



### Full Length Article

## Influence of Different Zinc Application Methods on Yield and Mineral Composition of Grains in Mungbeans (*Vigna radiata* Wilczek)

Muharrem Kaya<sup>1\*</sup>, Ruziye Karaman<sup>1</sup> and Aykut Şener<sup>1</sup>

<sup>1</sup>Department of Field Crops, Faculty of Agriculture, University of Suleyman Demirel, Isparta-32260, Turkey

\*For correspondence: muharremkaya@sdu.edu.tr

### Abstract

The aim of this study was to determine the effects of different zinc application methods on yield and its components, and the mineral composition of grains in mungbeans. The experiment was conducted under field conditions in completely randomized block design as three repetitions during 2011–2012 in the Isparta/Turkey (37°49'37.0"N 30°32'09.1"E). In the study, Partow mungbean variety underwent seed treatments by keeping the grains in solutions prepared with distilled water containing 0.04% Zn, 0.05% Zn, and 0.06% Zn at 25°C for 6 h. After soaking, the seeds were dried in the oven (25 ± 1°C) until reaching their initial weights. In addition, for inoculating the seed with Zn, 7.5 g ZnSO<sub>4</sub> 7H<sub>2</sub>O was dissolved in 250 mL distilled water. The solution was sprayed on the seeds at 1% of the seed weights, and then the seeds were immediately planted. Also, zinc sulfate fertilization to soil was carried out using 50 kg ha<sup>-1</sup>. In addition to the 100 grain weight, both seed treatments and zinc inoculations had a positive effect on fruit and grain number, grain yield per unit area, and protein ratio properties compared to control. Grain yield was 1155 kg ha<sup>-1</sup> in the control and 1338 kg ha<sup>-1</sup> in the hydro-priming with percent increase of 15.84%. The average value for all zinc application methods increased as much as 1466 kg ha<sup>-1</sup>. Zinc applications reduced the phosphorus content of the grains; however, iron, potassium, and nitrogen content increased. Zinc content increased from 35.5 mg kg<sup>-1</sup> to 39.1 mg kg<sup>-1</sup> with the hydro-priming, and the average zinc content of all the zinc applications increased to 44.6 mg kg<sup>-1</sup>. © 2017 Friends Science Publishers

**Keywords:** Mungbean; Seed treatment; Yield; Grain Zn contents; Nutrient

### Introduction

Zinc is important for human and animal nutrition and its deficiency causes serious diseases in humans and health problems, including decline in growth and learning abilities, incomplete development of the immune system, negative effects on the central nervous system, and adversities in the reproductive system (Kaya *et al.*, 2005). Approximately 3 billion people in the world, especially in developing countries, have health problems related to zinc deficiency. A diet based on grains of cereals and legumes rich in respect to phytic acid is shown as the most important reason for these deficiencies (Çakmak *et al.*, 1996). Additionally, zinc has a regulatory role in many enzyme systems and used in the synthesis of nucleic acids, production of chlorophylls and carbohydrates, and in metabolism of the plant hormone called auxin; therefore, it has a great role in plant nutrition (Ahmad *et al.*, 2008; Penas *et al.*, 2010). Zinc deficiency occurs in 30% of agricultural soils in the world, and approximately half are present in Turkey (Çakmak *et al.*, 1996; Erdal, 1998). Soil and environmental conditions, including low organic matter content, high lime content, high pH and alkalinity, cold and damp conditions, soils rich in phosphorus or excessively fertilized soils, and high

carbonate and bicarbonate content in irrigation water and associated high pH, negatively affect the solubility and bioavailability of nutrient elements (Mut and Gülümser, 2005; Kacar and Katkat, 2011). Fertilization with zinc can increase both the zinc content and bioavailability in cereals and legumes (Graham and Welch, 1996). In plant production, fertilizers containing zinc can be applied to soil and seed, and can be sprayed onto the leaves. In addition, seeds are treated by soaking the seeds in osmotic solutions containing different concentrations of salts for a period through a process called seed priming (Kaya *et al.*, 2005). Seed treatments can be done by hydro-priming as well as using osmotic solutions containing various salts or plant growth regulators to increase the efficacy of the procedure (Harris *et al.*, 1999; Chiu *et al.*, 2002; Şanlı, 2007). Treatment of maize seeds with 1% and 2% zinc solutions for 16 h had a positive effect on yield and its components, and seed inoculation in corn is economical compared to soil application (Harris *et al.*, 2007; Imran *et al.*, 2016). Mungbeans are very sensitive to zinc deficiency and very high, especially in alkaline soils (Jayne, 2010). In many studies on mungbeans, it was determined that different zinc application methods had positive effects on yield, plant characteristics, and the mineral composition of the grains.

Rahman *et al.* (2015), in their study on mungbeans conducted in Bangladesh, reported that plant lengths, pod number, seed counts, fruit length, and the 1000 grain weight increased with increased doses of zinc. The researchers had reported that grain yield was 1.27 t/ha in the control, and this value increased as high as 1.45 t/ha with zinc application with percent increase of 14.17%. It had been reported that applying 5 L 30% zinc sulfate foliar to one-ton mungbean seed, increased the yield in alkaline and arid areas (Jayne, 2010). In studies on zinc applications on mungbeans conducted in arid and semi-arid areas, dry agricultural areas, and soils with high lime content, it was observed that yield, growth parameters, and plant properties improved (Thaloot *et al.*, 2006). Mineral composition of the grain improved, especially N, S, Zn and K (Thomas *et al.*, 2007; Hossain *et al.*, 2011; Ali and Mahmoud, 2013). However, zinc applications reduced P content of the grain (Hossain *et al.*, 2011). Zinc and boron applications increased the grain yield and quality of mungbeans even in floodplain soils with low lime content (Quddus *et al.*, 2011). In a study conducted in Pakistan, distilled water, 0.04% Zn, 0.05% Zn, and 0.06% Zn were applied to chickpea seeds for 6 h. Zinc content in the control group was 49 mg kg<sup>-1</sup>, while the average Zn content of grains treated with solutions containing Zn was as high as 80.6 mg kg<sup>-1</sup>. Moreover, yield increased by hydro-priming was 7%, and by zinc priming was 19% (Harris *et al.*, 2008). The purpose of this study was to determine the effects of different zinc application methods on yield and its components, and the mineral composition of grains in mungbeans.

## Materials and Methods

This study was conducted in 2011–2012 for two years in the Isparta (Turkey) located as crossover zone between the Mediterranean climate and terrestrial climate zone dominant in the Central Anatolia Region. The altitude of the experimental site is approximately 1050 m. The winters are relatively cool-cold and rainy, while the summers are hot and have semi-arid climatic conditions. Total rainfall values in the trial years were close to the long-term annual averages, and the monthly distribution of rainfall was regular except in July and August. In the experiment, Partow mungbean variety seeds were used as the plant materials. The first year of the experiment was conducted in plots with heavy clay, poor in organic matter (1.9%), high lime content, and pH (8.12), while during second year soil was moderate loam, poor in organic matter, pH close to neutral (7.78), and moderate-high lime content. The EC of both locations was 0.421 dS m<sup>-1</sup>. Zinc content of the soil in the experimental site was 0.44 mg kg<sup>-1</sup>, lower than the critical limit required for the plants.

The study included seven treatments : the control (no Zn) , four seed priming treatments including with distilled water (hydro-priming), with 0.04% Zn, 0.05% Zn, 0.06% Zn solutions, zinc soil fertilization (50 kg ha<sup>-1</sup>), and zinc

inoculation (7.5 g ZnSO<sub>4</sub> 7H<sub>2</sub>O was dissolved in 250 mL distilled water). The solution was sprayed to the seeds at 1% to the weight of the seeds, and then the immediately planted. Planting was conducted manually in 25 cm intervals, with 6 rows in each plot, in 9 (6 m x 1.5 m) m<sup>2</sup> plot size. Seven hundred and twenty seeds were counted for each treatment, and planted in early May when the soil temperature was 10°C. Basic fertilization was conducted at the start of planting with 30 kg ha<sup>-1</sup> N and 60 kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub> (Meral *et al.*, 1998; Kaya, 2000). Weeds were controlled by hoeing where necessary and irrigation carried out two times, one being right after sprouting and other during the pod formation period.

## Seed Priming Treatments

The mungbean seeds were dipped in 1% NaHClO<sub>4</sub> solution for 10 min. surface washed with distilled water three times and dried. A germination test was applied to the seed samples in four repetitions, and the germination rate found was 96%.

For zinc seed priming of mungbeans, according to the method by Harris *et al.* (2008), 250 mL 0.04%, 0.05%, and 0.06% Zn stock solutions were prepared using 99% zinc sulfate (ZnSO<sub>4</sub> 7H<sub>2</sub>O) fertilizer. Seven hundred and twenty seeds for each treatment were placed in 500 mL flasks, and added with 250 mL Zn solution. For hydro-priming, 250 mL distilled water was added to the seeds. The beakers were sealed tightly with aluminum foil and kept in an oven at 25°C for 6 h. Then seeds were filtered, surface dried with blotting paper, and thereafter at 25°C until their initial weights. Seed samples were kept in sealed bags in the refrigerator at 4°C until planting (Sundstrom *et al.*, 1987; Şanlı, 2007).

## Yield Traits and Mineral Analysis

In all treatments, pod number and grain number, plant yield, 100 grain weight, and grain yield were recorded according to the methods of Kaya (2000). P, Fe, K, N and Zn contents and crude protein contents of the grain samples were analyzed according to Kacar and Inal (2010). To determine the P, Fe, K, Zn content, 0.5 g ground samples were digested with a microwave digester. The samples were filtered and volume filled up to 100 mL with distilled water. Phosphorus content was determined with a spectrophotometer at 430 nm according to the vanadomolybdophosphoric acid method. The other elements were measured by an atomic absorption spectrophotometer (Kacar and Inal, 2010). Nitrogen content of samples was determined according to the Kjeldahl method (Bremner, 1965).

## Statistical Analysis

The data obtained from the experiment were analyzed using TOTEMSTAT statistical analysis software according to

randomized block design. The results were compared using the Duncan Test ( $P \leq 0.05$ ).

## Results

The differences between pod number, grain number and grain yield per unit area in terms of years and Zn treatments and their interaction were very significant ( $P \geq 0.01$ ). The differences between Zn treatments in terms of 100 grain weight and their interaction were also significant ( $P \geq 0.01$ ). In plant yield and grain protein ratio, their interactions were not significant, but differences between applications ( $P \geq 0.01$ ) and years ( $P \geq 0.05$ ) were significant.

The average pod number and grain number and grain yield for unit area were the lowest in the control treatments. Zn application through priming, soil fertilization, and seed inoculation had positive effects on pod number, grain number, and grain yield properties in both years. Although it varied by year, and the highest mean values were obtained by zinc inoculation (Table 1). During first year of experiment, seed priming with 0.05% Zn, 0.06% Zn, and zinc inoculation had the highest average values and followed by the zinc fertilization treatment. Seed priming increased the average numbers of grains and the highest values were obtained with 0.05% Zn seed priming. In both years, grain number values decreased with soil fertilization compared to 0.05% Zn and 0.06% Zn seed priming and seed inoculation methods. All seed priming, zinc fertilization, and seed inoculation applications significantly increased the grain yield per unit area. The mean grain yield of two years in the control was 1155 kg ha<sup>-1</sup>, and it was increased approximately by 15.84% with hydro-priming, 24.58% with Zn seed priming, 28.31% with zinc fertilization, and 32.64% with seed inoculation, respectively (Table 1).

Interaction for plant yield and grain crude protein content was not significant. The lowest plant yield and crude protein rate was recorded in the control and the highest plant yield with seed inoculation methods. The highest crude protein values were found with soil zinc fertilization and seed inoculation (Table 1).

In terms of 100 grain weight, the highest average values were in the control while priming and zinc fertilization reduced the weight of the grains. The lowest average value during the first year (4.47 g) were obtained with the 0.05% Zn application, while the lowest average value in the second year (4.60 g) with seed inoculation method. All of applications were lower than control. 100 grain weight mean of these values in order: Control > % 0.04 Zn > D. Water > Zn Seed > Zn Soil > % 0.06 Zn > % 0.05 Zn, respectively (Table 1).

Priming, soil zinc fertilization and seed inoculation positively affected and improved all the plant properties except 100 grain weight in mungbeans. Zinc fertilization slightly reduced pod number (Zn Seed > % 0.06 Zn = % 0.05 Zn > Zn Soil > % 0.04 Zn > D. Water > Control, respectively), grain number (% 0.05 Zn > Zn Seed > % 0.05

Zn > % 0.04 Zn > Zn Soil > D. Water > Control, respectively), plant grain yield (Zn Seed > % 0.06 Zn > % 0.05 Zn > % 0.04 Zn > Zn Soil > D. Water > Control, respectively) and grain yield (Zn Seed > Zn Soil > % 0.06 Zn > % 0.05 Zn > % 0.04 Zn > D. Water > Control, respectively) of unit area characteristics. But crude protein value compared to those in the osmo-priming (especially in 0.05% and 0.06% Zn doses) and zinc application to the seed groups. Zn application of mungbean seed the increasement in crude protein ratios indicating average net improvement were in the rank according to control (22.8%): Zn Seed (13.6%) > Zn Soil (12.7%) > % 0.06 Zn (11.4%) > % 0.05 Zn (10.5%) > % 0.04 Zn (8.8%) > D. Water (3.5%) respectively) (Table 1).

The differences between the years and year x application interaction in terms of phosphorus, iron, and potassium contents were highly significant ( $P \leq 0.01$ ). The differences between the groups in terms of nitrogen and zinc contents and year x application interactions were significant ( $P \leq 0.01$ ).

The highest average grain phosphorus contents in mungbeans in both experimental years were detected in the control and hydro-priming. Seed treatments with zinc solutions and other zinc applications, the phosphorus contents of the grains negatively affected and decreased than control, these varieties were in the orders: Control > D. Water > % 0.04 Zn > % 0.05 Zn > % 0.06 Zn > Zn Soil > Zn Seed, respectively (Table 1). During first year, the lowest average phosphorus value (3954.3 mg kg<sup>-1</sup>) was in the zinc application to the seed group and during second year, the lowest average values were obtained from zinc applications applied to the soil and the seeds. However, 0.05% Zn and 0.06% Zn seed treatments ranged in the same group (Table 1).

The lowest iron, potassium, nitrogen, and zinc grain contents were obtained in the control during both years followed by distilled water and seed priming groups. Seed priming, soil fertilization, and seed inoculation methods had positive effects on the mineral composition of the mungbean grains. During first year, the highest iron content (243.9 mm kg<sup>-1</sup>) was found in the seed inoculation group and similar results were obtained in the second year with seed inoculation, soil fertilization, and 0.05% Zn seed priming applications (Table 1). In terms of potassium contents, seed inoculation, soil fertilization and 0.06% Zn seed priming applications (1.47%, 1.47% and 1.45%, respectively) had the highest values in the first year, while seed inoculation, soil fertilization and 0.04% Zn seed priming applications in the second year. In terms of grain nitrogen content, similar to the potassium content, seed inoculation and soil fertilization had the highest values. After zinc application to the seed, grain zinc contents increased by 38% in the first year and by 33% in the second year compared to those of control (Table 1). In our study, potassium, iron, nitrogen, and zinc contents of mungbean grain increased in all applications, related to soil zinc applications.

**Table 1:** The average yield, mineral nutrients content of and some other properties of mungbeans treated with different seed applications and zinc fertilization

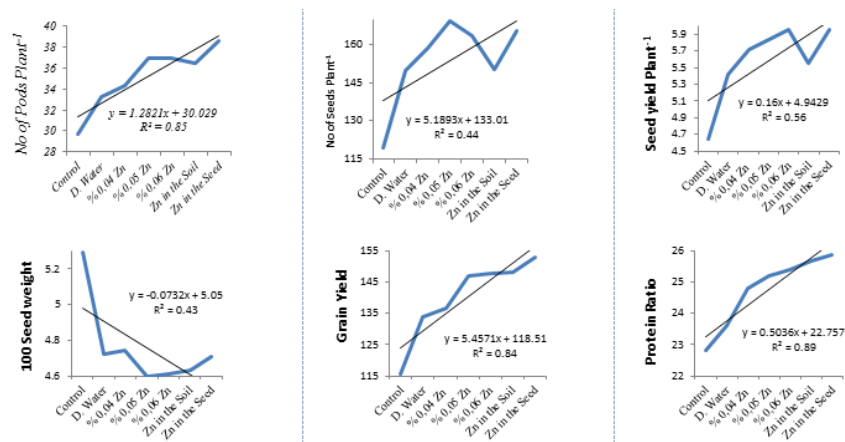
Treatments	Number of pods plant <sup>-1</sup>			Number of seeds plant <sup>-1</sup>			Seed yields plant <sup>-1</sup>		
	1.year	2.year	Mean	1.year	2.year	Mean	1.year	2.year	mean
Control	29.1 c	30.3 e	29.7	114.3 d	124.1c	119.2	4.45	4.82	4.64 e
D. Water	32.7 b	33.8 d	33.2	156.6 abc	142.7b	149.7	5.50	5.34	5.42 d
% 0.04 Zn	33.6 b	35.1 cd	34.3	146.8 c	170.3a	158.6	5.63	5.78	5.71 bc
% 0.05 Zn	37.1 a	36.6 bc	36.9	165.7 a	172.9a	169.3	5.81	5.86	5.84 ab
% 0.06 Zn	36.6 a	37.1 b	36.9	157.1 ab	170.4a	163.8	5.96	5.94	5.95 a
Zn in the Soil	33.9 b	39.1 a	36.5	149.1 bc	151.4b	150.3	5.31	5.80	5.56 cd
Zn in the Seed	37.9 a	39.3 a	38.6	156.8 abc	174.2a	165.5	5.90	6.03	5.96 a
Mean	34.4	35.9		149.5	158.0		5.51b	5.65a	
C.V.		2.63			4.00			3.26	
	Weight of 100 seeds (g)			Seed yield (kg ha <sup>-1</sup> )			Protein ratio (%)		
	1.year	2.year	Mean	1.year	2.year	Mean	1.year	2.year	mean
Control	5.59 a	4.99a	5.29	1097 c	1213 d	1155	22.7	22.9	22.8 e
D. Water	4.65 bc	4.78 ab	4.72	1395 b	1280 cd	1338	23.6	23.5	23.6 d
% 0.04 Zn	4.64 bc	4.84 ab	4.74	1386 b	1351 c	1369	24.6	24.9	24.8 c
% 0.05 Zn	4.47 c	4.73 ab	4.60	1455 ab	1484 b	1470	24.8	25.6	25.2 bc
% 0.06 Zn	4.55 bc	4.67b	4.61	1443 ab	1514 b	1478	25.0	25.8	25.4 ab
Zn in the Soil	4.57 bc	4.69b	4.63	1439 ab	1525 ab	1482	25.6	25.9	25.7 a
Zn in the Seed	4.82 b	4.60b	4.71	1471 a	1592 a	1532	25.9	25.9	25.9 a
Mean	4.76	4.76		1384	1423		24.6 b	24.9 a	
C.V.	3.72			3.13			1.69		
	P (mg kg <sup>-1</sup> )			Fe (mg kg <sup>-1</sup> )			K (%)		
	1.year	2.year	Mean	1.year	2.year	Mean	1.year	2.year	mean
Control	4554a	4508a	4531	215.1e	220.3d	217.7	1.38c	1.31d	1.35
D. Water	4535a	4524a	4530	212.3e	223.9d	218.1	1.45b	1.38c	1.41
% 0.04 Zn	4381b	4386b	4384	229.7d	230.9c	230.3	1.45b	1.45ab	1.45
% 0.05 Zn	4337b	4345bc	4341	233.4cd	236.9ab	235.2	1.45b	1.43b	1.44
% 0.06 Zn	4294b	4353bc	4324	235.2c	235.2b	235.2	1.45ab	1.44b	1.44
Zn in the Soil	4119c	4254c	4187	239.8b	237.1ab	238.5	1.47ab	1.46ab	1.46
Zn in the Seed	3954d	4253c	4104	243.9a	240.0a	241.9	1.47a	1.46a	1.47
Mean	4311	4375		229.9	232.0		1.44	1.42	
C.V.		1.51			0.96			1.10	
	N (%)			Zn (mg kg <sup>-1</sup> )					
	1.year	2.year	Mean	1.year	2.year	Mean			
Control	3.74c	3.74d	3.74	35.1e	36.0e	35.5			
D. Water	4.10b	3.89c	4.00	39.8d	38.4d	39.1			
% 0.04 Zn	4.09b	4.24b	4.17	42.2c	42.5c	42.4			
% 0.05 Zn	4.19b	4.18b	4.18	41.5c	43.2c	42.4			
% 0.06 Zn	4.18b	4.46a	4.32	44.2b	45.4b	44.8			
Zn in the Soil	4.48a	4.47a	4.48	45.1b	45.0b	45.1			
Zn in the Seed	4.56a	4.54a	4.55	48.5a	47.9a	48.2			
Mean	4.19	4.22		42.4	42.6				
C.V.	2.07			1.44					

D. Water: Distilled Water, C.V.: Coefficient of Variation

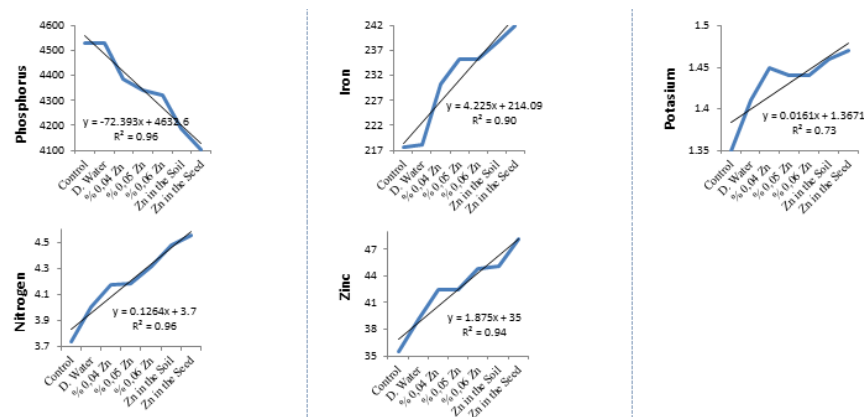
## Discussion

In our study, all zinc applications including the hydro-priming had a positive effect on the yield and plant traits including 100 grains weight. Some of researchers were reported that zinc applications improve the growth and quality parameters in mungbeans (Thomas *et al.*, 2007; Tayyeba *et al.*, 2013). In a study on the interactive effects of nitrogen and zinc fertilization on the grain yield and mineral composition of the grains in three chickpea varieties conducted in Isparta, located in an arid/semi-arid zone, it was determined that zinc significantly increased the grain yield and the crude protein content of the grains (Kaya *et al.*, 2009). In another study on mungbeans conducted in Egypt, Zn and Mg leaf applications under water stress conditions positively affected the growth, yield, and yield parameters (Thalooth *et al.*, 2006). Zinc deficiency is one

of the most common in soils with high lime content in arid and semi-arid zones in the world. Zinc deficiency, related to the reductions in enzyme activities, disrupts carbohydrates, and the metabolism of proteins and auxins. Chlorophyll content decreases dramatically, and photosynthesis is reduced 50–70%. Therefore, zinc fertilization can increase yield and yield parameters significantly in soils with zinc deficiency (Kacar and Katkat, 2011). In fact, zinc and sulfur fertilization significantly increases plant length, branch, node, fruit and grain number, grain yield and protein contents in mungbeans under Pakistan conditions (Surendra and Katiyar, 2013). Similar to the results in our study, Harris *et al.* (2007) have reported that treatment of corn seeds with 1% and 2% zinc solutions for 16 h had a positive effect on the yield and yield components; seed priming in corn was more economic than the soil application.



**Fig. 1:** Changes in the average yield and some other properties of mungbeans treated with different seed applications and zinc fertilization



**Fig. 2:** Changes in the content of mineral nutrients in mungbeans treated with different seed applications and zinc fertilization

Grain yield evidently increased by seed priming, zinc fertilization and inoculation applications. This increase was associated with the increase in the numbers of flowering fruits and grains depending on the zinc application. Significant increase in fruit and grain number can be due to smaller grains and the grain weights decreased. Ricemear and Jones (1959) argued that supplementing the nutrient medium with zinc would not affect the grain weights and zinc had an effect on the formation of the grain rather than the grain growth. Barut (2012) examined the effects of nitrogen and zinc fertilization on grain yield and the mineral composition of the wheat grains in Mediterranean climatic conditions and, similar to the results of our study, reported that the increase in zinc doses increased the grain weights.

Seed priming or seed inoculation methods may have helped the germinating seeds and seedlings to find the required zinc more easily. In fact, it was determined that grains with high zinc content had better vegetative growth in soil with zinc deficiency and the grain/product ratio was higher. It is known that genotypes containing high levels of Zn in their grains developed a stronger root system during

the initial growth stages of their development, and these kinds of plants utilized better zinc found in the medium (Kacar and Katkat, 2011). In addition to  $H^+$ ,  $HCO_3^-$ , and  $OH^-$ , organic acids are also secreted to the roots of the plants with strong root systems and rhizosphere area. Organic acids secreted by the roots in addition to  $CO_2$  formed as a result of the associated increased microbiological activity decrease in the pH of the soil around the rhizosphere area with increased zinc uptake (Çakmak and Marschner 1988; Takagi *et al.*, 1988; Kacar and Katkat, 2011). In zinc uptake of plants, diffusion and exchange contact apply rather than mass flow theory. Zinc fertilization may have possibly not been distributed to the root parts homogeneously during planting. Additionally, zinc bioavailability is influenced especially by climatic conditions with cold springs, rainfalls, and little sunshine and changing soil conditions (Kacar and Katkat, 2011). Additionally, it was seen that the second year data had higher average values (Table 1), which can be associated with the changing climatic and soil conditions. Zinc can become unavailable as a result of the adsorption of zinc by carbons or the formation of compounds with very

low densities including  $\text{ZnCO}_3$  and  $\text{Zn(OH)}_2$  in soils with high pH and lime. Zinc can become unavailable as a result of its replacement with  $\text{Ca}^{+2}$  (Kacar and Katkat, 2011). In our study, the pH value of the experimental area soil in the second year was neutral or close to neutral, while the level of lime was moderate. Especially in the first year of the experiment, the pH value of the soil was high as 8.1. In terms of climatic data, total rainfall in the vegetation period of the second year was higher, and the monthly distribution was regular. The average temperature was also higher than of the first year.

Similar to the results obtained in our study, many researchers reported that there was a negative relationship between zinc and phosphorus in plants and zinc fertilization reduced the phosphorus contents of the grains (Kacar and Katkat, 2011). Although there was an adequate amount of phosphorus in the leaves, but it did not travel to the roots via phloem and therefore the uptake mechanism could not be controlled and the plant absorbed increased amounts of P (Marschner, 1995). Also, P intake may increase with the increase in mycorrhizal activity due to amino acids, carbohydrates, and phenols secreted to the rhizosphere by the plant roots due to the zinc deficiency. However, the addition of increased rates of zinc to the medium reduced the phosphorus uptake of the plants (Çakmak and Marschner, 1988; Gök, 2007). In studies on mungbeans, it was determined that zinc prevented phosphorus transport from the plant roots to the upper parts, and phosphorus contents decreased as a result of zinc applications especially under low lime conditions (Hossain et al., 2008; Hossain et al., 2011; Tayyeba et al., 2013). Similarly, zinc fertilization in different plants significantly decreased the phosphorus contents of the grains (Mut and Gülümser, 2005; Kaya et al., 2009; Sonmez et al., 2013; Erdal et al., 2014).

Many studies reported an increase in potassium, iron, nitrogen, and zinc content in plants and grains with different zinc fertilization methods (Mut and Gülümser, 2005; Thalooth et al., 2006; Thomas et al., 2007; Hossain et al., 2008; Kaya et al., 2009; Hossain et al., 2011; Sonmez et al., 2013; Tayyeba et al., 2013; Roy et al., 2014). In our study, seed treatments with zinc and zinc fertilization increased the iron content of mungbeans. However, different studies have reported that there might be iron-zinc interactions and iron content might be negatively affected by excessive zinc uptake, and vice versa (Kacar and Katkat, 2011). It is proposed that iron-zinc interaction was caused by the transport of iron and zinc from the plant roots to the inner parts via the same active carriers. Mut and Gülümser (2005) reported that zinc fertilization increases grain potassium and zinc content of chick pea; however, zinc fertilization created an unstable situation in terms of iron content. Similar to our study, zinc applications on wheat conducted significantly increased the iron uptake and its content in the grains. This can be explained as iron bioavailability compensation because of partial resolution of other negativities with the formation of good nutrition conditions formed in the

rhizosphere area especially with the help of zinc applications. Additionally, it can be thought that zinc doses have not reached a certain threshold to invoke and Fe x Zn interaction.

The average phosphorus, iron, potassium, nitrogen, and zinc contents of mungbeans except phosphorus have positive trend and are close to a linear equation. Phosphorus content of the grains was affected by seed treatments compared to the control, and it can be argued that zinc had a negative effect. Upon examining the regression equation and the coefficients of determination, it can be said that estimations will be made according to the treatments, especially in terms of phosphorus, iron, nitrogen, and zinc contents, will be highly accurate (Fig. 2).

Plants absorb Zn from the soil by diffusion and contact ion exchange mechanism. For this reason, soil moisture and temperature are among the most effective factors to Zn absorption. Plants that have high Zn content, have first rapid root growth and wider root surface, get absorb more zinc from soil. In the current study, zinc content of the soil was increased by means of enzyme activity with the priming treatment. Consequently, Zn seed treatment and Zn seed inoculation affected yield, yield components and mineral content of grain positively.

Conclusively, 0.06% Zn seed priming or seed inoculation in mungbeans, especially in arid and semi-arid zones with high pH and lime content, can improve yield, yield components, and the mineral composition of the grains.

## References

- Ahmad, M.S.A., M. Hussain, S. Ijaz and A.K. Alvi, 2008. Photosynthetic performance of two mung bean (*Vigna radiata* L.) cultivars under lead and copper stress. *Int. J. Agric. Biol.*, 10: 167–172
- Ali, E.A. and A.M. Mahmoud, 2013. Effect of foliar spray by different salicylic acid and zinc concentrations on seed yield and yield components of mungbean in sandy soil. *Asian J. Crop Sci.*, 5: 33–40
- Barut, H., 2012. Effect of various doses of zinc and nitrogen applied at different times on wheat grain zinc concentration. University of Cukurova Institute of Natural and Applied Sciences, Department of Soil Science and Plant Nutrition. *Ph.D. Thesis*, p: 144. Adana, Turkey
- Bremner, J.M., 1965. *Methods of Soil Analysis*. American Society of Agronomy Inc., Madison, Wisconsin, USA
- Çakmak, I., N. Sari, H. Marschner, H. Ekiz, M. Kalayci, A. Yilmaz and H.J. Braun, 1996. Phytosiderophore release in bread and durum wheat genotypes differing in zinc efficiency. *Plant Soil*, 180: 183–189
- Çakmak, I. and H. Marschner, 1988. Increase in membrane permeability and exudation of roots of zinc deficient plants. *J. Plant Physiol.*, 132: 356–361
- Chiu, K.Y., C.L. Chen and J.M. Sung, 2002. Effect of priming temperature on storability of primed sh-2 sweet corn seed. *Crop Sci.*, 42: 1996–2003
- Erdal, İ., 1998. The effect of zinc application on grain zinc and phytic acid concentration of different cereal species and wheat genotypes grown in Central Anatolia. University of Ankara Institute of Sciences, Department of Soil Science. *Ph.D. Thesis*, p: 135. Ankara, Turkey
- Erdal, İ., M. Kaya and Z. Kucukyumuk, 2014. Effects of zinc and nitrogen fertilizations on grain yield and some parameters effecting zinc bioavailability in lentil seeds. *Leg. Res.*, 37: 55–61

- Gök, S., 2007. Effects of sulfur and zinc on phosphorus nutrition status of corn genotypes growing under low phosphorus conditions. Department of Soil Science Institute of Natural and Applied Sciences University of Cukurova. *MSc Thesis*, p: 74. Adana, Turkey
- Graham, R.D. and R.M. Welch, 1996. *Breeding for Staple-food Crops with High Micronutrient Density*, pp: 1–72. Agricultural Strategies for Micronutrients Working Paper 3, International Food Policy Research Institute, Washington DC, USA
- Harris, D., A. Joshi, P.A. Khan, P. Gothkar and P.S. Sodhi, 1999. On-farm seed priming in semi-arid agriculture: development and evaluation in maize, rice and chickpea in India using participatory methods. *Exp. Agric.*, 35: 15–29
- Harris, D., A. Rashid, G. Miraj, M. Arif and H. Shah, 2007. Priming seeds with zinc sulphate solution increases yields of maize (L.) on zinc-deficient soils. *Field Crops Res.*, 102: 119–127
- Harris, D., A. Rashid, G. Miraj, M. Arif and M. Yuna, 2008. On-farm seed priming with zinc in chickpea and wheat in Pakistan. *Plant Soil*, 306: 3–10
- Hossain, M.A., M. Jahiruddin, M. R. Islam and M.H. Mian, 2008. The requirement of zinc for improvement of crop yield and mineral nutrition in the maize–mungbean–rice system. *Plant Soil*, 306: 13–22
- Hossain, M.A., M. Jahiruddin and F. Khatun, 2011. Response of maize varieties to zinc fertilization. *Bangl. J. Agric. Res.*, 36: 437–447
- Imran, M., A. Rehim, S. Hussain and H. Rehman, 2016. Efficiency of zinc and phosphorus applied to opening pollinated and hybrid cultivars of maize. *Int. J. Agric. Biol.*, 18: 1249–1255
- Jayne, G., 2010. *Mungbean Management Guide*, 2<sup>nd</sup> edition. [https://www.daff.qld.gov.au/\\_data/assets/pdf\\_file/0005/57623/mung-manual2010-LR.pdf](https://www.daff.qld.gov.au/_data/assets/pdf_file/0005/57623/mung-manual2010-LR.pdf) (Accessed: 01 February 2015)
- Kacar, B. and A.V. Katkat, 2011. *Plant Nutrient*, p: 678. Nobel Academic Published, Series of Science and Biology Ankara, Turkey
- Kacar, B. and A. Inal, 2010. *Analysis of Plant*. Nobel Published, 1241, 892s. Ankara, Turkey
- Kaya, M., 2000. The effect of different inoculation methods, nitrogen doses and sowing times on yield and yield components in winner variety of peas (*Pisum sativum* L.). University of Ankara Institute of Sciences, Department of Field Crops. *PhD Thesis*, p: 180. Ankara, Turkey
- Kaya, M., M. Atak, K.M. Khawar, C.Y. Çiftçi and S. Özcan, 2005. Effect of pre-sowing seed treatment with zinc and foliar spray of humic acids on yield of common bean (*Phaseolus vulgaris* L.). *Int. J. Agric. Biol.*, 7: 875–878
- Kaya, M., Z. Küçükyumuk and İ. Erdal, 2009. Phytase activity, phytic acid, zinc, phosphorus and protein contents in different chickpea genotypes in relation to nitrogen and zinc fertilization. *Afr. J. Biotechnol.*, 8: 4508–4513
- Marschner, H., 1995. *Mineral Nutrition of Higher Plants*, 2<sup>nd</sup> edition. Academic Press. London, England
- Meral, N., C.Y. Çiftçi and S. Ünver, 1998. Effects of yield and yield components on chickpea (*Cicer arietinum* L.) of bacteria inoculation and different nitrogen doses. *J. TARM*, 7: 44–49
- Mut, Z. and A. Gülümser, 2005. The effects of bacteria inoculation, zinc and molybdenum application on some quality traits of Damla-89 chickpea cultivar. *J. Fac. Agric. Omu*, 20: 1–10
- Penas, E., R. Gomez, J. Frias and C. Vidal-Valverde, 2010. Effect of combined treatments of high pressure, temperature and antimicrobial products on germination of mungbean seeds and microbial quality of sprouts. *Food Cont.*, 21: 82–88
- Quddus, M.A., M.H. Rashid, M.A. Hossain and H.M. Naser, 2011. Effect of zinc and boron on yield and yield contributing characters of mungbean in low ganges river floodplain soil at Madaripur, Bangladesh. *Bangl. J. Res.*, 36: 75–85
- Rahman, M.M., M.J. Adan, M.S.N. Chowdhury, M.S. Ali and T.S. Mahabub, 2015. Effects of phosphorus and zinc on the growth and yield of mungbean (Bari mug 6). *Int. J. Sci. Res. Public.*, 5: 1–4
- Ricemeane, D.C. and G.B. Jones, 1959. Distribution of zinc and copper in subterranean clover (*Trifolium subteraneum* L.) grown in culture solution supplied with graduated amount of zinc. *Aust. J. Agric. Res.*, 9: 73–122
- Roy, P.D., R.P. Narwal, R.S. Malik, B.N. Saha and S. Kumar, 2014. Impact of zinc application methods on green gram (*Vigna radiata* L.) productivity and grain zinc fortification. *J. Environ. Biol.*, 35: 851–854
- Sönmez, F., F. Çig, M. Erman and Ş. Tüfenkeci, 2013. Effects of zinc, salt and mycorrhiza applications on the development and the phosphorus and zinc uptake of maize. *Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi J. Agric. Sci.*, 23: 1–9
- Sundstrom, F.J., R.B. Reader and R.L. Edwards, 1987. Effect of seed treatment and planting method on tabasco pepper. *J. Amer. Soc. Hort. Sci.*, 112: 641–644
- Surendra, R. and T.P.S. Katiyar, 2013. Effect of sulphur and zinc on the seed yield and protein content of summer mungbean under arid climate. *Int. J. Sci. Nat.*, 4: 563–566
- Şanlı, A., 2007. The effects of seed treatments and different sowing times on chickpea (*Cicer arietinum* L.) yield and some yield components. SDU Institute of Sciences, Department of Field Crops. *MSc Thesis*, p: 80. Isparta, Turkey
- Takagi, S., S. Kamei and M.H. Yu, 1988. Efficiency of iron extraction from soil by mugineic acid family phytosiderophores. *J. Plant Nutr.*, 11: 643–651
- Tayyeba, S., H.U.S. Humaira, U. Saleem and J. Muhammad, 2013. Zinc effect on growth rate, chlorophyll, protein and mineral contents of hydroponically grown mungbeans plant (*Vigna radiata*). *Arab. J. Chem.* Article in press. <http://dx.doi.org/10.1016/j.arabjc.2013.07.005>
- Thalooth, A.T., M.M. Tawfik and H. Magda Mohamed, 2006. A comparative study on the effect of foliar application of zinc, potassium and magnesium on growth, yield and some chemical constituents of mungbean plants grown under water stress conditions. *World Agric. Sci.*, 2: 37–46
- Thomas, J.R., K.L. Sahrawat, S.P. Wani and G. Pardhasaradhi, 2007. Widespread deficiencies of sulfur, boron and zinc in Indian semi-arid tropical soils: On-farm crop responses. *J. Plant Nutr.*, 30: 1569–1583

(Received 15 March 2016; Accepted 06 April 2017)