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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

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ABSTRACT

A field experiment was conducted in 2016 to assess the effects of zinc fertilization methods on Zn uptake, grain and other yield components of maize hybrids. The treatments consisted of three methods: soil, foliar, soil-foliar applied at 20 kg Zn ha^{-1} with a control and, five maize hybrids: TZSR-Y, Oba supper II-Y, Pioneer Seed-W, Oba Super I-W and Bende white, arranged in a factorial randomized complete block design (RCBD) with four replications. The soil of the study site showed deficiency in base cations especially the available zinc. The results showed substantial differences in Zn uptake, grains yields and other yielding components as influenced by method of Zn fertilization and maize hybrids. The results indicated that amongst the hybrid maize, pioneer seed-W produced 16.87 %, 11.65 % and 38.86 % higher grain yields than Oba super 1-W, Oba super 2-Y and Bende-W, respectively and followed by TZSR-Y which produced, 14.46 %, 9.09 % and 37.19 % higher grain yields than Oba super 1-W, Oba super 2-Y and Bende-W, respectively. Moreover, the combined soil-foliar application of ZnSO4 gave 23.79 % and 29.26 % more grain yields than the single foliar and soil applied, respectively. Positive correlations were obtained between grain yield and number of grains per cob (R = 0.858), grain weight per cob (R = 0.828**) and Zn-grain uptake (R = 0.819**). Zinc-grain uptake had significant higher correlation with grain weight per cob (R = 0.922**) and Zn-grain concentration (R = 0.871**). The study concludes that, the combined foliar and soil ZnSO4 fertilization was better in maximizing zinc uptake and grain yield for Zn deficient soil and this depends on the maize variety.*

Keywords: *Foliar spray, grain yield, soil application, maize hybrids, ZnSO4, Zn uptake.*

INTRODUCTION

Maize (Zea mays L.) is a very important cereal crop in Nigeria, as it provides an inexpensive nutritious food that helps to sustain rapidly increasing population (Iken *et al.*, 2002). Apart from providing the staple diet for the population, maize is also an important crop in industrial and livestock production in the country (FAO, 2012). The level of maize production in Nigeria was estimated at almost 5.5 million tons per year (Olaniyan and Lucas, 2004). This is by far below the total demand of the nation as the frequent rise in price shows stronger force of demand relative to supply (Adenola and Akinwumi, 1993). The average poverty reduction due to maize research in Nigeria was 3% equivalent to 1.2 million people per year (IITA, 2014). There are different varieties of maize in the world today and the type choose to produce will depend on consumer preferences and market demand. In some localities, white corn is more popular than the yellow variety. While in some other areas, it is vice-versa. However, the best maize varieties grow fast, are high yielding, mature earlier than the local varieties and are resistant to major pests and diseases.

Maize grain yield potential is twice as high as compared to other cereal crops (Potarzycki and Grzebisz, 2009), even if the quantitative requirements for nutrients are almost the same, the actual harvested yields are low (FAOSTAT, 2005). Cultivation of hybrid maize has recently been adopted by very few farmers from the eastern region as compared to those in the western and northern Nigeria (Iken and Amusa, 2004). Before the introduction of hybrid maize by the Pioneer Seed Company, cultivation of local varieties has been a common practice. Maize hybrid seeds are high yielding and require more nutrients (Brkie *et al.*, 2004) as compared to the local varieties that were being cultivated by the local farmers. The hybrid maize grow faster and exploit the soil nutrients more aggressively (Rastija *et al.*, 2010).

Among many factors which contributes to maize low yield in soils are, imbalanced supply of micronutrients (Sillanpaa, 1990; Chude *et al.*, 2004). Already, the tropical soils of southeastern Nigeria are generally characterized by low pH and organic matter content, high rainfall, highly weathered and leaching of plant nutrients with coarse textured soils (Enwezor, 1981). Such properties are reported to reduce the availability of the micronutrients such as Zinc (Zn), Copper (Cu), Iron (Fe) and Manganese (Mn) to crop plants (Sillanpaa, 1990; Kabata-Pendias and Pendias, 2001). Maize is a crop of high nutrient demanding and appears to be highly sensitive to Zn deficiency in soil (Kanwal *et al.*, 2009; 2010) and to many external and internal stress, which in turn induce grain yield reduction (Rastija *et al.*, 2010). Unfortunately, there is no practice among the farmers in this area to apply Zn fertilizer to maize crop except for NPK (Enwezor, 1981; Chude *et al.*, 2004). The application of $ZnSO_4$ fertilizers to maize crop will not only enhance its production potential but, will also increase the Zn content in the maize grain and other yield components and this will further contributes to cure Zn deficiency problem in human beings.

Many crop cultivars within a species were reported to vary in their Zn requirement and utilization efficiency (Cakmak, 2008). Thus, the selection of these varieties which have maximum nutrient content in their edible parts is a promising approach for nutritional purpose (Furlan *et al.*, 2005). A number of attempts have been made to increase Zn concentration in grain crops by the fertilization of essential nutrient to increase the Zn nutrient contents.

Moreover, the proper method of Zn nutrient application can be another approach for better uptake and utilization of Zn. Most studies on Zn application methods focused on alleviating its deficiencies (Alloway, 2009; Cakmak, 2008). Amongst the different methods; the foliar spray of micronutrients found efficient for enhancement of crop productivity (Ullah *et al.*, 2015; Manasa and Devaranavadagi, 2015). This way of nutrient application is an easy and simple method for improvement of plant nutritional condition, as reported for maize and wheat (Grzebisz *et al.*, 2008). Reasons for effectiveness of foliar spray are simple due to its direct application to the leaves (Potarzycki and Grzebisz, 2009; Shaaban, 2001). On the other hand, $ZnSO_4$ can be applied directly into the soil as well for effective and enhancement of grain yield while, Zn concentration in grain can be improved through foliar spray of Zn fertilizer (Keram *et al.*, 2012).

Many factors such as pH, soil organic matter content and fertilizer application affects the concentration of mineral nutrients of the soil and the availability of nutrient concentration to the crop (Cakmak, 2008; Kabata-Pendias and Pendias, 2001). It is also known that nutrient absorption from soil by the root depends on the nutrient concentration in soil solution (Kabata-Pendias and Pendias (2001). Accordingly, Mortvedt *et al.* (1991) showed that soil and foliar applications of zinc enhances the yield of crops whereas, Lungu *et al.* (2011) and Ullah *et al.* (2015) observed that increase in Zn uptake and accumulation in crop grain was a combine effects of the soil and foliar application. The purpose of this study therefore, was to assess the effects of zinc fertilization methods on zinc uptake, grain and other yield components of maize (*Zea mays L.*) hybrids, in a marginal coastal plain sand soil.

Materials and Methods

Description of Experimental Site

A field experiment was conducted in July, 2016 at the Eastern wings of the National Root Crop Research Institute Farms, Umudike (latitude 05^{o} 9'N and longitude 07^{o} 33'E with an altitude of 122 meters above sea level) of Umudike in Southeastern, Nigeria. The climatic weather situations of the study site as presented in Table 1, was characterized with an average rainfall of 194.41 mm, and distributed in a bimodal pattern, starting appreciably in April, with peaks in July and in October. The rainfall distribution is demarcated by dry season spell known as "August break". The monthly minimum and maximum temperatures ranges from 25 to 33^{o}C respectively while, monthly relative humidity varies from 41 to of 89%.The field experiment was conducted from a site previously cultivated with cassava intercropped with melon and maize in 2013/2014 cropping season and Sweet potato intercropped with maize in 2014/2015.

Table1. *Meteorological data of the experimental site during the cropping seasons*

Month	Rainfall (mm)	Temperature (°C)	Relative humidity (%)	Sunshine duration (hrs/day)	Wind speed (km/hr)	ETo mm/Day
January	16.65	32.20	49.34	4.82	9.50	3.71
February	47.41	33.20	66.86	5.19	10.20	3.76
March	92.86	29.05	68.43	4.29	10.20	4.03
April	172.37	28.00	70.43	5.23	8.80	4.04
May	241.05	27.60	75.93	4.63	8.80	4.00
June	304.02	27.75	79.86	4.53	8.80	3.48
July	371.30	26.20	89.07	3.48	9.50	3.26
August	114.99	29.95	71.43	2.27	7.30	2.24
September	334.07	25.15	85.00	2.70	8.80	3.14
October	462.77	26.10	88.07	3.75	8.90	3.44
November	126.25	29.50	52.00	5.08	8.80	3.72
December	39.21	30.75	41.79	5.97	9.50	3.63
Total	**2432.95**	**329.45**	**838.21**	**51.94**	**109.1**	**42.45**
Mean	**194.41**	**27.45**	**69.85**	**4.33**	**9.09**	**3.54**

Key: ETo=reference crop evapotranspiration.

Preliminary Soil and Analysis

Soils from the experimental site was developed from coastal plain sand and classified as Typic Paleudults according to USDA soil classification. Surface (0-20cm) bulked soil samples used for the study, was collected from previously cultivated marginal and eroded coastal plain sand soil. The soil was analyzed in the laboratory according to standard procedures described by Eteng *et al.*, (2014a) in order, to have a fair position of the physiochemical properties and Zn content of the study area. Zinc concentration in the soil was determined by AAS.

The status of the soil properties are presented in Table 2 which showed that the soil was dominated by sand fraction with a value of 756 g kg^{-1}. Generally, the texture of the soil was determined as sandy loam. The pH ($CaCl_2$) of the soil was very strongly acidic with a value of 4.35. The organic matter of the soil was low with a value of 1.09 g kg^{-1}. ECEC was very low probably due to relatively high sand and low organic matter contents of the soils with a base saturation of 53.12% which indicates that the soil was marginally in exchangeable bases. The total and extractable Zn determined in the soil was 14.02 and 3.34 $mgkg^{-1}$, respectively. Previous studies on this soil indicated that micronutrients especially zinc was grossly deficient and couldn't support crop performance to attained optimum yield (Eteng *et al.*, 2014b).The results of the physical and chemical properties of the soil used was at par with general results reported by Enwezor *et al.* (1990) for soils of southeastern Nigeria.

Table2. *Initial physical and chemical properties of the soil used for the field experiment (2016)*

Soil properties	Values
Physical properties	
Sand (gkg^{-1})	756
Silt (gkg^{-1})	77
Clay (gkg^{-1})	167
Textural class	Sandy loam
Chemical properties	
pH (1:2.5) $CaCl_2$	4.35
Org. matter (gkg^{-1})	1.09
Exchangeable acidity ($Cmolkg^{-1}$)	1.63
Exchangeable bases ($Cmolkg^{-1}$)	2.29
Effective cation exchange capacity ($Cmolkg^{-1}$)	4.42
Base saturation (%)	53.12
Nutrient Concentration (Available Nutrient)	
Total nitrogen N (%)	0.18

Available P (mgkg^{-1})	14.51
Calcium Ca (Cmolkg^{-1})	0.86
Magnesium Mg ,,	0.64
Sodium Na ,,	0.13
Potassium K ,,	0.32
Total Zn (mgkg^{-1})	14.02
0.05M EDTA-extractable Zn (mgkg^{-1})	3.34

Experimental Treatments and Design of the Field Experiment

The experimental treatments comprised of three (3) methods of zinc applications via; Zn soil, Zn foliar, soil-foliar applied at 20 kg/ha and a control where, $ZnSO_4$ was not applied and, five (5) maize hybrids namely; TZSR-Y, Oba supper II-Y, Pioneer Seed-W, Oba Super I-W and Bende white (Local variety). The experimental plots were laid out in a randomized completely block design (CRBD) with four replications in a factorial arrangement, giving 80 plots, measuring 5m x 4m (20 m^2). A total field area of 0.24 ha was cultivated.

Three seeds each of the maize varieties per stand were sown at a planting distance of 50 cm by 75 cm apart. Two weeks after emergence, plants were thinned down to two plants per stands to give a plant population of 53, 333 stands per hectare. A single dosage 20 kg Zn ha^{-1} as $ZnSO_4.7H_2O$ in solution form were applied as both foliar spray on maize leaves and soil application and, these were applied at a week after germination, respectively. The rate was chosen after being informed from the previous study that the soil was deficient in Zn (Eteng *et al.*, 2014b). The foliar spray of 5% $ZnSO_4.7H_2O$ solution according to Zn rate was prepared and sprayed onto the plant leaves in two splits at 2 WAE and 6 WAE, respectively. For the soil application, 20 kg Zn ha^{-1} as $ZnSO_4.7H_2O$ in solution form was applied into the soil at two weeks after emergence (WAE) while. the combined method was soil split applied at 14 DAE and the second half was foliar applied at 48 DAE. The foliar spray was carried out with a simple hand spray-pump of one liter container after thinning. For the control treatment, pure water was sprayed on to the leaves and during each spraying, the soils surface was covered with plastic material to prevent $ZnSO_4$ contamination. This was followed with a recommended basal dose of NP K; 20:10:10 at the rate of 200kg/ha (Enwezor, *et al.*, 1989; Chude *et al.*, 2004). All the recommended cultural practices were followed uniformly throughout the growing season. Chemical weeding was carried out by the use of Atrazine pre-emergence at the rate of 3 kg ai/ha on a clean seed bed before sowing of maize seed. A pressurized Knapsack sprayer (CP 3) 400 liters capacity of water per hectare was used to spray the herbicide. There was no need for insecticide as there was no trace of insect attacked on the crop.

Data Collection

At the end of the experiment, 105 days after planting at (15 WAE), matured maize cob were harvested, separated from the plants, put in the bags and labeled according to the experimental treatments. Data regarding, ear weight (g/plant), No. of seeds per Ear, 100 seeds weight (g) were recorded using standard procedures. Grain yield (t/ha) was determined after air-dried for one week, weighed and corrected for moisture contain at 12.5%. For the determination of Zn concentration in grains, the grains were oven-dried, ground into fine powder and digested in hot H_2SO_4–H_2O_2 solution (Eteng *et al.*, 2014a) and measuring on an atomic absorption spectrophotometer (AAS). Zinc uptake (mg/plant) was calculated as a product of grain yield (t/ha) and Zn concentration (mgkg^{-1}) in grain (Yerokun and Chirwa, 2014).

Statistical Analysis

The data were evaluated statistically by using analysis of variance (ANOVA) technique and least significant difference (LSD) test at 5% probability level was applied to compare the treatments' means using the computer Genstat software. The relationship between Zn uptake and grain yield variables were evaluated using simple linear correlation analysis.

Results and Discussion

Influence of Methods of Zinc Application on Yield Component of Maize Grains Hybrids Ear Weight

The result of ear weight as influenced by method of Zn application on maize hybrids is presented on Figure 1. Ear weight of maize differ significantly ($P < 0.05$) among the method of Zn application and among the maize hybrids and their interactions. Among the hybrid maize, TZSR-Y produced more ear weight (220.59 gplant^{-1}) when Zn was applied in the soil followed by Oba super 2-Y (209.63 gplant^{-1}) when $ZnSO_4$ was foliar applied. Bende-W produced relatively the lowest ear weight. Similar results were reported by Yerokun and Chirwa *et al.* (2014). Soil application of $ZnSO_4$ had significant higher ear weight (189.09 g plant^{-1}) followed by foliar spray of Zn (181.37 g plant^{-1}) relative to other methods. Hence, soil application of $ZnSO_4$ produced 4.14 %, 4.08 % and 25.32% more ear weight of maize than soil-foliar, foliar application and control treatment respectively. These results are confirmed by Potarzycki and Grzebisz (2009); Tariq *et al.* (2014) who obtained similar results. Ear weight of maize is a very important yield component which influences the other yield components. Also in Table 3, positive correlations were obtained between ear weight and method of Zn application (R= 0.576*). Ear weight correlated significantly with no. of grains per cob (R= 0.802**), 100 grain weight (R= 0.818**), grain weight per cob (R= 0.568**), Zn concentration (R= 0.721**), Zn uptake (R= 0.716**) and grain yield (R= 0.732**). Potarzycki and Grzebisz (2009) and Yerokun and Chirwa *et al.* (2014) found similar relationships.

Number of Grains Per Cob

The result of the number of grains per cob as influenced by method of Zn application on maize genotypes is presented in Figure 1. The number of grains per cob differ significantly ($P < 0.05$) among the genotypes and method of Zn application, respectively. Among the genotypes significant higher number of grains per cob, was obtained by Oba super 2-Y (361.51), where $ZnSO_4$ was applied as soil-foliar followed by pioneer seed-W (355.35) when $ZnSO_4$ was applied as foliar spray. However, the lowest number of grains per cob (109.83), was obtained from Bende-W where Zn was applied as foliar spray. These findings agrees with results reported by Erenoglu *et al*. (2002); Grzebisz *et al.* (2008). Among the methods of application, higher number of grains per cob was counted from the combined application of $ZnSO_4$ soil-foliar (306.48). This was significantly ($P < 0.05$) higher relative to relative to other methods (Fig. 1). However, soil-foliar application of $ZnSO_4$ produce 8.17 %, 14.57% and 30.71% more grain weight per cob than $ZnSO_4$ foliar spray, soil $ZnSO_4$ and control treatments, respectively. These findings are similar to those presented by Yerokun and Chirwa *et al.* (2014) and Tariq *et al.* (2014). Positive correlations was obtained between number of grains per cob as affected by the maize ear weight (R= 0.802**) while, methods of Zn application and maize hybrids had no significant influence on number of grains per cob (Table 1). Nevertheless similar studies by Potarzycki and Grzebisz (2009) had significant influence of foliar Zn application on number of grains per cob while, Fecenko and Lozek (1998) had significant influence of soil Zn application on number of grains per cob.

100-Grain Weight

The result of 100 grain weight as influenced by method of Zn application on maize hybrids is presented in Figure 1. 100-grain weight of maize differ significantly ($P < 0.05$) among the method of Zn application and among the hybrids and their interactions effect (Table 1). Among the hybrids, TZSR-Y had significantly ($P < 0.05$) higher 100 seed weight (40.07 g) where soil $ZnSO_4$ was applied relative to other hybrids. Kanwal *et al.* (2009; 2010) reported similar result. Unlike the other yield parameters, soil application of $ZnSO_4$ had significant higher 100-grain weight (34.41 g) followed by soil-foliar application (31.71 g) relative to other methods. The significant increment amounted to, soil application of $ZnSO_4$ producing 7.85 %, 13.72 % and 37.11 % more 100-grain weight than soil-foliar, single foliar application and control treatments, respectively. This finding is in agreement with previous studies by Tariq *et al.* (2014) and Yerokun and Chirwa *et al.* (2014). Positive correlations were also observed between 100 grain weight and ear weight (R= 0.819**) and number of grains per cob (R= 0.731**) (Table 1). The results also showed that the quality of the 100 grains weight was significantly influenced by the method of $ZnSO_4$ application and maize hybrids. Similar results were observed and reported by Hossain *et al.*, (2011).

Grain Weight Per Cob

The grains weight per cob differ significantly ($P < 0.05$) among the methods and among the hybrids (Fig.1). Among the maize hybrids, Pioneer seed-W had significantly ($P < 0.05$) higher grain weigh per cob (87.32 g) where $ZnSO_4$ was applied as soil-foliar followed by Oba super 2-Y (76.51 g) were $ZnSO_4$ was applied as foliar spray relative to other hybrids.

On the whole, Bende-W (local hybrid) had lower grain weight per cob (38.93 g) in control treatment. Among the methods of application, combined soil-foliar $ZnSO_4$ application significantly ($P < 0.05$) had more grains weight per cob (69.38 g) followed by Zn foliar applied (60.22 g) and these had significant ($P < 0.05$) higher grain weight per cob relative to the other methods (Fig. 1). The results further shows that, combined soil-foliar application of $ZnSO_4$ produced 13.32 %, 16.01 % and 34.68 % more grains weight per cob than single foliar Zn, soil Zn and control treatments respectively. The findings are in par with those results reported by Tariq *et al.* (2014); Potarzycki and Grzebisz (2009); Kanwal *et al.* (2010). Moreover, the correlation between grain weight per cob were highly affected by ear weight (0.721**), number of grains per cob (R= 0.846**) and 100 grain weight (R= 0.647**). However, there was not significant relationship between the method of $ZnSO_4$ application and maize hybrids (Table1).

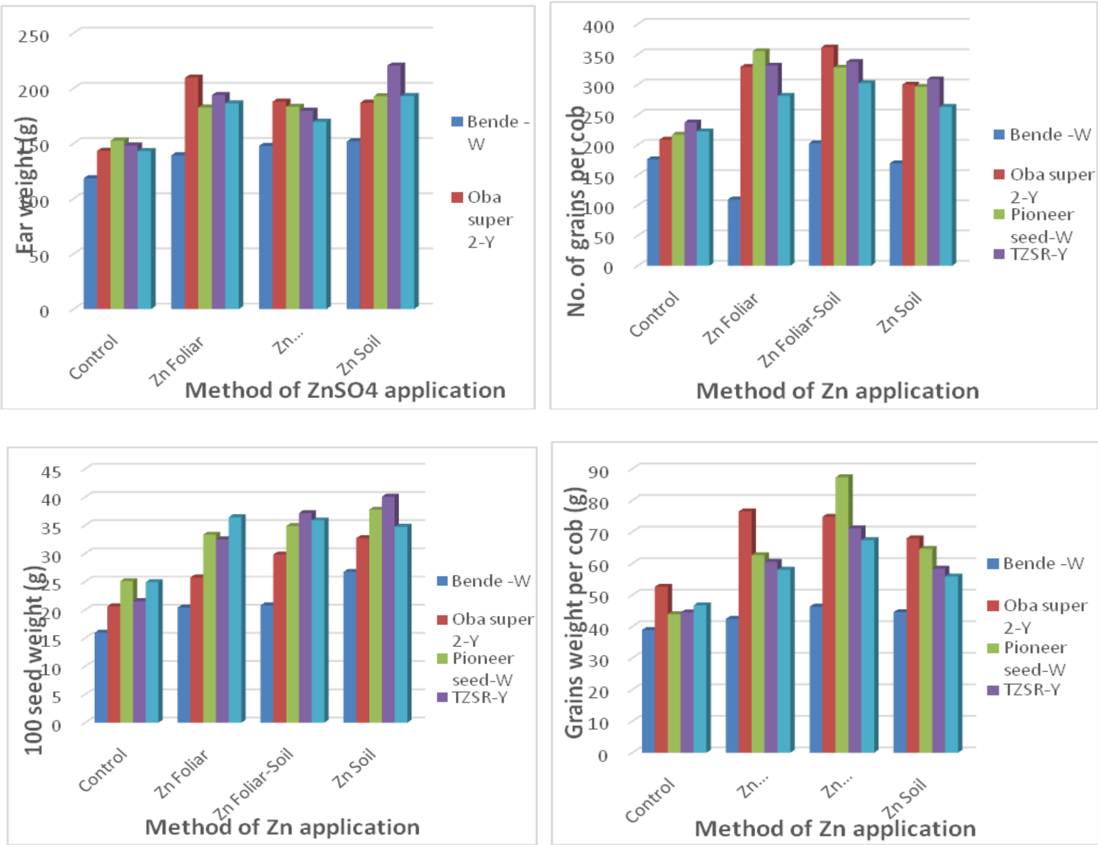

Figure1. *Chart showing the interaction effects of method of $ZnSO_4$ application and maize hybrids on some yielding components of maize.*

Grain-Zn Concentration

The effects of methods of Zn application, maize hybrids and their interactions had significant ($P<0.05$) effects on Zn concentration in maize grains (Fig. 2). Among the hybrids, higher Zn concentrations in maize grain, was obtained from Pioneer seed-W (55.55 $mgkg^{-1}$), followed by Oba super 1-Y (49.38 $mgkg^{-1}$). These were obtained, where $ZnSO_4$ was applied in the combined soil-foliar while, the lowest Zn concentration in grain, was obtained from Bende-W (17.02 $mgkg^{-1}$) variety where no $ZnSO_4$ was applied (Fig. 2). This finding is at par with those reported by Graham *et al.* (1992); Furlani *et al.* (2006). Among the application methods, higher concentration of Zn was accumulated in maize grains where combined Zn soil-foliar (44.96 $mgkg^{-1}$) was applied followed by single $ZnSO_4$ foliar application (38.70 $mgkg^{-1}$) and this differ significantly ($P < 0.05$) higher relative to the other methods (Fig. 2). These result are in par with those of Mosana and Behrozyar (2015)**;** Hossain *et al.* (2011); Kanwal *et al.* (2010). It was noted that, the increase in Zn conc. in maize grains, due to combined soil-foliar application of $ZnSO_4$ resulted to higher production of 13.79 %, 29.00% and 43.68% of more zinc concentration in maize grains than Zn foliar, soil Zn and control treatments, respectively (Fig. 2). The results presented in Table 1 showed that positive correlations were obtained between Zn concentration in grain and maize grain weight per cob (R= 0.827**). Zinc concentration was not affected by method of $ZnSO_4$ application and maize hybrids (Table 3). Kanwal *et al.* (2009); Tariq *et al.* (2014) and Potarzycki and Grzebisz (2009) reported similar results to confirm these findings.

Grain-Zn Uptake

Methods of Zn application, genotypes and their interactions had significant (P<0.05) effects on Zn uptake in grain (Fig. 2). Among the hybrids higher Zn uptake in grain, was obtained from Pioneer seed-W (3.861 mg $plant^{-1}$), followed by Oba super 2-Y (3.488 $mgplant^{-1}$). Both were obtained where, $ZnSO_4$ was applied as combined soil-foliar while, the lowest Zn uptake in grain (0.577 $mgplant^{-1}$), was obtained from Bende-W where no Zn was applied (Fig 2). Previous studies by Graham *et al.* (1992) noted similar results in a study on, selecting zinc-efficient varieties for soil of low zinc status while, Furlani *et al.* (2006) reported similar results in another study on the efficiency of maize cultivars for zinc uptake and use. Among the application methods, combined soil-foliar application of $ZnSO_4$ accumulated more Zn uptake in grain (3.11 mg $plant^{-1}$) over single $ZnSO_4$ foliar (2.37 $mgkg^{-1}$), soil (2.20 mg $plant^{-1}$) and control (0.875 $mgplant^{-1}$) treatments. Similar result was reported by Lungu *et al.* (2011). The combined soil-foliar application of $ZnSO_4$ significantly (P<0.05) increased Zn uptake in grain by 23.79 %, 29.26% and 72.99% more than foliar application, soil and control treatments, respectively. In contrast, Mosana and Behrozyar (2015); Hossain *et al.* (2011); Yerokun and Chirwa *et al.* (2014) observed that, the soil application of Zn resulted in higher Zn uptake in grain over foliar application. However, previous studies by some other authors (Grzebisz *et al.*, 2008; Potarzycki and Grzebisz, 2009; Tariq *et al.*, 2014) noted that foliar application of $ZnSO_4$ was a better method for increasing the grain yield of maize hybrids. Supporting the above authors, Alloway (2009); Keram *et al.* (2012) found out that zinc external supply is a primary factor accelerating plant root growth and in turn increasing zinc uptake. Moreover, the result in Table 1 showed that, Zn uptake in grain significantly (P<0.01) correlated positively with grains weight per cob (R= 0.922**) and Zn concentration (R= 0.871**). This finding is at par with those of Manasa and Devaranavadagi (2015); Mosana and Behrozyar (2015), who studied on the effect of foliar application of micronutrients on growth, yield and nutrient uptake of maize. The correlation between zinc uptake and method of $ZnSO_4$ application was significant at 5% while that with maize hybrid was not significant.

Grain Yield

The result of grain yield as influenced by method of $ZnSO_4$ application on maize hybrids are presented on Figure 2. Maize grain yield was significantly (P < 0.05) affected by the maize hybrids and method of $ZnSO_4$ application, respectively. Among the hybrids, higher grain yield 3.18 t ha^{-1} and 3.17 t ha^{-1}, were obtained from TZSR-Y and Pioneer seed-W where, $ZnSO_4$ was applied as foliar and soil-foliar, respectively while, the lowest grain yield (1.23 t ha^{-1}), was harvested from Bende-W where no $ZnSO_4$ was applied. Lungu *et al.* (2011); Graham *et al.* (1992) observed similar results. Among the $ZnSO_4$ application methods, soil application of $ZnSO_4$ produced more grain yield of 2.22 t ha^{-1} over foliar $ZnSO_4$ application and control treatment. However, the combined soil-foliar application of $ZnSO_4$ significantly increased grain yield by 2.83 %, 16.19 % and 30.01 % more than Zn foliar, Zn soil application and control treatments, respectively. These results are at par with those of Mosana and Behrozyar (2015)**;** Hossain *et al.* (2011); Kanwal *et al.* (2010) who also reported that, the soil application of $ZnSO_4$ resulted in an increase in the grain yields of maize over foliar application. The result is confirmed by Yerokun and Chirwa *et al.* (2014) who observed that maize grain yields was 56% more and significantly higher when Zn was applied to soil compared to foliar Zn application. Nevertheless, foliar spraying is normally adopted to increase plant nutrient uptake when soil immobilization mechanisms reduce $ZnSO_4$ movement in the soil. Although, foliar spray may be a cheaper method to apply nutrient to plants, in this study, it soil application and absorption through the roots was a more effective alternative to increase grain yields. However, these findings disagreed with those of Tariq *et al.* (2014) and Potarzycki and Grzebisz (2009) who reported that foliar application of $ZnSO_4$ was a better method to increase the grain yield of maize hybrids. This study suggests that, foliar and/or soil $ZnSO_4$ fertilization can be an effective way of maximizing maize grain yield and this depends of the crop genotype. Moreover, maize gain yield was significantly (P<0.01) correlated with number of grains per cob (R= 0.858**), grain weight per cob (R= 0.828**) and Zn uptake in grain (R= 0.819**) (Table 1). The correlation between maize grain yield with method of zinc application and maize hybrids was not significant (Table 3). However, previous studies Potarzycki and Grzebisz (2009) reported significant influence of foliar Zn application on number of grains per cob while, Fecenko and Lozek (1998) noted a significant influence of soil Zn application on number of grains per cob. The results suggest that the yield components which correlated significantly, contributed to the increased in the grain yield. Several authors Mosana and Behrozyar (2015); Yerokun and Chirwa *et al.* (2014); Eteng *et al.* (2015b) had similar results. Grain yield which is an ultimate end product of many yield contributing attributes, physiological and morphological processes takes place in plant during growth and development (Tariq *et al.*, 2014), and this may be attributed to the impressive result of gain weight per ear, Zn in grain and Zn uptake in grain obtained in this study, respectively.

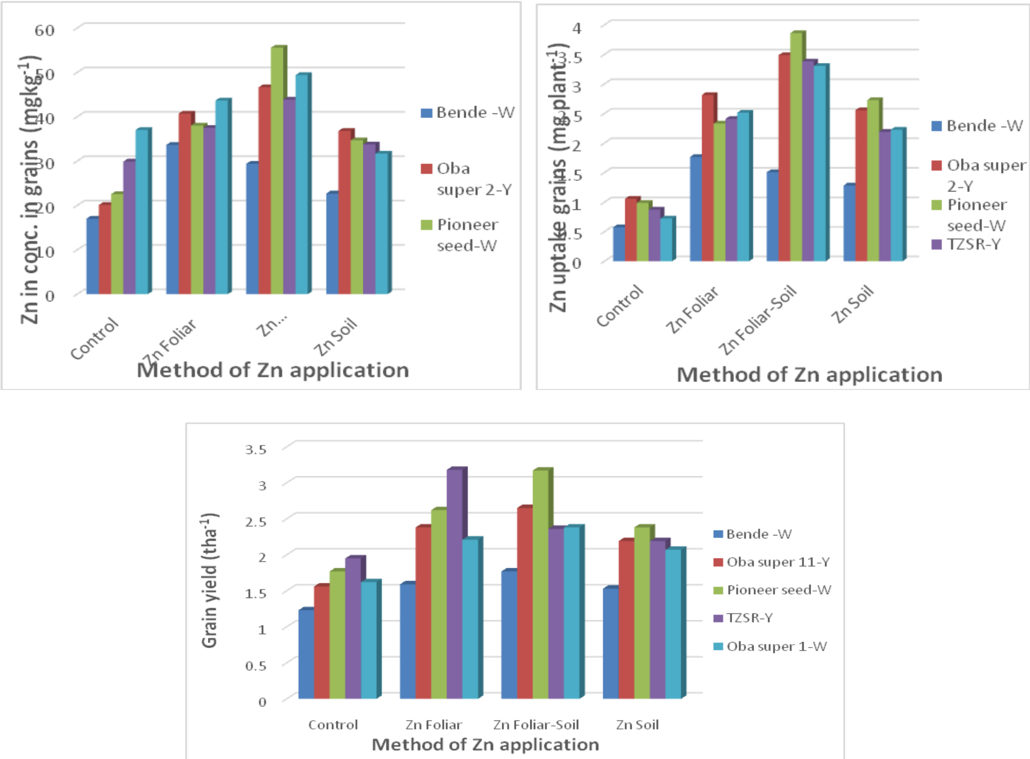

Figure2. *Chart showing the interaction effects of method of ZnSO4 application and maize hybrids on maize grain yield and some yielding components of maize.*

Table1. *Correlation coefficient (r) amongst maize yield components, as influenced by method of Zn application on maize hybrids*

Maize yield components	Zn method	Maize hybrids	Ear weight	No of grain wt.	100 grain wt.	Grain wt./cob	Zn in grain	Zn uptake in grain	Grain yield
Zn method	-								
Maize hybrids	0.000 ^{ns}	-							
Ear weight	0.576 *	0.385 ^{ns}	-						
No of grain wt	0.311	0.432 ^{ns}	0.802 **	-					
100 grain wt	0.650 *	0.604 **	0.819 **	0.731 **	-				
Grain wt/cob	0.416ns	0.202 ^{ns}	0.721 **	0.846 **	0.647 **	-			
Zn in grain	0.299	0.431ns	0.568 **	0.701 **	0.637 **	0.827 **	-		
Zn uptake grain	0.554*	0227ns	0.716**	0.770**	0.737**	0.922**	0.871**	-	
Grain yield	0.306ns	0.359ns	0.732**	0.858**	0.683**	0.828	0.784**	0.819**	-

***. Correlation is significant at the 0.01 level (2-tailed).*

**. Correlation is significant at the 0.05 level (2-tailed).*

CONCLUSIONS

The study indicated that amongst the type of hybrid maize, pioneer seed-W produced 16.87 %, 11.65 % and 38.86 % higher grain yields than Oba super 1-W, Oba super 2-Y and Bende-W, respectively and followed by TZSR-Y which produced, 14.46 %, 9.09 % and 37.19 % higher grain yields than Oba super 1-W, Oba super 2-Y and Bende-W, respectively. Moreover, the combined soil-foliar application of $ZnSO_4$ gave 23.79 % and 29.26 % more grain yield than foliar and soil applied and 72.99 % higher than control treatment. Consequently, types of maize hybrids, method of $ZnSO_4$ fertilization have strong influence on Zn uptake, grain yield and yielding components. Combined soil-foliar application of $ZnSO_4$ has more influence on maize grains yield as compare to soil applied and foliar methods. The study further concludes that, the combined foliar and soil $ZnSO_4$ fertilization method can be an effective way of maximizing zinc uptake and grain yield in maize production in a Zn deficient marginal and eroded soil and this depends on the genetic functioning of the maize variety.

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