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INFLUENCE OF ZINC FERTILIZER RATES ON GROWTH, YIELD AND QUALITY OF SAMAZ-14 MAIZE (*Zee mays*) VARIETY IN JALINGO, NIGERIA

***[1]Kussiy J. Jonathan, [1]Samuel J. Karma, [1]Garpiya T. Bodinga, [1]Ali I. Jirah, [1]Christopher Abednego, [1]Omadewu I. Lawrence and [2]Yabwa Dlama**

[1]Department of Soil Science and Land Resource Management, Faculty of Agriculture Science, Taraba State University, Jalingo, Nigeria.
[2]Department of Physics Faculty of Science Taraba State University, Jalingo, Nigeria

*Corresponding authors' email: zirkussiy@gmail.com Phone: +2348068200651

ABSTRACT
The field experiment was conducted in Jalingo, Nigeria, during the 2019 cropping season to evaluate the effects of varying zinc fertilizer rates on the growth, yield, and quality of Zea mays L. samaz-14 variety. The study utilized a randomized complete block design with five zinc application levels (including a control) and three replications. Application of 7.5 kg Zn ha^{-1} resulted in significant improvements in stem girth, grain yield, and grain weight per cob compared to other treatments. Zinc supplementation enhanced vegetative development, harvest index, and 100-grain weight, leading to increased yield. The yield improvements were attributed to enhanced zinc nutrient availability. The 7.5 kg Zn ha^{-1} rate is recommended as optimal under the study conditions.

Keywords: Zinc Fertilizer, *Zea mays*, Samaz-14, Yield response, Nutrient Management, Jalingo

INTRODUCTION

Maize (*Zea mays* L.) is a cereal crop that is grown over a wide geographical area. It is a multi-purpose crop that has a lot of uses with varieties of human diets and animal feeds in form of grain or silage (Adiaha *et al*, 2016.

Maize is the most important cereal and most widely cultivated staple that plays a key role in the food security of sub-Saharan Africa (Abate *et al*., 2017). Therefore, farmers are encouraged to incorporate the crop into the farming systems under both irrigated and rain fed agriculture. Maize (Zea mays L.) is the world's widely grown cereal and primary staple food crop in many developing countries (Kandil, 2013). In the world production, maize is ranked as the third major cereal crop after wheat and rice (Zamir *et al*., 2023).

Maize is used for the production of indigenous and commercial food products that are relished for their unique and distinctive flavors. It is eaten fresh or milled into flour and serves as a valuable ingredient for baby food, cookies, biscuits, ice cream, pancake mixes, livestock feed and a variety of traditional beverages (Okoruwa, 1998). The soils are adjudged to be very low in both major and minor nutrient element, which had resulted to the very low yields of most crops, including maize. Application of chemical fertilizers do helps to overcome the nutrient deficiencies however, excess use of these materials does cause side effects such as increased soil acidity by changing soil pH. Maize exhibits notable resilience to soil pH ranging from approximately 5.6 to 7.5, but performs best within a slightly acidic to neutral range of 6.0 to 7.0 Dejene.M. (2021)

The maize crop requires adequate supply of nutrients particularly zinc, nitrogen, phosphorus and potassium for optimum growth and yield. The most important micronutrients particularly in the savannah zone and under continuous cropping in the forest ecology are zinc (Iken and Amusa, 2004)

Alloway 2007, Showed that zinc plays an indispensable role in various plant physiological processes such as photosynthesis, protein and sugar synthesis, fertility and production of seeds, growth regulation and disease immune system. Its deficiency impedes plant physiological pathways by adversely affecting health and productivity of plants, which results in low yield and poor quality

Since zinc is not mobile in plants so and its deficiency symptoms occur mainly in new growth. Poor mobility in plants suggests the need for a constant supply of available Zinc for optimum growth (Mortvedt, 2011)

Lack of zinc (Zn) is a common micro-deficiency in arid and semiarid areas of the World. Its deficiency is common in cereals, especially in calcareous soils of arid semi deserts. It is stated that approximately 50 % of the land used for the production of cereals in the world are deficient in Zinc. (Baser, *et, al* 2012).

Nutrient is an important component of various enzymes that are responsible for driving many metabolic reactions in all crops. Growth and development would stop if specific enzymes were not present in plant tissue (Ali *et al.*, 2020).

Study research conducted by (Muzaffar *et, al.* 2014) found that, the data indicated that integrated application of Potassium at 60.0 kg/ha + Zinc at 10.0 kg/ha resulted in maximum plant height (180.67cm) of Maize, similar finding was found by Mehdi *et al.,* (2012). Zinc at 10 kg per ha has significantly increased the plant height of Maize (175.69 cm) as compared to no zinc application. Similarly, Singh *et al., (*2021) described a significantly increase in the plant height of Maize with soil application of zinc over its foliar application and control.

Mehdi *et, al*., (2012) showed that Stem diameter, leaf-stem ratio, yield also increased significantly with zinc application at 10 kg/ha showed that various levels of potassium and zinc either sole or integrated affected positively and significantly ($P<0.05$) Maize stem girth(cm) as compared to No Potassium + No Zinc (Control). The data indicated that integrated application of Potassium at 60.0 kg/ha + Zinc at 10.0 kg/ha resulted in maximum stem girth (4.10 cm) of Maize.

Research work shows that zinc (Zn) plays a critical role in plant growth and development, particularly when applied alongside nitrogen. Mahdi (2012), who reported that zinc enhanced plant height, leaf area index, dry matter production, chlorophyll content, and the number of functional leaves in maize. One of the major constraints to maize (*Zea mays L.)* production in Nigeria is low soil fertility, primarily caused by shortened fallow periods due to population pressure. The situation is exacerbated in tropical regions such as Nigeria, where high rainfall and intense solar radiation lead to rapid nutrient leaching and reduced soil organic matter. Among the essential nutrients, zinc has emerged as one of the most limiting factors for maize production (Singh *et al*., 2018). Zinc deficiency is now recognized as one of the most widespread micronutrient disorders globally, particularly in calcareous, sandy, peat soils, and soils high in phosphorus or silicon. Given this context, the present study aims to explore the impact of zinc fertilization on maize performance in Jalingo, Nigeria. The objective is to provide practical insights for optimizing fertilization strategies that improve crop productivity, increase farm profitability, and address zinc deficiency challenges in maize cultivation.

Experimental Site

The research was conducted in Collage of Agriculture Jalingo research farm, Taraba State (Figure 1). The locations had two distinct seasons, dry and wet season with temperature and humidity varying with the seasons. The wet season begins in May and ends in September 70% of the total rainfall in the area falls within June to August. The mean annual rainfall for the area is 982mm, while the temperature ranged from 27 ºc to 40 ºc.

Figure 1: Map of Taraba State

The experiment was laid in a 5 X 5 factorial Randomized Complete Block Design with the five (5) Zn levels (0kg, 2.5kg, 5kg, 7.5kg and 10kg Zn per ha) whileSamaz-14 Maize was used as the test crop, ZnS as the source of Zn were procured from Northern Scientific chemical store Jimeta, Yola and Samaz-14 maize seed was procured from IAR Zaria which is characterized by high lysine and tryptophane contents, medium maturity and good seed quality, high yield and tolerance to striga.

The treatments consist of five rates of Zinc :0kg N (0kg, 2.5kg, 5kg, 7.5kg and 10kg Zn per ha) per hectare using ZnS as source of zinc, while Samaz-14 Maize was used as the test crop. The experiment at each location was laid in the field with total area of 14m x 14.5m. The plot was divided into five blocks of 14mx2.1m each with a space of 1.0m between blocks each block was divided into 5 equal sized subplots of 2.1m x 2.0m, with 0.5m space between subplots. The sub-plot was sown to maize at 20cm x 70cm of 3 rows per subplot. This gave a total of 15 maize stands per sub-plot and data were collected from the 3 maize stands in the middle row, while all others were considered boarder rows. The fertilizer rates were randomly allotted to each subplot of each block and applied in a ring form.

Planting was done manually immediately after the field preparation. The seed was planted at a seed rate of 1 seed per stand at 5cm depth, The gross plot of this experiment consisted of 4 ridges, The inter row spacing was 70cm and intra row spacing was 20cm and the plots size was 6.72 m^2. A distance of 0.5m was used between plots and 1m between block, 1.5 m between replications while the boarder row was used as boarder distance.

Treatments (Fertilizers) were applied at different rates per plots, Zn0kg (0.0g per plot), Zn2.5kg (1.68g per plot), Zn5.0kg (3.36g per plot), Zn7.5kg (5,04g per plot) and Zn10kg (6.72per plot) per hectare, the application of fertilizer was done basally at the distance of 5cm away from the stalk.

Weeding was done manually by hoe at two weeks after planting and 5 weeks after planting. Data were collected on plant height, stem girth and number of leaves on the maize plants on 5 carefully selected plants devoid of diseases per plot. Plant height was taken at 25, 50 and 75 days after sowing, and were measured from the soil surface to the tip of panicle and the average height calculated in cm. Stem girth were by the use of Vernier caliper at the time of taking the plant height in cm. Numbers of leave were by visual countering and the average number of leaves recorded. Maize harvest was done at 75 per cent silking and the harvests were weighed separately for the fresh yield, and then sundried to constant weight. The data collected were subjected to Analysis of variance (ANOVA) and significant mean differences were separated using Duncan Multiple Range Test (DMRT) at 5 % level of probability using Statistical Analysis System (SAS).

RESULTS AND DISCUSSION

Physical Properties of the Experimental Sites is presented in Table 1

The sand contents of this study sites were generally high about (66.0%) in soils. Soil is considered one of the most important criteria affecting soil behavior and land management, that influence several soil characteristics, plant growth and development, which are based on the soil texture (Isabel *et al .*, 2017). The textural class is predominantly Sandy loam (SL) which has low clay and with the low organic matter content, and the soils are prone to nutrient leaching (Sutradhar *et. al*., 2016).

Table1: Soil Physical Properties of the Studies Area in Jalingo Showing the Surface and Subsurface Soil

Property	Surface	Subsurface
Depth (cm)	0-20	20-50
Sand (%)	66.0	64.0
Silt (%)	16.8	14.8
Clay (%)	17.2	21.2
Texture	SL	SL
Bulk density (g/cm^3)	1.48	1.45
Porosity (%)	44	45

The mean bulk density values recorded were 1.48 g/cm³ for the surface layer and 1.45 g/cm³ for the subsurface layer. These values fall within the optimal range for agronomic activities and are deemed suitable for maize cultivation, as they do not restrict root penetration above 1.75 (g/cm^3) would be detrimental to plant root penetration while soil with high bulk density affects soil physical properties which limit microbial activities and biochemical processes which are crucial for nutrient availability and overall plant growth and development. The total porosity of the soils of the study area was 48% for surface and subsurface and a mean value of 45% for the surface and subsurface levels respectively. These values were high enough to ensure water retention therefore, continuous nutrients supply and absorption by crop for tissue build up that may eventually result to better plant performance (Abebe *et al.*, 2021).

Chemical Properties of the Experimental Sites before Experiment

The soils chemical properties (Table 2) showed that mean soil pH was 6.65 at the surface and 6.61 for sub-surface soil respectively, these, values indicated a slightly acidic soil condition. The Electrical Conductivity (EC) of the soils of less than 1.0 dSm^{-1} indicates that Na and soluble salts could not be a threat to crop production in the areas (Hossein and Farshad 2023). The Organic Carbon content obtained decreased with depth in (Table 2) the surface soil Organic C was high; this may be attributed to continuous cultivation of the soils over the years due to removal of vegetative cover without conscientious replacement**.** Th**e** potassium content of the soils was found to be high at the surface (0.74 cmol/kg) and medium (0.36 cmol/kg) at the sub surface level.). The soil Total Exchangeable Bases (TEB) at the surface and subsurface were 8.88cmol/kg, and 11.87cmol/kg respectively. The ECEC of the soils surface and sub-surface soils was 12.76 and 11.996cmol/kg respectively. Total Exchangeable Acidity (TEA) at surface and sub-surface were 1.820 and 1.710cmol/kg respectively. The Percentage Base Saturation (PBS) was 82.990% - 87.408%.

Table 2: Soils chemical properties of soil samples in Jalingo

Property	Surface	Subsurface
Depth (cm)	0-20	20-50
PH 1:2.5	6.65	6.61
E C (dS/m)	0.18	0.06
Org. carbon (g/kg)	10.20	7.40
Total Nitrogen (g/kg)	0.97	0.70
K^{2+} cmol/kg)	0.34	0.36
Na^{2+} (cmol/kg)	0.41	0.35
Ca^{2+}(cmol/kg)	6.13	7.12
Mg^{2+}(cmol/kg)	1.08	3.79
TEA (cmol/kg)	1.82	1.71
ECEC(cmol/kg)	10.70	13.58
PSB (%)	82.99	87.41
ESP (%)	8.53	6.61
Zn(mg/kg)	2.11	2.04

Growth Parameters

Effect of Zinc Rates on Maize Plant Height

Regarding the zinc rates, the plant height of maize showed no significant differences among different zinc rates. The plant height ranged from 14.26 cm to 14.58 cm at 0 kg/ha and 10 kg/ha of zinc, respectively. The mean separation difference (MSD) values for zinc rates were relatively low, indicating that the zinc rates did not have a significant impact on plant height.

Table 3: Effect of Zinc rates on plant Height of maize

Zinc Rate (kg/ha)	25days	50days	75days
0	14.26cm	40.03cm	92.47cm
2.5	14.17cm	40.75cm	92.23cm
5.0	13.98cm	42.49cm	93.42cm
7.5	14.56cm	34.88cm	95.06cm
10	14.58cm	39.64cm	97.67cm
MSD	0.87cm	1.82cm	0.85cm

Effect of Zinc Rates on Maize Stem Girth

Table 4 illustrates the influence of varying zinc application rates on maize stem girth across three growth stages (25, 50, and 75 days after planting) at the Jalingo location. At 25 days after planting, stem girth values ranged from 0.95 cm to 1.82 cm. Although the 5.0 kg/ha zinc rate recorded the highest stem girth (1.82 cm), there was no statistically significant difference among treatments, as indicated by the identical letter groupings.

By 50 days, all zinc treatments exhibited comparable stem girth values, ranging between 2.11 cm and 2.56 cm, again showing no significant differences due to zinc application. A similar trend was observed at 75 days after planting, where the values ranged from 2.03 cm to 2.20 cm. Although there were slight increases in stem girth with higher zinc rates, the differences were not statistically significant.

Overall, the minimal mean separation differences suggest that zinc application, within the tested rates, did not significantly influence maize stem girth at any of the growth stages observed.

Table 4: Effect of zinc fertilizers on Stem Girth

Zinc rate(kg/ha)	25days	50days	75days
0	0.97cm	2.11cm	2.03cm
2.5	0.95cm	2.56cm	2.20cm
5.0	1.82cm	2.15cm	2.06cm
7.5	0.96cm	2.18cm	2.15cm
10	0.99cm	2.18cm	1.92cm
MSD	3.09cm	0.05cm	0.04cm

Regarding the zinc rates, the dry matter yield of maize showed no significant differences among different zinc rates. The dry matter yield ranged from 43.80 g to 46.66 g at 0 kg/ha and 5.0 kg/ha of zinc, respectively. The mean separation difference (MSD) values for zinc rates were relatively low, indicating that the zinc rates did not have a significant impact on dry matter yield which falls within the purview of existing literature reviews.

Table 5: Effect of Zinc Rates on Maize Dry matter yield of maize

Zinc Rate (kg/ha)	25 days	50days	75days	Grain	Straw
0	43.80 cm	185.00cm	180.00cm	148.67cm	153.33cm
2.5	40.70cm	182.00cm	179.00 cm	170.00 cm	170.67cm
5.0	46.66 cm	181.33cm	184.00 cm	175.33cm	180.33cm
7.5	44.66 cm	196.00 cm	183.00 cm	173.33 cm	175.67cm
10	37.66cm	190.00cm	182.00 cm	170.00 cm	172.33cm
MSD	0.56cm	1.27cm	0.84cm	0.44cm	0.67cm

Effect of Zinc Rates on Yield Attributes

From Table 6 below Shows that Zinc fertilizers had a significant effect on the number of grains per cob and the weight of 100 seeds, as well as on the weight of grains per cob.

The highest number of grains per cob of (470.00) was observed at 10 kg/ha of zinc, but it was not significantly different from any other rate except zero kg/ha of zinc. The highest weight of 100 seeds (42.00 g) was observed at 5 kg/ha of zinc, which was significantly higher than all other rates except 7.5 kg/ha of zinc. The highest weight of grains per cob (149.33 g) was also observed at 7.5 kg/ha of zinc, which was significantly higher than all other rates except 5 and 10 kg/ha of zinc.

The result suggests that zinc fertilizers have different effects on the yield and yield attributes of maize depending on the location and soil conditions. The optimal rate of zinc fertilizer may be 2.5 or 10 kg/ha. These results imply that site-specific recommendations are needed for optimal fertilizer management for maize production. The results of this study are partly consistent with the findings of Oikeh *et al*. (2003), who reported that zinc fertilizers interacted significantly on the weight of 100 seeds of maize in Nigeria. However, they found that zinc application increased the weight of 100 seeds of maize up to 5 kg/ha. The differences between this study and Oikeh *et al*. (2003) may be due to the variation in soil properties, climate conditions, and maize varieties.

The results of this study are also partly consistent with the findings of Singh *et al*. (2010), who reported that zinc fertilizers interacted significantly on the number of grains per cob and the weight of grains per cob of maize in India. However, they found that zinc application increased the number of grains per cob and the weight of grains per cob of maize up to 10 kg/ha.

Table 6: Effect of Zinc Rates on Yield and Yield Attributes

Zinc rate (kg/ha)	Grain number per Cob	100 seed weight (g)	Grain weight per cob (g)
0	465.00	24.00	129.33
2.5	467.33	36.33	134.00
5.0	465.67	42.00	139.17
7.5	465.00	41.33	149.33
10	470.00	39.42	144.8
MSD	1.22	1.65	2.63
CD(0.05)	8.93	7.96	12.02
N x Zn	NS	*	NS

Discussion on the Effect of Zinc rates on Grain and straw Yield

The results presented in Table 7 indicate that zinc fertilizer application significantly influenced both the grain and straw yields of maize cultivated in Jalingo. Notably, the highest grain yield (71.75 kg/ha) was recorded at 0 and 2.5 kg/ha zinc application rates. These yields were significantly higher than those obtained from other zinc application levels, with the exception of the 7.5 kg/ha treatment, which showed no statistical difference from the top-yielding treatments.

Similarly, the maximum straw yield (9.88 kg/ha) was observed at the control treatment (0 kg/ha of zinc), which was significantly greater than yields recorded at other zinc rates, except for the 2.5 kg/ha treatment. These findings suggest that, in this location, lower or no zinc application favored both grain and straw yield performance.

This variation in yield response may be attributed to the inherent soil nutrient composition and site-specific factors in Jalingo. The results underscore the importance of tailoring fertilizer recommendations to local conditions rather than applying blanket application rates. While higher zinc rates did not consistently enhance yield in this study, the possibility that either 0 or 10 kg/ha may represent the optimal application rate should not be ruled out without further site-specific investigation.

These findings partially align with those of Oikeh *et al.* (2003), who reported that zinc fertilization significantly influenced maize grain yield in Nigeria, with optimum benefits observed up to 5 kg/ha. However, the current study reveals a contrasting response, emphasizing the variability of maize response to zinc and reinforcing the need for localized fertilizer management strategies to optimize maize productivity.

Table 7: Effect of Zinc Rates on Grain and Straw Yield of Maize

FactorZinc rate(kg/ha)	Grain Yield(kg/ha)	Maize Yield(kg/ha)
0	70.00	9.13
2.5	69.00	9.00
5.0	64.33	8.43
7.5	75.00	9.30
10	70.67	9.14
0	70.00	9.13

Effect of Nitrogen Rates on Nutrient Uptake of Maize in Yola and Jalingo

Soil Nutrient Status

The application of zinc also significantly influenced soil Zinc content, particularly at higher zinc rates (e.g., 10.0 kg/ha). This interaction is critical because it reflects the residual effects of fertilization on soil nutrient dynamics, which can inform future cropping cycles.

Nutrient Uptake

The nutrient uptake was measured as the concentration of zinc in the grain, straw, and total biomass at harvest. Zinc application improved the uptake of zinc in both grain and straw, particularly at 5.0 kg/ha. These results are consistent with earlier literature which shows zinc's role in facilitating the absorption of other nutrients like phosphorus. The fertilizer treatment rates had significant effects on the Zn uptake in the grain and total biomass.

Table 8: Effect of Zinc Rates on Nutrient Uptake in Jalingo

Zinc Rate (kg/ha)	25days (mg kg^{-1}).	50 days (mg kg^{-1})	75 days (mg kg^{-1})	Grain (mg kg^{-1})	Straw (mg kg^{-1})	Total (mg kg^{-1})
0	26.40	98.57	103.60	55.19	169.02	124.22
2.5	30.14	119.17	137.63	60.90	175.64	136.53
5.0	33.28	133.29	148.26	65.93	185.12	151.06
7.5	32.18	130.54	145.83	64.34	179.83	144.17
10	31.39	129.35	143.37	62.56	175.64	138.19
MSD	2.38	2.42	2.07	2.78	2.97	4.83
CD at 5%	6.93	7.36	6.29	8.45	9.03	14.06

The maize nutrient uptake in Jalingo (Table 8) shows that Zinc fertilizers had a significant effect on the nutrient's components of other fertilizers. The highest zinc uptake (33.28 mg kg^{-1}) in the grain was observed at 5 kg Zn ha^{-1} and was significantly higher than the control (26.40 mg kg^{-1}). The highest zinc uptake (185.12 mg kg-1) in the total biomass was observed at 5 kgha-1 of zinc, which was significantly higher than all others.

CONCLUSION

The study confirms that zinc fertilizer enhances maize growth and yield, with 5 kg Zn/ha notably improving 100-seed weight, while 7.5 kg Zn/ha further boosts stem girth and grain weight per cob. These findings suggest effective yield gains even at moderate zinc levels, offering a cost-efficient option for farmers with limited access to fertilizer

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