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Research Article

Unlocking Chickpea Potential: Zinc and Iron Foliar Treatments for Enhanced Growth and Yield

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ABSTRACT
Chickpea is one of the most important crops of Pakistan. In the current study, the effect of five doses of zinc and iron was investigated on the growth and yield of chickpeas. The treatments include basal dose of 33% ZnSO4@25kg/ha, basal dose of 33% ZnSO4 @50kg/ha, foliar application of Zn @1% solution, foliar application of Zn @ 2% solution for zinc while the iron treatments were basal dose of FeSO4 @25kg/ha, basal dose of FeSO4 @50kg/ha, foliar application of Fe @1% solution, foliar application of Fe @ 2% solution. The experiments were conducted during two growing seasons 2022 and 2023. The results indicated that foliar application of 2% zinc resulted in higher plant height (50.77-50.96 cm), more numbers of branches (16.16-16.18), pods per plant (16.71-16.92), numbers of grains per pod (1.81-1.85) and yield (1466.1-1475.5 kg per ha) compared to control and other treatments. Similarly, foliar application of 1% iron caused a significant increase in plant height (49.86-50.20), number of branches (15.97-16.20), pods per plant (16.81-16.91) and yield (933.56-1011.56 kg per ha). Therefore, the application of 2% Zn and 1% Fe is recommended to get a higher yield of chickpea.

Keywords: Foliar spray, foliar micronutrients, chlorophyll content, critical growth stages.

INTRODUCTION

Chickpea, *Cicer arietinum* L. (Family Fabaceae, subfamily Papilionaceae), is one the most important pulse crop around the world [1]. It is mainly grown in 50 countries including India, Australia, Turkey, Ethiopia, Russia, Pakistan, Iran and United States of America [2]. Because of its high protein content (25%) and starches (60%), it plays an important role in meeting nutritional requirements of human beings [3,4].

The yield capability of chickpeas in Pakistan is extremely high yet we are getting exceptionally low yields because of unfortunate practices like low-quality seed, lack of plant populace, ill-advised supplement the board, and unfortunate water system booking and the executives. Lopsidedness sustenance is one of the significant reasons for the low yield of chickpeas in the country. Consistent trimming with high-yielding harvest assortments, nonstop development of a similar harvest, and less interest in coordinated supplements the executives have brought about a decrease of natural matter in the dirt prompting a lack of micronutrients [5].

Even though they are needed in much smaller quantities, micronutrients are essential for plant growth [6]. It contains Zinc (Zn), Copper (Cu), Boron (B), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Cobalt (Co) and Nickle (Ni) among other micronutrients. According to Imtiaz et al. [7], each nutrient has a narrow range of toxicity and insufficiency. The application of micronutrients aids in improving grain micronutrients in addition to increasing grain production [8]. Application of microelements can

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increase a plant's tolerance to environmental stresses including salinity and drought [9]. Supplementing these nutrients is crucial to make up for the lack of micronutrients in the soil.

Iron in the soil is the fourth most abundant element on the earth, but its amount is low or not available for the plant's and microorganisms' needs due to the low solubility of minerals containing iron in many places in the world, especially in arid regions with alkaline soils. Iron is essential for important enzymes, including cytochrome which is involved electron transport chain, synthesizing chlorophyll, maintaining the structure of chloroplasts, and enzyme activity [10]. Often iron is found in the form of trivalent (Fe 3+) in aerobic soils, which has low solubility, and in most cases, this is not enough to meet the needs of plants [11,12].

Chloroplast protein is greatly decreased by iron shortage because iron deficiency has such a strong impact on it. Cell division ceases under conditions of acute iron shortage, which results in a reduction in leaf growth [13]. Iron deficiency in individual plants is characterized by yellow leaves and dark green veins (interveinal chlorosis). In chickpeas, plants appeared yellow due to chlorosis, without weathering, and die off. If the condition is severe, the whole plant may be affected and turn very light yellow or even white. In many cases where moderate deficiencies occur early in the season, plants tend to recover later [15].

Zinc (Zn) is a crucial micronutrient required by both humans and plants. It helps activate various enzymes involved in metabolic processes in different crop plants. Growth and development of plants would be hindered in the absence of such enzymes [15]. Nearly half of the cereal and pulse crops in the world have considerable zinc deficiency, which lowers agricultural productivity [16,17]. Numerous agricultural nations around the world, particularly China, where zinc deficiency still exists in almost 50% of agricultural soils, struggle with this issue. All around the world, zinc insufficiency is a problem. Nevertheless, acute zinc deficiency occurs in arid to semi-arid regions of the world [18]. Numerous crops' growth and productivity might be impacted by zinc deficiency. Rashid [19] indicated that around 70% of Pakistan's farmed land is zinc deficient. Pulses with low levels of zinc have smaller leaves, known as tiny leaves, and shorter internodes. The reduction of propagation and cell development is one of the key signs of zinc deficiency in plants.

Due to controlled nutrient delivery and decreased losses, the application of accessible organic sources in combination with the right amount of inorganic fertilizers, particularly micronutrients, ensures good sustained output [20]. In different parts of the country, the yield of chickpeas can rise from 30 to 60% with balanced fertilizer use [21].

The current study is intended to evaluate the individual effects of iron (Fe) and zinc (Zn) on the growth and yield of chickpeas, taking into account the significance of Fe and Zn as critical micronutrients in the current context for increasing the agricultural productivity of chickpeas. We hypothesize that higher dose of Fe and Zn improve the growth and yield of chickpea significantly.

MATERIAL AND METHODS

Layout of Experiment

Chickpea cultivar was obtained from the Plant Genetic Resources Institute (PGRI), National Agriculture Research Centre (NARC), Islamabad, Pakistan. The crop was sown using standard protocols as per production technology. The trials were conducted under randomized complete block design (RCBD). The treatments include: Z1 (control), Z2 (basal dose of 33% $ZnSO_4$@25kg/ha), Z3 (basal dose of 33% $ZnSO_4$ @50kg/ha, Z4 (foliar application of Zn @1% solution), Z5 (foliar application of Zn @ 2% solution for zinc; F1 (control), F2 (basal dose of $FeSO_4$ @25kg/ha), F3 (basal dose of $FeSO_4$ @50kg/ha), F4 (foliar application of Fe @1% solution), F5 (foliar application of Fe @ 2% solution) for iron. Each treatment was replicated three times. The plot size for each replication was 4.0×1.8 m. Based on the soil analysis, the values of ECe, pH, organic matter, total nitrogen, accessible phosphorous, potassium, and zinc were 2.43dS m-1, 8.6, 0.86%, 0.054%, 5.5, 1.6, and 0.36mg kg-1, respectively. Field plots holding 70kg/ha of seeds were seeded with seeds of particular genotypes. The adoption of all advised agronomic procedures was uniform. All plots received 10kg of DAP, and additional fertilizers were also applied in two splits at the prescribed rates.

Growth Parameters

Each experimental unit's one square meter (1m2) area was manually picked before the plant reached its maturity. To calculate them the plants were tied into bundles and weighed. To calculate the plant height at maturity (cm), the total number of branches, the number of pods bearing branches, and the number of pods per plant these bundles were manually thrashed [22].

Yield Parameters

Each experimental unit's one square meter (1m2) area was manually picked in the first two weeks of April as it reached maturity. To measure biological yield, the plants were tied into bundles and weighed. To calculate the biomass per plant (kg), biomass per hectare (kg/ha), grain yield (kg/ha), and soil analysis, these bundles were manually thrashed [23].

Data Analysis

With the use of Fisher's analysis of variance, data were computed and examined in Statistix 8.1. The means were compared using the least significant difference (LSD) at 5% probability level [23].

RESULT AND DISCUSSION

The results indicated that foliar application of Zn at 2% solution caused statistically more plant height (50.77-50.96 cm), numbers of branches (16.16-16.18), numbers of pods bearing branches (13.17-13.18) and numbers of pods per branch (16.71-16.92) as compared to other treatments and control (Table 1). Similarly, 2% Zn solution application resulted in significant increase in yield parameters of chickpea (1.81-1.85 numbers of grains per pod, 31.83-31.85 g 100 grain weight, 5077.20-5082.95 kg per ha biological yield and 1466.1-1475.5 kg per ha grain yield) (Table 2).

Foliar application of 1% iron caused a significant increase in plant height (49.86-50.20), numbers of branches (15.97-16.20) and pods per plant (16.81-16.91) (Table 3). The numbers of grains per pod, 100 g grain weight, biological yield and grain yield were also statistically higher in plots where 1% iron solution was sprayed while the values of these parameters were significantly less in control plots (Table 4).

Table 1: Effect of Zinc on plant height, No. of branches, pods bearing branches, No. of pods per plant in 2022-2023

Treatments	Plant Height (cm)		No. of branches		Pod bearing branches		No. of Pods/ plant	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Z1	46.60c	46.25c	15.09b	15.08b	11.57c	11.58c	13.98d	14.285d
Z2	47.43c	47.42c	15.11b	15.25b	12.2bc	12.17bc	14.78c	14.885c
Z3	47.61c	47.6c	15.27b	15.23b	12.5b	12.525b	15.4bc	15.6bc
Z4	49.14b	49.73b	15.31b	15.29b	12.3b	12.2775b	15.49b	15.65b
Z5	50.77a	50.96a	16.18a	16.16a	13.17a	13.18a	16.71a	16.92a
Mean	48.31	48.382	15.392	15.401	12.33	12.35	15.27	15.27

Analysis 1: LSD (Y1) 0.05***p***= **P.H**=1.45, **No. of B**=0.59, **P.B.B**=0.62, **No. of P/P**=0.67, **No. of G/P=**0.19, 100 **G.W**=0.7, **B.Y**=335.89, **G.Y**=129.26

Table 2: Effect of Zinc on No. of grains/pod, 100-grain weight, biological yield, and grain yield in 2022-2023

Treatments	No. of grains/ pod		100-grain weight (g)		Biological Yield (kg/ha)		Grain Yield (kg/ha)	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Z1	1.32c	1.427c	28.43d	28.43d	3595.7d	3596.5d	902d	911d
Z2	1.34c	1.425c	29.15c	29.20c	3966.6c	3971.475c	1053.9c	1063c
Z3	1.55b	1.66b	29.62c	29.64c	4183.8bc	4186.3c	1186.7b	1193.2b
Z4	1.56b	1.62b	31.06b	31.06b	4305.60b	4313.1b	1205.2b	1223b
Z5	1.81a	1.85a	31.83a	31.85a	5077.20a	5082.95a	1466.1a	1475.5a
Mean	1.516	1.596	30.018	30.04	4225.78	4230.07	1162.78	1173.14

Analysis 1: LSD (Y2) 0.05***p***= **P.H**=1.47, **No. of B**=0.62, **P.B.B**=0.64, **No. of P/P**=0.71, **No. of G/P**=0.22, **100 G.W**=0.8, **B.Y**=342.92, **G.Y**=132.16

Table 3: Effect of iron on plant height, No. of branches, pods bearing branches, No. of pods per plant in 2022-2023

Treatments	Plant Height (cm)		No. of branches		Pod bearing branches		No. of Pods/ plant	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
F1	46.07c	46.15c	15.14b	15.5b	11.38c	11.42c	13.39c	13.45c
F2	47.5b	47.9b	15.28b	15.56b	11.93b	11.98b	14.39b	14.45b
F3	48.17b	48.5b	15.28b	15.36b	12.047b	12.067b	14.82b	14.95b
F4	49.86a	50.2a	15.97a	16.2a	12.88a	13.1a	16.81a	16.91a
F5	48.61b	48.9b	15.07b	15.21b	12.33b	12.43b	15.07b	15.27b
Mean	48.042	48.33	15.348	15.57	12.113	12.199	14.896	15.006

Analysis 2: LSD (Y1) 0.05***p***= **P.H**=0.79, **No. of B**=0.60, **P.B.B**=0.51, **No. of P/P**=0.99, **No. of G/P**=0.20, **100 G.W**=0.40, **B.Y**=280.5, **G.Y**=104.50

Table 4: Effect of iron on plant height, No. of branches, pods bearing branches, No. of pods per plant in 2022-2023

	No. of grains/ pod		100-grain weight (g)		Biological Yield (kg/ha)		Grain Yield/plot (kg/ha)	
Treatments	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
F1	1.21c	1.25c	29.08d	29.13d	3411.40d	3422.4d	666.89d	668d
F2	1.38c	1.39c	29.53c	29.61c	3872.7c	3879.7c	750.5c	752.5c
F3	1.48b	1.52b	29.70c	29.76c	4250.4b	4359.4b	844.7b	848.7b
F4	1.74a	1.84a	30.97a	31.01a	4922.8a	5019.8a	993.56a	1011.56a

F5	1.47b	1.52b	30.13b	30.23b	4266.7b	4322.7b	863.11b	893.11b
Mean	1.456	1.504	29.882	29.95	4144.8	4200.8	823.75	834.77

Analysis 2: LSD (Y2) 0.05***p***= **P.H**=0.80, **No. of B**=0.64, **P.B.B**=0.56, **No. of P/P**=1.09, **No. of G/P**=0.22, **100 G.W**=0.43, **B.Y**=288.59, **G.Y**=106.16

Abbreviations**:** Analysis 1 (Zinc application), No. (Number), kg (kilogram), ha (hector), g (grams), Z1 (control), Z2 (basal dose of 33% $ZnSO_4$@25kg/ha), Z3 (basal dose of 33% $ZnSO_4$ @50kg/ha, Z4 (foliar application of Zn @1% solution), Z5 (foliar application of Zn @ 2% solution. Analysis 2 (Iron application), F1 (control), F2 (basal dose of $FeSO_4$ @25kg/ha), F3 (basal dose of $FeSO_4$ @50kg/ha), F4 (foliar application of Fe @1% solution), F5 (foliar application of Fe @ 2% solution), LSD (Lest Significant Difference), Y1 (The year 2021-22), Y2 (Year 2022-23), ***p*** (probability level), P.H (plant height), No. of B (Number of branches), P.B.B. (Number of pods bearing branches), No. of P/P (Number of pods per plant), No. of G/P (number of grains per pod), G.W (grain weight), B.Y (biological yield), G.Y (grain yield).

Micronutrients are very essential for plant growth although required in small quantities [6,7]. These micronutrients not only help to enhance yield but also improve nutritional value of the product [8]. Although iron is the fourth most abundant element on earth but it is not available to plants due to low solubility of minerals containing iron. The current findings revealed that Zn 2% and Fe 1% both are very helpful in increasing the plant height of chickpeas. The increase in the availability of iron to plants might have stimulated the metabolic and enzymatic activities thereby increasing the growth of the plant reported by Trivedi et al. [24]. Zinc application influences the synthesis of auxin which enhances the plant growth and development of crops [25].

Plant height is primarily influenced by the crop's genetic composition and the growing environment. Good plant height is ensured by balanced plant feeding. Information displayed in both years. It displays the impact of applying Zn and Fe on chickpea plant height. Plant heights in the plots treated with Zn foliar spray differed significantly from one another. Plots that received foliar applications of zinc at 2% solution and zinc at 1% solution first showed the maximum plant height. Similarly, the plots where Fe was applied also produced noteworthy outcomes. Plots that received foliar treatment of Fe @ 1% solution showed the highest plant height. The minimal plant height was displayed in control plots. Significant variations in plant height caused by Zn and Fe administration have also been documented by Khan et al., [26]. Deficiencies of mineral nutrients may limit symbiotic nitrogen fixation in legumes through specific effects on survival and growth of rhizobia in the external media, on nodule initiation, development, and nodule function [27] and reported that inhibition or reduction in nodulation and nitrogen fixation due to Zn deficiency and toxicity by interference in the host and Rhizobium nutrition. Rai et al. [28] found that decrease in the nodule number and mass in chickpeas due to iron deficiency.

On the other hand, when it came to applying Fe, the pots with the highest number of pod-bearing branches were those where Fe was sprayed foliar at a concentration of 1%, then 2%. In both seasons, we received the fewest number of branches from other treatments. The outcomes closely resemble those of Sanchez-Rodriguez et al. [29].

One of the main factors influencing yield is the quantity of pods on a plant. The information about how zinc and iron affect the number of pods produced by a chickpea plant is displayed in Fig. Table, which indicates that these factors had a considerable impact on the number of pods produced by a chickpea plant. Plots getting Zn as a foliar spray at 2% solution produced the most pods per plant, while plots receiving Zn as a foliar spray at 25 g/5 L water produced the most pods per plant. The 1% solution applied topically to Zn was statistically comparable to the 33% ZnSO4 basal dose. In contrast, when it came to the application of Fe, the highest number of pods per plant was observed in the plots where Fe was first applied as a 1% solution through foliar spray, and then as a 2% solution. Similar results were reported by Janmohammadi et al., [30].

One of the main characteristics that determine yields is the quantity of grains per pod. Table. 2 displays information about how zinc and iron affect the quantity of grains in each chickpea pod. The table demonstrates the significant impact of zinc and iron on the number of pods produced by a chickpea plant (Table 2). Plots receiving a 2% solution of zinc as foliar spray produced the highest number of grains per pod; these plots also had the highest number of grains per pod when given a 1% solution of zinc as a foliar spray and a basal dose of 33% ZnSO4 at 50 kg/ha. Major outcomes were also observed in plots where iron was administered as a therapy. When applying iron at a 1% solution topically, the highest number of grains per pod was noted; this was followed by the number of grains per pod when applying iron at a 2% solution topically. These outcomes closely resemble those of Eskandari et al. [31].

The total amount of seeds produced by a crop is directly influenced by seed weight. It displayed the information regarding the impact of varying Zn and Fe concentrations on the chickpea's 100-grain weight. The data indicated that there was a considerable impact of Zn and Fe on the chickpea's 1000-grain weight. Plots treated with a foliar spray of Zn @ 1% solution did not yield a significant maximum grain weight of 100 when Zn @ 2% solution was sprayed. For the variable or 100-grain weight, the Fe application had slightly different outcomes than the Zn application. A maximum of 100-grain weight Fe @ 1% solution was produced by a foliar spray of Fe @ 2% solution. These results are quite in line with those of Briat et al., [11], Eskandari [32] and Schulte et al., [12].

The total biomass that a crop produces from a unit area is known as its biological yield. The table shows the impact of varying zinc and iron levels on chickpea biological production. Table indicates that iron and zinc have a considerable impact on chickpea biological production. Plots receiving a 2% solution of Zn administered as a foliar spray had the highest biological yield. Regarding the application of Fe, the highest biological output was seen in the plots where Fe was first applied as a 1% solution through the foliar spray, and then as a 2% solution. These outcomes closely resemble those of Fang et al. [33].

Since grain production is the ultimate goal of most crop growth, grain yield is a crucial metric for assessing the efficacy of any therapy. The data shown in the table shows that iron and zinc had a considerable impact on chickpea grain production (table). The highest grain yield per plot was achieved when a 2% solution of Zn was sprayed on the leaves. Major outcomes were also observed in plots where iron was administered as a therapy. Plots, where 1% solution of Fe was sprayed foliar and then 2% solution of Fe, was applied yielded the most grain production.

Conclusion: The present study concluded that micronutrients are important for maximum production of chickpeas. So, foliar application of Fe @2% solution and Zn 2% solution is recommended to get optimum yield of chickpea crop.

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