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BIOFORTIFICATION OF MAIZE WITH ZINC IN THE SEMI-DECIDUOUS ZONE IN GHANA

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Abstract

This study sought to determine the effect of Zinc fertilizer (its method, stage and rate of application) on growth, yield and nutrient content of the maize crop. There were eight treatments with 3 replications; T1(control), T2 (NPK only), T3(NPK + Zn_{fv}) NPK + Foliar Zn @ vegetative stage (full dose), T4(NPK + Zn_{fr}) NPK + Foliar Zn @ reproductive stage (full dose), T5(NPK + Zn_{fs}) NPK + Foliar Zn @ both vegetative stage and reproductive (split), T6(NPK + Zn_{sv}) NPK + Soil Zn @ vegetative stage (full dose), T7 (NPK + Zn_{sr}) NPK + Soil Zn @ reproductive stage (full dose) T8 (NPK + Znss) NPK + Soil Zn @ both vegetative stage and reproductive (split). The GENSTAT statistical software (12th Edition) was used to analyze all the data, and treatment differences were compared using turkeys at a probability level of 5%. During the minor season, Zinc fertilizer application significantly affected both growth and yield parameters of maize except for, mean seed weight and harvest index. Application of zinc fertilizer through foliar method improved the grain Zn content with T3 (NPK + Zn_{fv}) NPK + Foliar Zn @ vegetative stage (full dose) and T4(NPK + Zn_{fr}) NPK + Foliar Zn @ reproductive stage (full dose) recording the highest values. Zinc fertilizer application also influenced the nitrogen and phosphorus content of the grain, but potassium content was not significantly affected. However, during the major season Application of zinc fertilizer on the grain Zn content was not statistically different. Zinc fertilizer application however influence the N and K content of the grain. The results suggest that application of zinc fertilizer through foliar method T3 (NPK + Zn_{fv}) NPK + Foliar Zn at vegetative stage (full dose) and T4(NPK + Zn_{fr}) NPK + Foliar Zn at reproductive stage (full dose) are options that can be used in terms of biofortifying maize grains with Zn.

Keywords
foliar Zn, grain content, vegetative and reproductive stage

Introduction

Cereals continue to be the main fundamental means of energy for greater than 962 million human population in the Africa region and are very important for food safety mitigation (OECD-FAO Agricultural Outlook, 2016)). Maize holds an important position among the cereal crops and used as food for human beings as well as animals feed. It is also used as a raw material in industrial manufacturing of starch related items, lubricant, protein, alcoholic drinks, biofuel, food candies, pharmaceuticals, make-ups, films, fabrics, gums, packaging, and paper industries (Naveenkumar et al., 2018). Its production accounts for 50-60 percent of aggregate cereal crops produced in Ghana. In sub-Saharan Africa, the usual low yield obtained mostly hovers around 1.7 tonnes per hectare in West Africa, 1.5 tonnes per hectare in East Africa, and 1.1 tonnes per hectare in the Southern part of Africa (Smale et al., 2011). In Ghana, where is a major staple, the national average maize productivity on farmers field is about 1.99 tonnes per hectare whereas the projected achievable grain yield is around 5.50 t/ha (Ministry of Food and Agriculture, 2016).

The Ghana Grains Development Project (1979–1997) and the Food Crops Development Project (2000–2008) both made significant investments in maize yield. Despite these initiatives, Ghana's average maize production is still among the lowest in the world and far lower than the average for Africa south of the Sahara.

The most prevalent micronutrient deficiency in agricultural soils worldwide is zinc (Zn) deficiency, which causes decrease in yields and lower nutritional quality in agricultural plants. Zn is important for plant growth because plants need a proper balance of all important nutrients for normal growth and maximum yield. Humans can get a lot of Zn through plant-based meals (Welch and Graham, 2004).

One of the eight essential trace elements for proper, healthy plant development and reproduction is zinc. Zinc is needed as a structural element in a large number of proteins, including transcription factors and metalloenzymes (Figueiredo et al., 2012).

According to Grujcic et al. (2021), one of the key strategies in the sustainable production of nutrient-rich and nutrient-dense food and feed is the agronomic bio fortification of field crops with micronutrients. Micronutrient insufficiency is linked to human health problems worldwide, particularly in developing nations, but it also has a severe impact on the productivity of agricultural animals raised in these areas. The considerable prevalence of micronutrient deficits in humans is caused by a deficiency in phytoavailable micronutrients in widely grown food and feed crops and agricultural soils.

Worldwide, deficiencies of critical macro and micronutrients in diets pose severe health issues (Hindu et al., 2018), although the effects are most pronounced in impoverished nations (Wessells and Brown, 2012). Because the majority of people mainly rely on cereals like maize, diets in developing

regions like sub-Saharan Africa (SSA) are characterized by insufficient levels of numerous nutrient (Jin et al., 2013). For instance, maize is relatively high in carbohydrates, but very low in other nutrients including vitamin A and the important amino acids lysine and tryptophan (Nuss and Tanumihardjo, 2011). Important minerals like Fe and Zn are in little amounts in the maize endosperm (Cakmak and Kutman, 2018).

Deficiencies in nutrients can lead to diseases like kwashiorkor and pellagra, which are caused by a lack of proteins and tryptophan, respectively Nuss and Tanumihardjo (2011); night blindness caused by lack of vitamin A (Halilu et al., 2016) and acute respiratory infections caused on by lack of zinc (Shahzad et al., 2014), are common in SSA due to the over-reliance on maize.

Many developed countries also have these types of malnutrition, however, since developed countries allow people to diversify their diets with extremely nutritious foods, the frequency is lower (Hefferon, 2015).

Vitamin-rich fruits and vegetables (Brookie et al., 2018), as well as carbohydrates from grains (Jin et al., 2013), can help to prevent malnutrition, however, the majority of households in developing nations cannot afford nutritious food. As a result, effective intervention measures are essential in developing countries to save lives. Crop biofortification is one of these strategies, which is considered as the most appropriate, cost-effective, and long-term solution for reducing nutritional deficiencies globally (Cakmak and Kutman, 2018).

In general, the word "biofortification" refers to the biological enrichment of food crops with macro or micronutrients using agronomic methods, traditional plant breeding, or genetic engineering (Bouis and Saltzman, 2017). Many biofortified maize cultivars have been produced in Sub Saharan Africa using conventional and molecular breeding approaches (Ekpa et al., 2018). Although, biofortification was planned primarily for certain limiting elements, such as Zn, vitamin A, lysine, or tryptophan (Prasad et al., 2014). However, because of the complexity of SSA's macro- and micronutrient deficiency and the inability of a single nutrient to treat them, these cultivars are unable to effectively address the problems on the ground; Growing a provitamin A cultivar does not help farmers address deficiency in zinc, lysine, or tryptophan because small-scale farmers, who produce the majority of the region's maize, rarely diversify their crop rotations (Goredema-Matongera et al., 2021).

Elsewhere, attempts are being made to develop wheat genotypes using traditional plant breeding or genetic engineering techniques that produce grains that are denser in Fe and Zn. This tactic requires enough time and resources. However, many nations do not favorably consider genetic engineering products. Additionally, there is a trade-off between grain biofortification and yield. This can be accomplished by agronomic biofortification with no yield penalties and no issues with product acceptance (Prasad et al., 2014). This study sought to determine the effect of Zinc fertilizer (its methods of application, stage of application and rate of application) on growth, yield and nutrient content on the maize crop.

Materials and Methods

The experiment was conducted at the Plantation crops and experimentation section, Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana (latitude 06° 43' N and longitude 01° 33' W), during the minor season in 2021 and the major season in 2022.

The site was cleared, ploughed, harrowed and layout of the field was done, with individual plot sizes of 5m x 5m. The initial chemical and physical characteristics of the soil is presented in Table 1.

Table 1. Initial chemical and physical characteristics of soil

Property	Values
pH	5.8
Total Nitrogen (%)	0.11
Available Phosphorus	31.32
%Organic carbon	1.05
Extractable Zn	3.02
Exchangeable bases (cmol/kg)	
Potassium	1.32
calcium	3.40
magnesium	1.00
sodium	0.15
Exchangeable acidity (cmol/kg)	
Aluminium	0.58
Hydrogen	0.29
Soil particles	
%Sand	80.96
%Clay	11.68
%Silt	7.36
Textural class	Sandy loam

Quality protein maize (Obatanpa) was used as a test crop. Zinc sulphate monohydrate ($ZnSO_4H_2O$) was applied at a rate of 10kg Zn/ha and 5kg Zn/ha as soil application method. Foliar Zn application was at a rate of 1kg Zn/ha and 0.5kg Zn/ha. NPK was applied at a rate of 90:60:60 kg/ha. 60:60:60 kg/ha of the total rate was applied 2 weeks after sowing (WAS)and 30kg N (ammonia sulphate) was applied 6 WAS.

Details of the eight treatments are shown in Table 2. Soil Zn application was done at 2 WAS at (vegetative stage) and tasselling (reproductive stage) whiles foliar application was done at 3 WAS and at tasselling (reproductive stage). Foliar application was done late evenings using a knapsack spraying machine.

Data collection started 6WAS. Plant height was taken from the base of the crop to the tip of the flag leaf. Leaves per plant were determined by visual counting of tagged plants in each

Table 2. Treatment details and abbreviations

Abbreviation	Treatment
T1(Absolute control)	No fertilizer application
T2(NPK only)	90:60:60 kg/ha
T3(NPK + Zn_{fv})	NPK + Foliar Zn @ vegetative stage (full dose)
T4(NPK + Zn_{fr})	NPK + Foliar Zn @ reproductive stage (full dose)
T5(NPK + Zn_{fs})	NPK + Foliar Zn @ both reproductive stage and vegetative (split)
T6(NPK + Zn_{sv})	NPK + Soil Zn @ vegetative stage (full dose)
T7 (NPK + Zn_{sr})	NPK + Soil Zn @ reproductive stage (full dose)
T8 (NPK + Zn_{ss})	NPK + Soil Zn @ both reproductive stage and vegetative (split)

Soil Zn application; 10kg Zn/ha (full dose) and 5kg Zn/ha (split). Foliar Zn application;1kgZn/ha (full dose) and 0.5kgZn/ha(split)

Table 3. Weather observation during the experimental period

Year	Month	Maximum temp (°C)	Minimum temp (°C)	Mean temp (°C)	Total rainfall (mm)	Relative humidity (%)
2021	August	30.1	22.1	26.1	88.3	78
	September	30.1	22.0	26.1	304.1	79
	October	32.0	22.0	27.0	234.9	73
	November	32.9	22.8	27.9	30.9	71
2022	April	33.3	23.4	28.4	135.9	73
	May	33.2	23.4	28.3	143.1	75
	June	30.9	23.1	27.0	175.1	77
	July	29.6	21.8	25.7	101.7	89

Source of Data: Meteo Station, KNUST

plot. Stem girth was taken 15cm above the ground with the use of a Vernier calliper.

Shoots were cut at soil level, and the aboveground biomass was determined after drying at 800°C for 48 hours. Harvest index was calculated as ratio of grain weight to weight of total biomass and expressed in percentage. Cobs per plant were obtained by counting the number of cobs of 10 tagged plants and the mean value was computed. One hundred (100) seeds were sampled and weighed using an electronic scale to get the 100 seed weight.

Plants from one-meter squared area within each plot were harvested, its grains were then dried to an average moisture content of 14% and Grain yield calculated.

Grain nutrient was determined dry ash digestion (Jones Jr and Case, 1990; Munter et al., 1984). All other agronomic activity was done as and when necessary.

Results and Discussion

Initial chemical and physical characteristics of soil

Chemical and physical properties of the initial soil of the study area are shown in Table 1. The soil was moderately acidic with low organic carbon of 1.057%. Total nitrogen was low with an average value 0.105%. ECEC was low and available phosphorus was high with values of 6.759 cmol/kg soil and 31.32 mg/kg respectively. The amount of extractable zinc was 3.029 mg/kg.

Effect of treatments on plant height, number of leaves and stem girth

Zinc fertilizer application had no significant effect on plant height during both the major and minor season as shown in Table 4.

During the major season, the treatment had no significant ($p > 0.05$) effect on number of leaves. However, during the minor season T3 recorded the highest value for number of leaves and it was significantly different ($p < 0.05$) from the other treatment means except for T2. T1 had the lowest value for number of leaves. T4 and T5 were also significantly similar ($p > 0.05$). Similar results have been reported by Kothaipriya et al. (2021).

During the major season, T 4, NPK + Foliar Zn at reproductive stage (full dose) had the highest value for stem girth which was significantly higher than the other treatments. However, with the minor season T5, NPK + Foliar Zn at both vegetative stage and reproductive stage (split) had the highest value for stem girth which was significantly similar to T4 but significantly higher than the other treatment means. This result is in agreement with Drissi et al. (2015), who reported that zinc fertilizer application to maize crop increased stem girth significantly at 9-10 leaf stage.

Effect of treatments on Dry matter and Harvest index

Effect of treatments on dry matter and harvest index is presented in Table 5, during the minor season, dry matter content for T5 was significantly higher than the other treatments. T2 (NPK) was significantly similar to the other treatments. Dur-

Table 4. Effect of treatments on plant height, number of leaves and stem girth

Treatments	Minor season			Major season		
	Plant height (cm)	Number of leaves	Stem girth	Plant height (cm)	Number of leaves	Stem girth
T1(control)	142.57b	13.40b	1.98b	138.70a	11.97a	1.57c
T2(NPK)	197.70a	14.70a	2.297ab	150.20a	11.83a	1.63bc
T3(NPK + Zn_{fv})	220.10a	14.83a	2.30ab	144.13a	12.57a	1.60bc
T4(NPK + Zn_{fr})	205.20a	14.17bcd	2.403a	159.77a	12.33a	1.77a
T5(NPK + Zn_{fs})	207.70a	14.33bcd	2.423a	140.33a	12.10a	1.57c
T6(NPK + Zn_{sv})	205.80a	14.53cd	2.323ab	150.93a	11.67a	1.70ab
T7(NPK + Zn_{sr})	194.60a	13.70ab	2.267ab	140.17a	12.07a	1.63bc
T8 (NPK + Zn_{ss})	204.80a	13.93abc	2.343ab	141.80a	12.10a	1.57c
CV (%)	5.75	4.94	5.50	11.95	4.80	4.31

Means followed by the same letter along the columns are not significantly different using Tukeys HSD ($p > 0.05$).

Table 5. Effect of treatments on Dry matter and harvest index

Treatments	Minor season		Major season	
	Dry matter (t/ha)	Harvest index (%)	Dry matter (t/ha)	Harvest index (%)
T1(control)	3.26b	29.00a	4.52ab	36.0a
T2(NPK)	4.70ab	28.37a	4.76ab	44.67a
T3(NPK + Zn_{fv})	5.70ab	36.00a	4.94ab	43.67a
T4(NPK + Zn_{fr})	5.34ab	34.40a	3.50ab	39.67a
T5(NPK + Zn_{fs})	6.48a	40.37a	5.16ab	41.67a
T6(NPK + Zn_{sv})	6.28ab	45.10a	5.75a	37.00a
T7(NPK + Zn_{sr})	5.38ab	35.33a	4.23ab	35.00a
T8 (NPK + Zn_{ss})	5.36ab	42.80a	3.09b	46.00a
CV (%)	20.70	24.24	28.94	16.17

Means followed by the same letter along the columns are not significantly different using Tukeys HSD ($p > 0.05$)

ing the major season, dry matter content for T6 was significantly higher than the other treatments and T2 (NPK) was significantly similar to the other treatments, according to (Asha et al., 2012; Krishnaraj et al., 2020) rise in the aforementioned growth parameters is as a result of zinc application and can be attributed to better plant development and an increase in photosynthetic and other metabolic processes. For harvest index, no significant effect was recorded during the major and the minor season.

Effect of treatment on number of grains per cob, hundred seed weight and grain yield

Table 6 shows the effect of treatment on number of grains per cob, hundred seed weight and grain yield for both seasons. During the minor season, there was a significant difference ($p < 0.05$) between T6 which recorded the highest number of grains per cob and the other treatments. T5 and T8 were significantly similar ($p > 0.05$) as well as T3, T4 and T7. However, T2 (NPK) was significantly lower than the other treatments that received zinc fertilizer, but significantly higher than T1 (control). Hundred seed weight was not affected by the treatment significantly ($p > 0.05$). For grain yield, T6 was significantly higher than the other treatments, while T3, T5 and T8 are significantly similar as well as T4 and T7 but are significantly higher than T2 (NPK). During the major season, there was a significant difference ($p < 0.05$) between T4 which recorded the highest value for number of grains per cob, hundred seed weight and grain yield and the other treatments. T1 recorded the lowest value for number of grains per cob, hundred seed weight and yield. With number of grains per cob there was no significant difference between T2 (NPK) and the other treatments that received zinc fertilizer. Similar findings for the number of grains per cob were reported by (Shahab et al., 2016), who reported that Zn fertilization significantly affected the number of grains per cob than the control. Similar findings on increase in number of grains per cob due to Zn application has been reported by (Ehsanullah et al., 2015; Shaaban, 2001).

Grain yield was enhanced by the application of Zn fertilizer in both the minor season and major season.

Effect of treatment on grain nitrogen and crude protein content

During the minor season, zinc fertilizer application significantly ($p < 0.05$) affected grain nitrogen and crude protein content as presented in Table 7. Foliar zinc fertilizer application at 1kg Zn/ha at reproductive stage (T4) recorded the highest value for nitrogen and crude protein followed by foliar Zn fertilizer application at 1kg Zn/ha at vegetative (T3) which was significantly similar to soil Zn fertilizer application at 10kg/ha at vegetative stage (T6) also T2 (NPK only) was significantly higher than foliar zinc fertilizer application at

Table 6. Effect of treatments on number of grains per cob, hundred seed weight and grain yield

Treatments	Minor season			Major season		
	Number of grains per cob	Hundred seed weight (g)	Grain yield (t/ha)	Number of grains per cob	Hundred seed weight (g)	Grain yield (t/ha)
T1(control)	139.00d	20.40a	1.68e	234.50b	27.60e	1.92c
T2(NPK)	196.70c	20.73a	2.47d	329.66ab	32.87bcd	3.22ab
T3(NPK + Zn_{fv})	252.00b	21.40a	3.26b	324.41ab	32.03cde	3.13abc
T4(NPK + Zn_{fr})	233.70b	21.73a	3.08c	373.81a	39.07a	4.29a
T5(NPK + Zn_{fs})	273.30b	21.33a	3.48b	310.52ab	31.63de	2.92bc
T6(NPK + Zn_{sv})	334.70a	21.63a	4.32a	340.74ab	36.90abc	3.83ab
T7(NPK + Zn_{sr})	248.00b	20.00a	2.96c	322.05ab	31.27de	3.00bc
T8 (NPK +Zn_{ss})	308.30b	20.93a	3.87b	316.85ab	37.77ab	3.58ab
CV (%)	16.3	9.00	16.30	20.23	8.81	22.68

Means followed by the same letter along the columns are not significantly different using Tukeys HSD ($p > 0.05$).

Table 7. Effect of treatment on grain nitrogen and crude protein content

Treatments	Minor season		Major season	
	Nitrogen (%)	Crude protein (%)	Total N (%)	crude protein (%)
T1(control)	1.42c	8.88c	1.93b	12.08b
T2(NPK)	1.93b	12.08bc	2.00ab	12.51ab
T3(NPK + Zn_{fv})	2.31b	14.45ab	2.20ab	13.77ab
T4(NPK + Zn_{fr})	2.62a	16.35a	2.42a	15.11a
T5(NPK + Zn_{fs})	1.80b	11.27bc	2.08ab	12.99ab
T6(NPK + Zn_{sv})	2.16a	13.51b	2.21ab	13.84ab
T7(NPK + Zn_{sr})	1.75b	10.97bc	1.86b	11.65b
T8 (NPK + Zn_{ss})	1.83b	11.44bc	1.88b	11.79b
CV (%)	12.40	12.40	13.21	13.20

PA- yam in alleys of pigeon pea PB- yam with pigeon pea as border SY-No pigeon pea/sole yam, Meloi - Meloidogyne spp., Scut - Scutellonema spp., Praty - Pratylenchus spp.

0.05kg Zn/ha both at vegetative and reproductive stage (T5), soil zinc fertilizer application at 10kg Zn/ha at reproductive stage (T7) and soil zinc fertilizer application at 5kgZn/ha both at vegetative and reproductive stage (T8). During the major season also, Zinc fertilizer application significantly ($p < 0.05$) affected grain nitrogen and crude protein content. Foliar zinc fertilizer application at 1kg Zn/ha at reproductive stage (T4) recorded the highest value for nitrogen and crude protein followed by foliar Zn fertilizer application at 1kgZn/ha at vegetative (T3) which was significantly similar to T5, T6 and T2. Soil zinc fertilizer application at 10kg Zn/ha at reproductive stage (T7) recorded the lowest value for grain protein content and was significantly similar to T1 and T8. There are reports of positive correlations between seed protein and Zn contents. According to Bhatt et al. (2020) Zn, Fe, and protein accumulation in grains show a favorable correlation and a close link with significant loci on the same chromosome and plant physiological systems.

Effect of treatment on Grain content of potassium, phosphorus and zinc

During the minor season, the treatment did not have any significant effect ($p > 0.05$) on grain potassium content, there was no significant differences between the absolute control (T1), T2 (NPK) and zinc fertilizers treatments (Table 8). However, Phosphorus content in the grains was influenced by the treatments. Phosphorus content in T5 and T6 was significantly similar ($P > 0.05$) but were significantly higher ($p < 0.05$) than the other treatments, with T1 having the lowest grain phosphorus content (Table 8). Also, treatments had a significant effect on grain zinc content. Grain zinc content for T3 and T4 were significantly similar ($p > 0.05$) but, were significantly higher than T1. From the results it can be said that foliar zinc application influenced grain zinc content as compared to soil zinc application. In a related study, Bhatt et al. (2020) found that enriching wheat grain with zinc through foliar treatment was more successful than doing so through soil application. Foliar Zn fertilizer application is a superior method to provide Zn to crops (Liu et al., 2016). Despite the fact that basal Zn fertilizer has been shown to have a significant residual effect (Liu et al., 2004), Zn can be fixed in some soils and is not utilised by the crop (Rengel, 2015). From these results, it can be reported that soil zinc application on the plants ability to translocate zinc to the grains was relatively low as compare to foliar zinc application. In the major season, the treatment did not have any significant effect ($p > 0.05$) on grain phosphorus and zinc content, there was no significant differences between the absolute control (T1), T2 (NPK) and zinc fer-

Table 8. Effect of treatments on potassium, phosphorus and zinc grain content

Treatments	Minor season			Major season		
	Potassium (mg/kg)	Phosphorus (mg/kg)	Zinc (mg/kg)	Phosphorus (mg/kg)	Potassium (mg/kg)	Zinc (mg/kg)
T1(control)	0.74a	0.12b	44.76b	0.17a	0.89a	54.94a
T2(NPK)	0.70a	0.18ab	59.78ab	0.75a	0.78ab	60.10a
T3(NPK + Zn_{fv})	0.77a	0.15ab	62.68a	0.69a	0.80ab	62.14a
T4(NPK + Zn_{fr})	0.74a	0.18ab	61.72a	0.68a	0.73b	59.29a
T5(NPK + Zn_{fs})	0.82a	0.25a	53.27ab	0.26a	0.82ab	55.32a
T6(NPK + Zn_{sv})	0.82a	0.24a	53.97ab	0.26a	0.86ab	55.88a
T7(NPK + Zn_{sr})	0.79a	60.18ab	53.43ab	0.21a	0.78ab	53.51a
T8 (NPK + Zn_{ss})	0.73a	0.18ab	49.83ab	0.22a	0.82ab	54.31a
CV (%)	12.40	19.50	9.90	118.03	10.94	10.54

Means followed by the same letter along the columns are not significantly different using Tukeys HSD ($p > 0.05$).

tilizer treatments. However, Potassium content in the grains was influence by the treatments. Potassium content in T1was significantly higher ($p < 0.05$) than the other treatments with T4 having the lowest grain Potassium content. Similar results were reported by Liu et al. (2016), who stated that foliar Zn fertilizer application is a superior method to provide Zn to crops Liu et al. (2016), because, despite the fact that basal Zn fertilizer has been shown to have a significant residual effect (Liu et al., 2004), Zn can be fixed in some soils and is not utilised by the crop (Rengel, 2015). It's probably that the roots' incapacity to absorb Zn from high Zn concentrations is the cause of maize's failure to uptake Zn. This disparity in Zn accumulation was thought to occur in all treatments due to the maize root's sensitivity to Zn and the low mobility of inorganic zinc fertilizers in the soil. Root surface area and the amount of zinc in the soil affect plants' ability to absorb zinc (Lindsay and Norvell, 1978). On the contrary, (Yang, Xi-Wen and Tian, Xiao-Hong and Lu, Xin-Chun and Cao, Yu-Xian and Chen, Zi-Hui, 2011) discovered that foliar spraying alone did not enhance Zn concentration in wheat grain by as much as foliar application plus soil application did. They also established that foliar zinc application during the grain filling stage produced the best results. (Shivay et al., 2010) reported that, compared to a soil application of 5.3 kg Zn ha^{-1}, foliar treatment of only 1.2 kg Zn ha^{-1} boosted zinc concentration in grain while maintaining grain production. However, all these finding have not stated whether their plots have had a zinc trial before as in the case of this study since Zn can be fixed in some soils and is not utilised by the crop (Rengel, 2015). It's probable that the roots' incapacity to absorb Zn from high Zn concentrations is the cause of maize's failure to uptake Zn.

Conclusion

During the minor season, Zinc fertilizer application significantly affected both growth and yield parameters of maize except for, mean seed weight and harvest index. Application of zinc fertilizer through foliar method improved the grain Zn content with T3 (NPK + Zn_{fv}) NPK + Foliar Zn @ vegetative stage (full dose) and T4(NPK + Zn_{fr}) NPK + Foliar Zn @ reproductive stage (full dose) recording the highest values. Zinc fertilizer application also influenced the nitrogen and phosphorus content of the grain, but potassium content was not significantly affected. However, during the major season Application of zinc fertilizer on the grain Zn content was not statistically different. Zinc fertilizer application however influence the N and K content of the grain.

On whole the results suggest that application of zinc fertilizer through foliar method T3 (NPK + Zn_{fv}) NPK + Foliar Zn at vegetative stage (full dose) and T4(NPK + Zn_{fr}) NPK + Foliar Zn at reproductive stage (full dose) are options that can be used in terms of biofortifying maize grains with Zn.

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