, reaching its peak around 80 days after sowing (DAS). Significantly highest value for plant height (77.92 cm) was recorded with Treatment 5 with the foliar application of Iron (100 ppm) combined with a Zinc (100 ppm), which was statistically similar to T₃ (69.81 cm), T₄ (69.81 cm), T₆

(76.26 cm), T₇ (71.29 cm) and T₉ (70.28 cm). The positive impact of iron and zinc on crop growth may be due to iron increases cell division, plays as a catalyst role in respiration process and several chemical reactions that are directly responsible for enhanced growth and development the result were in accordance with (Khosa *et al.* 2011) [5]. Zinc application resulted in significant and maximum plant height. It may be because zinc plays a key role in the metabolism of ribosomal content and RNA in plant cells, which stimulates the production of proteins, carbohydrates, and DNA. It is also necessary for the synthesis of tryptophan, which is a precursor to IAA, a chemical that promotes growth. Similar results were shown by Mohammed *et al.* (2020) [12]. When Iron (200 ppm) and Zinc (200 ppm) were applied topically, the highest dry weight (15.40 g) was seen in Treatment 8, which was statistically comparable to T₅ (15.40 g) and T₉ (15.20 g). This suggests that iron (Fe) is a cofactor for about 140 enzymes that catalyze distinct biochemical events and play a number of crucial roles in the growth and development of plants, such as the creation of chlorophyll, thylakoids, and chloroplasts. Similar findings by Miller *et al.* (1995) [10] can support these. According to Singh *et al.* (2018) [17], zinc is required for the biosynthesis of auxin, indole-3-acetic acid, aids in protein metabolism and cell division, is involved in photosynthesis and CO₂ sequestration, and is involved in the formation of chlorophylls.

Yield Attributes

The data on yield-attributing traits are summarized in Table 2. The highest number of Spikes per plant (13.87) was observed in control plot, referred to as Treatment 9, however, this result was found to be statistically not significant. A higher number of Seeds per Spike (292) was recorded in Treatment 5 with the foliar application of Iron (100 ppm) combined with Zinc (100 ppm), which was statistically similar to T₃ (272.3) and T₄ (284.7). This may be because iron aids in the biosynthesis of cytochrome and chlorophyll in addition to its role in the metabolism of chloroplast RNA, which increases the amount of biosynthesis materials produced and accumulated. As a result, growth was accelerated and more spikes were produced. In Marschner *et al.* 1994 [9] Additionally, zinc plays a role in the growth of flower buds, tryptophan synthesis, and the transport of carbohydrates to the bud or to the bud itself (Kumar *et al.*, 2010) [8]. With the application of zinc (100 ppm), Treatment 3 also produced the highest test weight (1.93 g); nevertheless, this outcome was likewise determined to be not statistically significant.

Seed Yield (q/ha)

The data on grain yield is summarized in Table 2. showed that significantly highest seed yield (6.52 q/ha) was observed with the foliar application of iron 100 ppm along with zinc 100 ppm *i.e.* (Treatment 5). However, T₁ (5.93 q/ha), T₄ (6.22 q/ha) and T₉ (5.73 q/ha) was found to be statistically at par with the treatment 1. According to Kobraee *et al.* (2013) [6], this could be because the foliar application strategy of iron and zinc led to the availability of nutrients, which may have increased the transfer of photosynthetic to sink and improved pollen viability, blooming, and seed production yield.

Haulm (q/ha)

The data on stover yield is summarized in Table 2, showed that a significantly maximum haulm yield (22.32 q/ha) was observed with the application of iron (100 ppm) along with zinc (100 ppm) *i.e.* (Treatment 5). However, T₁ (21.63 q/ha), T₄ (21.43 q/ha), T₆ (21.82 q/ha) and T₉ (20.64 q/ha) The results showed that it was statistically equivalent to treatment 5. Iron uptake by plants was linked to the Fe concentration in the nutrient solution, and the uptake rate during the growth season peaked during the seed formation stage, which may account for any further increase in haulm yield. As the concentration of iron in the nutritional solution rose, so did the iron content of the leaves and roots. These findings concur with those of Yeritsyan *et al.* (2002) [21]. Increased plant height and higher dry matter accumulation at harvest, which most likely resulted from the plants' enhanced assimilate production, could be the cause of the stover yield increase. Zn's role in ribosomal, RNA, indole acetic acid, and glucose metabolism may be the cause of the improvement in chia growth and yield. By accelerating photosynthesis, chlorophyll synthesis, and Crop Growth Rate (CGR), zinc supply enhanced crop growth and production. (Mumivand *et al.*, 2021) [13] published a similar report.

Harvest Index (%)

The data on harvest index is summarized in Table 2, showed that the highest harvest index (26.51%) was observed with the foliar application of iron (200 ppm) along with zinc (100 ppm) *i.e.* (Treatment 7), However T₄ (22.54%), T₅ (22.59%) and T₈ (22.93) was found to be statistically at par with treatment 7. Which might be iron and zinc acts as a significant role in reclamation of materials, increasing the synthesis of mRNA, regulation of plant water and stomatal openness. Same result were obtained by (Yadegari, 2017) [20].

Economics

The data on the economics of different treatments summarized in Table 3. The cost of cultivation of chia ranged from Rs 20087.00 to Rs 30852.40 ha⁻¹. The higher cost of cultivation (Rs 30852.40 ha⁻¹) was noticed with the foliar application of Iron (200 ppm) along with Zinc (200 ppm) in treatment 8. The lower cost of cultivation (Rs 20087.00 ha⁻¹) was recorded in control plot in treatment 9. The higher gross return (82584.20 INR/ha), Net return (56811.20 INR/ha) and B:C ratio (2.20) was observed with foliar application of Iron (100 ppm) along with Zinc (100 ppm) in treatment 5. According to research, applying iron and zinc topically may enhance the amount of new herbage biomass per plant. This, in turn, may increase the number of leaves, branches, and plant height, among other growth characteristics, ultimately leading to a larger herbage output. According to research on mint by Kumar *et al.* (2010) [8], the treatment of micronutrients increased leaf area for adequate photosynthetic surface, which raised chia crop haulm and seed yield. Benefit and net return: The cost ratio is a metric used to assess a crop production system's economic feasibility. Due to the varying costs of iron and zinc concentrations associated with various treatments, there was variation in the cost of cultivation.

Table 1: Influence of foliar application of Iron and Zinc on growth attributes of chia.

	Treatment Combinations	Plant Height (Cm)	Plant Dry Wt. (g)	CGR (g/m ² /day)	RGR (g/g/day)
1.	Iron 100 ppm	63.28	12.80	7.46	0.080
2.	Iron 200 ppm	62.47	11.73	6.57	0.071
3.	Zinc 100 ppm	69.81	12.40	7.31	0.080
4.	Zinc 200 ppm	69.81	11.13	6.42	0.076
5.	Iron 100 ppm+Zinc 100 ppm	77.92	15.40	8.94	0.077
6.	Iron 100 ppm+ Zinc 200 ppm	76.26	9.73	5.28	0.066
7.	Iron 200 ppm+ Zinc 100 ppm	71.29	13.33	7.60	0.074
8.	Iron 200 ppm+ Zinc 200 ppm	66.77	15.53	9.38	0.085
9.	Control (60:40:40 Kg NPK/ha)	70.28	15.20	8.40	0.069
	SEm(±)	3.10	0.69	0.44	0.004
	CD (p = 0.05)	9.28	2.08	1.35	-

Table 2: Influence of foliar application of Iron and Zinc on yield attributes at harvest of chia.

	Treatment Combinations	No. of Spikes/Plant	No. of Seeds/Spike	Test weight (g)	Seed yield (q/ha)	Haulm yield (q/ha)	Harvest index (%)
1.	Iron 100 ppm	10.93	227.7	1.78	5.93	21.63	21.47
2.	Iron 200 ppm	10.00	223.1	1.41	4.94	20.24	19.57
3.	Zinc 100 ppm	9.73	272.3	1.93	5.33	20.54	20.63
4.	Zinc 200 ppm	13.27	284.7	1.20	6.22	21.43	22.54
5.	Iron 100 ppm + Zinc 100 ppm	12.87	292.0	1.23	6.52	22.32	22.59
6.	Iron 100 ppm+ Zinc 200 ppm	9.80	257.0	1.83	4.94	21.82	18.48
7.	Iron 200 ppm + Zinc 100 ppm	10.53	243.2	1.28	5.63	15.60	26.51
8.	Iron 200 ppm+ Zinc 200 ppm	11.40	241.6	1.73	5.43	18.27	22.93
9.	Control (60:40:40 Kg NPK/ha)	13.87	231.3	1.74	5.73	20.64	21.76
	SEm(±)	1.88	5.72	0.29	0.28	0.59	1.37
	CD (p = 0.05)	-	17.15	-	0.85	1.77	4.11

Table 3: Influence of foliar application of Iron and Zinc on economics of chia

	Treatment Combinations	Cost of cultivation (INR/ha)	Gross returns (INR/ha)	Net returns (INR/ha)	B:C ratio
1.	Iron 100 ppm	22930.00	63125.93	40195.93	1.75
2.	Iron 200 ppm	25473.00	72449.38	46976.38	1.84
3.	Zinc 100 ppm	22930.00	68068.64	45138.64	1.97
4.	Zinc 200 ppm	25466.40	78926.42	53460.02	2.10
5.	Iron 100 ppm+Zinc 100 ppm	25773.00	82584.20	56811.20	2.20
6.	Iron 100 ppm+ Zinc 200 ppm	28309.40	75165.43	46856.03	1.66
7.	Iron 200 ppm+ Zinc 100 ppm	28316.00	70560.99	42244.99	1.49
8.	Iron 200 ppm+ Zinc 200 ppm	30852.40	68814.32	37961.92	1.23
9.	Control (60:40:40 Kg NPK/ha)	20087.00	62928.40	42841.40	2.13

Conclusion

Based on one year of experimentation, the combined foliar application of iron at (100 ppm) along with zinc (100 ppm) as in Treatment 5—proved most effective in maximizing both yield and economic returns from chia cultivation.

Acknowledgement

I am thankful to the Department of Agronomy, Naini Agriculture Institute, SHUATS, Prayagraj for their immense support during my trial.

References

1. Aziz MZ, Yaseen M, Abbas T, Naveed M, Mustafa A, Yasir H, Saeed Q, Xu M. Foliar application of micronutrients enhances crop stand, yield and the biofortification essential for human health of different wheat cultivars. *Journal of Integrative Agriculture*. 2021;18:1369-1378.
2. Boghdady MS. Role of micronutrients in improving yield and quality of seeds in fenugreek plants (*Trigonella foenum-graecum* L.). *Egyptian Journal of Agronomy*. 2017;39(3):267-277.
3. Bresson J, Flynn A, Heinonen M. Opinion on the safety of chia seeds (*Salvia hispanica* L.) and ground whole chia seeds as a food ingredient. *EFSA Journal*. 2009;996:1-26.
4. Ixtaina V, Nolasco S, Tomás M. Physical properties of chia (*Salvia hispanica* L.) seeds. *Industrial Crops and Products*. 2008;28:286-293.
5. Khosa SS, Younis AYA, Rayit ARA, Yasmeen S, Riaz AR. Effect of foliar application of macro and micro nutrients on growth and flowering of *Gerbera jamesonii* L. *American-Eurasian Journal of Agricultural & Environmental Sciences*. 2011;11(5):736-757.
6. Kobraee S, Noor Mohamadi G, Heidari Sharif Abad H, Darvish Kajori F, Delkhosh B. Micronutrients distribution in soybean plant with Zn, Fe, and Mn application. *Annual Research & Review in Biology*. 2013;2:83-91.
7. Kon IY, Shilina MN, Gmshinskaya MB, Bessonov VV, Kochetkova AA, Gurchenkova MA. A report on the research on the medical and biological foundation for the possibility of using chia seed flour in the diets of children over the age of three. *FSBI Institute of Nutrition, Moscow*. 2013;20-22.
8. Kumar A, Patro HK, Kewalanand. Effect of zinc and sulphur on herb, oil yield and quality of menthol mint

- (*Mentha arvensis* L.) var. Kosi. Journal of Chemical and Pharmaceutical Research. 2010;2(4):642-648.
9. Marschner H, Römheld V. Strategies of plants for acquisition of iron. Plant and Soil. 1994;165:375-388.
 10. Miller GW, Huang IJ, Welkie GW, Pushnik JC. Function of iron in plants with special emphasis on chloroplasts and photosynthetic activity. In: Abadia J, editor. Iron nutrition in soils and plants. Dordrecht: Springer; 1995. p. 19-28.
 11. Mohd Ali N, Yeap S, Young Ho W, Beh Kee B, Tan Wei S. The promising future of chia, *Salvia hispanica* L. Journal of Biomedicine and Biotechnology. 2012;2012:171956.
 12. Mohamed YFY, Ghatas YAA. Effect of some safety growth stimulants and zinc treatments on growth, seeds yield, chemical constituents, oil productivity and fixed oil constituents of chia (*Salvia hispanica* L.) plant. Scientific Journal of Flowers & Ornamental Plants. 2020;7(2):163-183.
 13. Mumivand H, Khanizadeh P, Morshedloo MR, Sierka KZG, Horaczek T, Kalaji HM. Improvement of growth, yield, seed production and phytochemical properties of *Satureja khuzistanica* Jamzad by foliar application of boron and zinc. Plants. 2021;10:2469.
 14. Peperkamp M. CBI tailored intelligence: chia from Bolivia-a modern super seed in a classic port cycle. The Hague: CBI Ministry of Foreign Affairs; 2015. p. 1-16.
 15. Prusty S, Sahoo RK, Nayak S, Poosapati S, Swain DM. Proteomic and genomic studies of micronutrient deficiency and toxicity in plants. Plants. 2022;11(18):2456-6470.
 16. Senthilkumar N. Effect of micronutrients on seed oil crops. International Journal of Current Advanced Research. 2018;7:15178-15192.
 17. Singh A, Singh NA, Afzal S, Singh T, Hussain I. Zinc oxide nanoparticles: A review of their biological synthesis, antimicrobial activity, uptake, translocation and biotransformation in plants. Journal of Materials Science. 2018;53:185-201.
 18. Singh A, Verma AK. A review on the potential use and cultivation of chia seeds (*Salvia hispanica* L.) in India. International Journal of Trend in Scientific Research and Development. 2022;6:2456-6470.
 19. Singh S, Parihar P, Singh R, Singh VP, Prasad SM. Heavy metal tolerance in plants: Role of transcriptomics, proteomics, metabolomics, and ionomics. Frontiers in Plant Science. 2016;6:1143.
 20. Yadegari Y. Effects of Zn, Fe, Mn and Cu foliar application on essential oils and morpho-physiological traits of lemon balm (*Melissa officinalis* L.). Journal of Essential Oil Bearing Plants. 2017;20(2):485-495.
 21. Yeritsyan N, Economakis C. Effect of nutrient solution's iron concentration on growth and essential oil content of oregano plants grown in solution culture. International Conference on Medicinal and Aromatic Plants. 2002;1(53):45-53.