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EFFECT OF NPK FERTILIZER AND AGROLYSER ON GROWTH, YIELD AND YIELD COMPONENTS OF MAIZE IN NORTHEASTERN NIGERIA

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ABSTRACT

A field experiment was conducted at the Teaching and Research Farm of the Federal University of Kashere in the 2018 and 2019 cropping seasons to evaluate the effectiveness of sole and combined application of NPK fertilizer and agrolyser (micronutrient) on the growth and yield of maize. The experiment was factorial and laid out in Randomized Complete Block Design with three replications, comprising 9 treatments. The treatments were three levels each of NPK fertilizer (0, 100 and 150 kg ha^{-1} NPK fertilizer) and agrolyser (0, 3 and 5 kg ha^{-1}). The results indicated that the combined application of NPK and agrolyser significantly increased ($p< 0.05$) plant height (129.8 to 64 cm) and grain yield (1534.4 to 2315.2 kg/ha) in the 2018 and 2019 seasons respectively. Application of NPK at the rate of 150 kg ha^{-1} increased the plant height (139 to 189 cm) and grain yield (1773 to 2619 kg/ha) in the 2018 and 2019 cropping seasons respectively. Application of agrolyser at the rate of 3 kg ha^{-1} increased all the studied characters, but a further increase in rate from 3 to 5 kg ha^{-1} did not significantly increase the studied parameters any further. A combination of NPK (150 kg ha^{-1}) and agrolyser (3 kg ha^{-1}) recorded the highest mean values of plant height (183.7 cm), the number of cobs (47.6), 100-grain weight (23.1 kg/ha) and grains yield (2353 kg/ha) in both harvest years. It was, therefore, concluded that combined application of NPK fertilizer and agrolyser at the rates of 150 and 3 kg ha^{-1} respectively are the most suitable rates for maximum grain yield of maize

Keywords: Agrolyser, micronutrient, maize grain yield

INTRODUCTION

Globally, maize (Zea mays L.) is one of the most important annual cereal crops, providing a staple food as well as a source of income for many populations in developing countries (Tandzi *et al.*, 2020). It is a versatile crop grown over a range of agro-climatic zones (Borase *et al.*, 2018). It is known as the "Queen of Cereals" due to its high productive potential compared to other cereal crop (Borase *et al.*, 2018; Nirere *et al.*, 2019). It is known as a C4 plant, due to its ability to utilize solar radiation more efficiently even at higher radiation intensity (Borase *et al.*, 2018). The area and production of the maize crop in Nigeria is increasing year by year due to its high demand for animal and poultry feed and also the ease of cultivation because it is less susceptible to pests and diseases. National Agricultural Extension, Research Liaison Service (NAERLS) (2019) reported that Nigeria is the third major maize producer in Africa with an estimated harvested area of 6.03 million hectares and an average annual yield of 2.09 tons/hectare. Despite its high production volumes, farmers in the country recorded an annual average yield of 1.8 metric tons ha^{-1}, which is one of the lowest among the top 10 maize producers in Africa. Nigeria lags behind Egypt and South Africa where the yields are 7.7 metric tons ha^{-1} and 5.3 metric tons ha^{-1}, respectively. This makes it difficult to totally meet the domestic and industrial maize demand (Agridemy, 2020). Thus, there has been a growing gap between maize demand and its supply arising from low productivity.

In the Sub-Sahara of West Africa, particularly Nigeria, the majority of farmers have limited access to modern inputs such as pesticides, fertilizers, hybrid seeds and irrigation without some form of public sector intervention (Ogunwole *et al*., 2004). Some other constraints limiting maize production in Nigeria are climatic factors (rainfall, temperature and solar radiation), soil factors, migration, socioeconomic considerations, government policies, pests and diseases among others. These constraints result in an 80 – 100% yield reduction (Kamara *et al*., 2008). To address these constraints, researchers have developed several technologies for dissemination among farmers such as varieties that are resistant to drought and Striga (Kamara *et al*., 2019), and the use of green manure crops in rotation with cereals to improve soil fertility (Franke *et al*., 2006) as well as balanced nutrient management approach known as integrated soil fertility management (ISFM) (Sanginga *et al*., 2003).

Soil fertility degradation is a serious challenge for increased crop production in Nigeria, with nitrogen (N) and phosphorus (P) as the most limiting elements. Ramanjineyulu et al. (2018) opined that a successful soil fertility program must include primary (macronutrients and micronutrients) and secondary nutrients critical for maize growth and development. Vinod Kumar *et al.* (2018) opined that Fertilizer plays a significant role in increasing maize yield and their contribution is about 40 – 50 per cent. Balanced and optimum use of nitrogen, phosphorous and potassium fertilizer plays a pivotal role in increasing the yield of cereals (Asghar *et al*, 2010). Fertilizers enhance the natural fertility of the soil or replace the chemical elements extracted from the soil via crop harvesting, grazing, leaching or erosion. Organic and inorganic fertilizers are the common fertilizer types used for soil amendment in Nigeria (Chukwuka et al., 2015). Nitrogen (N) is the most important constituent element of proteins and also a component of several compounds such as chlorophyll and enzymes (Shamim *et al*., 2015). Studies have shown that N increases grain yield in maize as well as proteins in grain. Phosphorus is another essential nutrient, it plays an important part in photosynthesis, respiration energy storage transfer, cell division and elongation (Vinod Kumar *et al.*, 2018). Phosphorus improves seed and fruit formation as well as crop maturation. However, it hastens the ripening of fruits thus counteracting the effect of excess nitrogen application to the soil (Jaggi, 1998). It also helps to improve the skeletal structure of the plant thereby preventing lodging. In addition, it affects the quality of the grains and it may increase the plant's resistance to diseases. Potassium plays significant roles in enzyme activation, protein synthesis, photosynthesis, osmoregulation, stomata movement, energy transfer, phloem transport, cation-anion balance, and stress resistance (Shamim *et al*., 2015)

Agrolysers are trace elements which are needed by crops in small amounts and play an active role in the plant metabolic reaction, the shortage of which results in deficiency symptoms and crop yield reduction. They are to be added into the soil before crop planting or applied directly to the crop to increase maize productivity (Borase *et al.*, 2018). Trace elements especially Zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) have become yield-limiting factors, and their utilization by crops is quite in low amounts (<2.4 kg/ha^{-1}). About half of the world's cultivated soils are deficient in plant bio-available trace elements, due to their slow replenishment from the weathering of soil minerals, soil cultivation and insufficient crop fertilization (El-Azab, 2016). Relevant micronutrient deficiencies occur more frequently in neutral to alkaline soils, under anaerobic conditions and in arid or semi-arid regions (El-Azab, 2016). This paper attempts to make available new vital information that could help in increasing cereals production to meet the ever-increasing Nigeria's demand for both its human and animal population. The present investigation was undertaken to evaluate the effectiveness of sole and combined application of NPK fertilizer and agrolyser on the growth, yield and yield components of maize

MATERIALS AND METHODS

Site description

The experiment was conducted at the Teaching and Research Farm of the Federal University of Kashere (9° 46' 0''N and 10° 57' 0'' E and 431 m asl), Gombe State, during the 2018 and 2019 wet seasons, the same field was used in all the two years of study. Maize seeds were sown at two seeds per hole on 13th July 2018 and 22nd July 2019. The area lies in the Dry Sub-Humid Azare - Gombe -Yola Plain of Nigeria (FPDD, 2012). The annual mean rainfall and temperature in the area are about 850 mm and 32 ˚C, respectively, while the vegetation of the state is that of savanna woodland (Abubakar, 2013). The study area was derived from the Limestone and Shale of the Pindiga formation. The soil falls within the Leptosols, Cambisols and Luvisols from the Limestone and Shale of the Pindiga formation. It is deep, whitish, clay loam and free from concretions and stones. It is well drained, with good moisture-holding capacity. It is easy to cultivate by hand and machines and supports many crops such as cereals, legumes, root, and tuber crops. The experimental plots used for the trial had not been cultivated for years; there was no record of fertilizer usage. The soil was well-drained and on a gentle slope.

Treatments and experimental design

The trials consisted of three levels each of NPK fertilizer (0, 100 and 150 kg ha^{-1}) and Agrolyser (0, 3 and 5 kg ha^{-1}), tested on maize (SYN 8 PVA). The experimental design was a 3 × 3 factorial design arranged in a randomized complete block design with three replications. Each experimental plot size was 3 m x 3 m = 9 m^2 and a total of 27 plots were used for the trial, with a 1.0 m path between blocks and 0.5 m between plots. The experimental area was ploughed, harrowed and demarcated into experimental units. SYN 8 PVA maize variety was used for the study and seeds were treated with apron-plus and planted at 0.75 m inter-row spacing and 0.25

m intra-row spacing, using 2 seeds/planting holes. However, two weeks after emergence, the plants were thinned to 1 plant/stand, resulting in a uniform plant density of 53,333 plants per hectare. Manual weeding was carried out at 3 and 6 weeks after planting (WAP). Fertilizer application was done at 3 WAP in the 2018 and 2019 wet seasons respectively, according to treatment combinations by band placement. Maize was harvested when the cobs reached physiological maturity. Further sun-drying of the maize cobs was done before shelling.

Soil sampling and analysis

Before the trial establishment, soil samples were taken from each experimental field and analyzed for initial nutrient status. The soil samples were collected using an auger from at least 5 points in a W-shape to have a representative sampling. The samples were taken from 0 – 15 cm from each plot and then bulked together to form a composite sample, and then passed through a 2 mm sieve. The composite sample was prepared using standard procedures and analyzed for physical and chemical properties. The soil sample was analyzed for soil texture, pH, organic carbon, total Nitrogen, available Phosphorus, exchangeable Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}, and cation exchange capacity. Soil texture was determined by the Bouyoucos hydrometer method (Bouyoucos, 1962). Soil pH was determined using the potentiometric method at the soil-to-water ratio of 1:2 (Miller and Kissel, 2010). Soil organic carbon was determined by the Walkley Black combustion method (Nelson and Sommers, 1996). Total nitrogen was analyzed by the modified Kjeldahl oxidation method where salicylic acid was added during digestion to include nitrate-N and nitrite-N (Okalebo *et al*., 2002), whereas available phosphorus was determined by Bray 1 method (Bray and Kurtz, 1945). Exchangeable Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} were determined by extraction with 1 N NH_4OAC. K^{+} and Na^{+} in the extract were determined with a flame photometer, while Ca^{2+} and Mg^{2+} were determined using an atomic absorption spectrophotometer following the procedures outlined by Udo *et al.* (2009).

Data Collection

Plant height was measured at harvest. This was done by measuring with a measuring tape from the base to the tip of the highest shoot/leaf of the plant. The diameters of ten cobs from each net plot were measured using measuring tape around the cob and the average values were recorded. Five plants in the net plot were sampled, the number of cobs on each plant was counted and the average value was determined and recorded. A total of 100 seeds from each plot were counted and weighed on an electronic top-loading Mettler balance to obtain the weight of 100 seeds. From the seed yield per plot, seed yield per hectare for each plot was computed by converting it into kilogram per hectare by extrapolation.

Data analysis

Data collected were subjected to Analysis of Variance (ANOVA) using Statistical Analysis System version 9.0 (2002). The treatment means were separated by the least significant difference (LSD).

RESULT AND DISCUSSION

Soil physical and chemical properties of the study area

The physical and chemical properties of the soil of the experimental site during the 2018 cropping seasons before the application of treatments are shown in Table 1. The soil is sandy loam, moderately acidic in pH (H_2O) 5.6 which is within the range considered optimum for most crop growth and development. The organic carbon (2.7 g kg^{-1}), total N (0.2 g kg^{-1}), available phosphorus (6.9 mg / kg), exchangeable K (0.1 cmol / kg), Fe (3.74 mg / kg), Cu (0.44 mg / kg), Zn (0.74 mg / kg), and Mn (3.94 mg / kg) respectively were found below the average critical limit (Esu, 1991). The results of soil analysis thus indicated that soil amendment was required in line with the observation of Agboola (1975) who reported that farmers in Africa require adequate soil amendments for good crop production.

Table 1: Pre-planting soil physical and chemical properties of the experimental site

Parameters	Description
Sand (g kg^{-1})	560
Silt (g kg^{-1})	290
Clay (g kg^{-1})	150
Soil texture	Sandy Loam
pH (H_2O)	5.7
Org. C (g kg^{-1})	2.7
Total N (g kg^{-1})	0.2
Available P (mg kg^{1})	6.9
Exchangeable cations (cmol kg^{-1}):	
Ca^{2+}	9.6
Mg^{2+}	3.2
K^{+}	0.1
Na^{+}	0.3
CEC (cmol kg^{-1})	4.0
Fe (mg kg^{1})	3.74
Cu (mg kg^{1})	0.44
Zn (mg kg^{1})	0.74
Mn (mg kg^{1})	3.94

Seasonal effects on maize production as influenced by NPK and Agrolyser fertilizers

The results, as shown in Figure 1, indicated that the plant height, yield and its components during both seasons were significantly ($p \leq 0.05$) increased by the NPK levels, Agrolyser and their interaction in the 2018 and 2019 wet seasons. Plant height (164 cm), number of cobs (47.3), and 100-grain weight (20.2 kg ha^{-1}) were found higher in the 2019 wet season than in the 2018 wet season which had plant height (129.8 cm), number of cobs (33.9), and 100-grain weight (20 kg ha^{-1}). It was found that a higher grain yield (2315 kg ha^{-1}) was produced in the 2019 cropping season compared to (1534 kg ha^{-1}) in the 2018 cropping season. The higher maize grain yield in the second year (2019) could be attributed to the residual effects of the previous year's treatment, coupled with the additional fertility improvements in the second year (Iren, 2019). It could also be attributed to the positive influence of increased water supply for vigorous plant growth and dry matter production, arising from the higher rainfall status in the 2019 cropping season. However, no significant disparity was found for 100-grain weight.

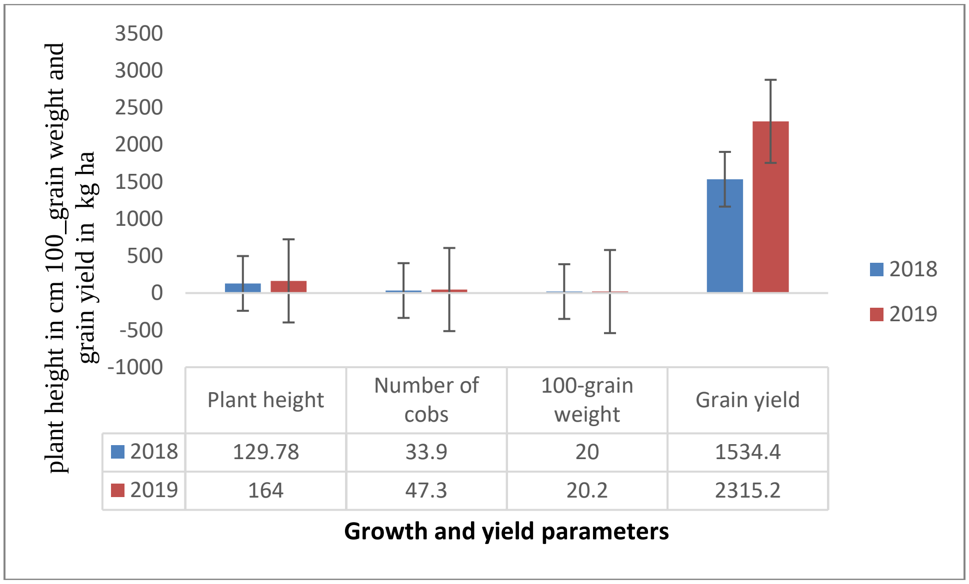

Figure 1 Seasonal effects on maize production as influenced by NPK and Agrolyser fertilizers

Effects of NPK levels on the plant height, yield and yield components of maize

The results as shown in Table 2, revealed that increasing the NPK rate from 0 up to 150 kg/ha^{-1} increased plant height and number of cobs. The lowest mean values of these parameters were found in the control treatment during the two growing seasons. However, the 100- grain weight, and grain yield differed and were increased significantly ($p \leq 0.05$) by 150 kg ha^{-1} NPK fertilizer (Table 3). In 2018 and 2019, the combined mean application of 150 kg NPK ha^{-1} produced significantly taller plants, more cobs, and heavier seeds. The increase in plant height, number of cobs and 100-grain weight with an increase in nitrogen fertilizer application clearly indicate the importance of inorganic fertilizer in the performance of maize (Ibrahim *et al* 2018). This clearly shows the effect of compound fertilizer as a basic component of many physiological processes in plants (Ibrahim *et al* 2018; Ananya *et al.,* 2019). Application of NPK fertilizer at the rate of 150 kg ha^{-1} gave the highest mean values of yield characters of maize, followed by 100 kg ha^{-1} of NPK fertilizer. The lowest values of the plant attributes were obtained in the control treatment during the two years of study.

Application of NPK significantly influenced grain yield in the two years of study and their combined mean (Table 3). In combined mean, application of 100 kg NPK ha^{-1}

significantly increase grain yield by 133% over zero NPK treatment. The increase in grain yield with an increase in nitrogen fertilizer application clearly indicates the important role of nitrogen enhancing chlorophyll, nucleotides, alkaloids, proteins, enzymes, hormones and vitamins production and photosynthesis which improved assimilates production for subsequent translocation to grains Bationo and Ntare (2000). This indicated the effect of nitrogen as a basic component of many physiological processes in plants (Ibrahim *et al* 2018; Ananya *et al.*, 2019). The significant increase in grain yield obtained in this study could be attributed to the fact that maize plants that received NPK used effectively the applied nitrogen to enhance better performance on yield components which could have led to better yield for NPK-treated plants than plants in the zero NPK control plots (Adesoji *et al.*, 2013). Similar increases in grain yield of maize with nitrogen application were reported by Inamulhaq and Jakhro, (1996); Usman *et al.* (2013) and El-Gizawy (2009).

Table 2: Effect of different treatment combinations of NPK and Agrolyser fertilizers on plant height and Number of cobs of Maize (*Zea mays L.*)

	Plant height (cm)				**Number of cobs**			
Treatment	**2018**	**2019**	**Mean**	**% Increase**	**2018**	**2019**	**Mean**	**% Increase**
NPK kg ha^{-1}								
0	49^c	58^c	54^c		19^c	20^c	20^c	
100	121^b	144^b	133^b	146	34^b	43^b	39^b	95
150	139^a	189^a	164^a	203	36^a	49^a	43^a	115
Se±	2.28	0.69	9.63		0.45	0.34	1.45	
Agrolyser **kg ha^{-1}**								
0	62^c	73^c	68^c		23^b	26^c	25^c	
3	163^a	184^a	174^a	162	47^a	53^a	50^a	100
5	147^b	166^b	157^b	131	39^b	43^b	41^b	64
Se ±	2.02	0.52	8.23		0.32	0.21	1.12	
Interaction								
N x A	**	**	**		**	**	**	

N x A = Interaction between NPK and Agrolyser. Means followed by the same letters (s) within the same column and treatment are not significantly different at a 5 % level of probability, using LSD Duncan's Multiple Range Test (DMRT)

Effects of the Agrolyser rates on the plant height, yield and yield components of maize

The effects of agrolyser effects on the plant height (cm), number of cobs, 100-grain weight (g), and grains yield (kg ha^{-1}) in both seasons are shown in Tables 2 and 3. The results demonstrated that 3 kg ha^{-1} agrolyser treatment significantly resulted ($p \leq 0.05$) in the tallest maize plants (163 cm) in 2018 and (184 cm) in 2019 and yield 1679 kg ha^{-1} in 2018 and 2460 kg ha^{-1} in 2019 compared to control lower values. Iren *et al.* (2012) opined that balanced fertilization is necessary for optimum plant growth which involves the application of both macro-and micronutrients in the right amount and proportions for optimum crop yield. Agrolyser fertilizer had earlier been reported by Iren (2019) to positively affect plant height and crop yield. Generally, 3 kg ha^{-1} agrolyser treatment significantly ($p \leq 0.05$) increased the numerous tested attributes during the two cropping seasons. The study conducted by Garba *et al*. (2018) reveal that the application of secondary macronutrients and or micronutrients enhances agronomic use efficiency of N, P and K. Similar increase in the grain yield of maize were reported by Agbede and Otonko (2004) where NPK and agrolyser were applied in combination or singly. In contrast, a study conducted by Adeyinka (2008) revealed that the combined application of Agrolyser with NPK has been reported to reduce the crop yield of maize on a typical tropical rainforest soil. The positive increase in plant height and yield obtained from the fertilizer additions was due to the low initial nutrient status of the soil. Moreover, agrolyser cannot be substituted for NPK fertilizer but it could be used as a soil amendment for the supply of micronutrients. Abdullahi *et al*. (2011) stressed the need for micronutrient inclusion in fertilizer packages as supplements of macronutrients for higher yield, especially in soils with micronutrients below critical levels. The average data for the years 2018 and 2019 showed that the application of 3 kg ha^{-1} agrolyser treatment significantly increased plant height by 162%, the number of cobs by 100%, 100-grain weight by 134% and grain yield by 161% over zero agrolyser treatment. A further increase up to 5 kg ha^{-1}, however, did not produce any significant difference on all the tested attributes, when compared with 3 kg ha^{-1} agrolyser treatment.

Table 3: Effect of different treatment combinations of NPK and Agrolyser fertilizers on 100-grain weight and grain yield of Maize (*Zea mays L.*)

Treatment	100-grain weight (g)				Grain yield kg/ha^{-1}			
	2018	2019	Mean	% Increase	2018	2019	Mean	% Increase
NPK kg ha^{-1}								
0	9.4^{c}	8.0^{b}	8.7^{c}		700^{c}	767^{c}	734^{c}	133
100	18.8^{b}	21.8^{b}	20.3^{b}	179	1530^{b}	2560^{b}	2045^{b}	157
150	21.2^{a}	23.6^{a}	22.4^{a}	199	1773^{a}	2619^{a}	2196^{a}	
Se ±	0.46	0.25	0.29		114.8	26.5	73.7	
Agrolyser kg ha^{-1}								
0	8.0^{b}	8.4^{c}	8.2^{c}	134	867^{c}	900^{c}	884^{c}	
3	20.6^{a}	22.2^{a}	21.4^{a}	120	1679^{a}	2460^{a}	2070^{a}	161
5	20.7^{a}	19.3^{b}	20.0^{b}		1518^{b}	2377^{b}	1948^{b}	144
Se ±	0.22	0.12	0.17		94.4	17.5	56.6	
Interaction								
N x A	**	**	**		**	**	**	

N x A = Interaction between NPK and Agrolyser. Means followed by the same letters (s) within the same column and treatment are not significantly different at a 5 % level of probability, using LSD Duncan's Multiple Range Test (DMRT)

Effect of the interaction between NPK and agrolyser levels on plant height, yield and yield components of maize

A significant interaction between NPK and agrolyser was observed in plant height, the number of cobs, 100-grain weight and grain yield in 2018 and 2019 (Figs. 2 and 5). The interaction between NPK and agrolyser on the mean plant heights showed that taller plants were obtained with a combination of 150 kg NPK ha^{-1} and 3 kg ha^{-1} agrolyser. At a given NPK rate, increasing agrolyser beyond 3 kg ha^{-1} did not produce a significant effect on plant height, the number of cobs, 100-grain weight, and grain yield of maize.

There was a significant interaction of NPK and agrolyser on plant height, number of cobs, 100-grain weight and grain yield of maize in which the combination of 150 kg ha^{-1} NPK and 3 kg ha^{-1} agrolyser was the best at increasing the measured parameters. This might be due to the balanced supply of nutrients from both NPK and agrolyser throughout the growth, grain filling, and development stages. In control plots, the shorter plants have the least number of cobs, 100-grain weight and grain yield were reported by Ibrahim *et al*. (2018) and the possible reason was the unavailability of nitrogen and less dry matter accumulation. Abdullahi *et al.* (2011) stressed the need for micronutrient inclusion in fertilizer packages as supplements to macronutrients for higher yield, especially in soils with micro-nutrients below critical levels.

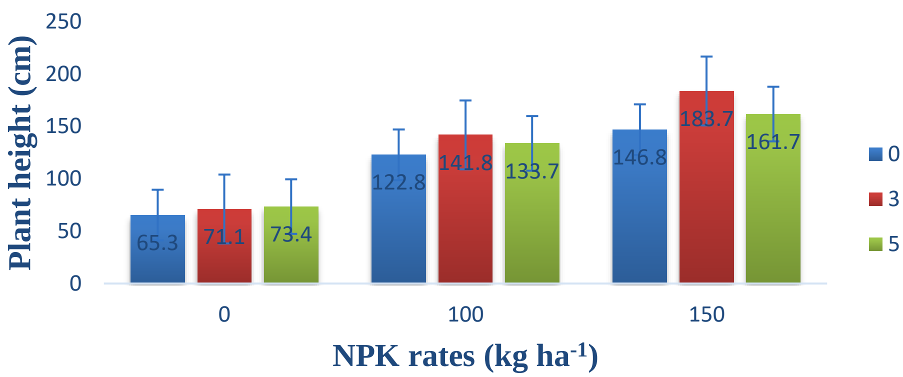

Figure 2: Interaction between NPK rates and Agrolyser level on Plant height (cm), LSD $_{0.05}$ = 4.51

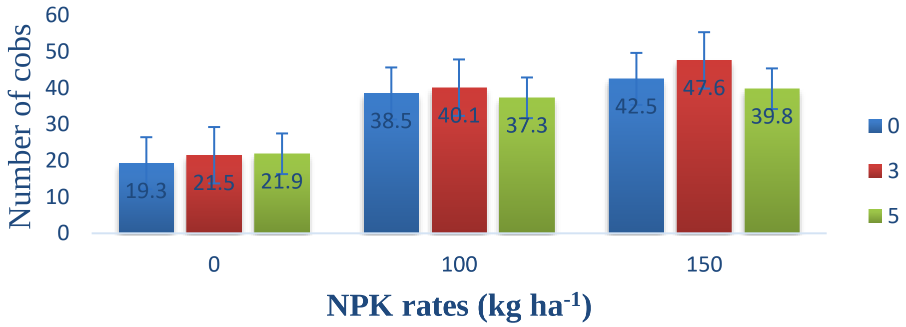

Figure 3: Interaction between NPK rates and Agrolyser level on the number of cobs, LSD $_{0.05}$ = 1.96

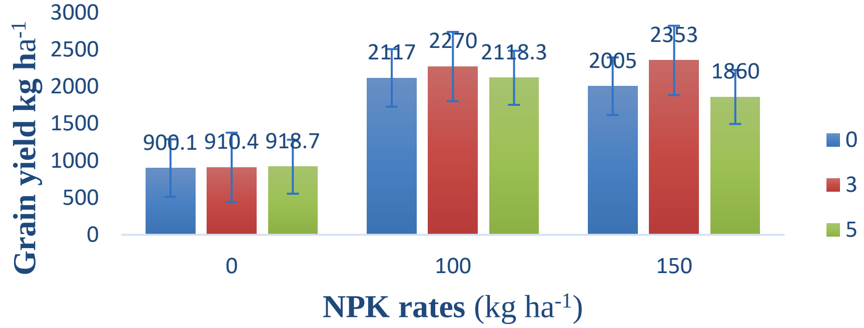

Figure 4: Interaction between NPK rates and Agrolyser level on grain yield (kg ha^{-1}), LSD $_{0.05}$ = 60.2

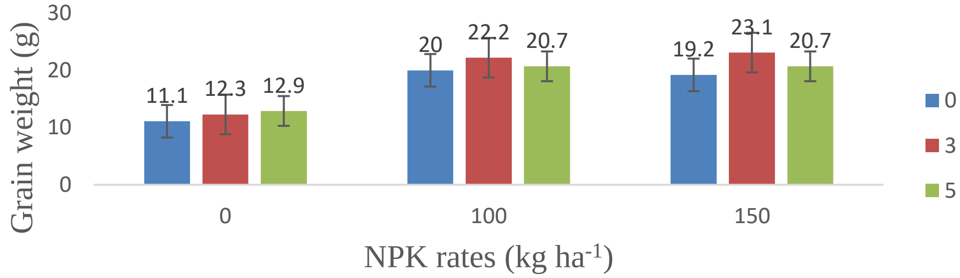

Figure 5: Interaction between NPK rates and Agrolyser level on 100-grain weight (g), LSD $_{0.05}$ = 2.62

CONCLUSION

On average, plant height, grain yield and yield components of maize crop were significantly increased by application of NPK, agrolyser and their combinations. The highest increases in plant height, number of cobs, 100-grain weight and grain yield were found with the combined application of NPK at the rate of 150 kg ha^{-1} and agrolyser at the rate of 3 kg ha^{-1}. Therefore, with the combination of NPK (150 kg ha^{-1}) and agrolyser (3 kg ha^{-1}), it is possible to attain a high yield of maize in the study area and its nearby environment However, additional study is needed to investigate the effect of higher levels of agrolyser and NPK fertilizer as soil amendments on maize yield and its effects on soil properties.

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