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Effects of zinc on the growth and yield of maize (*Zea mays* l.) cultivated in a tropical acid soil using different application techniques

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Abstract. In Malaysia, the application of micronutrients fertiliser is not a standard practise although several previous studies have indicated that the procedure contributes to a major impact on plant growth and development. The aim of this study is to investigate the effect of the concentration and application of zinc (Zn) on maize growth and yield. There were nine treatments including; no fertiliser applied as control (T0), NPK 16:16:16 only (T1), NPK + 5kg/ha Zn (T2), NPK + 10kg/ha Zn (T3), NPK + 15kg/ha Zn (T4), NPK + foliar Zn (T5), NPK + 5kg/ha Zn + foliar Zn (T6), NPK + 10kg/ha Zn + foliar Zn (T7), NPK + 15kg/ha Zn + foliar Zn (T8). Plant height was recorded during 30, 45 and 60 days of plant ages. Maize ear length, diameter and numbers of kernel's row were recorded on harvesting day (100 days). The findings suggest a significant difference in maize ear length, diameter and kernel row at $p<0.05$ for most treatment groups compared with control A and B. Ear length and diameter increased up to 20% with Zn application while kernel rows improved by 12% on the highest. The foliar application results showed significant increase of 0.6 cm diameter and 2.4 cm length of maize ear. However, there were no significant differences among treatments on plant height. Foliar and combination technique of Zn application also showed indecisive result on maize ear kernel's row. Application of Zn shows increased diameter, length and kernel row of maize ear though plant height is unaffected. The combination of the application techniques obtained the optimum yield of maize.

1. Introduction

According to the Eleventh Malaysia Plan [1] in strategy paper 20, one of the strategies is to increase the local feedstuff to enhance the national livestock industry. Hence, the Ministry of Agriculture and Agro-based Industry [2] has initiated a program to produce the livestock feed locally to reduce the imports and feed cost [3] thus, increase the production of livestock animal [4]. The maize for animal feed has not been planted commercially in Malaysia due to the high production cost and competition of land use for agriculture crops planting to support human consumption [5]. Thus, there is a need to identify any potential land, including the area with low fertility soil to accommodate the production of animal feed. The optimum maize production can be achieved by having soils consisting of accessible macronutrients (N, P, K, Ca, Mg, and S) and micronutrients (Zn, B, Cu, Mn, Mo, Ni and Fe). Even though the micronutrients are required in a small amount, it is equally vital for plant growth and development [6] as its role in improving quality and yield increment [7]. A study by Brown et al. [8] concluded that by balancing a good ratio of micronutrients, grain yield increased up to 50% and improved macronutrient-use efficiency. Among the micronutrients, Zn is considered the most critical micronutrient responsible for protein synthesis in plants [9] besides its function in catalytic action in metabolism for all crop, especially maize [10]. Suggested Zn application amount for maize planting is 5.6kg/ha [11]. In Malaysia, micronutrient fertiliser application is not common, even though many previous studies suggested that the practice exerts significant implications for plant growth and production. The micronutrients are not required in immense amount but they are essential for plant growth and become crucial in low fertility soils such as beach ridges interspersed with swales (BRIS) and acid sulphate soil. Therefore, this study was carried out to identify the effect of different zinc concentration and type of application on maize growth and yield in Malaysia.

2. Materials and Methods

2.1. Experiment location and description of materials

Field experiment was conducted in a greenhouse of Agriculture Department Office, District of Jeli, Kelantan (34°40′12″N, 114°32′24″E). The maize was planted with 3 kg Chempaka Siri soil in the 18x18 inch size polybag with three replications for each treatment. Chempaka Siri soil is susceptible to nutrient deficiencies due to it sandy-silky loam characteristic, low Cation Exchange Capacity (CEC) and base saturation [12]. The polybags were randomly arranged with a distance of 20 cm within row and 70 cm between rows. Irrigations were applied whenever needed by the crop. The plants were monitored for weeds via manual weeding while insect pest was controlled with proper chemicals application.

2.2. Experimental design and treatment

This study was conducted using the Completely Randomized Design layout, according to Maize Planting Manual [13]. This is the control A (T_0) for the experiment. NPK Green fertiliser (grade of 15-N: 15-P: 15-K) was applied immediately after sowing and 40 days after sowing at a rate of 150 kg/ha respectively. Between that, urea (46%N) is applied on day 18 at a rate of 150 kg/ha. No zinc application (T_1) is recommended according to the standard DOA manual will be control B for this experiment. Zinc applied to the soil (as a Zn-EDTA) at a rate of 5 kg/ha (T_2), 10 kg/ha (T_3) and 15 kg/ha (T_4). The rate of 0.1 % Zn-EDTA was applied for the foliar application method (T_5) at the nine leaves stages. The same three rates of Zn through soil application will be combined with 0.1% Zn-EDTA using foliar application method on maize plant as 5 kg/ha + 0.1% Zn-EDTA (T_6), 10 kg/ha + 0.1% Zn-EDTA (T_7) and 15 kg/ha + 0.1% Zn-EDTA (T_8). List of treatment as in Table 1.

2.3. Measurement of growth and yield of maize

Data of plant height was recorded at 30, 45, 60 days of plant maturity. All plants were harvested after plant maturity on 100 days after planting and their yield were measured. The length and diameter of maize ear have been measured using ruler and vernier calliper. Maize kernel row was measured by manual counting.

2.4. Data analysis

Collected data were subjected to analysis of variance using SPSS software (version 23). The normality or non-normality of distribution were determined. A one-way ANOVA was used to analyse the collected data for plant height, kernel rows, maize ear length and diameter. The differences between treatments were compared using Duncan Multiple Range Test (DMRT) at the 5% probability levels. The data are presented as the mean and standard error of the means (SEM) for all values.

Table 1. List of treatments.

	Treatments
Control A	T0: Soil only
Control B	T1: Soil + 150kg/ha NPK 15:15:15
Soil Zn Application Only	T2: Soil + 150kg/ha NPK 15:15:15 + 5kg/ha Zn
	T3: Soil + 150kg/ha NPK 15:15:15 + 10kg/ha Zn
	T4: Soil + 150kg/ha NPK 15:15:15 + 15kg/ha Zn
Foliar Spray Application Only	T5: Soil + 150kg/ha NPK 15:15:15 + 0.1% Zn-EDTA foliar spray
Combination Techniques	T6: Soil + 150kg/ha NPK 15:15:15 + 5kg/ha Zn + 0.1% Zn-EDTA foliar spray
	T7: Soil + 150kg/ha NPK 15:15:15 + 10kg/ha Zn + 0.1% Zn-EDTA foliar spray
	T8: Soil + 150kg/ha NPK 15:15:15 + 15kg/ha Zn + 0.1% Zn-EDTA foliar spray

3. Results and Discussion

Results for plant height, maize ear diameter, ear length and rows of kernel were shown in Table 2. The findings were consistent with that of Tariq et al. [14] in which application of zinc sulphate at the rate of 12 kg/ha (4.8 kg of Zn) had promotive effects on the growth and yield of maize. Similar finding was reported in a study by Shahab et al. [15].

Table 2: Effect of Zn concentrations and application techniques on plant height, maize ear diameter, ear length and number of kernel row.

	Plant Height (cm)	Ear Diameter (cm)	Ear Length (cm)	Kernel Row
Control A	150.0	2.7^{a}	11.5^{a}	11.0^{a}
Control B-T1	160.5	3.6^{bc}	14.6^{ab}	12.5^{abc}
T2	144.8	3.1^{ab}	13.4^{ab}	12.0^{ab}
T3	137.8	3.6^{bc}	14.7^{ab}	13.0^{bc}
T4	141.5	4.2^{de}	17.0^{c}	13.5^{bc}
T5	155.0	4.2^{de}	17.0^{c}	13.0^{bc}
T6	148.8	4.0^{cde}	17.1^{c}	14.0^{c}
T7	148.3	4.3^{de}	17.5^{c}	14.0^{c}
T8	141.5	4.0^{cde}	17.0^{c}	13.5^{bc}
P value	ns	*	*	*

Note: Mean values within column with different letter(s) indicate significant difference between treatments by Duncan Multiple Range test at $p \leq 0.05$.

3.1. Effect of Zn concentrations and application techniques on growth of maize

Figure 1 shows the data means of plant height at 60 days after sowing. All maize plants reach maximum height at tasselling stage which happen before the 60 days after planting. The maize growth results show no significant difference between treatment on plant height. This study found that additional Zn application did not significantly affect the plant height. This result supports the recent finding by Khalid et al. [16] and Munirah et al. [17]. This experiment was performed by using soil as the media where plants could accumulate some soil-Zn concentration, so the external Zn application could not influence the height of the plant. This may also due to other nutrients may act as a co-factor and increase the Zn uptake by maize plants so that the effects of Zn applications in terms of plant height may not be observed.

3.2. Effect of Zn on concentrations and application methods on yield of maize

The result show that T4, T5, T6, T7 and T8 significantly different compared to control A, control B, T2 and T3 on the length of the ear as shown in figure 3. This is consistent with that study of Khalid et al. [16]. Montalvo et al. [18] agreed that foliar Zn application is more effective than soil Zn application with the study show that Zn uptake was higher for foliar spray technique. This indicates that foliar Zn spray improves the ear length while soil application needs a high amount of Zn to be applied. Figure 2 show treated maize indicate significant increase in ear diameter as compared to control A and T2. However, the result is indecisive of Zn treatment on maize ear diameter compared to control B, which no Zn fertiliser been added. Only T4, T5 and T7 are different significantly compared to control B. The finding was inconsistent with the result by Anjum et al. [19]; Chand et al. [20]; Patil [21]. The finding differences may due to the type of trial and size of data that involved in the studies. Zn application on maize kernel rows are ineffective by none of the treatments shows any significant difference compared to control B. The result is in line with the finding by Ehsanullah et al. [22]. However, higher Zn amount shows a significant increase of kernel rows compared to the control. This observation was found in T3, T4, T5, T6, T7 and T8 with significantly higher kernel rows than control A. It is known that Zn physiological function is related to chlorophyll content in plant [23]. Higher chlorophyll content was the cause of the increase in yield characteristics due to the application of zinc, and this apparently had a positive impact on photosynthetic activity, synthesis of metabolites and growth-regulating substances, oxidation and metabolic activities, and ultimately improved crop growth and development, leading to an increase in maize yield characteristics.

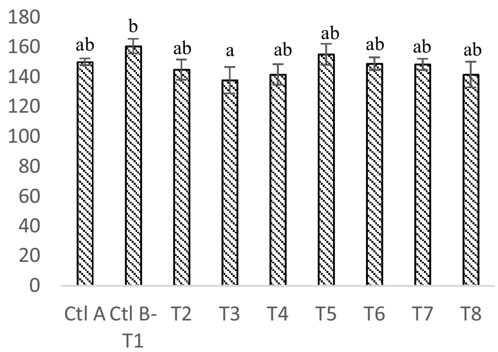

Figure 1. The effect of Zn on the maize plant height.

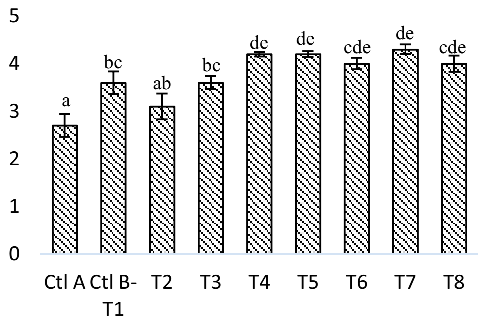

Figure 2. The effect of Zn on the diameter of maize ear.

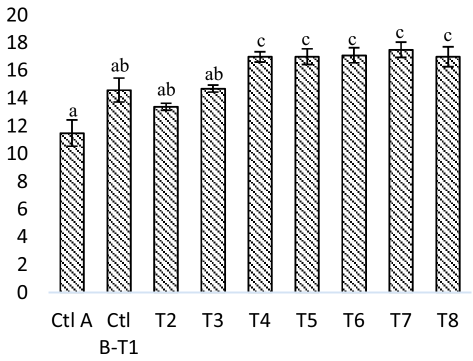

Figure 3. The effect of Zn on the length of maize ear.

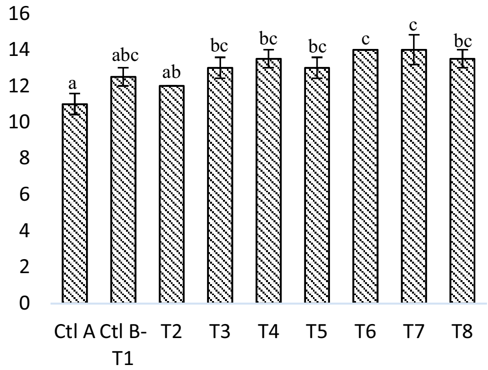

Figure 4. The effect of Zn on the maize kernel row.

Note: Mean values between columns with different letter(s) indicate significant difference between treatments by Duncan Multiple Range test at $p \leq 0.05$. Columns represent the mean values ± SE.

4. Conclusion

In this research, Zn application shows an increase of maize ear length and kernel row but did not exert any effect on the plant height and provide unconclusive effect on ear diameter. Foliar technique showed an improvement compared to Zn soil application for maize ear yield whereas combination technique (soil application and foliar application) produced the maximum yield at 10 kg/ha Zn with foliar Zn-EDTA spray.

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References

[1] Prime Minister Office (PMO) Malaysia 2015 Speech By the Prime Minister Eleventh Malaysian Plan, (May 2015)

[2] MOA 2016 Agrofood Statistics 2016, 157. Retrieved from http://www.moa.gov.my

[3] Mat K, Taufik H A, Rusli N D, Hasnita C H, Al-Amsyar S M, Rahman M M and Mahmud M 2020 Effects of fermentation on the nutritional composition, mineral content and physical characteristics of banana leaves *IOP Conf. Ser.: Earth Environ. Sci.* **596** 012089 doi:10.1088/1755-1315/596/1/012089

[4] Rahman M M, Ismail S N, Mat K, Gondo T, Mohamad Nor M and Akashi R 2020 Effects of diets containing *asyastasia gangetica* and *brachiaria decumbens* on intake, digestibility and growth performance of growing rabbits *Pertanika J. Trop. Agric. Sci.* 43 (4) 609–19 doi.org/10.47836/pjtas.43.4.14

[5] Rahman M M, Abdullah R, Mat K, Ishigaki G, Nor M M and Akashi R 2020 Replacement of soybean meal with levels of inclusion of soya waste in the diet of growing goats *Trop. Anim. Health Prod.* **52** 3085–90 doi.org/10.1007/s11250-020-02330-6

[6] Alloway B J 2004 *Zinc in Soils and Crop Nutrition*. International Zinc Association.

[7] Baloch Q B, Chachar Q I and Tareen M N 2008 Effect of foliar application of macro and micro nutrients on production of green chilies (*Capsicum annuum* L.) *J. Agric. Technol.* ***4*(2)** 177–84

[8] Brown P H, Cakmak I and Zhang Q 1993 Form and function of zinc plants *Zinc in Soils and*

Plants 93–118 doi.org/10.1007/978-94-011-0878-2
[9] Cakmak I, Tolay I, Ozdemir A, Ozkan H, Ozturk L and Kling C I 1999 Differences in zinc efficiency among and within diploid, tetraploid and hexaploid wheats *Annals Bot.* **84** 163–71
[10] Cakmak I 2000 Role of zinc in protecting plant cells from reactive oxygen species *New Phytologist* **146(111)** 185–205
[11] Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln. (2019). Nutrient Management Suggestions for Corn.
[12] Department of Agriculture, Malaysia 2008 Guildeline of Main Soil Siries in Peninsular Malaysia
[13] DOA District of Kemaman 2017 Maize Planting Manual. (unpublish)
[14] Tariq A, Anjum S A, Randhawa M A and Ullah E 2014 Influence of zinc nutrition on growth and yield behaviour of maize (*Zea mays* L .) hybrids, (August), 2646–54
[15] Shahab Q, Afzal M, Hussain B, Abbas N, Hussain S W, Zehra Q, … Abbas Y 2016 Effect of different methods of zinc application on maize (*Zea mays* L.) *Int. J. Agron. Agric. Res.* **9(2223–7054)** 66–75
[16] Khalid F, Tahir M, Fiaz N and Ather M 2013 Hybrid maize response to assorted chelated and non chelated foliar applied zinc rates **9(2)** 295–309
[17] Munirah N, Khairi M, Nozulaidi M and Jahan M 2015 The Effects of zinc application on physiology and production of maize plants *Aust. J. Basic & Appl. Sci*. **9(92)** 362–67
[18] Montalvo D, Degryse F, da Silva R C, Baird R and McLaughlin M J 2016 Agronomic effectiveness of zinc sources as micronutrient fertilizer *Adv. Agron.* **139** Elsevier Inc. doi.org/10.1016/bs.agron.2016.05.004
[19] Anjum S A, Saleem M F, Shahid M, Shakoor A, Safeer M, Khan I, … Nazir U 2017 Dynamics of soil and foliar applied boron and zinc to improve maize productivity and profitability *Pakistan J. Agric. Res.* **30(3)** doi.org/10.17582/journal.pjar/2017.30.3.294.302
[20] Chand S W, Susheela R, Sreelatha D, Shanti M and Hussain S A 2017 Effect of zinc fertilization on yield and economics of baby maize (*Zea mays* L.) *J. Pharmacog. Phytochem.* **6(5)** 989–92
[21] Patil S 2017 Effect of zinc application through soil and foliar means on bio-fortification of zinc in rainfed maize (*Zea mays* L.) *Int. J. Pure Appl. Biosci.* **5(1)** 246–53 doi.org/10.18782/2320-7051.2471
[22] Ehsanullah D, Tariq A, Randhawa M A, Anjum S A, Nadeem M and Naeem M 2015 Exploring the role of zinc in maize (*Zea mays* L.) through soil and foliar application *Universal J. Agric. Res.* **3(3)** 69–75 doi.org/10.13189/ujar.2015.030301
[23] Pandey R 2015 Mineral Nutrition of Plants. Plant Biology and Biotechnology: Plant Diversity, Organization, Function and Improvement (Vol. 1) doi.org/10.1007/978-81-322-2286-6