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Comparison of Maize Yield from Different Yara Fertilization Regimes in Four Locations in the Guinea Savanna Zone of Ghana

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ABSTRACT

Low soil fertility has been a major constraint to the increased and sustainable production of maize in the savanna ecology of Ghana. Studies were conducted to compare the yield of maize from different application regimes of YARA fertilizer (Actyva, Unik-15, NPK, Sulfan, Urea and Sulphate of Ammonia) in four locations (Nyankpala, Yendi, Walewale and Damongo) within the Guinea savanna zone of Ghana. The fields were laid out in a randomized complete block design with four replications for each treatment. Data were taken on grain yield and 100 seed weight of maize, and subjected to analysis of variance, with treatment means separated at a probability of 5% using the least significant difference. There was no significant difference in maize yield between Act@125kg/ha+Act@250kg/ha and Act@250kg/ha+Act@125kg/ha. However, Act@250kg/ha+Sul@125kg/ha, though inferior to the other Actyva treatments, gave higher yield than U15@250kg/ha+SOA@125kg/ha. Soils at the different locations responded differently to the fertilization regimes. Damango tended to have similar maize yields on plots that received fertilization. In Walewale, all the Actyva treatments gave similar high yields that were greater ($p<0.05$) than yields of U15@250kg/ha+SOA@125kg/ha and the unfertilized plot. For Yendi, Uk15@250kg/ha+SOA@125kg/ha gave similar yield as NPK@250kg/ha+Urea@125kg/ha. In both Walewale and Yendi, Sulfan top dressed treatment gave similar high yield as the Actyva top dressed treatment., indicating superior performance of Sulfan to SOA or Urea top dressed treatments. Yield increase of up to 500% were recorded in the Actyva treatments, and attributed to the inclusion of S, B and Zn that enhanced synergy in growth promoting factors, and improvements in P and N-uptake that favoured maize growth and yield. Farmers can achieve maximum maize yield in the ecology through fertilization with Actyva formulations.

INTRODUCTION

Maize is among the most important and widely consumed staple food in tropical Africa (FAO, 2020). In the savanna ecology of Ghana, maize is produced predominantly by smallholder, resource-poor farmers under rain-fed conditions (Kankam-Boadu et al., 2018). Sun *et al*. (2019) reported that maize is most popular cereal crop in northern Ghana due to its high yield, ease of processing and low cost of production. However, the average yield of about 1.5 t/ha is below the achievable yields of up to 6 t/ha (Oppong-Abebrese et al., 2019. Soil fertility is crucial in increasing cereal crop yields, and low soil fertility and low application of external inputs are the major factors affecting productivity of maize, and these account for the low yield of the crop. Improving yields through increased productivity of the savanna soils can be achieved by external inputs of nutrients which are available mainly in the form of inorganic fertilizers. Across the north of Ghana, the most sourced of inorganic fertilizers are commercial fertilizers, which farmers can easily access on the local market.

The main limiting nutrients in the soils of the major maize growing areas in northern Ghana have been organic carbon (<1.5 %), total nitrogen (< 0.2 %), exchangeable potassium (<100 mg/kg) and available phosphorus (< 10 mg/kg) (Abumere et al., 2019). For many decades, a one-cap-fits-all fertilizer recommendations have been made for maize and other crops in Ghana. Moreover, soil conditions are dynamic over the years and the old recommendations are not always efficient. Hence, the need to constantly update or make site-specific fertilizer recommendations for maize in the northern agroecological zone of Ghana.

Over the years, use of NPK fertilizers have been the primary means of nutrient replenishment. This is understandable as NPK remains the most important nutrients required for crop production (Abumere et al., 2019). Sole application of NPK has helped to increase maize yield significantly. However, some room remains for further yield increment. It has been postulated that the inclusion of secondary nutrients such as sulphur (S) and micro nutrients such as boron (B) and Zinc (Zn) in fertilizer blends could increase maize yields sharply, beyond levels achieved by use of sole NPK (Njoroge et al., 2018). This postulate has not been confirmed nor denied in savanna ecology of Ghana. In view of this, fertilizer blends/formulation in northern Ghana remains primarily of N, P and K which may be limiting possible yield increment through secondary and micro-nutrient inclusion. There is the need to study the growth and yield increment of fertilization through inclusion of secondary and micronutrient elements in fertilizer formulations.

YARA Ghana is an agro input company involved in the importation and sale of mineral fertilizers to improve agricultural production and income of farmers. Yara Ghana has recently introduced standard fertilizer formulations for cereal crop production, namely Actyva (23N+10P+5K+2MgO+3S+0.3Zn), Unik-15 (15N+15P+15K+2.2S), NPK (15N+20P+20K), Urea (46N), Sulfan (24N+6S) and SOA (21N+24S). The comparative agronomic efficacy of these formulations within the different agro ecological zones in northern Ghana remains largely unknown. There is the need to compare the relative productivity of the fertilizer regimes to enable subsequent recommendation to the resource-poor farmer for maize production in the ecology. This study sought to establish and compare the yields of maize obtained from treatments with the various YARA fertilizer formulations within the different agroecological zones of northern Ghana.

MATERIALS AND METHODS

Study sites

The trial was conducted during the 20219 cropping season in farmers' farms in four locations, namely, Nyankpala, Walewale, Yendi and Damongo, in the northern Guinea savanna zone of Ghana. Generally, the savanna ecology is that of a tropical continental with a single rainy season, usually from May to October (and peaks around late August or early September), followed by an extended dry season (FAO, 2020; Tetteh et al., 2016). The four locations for this study share ecological traits similar to the Guinea savanna ecological zone. However, there are some differences. Nyankpala is at an altitude of about 183 m above sea level and mean annual rainfall of about 1000 – 1300 mm. The area has a gentle undulating to flat terrain (Kumah, 2016). The area is largely characterized by low-lying areas of grassland with few spread perennial woody species. Some crops cultivated in this ecology include maize, rice, soybean and cowpea. Soils in this region are largely developed from voltaian shale and sandstone with texture being largely sandy loam to loamy sand (Yidana et al., 2011) and classified as a Ferric Luvisol.

Yendi largely shares similar ecological traits with guinea savanna. On the other hand, unique traits include average annual rainfall which ranges between 1005 – 1150 mm. The area has a relatively flat terrain with gentle slopes. Soils here are developed over shale, usually shallow (15-30 cm) to very shallow (<15 cm) and are generally sandy loan at the top and sandy loam or silty loam in the subsoil. Crops mostly cultivated include maize, rice, sorghum and millet. Damango records average annual rainfall as being between 1100-1200 mm and the terrain is mostly flattened with gentle slopes (Tetteh et al., 2016). Soils are over sandstone with sandy loam texture. Popular crops in this ecology include millet, maize, soybean, sorghum and groundnuts. Walewale records average annual rainfall between 900 – 1000 mm (Tetteh et al., 2016). Soils are developed from granite or upper Birimian phyllite and the top soil texture is usually coarse sandy loam or loamy sand. The terrain of this ecology is sloppy and crops cultivated include maize, millet, rice, groundnuts, beans, sorghum and yam.

Land preparation, experimental design and treatments

At each location, stumps were initially removed from the fields to ease demarcation. Each field was disc-ploughed and harrowed (with a hoe) during the first week of July.

The single factor experiment, laid out in a Randomized Complete Block Design (RCBD), with five treatments and four replicates for each treatment, was used. Field size of 35 m x 19 m with plot size of 5 m x 5 m were used. A 1 m and 2 m alleys were allowed between treatments in each block and between blocks, respectively. The treatments included five different fertilization regimes (Table 1). The treatments were based on a protocol provided by YARA Ghana limited for the conduct of the trial.

Table 1: Fertilizer treatment protocols used for the trial

Treatment	Description
Act@125+Act@250	Actyva @ 125 kg/ha at 2 WAP; Actyva @ 250 kg/ha at 4 WAP
Act@250+Act@125	Actyva @ 250 kg/ha at 2 WAP; Actyva @ 125kg/ha at 4 WAP
Act@250+Sul@125	Actyva @ 250 kg/ha at 2 WAP; Sulfan @ 125kg/ha at 4 WAP
U15@250+SOA@125	Unik15 @ 250 kg/ha at 2 WAP; SOA @ 125kg/ha at 4 WAP
NPK@250+Urea@125	NPK @ 250kg/ha at 2 WAP; Urea @125kg/ha at 4 WAP
Control	No fertilization

WAP: Weeks after plant emergence

Planting, application of treatments and crop husbandry

The Obatanpa maize variety obtained from the Ganoma agro inputs shop, Tamale, Ghana, was used for planting. Sowing was done during the second week of July at the rate of two plants per hill. The plants were spaced at 75 cm between rows and 40 cm within rows. The pre-emergence herbicide Glyphader 480 (360g/l glyphosate a.e.; SL) was applied at planting to control surviving weeds.

At each trial site, application of the fertilizer treatments was done strictly according to the protocol indicated in Table 1 above. The basal (2 after crop emergence) application of Actyva and Unil-15 treatments was done by deep placement while top dress (4 after crop emergence) application with Actyva, Sulfan, Sulphate of Ammonia and Urea was done by band placement.

Post-emerged weeds were controlled with atrazine (WP 80 g/l/ha, a.e. SL) at 3 and 6 weeks after planting. Bunds were constructed around each plot prior to application of the treatments to avoid fertilizer drift into adjacent plots. The crops were sprayed with Emastar (Emamectin Benzoate 12g/L + Acetamiprid 64g/L) at 2 and 5 WAP to control fall armyworms.

Estimation of maize yield and analysis of data

Sampling for yield data was done after harvest of the maize. Maize cobs from each plot were manually removed from the plants after maturity. De-husking, threshing and winnowing were also done manually based on farmer practice. Threshed grains were air dried and oven dried to 13% moisture content by weight. The weighed grains were converted into weight per unit area (kg/ha).

The mass of 100 grain of maize was also taken to investigate the effect of nutrient regime on grain weight.

The maize yield data were analyzed using analysis of variance (ANOVA) in GenStat Statistical package 12th edition. The treatment means were separated and compared using the Least Significant Difference (LSD) at 5% level of probability.

RESULTS

Maize yield was significantly affected by fertilization regimes at Damango (*p=0.008*). Maize yield ranged from 4165 kg/ha in Act@250+Act@125 to 1688 kg/ha in the control (unfertilized plot) (Figure 1). However, the highest yield in Act@250+Act@125 at Damango was not statistically different from those of Act@125+Act@250 (3749 kg/ha), Act@250+Sul@125 (4144 kg/ha), U15@250+SOA@125 (4073 kg/ha), and NPK@250+Urea@125 (3648 kg/ha), which together differed from the lowest yield of 1688 observed for the unfertilized field. Yield increases of 122%, 146%, 145%, 141% and 116% due to fertilization was recorded for Act@125+Act@250, Act@250+Act@125, Act@250+Sul@125, U15@250+SOA@125 and NPK@250+Urea@125, respectively over the unfertilized field.

In contrast to the observation in Damango, the fertilization regimes had no significant effect on maize yield at Nyankpala (*p=0.263*), which ranged between 1528 kg/ha to 1890 kg/ha (Figure 2) and was generally in the order Act@125+Act@250 > U15@250+SOA@125 > Act@250+Act@125 > NPK@250+Urea@125 > Act@250+Sul@125 > control plot.

At Walewale, maize yield was significantly affected by the fertilization regimes (*p<0.001*). The yield ranged from 3447 kg/ha in Act@250+Act@125 to 493 kg/ha in the control plot (Figure 3). However, the highest yield in Act@250+Act@125 was statistically comparable to that of Act@125+Act@250 (3140 kg/ha) and Act@250+Sul@125 (3079 kg/ha), which differed significantly from the other treatments. But similar yields were observed for NPK@250+Urea@125 and U15@250+SOA@125 which were significantly higher than that of the control. Yield increases of 536%, 599%, 524%, 351% and 428% due to fertilization were recorded for Act@125+Act@250, Act@250+Act@125, Act@250+Sul@125, U15@250+SOA@125 and NPK@250+Urea@125, respectively over the control plot.

As in the case of Walewale, the fertilization regimes significantly affected maize yield at Yendi (*p=0.008*). Maize yield at Yendi ranged from 1861 kg/ha in Act@250+Act@125 to 417 kg/ha in the control (Figure 4). Here again, the highest yield in Act@250+Act@125 was statistically comparable to that of Act@125+Act@250 (1849 kg/ha), Act@250+Sul@125 (1496 kg/ha) and U15@250+SOA@125 (1353 kg/ha) which differed significantly from that of NPK@250+Urea@125 (965 kg/ha) and the control (417 kg/ha). However, yields from Act@250+Sul@125, U15@250+SOA@125 and NPK@250+Urea@125 were statistically similar. Apart from the yield of NPK@250+Urea@125 which was not significantly different from the control plot, yields of all fertilized treatments were significantly higher than that of the control. Yield increases of 343%, 346%, 258%, 224% and 131% due to fertilization were recorded for Act@125+Act@250, Act@250+Act@125, Act@250+Sul@125, U15@250+SOA@125 and NPK@250+Urea@125, respectively over the control plot.

Unlike maize yield, the fertilization regimes did not have significant impact on 100 seed weight of maize grown at Damango (*p=0.783*), Nyankpala (*p=0.611*), Walewale (*p=0.094*), and Yendi (*p=0.114*). For Damango, 100 seed weight of maize ranged from 25.1 g to 27.4 g (Figure 5) and was generally in the order U15@250+SOA@125 > Act@250+Sul@125 > Act@125+Act@250 > NPK@250+Urea@125 > Act@250+Act@125 = Control.

Similar trends were observed in Nyankpala. The 100 seed weight recorded for Nyankpala ranged from 30.0 g to 28.3 g (Figure 6) and was in the order U15@250+SOA@125 = Act@250+Sul@125 = Act@250+Act@125 > Act@125+Act@250 > Control > NPK@250+Urea@125. The 100 seed weight recorded for Walewale ranged from 29.0 g to 25.0 g (Figure 7) and was in the order U15@250+SOA@125 > Act@250+Sul@125 >Contro l> NPK@250+Urea@125 > Act@125+Act@250 > Act@250+Act@125. At Yendi, 100 seed weight ranged from 24.0 to 27.3 g (Figure 8) and was in the order U15@250+SOA@125 > Act@250+Act@125 > Act@250+Sul@125 >Control > Act@125+Act@250 > NPK@250+Urea@125.

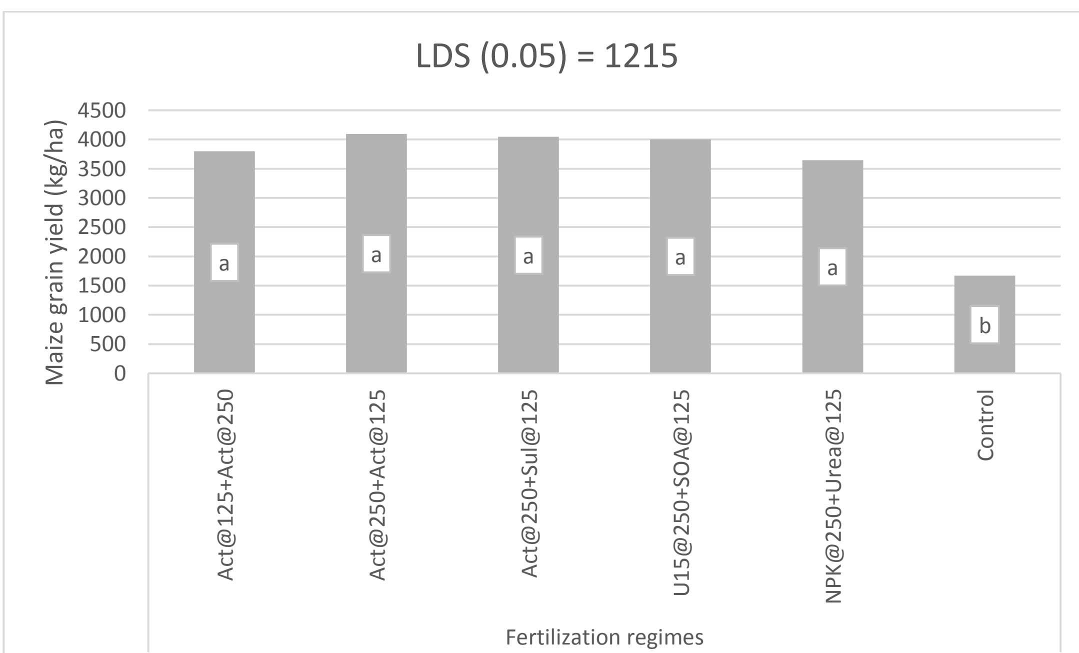

Figure 1: Impact of fertilizer regime on maize yield (kg/ha) at Damango during the 2019 cropping season. Bars with the same letters are not significantly different (p < 0.05).

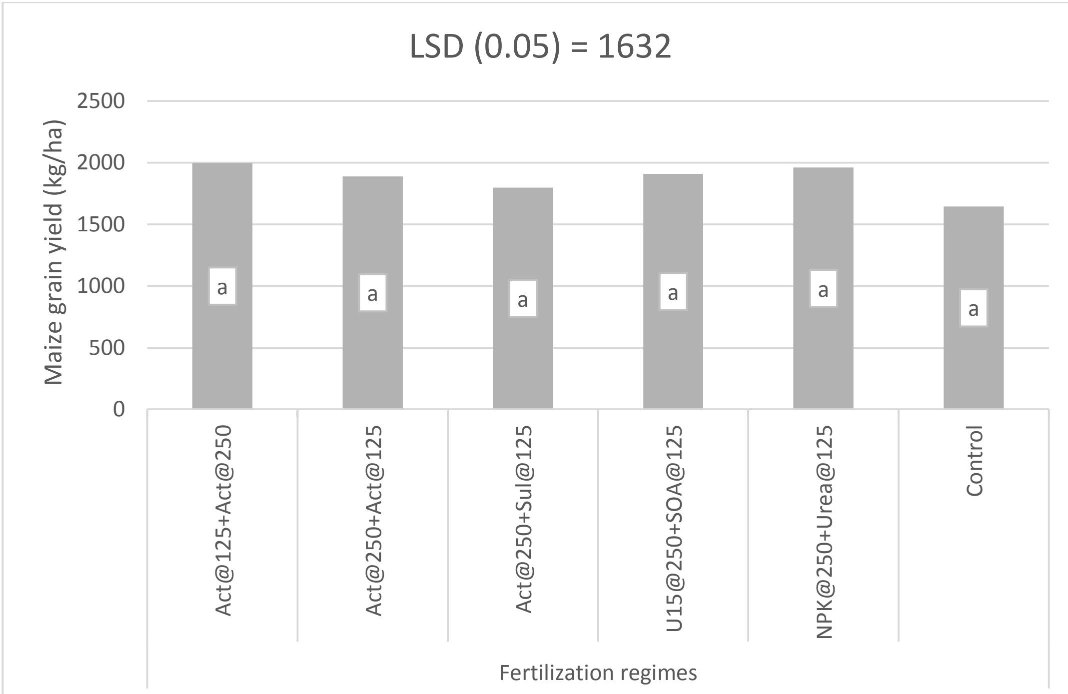

Figure 2: Impact of fertilizer regime on maize yield (kg/ha) at Nyankpala during the 2019 cropping season. Bars with the same letters are not significantly different ($p < 0.05$).

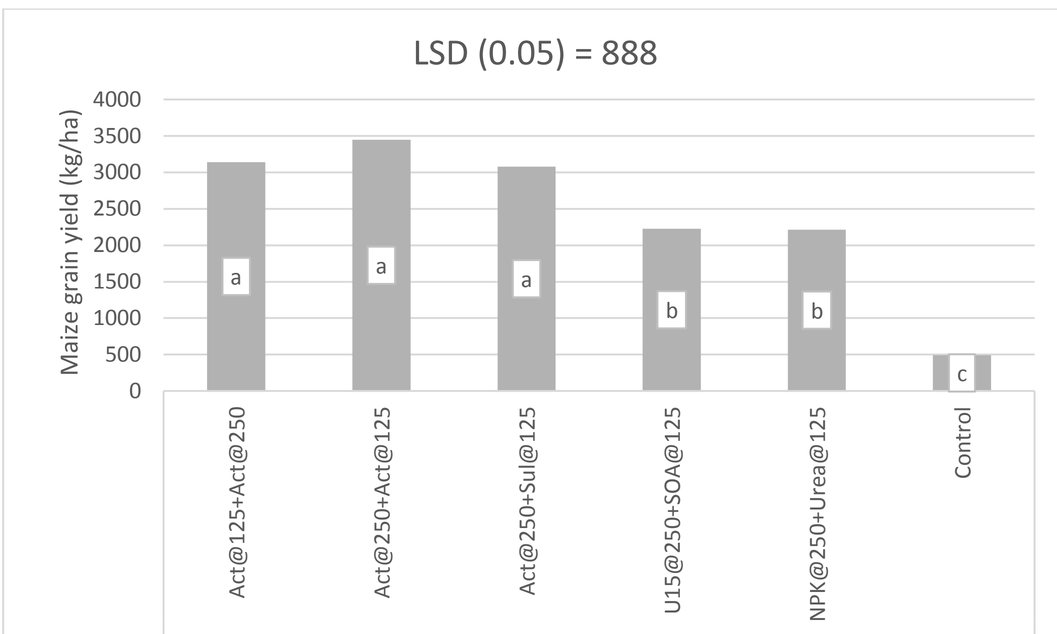

Figure 3: Impact of fertilizer regime on maize yield (kg/ha) at Walewale during the 2019 cropping season. Bars with the same letters are not significantly different ($p < 0.05$).

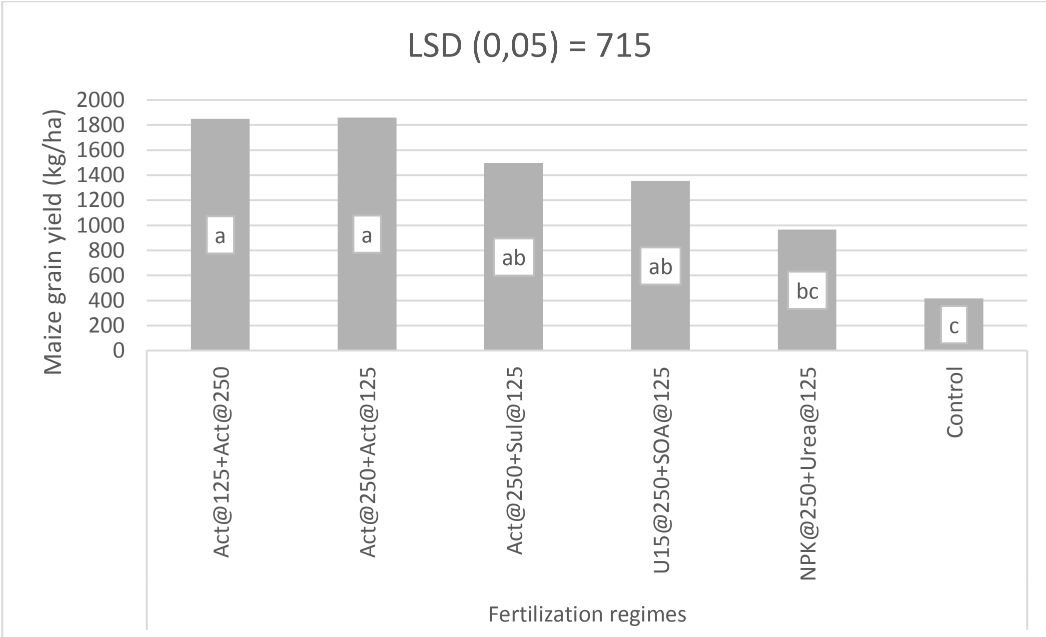

Figure 4: Impact of fertilizer regime on Maize yield (kg/ha) at Yendi during the 2019 cropping season. Bars with the same letters are not significantly different (p < 0.05).

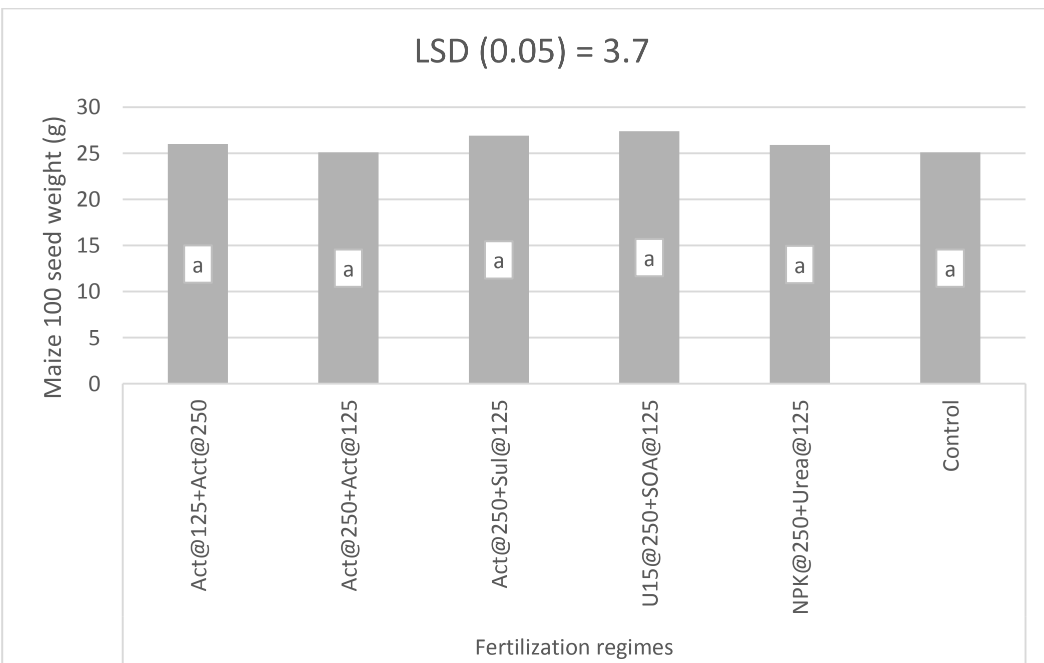

Figure 5: Impact of fertilizer regime on 100 seed weight of maize grown at Damango during the 2019 cropping season. Bars with the same letters are not significantly different (p < 0.05).

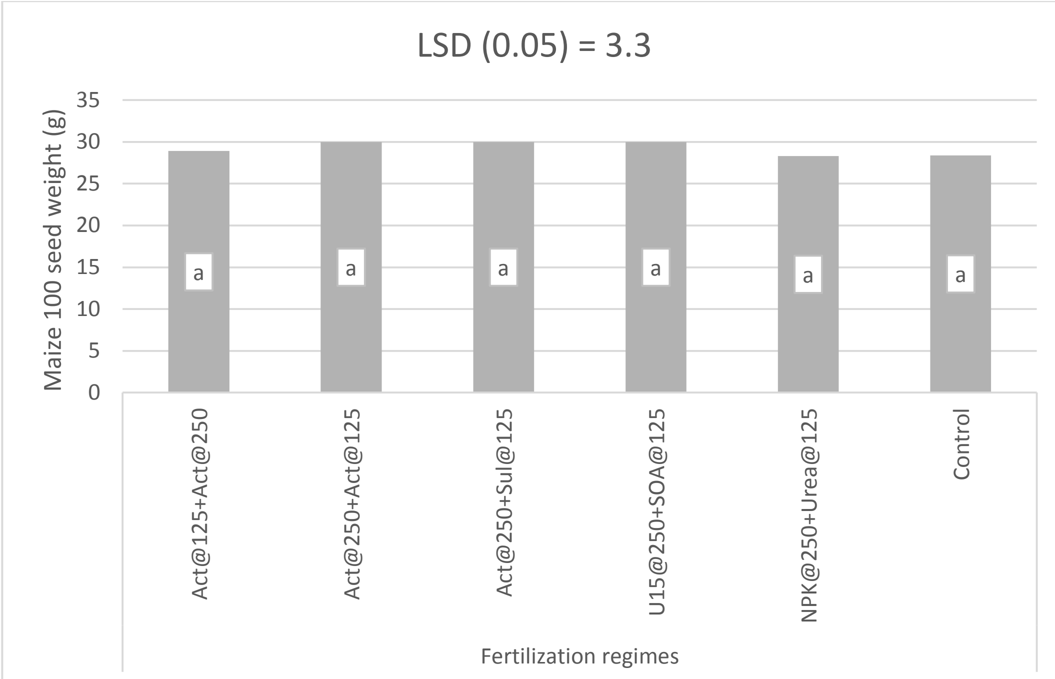

Figure 6: Impact of fertilizer regime on 100 seed weight of maize grown at Nyankpala during the 2019 cropping season. Bars with the same letters are not significantly different ($p < 0.05$).

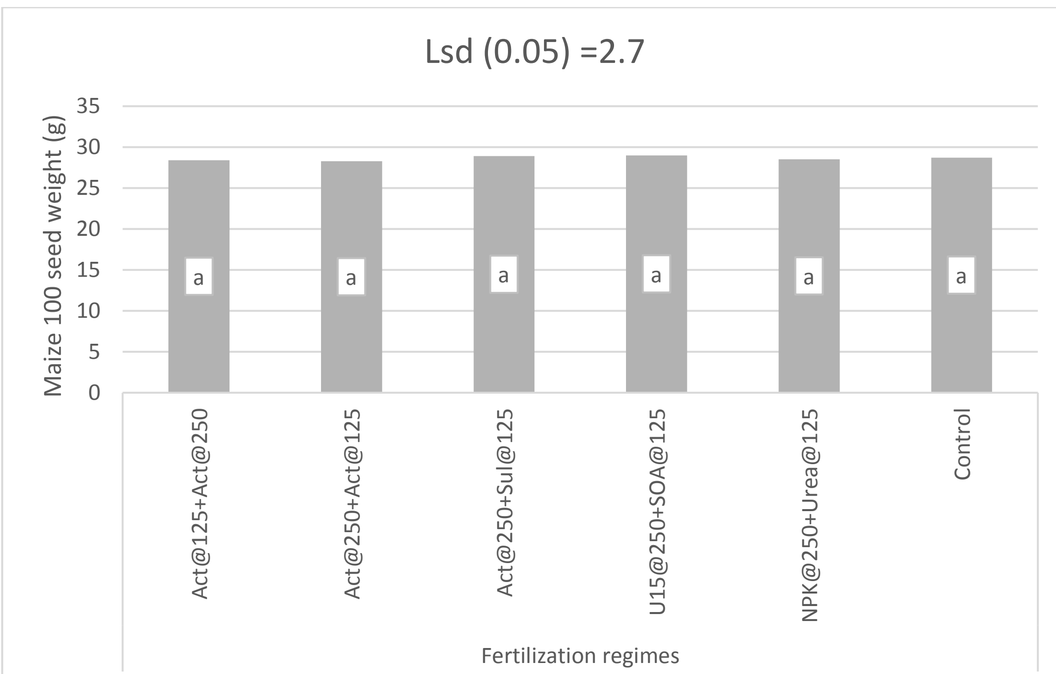

Figure 7: Impact of fertilizer regime on 100 seed weight of maize grown at Walewale during the 2019 cropping season. Bars with the same letters are not significantly different ($p < 0.05$).

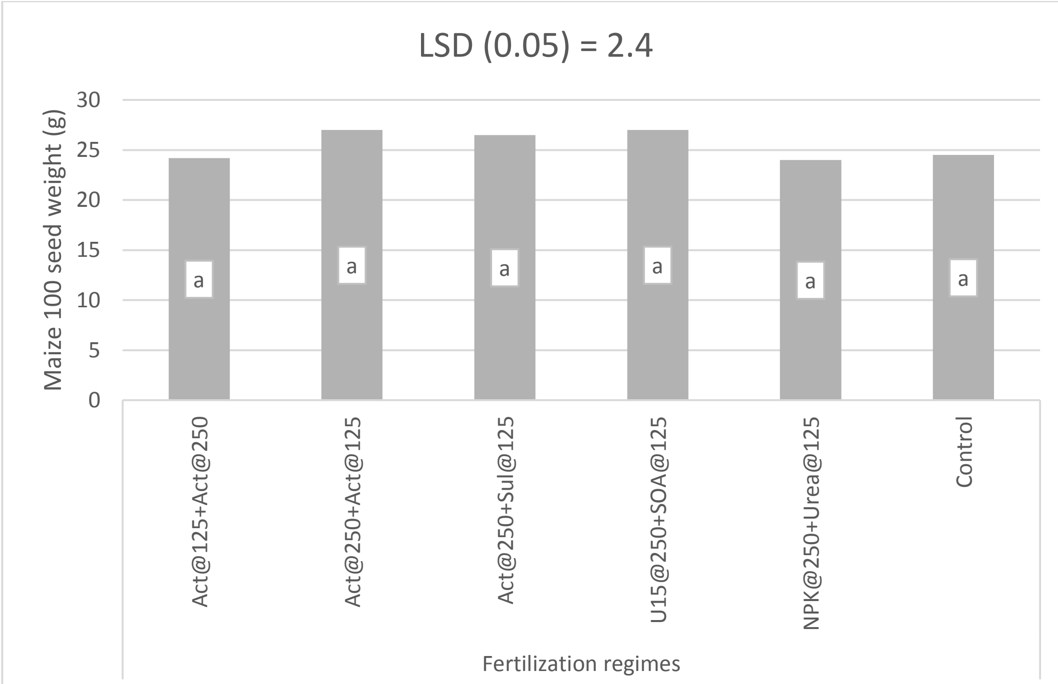

Figure 8: Impact of fertilizer regime on 100 seed weight of maize grown at Yendi during the 2019 cropping season. Bars with the same letters are not significantly different ($p < 0.05$).

DISCUSSION

Generally, the statistically similar 100 seed weight of maize as observed for the fertilization regimes across all sites showed the existence of relatively low impact of the nutrient regimes on grain filling and grain mass. One would have expected that different fertilization regimes would potentially affect the extent of grain filling as reported by Njoroge et al. (2018) and Lisuma et al. (2016. Moreover, the findings of this study contradict these previous findings, and show that the nutrient regimes used for the study may not significantly impact grain filling and grain mass of maize. In another study, however, Kugbe et al. (2019), found that grain mass was significantly affected by chemical fertilization regime. It is therefore likely that other nutrient regimes, aside the protocol used in this study may impact on the extent of grain filling and grain mass of maize.

The non-significant effect of fertilization regimes on maize yield at Nyankpala and Yendi, and on maize yield at Nyankpala may be attributed to non-responsive soils of the sites. With the differences in nutrient input, one would have expected differences in impact of the nutrient regimes that is attributable to fertilization. The non-responsive nature of the soils to chemical fertilization suggests the need for physical remediation of these soils to enhance their productivity. Apart from Nyankpala, the relatively high response to fertilization of up to 5-fold increases in yield showed that fertilization is important to achieve high yields in the nutrient-poor soils of northern Ghana. The highest yield of 5450 kg/ha for maize achieved from Act@250+Sul@125 at Walewale, and its comparableness to yields of Act@125+Act@250 and Act@250+Act@125 showed similarity in performance of the Actyva fertilizer formulations. Soils at Damango tended to have similar yields with the fertilization regimes, and the Actyva treatments had similar high yields that were greater than that of the control and Unik 15 in both Walewale and Yendi, indicating superior performance of Actyva to the Unik 15 and NPK formulations.

Though the fertilization regime tended to have similar rate of NPK, inclusion of Sulphur as secondary nutrient, and Boron and Zinc as micronutrients in the Actyva formulations may have contributed to their enhanced productivity in treatments that contain these fertilizers. As shown by Daphade et al. (2019), B and Zn as micronutrients enhance availability of primary and secondary nutrients to enable uptake by crops. The results showed that inclusion of micro nutrients in NPK fertilizer grade could increase photosynthetic activity and result in high grain yield. The findings of the study showed that sole availability of N, P and K only, as found in primary NPK fertilizers, even at higher application rates may not be adequate for enhanced photosynthetic ability in maize production for the nutrient-poor soils of northern Ghana. The increase in yield in Actyva-treated plots might also be due to uptake synergy as the micro nutrients contained in these fertilizers are reported to enhance availability of the other nutrients (Daphade et al., 2019). The superior performance of Actyva show the need for Sulphur and micro nutrient inclusion in chemical fertilizer formulation as proposed by Yigermal et al. (2019), and further agrees with Olowookere et al. (2017) who reported that micronutrient application enhanced the yield of maize biomass and grain yield.

To the resource-poor farmer, grain yield is the most economic end result of morphological and physiological processes that occur during growth and development of the maize plant. The reduction in grain yield in the lots that received no fertilization might have been due to deficiency of important nutrients including N, P and K. This result is similar to the findings of Kihara et al. (2017), Njoroge et al. (2018) and Lisuma et al. (2016), who revealed that grain yield could be significantly increased through secondary and micronutrient addition. The increase in grain yield due to secondary and micro nutrient inclusion relative to the control plot could be due to improvement in soil nutrient deficiency and imbalances. Sulfur is required by plants for synthesis of major metabolic compounds such as glutathione, proteins and amino acids and sulpho-lipids required for healthy crop growth (Qahar and Ehmad, 2016). While inclusion of Mg as a secondary nutrient in NPK formulation may have comparatively low effect on maize growth and yield, inclusion of Sulphur in plant nutrition is known to better enhance and synergize the uptake of other essential nutrients like N, thereby increasing both N use and S use efficiency and promoting the growth of the plant (Fismes et al., 2000).

Like Sulphur, Boron increases protein contents in the plant and also plays vital roles in cell wall division, synthesis, elongation and nucleic acid metabolism that translates into rapid plant growth (Tahir et al., 2012). Boron and zinc also work in synergy with hormones and enzymes that perform various functions in the metabolism of carbohydrate and protein and efficient water use in the crop (Ceyhan et al., 2008; Rudani et al., 2018). Under the prevailing rainfed system, which was marked by draught in the 2019 cropping season, enhanced water use efficiency is critical for the crops' development. These explain the observed high yield in plants that received boron and zinc micro nutrients compared to those that did not. As noted by Irfan et al. (2019), a synergy that is generated in Phosphorus uptake by Boron, enhances crop production even under Phosphorus-deficient soils upon Boron addition. Zinc plays roles in resistance to heavy metal concentration (Rizwan et al., 2019), diseases and enhances photosynthesis and carbohydrate accumulation (Rudani et al., 2018). The combined effect of Sulphur, boron and zinc may have synergistically resulted in the observed better growth and high yields in fertilizer formulations that included all three nutrients. This finding is in consonance with that reported by Kugbe et al. (2019). The foregoing reasoning explains why there were no significant difference between T1 and T2 for maize production, and also explains why T3 was higher than T4 in maize production in Walewale.

CONCLUSION

Maize grain yield obtained from each of the fertilizer treatments was significantly higher than the control. However, there were no significant differences between Act@125+Act@250 and Act@250+Act@125for maize production. Moreover, Act@250+Sul@125 had higher grain yield than U15@250+SOA@125 in maize production in Walewale while there was no significant difference between the two treatments at other locations. Soils at different sites responded differently to the fertilizer regimes. Damango tended to have similar maize yields on fields that received fertilization, but the Actyva treatments gave yields that were greater than yields of U15@250+SOA@125 and NPK@250+Urea@125 formulations. In all locations, the Actyva formulations gave similar high yields, indicating superior performance of these treatments to Unik 15 and NPK formulations. Yield increases of up to 500% were recorded and attributed to S, B and Zn inclusion that enhanced synergy in growth promoting factors- including protein and amino acid synthesizing properties of S, enhanced physiological and environmental tolerance to diseases, water stress, and improvements in P and N-uptake that promoted maize growth. Farmers can achieve maximum maize yield in the ecology through fertilization with Actyva formulations.

Competing interest

Authors have no conflict of interests

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