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Grain Yield and Seed Quality Attributes of Maize Grown Under Different Zinc Sulphate Application Techniques in Moor Plantation, Ibadan, Nigeria

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ABSTRACT: Optimizing crop yield is a function of the effectiveness of agronomic practices, inherent crop quality in relation with favourable environmental condition. The objective of this study was to evaluate the grain yield and seed quality attributes of maize (*Zea mays* L) grown under different zinc sulphate application techniques in Moor Plantation, Ibadan, Nigeria. The treatment consisted of two maize varieties (V); (BR9928DMR-SR-Y and ILE-1-OB), six zinc application methods (T); [seed primed in distilled water (S1), 1% (S2) and 2.0 % (S3) of ZnSO4, 1% ZnSO4 foliar spray (S4), soil placed ZnSO4 (S5) (7.0 kg ha^{-1}) and the control (S6-farmer's practice)]. At harvest, data were collected on grain yield (GY, Kg ha^{-1}), germination index (GI) and seed conductivity (SC). From the result, the T and V differed significantly (P<0.01). The S1 (4.58) and S2 (4.73) plots had the highest GY but lowest in S6 (2.20), while variety BR9928DMR-SR had higher GY (4.04) than ILE-1-OB (2.77). The T and V differed significantly (P<0.05) for GI (P<0.01), for SC, T varied (P<0.01), V (P<0.05). Earliest GI of 4.42 days were observed in seeds of S2 plots than seeds of other treatments. Seed conductivity was highest in S3 (10.74), but lowest in S6. Priming maize seed in distilled water or 1% ZnSO4 significantly enhanced grain yield and seed quality of maize in this study.

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Maize is an important cereal crop in Nigeria and most sub-Saharan African countries. This crop has a broad base of utilization across different cultural and social strata. Report available shows that close to 60% of local maize production is utilize for poultry feeds formulation in the recent times and approximately 25% of locally produced maize goes to the food and beverage industry, while the remaining 15% is available for household consumption (Okojie, 2021). Despite, being the second-largest grower of maize in Africa and 13th globally, the yield of maize per hectare in Nigeria has remained very low, as production could not match the increasing population growth demands.

The general imbalance in the demand and supply of maize in Nigeria could be attributed to limited access to agricultural inputs, inherent low soil fertility, pest and disease and poor agronomic practices. The prevailing climate change, Covid-19 global pandemic and increasing level of national insecurity could also be implicated for the low maize output in the recent years. Although, quite a number of maize yields enhancing research findings have been documented over the years from Research Centers and Agencies across the country. However, the need to optimize maize yield potential by breaching the gap between

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actual maize demand and supply toward national food security and sustainability cannot be overemphasized.

Zinc is an important plant micro nutrient that plays critical roles in plant functions and metabolic processes. It is a co-factor for no less than 300 enzymes responsible for the production of tryptophan a major precursor for plant growth hormone “auxin” (Aravind and Prasad, 2003). Zinc is actively involved in protein synthesis, photosynthesis, pollen formation and disease resistance in plants (Hjiboland and Amirzal, 2010; Rudni *et al*., 2018). Earlier studies reported significant improvement in the growth and grain yield of maize due to zinc application (Tariq *et al*., 2014; Kumar *et al*., 2017). This nutrient is available inform of salts and could be applied to plant as soil placement, dissolve in aqueous solution and applied as foliar spray or nutrient priming for seeds. Several studies had enumerated the benefits and limitations of each of the application methods. However, there is dearth of information on the various benefits of various zinc application techniques on grain yield and seed quality of maize in this part of the world. Therefore, the objective of this study is to compare the effects of the various zinc application techniques on yield and seed qualities of maize. In addition to identifying the most cost-effective, sustainable and environmentally friendly method of zinc application for maize production.

MATERIALS AND METHODS

This study was conducted under rain fed on the Research field at the Institute of Agricultural Research and Training (I.A.R and T) Moor Plantation, Ibadan, during the second growing season of maize in Southern Ecology of Nigeria in 2021. The Institute (I.A.R and T) is located in the Rainforest Savanna transition zone (07°38’N, 03°84’E 182M).

A factorial experimental design consisting of combination of zinc sulphate application techniques and maize cultivars was used. The experimental design was a 6 x 2 split plot arranged in a randomized complete block with three replications. Zinc sulphate application method constituted the main plot, while the two maize varieties, BR9928DMR-SR-Y and ILE-1-OB, constituted the subplots. The maize seeds were obtained from the seed store of the Institute (I.A.R and T). The zinc treatment included three priming levels of $ZnSO_4$ which were 0 % (soaking in distilled water), 1% and 2.0 % of solution of ZnSO4 (500 g of maize seeds of each of the varieties were soaked in the zinc solutions for 16 hours), foliar spray of 1% zinc sulphate solution and no zinc sulphate application (farmer practice). The 1% and 2% zinc solutions were prepared by dissolving 10 and 20 g of $ZnSO_4$ in one litre of distilled water, respectively (Sharma and Parma, 2018). The seeds were air-dried in a shade after draining from the priming solution. After land preparation, the seeds were planted on the designated plots of each plot size 2.25 by 5.0 m. Zinc sulphate at the rate of 7.0 kg ha^{-1} was applied to the designated plots basally by broadcasting (for soil placement). Equal amount of inorganic fertilizer NPK 20-10-10 was applied across the plots basally, while urea was applied six weeks after planting at the rate of 100 kg N ha^{-1}. At flowering, ten (10) plants were bulk pollinated from the experimental rows and harvested separately for seed quality assessments.

At harvest, the following data were collected on: Plant height: This was determined using meter rule from the base of the stalk to the base of the tassel; Ear height: distance from the base of the maize stalk to the base of the first ear, obtained by using the meter rule; Cob length: distance between the base of the cob to the tip of the cob was measured in centimeter using a ruler; Number of kernels per row: The number of kernels per row was determined by visual counting. Grain yield: The final grain yield was adjusted to 15% moisture content according to equation 1: (CIMMYT (1985).

$$Grain\ yield = \frac{(\mathrm{GW\ (kg)})}{(7.5\ \mathrm{m}^2)}\, x\, \frac{(100-\mathrm{MC})}{(100-15\%)} x 10,000\ \mathrm{m}^2 \quad (1)$$

Where GW = Grain weight, MC = grain moisture content at harvest, storage moisture content = 15%, plot area = 10 m^2 and 1 ha = 10,000 m^2

Seed Quality Assessments: The quality of seeds harvested from the different treatments were assessed with the following tests in the seed testing laboratory of the Institute of Agricultural Research and Training, Moor Plantation, Ibadan.

Standard germination: This was carried out in three replications of 100 seeds per replicate. Plastic germination bowls were filled with moistened sharp sand and seeds were evenly spaced on the sand. Thereafter, the seeds were thinly covered with moistened sand and lightly pressed for a good seed-substratum contact. The bowls were covered with nylon sheets to prevent evaporation. Germination counts were taken daily from the 3rd to 8th day after planting. On the 9th day, seedling analysis was carried out and the numbers of normal and abnormal seedlings were recorded. Germination was interpreted as the percentage of seeds producing normal seedlings (International Seed Testing Association, 2018).

$$\mathrm{SG} = \frac{\mathrm{NSE}}{\mathrm{TSP}}\ x\ 100 \quad (2)$$

Where SG = Standard Germination; TSP = Total number of seeds planted ; NSE = Number of normal seedlings emerged

From the germination data above, germination index (GI) was calculated for each replicate according to Ajayi and Fakorede (2000) as follows.

$$SGI = \frac{\sum(\mathrm{Nx})\mathrm{DAP}}{\mathrm{TE}} \quad (3)$$

Where SGI = standard germination index; Nx is the number of seedlings that emerged on day x after planting; DAP is the days after planting; TE = Total number of seedlings that emerged on the final day.

100 Seed Weight: A 100-seed weight in 3 replicates from each treatment was determined and expressed in gramme

Evaluation of seedling traits: One out of every 10 normal seedlings, that is, 10% of the total number of normal seedlings, in each replicate, at the final germination count was used to obtain data on the following seedling vigour parameters.

Seedling Length (SDL): The length from the tip of the root to the shoot tip of the seedling in 10 randomly selected seedlings and expressed in cm.

Root Length (RLT): The length from shoot level to the tip of the plant root of seedling in 10 randomly selected seedlings and expressed in cm.

Seedling Dry Weight (SDWT): 10 randomly selected seedlings oven dried at 108^{o} C until constant weight and averaged.

Seedling Vigour Index (SVI): The seedling vigour levels of each treatment was calculated by multiplying percent seed germination by average of seedling root and shoot length of each variety after 7 days of germination and divided by 100.

$$\mathrm{SVI} = \frac{\%\, \mathrm{G} * \mathrm{RL} * \mathrm{SL}}{100} \quad (4)$$

Where SVI = Seedling Vigour Index ; G = germination, RL = Root Length; SL = Shoot Length

Electrical conductivity: Fifty clean and apparently intact seeds in three replicates were counted, weighed, and placed in a glass flask containing 100 ml of distilled water. The flasks were covered with aluminum foil to prevent contamination and gently shaken intermittently. Conductivity measurements were taken after 24 h using Mettler Toledo MC126 conductivity meter. All measurements were expressed as $\mu Scm^{-1}g^{-1}$ and the results were interpreted as suggested by Hampton and TeKrony (1995).

$$\mathrm{Cond.}\left(\mu\frac{\frac{\mathrm{S}}{\mathrm{cm}}}{\mathrm{g}}\right) = \frac{\mathrm{Cond.}\,(\mu)\text{of each flask} - \text{Cond. of water}}{\text{Inital weight of seed smple}} \quad (5)$$

Where Cond. = conductivity

$$\text{Water Imbibed (WIM)} = \text{Initial seed weight} \quad (6)$$

Statistical Analysis: The various data generated were subjected to analysis of variance (ANOVA) using Statistical Tool for Agricultural Research Software package (STAR, 2014) while the means were separated using the least significant difference at 5 % level of probability.

RESULTS AND DISCUSSION

From the result of soil sample analyzed shows that the soil was a loamy-sandy soil of classification series Typic Kanhaplustalf. There were slight variations in the soil chemical properties as shown in Table 1. The pH value of the soil samples is neutral (7.21), the soil total nitrogen appeared very low (0.06%), the available phosphorus is low (5.92 mg kg^{-1}), organic carbon is very low (0.40 %), potassium and the micro-nutrients were very low compared with Nigerian soils recommendation.

Growth and yield of maize grown under different $ZnSO_4$ application techniques: Seed treatments and the applications of plant nutrients through various techniques such as foliar spray, soil application and water and nutrient priming with micro nutrients have the potential to enhance crop growth and productivity. This study attempts to evaluate the various zinc application techniques with the aim of determining the most affordable and sustainable method of enhancing maize yield and seed quality of maize in comparison with the regular farmers practices. From this study, the application of $ZnSO_4$ has no significant effect on the plant height and cob length. As shown in tables 2 and 3, maize variety BR9928DMR-SR-Y (170.36 cm) appeared taller than ILE-1-OB (155.36 cm) ($P<0.05$). EHT (91.35 cm) was highest when maize seeds were primed in 1% Zinc Sulphate solution ($P<0.05$). Maize variety BR9928DMR-SR-Y had longer cob length of 16.51 cm compared with ILE1OB (13.54 cm) ($P<0.01$) in response to zinc application. The number of kernels per row were significantly influenced by the treatment and the variety ($P<0.05$) (Tables 2 and 3). Water primed seed had higher K/R (35.24), no significant differences were observed among other treatments except 2% $ZnSO_4$ (25.17) which had least K/R. Maize variety BR9928DMR-SR-Y (32.36) had significantly higher K/R than ILE-1-OB (28.29). The weights of 100 grains were significantly influenced by treatment and the variety effects ($P<0.05$). Maize plots grown with 1% (28.18 g), 2% (27.90 g) $ZnSO_4$ and water primed (27.57 g) seeds had higher 100-grain weights compared with 100-grain weights obtained in foliar applied (24.72 g) and soil placed $ZnSO_4$ (23.03 g) and the control (23.20 g) plots. Maize variety BR9928DMR-SR-Y (26.76 g) had higher 100-grain weights than ILE-1-OB (24.78 g). Grain yield was significantly influenced by treatment and maize variety ($P<0.01$) (Table 2 and 3). Highest grain yield was obtained in plots sown with 1% $ZnSO_4$ (4.73 t ha^{-1}) and water primed seeds (4.58 t ha^{-1}). The increase in grain yield of maize primed in water had earlier been reported by Rashid et al. (2002), El-Sanatawy *et al.* (2021) and Farajollahi and Eisvand (2016).

Table 1: Pre-planting physico - chemical properties of the experimental soil

Property	Value
pH (H_20)	7.21 (Neutral)
Organic carbon (%)	0.40 (very low)
Total nitrogen (%)	0.06 (very low)
Available P (mg/kg)	5.92 (low)
ECEC(cmol)	4.11
Base saturation (%)	99.03
Exchangeable cation (cmol kg^{-1})	
K	0.25 (low)
Mg	0.87
Na	0.66
Ca	2.29
Al+H	0.04
Exchangeable micro-nutrient (mg/kg)	
Fe	9.65
Zn	3.14 Medium
Cu	0.23
Mn	49.95 Moderate
Soil particle analysis	
Sand g/kg	77.2
Silt g/kg	13.4
Clay g/kg	9.4
Textural class	loamy -Sandy

There was no significant difference between grain yield obtained from maize plots with foliar applied $ZnSO_4$ solution (3.23 t ha^{-1}) and plots sown with 2% ZnSO4 primed seeds (3.35 t ha^{-1}). The GY's obtained in soil placed $ZnSO_4$ (2.35 t ha^{-1}) and the control (2.20 t ha^{-1}) were not significantly different. Higher GY was obtained in maize variety BR9928DMR-SR-Y (4.04 t ha^{-1}) than ILE-1-OB (2.77 t ha^{-1}). Delivering Zn to seed through priming have been reported to proffer the benefits of initial nutrient availability for plant uptake, less costly, increased grain yield and averting uneven distribution associated with soil zinc application (El-Sanatawy *et al.*, 2021). Yilmal et al. (1998) and Adornis *et al.* (2020) reported that planting seeds with elevated micro nutrient content has the potential to improve seedling vigour and also increase crop yield. Priming maize seeds with $ZnSO_4$ impacted significantly on growth and yield of maize in this study, this finding aligns strongly with earlier studies that emphasized the importance of seed nutrients priming at improving seed nutrient content reserves, thereby improving better crop establishment and seedling growth (Imran *et al*., 2013; Muhammad *et al*., 2015; Nciizah *et al.*, 2020). From this study, the maize plants appeared not to have benefited with regard to growth and yield improvement from additional increase in the $ZnSO_4$ priming concentration solution above 1% concentration. Germination percentage (CGPT) and seedling dry weight (SDW) were not statistically influenced by the treatments and the varieties in this study (Table 2 and 3) ($P<0.05$). Germination index (GI) was significantly influenced by $ZnSO_4$ treatments and the variety ($P<0.05$). Highest germination index was observed in seeds harvested from plots sown with 1% $ZnSO_4$ primed seeds (4.42) (Table 3). No significant difference was observed in GI obtained in other treatments, while seeds harvested from plots sown with 2% ZnSO4 primed seeds gave the lowest GI of 4.16. Maize variety BB9928DMR-SR-Y (4.42) had better GI than ILE-1-OB (4.18). Seedling length (SDL) was significantly influenced by $ZnSO_4$ application ($P<0.05$) and variety ($P<0.01$) (Table 2 and 3). Highest seedling length of 19.20 cm was observed in seeds harvested from plots sown with 1% ZnSO4 primed seeds. Higher SDL was observed in ILE-1-OB (18.13 cm) compared with BB9928DMR-SR-Y (16.44 cm). Root length in this study was not significantly influenced by the treatments, although variety ILE-1-OB (13.43 cm) had longer RL than BR9928DMR-SR-Y (11.63 cm) (Table 2 and 3). The seedling vigour index (SVI) was significantly influenced by treatment and variety effects ($P<0.05$) (Table 2 and 3). Significantly higher SVIs were observed in seedlings grown from seeds harvested from soil paced $ZnSO_4$ (30.9) and 1% $ZnSO_4$ (33.49) treatment plots, while seeds harvested from the control and water primed treatment plots gave the least SVI of 26.77 and 25.93, respectively (Table 2 and 3). Maize variety ILE1OB (30.70) showed higher SVI than BB9928DMR-SR-Y (26.73). Treatments had no significant effect on seed water imbibition (WIM) in this study ($P<0.05$), however variety BB9928DMR-SR-Y (11.52) showed better water imbibition than ILE-1-OB (10.19) (Table 3).

Table 2: Mean Squares of ANOVA of growth, yield and seed quality traits of maize grown under different zinc sulphate application methods

Source of variation	D.F	PHT (cm)	EHT (cm)	CBT (cm)	K/R	100-GWT (g)	GY (t ha^{-1})	GCPT	GI (days)	SDL (cm)	RL (cm)	SDW (g)	SVI	WIM	COND
Treatment (T)	5	688.08	718.03*	6.94	92.99*	34.55*	6.88**	38.77	0.05*	8.54*	14.10	0.0021	50.29*	1.76	12.05**
Error (a)	10	232.45	132.84	3.61	23.42	9.26	1.072	48.86	0.013	4.032	5.98	0.0016	15.53	1.22	1.58
Variety (V)	1	2023.50*	67.78	79.29**	149.16*	35.20*	14.45**	28.44	0.54*	25.50**	29.34*	0.0013	142.08*	15.73**	25.6*
T x V	5	71.30	21.99	2.11	4.26	9.15	0.40	45.64	0.05	2.49	12.87*	0.003	22.82	1.27	1.99
Error (b)	12	260.59	198.99	5.09	27.21	4.29	0.415	58.52	0.061	2.016	3.10	0.0018	9.85	0.55	2.20
Total	33														

** ** Significant at 5 and 1% probability levels. D.F= Degree of freedom. PHT=Plant height, EHT=Ear height, CBT=Cob Length, K/R=Kernel per row, 100-GWT=100-Grain weight, GY=Grain Yield, GCPT=Germination Percentage, GI= Germination Index, SDL= Seedling Length, RL=Root Length, SDW=Seedling Dry weight, SVI=Seedling Vigour Index, WIM= Water Imbibed, Cond= Conductivity.*

Table 3: Effects of different methods of Zinc Sulphate applications on the growth, yield and seed qualities of two maize varieties grown in Ibadan.

	PHT (cm)	EHT (cm)	CBT (cm)	K/R	100-GWT (g)	GY (t ha^{-1})	GCPT	GI (days)	SDL (cm)	RL (cm)	SDW (g)	SVI	WIM	COND
(Farmer's practice)	160.29a	70.42ab	13.54a	26.52ab	23.20b	2.20b	94.5a	4.31ab	15.57b	11.15a	0.200a	26.77b	11.30a	7.25c
Water prime	165.92a	77.52ab	16.16a	35.24a	27.57a	4.58a	93.95a	4.36ab	17.20ab	12.06a	0.188a	25.93b	11.18a	7.45bc
Foliar $ZnSO_4$	156.52a	61.52b	15.83a	32.78ab	24.72b	3.23ab	93.50a	4.32ab	17.27ab	12.69a	0.200a	28.04ab	10.57a	9.79ab
Soil placed $ZnSO_4$	160.03a	69.47ab	13.90a	29.55ab	23.03b	2.35b	99.16a	4.22ab	17.73ab	13.45a	0.200a	30.9a	9.99a	9.58abc
1% $ZnSO_4$ prime	182.55a	91.35a	15.04a	32.70ab	28.18a	4.73a	98.00a	4.42a	19.20a	14.97a	0.185a	33.49a	10.67a	8.13bc
2% $ZnSO_4$ prime	151.83a	63.33b	15.67a	25.17b	27.90a	3.35ab	98.50a	4.16b	16.75ab	10.85a	0.165a	27.17ab	11.30a	10.74a
Variety (V)														
V1	170.36a	70.89a	16.51a	32.36a	26.76a	4.04a	95.38a	4.42a	16.44b	11.63b	0.15a	26.73b	11.52a	9.66a
V2	155.36b	73.64a	13.54b	28.29b	24.78b	2.77b	97.22a	4.18b	18.13a	13.43a	0.19a	30.70a	10.19b	7.99b
Means	162.86	72.27	15.02	29.74	25.77	3.41	96.28	4.30	17.29	12.53	0.19	28.72	10.86	8.82
SE ±	3.02	2.44	0.42	1.11	0.58	0.23	1.17	0.04	0.35	0.47	0.01	0.80	0.20	0.33

* ** Significant at 5 and 1% probability levels. Means followed by the same alphabets are not significantly different according to Fisher's LSD. V1= BB9928DMR-SR-Y and V2= ILE-1-OB. PHT=Plant height, EHT=Ear height, CBT=Cob Length, K/R=Kernel per row, 100-GWT=100-Grain weight, GY=Grain Yield. GCPT=Germination Percentage, GI= Germination Index, SDL= Seedling Length, RL=Root Length, SDW=Seedling Dry weight, SVI=Seedling Vigour Index, WIM= Water Imbibed, Cond= Conductivity.

The seed conductivity (COND) was significantly influenced by treatment ($P<0.01$) and varietal ($P<0.05$) effects (Table 2 and 3). Seeds harvested from plots sown with 2% $ZnSO_4$ (10.74) showed the highest conductivity followed by seeds from foliar applied (9.79) plots, while seeds harvested from the control plots had the least seed conductivity of 7.25 (Table 3). Seed conductivity was significantly higher in maize variety BB9928DMR-SR-Y (9.66) than ILE-1-OB (7.99). Seed priming activates plant enzymes and enhances the antioxidising system and the enlargement of seed embryo (Sliwinska *et al*., 2009; Hussain, 2015). The seed germination and seedling growth processes are facilitated by the activation of α and β amylases and the compound obtained from the conversion of stored reserves (protein, carbohydrates, fats and lipid) (Monajjem *et al*., 2023). Priming enhances the respiratory activities in seed while the adenosine triphosphate (ATP) produced promotes metabolic activity and hasten seed germination process (Varier *et al*., 2010). Highest percentage and germination speed (GI), seedling length and seedling vigour indices observed in seeds harvested from plots sown with 1% $ZnSO_4$ indicates superior seed quality due to nutrient zinc nutrient priming effects on the resulting seeds. Increasing zinc nutrient priming to 2% might have possibly resulted in cell toxicity which probably led to impaired seeds of low quality which is a common problem associated with nutrient-seed priming (Harris *et al*., 2007). Damalas *et al.* (2019), described seed germination and seedling vigour as decisive factors for the establishment of field crops. Highest conductivity observed in seeds obtained from plots sown with 2% $ZnSO_4$ primed seeds could be linked to low germination as due to non-viable seeds.

Mattew and Powell (2006) described conductivity test as a measure of electrolytes leaking from seeds which indicates seed non-viability. The leakage in electrolytes has been attributed to deterioration of membrane due to impairment (McDonald, 1999). Mattew and Powell (2006) described high levels of leakage as a characteristic of low vigour seed lots. It is worth noting that maize varieties differed significantly in the responses to some of the seed quality attributes evaluated in this study.

Conclusion: Priming of maize seeds in each of distilled water and 1% ZnSO4 solution enhanced the growth, grain yield and the seed quality attributes of maize than other application techniques and priming in 2% zinc solution in this study. The yellow maize variety BB9928DMR-SR-Y had higher grain yield than ILE-1-OB (white maize variety). However, maize variety ILE-1-OB seeds obtained from various zinc treatment plots maize had superior seed quality attributes than seeds of BB9928DMR-SR-Y. Priming in each of distilled water and 1% ZnSO4 solution is cost effective, environmentally friendly and highly sustainable method of enhancing grain yield and seed quality of maize.

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