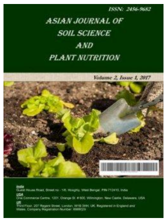

Asian Journal of Soil Science and Plant Nutrition

3(2): 1-10, 2018; Article no.AJSSPN.42897
ISSN: 2456-9682

The Effect of Some Growth Regulators Foliar Sprayed with the Fertilization by Fe and Zn on the Yield and Quality of Lentil Grown in Sandy Soil

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Authors' contributions

This work was carried out in collaboration between all authors. Author RAH designed the study, arranged and followed up the field work and shared the revision of the manuscript. Authors FAEK and MSM performed the field work. Author RTR carried out the experimental work, managed literature searches, the statistical analysis of the study data and wrote the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJSSPN/2018/42897
Editor(s):
(1) Dr. Pankaj Gupta, Professor, Dolphin (PG) College of Science & Agriculture, Punjabi University, India.
Reviewers:
(1) Hakan Kurt, N. E. U. Ahmet Kelesoglu Education, Turkey.
(2) Dennis Simiyu Wamalwa, Maseno University, Kenya.
Complete Peer review History: http://www.sciencedomain.org/review-history/25568

Original Research Article

Received 1st May 2018
Accepted 10th July 2018
Published 16th July 2018

ABSTRACT

Aims: A field experiment has been carried out under the sandy soil conditions. Its aim was to evaluate the effect of some plant growth regulators (PGRs) foliar sprayed along with the fertilization by Fe and/or Zn on the lintel (*Lens culinaris Medikus*) yield and quality.
Study Design: A complete randomized block design.
Place and Duration of Study: Winter seasons of 2016/2017 – 2017/2018 at the Ismailia Agricultural Research Station, (30° 35' 30" N 32° 14' 50" E elevation 3 m), Agricultural Research Center (ARC) - Egypt.
Methodology: The PGRs foliar sprayed included the recommended doses of gibberellic acid (GA_3, 100 ppm), salicylic acid (SA, 100 ppm), K-humate (6000 ppm) and K-silicate (K_2SiO_3, 200). The Fe (60 ppm) and/or Zn (100 ppm) were applied as EDTA chelated. Lintel grains were inoculated by efficient strained *Rhizobium leguminosarum* then sowed. Foliar spray of the different treatments was carried out 30, 45, and 60 days after sowing.

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Results: The effect of Zn treatments on the estimated yield components and growth parameters was more pronounced than Fe except for the plant height and the number of branches/plant. The Fe and Zn foliar spray significantly increased the lentil seed yield by 20.8% and 28.8%, respectively, compared with control. All treatments significantly increased the protein (%) and N (g/kg) in seeds compared with the control. The humate combined with the Fe or Zn (Fe + H and Zn + H) showed the most significant increase in the Fe in the seeds (by 54.89 and 100.16%, respectively). The combination between the silicate with Fe (Fe + Si) increased the Zn content in seeds more than the silicate with Zn (Zn + Si).

Conclusion: The seed yield (kg/ha) has significantly increased compared to the control in the order: Zn + GA_3 > Zn + Si > Zn + H > Fe + GA_3 > Fe + H > Fe + Si > Zn (Cont.) > Fe (Cont.) > Fe + SA > Zn + SA. Lentil may be a Zn-demanding plant and to less extent a Fe-demanding one. Their foliar application along the humate and silicate may be preferred over the GA_3 for environmental aspects.

Keywords: Gibberellic; humate; lentil; salicylic; sandy soil; silicate.

1. INTRODUCTION

The reclaimed sandy soils are promising for the agricultural expansion. A good agronomic management and improving the soil nutritional statue increase their total production. The reclaimed soil area which is grown by lentil (*Lens culinaris Medikus*) is increasing [1,2]. It is one of the most important leguminous winter crops grown in Egypt [3,4]. Lentil growing in the arid and semi-arid zones of the Mediterranean region experiences multiple environmental stresses such as drought, salinity, and heat [5,6,7]. The proper nutrients supply and the water management are of the major constraints in increasing the lentil yield [8,9].

Lentil has the third-highest level of protein, after soybean and hemp [10]. It contains dietary fiber, vitamin B1, and minerals. It is also a good source of iron (Fe). Lentil production diminishes mainly due to the cultivation of low yielding and environment sensitive genotypes. Seed germination is the most sensitive stage to stress and affects the final crop yield [6,7]. The stress conditions reduce growth by affecting the cell division, restricting the amount of the plant available water, and changing the balance of the plant endogenous levels of phytohormones [11].

Plant hormones are involved in the induction of plant stress responses [6]. A decreased cytokinin and gibberellic acid (GA_3) and increased abscisic acid contents have been observed in some salt-stressed plants [12]. To mitigate the adverse effect of such environmental stresses, the exogenous application of the plant growth regulators (PGRs) has obtained a substantial interest [7,13]. The PGRs like auxins and gibberellins are organic substances that regulate the intracellular processes to improve the plant growth [14]. The choice of the compound depends on the environmental condition, plant species, and available facilities. The seed priming with the gibberellic acid (GA_3), salicylic acid (SA) and ascorbic acid (ASC) has been found to increase the germination and seedling characteristics of lentil aged seeds [10].

The exogenously applied PGRs protect the plant against the water stress injury and retard the proline synthesis and transformations [7]. It may be a management tool improves the tolerance of agricultural crops against stress and accelerates a potential crop yield in near future [15].

Gibberellins (especially GA3) are important compounds enhance the productivity of commercial crops and improve most of the yield components [11,16]. They are natural penta-cyclic di-terpenoid carboxylic acids associated with various plant growth and development processes. For example, seed germination, stem elongation, leaf expansion, floral organ development, reduced time to flowering, increased the flower number and size and induction of some hydrolytic enzymes in the aleurone of cereal grains [7].

Genes may be involved in both GA biosynthesis and response pathways. The cereal aleurone layer is a well-characterized hormone signal (GA_3). During germination, the aleurone layer synthesizes and secretes hydrolases to the starchy endosperm to start and sustain reserve mobilization. The aleurone membrane systems often participate in elaborating the response to GA_3. There is evidence that suggests that GA_3 perception occurs at the plasma membrane [17].

The endogenous GA content in maize, poplar, and sorghum, might be promoted by the exogenous GA_3 that contribute to the increased plant growth [18]. Lentil is well adapted to semiarid plain regions where the soil profile is often not fully recharged with water. Lentil has a relatively shallow root system 0.6 m according to the genotypes [11]. Increasing the concentrations of the phytohormones GA_3 could reverse the adverse effects of water and salt stress on lentil [19].

Salicylic acid (SA) is a common hormone-like endogenous PGR and a natural signaling molecule. It is involved in the plant defense response against pathogen infection, biotic and environmental stress by influencing various physiological processes and biochemical reactions [15]. The foliar application of the SA on sunflower has enhanced the biomass production, photosynthetic pigments and the photosynthetic process [20].

Salicylic acid (SA) is distributed in the whole plant kingdom and has been characterized in 36 plants. In the plants, such as rice, crabgrass, barley and soybean the level of salicylic acid is ~1 µg/g fresh mass [21]. It shows diverse regulatory roles in the plant metabolism of plant growth, development, seed germination, fruit yield, ion uptake and transport, photosynthetic rate, stomatal conductance, and transpiration. It may contribute to regulating the antioxidant enzyme activity and gene expression [6].

Pre-treatment with SA improved the majority of physiological and morphological parameters in capsicum seedling and plants [13]. The foliar application of SA with farmyard manure during the vegetative and reproductive stages gave the highest lentil grain yield [19]. The proline metabolism in lentil was significantly altered maintaining the accumulation of higher levels of free proline and supporting its protection from salt stress [20].

The use of PGRs must be under strict control because they can provoke several diseases. The use of a silicon adjuvant improved growth regulator uptake by cotton and reduced the need of reapplication by at least 50% [22]. Foliar spray of Silicon alone at 50-ppm may result in a bad influence on the human body [23]. The humic acids play a role similar to the PGRs [24,25].

Additionally, legumes have a high iron (Fe) requirement for the heme components of the hemoglobin, nodule formation, enzymes like nitrogenase complex and hydrogenases and for ferredoxin electron carrier [26]. It has been found that a reduced rate of nitrogenase activity has been observed in the Fe limited peanut nodules, indicating a possible direct limitation by Fe deficiency on nodule function [27]. Similar results were obtained previously [1,28,29].

Zinc (Zn) plays a role in the photosynthesis in leaves and the carbohydrate metabolism and their conversion of sugar to starch [30]. Zinc is a constituent of several plant enzymes that contribute to its rate of metabolism and protein synthesis [31]. The zinc deficient plant produced lower seed yields and reduced the availability of seeds by ~ 50% compared to a plant with sufficient levels of Zn [1,8].

The present study aims to study the variation in the yield and quality of lintel (*Lens culinaris Medikus*) in sandy soil under the effect of the foliar spray of gibberellic acid (GA3), salicylic acid (SA), K-humate and K-silicate with fertilization by Fe and Zn.

2. MATERIALS AND METHODS

A field experiment was carried out during the winter seasons of 2016/2017 – 2017/2018 under the conditions of sandy soil (Typic Torripsamment; Entisol [Arenosol AR] [32]) of the Ismailia Agricultural Research Station, (30° 35' 30" N 32° 14' 50" E elevation 3 m) Agricultural Research Center (ARC) - Egypt. Some of the physical and chemical properties of the experiment soil are shown in Table 1.

2.1 Planting

Many investigations were conducted in Egypt to develop promising lentil cultivars using local and exotic accessions, which were evaluated under variable conditions of Egyptian environments. Several cultivars such as Giza 9, Sinia 1 (Precoz) and Giza 370 were recommended due to multi-locations stability and responses against stress [3].

Lintel grains Giza 9 variety were obtained from Field Crop Research Department, Field Crops Institute, Agriculture Research Centre/Egypt. Grains without visible defect, insect damage, and malformation were selected.

Table 1. Some characteristics of the experiment soil before cultivation

Character		
Particle size distribution (%)	**Coarse Sand**	72.12
	Fine Sand	14.32
	Silt	3.22
	Clay	10.34
Texture class		Sandy
$CaCO_3$ (%)		0.36
Organic Matter (OM, %)		0.23
pH (1:2.5 soil : water suspension)		8.01
Saturation Percent (SP, %)		25.00
Electrical Conductivity (EC, dS/m) (1:5 soil : water extract)		0.30
Available nutrients (mg/kg)	**N**	20.50
	P	2.01
	K	50.13

Lintel grains were inoculated by efficient strained *Rhizobium Leguminosarum* (supplied by the Department of Microbiology at SWERI/ARC) as follows: an amount of starch as adhesive glue material suitable for the grains quantity was wetted by 50 mL of warm water then mixed thoroughly with grains. The bacteria were mixed with the starch-wetted grains and dried for 90 min.

Sowings were performed in December. 2016, 2017 where two grains/hill were hand sown with 5 cm apart between hills. Eight treatments listed in Table 2 were applied in a complete randomized block design with three replicates in 24 plots (9 m^2 each). Fertilization by foliar spray was carried out 30, 45, and 60 days after sowing using the following treatments: 60 and 100 ppm of EDTA chelated Zn and/or Fe, respectively, 6000 ppm of K-humate, 200 ppm of K-silicate (K_2SiO_3), 100 ppm of SA and/or 100 ppm of GA3. Planting and the other agronomic practices were applied as recommendations of the Ministry of Agriculture.

Fertilizers were applied during the seedbed preparation as follows: 40 N units/ha as ammonium sulphate (20% N), 100 P_2O_5 units/ha as mono-calcium superphosphate (15.5% P_2O_5) and 100 K_2O units/ha as potassium sulphate (48% K_2O).

At harvest time, (May 2017 and May 2018 - 150 days from sowing) ten plants from each plot were randomly selected, picked up by hand to avoid seed loss and air-dried. Some of the growth parameters such as the plant height (cm), number of branches/plant and the number of pods/plant were recorded. Yield components such as the weight of 1000 seeds (g), the seed yield (ton/ha) and the straw yield (kg/ha) have been calculated according to the total seed yield per plot area and the mean of the two seasons was recorded.

2.2 Analysis of Plant and Soil Samples

Lentil grains and straw were dried at 70ºC for 48h and ground. A half gram of ground grains or

Table 2. The treatments used in the experiment

Ser. no.	Treatment	Symbol
1	Control	Cont.
2	Fe (Control)	Fe (Cont.)
3	Fe + K-humate	Fe + H
4	Fe + Salicylic Acid	Fe + SA
5	Fe + Silicate	Fe + Si
6	Fe + Gibberellic Acid	Fe + GA_3
7	Zn (Control)	Zn (Cont.)
8	Zn + K-humate	Zn + H
9	Zn + Salicylic Acid	Zn + SA
10	Zn + Silicate	Zn + Si
11	Zn + Gibberellic Acid	Zn + GA_3

straw was wet digested using the acid mixture (1:1 $H_2SO_4/HClO_4$) [33]. After harvesting, soil available N, P, K were extracted by 1% K_2SO_4, 0.5 N $NaHCO_3$, and 1 N NH_4OAc (pH 7.0), respectively. Total percentage of N, P and K in digested plant samples and the available in the soil extracts were estimated by distillation using Kjeldahl apparatus, colorimetrically by UV-Vis. Spectrophotometer using the $SnCl_2$ indicator and by the flame photometer, respectively [34,35]. Protein percentage in grains was calculated as an N% × 6.25. Iron (Fe), Zn, and Si were measured for both grains and straw by Inductively Coupled Plasma Spectrometry (ICP-*Ultima 2 JY* Plasma).

2.2 Statistical Analysis

The one-way analysis of variance (ANOVA) was carried out using the Co-State software (Ver. 6.311) to determine the statistical significance (LSD) of the treatment effects at a significance level *P = .05* [36].

3. RESULTS AND DISCUSSION

3.1 Soil Available Nutrients

Table 3 shows the variation in the soil available NPK resulted from the different treatments as a mean of the two seasons. Foliar application of Fe and/or Zn significantly increased the soil available N by 235.3% and 34.8%, P by 355% and 235%, and K by 140%, respectively. The combination between the K-humate and Fe or Zn significantly increased the available P (by 115 and 65%) and K (by 103.1 and 42.5%), respectively, but no effect on the available N. A combination between the SA and Fe or Zn significantly increased the K only, but affected the available N and P in an opposite direction. The K-silicate application significantly decreased the available N and almost no effect on the P or K when combined with the Fe. When combined with the Zn, it significantly increased the NPK. Foliar application of the GA_3 combined with the Fe and/or Zn significantly increased the soil available N (by 34.8 and 51.2%), P (by 65 and 85%) and K (by 59.5 and 91.1%), respectively.

3.2 Yield and Yield Components

Table 4 shows some of the lentil yield components as affected by the studied treatments as a mean of the two seasons. According to the LSD values at the *P* = .05 significance level and comparing with the control, the lentil plant height significantly increased by different treatments, except for the foliar application by SA along with both Fe and Zn which was non-significant. Same treatment gave the lowest significance increase by 12.5% for the number of branches/plant. The Fe + Si treatment gave the most significant increase in the plant height and the number of branches/plant by 28.57% and 58.33%, respectively. The Fe and Fe + SA treatments were non-significant and the lowest significant increase effect on the number of pods/plant. The most significant increase by 42.86% was shown by the foliar application of silicate along with Fe or Zn (Fe + Si and Zn + Si treatments) and the GA_3 with Zn. Variation in the 1000-seed weight was non-significant for all treatments.

Table 3. Soil available NPK (mg/kg) after lentil harvest (Ismailia, winter seasons 2016/2017 – 2017/2018)*

Treatment	Available NPK (mg/kg)		
	N	P	K
Cont.	20.1	2.1	65.0
Fe (Cont.)	23.1	2.5	70.0
Fe + H	21.2	2.7	78.0
Fe + SA	20.2	2.6	75.1
Fe + Si	19.1	2.5	78.5
Fe + GA_3	23.1	2.3	80.7
Zn (Cont.)	22.1	2.4	75.0
Zn + H	21.2	2.5	80.6
Zn + SA	23.0	2.6	70.0
Zn + Si	22.2	2.7	90.0
Zn + GA_3	24.0	2.7	90.0
L.S.D. $_{5\%}$	2.26	0.68	8.35

**Data are average values of the two seasons*

Again, the foliar spray by SA along with both Fe and Zn was non-significant for both the seeds and straw yield (kg/ha) as yield parameters. The highest significant increase in the seeds and straw yield (kg/ha) was by 36, 44 and 48% and by 26.93, 34.4 and 38.13% resulting from the treatments Fe + GA_3, Zn + Si and Zn + GA_3, respectively.

Comparison between Fe and Zn different treatments indicated that the effect of Zn treatments is more pronounced than Fe for the estimated yield components except for the plant height and the number of branches/plant. The Fe and Zn foliar application significantly increased the lentil seed yield by 20.8% and 28.8%, respectively.

Table 4. Yield and yield components for lentil (Ismailia, winter seasons 2016/2017 – 2017/2018)*

Treatment	Plant height (cm)	No. branches/plant	No. Pods/plant	1000 seed wt. (g)	Seed yield (kg/ha)	Straw yield (kg/ha)
Cont.	28	2.4	14	27.5	1250	3750
Fe (Cont.)	32	3.2	16	29.3	1510	4228
Fe + H	35	3.6	19	29.5	1650	4455
Fe + SA	29	2.7	15	28.0	1320	3960
Fe + Si	36	3.8	20	28.1	1630	4564
Fe + GA_3	35	3.5	19	28.2	1700	4760
Zn (Cont.)	31	3.1	17	28.2	1610	4508
Zn + H	34	3.6	19	29.1	1720	4730
Zn + SA	29	2.7	17	27.5	1310	3930
Zn + Si	35	3.7	20	29.3	1800	5040
Zn + GA_3	35	3.6	20	29.3	1850	5180
L.S.D. $_{5\%}$	2.1	0.3	2.1	3.6	99.2	280.5

**Data are average values of the two seasons*

The significant effect of Zn on the lentil yield may be due to its role as a critical micronutrient for healthy plant function during essential stages of growth and development. It has been reported that the high Zn concentration has improved vigour seed compared to those with lower Zn [30]. The data obtained confirm with data obtained [1,2].

Application of humate combined with Fe and/or Zn increased the seed yield by 32% and 37.6%, respectively, compared to control. The mechanism of humate activity in the plant growth simulation has been proposed as increasing cell membrane permeability, nutrient and oxygen uptake, respiration in the cell of plant tissue, enhanced root, leaf and shoot growth and simulated germination. Plant shows improved physiological and metabolic processes and increased respiratory activity attributed to the inner venation of humic acid.

The combined application of Si with Fe and Zn significantly increased the lentil height, branches number and seed yield (kg/ha) by 30.4 and 44% for the Fe + Si and Zn + Si, respectively. Silicon affects the plant growth mechanisms, i.e. alleviates much abiotic stress, like lodging, drought, radiation, high temperature, salt, nutrient imbalance, and increasing the photosynthetic activity. Silicon is applied in several countries for increasing productivity and sustainable production. It was beneficial for barley, wheat, corn, sugar cane, cucumber, tomato and other crops. The silicon (Si) foliar application has increased the pea dry shoot, NPK contents, maize yield and its components at 100 and 200 ppm Si [16].

The treatments Fe + GA_3 and Zn + GA_3 showed the highest significant increase of the seeds yield (kg/ha) by 36 and 48%, respectively. The obtained data are in agreement with those obtained previously. Application of GA_3 significantly affected the growth, yield, and yield components of maize grain yield [16].

3.3 Nutrient Content in the Lentil Seeds and Straw

3.3.1 The NPK (g/kg) total content

Data in Table 5 present the mean of the two seasons for the variation in the total NPK content in both lentil seeds and straw in addition to the seeds' protein. All treatments significantly increased the protein (%) and n (g/kg) in seeds compared with the control at a significance level $P = .05$. Individual application of Fe or Zn increased the protein (%) by 23.53 and 17.03%, and the n (g/kg) by 19.06 and 17.06%, respectively. The combination of SA with either Fe or Zn resulted in the most significant increase by 38.7 and 84.21% in the protein (%) and by 38.74 and 84.26%, respectively. The combined Zn different applications increased the protein (%) more significantly than the combined Fe applications.

Table 5. Total NPK (g/kg) in lentil seeds and straw, (Ismailia, winter seasons 2016/2017 – 2017/2018)*

Treatment	Seeds, (g/kg)				Straw, (g/kg)		
	Protein %	N	P	K	N	P	K
Cont.	19.38	31.00	2.10	5.10	8.10	1.20	11.2
Fe (Cont.)	23.94	38.30	3.95	6.14	8.06	1.20	12.42
Fe + H	26.04	41.66	4.45	6.14	9.41	1.05	7.33
Fe + SA	26.88	43.01	4.05	6.14	8.06	1.05	11.31
Fe + Si	24.57	39.31	4.05	7.49	6.72	1.05	13.19
Fe + GA_3	24.36	38.98	4.00	7.33	9.41	1.13	7.80
Zn (Cont.)	22.68	36.29	3.63	6.01	10.08	0.85	5.04
Zn + H	29.40	47.04	4.15	5.30	9.41	1.13	5.6
Zn + SA	35.70	57.12	4.05	7.33	10.75	1.3	5.87
Zn + Si	30.24	48.38	3.55	5.87	8.74	0.80	7.33
Zn + GA_3	28.14	45.02	4.25	6.14	11.42	1.10	5.73
L.S.D $_{5\%}$	1.58	1.38	n.s.	1.03	1.38	0.41	1.72

**data are average values of the two seasons*

The variation in the seeds' content of P (g/kg) was non-significant compared to the control. Foliar application of either Fe or Zn increased the P (g/kg) by 88.1 and 72.86%, respectively. The Fe + H and the Zn + GA_3 treatments showed the maximum increase by 111.9 and 102.38%, respectively.

All the Fe treatments while only two Zn treatments (Zn + SA and Zn + GA_3) that significantly increased the K (g/kg) in seeds. The Fe + Si treatment showed the most significant increase by 46.86%, while the Zn + H treatment exhibited the minimum non-significant increase by 3.92% compared to the control.

For the straw, only three Zn treatments that significantly increased the N (g/kg) by 24.44%, 32.72% and 40.99% for the Zn, Zn + SA and Zn + GA_3 treatments, respectively. Again, the variation in the P (g/kg) was non-significant and all treatments decreased it in the straw compared with the control. The Fe + Si was the sole treatment significantly increased the K (g/kg) in the straw by 17.77%. The Fe and Fe + SA treatments increased it by 0.97 and 0.98%, respectively. Other treatments significantly decreased the K (g/kg) in the straw and the least significant decrease by 55% due to the Zn treatment.

3.3.2 The Fe, Si, and Zn (mg/kg) content

Table 6 exhibits the content of the Fe, Si, and Zn (mg/kg) in the lentil seeds and straw as a mean of the two seasons. Foliar application of the humate combined with the Fe or Zn (Fe + H and Zn + H) showed the most significant increase in the Fe in the seeds (by 54.89 and 100.16%, respectively) and the maximum non-significant increase in the straw (57.86 and 38.23%, respectively). The second most effective in enhancing the Fe content treatments were the Zn + GA_3 for the seeds and the Fe + SA for the straw [9].

Foliar application of Fe or Zn significantly increased the Si (mg/kg) in the seeds and straw by 7.96, 7.15% and 56.56, 18.33%, respectively. Combination between the humate with either the Fe or Zn significantly increased the Si (mg/kg) by 145.74% and 16.65%, respectively, in the seeds' and by 17.44% and 56.79%, respectively, in the straw. The Si increased by the combined Fe treatments in the order Si < GA_3 < SA for seeds and GA_3 < Si < SA for the straw. However, it decreased by the combined Zn treatments in the order SA < Si < GA_3 for seeds and by the SA for the straw.

The combination between the silicate and Fe (Fe + Si) increased the seed content of Zn more than the silicate and Zn (Zn + Si).

The foliar application of GA_3, Si, and SA mediated the accumulation levels of some heavy metals in maize leaves. The chemical structure of the GA_3, SA, and silicates affects the absorption of cations (or anions) by plant tissues [1,16,37].

Table 6. The content of Fe, Si and Zn (mg/kg) in the seeds and straw of lentil (Ismailia, winter seasons 2016/2017 – 2017/2018)*

Treatment	Seeds (mg/kg)			Straw (mg/kg)		
	Fe	Si	Zn	Fe	Si	Zn
Cont.	57.0	46.0	33.0	66.0	48.0	15.0
Fe (Cont.)	78.1	49.7	38.0	138.9	75.2	20.4
Fe + H	117.7	113.0	44.4	72.8	56.4	29.2
Fe + SA	85.4	68.8	45.6	111.0	75.4	44.8
Fe + Si	98.6	47.9	80.4	95.6	55.6	22.0
Fe + GA_3	76.3	51.2	43.2	79.2	34.6	10.8
Zn (Cont.)	82.4	49.3	35.2	96.9	56.8	24.8
Zn + H	152.1	53.7	42.8	121.6	75.3	30.8
Zn + SA	91.4	41.2	50.4	94.4	43.1	12.8
Zn + Si	90.8	42.8	34.8	97.9	50.2	14.0
Zn + GA_3	107.6	44.3	47.2	107.8	113.8	36.8
L.S.D. $_{5\%}$	3.39	2.73	3.67	3.75	2.76	4.38

**Data are average values of the two seasons*

4. CONCLUSION

The lintel (*Lens culinaris Medikus*) yield and quality in the sandy soil were affected by the foliar spray of gibberellic acid (GA_3), salicylic acid (SA), K-humate and K-silicate accompanying the fertilization by EDTA chelated Fe and/or Zn. The data as a mean of two seasons were recorded and statistically analyzed. The sole application of either Fe or Zn treatment significantly increased the soil available NPK followed by the ga3 application with either Zn or Fe then the Zn + Si treatment compared to the control. Other treatments exhibited a diverse effect on the soil available NPK. Generally, almost all treatments significantly increased the available K. The available n decreased by the Fe treatments (+ H, + SA, + Si) while increased by the Zn treatments (+ SA, + Si).

The lentil seed yield (kg/ha) was enhanced by the Zn treatments more than the Fe treatments. Foliar application of SA with either Fe or Zn increased the seed yield but non-significantly. Other treatments significantly increased the lentil seed yield compared to the control in the following order: Zn + GA_3 > Zn + Si > Zn + H > Fe + GA_3 > Fe + H > Fe + Si > Zn (Cont.) > Fe (Cont.) > Fe + SA > Zn + SA.

Application of the humate combined with the Fe or Zn (Fe + H and Zn + H) showed the most significant increase in the Fe in the seeds by 54.89 and 100.16%, respectively. Foliar application of Fe or Zn significantly increased the Si (mg/kg) in the seeds and straw by 7.96, 7.15% and 56.56, 18.33%, respectively. The Si increased by the combined Fe treatments in the order Si < GA_3 < SA for seeds. However, it decreased by the combined Zn treatments in the order SA < Si < GA_3 for seeds and by the SA for the straw. The combination between the silicate and Fe (Fe + Si) increased the seed content of Zn more than the silicate and Zn (Zn + Si).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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