Research Article

Comparative Efficacy of Different Zinc Sources for Fertilization of Maize (*Zea mays* L.) on Alkaline Calcareous Soil

Munazza Yousra[1]*, Sair Sarwar[1], Muhammad Mahmood Ul Hassan[1], Muhammad Zameer khan[1], Abdul khaliq[2], Shahbaz Ahmad[1] and Shamim Ul Sibtain Shah[3]

[1]Land Resources Research Institute, National Agricultural Research Centre, Pakistan; [2]University of Poonch, Rawalakot, Azad Jammu and Kashmir, Pakistan; [3]Directorate of Farm Operations and Services, National Agricultural Research Centre, Pakistan.

Abstract | The incubation and greenhouse experiments were conducted at National Agricultural Research Centre, Islamabad during 2015-2016 to evaluate the response of maize to different rates of $ZnSO_4.7H_2O$ and Zn-EDTA in sandy loam soil. Treatments included Zn @ 0, 2, 4, 6, 8 mg kg^{-1} as $ZnSO_4.7H_2O$ and Zn-EDTA, arranged in completely randomized design with three replications. In Incubation study, the soil was incubated at 29°C and field capacity was maintained to compare the release pattern of Zn from both sources. Zn release pattern from both Zn sources showed that Zn concentration was maximum on the first day in all treatments except control. Zinc release from Zn-EDTA was much higher as compared to $ZnSO_4$. Similarly, the pot experiment conducted with the same set of treatments and crop responded well to Zn fertilizer application. The results showed a consistent increase in Zn concentration with the increasing Zn doses in both varieties. The maximum Zn concentration recorded was 67.6 and 79.5 mg kg^{-1} @ 8 mg Zn kg^{-1} by using both Zn sources, respectively. The highest dry matter production of 65 and 76 g $plant^{-1}$ was recorded using Zn treatment @ 8 mg Zn kg^{-1} by $ZnSO_4.H_2O$ and Zn-EDTA in both varieties, respectively. Similarly, the Zn uptake was also shown significant increase over control at the Zn rate applied @ 8 mg kg^{-1} with $ZnSO_4.H_2O$ (3.97) and Zn-EDTA (5.03 mg $plant^{-1}$) source in both varieties. The results indicated that Zn-EDTA is the most effective source of Zn as compared to $ZnSO_4.7H_2O$ to meet plant requirements.

Received | September 10, 2018; **Accepted** | July 03, 2019; **Published** | July 15, 2019
***Correspondence** | Munazza Yousra, Land Resources Research Institute, National Agricultural Research Centre, Pakistan; **Email:** munzkhan04@gmail.com
Citation | Yousra, M., S. Sarwar, M.M. Hassan, M.Z. khan, A. khaliq, S. Ahmad and S.S. Shah. 2019. Comparative efficacy of different zinc sources for fertilization of maize (Zea mays L.) on alkaline calcareous soil. *Pakistan Journal of Agricultural Research,* 32(3): 480-485.
DOI | http://dx.doi.org/10.17582/journal.pjar/2019/32.3.480.485
Keywords | Calcareous soil, Maize, Growth, Local and Hybrid varieties, Zn sources, $ZnSO_4$, Zn-EDTA

Introduction

The soils of Pakistan are generally alkaline and of calcareous nature and are more prone to zinc deficiency. This is because these lands are inherently low in the available Zn (Slaton et al., 2005). The main soil factors that influence the availability of Zn to plants are low total content of Zn, high pH, high content of calcite, less organic matter and high concentrations of Na, Ca, Mg, bicarbonate and phosphate in the soil solution (Abbas et al., 2010). Moreover, zinc also precipitate or sorbs in unavailable forms in these soils (Khoshgoftar et al., 2004).

Some research has been conducted comparing different sources of Zn and their mobility in the soil, and it was discovered that Zn has a very limited mobility in the soil. Gangloff et al. (2006) conducted a

leaching experiment that compared different sources of Zn and their mobility in the soil. They found that Zn-EDTA, $ZnSO_4$ and Zn lignosulphonate were more mobile relatively because of their solubility. The Zn oxysulphate was less mobile but seemed to meet the needs of the plant, while other less soluble oxysulfate and sucrate Zn sources were also relatively immobile. The key to the success of Zn fertility is water solubility. The water solubility of Zn will determine how effective it will be to meet the needs of the plant (Shukla and Morris, 1967). The solubility in water allows the Zn to move over short distances in the ground and be absorbed by the plant roots.

Maize (*Zea mays* L.) is an important cereal crop with great economic value (Harris et al., 2007). The climatic conditions of Pakistan and its soil are ideal for the production of maize. The balance in the availability of essential nutrients is necessary for the good yield of all crops, including maize (Preetha and Stalin, 2014). Several reports have indicated low levels of zinc in the maize kernel, which could be alarming as it affects the health of plants, animals and humans. There are some notable examples of health problems caused by micronutrients in the world (Laker, 1979). During zinc deficiency, protein synthesis is reduced due to low levels of RNA, as zinc plays an essential role in RNA polymerase (Bell and Dell, 2008). The zinc deficiency is often corrected by the application of its fertilizers in crops mainly in maize, which is very sensitive to the application of zinc. Several authors have studied the effectiveness of different sources of Zn because of their physical state, chemical reactivity and availability on maize growth (Brown and Krantz, 1966; Mortvedt and Gilkes, 1993; Sarwar et al., 2015).

Zinc availability per unit of Zn application is more from Zn chelates compared to other inorganic sources, since they provide better distribution of this nutrient in the soil due to its solubility (Brown and Krantz, 1966). Synthetic chelating agents are used to provide plants with elements such as Fe and to a lesser extent, Zn and Mn (Tinkler and Lauchli, 1984) because they overcome the fundamental problem of keeping these elements in a more available form. Chelated metal is generally considered in a form more available to plants. It is noted that chelated forms often show more Zn availability for maize harvesting.

The objective of this study was to compare the Zn release pattern of $ZnSO_4.7H_2O$ and Zn-EDTA and to evaluate the effect of both Zn sources on the Zn availability to maize crop in calcareous soil.

Materials and Methods

Experimental layout and treatments

Incubation study: Incubation experiment was carried out at Land Resources Research Institute, National Agricultural Research Centre, Islamabad, to compare the release pattern of Zn from $ZnSO_4.7H_2O$ (35% Zn) and Zn-EDTA (12% Zn) using a calcareous soil. A representative and sufficient amount of soil was collected, air-dried and sieved through a 2mm sieve and analyzed for different physio-chemical characteristics using standard methods (Randhawa and Arora, 2000) (Table 1). An electronic scale was then used to weigh 10 g soil into plastic polyethylene tubes. The soil within the plastic tubes was treated with $ZnSO_4.7H_2O$ and Zn-EDTA to increase their zinc content with different treatments. There were nine treatments consisting of one control with 4 levels of Zn (0, 2, 4, 6 and 8 mg Zn kg^{-1}) in the form of $ZnSO_4.7H_2O$ and Zn-EDTA applied on alkaline calcareous soil incubated under aerobic condition up to 16 days.

Table 1: *Physio-chemical properties of selected soil.*

Parameters	Reading
pH (1:1)	8.01
EC (1:1) dS m^{-1}	0.24
Na (mg kg^{-1})	56
K (mg kg^{-1})	83
P (mg kg^{-1})	1.125
NO_3 (mg kg^{-1})	2.68
Zn (mg kg^{-1})	0.47
Fe (mg kg^{-1})	6.47
Cu (mg kg^{-1})	0.52
Mn (mg kg^{-1})	2.9
Class	Loam

To maintain the aerobic condition in the incubated tubes, water was added on the basis of soil field capacity and incubated at about 28 °C, maintained for about 16 days under incubation conditions. The experiment was set down in a completely randomized design (CRD) with three repetitions. The destructive sampling was performed at 0, 1, 2, 4, 8, 16 days' interval under aerobic conditions. The soil was extracted with a $CaCl_2$ solution (0.01 M) and Zn concentration was determined using an atomic absorption spectrophotometer (AAS 700).

Greenhouse experiment: The experiment was set down in a completely randomized design with three repetitions. The 7 kg of air-dried soil was placed in clay pots. The soil was treated with two sources of Zn, i.e., $ZnSO_4$. $7H_2O$ and Zn-EDTA @ 2, 4, 6 and 8 mg of Zn kg^{-1} with the basal application of NPK dose as recommended (250: 150: 90 NPK kg ha^{-1}). Each fertilizer was prepared in the form of solution according to the recommendation and applied on the basis of fixed treatments. As a basal dose, 25% of N, the entire dose of P and K at the time of sowing were applied, while the remaining 50% of N was applied at the vegetative phase (25 days after sowing). Five seeds per pot were sown for maize cultivars, namely DKC 6590 (hybrid variety) and Islamabad Gold (local variety) and one seedling per pot was maintained after germination of about ten days of sowing. At the tasseling stage, the above ground part of the crop was harvested. The harvested portion of the crop was cut into pieces and dried in an oven at 70°C to obtain constant weight. The dry matter production was recorded and the Zn content in dry matter was analyzed by the di-acid extract (HNO_3 and $HClO_4$) using atomic absorption spectrophotometer (AAnalyst 700).

Results and Discussion

Incubation Study

Incubation study was conducted on Zn release pattern with respect to time with two Zn sources i.e., $ZnSO_4$. $7H_2O$ and Zn-EDTA. The concentration of zinc extracted with $CaCl_2$ from incubated control soil and from the incubated samples with soil amended with different Zn sources are shown in Figure 3. The incubation hardly affected the Zn concentration extracted in control and found less than 0.5 mg kg^{-1}, which is considered deficient in alkaline soils for most crops. The average concentration of Zn released from $ZnSO_4$. $7H_2O$ in all treatments at the 1st day of incubation was found maximum (1.535 mg Zn kg^{-1}) then a continuous decline in Zn concentration up to 0.726 mg Zn kg^{-1} was observed till 16th day of incubation (Figure 1). The Zn release pattern from Zn-EDTA was almost similar to $ZnSO_4$ release pattern. The average amount of Zn released at 1st day was 3.065 mg Zn kg^{-1} and decreased consistently to 1.619 mg Zn kg^{-1} till the end of incubation period (Figure 2). The potentially available zinc decreased in soil during the incubation period in soil treated with different Zn rates (Alvarez and Rico, 2003). The maximum release of Zn @ 8 mg kg^{-1} from $ZnSO_4$.$7H_2O$ and Zn-EDTA was 2.80 and 6.35 mg Zn kg^{-1} at the 1st day of incubation, respectively. In comparison of both Zn sources, the highest concentration of $CaCl_2$ extractable Zn occurred with the Zn-EDTA treatment. It is reported that the highest concentration of Zn is obtained with Zn-EDTA treatments. The soil treated with zinc sulphate showed greater fixation and adsorption of Zn between different soil components (Karak et al., 2005).

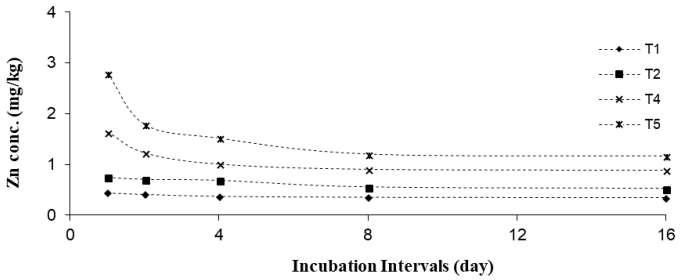

Figure 1: *Zinc release pattern in soil from $ZnSO_4$ $7H_2O$.*

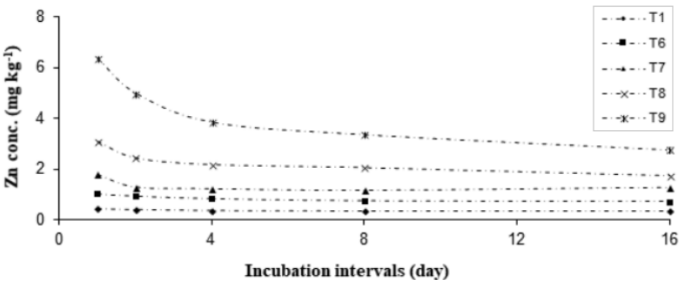

Figure 2: *Zinc release pattern in soil from Zn-EDTA.*

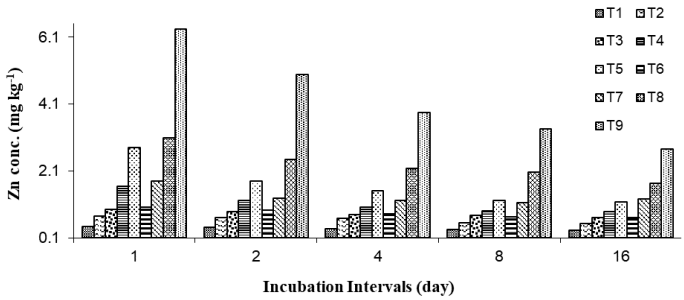

Figure 3: *Comparative zinc release pattern in soil from $ZnSO_4$ $7H_2O$ and Zn-EDTA.*

It has been revealed that when Zn-EDTA was used as a reference material, it was found most effective Zn source on plant uptake basis by Gangloff et al. (2006). The Relative Availability Coefficient (RAC) of $ZnSO_4$ was 23% and that of Zn lignosulfonate was 22%. All other sources including Zn oxysulfate are less effective compounds ranging from 0.5 to 12% and the Zn sucrate (organic complex) with 5% RAC. The above findings showed a significant difference between Zn-EDTA and all other Zn sources.

Greenhouse Experiment

Zn concentration: The data on Zn application both as $ZnSO_4.7H_2O$ and Zn-EDTA showed a consistent increase in Zn concentration with the increase in Zn doses (2, 4, 6 and 8 mg Zn kg^{-1}) in both varieties (Table 2). Both sources result in a significant increase in Zn concentration of maize plants over control. The highest increase in Zn concentration was observed with the application of Zn-EDTA compared to $ZnSO_4$. The maximum Zn concentration recorded was 68 and 80 mg kg^{-1} @ 8 mg Zn kg^{-1} by using $ZnSO_4$ and Zn-EDTA sources, respectively. Several researchers have examined the effectiveness of various sources of zinc for plant growth (Wallace, 1963; Giordano and Mortvedt, 1972; Lindsay, 1972; Mortvedt and Gilkes, 1993). They reported that under greenhouse conditions, chelated forms of zinc were more effective than inorganic forms of zinc. Kanwal et al. (2009) reported that the application of Zn resulted in an increase in the concentration of Zn in maize. Karak et al. (2005) reported that variations of the Zn content in dry rice matter varied with different sources of Zn, being higher with the application of Zn chelates compared to the corresponding levels of $ZnSO_4$ application. The concentration of Zn in the hybrid maize variety (60 mg of Zn kg^{-1}) was found higher compared to the local variety (34 mg kg^{-1}). Relatively, a higher concentration of Zn was obtained in hybrid cultivars compared to local ones. (Sarwar et al., 2015).

Dry Matter Production and Zn uptake by Maize: The data on the production of dry matter and uptake of Zn by maize plant is presented in Table 3 showed that both parameters differ significantly with the application of Zn by both sources. The highest dry matter production of 65 and 76 g $plant^{-1}$ was recorded using Zn treatment @ 8 mg Zn kg^{-1} by $ZnSO_4.H_2O$ and Zn-EDTA in both varieties, respectively. The Zn application by both sources resulted in highest shoot matter production in hybrid variety (72 g $plant^{-1}$) compared to local variety (46 g $plant^{-1}$).

Kanwal et al. (2009) reported that the Zn application has led to an increase in dry matter production of maize crop. Several former workers namely Alvarez and Rico (2003) and Hoffland et al. (2006) also reported an increase in shoot dry matter production in different crops with the addition of Zn. Zn-EDTA is considered to be 2 to 5 times more effective than zinc sulphate (Mortvedt and Gilkes, 1993). Karak et al. (2005) stated that the amount of Zn in both grain and straw was always significantly higher with the application of different chelated-Zn (Zn-EDTA) levels and modes than the application of $ZnSO_4$.

Table 2: *Effect of Zn Sources ($ZnSO_4$ and Zn-EDTA) on Zn concentration of both local and hybrid varieties of maize.*

Treatment	Zn concentration (mg kg^{-1})		
	V_1	V_2	Mean
$ZnSO_4$ T1	17	60	38^{f}
T2	34	54	54^{e}
T3	35	67	61^{cd}
T4	45	68	67^{bc}
T5	45	71	68^{bc}
Zn-EDTA T6	36	67	52^{e}
T7	54	54	64^{c}
T8	56	71	74^{ab}
T9	52	77	80^{a}
Mean	34^{b}	60^{a}	
Variety	*		
LSD (p<0.05)			
Treatment	8.49		
Tr. x cv.	12.01		

V_1: *Local variety;* **V_2:** *Hybrid variety;* **Tr.:** *Treatment;* **cv.:** *cultivar.*

Similarly, the maximum Zn uptake was observed i.e., 3.79 with $ZnSO_4.H_2O$ and 5.03 ug $plant^{-1}$ with Zn-EDTA source at the Zn rate applied @ 8 mg kg^{-1} in both varieties. The percentage increase of Zn content in straw uptake was also recorded higher by the Zn-EDTA than $ZnSO_4$ application (Karak et al., 2005). The results showed that when the available Zn status of soil is low, the response to zinc fertilizer application is enormous. The higher Zn uptake was observed in hybrid variety (4.53 ug $plant^{-1}$) compared to local variety (1.69 ug $plant^{-1}$). Preetha and Stalin (2014) reported that seemingly the increased Zn uptake is related to more production of dry matter with the increasing rates of Zn doses. Similarly, zinc uptake in maize shoot usually increased with increasing rates of Zn application. This statement is in agreement with Maftoun and Karimian (1989) work. In a field study conducted by Sarwar et al. (2015) on two calcareous Zn-deficient sites using maize as test crop, increase in grain yield of hybrid cultivar was found more than local cultivar. He also observed more Zn uptake by hybrid than local cultivar.

Table 3: *Effect of Zn Sources ($ZnSO_4$ and Zn-EDTA) on dry matter production and Zn uptake in both local and hybrid varieties of maize.*

Treatment	Dry Matter (g plant^{-1})			Zn Uptake (ug plant^{-1})		
	V_1	V_2	Mean	V_1	V_2	Mean
$ZnSO_4$ T1	27	47	37^{f}	0.45	1.69	1.07^{e}
T2	36	66	51^{e}	0.86	3.56	2.21^{de}
T3	37	75	56^{de}	0.91	5.17	3.04^{cd}
T4	48	77	63^{cd}	1.7	5.28	3.50^{bc}
T5	47	83	65^{bc}	1.63	5.95	3.79^{bc}
Zn-EDTA T6	38	60	49^{e}	1.08	2.87	1.97^{ef}
T7	56	66	61^{cd}	2.48	3.56	3.02^{cd}
T8	60	82	71^{ab}	2.79	5.8	4.34^{ab}
T9	63	89	76^{a}	3.26	6.81	5.03^{a}
Mean	46^{b}	72^{a}		1.69^{b}	4.53^{a}	
Variety	*			*		
LSD (p<0.05)						
Treatment	8.17			1.02		
Tr. x cv.	11.56			1.44		

Conclusions and Recommendations

It is concluded that in comparison of both Zn sources, Zn-EDTA has been proved efficient in relation of incubation study in which it caused more Zn release from calcareous soil than $ZnSO_4.7H_2O$. On basis of its release pattern, its application to maize crop with the same rates results in improved growth and uptake @ 8 mg Zn kg^{-1} application by both local and hybrid maize varieties.

Author's Contribution

Munazza Yousra: Overall Management of article, data analysis, results and discussion.
Sair Sarwar: Results and discussion, provision of technical inputs.
Muhammad Mahmood Ul Hassan: Introduction, sowing of experiment, data collection.
Muhammad Zameer khan: Abstract, cultural operation, data collection.
Abdul Khaliq: Methodology, data collection.
Shahbaz Ahmad: References, data collection.
Shamim Ul Sibtain Shah: Data collection.

References

Abbas, G., G. Hassan, M.A. Ali, M. Aslam and Z.A. Abbas. 2010. Response of wheat to different doses of $ZnSO_4$ under Thal desert environment. Pak. J. Bot. 42(6): 4079-4085.

Alvarez, J.M. and M.I. Rico. 2003. Effect of Zinc complex on the distribution of zinc in calcareous soil and zinc uptake by maize. J. Agric. Food Chem. 51: 5760-67. https://doi.org/10.1021/jf030092m

Bell, R.W. and R.W. Dell, 2008. Micronutrients for sustainable food, feed, fiber and bioenergy production. Paris, France. Int. Fert. Ind. Assoc.

Brown, A.L. and B.A. Krantz. 1966. Source and placement of zinc and phosphorus for maize (*Zea mays* L.) Proce. Soil Sci. Soc. Am. 30: 86-89. https://doi.org/10.2136/sssaj1966.03615995003000010030x

Gangloff, W.J., D.G. Westfall, G.A. Peterson and J.J. Mortvedt. 2006. Relative availability co-efficients of organic and inorganic Zn fertilizers. J. Plant Nutr. 25: 259-263. https://doi.org/10.1081/PLN-100108834

Giordano, P.M. and J.J. Mortvedt. 1972. Zinc sources and methods of application for rice. J. Agron. 65: 51-53. https://doi.org/10.2134/agronj1973.00021962006500010015x

Harris, D., A. Rashid, G. Miraj, M. Arif and H. Shah. 2007. On-farm seed priming with Zn sulphate solution-A cost effective way to increase the maize yields of resource-poor farmers. Field Crops Res. 110: 119-127. https://doi.org/10.1016/j.fcr.2007.03.005

Hoffland, E., C. Wei and M. Wissuwa. 2006. Organic anion exudation by lowland rice (*Oryza sativa* L.) at zinc phosphorus deficiency. Plant Soil. 283: 155-162. https://doi.org/10.1007/s11104-005-3937-1

Kanwal, S., M.A.R. Maqsood and H.F.S.G. Bakhat. 2009. Zinc requirement of maize hybrids and indigenous varieties on Udic Haplustalf. J. Plant Nutr. 32: 470-478. https://doi.org/10.1080/01904160802661782

Karak, T., U.K. Singh, S. Das, D.K. Das and Kuzyakov. 2005. Comparative efficacy of $ZnSO_4$ and Zn-EDTA application for fertilization of rice (*Oryza sativa* L.). Arch. Agron. Soil Sci. 51: 253-264. https://doi.org/10.1080/03650340400026701

Khoshgoftar, A.H., H. Shariatmadari, N. Karmian, M. Kalbasi, S.E.A.T.M.V. Zee and D.R. Parker. 2004. Salinity and Zinc application effects on Phytoavailability of cadmium and zinc. J. Soil Sci. Soc. Am. 68: 1885-1889. https://doi.

org/10.2136/sssaj2004.1885

Laker, M.C. 1979. Several chapters. In environmental associations with oesophageal cancer in Transkei, ed. S. J. van Rensburg, Tygerberg.

Lindsay, W.L. 1972. Zinc in soils and plant nutrition. Adv. Agron. 24: 147-186. https://doi.org/10.1016/S0065-2113(08)60635-5

Maftoun, M. and N. Karimian, 1989. Relative effiency of two zinc sources for maize in two calcareous soils from an arid area of Iran. Agron. 9: 771-75. https://doi.org/10.1051/agro:19890804

Mortvedt, J.J. and R.J. Gilkes. 1993. Zinc fertilizers. In: A.D Robson (ed). Zinc in soil and plants. Kluwer Acad. Publ. https://doi.org/10.1007/978-94-011-0878-2_3

Murphy, L.S. and L.M. Walch. 1972. Correction of micronutrient deficiencies with fertilizers. In Micronutrients in Agriculture, eds. J. J. Mortvedt et al., Madison, Wisconsin: SSSA.

Preetha, P.S. and P. Stalin. 2014. Response of maize to soil applied zinc fertilizer under varying available zinc status of soil. India. J. Sci. Technol. 7: 939-944.

Randhawa, P.S. and C.L. Arora. 2000. Phosphorus sulfur interaction effects on dry matter yield and nutrient uptake by wheat. Indian J. Soil Sci. Soc. 48: 536-540.

Ryan, J., G. Estefan and A. Rashid. 2001. Soil and plant analysis laboratory manual. Int. Centre Agric. Res. Dry Areas (ICARDA). Islamabad, Pak. p. 172.

Sarwar, S., E. Rafique, S.M. Gill and M.Z. Khan. 2015. Improved productivity and zinc content for maize grain by different zinc fertilization techniques in calcareous soils. J. Plant Nutr. 40: 417-426. https://doi.org/10.1080/01904167.2016.1245322

Shukla, U.C. and H.D. Morris. 1967. Relative efficiency of several zinc sources for maize (*Zea mays* L.). J. Agron. 59: 200-202. https://doi.org/10.2134/agronj1967.00021962005900020024x

Slaton, N.A., E.E. Gbur, C.E. Wilson and R.J. Norman. 2005. Rice response to granular zinc sources varying in water soluble zinc. J. Soil Sci. Soc. Am. 69: 443-452. https://doi.org/10.2136/sssaj2005.0443

Tinkler, P.B. and A. Lauchli. 1984. Advances in plant nutrition. Acad. Publ. San Deigo, CA.

Wallace, A. 1963. Review of chelation in plant nutrition. J. Agric. Food Chem. 11: 103-107. https://doi.org/10.1021/jf60126a002

Wallace, A. and E.M. Romney. 1970. The effect of zinc sources on micronutrient contents of golden bantam maize. Soil Sci. 109: 66-67. https://doi.org/10.1097/00010694-197001000-00012