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Effect of Foliar Application of Zinc and Iron on Seed Yield and Yield Components of Common Bean (*Phaseolus vulgaris*)

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ABSTRACT

The effects of foliar application of iron and zinc were evaluated on Guilanian landrace of common bean in Rice Research Institute of Iran. A factorial experiment with three replication was conducted based on randomized complete block design. Two doses of Fe as iron chelate (0 and 0.4%) and five doses of Zn as zinc chelate (0, 0.1, 0.2, 0.3 and 0.4%) were sprayed at flowering and pod formation stages. The effects of iron and zinc in foliar form were significant on seed yield, a hundred seed weight and content of zinc and iron in aerial plant parts. The interaction effects of two factors was significant on seed yield, number of pods per plant, plant height, pod length, number of seeds per pod, a hundred seed weight and content of Zn and Fe in aerial parts of plant. In the absent of and 0.4% Fe foliar treatments, the highest value of seed yield were observed when 0.4% and 0.3% zinc were applied, respectively. The content of iron and zinc in aerial parts of plant were increased in line with foliar application of zinc. Spraying 0.4% Fe combined with 0.3% Zn was recommended for the yied improvement on common bean.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) as an important grain legume needs to large amounts of macro nutrients because of its tolerance to P deficiency and the symbiotic N fixation rates is low compared to other legumes. Much smaller quantities of micronutrients are required for dry bean and are essential for optimum growth and yield. Iron (Fe) is an important micronutrient element chlorophyll and enzyme structures, photosynthesis and respiration of plants (Malakooti et al., 2017). Zinc has a noticeable role in production of biomass, chlorophyll and many of enzymes because it is either as a functional, structural and regulatory cofactor of very much enzymes or as a component of other enzymes (Malakooti et al., 2017). Chlorosis due to iron deficiency is a common nutritional disturbance and mainly related to high pH (the pH is above 6.5) like calcareous soils. In these soils, Fe accessibility is usually very low and defect of iron is extensive. Ebrahimian & Bybordi (2011) stated iron deficiency in the soil is rare, but it can be unavailable for absorption in soils with pH below 5 and above 6.5. Also, iron deficiency can develop in soils with high waterlogged or over fertilized. The high amounts of calcium, zinc, manganese, phosphorus and copper can tie up iron. The reasons of zinc deficiency are high soil pH, high levels of available soil phosphorus and cool and wet conditions, especially in early growing. Therefore, although these two micronutrients may be present in the soil, crops are severely deficient. Hence, Fe and Zn deficiency can be absolutely defeated by foliar spraying (Stanton et al., 2022). The foliar application of fertilizer could be much more effective than soil application (Naseri Rad et al., 2014).

Several researchers studied the effect of iron and zinc fertilization in legume crops. Ibrahim & Ramadan (2015) indicated the increase of growth and yield of dry bean by foliar application of zinc at the rate of 100 ppm. Bozorgi et al. (2011) revealed significant effects of zinc on biomass, yield, plant height, harvest index, pods per plant, 100 seed

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weight and seeds per pod in faba bean. Valenciano et al. (2010) indicated common bean yield was increased with Zn spraying at 50 g/ha (17.0%) and 100 g/ha (16.3%). Heidarian et al. (2011) exhibited the significant effect of combination treatment of zinc and iron on seed yield, a thousand seed weight and pods per plant in soybean. Seifi Nadergholi et al. (2011) and Nasri et al. (2011) also reported the enhancement of seeds per pod and pods per plant in common bean. Nasri et al. (2011) also reported the increase of plant growth, biological yield and seed yield using iron application in bean. Mansour et al. (2012) displayed Fe foliar application enhanced seed yield, plant growth, yield components and plant dry weight and increased concentration of chlorophyll and carotenoids in leaves of pea. Salih (2013) explain that the foliar fertilization of Zn and Fe might have a probability role for increasing the seed yield of cowpea. Malakooti et al. (2017) indicated the application of iron and zinc can improve yield and seed quality and growth of soybean. Heidarian et al. (2011) and Bozorgi et al. (2011) reported seed yield significantly and positively correlated with seeds per pod, pods per plant and a thousand seed weight.

The different combinations of iron and zinc on the growth and yield of Guilanian landrace of common bean has not been experimented yet in this regard. The objective of this investigation was to evaluate the influence of iron and zinc spraying on seed yield and growth of common bean.

MATERIALS AND METHODS

The present study was carried out in Rice Research Institute of Iran (RRII) in Rasht, north of Iran (with 49° 38´ E longitude, 37° 12´N latitude and an altitude of 7 m below the mean of sea level) during 2013-2014 cropping season. The soil texture of the research site was loam with a pH of 6.64. The physical and chemical characteristics of soil displayed in Table 1. The experiment was conducted in in a factorial randomized complete block design with three replications. Guilanian landrace of common bean was planted on April 23, 2014. Basal fertilizers were used at the rates of 150 kg N/ha, 70 kg P_2O_5/ha and 60 kg K_2O/ha as urea, triple supper phosphate and potassium sulfate, respectively. One third of nitrogen and all of phosphorus and potassium were used at the planting time. The remaining amount of nitrogen was applied at flowering and grain filling, respectively. Two doses of Fe as Iron chelate (0 and 0.4%) and five doses of Zn as zinc chelate (0, 0.1, 0.2, 0.3 and 0.4%) were sprayed in two stages including flowering and pod formation. To prevent any Fe and Zn contamination, the soil surface was covered with plastic during foliar application. Spraying was done during cool hours of day to obtain the maximum uptake of these two micronutrients.

Table 1. Some of soil characteristics in experimental field

Soil Characteristics	Value
Zn (mg/kg)	3.3
Ca (ppm)	1.7
Mn (ppm)	22.1
Clay (%)	32
Loam (%)	56
Acidity or pH	6.64
Electrical conductivity (dS/m)	0.61
Depth of sampling (cm(	0-30
Fe (ppm)	0.02
Mg (ppm)	1.3
Available potassium)ppm)	203
Available phosphorus (ppm)	15.4
Nitrogen (%)	0.102
Carbon (%)	0.95
Tissue	Loam
Sand	12

Remarks: The critical level (threshold) of Fe and Zn for common bean plant needs to be reported

The density of common bean seeds was 22 per m^2 (30 × 15 cm spacing distance) and the dimensions of experimental plots were 3 × 4 m. The plots were irrigated as required and control of weeds was conducted throughout growing seasons. Plants were harvested at maturity stage of pods during June. Number of pods per plant and seeds per pod, pod length, plant height and 100 seed weight were randomly evaluated in ten mature plants from each plot. Six meter square of each plot was used to measure the seed yield. The nitrogen content was determined by Kjeldahl extraction method (Rajput et al., 2019). Iron (Fe) and zinc (Zn) contents were measured using atomic absorption method (Rajput et al., 2019). Statistical analysis was performed by SAS 9.1. LSD (least significant differences) tests were used for comparison of means.

RESULTS AND DISCUSSION

Plant Growth

Iron foliar application had significant effect on a hundred seed weight, seed yield and iron and zinc content in aerial organs. Zn was also had significant effect on plant height, seed yield, a hundred seed weight and content of iron and zinc in aerial organs. The interaction effects of two factors was significant on plant height, pod length, a hundred seed weight, seed yield, pods per plant, seeds per pod, and content of iron and zinc in aerial organs. Zn, Fe and N concentrations in seed and calcium content in aerial organs were not affected by Zn and Fe applications and interaction effects of two factors (Table 2). It seems that foliar application of micronutrients is a critical strategy of crop nutrient management in maximizing crop yields. The soil application of nutrients leads to their absorption by roots and translocation to aerial organs, whereas the nutrients pass into the stomata or the cuticle of the leaf and then enter the cells by foliar application. Hence, the response of crop happens in shorter time in foliar applying in comparison to edaphic usage. The rate of an ion travel through the leaves depends on concentration of the ion and its chemical and physical properties (Reshma & Meenal, 2022). Foliar spraying had the most important usage for micronutrients application.

In non Fe foliar treatments, the tallest plants (29 cm) were obtained by 0.4% Zn foliar. In 0.4% Fe foliar application condition, plant height was significantly increased with Zn spraying to 0.3% (Table 3). This finding is comparable with the findings that the increase of the stem height in common bean by Zn and Mn spraying (Teixeira et al., 2004; Bozorgi et al., 2011). Zinc activated some of enzymes with important role in cell division and lengthening, which these enzymes lead to the increase the stem height (Seifi Nadergoli et al., 2011). The results of present study also revealed iron fertilizer application causes a significant increase in the plant height in comparison to control treatment. Effects of foliar application with Zn and Fe could be due to the crucial in photosynthesis, respiration and other biochemical and physiological activities and their importance in obtaining higher yields (Rietra et al., 2017; Khan et al., 2022).

Pods per Plant

Mean comparison indicated in Fe non foliar condition, the minimum pods per plant (7.4) belonged to non Zn spraying treatment, while the maximum number of pods per plant (9.67) was obtained by 0.4% Zn spraying. In Fe foliar condition at the rate of 0.4%, Zn spraying significantly increased the number of pods per plant to rate of 0.2%, but reduced slowly as Zn application rate increased from 0.2 to 0.4% (Table 3). In agreement with our finding, the enhancement of pod number per plant by foliar spraying of micronutrients was reported in lentil (Zeidan et al., 2006). Increase of pods per plant using Zn spraying reported by Teixeira et al. (2004) in common bean. Valenciano et al. (2010) showed pod number per plant were greater with Zn application. They stated the application of micronutrients specifically zinc, positively influenced formation of stamens and pollens and increased the pod number per plant. Common bean is a self-pollinated plant, therefore the increase the activity of stamens would cause the flowers fertile and promoted more production of pods (Seifi Nadergoli et al., 2011). Favorable effect of iron and zinc in increasing the pod per plant can be explained by the role of these micronutrients in biochemical processes, synthesis of amino acids and sugars and increasing the amount of hormones at flowering stage (Ebrahim & Aly, 2004). Decrease in flower shedding, increase in pod formation and development in photosynthetic material distribution to these organs also could increase the pod per plant (Mady, 2009).

Seeds per Pod

In Fe foliar treatment at the rate of 0.4%, the maximum seed number per pod (3.87) was obtained from 0.3% Zn foliar application. In this condition, the lowest number of seeds per pod (2.87) belonged to 0.4% Zn foliar application. In non Fe foliar treatment, there was no significant difference between Zn foliar treatments (Table 3). This results in agreement the reports of other researchers that indicated the foliar application of Zn increased seeds per pod in common bean (Teixeira et al., 2004; Seifi Nadergholi et al., 2011; Nasri et al., 2011) and faba bean (Bozorgi et al., 2011). This increase in response to zinc consumption may be because of the role of this element in cell division and the key role of zinc in seed formation, due to its effect on reproductive processes and materialization (Mohsin et al., 2014).

Table 2. Analysis of variance for yield and yield components

SOV	DF	SY	PH	NPP	NSP	PL	HSW	ZnS	FeS	NS	FeA	ZnA	CaA
R	2	1969.16	1.24	0.11	0.50	1.59	13.83	185.44	615.20	0.006	456.1	132.1	0.003
Fe	1	874342.48**	0.05	2.94	0.26	1.02	449.46**	1.40	25.53	0.004	824.2*	381.5*	0.006
Zn	4	28278.44**	17.75**	2.04	0.07	1.38	49.80**	113.57	284.07	0.014	654.1*	335.9*	0.0053
Fe*Zn	4	399411.14**	31.17**	5.62**	0.56*	3.21**	275.65**	26.00	210.77	0.041	651.1*	296.8*	0.006
Error	18	1009.09	1.08	0.96	0.16	0.51	10.17	64.51	158.39	0.012	179.3	85.76	0.002
CV		5.09	3.78	12.21	11.19	7.57	7.40	10.27	18.33	2.54	12.43	10.50	2.21

Remarks: SOV: Source of variation, DF: Degree of freedom, R: Replication, Fe: iron fertilizers, Zn: Zinc fertilizer, CV: Coefficient of variation, SY: seed yield, PH: plant height, NPP: number of pods per plant, NSP: number of seeds per pod, PL: pod length, HSW: hundred seed weight, ZnS: Zinc content in seed, FeS: Iron content in seed, NS: Nitrogen content in seed, FeA: Iron content in aerial organs, ZnA: Zinc content in aerial organs, CaA: Calcium content in aerial organs; *, ** significant at 5% and 1% probability levels, respectively.

Table 3. Interaction effects of zinc and iron fertilizers on some of bean traits

Fe(ppm)	Zn (ppm)	ZnA (mg/kg)	FeA (mg/kg)	HSW (gr)	PL (cm)	NSP	NPP	PH (cm)	SY (kg/ha)
0	0	74.45c	78.45c	33.71b	8.15b	3.37a	7.40b	26.47b	309.23c
0	1	80.45b	98.41b	36.06b	8.97b	3.47a	7.53b	26.73b	319.90c
0	2	86.75ab	101.85b	37.85b	9.25ab	3.67a	8.27ab	27.20b	387.27b
0	3	98.45a	110.41ab	43.98a	9.50ab	3.70a	9.00ab	28.65a	412.75b
0	4	99.8b	112.81a	44.42a	10.40a	4.07a	9.67a	29.00a	632.00a
	LSD (5%)	7.21	12.18	5.28	1.42	0.82	1.99	1.06	65.39
4	0	81.15b	85.31c	40.54cd	8.72b	3.43a	6.93b	27.30b	800.40c
4	1	82.45b	97.91c	46.62bc	9.82ab	3.63a	8.80a	28.73ab	860.33b
4	2	88.75a	112.16bc	51.33b	10.18a	3.73a	9.20a	29.80a	861.77b
4	3	93.7ab	138.19a	59.93a	10.77a	3.87a	7.67ab	30.80a	1149.03a
4	4	90.9a	121.76b	36.31d	8.63b	2.87b	6.13b	21.00c	296.80d
	LSD (5%)	6.95	14.19	6.33	1.26	0.65	1.70	2.41	56.62

Remarks: The columns having common letter(s) in each levels of Fe, do not differ significantly at 5% level; Fe: iron fertilizers, Zn: Zinc fertilizer, PH: plant height, PL: pod length, NPP: number of pods per plant, SY: seed yield, HSW: hundred seed weight, FeA: Iron content in aerial organs, ZnA: Zinc content in aerial organs, LSD: least significant differences.

Pod Length

Means comparison indicated that in non Fe application treatment, the longest pod (10.4 cm) was obtained from 0.4% Zn spraying, which significantly differed from control (without Zn) and 0.1% Zn foliar. When Fe and Zn sprayed together, the shortest (8.63 cm) and longest pods belonged to the 0.4% Fe and 0.3% Zn foliar application, respectively (Table 3). The increase of yield components in crops by micronutrients application may be caused by their positive effects on improvement of plant growth, activation of photosynthetic enzymes, assimilates translocation and chlorophyll formation (Movahhedy-Dehnavy et al., 2009).

Hundred Seed Weight

In non Fe foliar treatments, the maximum hundred seed weight (44.42 g) was obtained from 0.4% Zn spraying, which significantly differed from 0, 0.1 and 0.2% Zn levels. In 0.4% Fe foliar application treatments, the highest hundred seed weight (59.93 g) occurred in 0.3% Zn foliar treatment, which significantly differed from other Zn levels (Table 3). This finding is similar to the result of other researchers which reported the increase of 100 grain weight in lentil (Zeidan et al., 2006) and bean (Nasri et al., 2011) by foliar spraying of zinc. Kakiuchi and Kobata (2008) stated enhancement of seed weight by moving of photosynthesis assimilates from vegetative organs to the other parts of plant. The microelements influence the leaf of plants and lead to produce larger amounts of assimilate (Naseri Rad et al., 2014). Since seeds are major source of assimilate, they promoted to have larger seeds (Seifi Nadergholi et al., 2011). Zn, which acts a major role as a functional, structural or regulatory co-factor of many of enzymes, involved on carbohydrates metabolism through photosynthesis and sugar transformations, and lack of it may result in reductions in net photosynthesis (Monjezi, Vazin and Hassanzadehdelouei, 2013).

Seed Yield

The results indicated seed yield significantly increased with Zn application in non Fe foliar treatments. The highest value of seed yield (632 kg/ha) in non Fe treatment was observed in treatments with 0.4% zinc and the lowest value of seed yield (309.23 kg/ha) was obtained in non-zinc treatment. There was no significant difference between 0 and 0.1% zinc concentrations. The highest value of seed yield was obtained by spraying 0.3% zinc and 0.4% iron (1149 kg/ha) (Table 3). Therefore, the results indicated Zn and Fe foliar applications increased bean seed yields. Zn application at the rate of 0.3% in combination with Fe increased seed yield and lead to the highest amounts of seed yield. In line with these findings, Ibrahim and Ramadan (2015) indicated Zn spraying increased seed yield and growth of dry bean. We found the increase of seed yield due to Fe and Zn spraying similar to the others in bean (Valenciano et al., 2010; Naseri Rad et al., 2014; Nasri, et al., 2011) soybean (Heidarian et al., 2011) and faba bean (Bozorgi et al., 2011).

Results indicated a positive reaction of common bean to an increase of Zn and Fe fertilizers, was due to the deficiency of these elements in the tested soil. Micronutrient elements play an important role on the increase the leaf area index, light absorption and dry matter accumulation. Foliar application of iron ascribed to the direct absorption of this element and lead to the increase of seed yield. Iron plays a critical function in chlorophyll formation, plant growth regulators and cytochrome, which contributed to different functions in metabolism of plants (Al-Bamarny et al., 2010). Iron enhanced plant photosynthesis, roots growth and transportation of assimilates to sinks, arrived to net photosynthesis and eventually increased seed yield (Álvarez-Fernández et al., 2006; Ebrahimian & Bybordi, 2011; Zeidan et al., 2006). The increase in dry weight by Fe foliar spraying may be caused by the vital role of Fe on enzymes activity, since Fe is an essential component of all enzymes system and electron carriers in which a heme prosthetic group is present. Iron present in heme containing enzymes and also in non heme compounds; such as peroxidase, catalase, cytochrome oxidase, ferodoxin and nitrate reductase (Naseri Rad et al., 2014).

Zinc provides the higher seed yield by improving the construction of photosynthesis and participation in the production of the reproductive organs (number of spike and increasing the weight of seed). Zinc had important role in auxin synthesis by biosynthesis of tryptophan as a precursor of auxin. Zinc is also found in phosphoenolpyruvate carboxylase structure (Movahhedy-Dehnavy, 2009). It may be caused by involvement of iron in chlorophyll synthesis and its role as a cofactor for many of enzymes that catalyzed biochemical reactions (Sheikha and Al-Malki, 2011). Zinc enhances the synthesis of plant enzymes, protein, RNA and DNA (Kobraee et al., 2011) and had important role in photosynthesis, cell division and sexual fertilization (Teixeira et al., 2004).

Advantages of foliar application may by caused by (a) much lower rate of fertilizer concentration compared to soil application; (b) obtain a easily uniform application; and (c) corrected the deficiencies during growing season due to immediately applied nutrient. The increase of seed yield by spraying zinc plus iron may be caused by their positive effects on nutritional status and vegetative growth, stomatal regulation, and increase the translocation of assimilates from sources to sinks (Sheikha & Al-Malki, 2011). Decreasing the dry seed yield according to low Zn may be associated with the deformed of apices and unusual floral development, with diminished number of flowers per plant and premature shedding of floral organs (Poblaciones & Rengel, 2016).

Higher amounts of Zn (0.4%) in combination with Fe negatively influenced seed yield of common bean. The lowest value of seed yield in 0.4% iron foliar treatment was obtained by 0.4% zinc foliar application (Table 3). This indicated the antagonistic effects between Fe and higher level of Zn. It seems that excessive amounts contribute to toxicity in plants. Zinc toxicity decreases the activity of photosystem II, RUBP carboxylase enzyme, ATP synthesis, photosynthesis and absorbing of P and Fe (Naseri Rad et al., 2014). There were synergistic, antagonistic, zero-interactive or Liebig-synergistic interaction between plant nutrients and therefore, the supply of one nutrient may influence the function of another nutrient and plant growth and yield (Rietra et al., 2017). Three possible mechanisms for this antagonism are competition between zinc and iron ions (Zn^{2+} and Fe^{2+}) during the uptake, the interference in the chelation process during Fe uptake and translocation (Kabata-Pendias, 2010) and competitive inhibition between zinc and iron during unloading in the xylem.

Nitrogen, Iron and Zinc Content in Seed

Results indicated that the effects of iron and zinc treatments and their interactions were not significant on nitrogen, iron and zinc concentration in seed. The discussion that can be made here is that, If the concentration of chemical elements has been measured, when the seed yield is high, compared to when the seed yield is low, the concentration of chemical elements will be lower; in other words, with the increase of seed yield, the concentration of chemical elements in the seed will be seen in a lower amount. While the absorption of chemical elements (the product of the dry weight of the seed in the concentration of elements) will give more in the plant with higher biomass. On the other hand, since in this research, the effect of chemical elements on seed yield was significant and by increasing the foliar application of chemical elements, more yield was obtained, according to the above explanations, the effect of foliar application on the concentration of chemical elements in the seed is not significant. Therefore, it seems that due to the fact that the spraying was done before seed formation, it had no effect on the content of elements in the seed.

Chemical Element of the Aerial Parts of Plant

The effect of Zinc and Iron spraying and interaction effects of these two factors were significant on the iron and zinc contents of the leave and shoot (aerial organs) in 5% probability level (Table 2). Mean comparisons showed that the foliar application with Zn in both of Fe foliar and non-foliar treatments increased the content of Zn and Fe in aerial organs than control treatment (Table 3). On the other side, after Fe and Zn treatments, leaf and shoot Fe and Zn concentrations increased and reached optimal levels. In non-Fe foliar treatment, the highest values of iron and zinc content in aerial organs (112.81 and 99.8 mg/kg, respectively) were obtained by spraying 0.4% zinc. In Fe foliar treatments, the highest values of iron and zinc in leave and shoots were obtained by foliar of zinc at the rate of 0.3% (138.19 and 93.7 mg/kg, respectively). In confirmed the results of present study, Baybordy & Mamedov (2010) indicated the increase of iron content in canola by foliar application of iron. Micronutrient concentrations in aerial organs were depends on their uptake by root during the development stage. Kazemi Poshtmasari et al. (2008) reported the enlargement of zinc and iron concentration in bean by using of zinc foliar application. Foliar application of iron produces higher density of iron compared to its soil application. The deficiency of iron in the leaves was characterized by chlorosis, and the reduction of absortioin on the respected element was due to the existence of calcium carbonate in the soil. Iron spraying is more efficient for rapid iron chlorosis and its absorption by leaves (Heidarian et al., 2011).

In the present study, it is observed that spraying iron at the rate of 0.4% reduced zinc content on aerial organs. The plant competition in iron and zinc absorption could be the reason of this phenomenon. The decrease of zinc due to the iron consumption is the reason for negative interaction between iron and zinc (Malakooti et al. 2000).

The improvement effect of zinc and iron treatment on the contents of nutrient in aerial organs can be ascribed to the desirable effect of Zn and Fe on biological activity and metabolism and their effect on translocation and accumulation of elements in the aerial organs (El-Tohamy & El-Greadly, 2007). Moreira et al. (2018) declared that by foliar application of Zn at flowering stage, the Zn concentration in leaf was increased because of genetic regulation on zinc uptake and translocation.

The main findings of this research is the significant effects of foliar application of Fe and Zn and their interactions on hundred seed weight, seed yield and iron and zinc content in aerial organs. Therefore, it seems that foliar application of micronutrients is a critical strategy of crop nutrient management in maximizing crop yields. The content of iron and zinc in aerial parts of plant were increased with foliar application of zinc and iron. The highest value of seed yield was obtained by spraying 0.3% zinc and 0.4% iron (1149 kg/ha).

CONCLUSION

As mentioned in the introduction, beans are one of the most important crops in the diet in developing countries, so any action that increases its production for the people of this countries are effective. One of the limitations in the production of this crop is the lack of microelements in the soil or their unavailability, which can be overcome by spraying and get a higher yield, which contributes to sustainable agriculture in these areas. The most important finding of this research is the increase in yield by spraying zinc and iron. The use of zinc (0.3% from Zn chelate) and iron (0.4% from Fe chelate) as foliar application can correct the deficiency of zinc and iron and increase plant growth and yield. Therefore these concentrations of zinc and iron foliar spray was suitable combination for the most of measured characters in common bean.

REFERENCES

Bozorgi, H. R., Faraji, A., Danesh, R. K., Keshavarz, A., Azarpour, E., & Tarighi, F. (2011). Effect of plant density on yield and yield components of rice. *World Applied Sciences Journal, 12*(11), 2053-2057. Retrieved from https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=4db23100f9c40e0bf212d5ca1afc0453157aaee2

Ebrahim, M. K. H., & Aly, M. M. (2004). Physiological response of wheat to foliar application of Zinc and inoculation with some bacterial fertilizers. *Journal of Plant Nutrition*, *27*(10), 1859-1874. https://doi.org/10.1081/PLN-200026442

Ebrahimian, E., & Bybordi, A. (2011). Effect of iron foliar fertilization on growth, seed and oil yield of sunflower grown under different irrigation regimes. *Middle-East Journal of Science and Reseearch, 9*(5), 621-627. Retrieved from https://www.idosi.org/mejsr/mejsr9(5)11/11.pdf

El-Tohamy, W. A., & El-Greadly, N. H M. (2007). Physiological responses, growth, yield and quality of snap beans in response to foliar application of yeast, vitamin E and zinc under sandy soil conditions. *Australian Journal of Basic and Applied Sciences, 1*(3), 294–299. Retrieved from http://www.ajbasweb.com/old/ajbas/294-299.pdf

Heidarian, A. R., Kord, H., Mostafavi, K., Parviz Lak, A., & Amini Mashhadi, F. (2011). Investigating Fe and Zn foliar application on yield and its components of soybean (*Glycine max (L) Merr.*) at different growth stages. *Journal of Agricultural Biotechnology and Sustainable Development, 3*(9), 189 -197. Retrieved from https://academicjournals.org/article/article1379436818_Heidarian%20et%20al.pdf

Ibrahim, E. A., & Ramadanb, W. A. (2015). Cross effect of zinc foliar spray alone and combined with humic acid or/and chitosan on growth, nutrient elements content and yield of dry bean (*Phaseolus vulgaris* L.) plants sown at different dates. *Scientia Horticulturae*, 184, 101–105. https://doi.org/10.1016/j.scienta.2014.11.010

Kabata-Pendias, A. (2010). *Trace elements in soils and plants* (4th ed.). Boca Raton: CRC Press. https://doi.org/10.1201/b10158

Kakiuchi, J., & Kobata, T. (2008). High carbon requirements for seed production in soybeans [*Glycine max* (L.) Merr]. *Plant Prodoction Science, 11*(2), 198-202. https://doi.org/10.1626/pps.11.198

Kazemi Poshtmasari, H., Bahmanyar, M. A., Pirdasht, H., & Ahmadishad, M. A. (2008). Effects of Zn rates application forms on protein and some micronutrients accumulation in common bean (*Phaseolus vulgaris* L.). *Pakistan Journal of*

Biological Science, 11(7), 1042-1046. https://doi.org/10.3923/pjbs.2008.1042.1046

Khan, M. M. H., Ahmed, N., Naqvi, S. A. H., Ahmad, B., Dawar, K., Rahie, A. A., … Danish, S. (2022). Synchronization of zinc and boron application methods and rates for improving the quality and yield attributes of *Mangifera indica* L. on sustainable basis. *Journal of King Saud University - Science, 34*(8), 102280. https://doi.org/10.1016/j.jksus.2022.102280.

Kobraee, S., Shamsi, K., & Rasekhi, B. (2011). Effect of micronutrients application on yield and yield components of soybean. *Annals of Biological Research*, *2*(2), 476-482. Retrieved from https://www.semanticscholar.org/paper/Effect-of-micronutrients-application-on-yield-and-y-Kobraee-Shamsi/b593aeaf16897ef4e6ec4dd00b53439999129781

Mady, M. A. (2009). Effect of foliar application with yeast extract and zinc on fruit setting and yield of faba bean (*Vicia faba* L.). *Journal of Biological, Chemical & Environmental Science*, *4*(2), 109-127. Retrieved from https://www.bu.edu.eg/portal/uploads/Agriculture/Botany/1299/publications/Mohamed%20Ahmed%20Mohamed%20Mady_5.pdf

Malakooti, S. H., Majidian, M, Ehteshami, S. M., & Rabiee, M. (2017). Evaluation of iron and zinc foliar and soil application on quantitative and qualitative characteristics of two soybean cultivars. *IIOAB Journal*, *8*(3), 1-7. Retrieved from https://www.iioab.org/articles/IIOABJ_8.3_1-7.pdf

Mansour, N. T. S., Mostafa, M. M., & Abd El-Hakim, W. M. (2012). Effect of potassium dissolving bacteria and foliar application with some microelements on growth, yield and quality of pea plant under sandy soil conditions. *Zagazig Journal of Agriculture Research*, 39(5), 837-848.

Mohsin, A. U., Ahmad, A. U. H., Farooq, M., & Ullah, S. (2014). Influence of zinc application through seed treatment and foliar spray on growth, productivity and grain quality of hybrid maize. *Journal of Animal and Plant Science*, *24*(5), 1494-1503. Retrieved from http://www.thejaps.org.pk/docs/v-24-5/29.pdf

Monjezi, F., Vazin, F., & Hassanzadehdelouei, M. (2013). Effects of iron and zinc spray on yield and yield components of wheat (*Triticum Aestivum* L.) In drought stress. *Cercetări Agronomice în Moldova*, *46*(1), 23-32. Retrieved from http://www.uaiasi.ro/CERCET_AGROMOLD/CA1-13-03.pdf

Moreira, A., Moraes, L. A. C., & Fageria, N. K. (2015). Zinc and aminoacids on the yield and nutritional state of alfalfa grown in the tropical soil. *Journal of Plant Nutrition*, *38*(5), 780-794. https://doi.org/10.1080/01904167.2014.944710

Movahhedy-Dehnavy, M., Modarres-Sanavy, S. A. M., & Mokhtassi-Bidgoli, A. (2009). Foliar application of zinc and manganese improves seed yield and quality of safflower (*Carthamus tinctorius* L.) grown under water deficit stress. *Industrial Crops and Products, 30*, 82-92. https://doi.org/10.1016/j.indcrop.2009.02.004

Naseri Rad, H., Sayad, V., & Naseri Rad, A. (2014). Effect of rhizobium bacteria (*Rhizobium leguminosarum*) and nano-Iron application on yield and yield components of different pinto beans genotypes. *Agricultural Communication, 2*(2), 22-27. Retrieved from https://www.researchgate.net/publication/261885406_Effect_of_Rhizobium_Bacteria_Rhizobium_leguminosarum_and_Nano-Iron_Application_on_Yield_and_Yield_Components_of_Different_Pinto_Beans_Genotypes

Nasri, M., Khalatbari, M., & Aliabadi Farahani, H. (2011). Zn-foliar application influence on quality and quantity features in *Phaseolous Vulgaris* under different levels of N and K fertilizers. *Advances in Environmental Biology, 5*(5), 839-846. Retrieved from http://www.aensiweb.com/old/aeb/2011/839-846.pdf

Poblaciones, M. J., & Rengel, Z. (2016). Soil and foliar zinc biofortification in field pea (*Pisum sativum* L.): grain accumulation and bioavailability in raw and cooked grains. *Food Chemistry, 212*, 427-433. https://doi.org/10.1016/j.foodchem.2016.05.189

Rajput, H., Rehal, J., Goswami, D., & Mandge, H. M. (2019). Methods for food analysis and quality control. In *State-of-the-Art Technologies in Food Science: Human Health, Emerging Issues and Specialty Topics* (pp.299-346). Apple Academic Press. Retrieved from https://www.researchgate.net/publication/330982949_Methods_for_Food_Analysis_and_Quality_Control

Reshma, Z., & Meenal, K. (2022). Foliar application of biosynthesised zinc nanoparticles as a strategy for ferti-fortification by improving yield, zinc content and zinc use efficiency in amaranth. *Heliyon, 8*(10), e10912. https://doi.org/10.1016/j.heliyon.2022.e10912

Rietra, R. P., Heinen, M., Dimkpa, C. O., & Bindraban, P. S. (2017). Effects of nutrient antagonism and synergism on yield and fertilizer use efficiency. *Communications in Soil Science and Plant*

Analysis, 48, 1895–1920. https://doi.org/10.1080/00103624.2017.1407429

Salih, H. O. (2013). Effect of foliar fertilization of Fe, B and Zn on nutrient concentration and seed protein of Cowpea "*Vigna Unguiculata*". *Journal of Agriculture and Veterinary Science, 6*(3), 42-46. https://doi.org/10.9790/2380-0633741

Seifi Nadergholi, M., Yarnia, M., & Rahimzade Khoei, F. (2011). Effect of zinc and manganese and their application method on yield and yield components of common bean (*Phaseolus vulgaris* L. CV. Khomein). *Middle-East Journal of Science and Research, 8*(5), 859-865. Retrieved from https://www.idosi.org/mejsr/mejsr8(5)11/3.pdf

Sheikha, S. A., & Al-Malki, F. M. (2011). Growth and chlorophyll responses of bean plants to chitosan applications. *Europen Journal of Science and Research, 50*(1), 124–134. Retrieved from http://iauconveris.iau.edu.sa/converis/portal/Publication/5034532?auxfun=&lang=en_GB

Stanton, C., Sanders, D., Krämer, U., & Podar D. (2022). Zinc in plants: Integrating homeostasis and biofortification. *Molecular Plant, 15*(1), 65-85. https://doi.org/10.1016/j.molp.2021.12.008

Teixeira, I. R., Boren, A. B., & Araujo, G. A. A. (2004). Manganese and zinc leaf application on common bean grown on a cerrado soil. *Scientia Agricola, 61*, 77-81. https://doi.org/10.1590/S0103-90162004000100013

Valenciano, J. B., Miguélez-Frade, M. M., Marcelo, V., & Reinoso, B. (2010). Response of irrigated common bean (*Phaseolus vulgaris*) yield to foliar zinc application in Spain. *New Zealand Journal of Crop and Horticultural Science, 35*(3), 325-330. https://doi.org/10.1080/01140670709510198

Zeidan, M. S., Hozayn, M., & Abd-El-Salam, M. E. E. (2006). Yield and quality of lentil as affected by micronutrient deficiencies in sandy soils. *Journal of Applied Sciences Research, 2*(12), 1342-1345. Retrieved from http://www.aensiweb.com/old/jasr/jasr/2006/1342-1345.pdf