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Foliar application of Fe, Zn and NPK nano-fertilizers on seed yield and morphological traits in chickpea under rainfed condition

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ABSTRACT:

There found only little information about the beneficial effects of nano-fetilizers on seed yield and plant growth in chickpea. Therefore, a field experiment was conducted for finding the effects of foliar application of Zn, Fe and NPK as nanofertilizers on chickpea at rainfed conditions. Plant height, number of branches, seed weight, biological yield and seed yield were significantly increased as compared to plants grown in normal (without fertilizer) condition. Highest seed yield (137.3 g/m^2) was obtained by Fe + Zn foliar application and caused 34% increase in the seed yield. The most increase in seed weight (~ 12%) was obtained by the foliar application of NPK and Fe + Zn. Interestingly, the combination of Fe + Zn with NPK showed no significant differences compared with the normal treatment. In conclusion, this study proved that foliar application of Zn, Fe and NPK, through the action as a growth promoter, can increase in the plant growth and seed yield in chickpea.

Keywords:
Chickpea, Iron, Zinc, nano-fertilizer, seed yield

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INTRODUCTION

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops in the world and valued for its nutritive seeds with high protein content of about 25.3–28.9% (Mafakheri *et al.,* 2011). Every year, the global population is increasing very fast and the most important thing is that global agricultural productivity must increase to feed the growing world population. On the other hand, the arable agricultural lands were reduced globally due to urbanization and growth of industries (Sekhon, 2014). Fertilizers are having important role in the present day cropping and increasing productivity. In most of the crops, the seed yield and its components are affected by many factors such as genotype, environmental conditions, soil fertility and cultural practices (Golzarfar *et al.,* 2012). In Iran, chickpea production areas are completely found in arid and semi-arid zones and usually the chickpea plants are exposed to increasing water deficit during flowering and maturity stages (Talebi *et al.,* 2011; Talebi *et al.,* 2013). In the recent decade of environmental pollution, especially water and soil, the overuse of pesticides and chemical fertilizers form the most serious problems for food and health security in most parts of the world (Manjili *et al.,* 2014). Nanofertilizer as a new technology and a suitable substitution for traditional chemical fertilizer in agricultural practice, it can prevent the soil and water pollution by gradual and controlled release of nutrients into the soil and subsequently on the plant (Naderi and Abedi, 2012; Sekhon, 2014). Micronutrients are normally needed in very small quantities for plant growth and development and thier deficiency may leadto disturbance in physiological and metabolomics pathways in the plant (Nadi *et al.,* 2013). Using micronutrients fertilizers mixed with common chemical fertilizers may not be useful for growing the crop and increasing the productivity (Bozorgi, 2012; Nadi *et al.,* 2013). El-Fouly *et al.* (1984) reported that the availability of micronutrients such as Fe, Mn and Zn in soil are much affected by the soil texture and pH and usually micronutrient-deficiency problems are very common in calcareous soil of arid and semi-arid regions. Each micronutrients has its own function in the plant development and graining quality. For example, it has been reported that zinc exert a great influence on physiological and morphological processes in plants, such as nitrogen metabolism as well as uptake and chlorophyll synthesis (Potarzycki and Grzebisz, 2009) and zinc deficiency symptoms include decrease in vegetative growth, sexual development etc., (Pathak *et al.,* 2012). Iron is a nutrient that all plants need to function. Many of the vital functions of the plant, like enzyme, chlorophyll production, nitrogen fixation, and development and metabolism are all dependent on iron. Without iron, the plant simply cannot function properly (Lopez-Millan *et al.,* 2000). Mostly, amounts of zinc

Table 1. Analysis of variance for seed yield and morphological traits in chickpea by foliar applications with nano-fertilizers

S.O.V	df	PH (cm)	DF	NSB	NPB	PP	SP	SW (g)	SY (g/m^2)	BY (g/m^2)	HI	Prot
Replication (R)	3	21.95**	0.84	2.12	0.29	38	26.9	2.08	926.04*	5419.8	12.4	0.08
Fertilizer (A)	5	12.72*	11.9*	8.62*	0.6*	10	18.7	25**	2157*	4493.2*	148**	0.86
R X A	15	5.99	3.19	7.54	0.15	15.5	22	6.9	775	3288.5	12.8	0.83
Genotype (B)	3	284.1*	10**	5.73	1.9**	444**	1645**	1840**	2248**	9230**	4.29	0.05
A X B	15	1.72	0.34	6.55	0.42	7.7	7.54	2.26	305.2	1491	15.23	0.53
Error	54	2.33	0.44	3.75	0.26	29.7	26.4	5.19	385	2180	11.7	1.38
CV		5.41	1.1	24.7	18.3	24.2	21.25	9.63	15.79	16.53	7.73	5.84

PH= Plant Height; DF= Day to Flowering; NSB= Number of Secondary Branches; NPB= Number of Primary Branches; PP= Number of Pods per Plant; SP= Number of Seeds per Plant; SW= Seed Weight; SY= Seed Yield; BY= Biological Yield; HI= Harvest Index; Prot= Seed protein content.
'**' and '*'are non-significant and significant at 5% level, respectively.

and iron in the soil are more than the plant needs but cannot readily be absorbed by plants.The best and alternative way is to use these micronutrients as foliar spray. Iranian researchers have produced the nano-organic iron-chelated and zinc fertilizer that is environmentally sustainable. Previous studies showed that the chickpea is minimally responsive to NPK fertilizer, but the positive response of chickpea to micronutrients were reported (Valadkhan *et al.,* 2015; Namvar *et al.,* 2011). In the previous studies the effect of Zn or Fe on chickpea yield were investigated separately. Therefore, the aim of this study is to investigate the effect of nano-iron, zinc and NPK foliar application on seed yield and yield components in chickpea under rainfed condition.

MATERIALS AND METHODS

In order to investigate the effect of foliar application of different nano-fertilizer (Zn, Fe and NPK) on the yield of chickpea (*Cicer arietinum* L.), a field experiment was conducted during spring and summer 2013 at the experimental research farm of Kherkeh Dryland Agricultural Institute (47° 8' N; 35° 43' E; altitude 2120 m), West of Iran. The long-term annual rainfall and mean temperature of the regions are 344 mm and 9.5°C respectively. Pattern of monthly rainfall (mm) and temperature (°C) during the crop season is presented in Fig 1. Some of the soil physicochemical characteristics were: sand 23.8.2%, silt 31.5%, clay 44.7%, pH 7.4, organic carbon 0.56% and available P and K as 7.94 and 276 mg L^{-1}, respectively. The trial was laid out in a split-plot arrangement based on the randomized complete block design in four replications. Six treatments of foliar application containing nano-fertilizer (Fe, Zn, Fe + Zn, NPK, NPK+Fe+Zn and control) were compared in main plots. Four different chickpea cultivars (ILC482, Azad, Pirouz and Kaka) were set up in sub-plots. Sowing was done in March 2013. Each plots consisted of four rows, 2 m long rows with 30 cm between each rows. Foliar spraying by nano-fertilizer and distilled water (control) were done three times during the vegetative growth and flower development period of the plant (first spraying at 4 to 6-leaf stage, the second spraying at 30 days later from the begining of flowering and third spraying during the pod filling). The amount of sprayed nano-fertilizer solution and distilled water was about 2 L per plot at each stage of spraying. Six plants were randomly chosen from each plot to measure the Plant Height(PH), Number of Secondary Branches (NSB), Number of Primary Branches (NPB), Number of Pods per Plant (PP), Number of Seeds per Plants (NSP), Seed Weight (SW). For seed yield (g/m^2) and biological yield (g/m^2), two middle rows in two meters long from each plots were

Table 2. Effect of various nano-fertilizers and genotypes of seed yield and morphological traits in chickpea.

Treatment	PH (cm)	DF	NSB	NPB	PP	SP	SW (g)	SY (g/m^2)	BY (g/m^2)	HI	Prot
Normal	26.37^{b}	60.12^{b}	6.56^{b}	2.5 ^{b}	22.06^{a}	22.59^{a}	22.48^{b}	102.3^{b}	265.5^{b}	38.8^{c}	19.7^{a}
Zn	28.25^{a}	60.18^{b}	8.43^{a}	3.06 ^{a}	22.88^{a}	23.27^{a}	23.3^{b}	127.1^{a}	277.7^{ab}	45.9^{a}	20.2^{a}
Fe	28.68^{a}	60.87^{a}	7.56^{ab}	2.75^{ab}	21.43^{a}	24.6^{a}	23.04^{b}	125.3^{a}	266.2^{b}	47.12^{a}	20.35^{a}
NPK	28.18^{a}	60.37^{b}	7.75^{ab}	2.93 ^{a}	23.36^{a}	24.35^{a}	25.11^{a}	128.1^{a}	303.2^{a}	42.6^{b}	20.14^{a}
Fe + Zn	28.56^{a}	60.25^{b}	7.93^{ab}	2.75^{ab}	23.31^{a}	25.45^{a}	25.32^{a}	137.3^{a}	302.2^{a}	45.9^{a}	20.36^{a}
NPK+ Zn+ Fe	28.75^{a}	60.25^{b}	8.62^{a}	2.87^{ab}	22^{a}	25^{a}	22.63^{b}	125^{a}	279^{ab}	44.8^{ab}	20.11^{a}
Kaka	27.75^{c}	59.66^{b}	7.25^{a}	2.45 ^{c}	25.16^{a}	34.9^{a}	13.64^{c}	112.9^{c}	257.8^{b}	44^{a}	20.17^{a}
Pirouz	23.45^{d}	59.9^{b}	8.25^{a}	3.12 ^{a}	27.17^{a}	26.5^{b}	18.9^{b}	119.6^{bc}	275.5^{ab}	43.7^{a}	20.2^{a}
Azad	31.25^{a}	60.9^{a}	8.16^{a}	2.75 ^{bc}	19^{b}	17.7^{c}	31.28 ^{a}	134.3^{a}	301.2^{a}	44.7^{a}	20.1^{a}
ILC482	30 ^{b}	60.8^{a}	7.62^{a}	2.9 ^{ab}	18.6^{b}	17.6^{c}	30.7^{a}	129.9^{ab}	294.7^{a}	44.3^{a}	20.11^{a}

PH= Plant Height; DF= Day to Flowering; NSB= Number of Secondary Branches; NPB= Number of Primary Branches; PP= Number of Pods per Plant; SP= Number of Seeds per Plant; SW= Seed Weight; SY= Seed Yield; BY= Biological Yield; HI= Harvest Index; Prot= Seed protein content.
Means with different letters at each column are statistically different at 5% level.

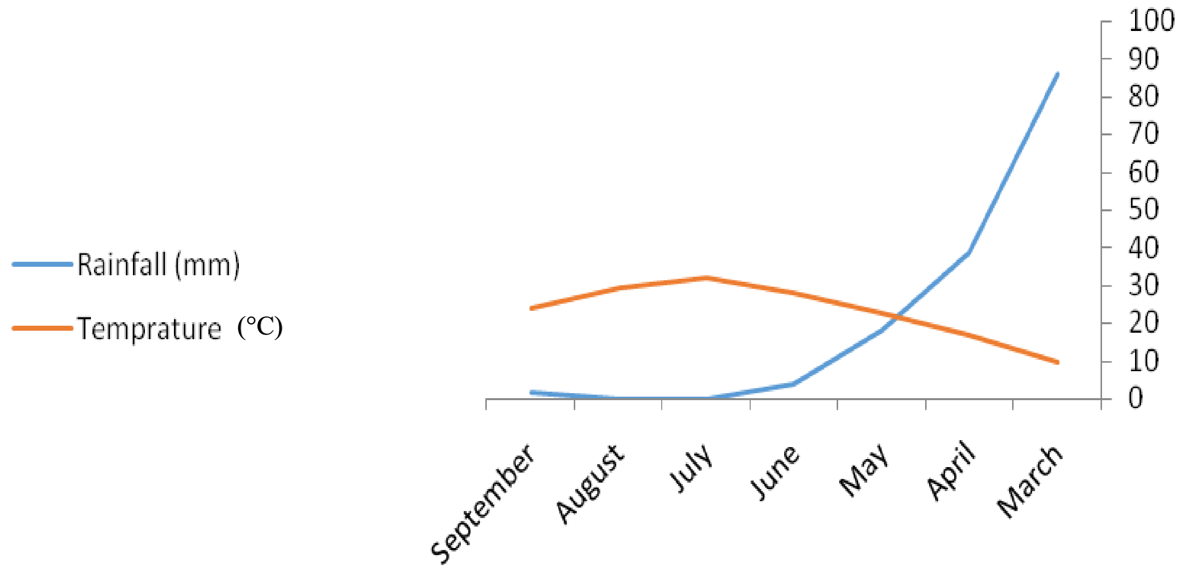

Figure 1. Pattern of monthly rainfall and temperature amounts recorded during the crop season 2014.

harvested. Representative samples of seeds were taken from each treatment and dried in an oven at 65^0C temperature for 24 hours and powdered by a mechanical grinder. Then, the nitrogen content of seed was determined by micro Kjheldahl's method (Jackson, 1967). Analysis of variance and comparison of means was done by the Least Significant Difference (LSD) test at the probability level of 0.05 using SAS (SAS Institute Inc. 2002). The correlation coefficient between seed yield and other quantitative traits were performed using STATISTICA software.

RESULTS

Analysis of variance of the data showed that nanofertilizer had significant effects on plant height, day to flowering, number of primary branches, seed weight, seed yield and harvest index (Table 1). Genotypes showed significant differences for all measured traits except for harvest index and seed protein content (Table 1). There is no significant intractive effect between genotypes and nanofertilizer. Salient features of the effects of different nanofertilizer upon foliar application on morphological traits and seed yield in chickpea genotypes are given below.

Plant height and day to flower

The present results have indicated that plant heights were significantly increased by foliar application of nanofertilizers (Table 2). All treatment showed higher plant height value compared to normal plants (check). Comparison of means of plant height showed that the application of foliar nanofertilizer led to the increase of plant height. Under normal treatment, the mean plant height was about 26.37 cm and it was nearly 10% lower height in case of application of nanofertilizer. Fe application showed significant effects on the day of flowering as compared to the normal plant and other nanofertilizer. In comparison between genotypes, higher plant height and longer days for flowering belonged to Azad and ILC482 (Table 2).

Number of primary and secondary branches

The results presented in Table 2 have demonstrated that number of primary and secondary branches per plant were significantly influenced by the foliar application of nanofertilizers. Among various treatments, application of Zn, NPK and combination of Zn+Fe+NPK showed maximum increase in the number pf branches per plant. There is no significant differences between genotypes for the number of secondary branches per plant, while the most primary branch observed is in Pirouz (Table 2).

Seed yield and 100-seed weight

The results have revealed that foliar application of nanofertilizer had significant effects on the seed yield (Table 2). Highest seed yield (137.3 g/m^2) is obtained by Fe+Zn foliar application and caused 34% increase in the seed yield. Same increase in the seed yield (~ 23%) was obtained by NPK, Fe and Zn foliar application. Effects of nanofertilizer foliar application on seed weight was varied. The highest increase in seed weight (~ 12%) was obtained by the foliar application of NPK and Fe+Zn. Interestingly, the combination of Fe+Zn with NPK showed no significant differences compared with the normal treatment (Table 2). In general, the seed weight and seed yield in Kabuli chickpea genotypes (Azad and ILC482) were higher than Desi chickpea genotypes (Kaka and Pirouz) (Table 2).

Biological yield and harvest index

Different nanofertilizer treatments showed significant increase in plant biomass on compared to normal treatment (Table 2). The highest increase in plant biomass (14%) compared to the normal treatment was obtained by the foliar application of NPK and Fe+Zn (Fig 5). By increasing the plant biomass, consequently the significant increase in harvest index by foliar application of nanofertilizer was observed (Table 2). Foliar application of Fe had the highest harvest index value (47.12%). Foliar application by Fe, Zn and combination of these micro nutrients with NPK showed ~18% increase in the harvest index.

DISCUSSION

Although fertilizers are very important for plant growth and development, most of the applied fertilizers are rendered unavailable to plants due to many factors, such as leaching, degradation by photolysis, hydrolysis, and decomposition. Micronutrients exist in very small amounts in both soil and plants, but their role is as important as the primary or secondary nutrients. Important micronutrients include six elements, namely, Fe, Mn, Zn, Cu, B and Mo (Steven, 2000). Hence, it is necessary to minimize nutrient losses in fertilization and to increase the crop yield through the exploitation of new applications with the help of nanotechnology and nanomaterials. Nanofertilzers or nano-encapsulated nutrients might have properties that are effective to crops, release the nutrients on-demand, controlled release of chemicals fertilizers that regulate plant growth and enhanced target activity (DeRosa *et al.,* 2010; Nair *et al.,* 2010). Researchers have reported in many articles about the effects of different micronutrients as nano particle on plant growth (Kahn *et al.,* 2004; Bala *et al.,* 2014; Valadkhan *et al.,* 2015). However, little studies have been done so far about the beneficial effect of these nanofertilizers in chickpea in dryland farming. In this study, effects of different nanofertilizers (Fe, Zn and NPK) on seed yield of chickpea were investigated. Plant with Zinc and Fe application showed higher values for plants with most of measured traits (Table 2). There are no significant differences for seed protein content in all treatments, but dramatically seed protein content increased in treatment with nanofertilzer. Prasad *et al.* (2012) in peanut; Sedghi *et al*. (2013) in soybean; Ramesh *et al.* (2014) in wheat and Raskar and Laware (2014) in onion reported that lower concentration of zinc exhibited beneficial effect on seed germination. Iron has a great role in increasing growth characters, being a component of ferrodoxin, an electron transport protein and is associated with chloroplast. It help in photosynthesis and hence, it have increased the growth (Hazra *et al.,* 1987). Kumar *et al.* (2009) showed that application of iron fertilizer increased the grain yield of chickpea by 17.3% over the control. Kobraee *et al*. (2011) reported that iron foliar application increased grain yield by influencing number of seeds per plant and seed weight. This is in agreement with our results that showed Fe, Zn and NPK lead to increasing in plant biomass (14%) and consequently increasing in seed yield (34%) when compared to the normal treatment (Table 2). It is clear from the present study that foliar application of Zn, Fe and NPK manipulates the growth of chickpea, resulting in beneficial changes in yield and yield components. The possible reason for such beneficial role is the increase in the activity of growth hormone or activity of phosynthetic system (Quary *et al.,* 2006) or might be due to the active role of these micronutrients in metabolic processes of plants and photosynthesis and thus, tended to increase flowering, and grain formation which ultimately increased the yield attributes. These results are in line with that reported by Kumar *et al*. (2009), Meena *et al*. (2010) and Kobraee *et al*.(2011).

CONCLUSION

Fertilizer management and choice of the optimal amount for use are the two major agronomic factors affecting productivity. The present study provides new findings about the effects of different nano-micronutrients on the yield and yield components of chickpea. Overall, the results showed that nanofertilizer had significant effects on most of the morphological traits and seed yield in chickpea undr field condition. It is clear from the present study that zinc, iron and NPK foliar application manipulates the growth of chickpea, resulting in beneficial changes in yield and yield components. Therefore, results revealed that nano-fertilizer applications in chickpea are promoting growth and yield. Also, more studies are needed to explore the mode of action of different micronutrients, their interaction with biomolecules and their impact on the regulation of gene expressions in plants.

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