Original Research Article

Effect of zinc application on growth and yield of summer maize (*Zea mays)*

ABSTRACT: A field experiment was conducted at the Instructional-cum-Research (ICR) Farm, Assam Agricultural University, Jorhat during the *summer* season of 2019 to find out the effect of zinc on growth and yield through soil and foliar application. The experiment consisted of nine treatments *viz*., 0 kg/ha $ZnSO_4$ (Control), 10 kg/ha $ZnSO_4$ soil application, 20 kg/ha $ZnSO_4$ soil application, 0.5% $ZnSO_4$ foliar spray at 25 DAS, 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS, 10 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS, 10 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS, 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS. The treatments were laid out in Randomized Block Design (RBD) and replicated thrice. The soil of the experimental site was sandy loam in texture, acidic in reaction (pH 5.4), medium in organic carbon (0.64%), low in available N (198.04 kg/ha), medium in available P_2O_5 (24.98kg/ha), low in available K_2O (187.30 kg/ha) and low in available zinc (0.56 mg/kg). Experimental findings revealed that growth attributing characters like plant height was recorded in the combined application of 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS. The Leaf Area Index (LAI) and yield attributing characters like weight of the cob with and without husk, number of grain rows per cob, number of grains per row, number of grains per cob as well as grain yield (43.05 q/ha) were recorded the highest in the combined application of 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS which was at par with the combined application of 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS.

Key words: Foliar spray, Soil application, Yield attributing characters, LAI.

INTRODUCTION

Maize is one of the most versatile crops grown across a wide range of climatic conditions of the world due to its wider adaptability. Maize is the third most important food grain in India after wheat and rice. Maize has high genetic potential than the other cereal crops. Hence it is called as “miracle crop” and also as “queen of cereals”. Maize, besides being an important staple food for human beings it is also an important animal and poultry feed. It is widely used for corn starch industry, corn oil production, baby corns, sweet corns, pop corns etc. It is also used as a source of raw material for the production of protein, starch, food sweeteners and alcoholic beverages and fuel source.

“Among the micronutrients, zinc is an essential nutrient for the standard and healthy growth and development of plants. Generally, zinc affects the synthesis of protein in plants hence it is considered to be the most critical micronutrient. Zinc is also crucial in taking part in plant development due to its catalytic action in metabolism for all crops especially maize whereas zinc is used by the plant in many of its vital processes such as synthesis of protein, structure and functions of membrane, expression of genes and oxidative stress tolerance. Similarly, application of $ZnSO_4$ significantly increased the maize yield. Boron and zinc have significant interaction with maize growth and tissue nutrient concentration. Therefore, the deficiency of zinc in soil causes deficiency in crops and altogether this has become a problem all over the world with acute zinc deficiency ranges in arid to semi-arid regions of the world. So, zinc deficiency is common phenomenon of crops especially in predominantly high pH soils having low zinc”. (Tariq et. al,, 2014)

In Assam, (north-eastern state of India), zinc deficiency ranged from 20 to 30% (Anonymous 2010-13). It is mostly adsorbed or fixed with Al and Fe oxide or hydroxide which decreased the availability of zinc. The proper method of nutrient application could be promising approach for better uptake and utilization of zinc. Amongst different methods, the foliar spray of micronutrients is an efficient one for enhancement of crop productivity. This way of nutrient application is easy and simple in improving plant nutritional condition of maize. Reasons for effectiveness of foliar spray are simple due to its direct application to leaves. However, micronutrients can be applied directly into the soil as well. Soil applied zinc is effective in enhancing the grain yield whereas zinc concentration in grain improves via foliar spray of zinc fertilizer. Soil and foliar applications of zinc enhance the yield of crops as well as increase zinc uptake and accumulation in crop grain.

MATERIALS AND METHODS

A field experiment was conducted on summer maize at the Instructional-cum-Research Farm, Assam Agricultural University, Jorhat during the year 2019. The climatic condition of Jorhat is sub-tropical humid with warm summer and cold winter. The weekly mean maximum temperature ranged from 24.7^{o}C to 33.8^{o}C and mean minimum temperature ranged from 15.8^{o}C to 25.9^{o}C during the period of crop growth. Based on 20 years rainfall data from 1994 to 2013, the average rainfall of Jorhat during the crop growing period (Feb to June) was workout as 520.89 mm. But during the crop season the total precipitation amounted was little bit higher than average *i.e.* 624 mm, out of which maximum amount (192.2 mm) was received in the first week of May. The weekly average relative humidity during the morning hours ranged from 89 per cent to 98 per cent while mean evening relative humidity ranged from 58 per cent to 84 per cent. The maize seed of the variety VMH-53 was sown on 15th of March (2019) and harvested on 15th June. Representative soil samples were collected prior to the experiment to study the physico-chemical properties of the experimental plot. The soil of the experimental site was sandy loam in texture, acidic in reaction (pH 5.4), medium in organic carbon (0.64%), low in available N (198.04 kg/ha), medium in available P_2O_5 (24.98kg/ha), low in available K_2O (187.30 kg/ha) and low in available zinc (0.56 mg/kg). A rectangular shaped upland plot 32.8 m in length and 14.6 m in breath equivalent to 478.88 m^2 was selected prior to the layout of the experiment for the experiment in the year 2019. Individual plot size is 13.44 m^2 (4.2 m× 3.2 m). The experiment consisted of nine treatments *viz.*,T_1[0 kg/ha $ZnSO_4$ (Control)], T_2 [10 kg/ha $ZnSO_4$ soil application], T_3 [20 kg/ha $ZnSO_4$ soil application], T_4 [0.5% $ZnSO_4$ foliar spray at 25 DAS], T_5[0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS], T_6 [10 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS], T_7 [10 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS], T_8[20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS] and T_9 [20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS]. The treatments were laid out in Randomized Block Design (RBD) and replicated thrice. The data collected on different observations were analyzed statistically using analysis of variance technique. The levels of significance used in 'F' and 't' tests was 0.05 probability.

RESULTS AND DISCUSSION

The results of the investigations entitled "Effect of zinc application on growth and yield of summer maize (*Zea mays*)" presented below revealed that various plant characters were greatly influenced by different levels of zinc treatments. In this article, an attempt has been made to assign reasons for such variations in various parameters under study providing causes and reasons in the light of scientific evidences as well as explanations by earlier researchers working in the similar line at different locations.

Effect of zinc

"Usually, micronutrients are required in minute amounts but impart significant effects on metabolism by working synergistically with hormones and enzymes normal functionality of system. Among the micronutrients, zinc is an essential nutrient for the standard and healthy growth and development of plants. Generally, zinc affects the synthesis of protein in plants hence is considered to be the most critical micronutrient" (Cakmak *et al*., 1998). "Zn is also crucial in taking part in plant development due to its catalytic action in metabolism for all crops especially maize" (Cakmak, 2000).

Importance of Foliar spray

"Application of foliar spray implies that nutrient applied will be absorbed from the point of application (leaves) to the point of utilization (growing tissue). An export of nutrient from leaves and transport within the stem occurs in phloem, while transport in the stem may occur in either phloem or xylem. The most effective method for increasing grain zinc is the soil + foliar application method which may result in an about 3 fold increase in grain zinc concentration" (Cakmak 2010). The proper method of nutrient application could be promising approach for better uptake and utilization of zinc. Amongst different methods, the foliar spray of micronutrients is an efficient one for enhancement of crop productivity. This way of nutrient application is easy and simple in improving plant nutritional condition of maize. Reasons for effectiveness of foliar spray are simple due to its direct application to leaves. However, micronutrients can be applied directly into the soil as well. Soil applied zinc is effective in enhancing the grain yield whereas zinc concentration in grain improves via foliar spray of zinc fertilizer. Soil and foliar applications of zinc enhance the yield of crops as well as increase zinc uptake and accumulation in crop grain.

The variations in various parameters resulting from application of different levels of zinc are discussed under following headings as depicted below:

Growth parameters:

Plant height

Different crop growth parameters were significantly influenced by different levels of zinc. The plant height was significantly higher with the combined application of 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS followed by treatment combination of 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS.

Increase in plant height with the addition of $ZnSO_4$ might be due to the availability of more nitrogen in soil. The increase in plant height with zinc application was also reported by Al-Doori (2014), Singh *et al*. (2017) and Arab *et al.* (2018).

Leaf Area Index

With increasing levels of Zn fertilization, there was increase in leaf area index (LAI). The LAI was highest in combined application of 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS which was at par with the 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 10 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS.

The increase in the LAI with Zn application probably due to increase in tryptophan amino acid and indole acetic acid hormone which are two main factors in leaf area expansion in maize. Similar findings were earlier reported by Seifi-Nadergholi *et al*. (2011), Drissi *et al*. (2015) and Panda *et al*. (2019).

Yield attributing characters:

Yield attributing characters like weight and length of the cob with and without husk, number of grain rows per cob, number of grains per row and number of grains per cob showed a positive response to the increased levels of zinc fertilizers and in all cases the highest values were recorded with the combined application of 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS which was found statistically at par with 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS.

Cob weight with and without husk

Cob weight with and without husk was significantly affected by Zn application techniques. The highest cob weight with husk (273.06 g) and without husk (218.22 g) was detected in treatment combination (soil + foliar) T_9 which was found statistically at par with T_8 and T_7 but these treatments were significantly higher than 0 kg/ha $ZnSO_4$ (Control). The lowest cob weight with husk (235.09 g) and without husk (170.99 g) was obtained from the treatment [T_1] 0 kg/ha $ZnSO_4$ (Control).

Increase in cob weight may be due to Zn extracts has a great influence on basic plant life processes such as nitrogen metabolism, uptake of nitrogen and protein quality, photosynthesis-chlorophyll synthesis and carbon anhydrase activity. Similar findings were reported by Iqbal *et al*. (2016) and Kumar and Salakinkop (2018).

Number of grain rows per cob, Number of grains per row and Number of grains per cob

Significantly maximum number of grain rows per cob, number of grains per row and number of grains per cob were found. The findings showed that number of grain rows per cob, number of grains per row and number of grains per cob was significantly affected by zinc fertilization. The maximum number of grain rows per cob (14.13), number of grains per row(32.31) and number of grains per cob(439.58)was obtained from treatment T_9 which was at par with treatment T_8but significantly higher than the treatment [T_1] 0 kg/ha $ZnSO_4$ (Control).The minimum number of grain rows per cob (13.11),number of grains per row(28.01) and number of grains per cob(367.21)was recorded under the treatment [T_1] 0 kg/ha $ZnSO_4$ (Control).

It is attributed due to the fact that Zn activates several plant enzymes that are involved in carbohydrate metabolism, protein synthesis and pollen formation ultimately increase in yield attributing characters. Similar findings were also reported by Iqbal *et al*. (2016), Eteng (2017) and Kumar *et al.* (2019).

Yield:

Grain yield

Maximum grain yield (43.05 q/ha)was registered with the combined application of 20 kg $ZnSO_4$/ha soil application + 0.5% foliar spray at 25 DAS and 45 DAS [T_9] which was at par with treatment combination of 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray 25 DAS [T_8]. The lowest yield of grain (32.30 q/ha) was obtained from the treatment [T_1]0 kg/ha $ZnSO_4$ (Control). This increment in the grain yield of maize was due to increase in number of grain rows per cob, number of grains per row and number of grains per cob. Higher yield due to zinc fertilization is also attributed to the enhanced synthesis of carbohydrates and their transport to the site of grain production. This result is in conformity with Anjum *et al.* (2017), Humtsoe *et al.* (2018) and Kumar *et al.* (2019). Also the application of Zn as foliar spray was efficiently absorbed by leaves and increased biomass production of plant which ultimately led to higher grain yield and better Zn use efficiency reported by Ghasal *et al*. (2017).

Table-1: Effect of zinc on plant height and LAI of summer maize

Treatments	Plant height (cm)		Leaf area index (LAI)	
	60 DAS	90 DAS	45 DAS	60 DAS
T_1 : 0 kg/ha $ZnSO_4$ (Control)	97.06	154.35	3.07	5.09
T_2 :10 kg/ha $ZnSO_4$ soil application	98.32	156.58	3.26	5.17
T_3 :20 kg/ha $ZnSO_4$ soil application	99.70	158.68	3.30	5.32
T_4 :0.5% $ZnSO_4$ foliar spray at 25 DAS	100.66	160.68	3.39	5.50
T_5 :0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS	101.71	162.91	3.43	5.69
T_6 :10 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS	104.99	163.98	3.53	5.79
T_7 :10 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS	105.26	164.84	3.62	5.95
T_8 :20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS	110.18	170.79	3.77	6.12
T_9:20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS	113.40	175.79	3.91	6.21
S. Ed (±)	**1.39**	**2.48**	**0.06**	**0.09**

C.D (0.05)	2.94	5.26	0.14	0.19

Table-2: Effect of zinc on weight of cob with and without husk, number of rows per cob, grains per row, grains per cob, and grain yield in summer maize

Treatments	Wt. of cob with husk (g/cob)	Wt. of cob without husk (g/cob	No. of grain rows per cob	No. of grains per row	No. of grains per cob	Grain yield (q/ha)
T_1 : 0 kg/ha $ZnSO_4$ (Control)	235.09	170.99	13.11	28.01	367.21	32.30
T_2 :10 kg/ha $ZnSO_4$ soil application	253.84	174.00	13.18	28.36	373.78	33.46
T_3 :20 kg/ha $ZnSO_4$ soil application	254.34	179.52	13.33	28.68	382.30	34.16
T_4 :0.5% $ZnSO_4$ foliar spray at 25 DAS	257.08	184.05	13.46	29.11	391.82	35.01
T_5 :0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS	263.89	189.13	13.53	29.78	402.92	36.15
T_6 :10 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS	264.45	196.44	13.79	30.05	414.38	37.12
T_7 :10 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS	269.43	201.74	13.92	30.79	428.59	38.13
T_8 :20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS	271.36	211.87	14.02	31.11	434.33	41.82
T_9:20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS	273.06	218.22	14.13	32.31	439.58	43.05
S. Ed (±)	**1.96**	**2.17**	**0.06**	**0.27**	**1.64**	**1.44**
C.D (0.05)	**4.16**	**4.60**	**0.14**	**0.57**	**3.48**	**3.06**

CONCLUSION

On the basis of the results obtained from the present experimentation, it may be concluded that treatment combination of 20 kg/ha $ZnSO_4$ soil application + 0.5% $ZnSO_4$ foliar spray at 25 DAS and 45 DAS can be considered suitable for zinc fortification in maize.

References

Al-Doori, S. A. (2014). Effect of different levels and timing of Zinc foliar application on growth, yield and quality of Sunflower genotypes (*Helianthus annuus* L.). *College of Basic Education Researches Journal*, **13**(1): 907-922.

Anjum, S. A., Saleem, M. F., Shahid, M., Shakoor, A., Safeer, M., Khan, I. and Nazir, U. (2017). Dynamics of soil and foliar applied boron and zinc to improve maize productivity and profitability. *Pakistan Journal of Agricultural Research*, **30**(3).

Arab, G., Ghazi, D. and El-Ghamry, A. (2018). Effect of Zinc application on Maize grown on alluvial soils. *Journal of Soil Sciences and Agricultural Engineering*, **9**(9): 419-426.

Cakmak, I., Torun, B., Erenoğlu, B., Öztürk, L., Marschner, H., Kalayci, M. and Yilmaz, A. (1998). Morphological and physiological differences in the response of cereals to zinc deficiency. *Euphytica*, **100**(1-3): 349-357.

Cakmak, I. (2000). Possible roles of Zinc in protecting plant cells from damage by reactive oxygen species. *New Phytology*, **146**: 185-205.

Cakmak, I. (2010). Biofortification of cereals with zinc and iron through fertilization strategy. In *19th World Congress of Soil Science, Brisbane.*

Drissi, S., Houssa, A. A., Bamouh, A. and Benbella, M. (2015). Corn silage (*Zea mays* L.) response to zinc foliar spray concentration when grown on sandy soil. *Journal of Agricultural Science*, **7**(2): 68.

Eteng, E. U. (2017). Response of Zn uptake, grain and other yield components of five Maize hybrids as influenced by Zinc fertilization methods in a marginal coastal plain sand soil. *International Journal of Research Studies in Science, Engineering and Technology*,**4**: 37-46.

Ghasal, P. C., Shivay, Y. S., Pooniya, V., Choudhary, M. and Verma, R. K. (2017). Zinc fertilization effect on macro and micro-nutrients concentrations and uptake in wheat (*Triticum aestivum*) varieties.

Humtsoe, B. M., Dawson, J. and Rajana, P. (2018). Effect of nitrogen, boron and zinc as basal and foliar application on growth and yield of maize (*Zea mays* L.). *Journal of Pharmacognosy and Phytochemistry*, **7**(6): 01-04.

Iqbal, J., Khan, R., Wahid, A., Sardar, K., Khan, N., Ali, M. and Ahmad, R. (2016). Effect of nitrogen and zinc on maize (*Zea mays* L.) yield components and plant concentration. *Advances in Environmental Biology*, **10**(10): 203-209.

Kumar, D., Dhar, S., Kumar, S., Meena, D. C. and Meena, R. B. (2019). Effect of Zinc application on yield attributes and yield of maize and wheat in maize wheat cropping system. *Int. J. Curr. Micro. App. Sci.* **8**(1): 1931-1941.

Kumar, N. and Salakinkop, S. R. (2018). Agronomic Biofortification of Maize with Zinc and Iron Micronutrients. *Mod. Concep. Dev. Agrono.* **1**(4): 87-90.

Panda, A., Bhale, V. M., Bhattacharjee, S. and Kadam, S. R. (2019). Effect of different nutrient management practices and Zinc fertilization on various growth and development stages of Maize (*Zea mays* L.) under dryland condition. *Int. J. Curr. Microbiol. App. Sci.* **8**(6): 81-89.

Seifi – Nadergholi, M., M. Yarnia and K.F. Rahimzade (2011). Effect of zinc and manganese and their application method on yield and yield components of common bean (*Phaseolus vulgaris* L. CV. Khomeini). Middle-East J Sci. Res. Vol. **8**(5): 859-865.

Singh, S., Singh, V. and Mishra, P. (2017). Effect of NPK, boron and zinc on productivity and profitability of late sown *kharif* maize (*Zea mays* L.) in western Uttar Pradesh, India. *Annals of Agricultural New Series*, **38**(3): 310-313.

Tariq A, Anjum SA, Randhawa MA, Ullah E, Naeem M, Qamar R, Ashraf U, Nadeem M. Influence of zinc nutrition on growth and yield behaviour of maize (Zea mays L.) hybrids. American Journal of Plant Sciences. 2014 Aug 7;2014.