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Effect of Foliar Application of some Macro and Micronutrients on the Growth and Yield of Maize

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Abstract: Maize is the most cultivated cereal crop in Ghana and plays a significant role in consumer diets. An ideal way of improving yield is through the use of balanced macro and micronutrient doses. Fertilizers supplied through soils are subjected to leaching, fixation, surface runoff, erosion, volatilization, extremely high or low pH render nutrients unabsorbable by plants. Foliar application of fertilizer supplies nutrients directly to the stomata and cuticle of the leaves which saves time and increases yield as proposed by crop physiologist. The experiment was designed as a multi-location study comprising eight treatments. These treatments were evaluated in a Randomized Complete Block Design (RCBD) with three replications. The experiment was conducted at the experimental field of University for Development Studies, Nyankpala (9° 24' 39'' N, 0° 59' 2'' W 170 m) and Kpaliga (9° 26' 44'' N, 0° 57' 58'' W 170 m) in the Northern region of Ghana. Application of nitrogen in a split form has the ability to broaden the leaf surface area to receive the foliar applied micronutrients. However, increasing nitrogen at basal application and reducing it at top dressing (NP_2K treatments) stands a better chance of broadening the leaf surface area. The general progression of leaf area index could be attributed to the adequate supply of macronutrients. NP_2K+[P+Zn+Fe] produced the highest grain yield. There was significant difference between foliar zinc and control (NP_2K). Maize plants responded to foliar application of phosphorus, zinc and iron, but not in terms of yield differences. It will be needful to repeat this experiment since the drought affected the response of maize to foliar applied fertilizer to yield. Socio economic analysis should be done to show whether the increment in grain yield will compensate for the cost of application of foliar fertilizer.

I. INTRODUCTION

Maize is the most cultivated cereal crop in Ghana and plays a significant role in consumer diets. For instance, it was discovered in a survey conducted nationwide in the year 1990 that 94 percent of households depend on maize for their day-to-day meals. Maize and maize-based products were reported to account for 10.8% and 10.3% of household food expenditures by the poor and all income groups respectively (Morris et al., 2001). However, the total production of maize in Ghana (with respect to area of cultivation) remained stable due to conventional methods of farming (MiDA, 2010). For some time now, the farming methods used by the farmers have been negatively affected by components such as climate (Ismaila et al., 2010), declining soil fertility and inadequate application of external inputs (Fosu et al., 2004; Fening et al., 2011) and constant mono-cropping. (Wopereis et al., 2006). One of the most effective ways of replenishing and correcting depleted soil nutrients is through the application of mineral fertilizer (Bationo et al., 2007). Therefore, providing ideal quantities of mineral nutrients in addition to the use of balanced macro- and micronutrient doses to crop is one way to improve crop yields (Zubillaga et al., 2002). Micronutrients are needed in small amounts to enhance directly or indirectly photosynthesis, respiration, protein synthesis and reproduction (Marschner et al., 1995).

Cakmak (2000) also hypothesized that stress caused by Zn deficiency may limit the activities of a number of antioxidant enzymes, resulting in a prevalent oxidative damage to the membrane nucleic acids, chlorophyll, proteins and lipids. Phosphorus on the other hand has been identified as a life-limiting element in the natural ecosystems. Phosphorus is a vital nutrient element and an essential component of several important compounds in plant cells (Taiz and Zeiger 1991). Soil applied Phosphorus becomes unavailable for plant uptake or utilization when bound in highly insoluble compounds (Ozanne 1980). Sulphur, known for its protein forming ability is progressively being documented as the fourth major nutrient for the growth of maize after nitrogen, phosphorous and potassium (Jamal et al., 2010).

Foliar applied sulphur compounds at critical crop stages enhances photosynthetic efficiency, photosynthate partitioning and increases chlorophyll contents, shoot dry matter and grain weight of maize. (Jagetiya and Kaur, 2006).

Iron is a component of many enzymes involved in the nutritional metabolism of plant. It is one of the most important nutrients needed by plants, precisely maize. One of the major factors which affect the growth and yield of maize is depleted soil nutrients due to continues farming on the same piece of land hence farmers have adopted the use of inorganic fertilizer application. These fertilizers are at least applied in two splits, i.e. the basal NPK application and top dressing with Urea or Ammonium Sulphate. The way of application of these fertilizers subjects the maize plant to several stresses which end up affecting it's yield and growth. Most farmers supply nutrients to their crops through the soil which has quite a number of setbacks. Fertilizers supplied through soils are subjected to leaching, fixation, surface runoff, erosion, volatilization, extremely high or low pH rendering nutrients unabsorbable by plants. Fertilizer application is costly and time consuming hence there is a need to evaluate other procedures of supplying the nutrients that the plants need. Foliar application of fertilizer supplies nutrients directly to the stomata and cuticle of the leaves which saves time, increases yield and improve protein content of maize.

Therefore, there is a need to investigate the effects of foliar application of P, S, and micronutrients Zn and Fe on grain yield maize. The main objective of the project is to determine maize response to foliar applied nutrients.

II. MATERIALS AND METHODS

The experiment was conducted at the experimental field of University for Development Studies, Nyankpala and Kpaliga in the Northern region of Ghana. Previous cultivation on the field involved the use of fertilizer which might have some residual effects even though no soil samples have been analysed to find out the quantities of those residual nutrients. The region has a unimodal rainfall pattern with an average annual rainfall of 900-1100mm distributed fairly from the month of April to October (SARI, 2004). The mean day temperatures of the dry season which begins from November to March is 33 ° C to 39 ° C while the mean night temperature ranges from 20 ° C to 26 ° C. The soils of the study areas are humus poor, rich in iron and aluminium oxides, and have a mineralogy dominated by quartz and low activity clays with low effective cation exchange capacity. The soil of the study areas has been classified as Typic Plinthustalf, Nyankpala series (Avornyo et al., 2020). The experiment was designed as a multi-location study comprising eight treatments. The eight treatments were evaluated in a Randomized Complete Block Design (RCBD) with three replications. Each block consisted of eight plots with a plot measuring 5m × 5m with an alley of 1.0m between plots and 2.0m between blocks. The treatment consisted of soil applied Nitrogen (N), Phosphorus (P) and Potassium (K) and foliar applied Phosphorus (P), Sulphur (S), Iron (Fe) and Zinc (Zn) in different combinations. The treatment structure is shown in Table 1. The fertilizer applied was NPK Yara Milla 23-10-5, phosphorus (TSP), sulphur (KSO4), zinc (ZnSO4) and iron (FeSO4). During basal application, NPK and MOP were applied directly to the soil at week 2 after planting. However, due to the drought top dressing with urea was done 7 weeks after planting (WAP). Foliar application of P, S, Zn and Fe were also done 7WAP for the same reason. In order to enhance a uniform mixture of the foliar nutrients to the water, alata soap was added. It was again added because of its ability to remain on the leaves till absorption takes place.

A. *Gravimetric Moisture Content*

Soils were randomly sampled from four plots in each replication with the help of an auger. These samples were sent to the lab and wrapped in a well labelled aluminium foil. The mass of the moist soil was recorded. The soil was then kept in an oven at 105ºC for 24 hours after which the dry weight was measured. Gravimetric water content was calculated as:

$$\frac{mass\ of\ wet\ soil - mass\ of\ dry\ soil}{mass\ of\ dry\ soil} \times 100$$

B. *Plant Height*

The height of the foliage or the main stem above the foliage was measured. A ruler was set at the base of the plant and measurement was carried out. When the plants were small a ruler was used but as they grew taller a meter stick was used.

C. *Leaf area Index*

The leaf area index was measured at 4 and 6 weeks after planting. The index was obtained by dividing the total leaf area by the ground area. The total leaf area was calculated by measuring the length and the breadth of three different leaves taken at (non-destructive sampling) the base, middle and the upper portion of the three leaves from the five sampled plants, totalling 15 leaves per plot and multiplied by a constant of 0.75. The total number of leaves on the plant was divided by the sampled number of leaves and multiplied by the total leaf area. The answer obtained was divided by the ground area which was calculated using the planting distance.

D. SPAD Value

The SPAD meter was calibrated before measuring the leaf chlorophyll content. The 5 selected and tagged plants in each plot were used to take the 3 SPAD readings on the 5th leaf and on the 6th leaf from the bottom. The average of 10 reading was recorded.

E. Grain Yield at Harvest

Harvesting of the maize was done on the 16th week after planting. Each plot was divided into four quadrats of which two were selected randomly to be harvested. After harvesting the fresh cobs were de-husked. This step was followed by de-graining and the fresh weight of the grains measured. The weight of the grains from each plot was measured in kilogram and recorded; these were subsequently converted to tons per hectare.

III. DATA ANALYSIS

The data collected were subjected to analysis of variance (ANOVA) using GenStat Statistical Package software, Teaching and Learning version, 18th edition. The two sites, Kpaliga and Nyankpala were considered as factors and the nutrients combinations were considered as another factor.

Table 1: Amounts of fertilizer products applied in grams per plot (25 m^2)

Treatment$^{\alpha}$	Soil basal application		Top dressing				
			Soil application	Foliar application			
	NPK	MOP	Urea	Zn	TSP	Fe	S
NP_1K	1000	100.4	152.2	0	0	0	0
NP_1K+[Zn+S+Fe]	1000	100.4	152.2	7.7	0	17	34.9
NP_1K+[Zn+Fe]	1000	100.4	152.2	7.7	0	17	0
NP_1K+[Zn]	1000	100.4	152.2	7.7	0	0	0
NP_2K	500	150.6	402.2	0	0	0	0
NP_2K+[P+Zn+S+Fe]	500	150.6	402.2	7.7	29.5	17	34.9
NP_2K+[P+Zn+Fe]	500	150.6	402.2	7.7	29.5	17	0
NP_2K+[P+Zn]	500	150.6	402.2	7.7	29.5	0	0

α Nutrients between [ ] denote foliar application

IV. RESULTS AND DISCUSSION

A. Gravimetric Moisture Content of the two Locations

At the onset of the rain, soil moisture was optimum for plant growth and development. As the crop progressed to its vegetative and critical period of growth, soil moisture declined sharply from week 2 to 6 at the Kpaliga site. (Fig 1). This was as a result of the short dry spell which coincided with the vegetative stage of the plant. However, the soil moisture content started increasing from week 6 and attained its highest peak at week 9. Unfortunately, at that time, irreversible harm had already been done and plants at Kpaliga were all stunted due to the moisture stress. Every year, there is some level of dry spell in Nyankpala and Kpaliga which mostly affect the yield of crops generally. The rainfall even though is 900-1100 mm annually but it's not evenly distributed throughout the year and since there is limited information of weather reports farmers are unable to plant their cropping season well to prevent the vegetative stage from coinciding with the drought (G. *et al.*, 2014). This study was designed to subject foliar application of crops to field conditions. The moisture stress affected the yield of maize by retarding the growth of plants at Kpaliga. This retardation caused the height of plants to be shorter with small leaf surface area and chlorophyll. This proved the research of Prasad and Staggenborg (2008) who said that water stress is one of the most important environmental factors limiting crop growth, development, and yield. Alam (1999); Viets (1972) explained it further by saying that water deficit or osmotic effect is probably the major physiological mechanism for growth reduction as both stresses lower the soil water potential. Therefor it is possible that soil nutrients were less mobile mainly because pores are filled with air and pathways for nutrient flux from soil to root surface are less direct (Fageria *et al.*, 2008). Drought also affected the primary nutrient uptake (NPK) by plant roots. Maize, has high rates of nutrient uptake during the V4 to VT stage (2 to 6 WAP) during which water demand may exceed supply. When the plants are unable to get enough water during this period, a great degree of damage which is irreversible will occur. This is because water stress is primarily responsible for stomatal closure there by reducing assimilation and growth. Therefore, there is the possibility that plants at Kpaliga could absorb all the foliar nutrients provided.

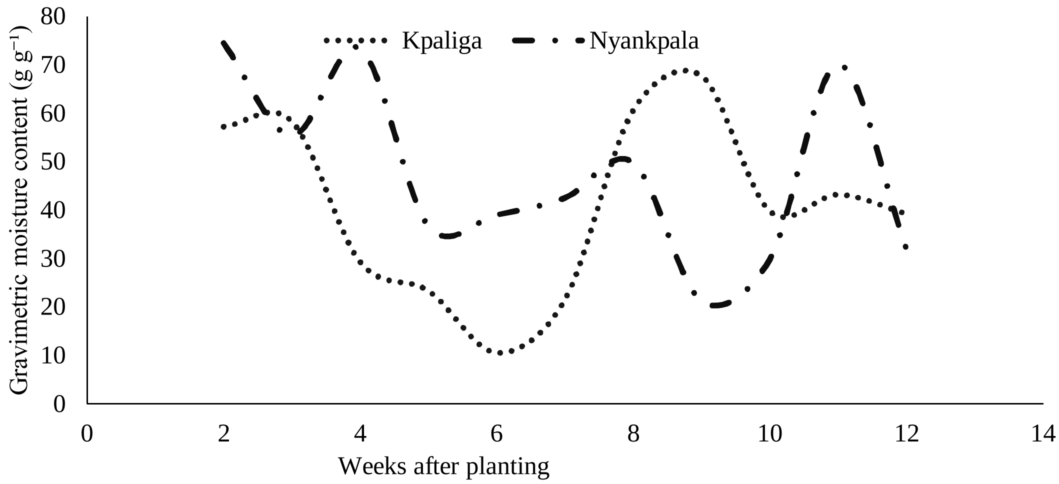

Figure 1: Gravimetric moisture content

B. *Effect of Fertilizer Treatment on Plant Height*

At week 4, maize plants had similar heights for all the treatments however, the variation in plants increased from week 6 to week 10 (Fig 2). Plots fertilized with NPK (120-20-40) (500g) and MOP (150.6g) (NP_2K treatment) as basal application produced the tallest plants. The main effect of location was highly significant from week 6 to 10 except week 4 which was not significant. After top dressing (week 7), plants treated with NP_2K+[P+Zn+Fe] grew taller than all the other treatments. The taller plants recorded by NP_2K+[P+Zn+Fe] treatments could be that NPK, Zn, Fe, P were fully utilized by the plants due to its timely availability (Witold *et al.*, 2008; Farooqi *et al.*, 2012; Abid *et al.*, 2016). It could also be attributed to possible sufficient availability of Phosphorus, Zinc and Iron. The results are in line with Y. Hu *et al.*, (2007) and Saeed and Mohammad (2012) who reported that foliar feeding has no significant influence on plant height. However, low phosphorus was compensated by foliar P treatments due to its timely availability (Witold *et al.*, 2008; Farooqi *et al.*, 2012; Abid *et al.*, 2016).

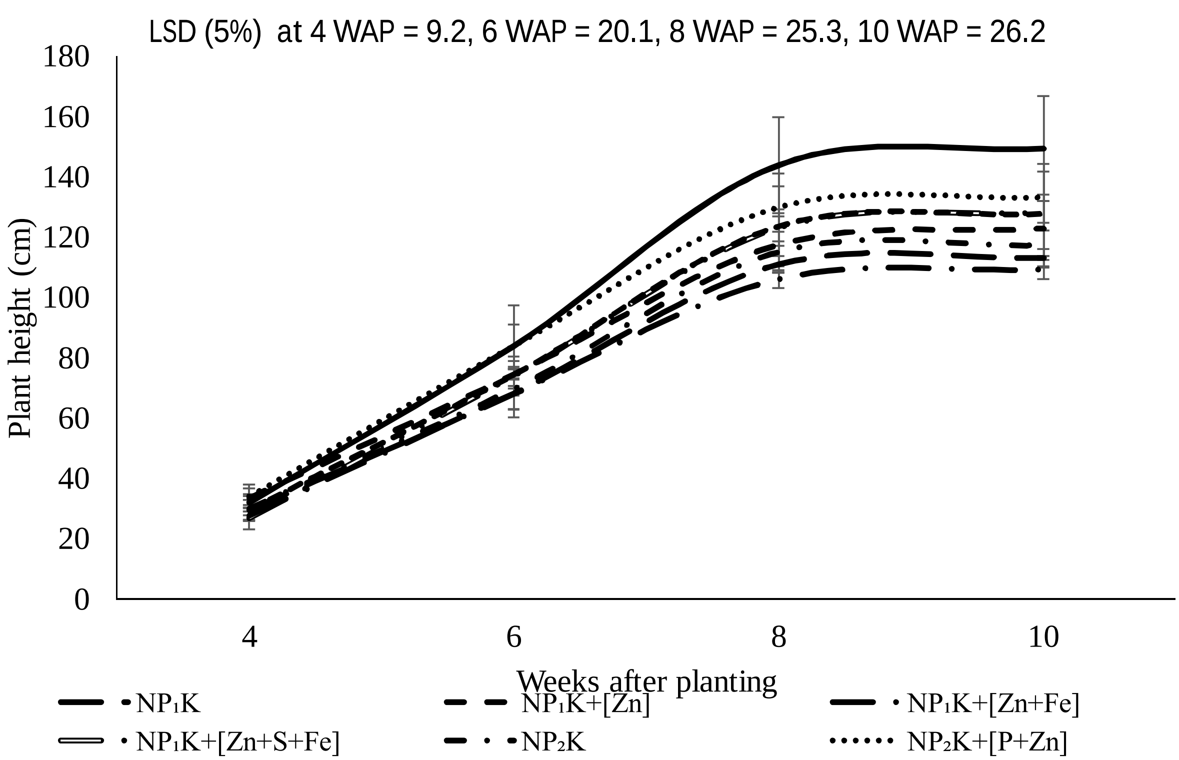

Figure 2: Influence of fertilizer treatment on plant height at 4, 6, 8, 10 WAP. Error bars represent SEM.

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C. Effect of Fertilizer Treatment on Leaf Area Index

At week 4, plant variance increased; nevertheless, maize plants of all treatments had similar leaf area index at week 6 (Fig 3). From week 4 through to week 6, the major influence of NP_1K+[P+Zn+Fe] was extremely substantial. This shows that the application of NPK (120-40-40) (1000g) and MOP (100.4g) during basal application can positively influence the leaf surface area of maize. According to Fageria *et al.*, (2009), leaf surface area has the ability to determine the absorption rate of micro and macronutrients. Therefore, all treatments stood a better chance of absorption of foliar nutrients however, NP_2K+[P+Zn+Fe] superseded them all. The general progression of leaf area index could be attributed to the adequate supply of primary nutrients as this is in line with the discovery of (Saeed and Mohammad, 2012).

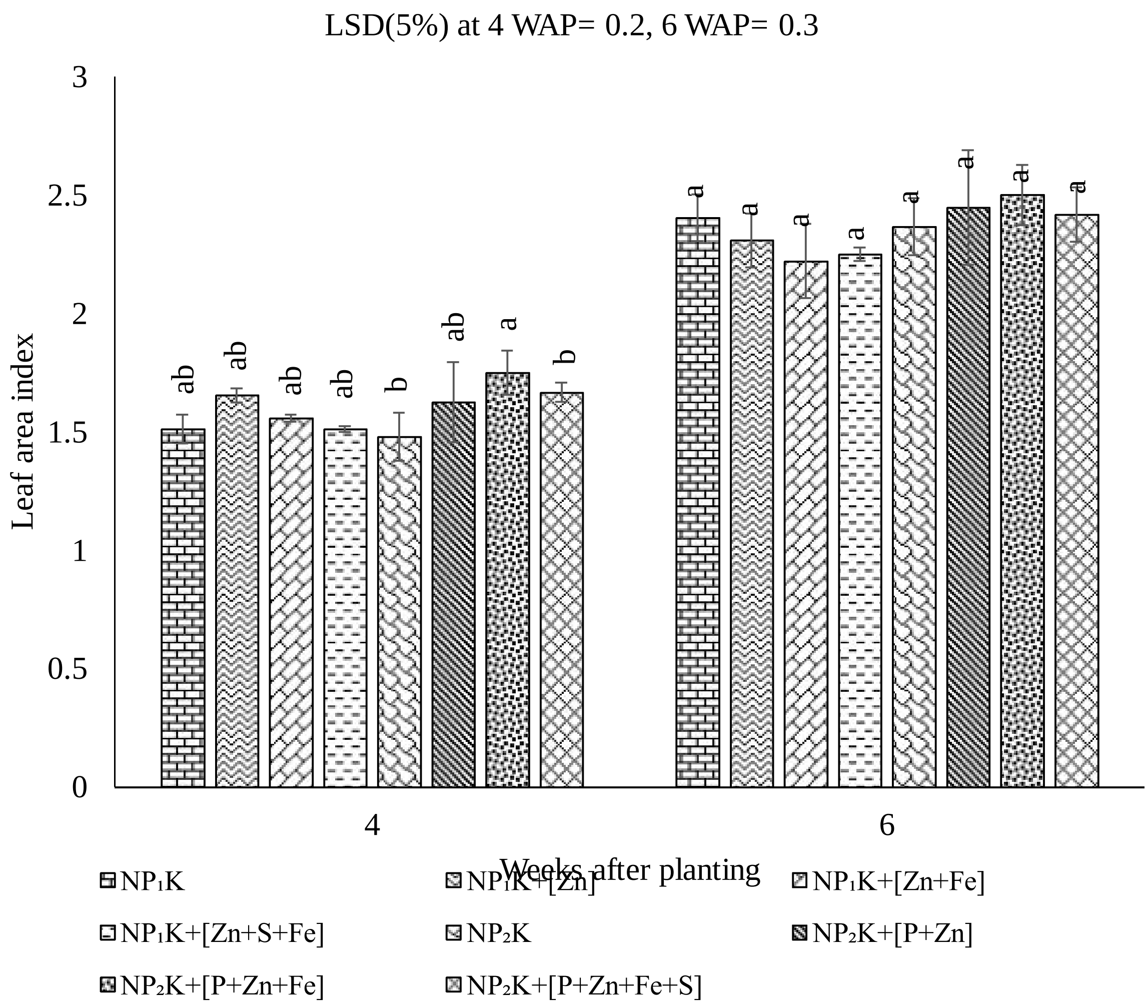

Figure 3: Influence of fertilizer treatment on leaf area index at 4, 6, WAP. Error bars represent SEM. Bars of the same design and colour with similar letters on top are not significantly different.

D. Effect of Fertilizer Treatment on SPAD Reading

At week 8, the major effect of fertilizer was similarly not substantial; nevertheless, variation increased from week 10 to week 12 (Fig 4). The highest SPAD reading was seen in plots treated with NP_2K+[P+Zn+Fe], NP_1K+[Zn+S+Fe], and NP_1K+[Zn+Fe] at week 8, 10 and 12 respectively. The results show that supplying higher rates of NPK in combination with Sulphur, Zinc and Iron at top dressing has a great impact on the SPAD value of maize. As stated by Rodriguez *et al.*, (1998), the supply of iron in sufficient amounts promotes photosynthesis therefore, the high SPAD readings recorded by the above mentioned treatments could be due to the presence of iron.

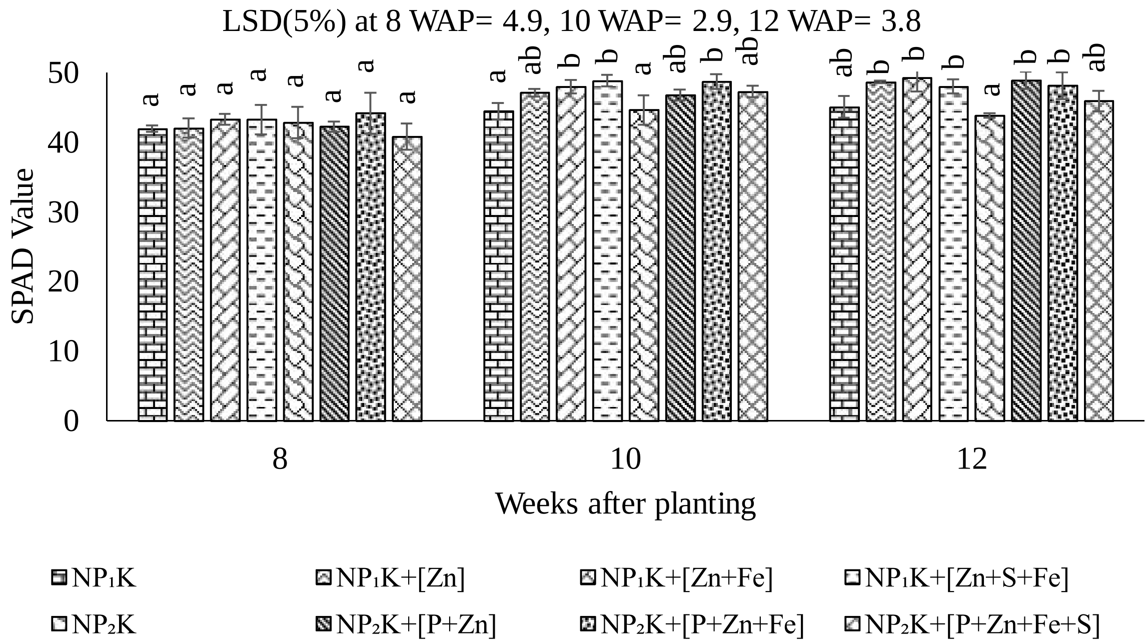

Figure 4: Effect of fertilizer treatment on SPAD values. Error bars represent Standard Error of Means (SEM). Bars of the same design and colour with similar letters on top are not significantly different.

E. Effect of Fertilizer Treatment on Grain Yield

The fertilizer treatments had no significant effect on grain yield (Fig 5a and 5b). Plants treated with NP_2K+[P+Zn+Fe] were more productive (Fig 5a). Statistically, all the eight treatments performed better at Nyankpala than those in Kpaliga because of the vast difference in the soil moisture content and probably as a result residual effect of long term fertilizer use at the Nyankpala site (Fig 5b). Rego *et al.*, (2007) and Esmaeili *et al.*, (2016) reported an increase in grain yield of maize by Zn and other micronutrient application. Moreover, maize was recognized by Leach and Hameleers (2001); Subedi and Ma (2009) as a crop of high response to phosphorus, zinc and other micronutrients. In spite of these findings in literature with regards to the benefits of P, Zn and Fe fertilization, this study showed that increased yield resulting from P, Zn and Fe fertilization was not significantly different from traditional fertilizer application.

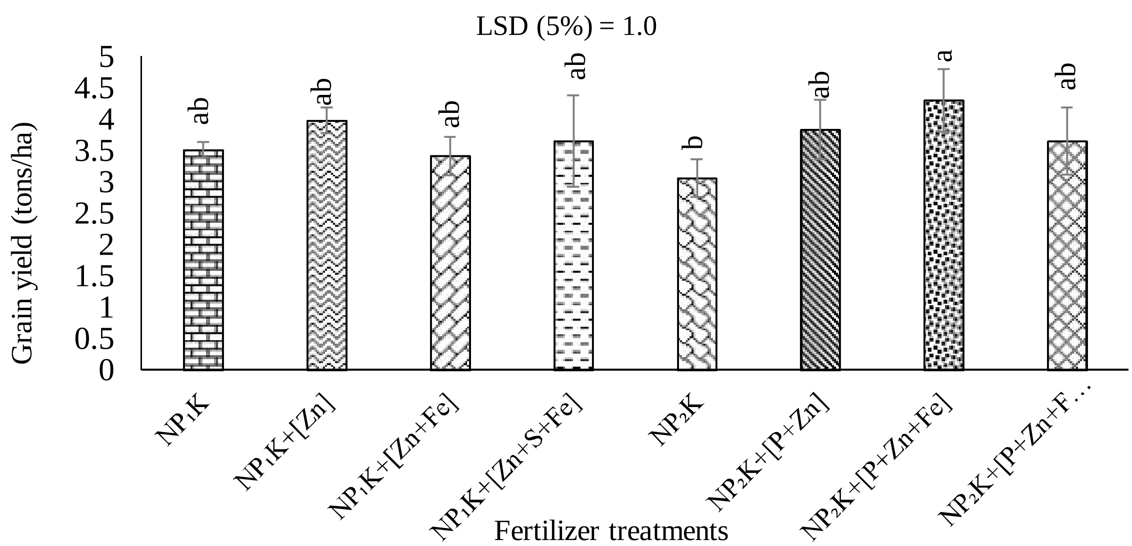

Figure 5a; Effect of fertilizer treatment on grain yield. Error bars represent Standard Error of Means (SEM). Bars of the same design and colour with similar letters on top are not significantly different.

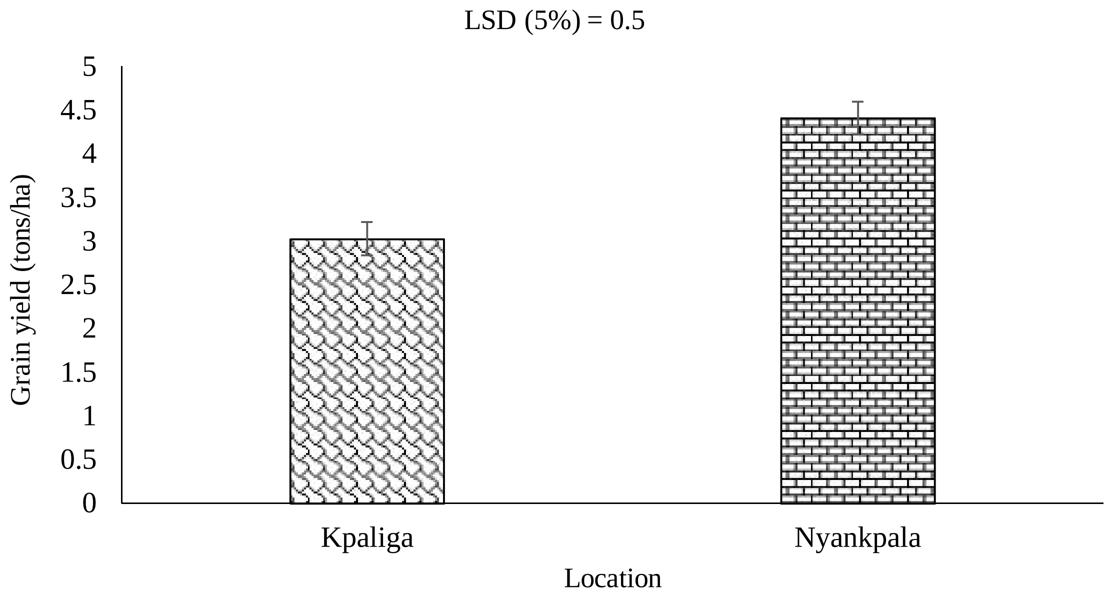

Figure 5b: Effect of location on grain yield. Error bars represent Standard Error of Means (SEM).

V. CONCLUSION

The following conclusions can be made from the obtained results. During the experiment the highest plant height was recorded from plants treated with NP_2K+[P+Zn+Fe]. A similar trend was observed in SPAD values, leaf area index and grain yield. Maize plants therefore responded to foliar application of phosphorus, zinc and iron, but not in terms of yield differences. The investigation proved that reducing nitrogen at basal application and increasing nitrogen at top dressing can positively influence the above mentioned growth parameters and grain yield.

A. Recommendation

It will be needful to repeat this experiment since the drought affected the response of maize to foliar applied fertilizer.

Socio economic analysis should be done to show whether the increment in grain yield will compensate for the cost of application of foliar fertilizer.

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