



Soil application of zinc improves the growth, yield and grain zinc biofortification of mungbean

Muhammad Umar Haider¹, Mubshar Hussain^{1,2*}, Muhammad Farooq^{3,4} and Ahmad Nawaz⁵

¹Department of Agronomy, Bahauddin Zakariya University, Multan, Pakistan.

²School of Veterinary and Life Sciences, Murdoch University, 90 South Street, Murdoch, WA 6150, Australia

³Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.

⁴Department of Crop Sciences, College of Agricultural and Marine Sciences, Sultan Qaboos University, Al-Khoud-123, Oman.

⁵College of Agriculture, BZU, Bahadur Sub-Campus Layyah, Pakistan.

Abstract

The grain legumes are a vital component of the sustainable crop production systems as these are not only a good source of dietary proteins but also help to improve soil nutrients status through biological nitrogen fixation. Mungbean (*Vigna radiata* (L.) Wilczek) is one of the leading grain legumes which is planted all across the globe. Zinc (Zn) is one of the most critical micronutrients required by crop plants, including mungbean, as well as for the human being. This study was carried out to optimize the Zn soil application for vigorous seedling growth, grain yield and grain biofortification of mungbean. Zinc was soil applied at 0, 2.5, 5.0, 7.5 and 10 mg Zn kg⁻¹ soil. The results showed that soil application of Zn improved the seedling growth, morphological and yield parameters, grain yield and grain Zn concentration of mungbean. However, Zn soil application at 10 mg Zn kg⁻¹ soil was significantly better for improving the seedling growth, morphological and yield parameters, grain yield and grain biofortification. It is recommended that Zn should be soil applied at 10 mg Zn kg⁻¹ soil to harvest better grain yield and Zn-enriched grains of mungbean to overcome Zn malnutrition.

Keywords: Zinc application, plant growth rate, 100-grain weight, mungbean yield, grain Zn contents

Introduction

Grain legumes are the important source of protein consumed all over the world. Mungbean (*Vigna radiata* L.) is a vital summer growing pulse crop in Pakistan and also known as green gram (Ahmad *et al.*, 2003). Due to its short duration period (Ahamed *et al.*, 2011), it can be grown two times in a year i.e. spring and summer season. It proliferates well under irrigated conditions but can also be sown under water stress conditions (Ahmad *et al.*, 2015). Its grains are easily digestible having more protein contents as compared to other pulse crops (Tabasum *et al.*, 2010). Production of mungbean is badly affected under saline and waterlogged conditions (Minhas *et al.*, 1990; Yadave *et al.*, 1998). Protein contents of mungbean vary from 18 to 25%. It consists of 50% carbohydrates, 3% fat, 4- 5% ash, 3-4.5% fibers, 367 mg phosphorus and 132 mg calcium per hundred-gram seed (Frauque *et al.*, 2000). Moreover, soil fertility is also enhanced due to mungbean planation owing to its ability to fix the atmospheric nitrogen (Ashraf *et al.*, 2003). Mungbean crop residues are also used as feed for the animals (Asaduzzaman *et al.*, 2008).

Sufficient supply of micronutrients is necessary for normal growth and yield of crops; and their scarcity in soil is a prevailing issue in the developing countries (Singh, 2009). A balance nutrition plan, having micro and macronutrients together, is necessary to attain high yield and quality (Sawan *et al.*, 2001) of field crops. Zinc (Zn) is an important element needed by the humans, animals and plants in minor quantity (Kabata-pendias, 2011). Shenkin (2006) reported that micronutrients like Zn and iron (Fe) are necessary for betterment in the human immune system, normal growth and development. Zn scarcity in Pakistani soils is a prevailing problem. Low Zn contents in plants affect the photosynthetic mechanism because it modifies the chloroplast pigments (Kosesakal and Unal, 2009). Short internodes, reduction in leaf size and late maturity are the visible symptoms of Zn scarcity (Brown *et al.*, 1993).

Zn is the structural and functional unit of many enzymes; such as alcoholic dehydrase, carbonic anhydrase, carboxy peptidase, alkaline phosphate, phospholipase (Coleman, 1991). Zn enhances nutrient use efficiency by reducing the leaching of nutrients like nitrates (Zahedi *et al.*,

*Email: mubashiragr@gmail.com

2009). Role of Zn includes improvement in the soil cation exchange capacity, selective nutrients uptake, soil reinforcement to improve tolerance against drought stress; it also optimizes fertilizer use efficiency (Ok *et al.*, 2003). Zn is necessary for plants and animals and is needed for plants metabolic events; activates many enzymes and takes part in metabolism of nucleic acid, lipid, protein and carbohydrate (Khan *et al.*, 2002). Zn acts as a cofactor for more than 300 enzymes and proteins which are engaged in nucleic acid metabolism, cell division, protein synthesis, gene transcription regulation and coordination of other biological mechanisms (Broadley *et al.*, 2007). Sarwar (2011) documented that Zn takes part in photosynthesis, cell division, protein synthesis, retaining integrity of membrane structure and resistance against infections caused by pathogens.

As pulses are considered a good source of protein for poor people, improving Zn contents in pulse seed might be useful to reduce malnutrition in human beings. Biofortification of different crops can be accomplished by adding the various micronutrients during the growth cycle of crops to attain maximum nutrients (White and Broadley, 2009). Fortified crops have capability to nurture the malnourished people. Thus, mungbean production with Zn-enriched grains is a viable option to overcome Zn malnutrition. Many studies are available on the optimization of soil Zn in different crops *i.e.* rice (Rose *et al.*, 2012), wheat (Singh, 2007), and chickpea (Khorgamy and Farina, 2009). However, no study has been conducted to optimize Zn soil application to enhance the stand establishment, grain yield and grain biofortification of mungbean. Previously, Usman *et al.* (2014) evaluated the role of Zn in mungbean but they have not evaluated the role of Zn on grain biofortification and root and leaf growth of mungbean. So, this study was conducted to evaluate the soil application treatments for enhancing the grain yield and grain biofortification of mungbean.

Materials and Methods

Site and experimental details

This pot study was conducted at wire house, Department of Agronomy, Bahauddin Zakariya University, Multan, Pakistan (71.43° E, 30.2° N and altitude 122 m) during the Kharif season of 2016. The climatic conditions of the study site are semi-arid, subtropical. Seeds of mungbean cultivar NM-2006 were obtained from Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan and used as experimental material. Earthen pots with 24 cm internal diameter and 30 cm height were filled with 15 kg of soil. The soil filled in pots was of sandy loam nature with pH of 7.9, electrical conductivity of 1.02 dS m⁻¹, soil

organic matter of 0.45%, available phosphorus of 5.2 mg kg⁻¹ and available potassium of 162 mg kg⁻¹. Zinc was applied as soil application at the rate of 0, 2.5, 5.0, 7.5, 10 mg Zn kg⁻¹ soil by using ZnSO₄·7H₂O as source. The experiment was designed in completely randomized design with four replicates.

Crop husbandry

Before sowing, the pots (24 cm × 30 cm in diameter) were subjected to filling with 10 kg of the soil and were irrigated to make the soil ready for sowing. When soil reached the workable moisture conditions for seed sowing, all the pots were cultivated with hand drawn tillage implement “*khurpa*” and fertilizers along with Zn were thoroughly mixed. Fertilizers were applied at the rate of 23, 58 and 30 kg ha⁻¹ of nitrogen, phosphorus and potassium, respectively, using triple super phosphate, urea and sulphate of potash as source, as recommended by Government of Punjab, Pakistan. Ten seeds were sown in each soil filled pot on June 20, 2016 and after attaining uniform emergence thinning was done to maintain 6 plants in each pot. All the pots were uniformly irrigated to save the plants from any moisture stress. Weeds were manually eradicated in each pot. The mature crop was harvested on September 28, 2016.

Data recording

Allometric and yield related traits

Plant sampling was done at 40, 55 and 70 days after sowing (DAS) of crop to record the root length, number of lateral roots, root/stem/leaf dry weight, and the leaf area per plant. At each sampling date, one plant from each pot was harvested to record data. The chlorophyll contents from plants of each pot were estimated using the SPAD-502 chlorophyll meter at 40 DAS. At harvesting, all three plants were used to record data of plant height, total numbers of vegetative and reproductive branches, and total number of pods per plant. Length of 10 random selected pods from each pot was recorded and averaged to record pod length and these 10 pods were threshed manually, total numbers of seeds were counted and averaged to estimate number of seeds per pod. At maturity, all three plants from each pot were harvested, sun dried for five days, weighed with the help of digital balance and then averaged to record biological yield per plant. After that, the pods from each pot were manually thrashed for seed separation from chaff. These isolated seeds were weighed on an electric balance to report grain yield per pot. Two sub-samples of 100 seeds were counted from seed lot and were put on the electric balance to measure the 100-grain weight. Moreover, grain yield was reported at 10% moisture contents. The harvest index was calculated as the ratio of grain yield to the biological yield and was expressed in percentage.



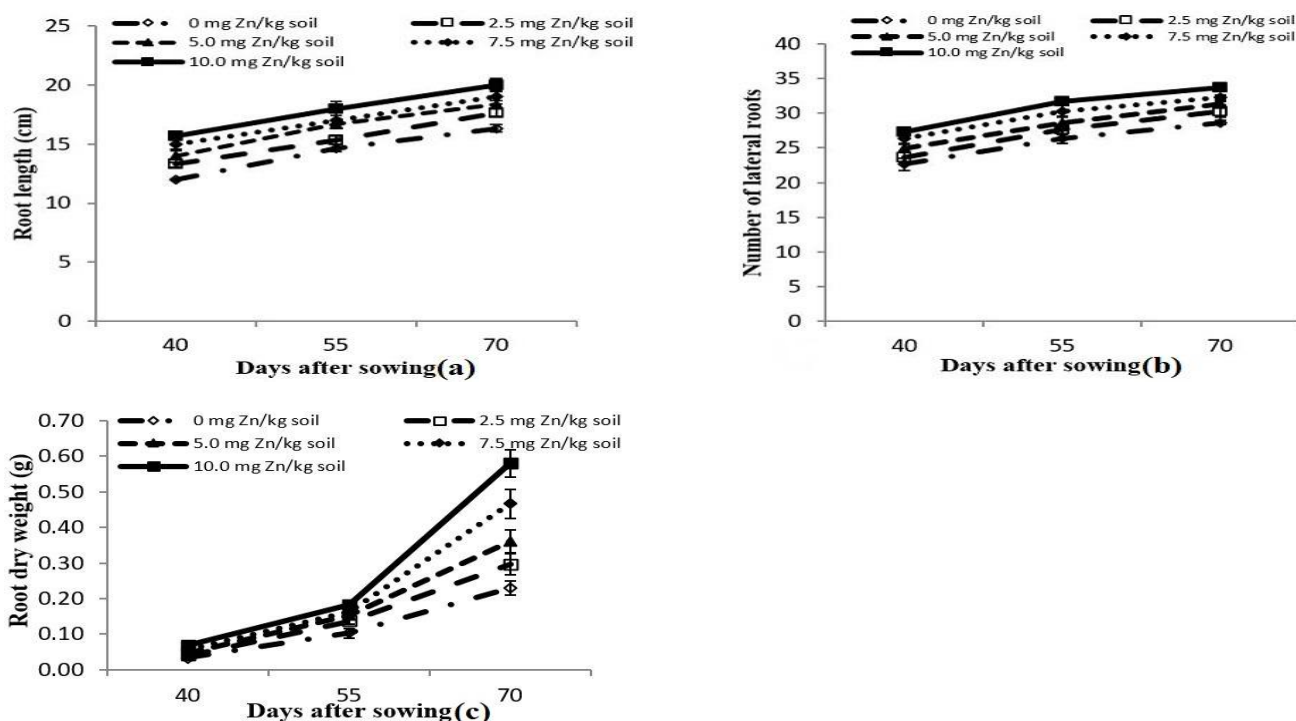


Figure 1: Influence of zinc soil application on root length, number of lateral roots and root dry weight per plant

Table 1: Effect of zinc soil application on plant height, chlorophyll contents, number of vegetative and reproductive branches, pod length and number of pods per plant of mungbean

Zinc level (mg Zn kg ⁻¹ soil)	Plant height (cm)	Chlorophyll contents (SPAD value)	Number of vegetative branches plant ⁻¹	Number of reproductive branches plant ⁻¹	Pod length (cm)	Number of pods plant ⁻¹
0	45.33 E	41.43 D	5.33 C	4.33 B	7.16 C	11.00 C
2.5	47.66 D	42.23 CD	5.66 BC	4.66 AB	7.44 B	11.33 C
5.0	52.00 C	43.36 BC	6.00 BC	5.00 AB	7.61 AB	12.66 B
7.5	54.33 B	44.63 AB	6.66 AB	5.33 AB	7.75 A	13.33 B
10.0	56.33 A	45.86 A	7.33 A	5.66 A	7.86 A	14.66 A
LSD ($p \leq 0.01$)	1.41	1.26	1.00	1.00	0.27	1.00

Means not sharing the same letters within a column differ significantly from each other at 1% level of probability.

Table 2: Effect of zinc soil application on yield related traits and grain Zn contents of mungbean

Zinc level (mg Zn kg ⁻¹ of soil)	Number of seeds per pod	100-seed weight (g)	Grain yield per plant (g)	Biological yield per plant (g)	Harvest index (%)	Grain Zn concentration (mg kg ⁻¹)
0	7.42 D	5.43 E	3.20 E	11.42 E	28.01 C	25.56 D
2.5	7.86 C	5.63 D	3.52 D	12.31 D	28.63 BC	30.86 C
5.0	8.12 B	5.73 C	3.96 C	13.27 C	29.82 ABC	37.26 B
7.5	8.23 A	5.84 B	4.25 B	14.11 B	30.12 AB	38.73 B
10.0	8.32 A	6.04 A	4.63 A	14.188 A	31.11 A	42.03 A
LSD ($p \leq 0.01$)	0.10	0.06	0.27	0.19	2.02	2.51

Means not sharing the same letters within a column differ significantly from each other at 1% level of probability.

Grain Zn contents

For determining grain Zn contents, the ground seed samples (0.5 g) were digested in 70% HClO₄ (2:1 v/v) and a

mixture of HNO₃ (5 mL) in Pyrex digestion flasks for overnight. This was followed by heating this mixture at temperature of 150 °C on hot plate to the point when the red fumes production was ceased. Then the temperature of



hot plate was moved to 250 °C until the samples of mixture became the transparent substance. These digested samples were diluted to 25 mL with distilled water followed by filtration. Grain Zn contents (mg kg^{-1}) were determined using atomic absorption spectrophotometer (Perkin Elmer, CA, USA) following the procedure of Prasad *et al.* (2006).

Statistical analysis

The data collected on the mungbean crop parameters was analyzed statistically using the Fisher's analysis of variance method and the treatments means were separated by using least significant difference test (LSD) at 1% probability level (Steel *et al.*, 1997). For graphical representation of data Microsoft Excel software along with \pm S.E. was used.

Results

Periodic data (Figure 1a-c) indicated that root dry weight, root length and the lateral roots plant^{-1} were gradually increased with life cycle of crop; and Zn application levels improved all root traits at 40, 55 and 70 days after sowing (DAS) as compared with control. Moreover, Zn application at 10 mg Zn kg^{-1} soil resulted in maximum root dry weight, root length and lateral roots plant^{-1} at all sampling dates from 40 to 70 DAS; while the plants grown in control pots performed poor in this regard (Figure 1). Likewise, leaf area plant^{-1} and plant growth rate was gradually improved starting from 40 to 70 DAS (Figure 2) due to Zn soil application. All Zn soil application levels performed better than control but soil application at 10 mg Zn kg^{-1} soil proved superior regarding improvement in plant growth rate and leaf area plant^{-1} at 40 to 70 DAS (Figure 2).

Zinc application showed significant effect on plant height, chlorophyll contents, vegetative/reproductive branches plant^{-1} , pods plant^{-1} and pod length of mungbean

(Table 1). All Zn application levels performed better than control; however, soil application of ZnSO_4 at 10 mg Zn kg^{-1} soil observed the highest plant height, chlorophyll contents, number of vegetative and reproductive branches plant^{-1} , pod length, and pods plant^{-1} against the minimum values of all above cited traits which were recorded in control. Zinc application at 10 mg Zn kg^{-1} soil was statistically similar with 7.5 mg Zn kg^{-1} of soil for chlorophyll contents, number of vegetative and reproductive branches plant^{-1} and pod length (Table 1).

Data revealed that Zn application showed significant effect on yield and yield contributing traits, harvest index and grain Zn concentration of mungbean (Table 2). Zinc application at all levels improved the yield parameters, and biological/grain yields, harvest index and grain Zn contents in ascending order with each higher level of Zn application against control (Table 2). Zinc application at 10 mg Zn kg^{-1} soil produced the highest seeds pod^{-1} , 100-seed weight, biological/grain yields and harvest index but it was at par with 7.5 mg Zn kg^{-1} soil for harvest index and seeds per pod (Table 2). Moreover, the maximum grain Zn contents were also recorded at higher level of Zn application i.e. 10 mg Zn kg^{-1} soil (Table 2).

Discussion

Application of Zn significantly improved plant growth, and grain yield and grain Zn contents of mungbean (Tables 1-2). Better seedling growth and grain yield in Zn soil application might be attributed to involvement of Zn in nitrogen metabolism, protein synthesis, photosynthesis, maintenance of integrity of membrane structure, cell division and resistance against infection of pathogens (Potarzycki and Grzebisz, 2009; Sarwar, 2011). In another study, maximum plant height (55.13 cm) of green gram was attained with the application of Zn at 15 kg ha^{-1} (Usman *et al.*, 2014).

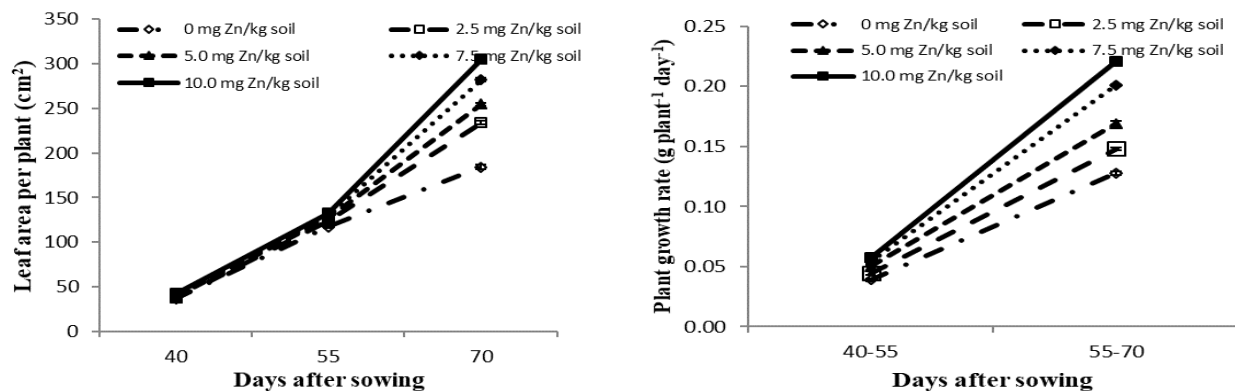


Figure 2: Influence of zinc soil application on leaf area per plant and plant growth rate



This study also indicated that the chlorophyll contents were also increased due to soil application of Zn (Table 1). Indeed, Zn improves the synthesis of chlorophyll and carotenoids which are finally involved in the plant photosynthetic mechanism (Aravind and Prasad, 2003), thus improving the chlorophyll contents as was observed in this study. Healthier root growth and increase in number of lateral roots due to Zn soil application in this study (Figure 1, 2) might be due to its involvement in root cell elongation thus reducing the free radical injury to the cell (Cakmak, 2000). Shojaei and Makarian (2015) also reported that Zn is necessary for the initiation of several metabolic enzymes in the plant body and roots.

The highest biological and grain yield was observed in mungbean crop with the application of 20 kg Zn ha⁻¹. This rise in seed yield might be attributed to enhanced growth and yield related traits (seed weight, seed number). In an earlier study, Nadergoli *et al.* (2011) found that Zn application improved the number of seeds pod⁻¹ in green gram. Usman *et al.* (2014) reported that 1000-seed weight of mungbean was enhanced with Zn application at 20 kg ha⁻¹. In another research, Shahab *et al.* (2016) documented that Zn soil application in maize crop resulted in greater biological yield.

Although Zn application at lower levels was quite effective for improvement in grain yield and grain Zn contents, nonetheless its application at higher rates was more effective for improvement in crop performance than lower rates. Zinc application at 10 mg Zn kg⁻¹ soil enhanced the grain yield and grain Zn contents by 54.06 and 64.4%, respectively, compared with no Zn application (Table 2). This indicated that mungbean respond better to Zn application even at higher rates without showing the symptoms of Zn toxicity. In an earlier study, Jamal *et al.* (2018) reported an increase of 121.1% in seed yield of mungbean when Zn was applied at the rate of 10 kg ha⁻¹. Thus, improvement in seed Zn contents in mungbean will be very useful for reducing the malnutrition due to Zn deficiency across the globe. In a recent study Haider *et al.* (2018) reported better mungbean grain yield along with Zn-enriched grains with foliar application of 0.5% Zn solution.

Conclusion

Zn soil application at either rate (i.e., 2.5, 5.0, 7.5 and 10 mg Zn kg⁻¹ soil) improved the seedling growth, grain yield and grain Zn content than no Zn application. However, Zn soil application at 10 mg Zn kg⁻¹ soil was more beneficial than other levels to harvest better grain yield along with Zn-enriched grains. Thus, Zn soil application at 10 mg Zn kg⁻¹ soil is a cheap and effective method to enhance growth, grain yield and grain Zn concentration in mungbean.

References

- Ahamed, K.U., K. Nahar, M. Hasanuzzaman, G. Faruq and M. Khandaker. 2011. Morphophysiological attributes of mungbean (*Vigna radiata* L.) varieties under different plant spacing. *The Journal of Agricultural Science* 7:234-245.
- Ahmad, A., M.M. Selim, A.A. Alderfasi and M. Afzal. 2015. Effect of drought stress on mungbean (*Vigna radiata* L.) under arid climatic conditions of Saudi Arabia. I. Miralles, J.L. Garcia and C.A. Brebbia. (Eds.). *Ecosystem and Sustainable Development*. 192:185-193.
- Ahmad, R., M. Ikram, Ehsanullah and A. Mahmood. 2003. Influence of different fertilizer levels on the growth and productivity of three mungbean (*Vigna radiata* L.) cultivar. *International Journal of Agriculture and Biology* 5:335-338.
- Aravind, P. and M.N.V. Prasad. 2003. Zinc alleviates cadmium induced toxicity in *Ceratophyllum demersum*, a fresh water macrophyte. *Plant Physiology and Biochemistry* 41:391-397.
- Asaduzzaman, M., M.F. Karim, M.J. Ullah and M. Hasanuzzaman. 2008. Response of mungbean (*Vigna radiata* L.) to nitrogen and irrigation management. *American Eurasian Journal of Scientific Research* 3:40-43.
- Ashraf, M., M. Mueen-Ud-Din and N. Warrich. 2003. Production efficiency of mungbean (*Vigna radiata* L.) as affected by seed inoculation and NPK application. *International Journal of Agriculture and Biology* 5:179-180.
- Broadley, M.R., P.J. White, J.P. Hammond, I. Zelko and A. Lux. 2007. Zinc in plants. *New Phytologist* 173:677-702.
- Brown, P.H., I. Cakmak and Q. Zhang. 1993. Form and function of zinc plants. p.93-106. In: Zinc in soils and plants. A. D. Robson (ed). *Developments in Plant and Soil Sciences*.
- Cakmak, I. 2000. Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. *New Phytologist* 146:185-205.
- Coleman, J.E. 1991. Zinc proteins: Enzymes, storage proteins, transcription factors and Replication Proteins. *Annual Review of Biochemistry* 61:897-946.
- Frauke, A., T. Haraguchi, O. Hirota and M.A. Rahman. 2000. Growth analysis, yield, and canopy structure in maize, mungbean intercropping. *Bulletin of the Institute of Tropical Agriculture Kyushu University Fukuoka, Japan*, 23:61-69.
- Haider, M.U., M. Farooq, A. Nawaz and M. Hussain. 2018. Foliage applied zinc ensures better growth, yield and grain biofortification of mungbean. *International*



- Journal of Agriculture and Biology* doi: 10.17957/IJAB/15.0840.
- Jamal, A., M.I. Khan, M. Tariq and M. Fawad. 2018. Response of mung bean crop to different levels of applied iron and zinc. *Journal of Horticulture and Plant Research* 3:13-22.
- Kabata-Pendias, A. 2011. Trace Elements in Soils and Plants, 4th Edition, Taylor & Francis Group, Boca Raton London New York.
- Khan, M., S. Umar, M. Qasim and M. Jamil. 2002. Effect of different levels of zinc on the extractable zinc content of soil and chemical composition of rice. *Asian Journal of Plant Sciences* 1:20-21.
- Khorgamy, A. and A. Farina. 2009. Effect of phosphorus and zinc fertilization on yield and yield components of chick pea cultivars. *African Crop Science Conference Proceedings*, 9:205-208.
- Kosesakal, T. and M. Unal. 2009. Role of zinc deficiency in photosynthetic pigments and peroxidase activity of tomato seedlings *IJFS Journal of Biology* 68:113-120.
- Minhas, P.S., D.R. Sharma and B.K. Khosla. 1990. Mungbean response to irrigation with waters of different salinities. *Irrigation Science* 11:57-62.
- Nadergoli, M.S., M. Yarnia and F.R. Khoei. 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 Scientific Research* 8:859-865.
- Ok, C.H., S.H. Anderson and E.H. Ervin. 2003. Amendments and construction systems for improving the performance of sand-based putting greens. *Agronomy Journal* 95:1583-1590.
- Potarzycki, J. and W. Grzebisz. 2009. Effect of zinc foliar application on grain yield of maize and its yielding components. *Plant, Soil and Environment* 55:519-527.
- Prasad, R., Y.S. Shivay, D. Kumar and S.N. Sharma. 2006. Learning by Doing Exercises in Soil Fertility (A Practical Manual for Soil Fertility), Division of Agronomy. *Indian Agricultural Research Institute*, New Delhi. pp. 68.
- Rose, T.J., S.M. Impa, M.T. Rose, J. Pariasca-Tanaka, A. Mori, S. Heuer, S.E. Johnson-Beebout and M. Wissuwa. 2012. Enhancing phosphorus and zinc acquisition efficiency in rice: A critical review of root traits and their potential utility in rice breeding. *Annals of Botany* 112:331-345.
- Sarwar, M. 2011. Effects of zinc fertilizer application on the incidence of rice stem borers (*Scirpophaga* species) (Lepidoptera: *Pyralidae*) in rice (*Oryza sativa* L.) crop. *Journal of Cereals and Oilseeds* 2:61-65.
- Sawan, Z.M., S.A. Hafez and A.E. Basyony. 2001. Effect of phosphorus fertilization and foliar application of chelated zinc and calcium on seed, protein and oil yields and oil properties of cotton. *Journal of Agricultural Science* 136:191-198.
- Shahab, Q., M. Afzal, B. Hussain, N. Abbas, S.W. Hussain, Q. Zehra, A. Hussain, Z. Hussain, A. Ali and Y. Abbas. 2016. Effect of different methods of zinc application on maize (*Zea mays* L.). *International Journal of Agriculture and Agronomy Research* 9:66-75.
- Shenkin, A. 2006. The key role of micronutrients. *Clinical Nutrition* 25: 1-13.
- Shojaei, H. and H. Makarian. 2015. The effect of nano and non-nano zinc oxide particles foliar application on yield and yield components of mungbean (*Vigna radiata* L.) under drought stress. *Iranian Journal Field Crops Research* 12:727-737.
- Singh, M.V. 2007. Efficiency of seed treatment for ameliorating zinc deficiency in crops. In: Zinc Crops Conference: Improving Crop Production and Human Health, May 24–26, Istanbul, Turkey.
- Singh, M.V. 2009. Micronutrient nutritional problems in soils of India and improvement for human and animal health. *Indian Journal of Fertilizers* 5:11-16.
- Steel, R.G.D., J.H. Torrie and D.A. Dicky. 1997. Principles and Procedures of Statistics: A Biometrical Approach, 3rd Edition, McGraw Hill Book Co. Inc. New York, pp:400–428.
- Tabasum, A., M. Saleem and I. Aziz. 2010. Genetic variability, trait association and path analysis of yield and yield components in mungbean (*Vigna radiata* (L.) Wilczek). *Pakistan Journal of Botany* 42:3915-3924.
- Usman, M., M. Tahir and M.A. Majeed. 2014. Effect of zinc sulphate as soil application and seed treatment on green gram (*Vigna radiata* L.). *Pakistan Journal of life and Social Sciences* 12:87-91.
- White, P.J. and M.R. Broadley. 2009. Biofortification of crops with seven mineral elements often lacking in human diets -iron, zinc, copper, calcium, magnesium, selenium and iodine. *New Phytologist* 182:49-84.
- Yadave, R.S., R.B. Khare and A.K. Pandey. 1998. Response of water logging on carbohydrates accumulation and seed yield of mungbean (*Vigna radiata* (L.) Wilczek). *Agricultural Science Digest* 18: 157-160.
- Zahedi, H., G. Noormohammadi, G., A.H.S. Rad, D. Habibi and M.M.A. Boojar. 2009. Effect of zeolite and foliar application of selenium on growth, yield and yield component of three canola cultivar under conditions of late season drought stress. *Notulae Scientia Biologicae* 1:73-80.

