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Effects of Variety and Plant Growth Regulators on the Growth and Yield of Some Maize (*Zea mays* l.) Varieties in Yola Adamawa State Nigeria

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Abstract
This study examines the effects of variety and plant growth regulators on the growth of some maize varieties in Yola with the aim of proffering vital recommendations towards improving maize yields in the area. Field trials were conducted during 2019, 2020 and 2021 growing seasons at the Department of Crop Production and Horticulture Teaching and Research farm, Modibbo Adama University Yola. The treatments consisted of three varieties of maize (M12M, SAMMAZ-37 and Admiral Improved Seed) and seven plant growth regulators (Cytokinins, Super-gro, Growth force, Boostract, Nanomix, Vitalon and Water as a control). The treatments were laid out in a split plot design replications three times. Maize varieties were assigned to the main plots and plant growth regulators assigned to sub plots. Data were collected on plant height, stem girth, ear diameter, ear length, grain weight per plant and grain yield kg ha^{-1}. Data collected were subjected to analysis of variance (ANOVA) using the Generalized Linear Model Statistical Package Version 9.1. Least Significant Difference (LSD) was used to separate the means at 5 % level of probability. The results indicated that variety significantly affects plant height, stem girth, ear length and grain yield. The results on plant growth regulators also shows a significant effect on plant height, ear diameter, ear length, grains weight per plant and grains yield. Higher grains yield (5.24 tones ha^{-1}) was obtained in variety M12M while application of cytokinins recorded the higher grains yield of 5.73 tones ha^{-1} though statistically similar with other growth regulators except with vitalon, and control recorded the least (4.06 tones ha^{-1}). There was no significant interaction between the varieties and plant growth regulators on all the parameters measured. The best variety in term of grains yield was M12M, while cytokinins was found to be the best plant growth regulator respectively thus recommended for the study area.

Keywords: Maize varieties, plant growth regulators, growth and yield

Introduction

Maize (*Zea mays* L.) is the third most important cereal crop in the world after wheat and rice (FAO, 2011). It is an important cereal crop in Nigeria with a total production of about 7.3 million tons in 2009 (FAO, 2011). Corn is a crop that originated in Mexico and spread all over the world as a major food crop. It is a member of the grass family and was introduced to west Africa by the Portuguese in the 10th century and has been in the Nigerian diet for decades. It is an important crop grown in commercial quantities and supply raw materials to many agro-based industries (Iken and Amusa, 2014). The global demand for maize almost hit 3 billion metric tons in 2019. This is because of its wide variety of uses industrially, serves as major staple food for families and because of its importance in producing livestock feed, while the global production was about 1,112.01 million MT leaving about a deficit of 1.9 million MT. In the same year 2019, Africa had a total production volume of about 90 million MT and Nigeria averaged production volume of about 11 million MT making it the 2nd largest producer in the continent, after South Africa with 16 MT and Ethiopia the 3rd with 8.4MT (FAO,2011). However, FAOSTAT (2012) reported that Nigeria is the largest producer of maize in Africa with about 10 million MT followed by South Africa, Egypt and Ethiopia.

The local demand for maize in Nigeria is as high as 12 million MT excluding exports leaving a deficit of over 2 million MT FAOSTAT (2012). This is one of the many reasons why it is keen on farmers having all the quality inputs and agrochemicals needed to increase production. Research has forecasted that the world population will reach 9.1 billion in 2050. To meet the demand of this growing population, production has to increase by 2.4 % in yield (Alexandratos and Bruinsma, 2012). Therefore, maize should be considered one of the main pillars for global food security (FAOSTAT, 2012). Besides, the use of traditional varieties may not be able to sustain production that can meet up with the ever-increasing population of globally.

Therefore, in the search for sustainability, plant biostimulants can be used as growth promoters for crops (Panfili *et al.,* 2019). Biostimulants are mixtures of natural or synthetic plant regulators, chemical compounds (vitamins and nutrients), algal extracts, microorganisms, and amino acids (Frasca *et al.,* 2020; Araújo *et al.,* 2021) that can improve crop quality and yield (Colla *et al.,* 2021; Vendruscolo *et al.,* 2021). Biostimulants containing auxin, cytokinins, and gibberellin may favor an increase in the absorption of water and nutrients by plants, thus allowing resistance to water stress. Vitamins such as nicotinamide can alleviate biotic and abiotic stresses by acting on electron transport and cellular and respiratory metabolism (Kirkland and Meyer, 2018), indirectly assisting in vegetative growth and development through cell elongation, leading to an increase in yield traits, especially under adverse conditions, as it acts directly on plant tissues (Berglund *et al*., 2017).

Biostimulants are natural or synthetic substances that can be applied to seeds, plants, and soil. These substances cause changes in vital and structural processes in order to influence plant growth through improved tolerance to abiotic stresses and increase seed and/or grain yield and quality. In addition, biostimulants reduce the need for fertilizers (Dujardin, 2015). Many classifications of biostimulants have been reported. According to Basak (2008), biostimulants could be classified depending on the mode of action and the origin of the active ingredient; while Bulgari and Cocetta (2015) proposed that biostimulants should be classified based on their action in the plants or, on the physiological plant responses rather than on their composition. In addition, (Du, 20119) has emphasized the importance of the final impact on plant productivity which suggests that any definition of biostimulants should focus on the agricultural functions of biostimulants, either on the nature of their constituents or on their modes of actions. Yakhin and Lubyanov (2017) defined biostimulants as a formulated product of biological origin that improves plant productivity because of the novel or emergent properties of the complex of constituents, and not as a sole consequences of the presence of known essential plant nutrients, plant growth regulators, or plant protective compounds. This definition is important as it emphasizes the principle that biological function can be positively modulated through the application of molecules, or mixtures of molecules, for which an explicit mode of action has not been defined. In small concentrations, these substances are efficient, enhancing nutrition efficiency, abiotic stress tolerance, and/or crop quality traits, regardless of its nutrients content. These substances when applied exogenously have similar actions to the groups of known plant hormones, whose main ones are auxins, gibberellins and cytokinins (Yaronskaya and Vershilovskaya, 2006). When applied correctly in the crops, it acts directly on the physiological processes providing potential benefits for growth, development, and/or responses to water stress, saline, and toxic elements, such as toxic aluminium (Du, 2019; Couto and Peixoto, 2012).

These products which differ from traditional nitrogen, phosphorus and potassium fertilizers may contain in their formula a variety of organic compounds such as humic acids, seaweed extracts, vitamins, amino acids, ascorbic acid, and other chemicals which may vary according to its manufacturer (Yaronskaya and Vershilovskaya, 2006). Biostimulants offer a potentially novel approach for the regulation and/or modification of physiological processes in plants to stimulate growth, to mitigate stressinduced limitations, and to increase yield. Several researches have been developed in order to evaluate the use of biostimulants in improving plant growth subjected to abiotic stresses. Furthermore, various raw materials have been used in biostimulants compositions, such as humic acids, hormones, algae extracts and plant growth-promoting bacteria (Du, 2019).

Plant growth regulators (PGRs) are chemicals used to modify plant growth such as increasing branching, suppressing shoot growth, increasing return bloom, removing excess fruit, or altering fruit maturity. The application of plant growth regulators is known to accelerate the adaptation response to drought stress through the spicing of the mRNA protein doubling mechanism (Neill *et al.*, 2019). Plant growth regulators has been found commercially and serves to protect as an abiotic agent of stress or climate change that is not optimal for plant growth. Broadly speaking, plant growth regulators can be classified into two groups, namely bio-stimulants and growth inhibitors, both of which fall into five types, namely, auxins, cytokinins, gibberellins, abscisic acid and ethylene (Rademacher, 2015).

Zhang *et al*. (2017), reported that the use of PGRs could increase maize yields by increasing plant density and reducing the percentage of plant lodging (weak roots). From the report of Spitzer *et al*. (2015), the application of PGRs can also be used to obtain optimal maize plant height, which decreases 40-90 cm in plant height.

Maize production in Nigeria is limited by several factors including inadequate use of improve varieties and poor soil fertility management. Most of our farmers are ignorant of selecting proper varieties and use of plant growth regulators for maize production that can give maximum yield. Considering the potential of biostimulants and plant growth regulators, this study hypothesizes that using these products in second-crop maize can improve production components and yield. The above challenges are justification for a need to improve yields by making agriculture more efficient, profitable and sustainable, particularly for small holders. The benefits of plant growth regulator, plant growth stimulant and proper selection of varieties as stated above cannot be overemphasized and this justify the reason for the experiment to be conducted. Therefore, the objectives of the study are to evaluate the effects of variety on the growth and yield of some maize varieties in the study area; evaluate the effects of plant growth regulators on the growth and yield of some maize varieties in the study area; and determine the best interaction of plant growth regulators and varieties that can give maximum growth and yield of maize in the study area.

Materials and Methods

Experimental Site

The research was carried out at the Teaching and Research Farm of the Department of Crop Production and Horticulture, Modibbo Adama University, Yola during the 2019, 2020 and 2021 growing seasons. Yola, located within the Northern Guinea Savannah zone of Nigeria lies between latitude 9^0 13” to 9^0 19’’ N and longitude 12^0 19” to 12^0 28” E, with annual mean temperature of 28^0 C and rainfall of 700 mm-1000 mm (Adebayo and Tukur, 2020).

Treatments and Experimental Design

The treatments consisted of seven (7) Plant Growth Regulators (PGRs): (Cytokinins, 0.4%, Super-gro, Brassinolide 0.01 %, Boostract, Nanomix, Vitalon 2000 and Water as a control), and three maize varieties (M12M, SAMMAZ-37 and Admiral Improved Seed). The treatments were laid out in split plot design replicated three times. The gross plot size is 4.5 m x 3 m (13.5 m^2) and net plot size is 3 m x 2 m (6 m^2). Maize varieties were assigned to the main plots and plant growth regulators assigned to sub-plots.

Agronomic Practices

Land cultivation

The land was cleared manually, ploughed using tractor, leveled and divided into plots and replicated as designed.

Sowing

Seeds of the three maize varieties were sown at the spacing of 75 cm x 25 cm with two seeds per hole and later thinned to one plant per stand at two weeks after sowing (WAS).

Fertilizer application
Compound fertilizer (NPK) were applied at the rate of 120 kg N, 30 kg P_20_5 and 30 kg K_20 ha^{-1} respectively. Half of the N together with P and K were applied at 2 weeks after sowing using NPK 20:10:10 and the remaining half of the N was applied 7 WAS using urea (46% N).

Weed control
Weed control was carried out using hand weeding at three (3) weekly interval using hoe from 3 WAS up to 9 WAS.

Harvesting
The crops were harvested when the husk turned yellowish brown, the ears was de-husked, shelled and winnowed to obtain grain yield.

Sources of Experimental Materials
The maize varieties (M12M, SAMMAZ-37 and Admiral Improved Seeds) where obtained from certified seed vendor in Yola town while plant growth regulators (Cytokinins, Brassinolide, Super-gro, Boostract, Nanomix and Vitalon) were obtained from Northern Scientific Ltd in Yola for used in the experiment.

Description of the Maize Varieties.

1. ***M12M:*** Early maturing, white colored grain, resistant to mildew, highly prolific, more tolerant to lodging with excellent plant and ear with yield potential of 5 – 9 tones ha^{-1} (Nigeria Seed Portal Initiative 2020).
2. ***SAMMAZ-37:*** Some of its outstanding characteristics includes: good quality grains, tolerance to maize streak virus diseases, drought and striga resistant with high yielding of about 5-9 per hectare (Nigeria Seed Portal Initiative 2020).
3. ***Admirals Improved Seed:*** The seed are white in colored with wide adaptability, resistant to drought and striga, high quality seeds, higher yielding, resistant to pest attacks with yield potential of about 4–7 tones ha^{-1} (Nigeria Seed Portal Initiative, 2020).

Application of Plant Growth Regulators
All the plant growth regulators were foliar applied at 2, 4, and 6 WAS. Cytokinins 0.4 % was applied at the rate of 300 ml per ha^{-1} (30 ml was diluted per knapsack of clean water), brassinolite 0.01 % was applied at the rate of 80 g per ha^{-1} (8 g was dissolved per knapsack of clean water) while Super-gro, Boostract, Nanomix, and Vitalon were applied at the rate of 200 ml per ha^{-1} each (20 ml were diluted per knapsack of clean water). And the control plots received no plant growth regulators were sprayed with water.

Data Collection
1. Plant height (cm): Five plants were tagged from each plots and plant height were measured using a meter rule from the ground level to the tip of the flag leaf at two weekly intervals from 2 to 12 WAS. The average mean was computed and recorded.
2. Stem girth (mm)**:** The stem girth of the five tagged plants was measured using a micro-meter screw gauge (vernier caliper) and the average mean calculated and recorded.
3. Ear diameter (cm): Ears diameter from the five tagged plants of each plot was taken at harvest and their diameter measured with a vernier caliper and the average mean computed and recorded.
4. *Ear length (cm*): Ears length from the five tagged plants from each plot was taken at harvest and their length measured with a meter rule and the average mean computed and recorded.
5. Grains weight per plant: Grains weight from the five tagged plants of each plot was taken at harvest and their average mean computed and recorded.
6. Grain yield (kg ha^{-1}): Grain yield was determined by harvesting and threshing of ears from the whole net plot of each treatment. The grain weight per net plot was calculated and then converts to the grains yield per hectare. (Weight of the grains divided by the area of the net plot and multiplied by 10,000 m^2).

Data Analysis

Analysis of variance (ANOVA) was carried out on each of the observation recorded as described by Gomez and Gomez (1984) for each year of study using SAS version 9.2 (2000). Mean values were separated using the least significant difference (LSD) at 0.05 level of probability.

Results

Effect of Maize Variety and Plant Growth Regulators on Plant Height per Plant of Maize (Zea mays L.) during 2019, 2020 and 2021 Growing Seasons

The result of the effects of variety and plant growth regulators on plant height (cm) per plant of maize during 2019, 2020 and 2021 growing seasons is presented in Table 1. The result shows that effect of variety on plant height of maize was highly significant ($P \leq 0.01$) at 4 WAS and significant ($P \leq 0.05$) at 12 WAS in 2019; significant ($P \leq 0.05$) at 10 and 12 WAS in 2020 and at 4 WAS in 2021. In 2019, 4 WAS, variety M12M produced the tallest plants of 22.95 cm which is statistically the same with SAMMAZ-37 (22.70 cm), while Admiral Improved Seed recorded the shortest plant with 18.85 cm. At 12 WAS, SAMMAZ-37 recorded the tallest plants (133.3 cm) which is statistically similar with M12M (126.0 cm) while Admiral Improved Seeds produced the shortest plants (120.30 cm).

In 2020 however, at 10 WAS, Admiral Improved Seed produced the tallest plants of 126.80 cm which is statistically similar with SAMMAZ-37 (119.40 cm), and M12M recorded the shortest plants of 112.20 cm. At 12 WAS, SAMMAZ-37 recorded the tallest plant (162.00 cm), followed by Admiral Improved Seed (127.40 cm) while M12M recorded the shortest plants (111.40 cm). In 2021 at 4 WAS, SAMMAZ-37 produced the tallest plants (43.50 cm) which is statistically similar with M12M (37.13 cm) and Admiral Improved Seed recorded the shortest plants (30.90 cm).

Effect of plant growth regulators on plant height was highly significant ($P \leq 0.01$) at 4 WAS in 2020 and at all the sampling periods in 2021. In 2020 at 4 WAS, foliar application of Vitalon recorded the tallest plants (21.88 cm) which are at par with all the rest of growth regulators and control recorded the lest (15.22 cm). Similarly, in 2021 at 2 WAS, Vitalon recorded the tallest plant (9.26 cm) which is also statistically similar with the other growth regulators except with Nanomix which are at par with the control and recorded the shortest plants (7.66 cm and 6.66 cm) respectively. At 4 WAS, Cytokinins produced the tallest plants of 40.76 cm which are at par with all the rest of growth regulators and control recorded the shortest plants (28.30 cm). At 6, 8, 10 and 12 WAS, application of Vitalon recorded the highest mean values of 89.3, 134.2, 146.8 and 152.0 cm which are statistically similar with all the rest of the plant growth regulators and control treatment recorded least mean values of 65.9, 100.2 112.3 and 117.6 cm respectively. There was no significant ($P>0.05$) interaction between varieties and plant growth regulators on plant height during the period of the research.

Effect of Variety and Plant growth regulators on Stem Girth of Maize (Zea may L.) during 2019, 2020 and 2021 growing seasons

The results on the effect of variety and plant growth regulators on stem girth of maize during 2019, 2020 and 2021 growing seasons is presented in Table 2. The result shows that varietal differences were only significant ($p \leq 0.05$) on stem girth at 8 WAS in 2019. Variety M12M recorded the highest value of 2.33 cm^2 which is statistically the same with SMMAZ-37 (2.24 cm^2), while Admiral Improve Seed recorded the lest stem girth (2.28 cm^2).

Effect of plant growth regulators on stem girth was highly significant ($p \leq 0.001$) at 4 WAS in 2020 and at all the sampling periods in 2021. In 2020, 4 WAS, application of Vitalon produced the thicker stem girth of 1.47 cm^2 which is statistically similar with the rest of the plant growth regulators and control recorded the least (0.52 cm^2). In 2021, at 2 WAS, application of Brassinolite recorded the thickest stem girth of 0.50 cm^2 which are at par with the rest of the plant growth regulators and control recorded the least girth (0.33 cm^2). At 4 WAS, application of Cytokinins recorded the highest stem girth of 1.39 cm^2 which is statistically the same with

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Super-gro (1.35 cm^2) and Vitalon (1.37 cm^2) while control recorded the least (1.03 cm^2). Similarly, at 6 WAS, application of Cytokinins recorded the highest stem girth of 2.03 cm^2 which are at par with the rest of the plant growth regulators and control recorded the least (1.56 cm^2). At 8 WAS however, application of Super-gro recorded the thickest stems of 2.14 cm^2 which did not differ statistically with the rest of the plant growth regulators and control treatment recorded the least (1.68 cm^2). At 10 WAS, Cytokinins recorded the thickest stems (2.21 cm^2) while control recorded the least (1.10 cm^2). At 12 WAS, the thickest stems were produced from the application of Cytokinins (2.32 cm^2) which are at par with the rest of the plant growth regulators except with Nanomix (2.19 cm^2), and control recorded the lest (1.72 cm^2). There was no significant ($p > 0.05$) interaction observed between the varieties and growth regulators on stem girth of maize during the three years of the study

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Table 1: Effect of Variety and Plant Growth Regulators on Plant height of Maize (*Zea mays* L.) at Various Sampling Periods in Yola During 2019, 2020 and 2021 Growing Seasons

	Plant height in 2019						Plant height in 2020						Plant height in 2021					
Treatments	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS
Varieties																		
M12M	11.52	22.95	68.50	96.00	105.00	126.00	6.27	18.75	35.80	107.00	112.20	111.40	7.95	37.13	76.00	121.00	134.40	140.30
Sammaz-37	19.67	22.70	64.80	140.10	112.00	133.30	5.85	21.15	36.20	118.60	119.40	162.00	9.06	43.50	87.50	131.60	144.70	148.70
Admiral	9.65	18.85	60.00	89.00	199.00	120.30	6.02	20.00	39.00	109.00	126.80	127.40	8.07	30.90	71.50	118.00	133.00	140.60
P of F	0.488	0.013	0.152	0.254	0.204	0.047	0.744	0.692	0.885	0.440	0.037	0.052	0.809	0.033	0.244	0.267	0.302	0.401
LSD	3.293	2.958	8.71	66.2	117.8	10.67	1.447	7.400	18.88	120.4	9.97	12.09	5.065	8.229	22.66	23.71	18.66	17.44
PGRs																		
Cytokinins	11.38	20.49	66.70	99.00	111.00	131.20	6.13	19.93	37.20	115.0	121.40	119.20	9.07	40.76	83.80	132.00	144.10	149.20
Super-gro	12.94	21.47	64.80	92.00	105.00	123.30	6.61	21.20	38.70	105.00	118.60	116.80	8.41	38.93	75.50	127.60	142.90	148.50
Brassinolite	10.02	20.13	71.20	100.00	110.00	133.10	6.13	19.69	39.50	104.00	117.70	127.70	8.78	36.80	79.10	127.30	140.20	147.60
Boostract	10.63	22.49	68.40	194.00	107.00	133.10	6.03	20.47	34.70	231.00	119.60	117.50	8.73	39.20	78.60	127.50	141.40	146.50
Nanomix	9.93	21.79	69.90	93.00	217.00	129.00	6.11	21.38	35.50	108.00	118.10	113.90	7.66	37.02	76.00	120.80	136.10	141.20
Vitalon	10.03	19.96	63.50	96.00	226.00	126.60	5.49	21.88	35.70	107.00	122.00	123.50	9.25	39.24	89.30	134.20	146.80	152.00
Control	10.30	24.20	46.30	85.00	95.00	110.40	5.82	15.22	37.90	114.00	117.00	117.10	6.66	28.30	65.90	100.20	112.30	117.60
P of F	0.824	0.442	0.066	0.386	0.620	0.122	0.162	0.016	0.945	0.473	0.978	0.251	0.001	0.001	0.001	0.001	0.001	0.001
LSD	4.954	4.535	15.70	109.1	201.2	16.80	0.762	3.671	9.83	136.4	12.64	11.45	1.127	4.250	7.75	11.85	9.78	8.88
Interaction																		
Var x PGRs	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

WAS= Weeks after sowing, NS= Not Significant, PGRs= Plant Growth Regulators, Var. = varieties.

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Table 2: Effect of Variety and Plant Growth Regulators on Stem Girth of Maize (*Zea mays* L.) (cm^2) at Various Sampled Period in Yola During 2019, 2020 and 2021 Growing Season

	Stem girth/plant 2019						Stem girth/plant 2020						Stem girth/plant 2021					
Treatments	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS
Varieties																		
M12M	1.45	1.46	1.97	2.33	2.66	2.91	0.43	1.19	1.39	1.43	1.43	1.40	0.41	1.24	1.94	2.05	2.06	2.18
Sammaz-37	1.12	1.37	1.88	2.24	2.59	2.82	0.39	1.23	1.38	1.40	1.46	1.43	0.51	1.39	0.93	2.03	2.05	2.15
Admiral	0.96	3.75	1.85	2.18	2.59	2.87	2.04	1.19	1.37	1.46	1.51	1.46	0.41	1.14	1.92	1.96	2.03	2.19
P of F	0.80	0.46	0.10	0.05	0.55	0.26	0.43	0.96	0.98	0.66	0.44	0.42	0.56	0.12	0.69	0.57	0.67	0.82
LSD	2.02	4.39	0.18	0.11	0.15	0.12	3.16	0.41	0.35	0.17	0.16	0.13	0.27	0.26	0.63	0.23	0.09	0.17
PGRs																		
Cytokinins	0.85	1.26	1.91	2.23	2.73	2.94	0.41	1.25	1.39	1.38	1.47	1.38	0.47	1.39	2.03	2.10	2.23	2.32
Super-gro	1.31	1.34	1.96	2.31	2.80	2.90	0.48	1.34	1.50	1.51	1.54	1.49	0.45	1.27	2.00	2.14	2.11	2.26
Brassinolide	1.24	1.43	1.96	2.23	2.71	2.85	0.40	1.16	1.36	1.38	1.43	1.46	0.50	1.35	1.10	2.07	2.10	2.24
Boostract	2.12	1.40	1.96	2.36	2.71	2.77	0.49	1.37	1.38	1.39	1.47	1.46	0.45	1.27	1.10	2.04	2.11	2.23
Nanomix	0.87	1.33	1.84	2.19	2.65	2.79	0.46	1.31	1.33	1.41	1.49	1.36	0.43	1.18	1.97	2.03	2.08	2.19
Vitalon	1.19	1.22	1.96	2.33	2.81	2.92	4.12	1.47	1.28	1.44	1.48	1.44	0.46	1.37	1.98	2.04	2.08	2.26
Control	0.67	1.38	1.79	2.09	1.89	2.68	0.31	0.52	1.12	1.20	1.30	1.31	0.324	1.029	1.558	1.678	1.103	1.719
P of F	0.411	0.471	0.836	0.441	0.155	0.460	0.458	0.001	0.574	0.447	0.179	0.599	0.001	0.001	0.001	0.001	0.001	0.001
LSD	1.339	7.128	0.299	0.277	0.718	0.309	4.063	0.297	0.221	0.165	0.182	0.149	0.0759	0.094	0.078	0.128	0.114	0.113
Interaction																		
Var x PGRs	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

WAS= Weeks after sowing, NS= Not Significant, Var. = Varieties, PGRs= Plant Growth Regulators.

Effect of Variety and Plant Growth Regulators on Ear Diameter of Maize (Zea mays L.) during 2019, 2020 and 2021 Growing Seasons

The result of the effects of variety and plant growth regulators on ear diameter of maize in 2019, 2020 and 2021 is presented in Table 3. Effect of variety was not significant ($p > 0.05$) on ear diameter of maize during the three years of study. However, effect of plant growth regulators was highly significant ($p \leq 0.01$) on ear diameter of maize in 2021 growing season. Application of Cytokinins recorded the highest ear diameter of 4.01 cm^2 which is statistically similar with the rest of the plant growth regulators except with Vitalon (3.84 cm^2), and control treatment recorded the least (3.53 cm^2). There was no significant ($p > 0.05$) interaction between the varieties and plant growth regulators on ear diameter of maize in during the period of the study.

Table 3: Effect of Variety and Plant Growth Regulators on Ear Diameter of Maize (*Zea mays* L.) in Yola During 2019, 2020 and 2021 Growing Seasons

	Ear Diameter (cm^2)		
Treatments	2019	2020	2021
Varieties (Var.)			
M12M	4.60	3.70	3.89
SAMMAZ 37	4.09	4.30	3.86
Admiral Improved Seed	4.21	3.85	3.89
P of F	0.403	0.363	0.914
LSD	0.709	1.064	0.200
PGRs			
Cytokinins	5.29	5.04	4.01
Super-gro	4.22	3.85	3.94
Brassinolide	4.22	4.72	3.96
Boostract	4.05	3.88	3.91
Nanomix	4.16	3.76	3.98
Vitalon	4.28	3.72	3.84
Control	3.88	3.66	3.53
P of F	0.356	0.481	0.001
LSD	1.270	1.445	0.150
Interaction			
Var. x PGRs	NS	NS	NS

PGRs= Plant Growth Regulators, NS= Not Significant

Effect of Variety and Plant Growth Regulators on Ear Length of Maize (Zea mays L.) during 2019, 2020 and 2021 Growing Seasons

The result of the effects of variety and plant growth regulators on ear length of maize during 2019, 2020 and 2021 growing seasons is presented in Table 4. Effect of variety on ear length of maize was highly significant ($p \leq 0.01$) in 2019. SAMMAZ-37 produced the longest ears of 15.41 cm which is statistically the same with M12M (15.21 cm) while Admiral Improved Seed recorded the shortest ears (14.49 cm). Effect of plant growth regulators on ear length of maize was significant ($p \leq 0.05$) in 2019 and highly significant ($p \leq 0.01$) in 2021. In both years, application Boostract recorded the longest ears (15.66 cm and 13.18 cm) which are statistically the same with all the rest of the plant growth regulators and control treatments recorded the shortest ears length (14.23 cm and 10.67 cm). There was no significant ($P>0.05$) interaction between variety and plant growth regulators on ear length of maize during the period of the studies.

Table 4: Effect of Variety and Plant Growth Regulators on Ear Length of Maize (*Zea mays* L.) in Yola During 2019, 2020 and 2021 Growing Seasons

	Ear length (cm)		
Treatments	2019	2020	2021
Varieties (Var.)			
M12M	15.21	11.29	12.46
SAMMAZ 37	15.41	11.70	12.33
Admiral Improved Seed	14.49	12.41	11.73
P of F	0.014	0.609	0.229
LSD	0.628	2.974	1.016
PGRs			
Cytokinins	15.66	11.87	13.18
Super-gro	15.00	11.49	12.71
Brassinolide	15.11	12.22	12.78
Boostract	15.57	11.51	11.33
Nanomix	14.76	11.56	12.49
Vitalon	14.92	12.51	12.09
Control	14.23	11.42	10.67
P of F	0.024	0.422	0.018
LSD	0.769	1.194	1.476
Interaction			
Var. x PGRs	NS	NS	NS

PGRs= Plant Growth Regulators, NS= Not Significant

Effect of Variety and Plant Growth Regulators on Grains Weight (g) Plant^{-1} of Maize (Zea mays L.) during 2019, 2020 and 2021 Growing Seasons

The result of the effects of variety and plant growth regulators on grains weight plant^{-1} of maize during 2019, 2020 and 2021 is presented in Table 5. Effect of variety was not significant (P>0.05) on grains weight plant^{-1}of maize during the period of the study. However, there was a highly significant (P ≤ 0.01) difference among the plant growth regulators on grains weight per plant of maize in 2020 and 2021. In 2020, application of Boostract produced the highest grains weight of 77.80 g which is statistically similar with all the rest of plant growth regulators and control treatment recorded the least (54.20 g). In 2021, application of Cytokinins produced the highest grains weight of 107.5 g which is statistically similar with all the plant growth regulators except with Vitalon (90.9 g), and control recorded the least grains weight of 76.1 g plant^{-1}. There was no significant (P>0.05) interaction between the varieties and plant growth regulators on grains weight per plant of maize during the period of the study.

Table 5: Effect of Variety and Plant Growth Regulators on Grains Weight (g) plant^{-1} of Maize (*Zea mays* L.) in Yola During 2019, 2020 and 2021 Growing Seasons

	Grains Weight (g) Plant^{-1}		
Treatments	2019	2020	2021
Varieties (Var.)			
M12M	97.00	76.40	100.30
SAMMAZ 37	99.00	66.00	97.20
Admiral Improved Seed	95.00	73.10	95.10
P of F	0.288	0.288	0.687
LSD	15.0	15.88	15.72
PGRs			
Cytokinins	108.00	74.30	107.50
Super-gro	100.00	76.70	104.60
Brassinolide	102.00	71.90	98.90
Boostract	100.00	77.80	102.00
Nanomix	105.00	74.70	102.80
Vitalon	96.00	73.20	90.90
Control	87.00	54.20	76.10

P of F	0.459	0.001	0.001
LSD	24.8	8.53	13.87
Interaction			
Var. x PGRs	NS	NS	NS

PGRs= Plant Growth Regulators, NS= Not Significant

Effect of Variety and Plant Growth Regulators on Grains Yield (kg ha^{-1}) of Maize (Zea mays L.) during 2019, 2020 and 2021 Growing Seasons

The result of the effects of variety and plant growth regulators on grains yield kg/ha^{-1} of maize during 2019, 2020 and 2021 is presented in Table 6. Effect of variety was only significant ($P \leq 0.05$) on grains yield in 2020. Variety M12M recorded the highest grains yield of 5,239 kg ha^{-1}, followed by SAMMAZ-37 (4,034 kg ha^{-1}) while Admiral Improved Seeds recorded the lest grains yield (3,903 kg ha^{-1}). However, effect of plant growth regulators on grains yield was highly significant ($P \leq 0.01$) in 2021. Application of Cytokinins recorded the highest grains yield of 5,734 kg/ha which is statistically similar with all the plant growth regulators except with Vitalon (4,852 kg), and control treatment recorded the least grains yield (4,058 kg ha^{-1}). There was no significant (P>0.05) interaction between the varieties and plant growth regulators on grains yield during the period of the study.

Table 6: Effect of Variety and Plant Growth Regulators on Grains Yield (kg ha^{-1}) of Maize (*Zea mays* L.) in Yola During 2019, 2020 and 2021 Growing Seasons

	Grains yield (kg ha^{-1})		
Treatments	2019	2020	2021
Varieties (Var.)			
M12M	5536	5239	5348
SAMMAZ-37	5328	4034	5074
Admiral Improved Seed	5163	3903	5185
P of F	0.077	0.050	0.683
LSD	408.8	407.4	436.9
Plant Growth Regulators			
Cytokinins	5770.00	3832.00	5734
Super-gro	5290.00	4092.00	5576
Brassinolide	5423.00	3837.00	5274
Boostract	5346.00	4065.00	5439
Nanomix	5387.00	3982.00	5481
Vitalon	5123.00	3865.00	4852
Control	4825.00	3480.00	4058
P of F	0.107	0.393	0.001
LSD	591.2	619.3	739.1
Interaction			
Var. x PGRs	NS	NS	NS

PGRs= Plant Growth Regulators, NS= Not Significant

Discussion

Effect of Variety and Plant Growth Regulators on Growth Characters of Maize

The significant performance of SAMMAZ-37 on plant height over M12M and Admiral Improved Seed could be due to its genetic makeup. Kareem *et al.* (2020) also reported that when two or more varieties of maize were treated equally, the genetic difference of the varieties manifested. However, they did not record any significant differences on the plant height due to varietal differences. Hasan *et al.* (2018) also reported a significant difference on the growth parameters of maize due to varietal differences but plant height was not affected by varietal differences. In contrast to their findings, and in line with the result of this study, Marfo-Ahenkora *et al.* (2023) observed a significant influence of variety on plant height of maize.

The maximum plant height recorded in the application of Vitalon though at par with rest of the plant growth regulators could be due the humic substance and nitrogen compound contained in Vitalon as a stimulant. Stimulant contained humic substance and nitrogen compound and when used in the form of soil preparation, powder, granules or solution added to the soil or as liquid foliar application enhances the growth of crop (Kocira *et al*., 2018). Jules *et al*. (1981) also stated that plant growth regulators influences plant growth and development of a crop. Peleg and Blumweld (2011) also noted that plant growth regulators are important regulators of plant growth and mediate responses to both biotic and abiotic stresses, they play central role in the ability of plant to adopt to changes in environment, by mediating growth, development, nutrient allocation and source/sink transition.

The none significant effect of variety on stem girth could be due to their adaptability to the environment as well as all the varieties are either hybrids or improved seeds. Kareem *et al*. (2020) also reported that the genetic makeup of each variety have influence on stem girth of maize. The significant influence of the plant growth regulators over the control on stem girth could be due to their positive effect on the growth and development of a plant. Latime and Secoggic (2010) also stated that application of plant growth regulators can result in sturdier and more compact plant with capacity to maintain tree structure. Oliveira *et al*. (2016) also reported a significant response of stimulant on stem girth of maize.

Effect of Variety and Plant Growth Regulators on Yield Attributes of Maize (Zea mays L.)

The significant effect of variety on ear length and its none significant on ear diameter and grain weight per plant could be due to their genetic variability. Kareem *et al*. (2020) reported that when two or more varieties of maize were treated equally, the genetic difference of the varieties manifested and observed a significant difference on ear length and ear diameter. On the other hand, Hasan *et al*. (2018) also observed a significant effect of variety on ear length and ear diameter of maize. The significant effect of the plant growth regulators with cytokinins lead on ear length and ear diameter over the control could be due to the influence of these plant growth regulators in enhancing the growth of the crop. Trivadi *et al.* (2017) also reported a higher yield component of maize after several application of the bio stimulant when compared with the control. Layek *et al.* (2016) also obtained higher ears length in the application of bio stimulant over the control. The result is also in line with the findings of Qandeel *et al*. (2020) who obtained higher ear length and ear diameter in the application of bio stimulant over the control.

Effect of Variety and Plant Growth Regulators on Grain Yield of Maize (Zea mays L.)

The significant influence of M12M variety over the rest of the varieties on grain yield could be due to its high yielding potential. The result is in line with the findings of Hasan *et al*. (2018) who reported that high yielding variety with higher genetic makeup also has the importance of getting highest yield. Kareem *et al*. (2017) also observed a significant influence of variety on grains yield per hectare of maize. Babaji *et al*. (2012) believed that new hybrids varieties have greater grain yield potential than the other varieties because these varieties are normally smaller, produce higher leaves, have higher leaf area and have low maturity leaf shading problem than the other cultivars. The significant effect of plant growth regulators with cytokinins producing the highest grain yield though statistically the same with other growth regulators over Vitalon and control confirmed the role of cytokinins and other growth regulators in enhancing grain yield of a crop. Stone *et al*. (1999) also observed an increased in biomass production and grain yield of maize with the application of bio stimulant when compared to the control. Significant higher biological and grain yield was also observed in the application of plant growth regulators over the control by Qandeel *et al*. (2020).

The none significant interaction between the varieties and plant growth regulators on all the growth, yield and yield attributes during this study demonstrated that the management of plant growth regulators on varietal differences may not influence the growth and yield of maize. This result is in line with the findings of Barcelos *et al*. (2019) who did not observe any significant interaction between maize genotypes and growth regulators on the variables: plant height, number of leaves, tassel weight, tang weight, tang length, leaf weight, number of spikes, stem weight, stem diameter, ear diameter and whole plant weight.

Conclusion

From the foregoing, it could be concluded that variety M12M produced better growth and grains yield while among the plant growth regulators Cytokinins produced the best growth and grains yield and are hereby recommended for adaption in the study area.

References

Adebayo, A.A. and Tukur, A.L. (2020). *Mean Annual Rainfall. Adamawa State in Maps.* 1st Edition. Paraclete Publishers Nigeria Ltd, Yola-Nigeria. 23-26.

Alexandratos, N. and Bruinsma, J. (2012). World Agriculture toward 2020 2050, ESA Working Paper.

Araújo, L.L.M., De, R., Brachtvogel, D. and Kovalski, E.A. (2021). Ação de bioestimulantes em cultivares comerciais de soja na região Norte do Vale Araguaia -MT. Revista Pesquisagro, (4), p.3-21, *The Scoop on Horticulture*, 1-3.

Babaji, B.A., Ibrahim, V.B., Mahadi, M.A., Jahya, M.M., Yahaya, R.A. and Sharifai, A.I. (2012). Response of extra early maize to verifying intra-row spacing and will density. *Global Journal of Bio-science and Bio-technology*, l (1) pp.110-115.

Barcelos, M.N., Reginaldo, C., Regina, M.Q., Lana, Uira, A., Ronaldo, S., Viana, T.A., Nagueira, R. and Ana, A. C. (2019). Effects of levels of Growth Regulator and Application periods in Maize Genotypes on the Agronomic Traits. *Journal of Agricultural Science*, Vol. 11, No. 16. ISSN 1916-9752 E-ISSN 1916-9760. Published by Canadian Center of Science and Education.

Basak, A. (2008). "Biostimulators – definitions, classification and legislation," in *Monographs Series: Biostimulators in Modern Agriculture. General Aspects*, ed Gawrońska, H., Battacharyya, D., Bangohari, M.Z., Rathor, B.D., Bangohari, M.Z., Rathor, P. and Prithiviraji, B. (2015). Seaweed Extracts as Biostimulants in Horticulture. *Science. Horticulture*, 196, pp.39-48.

Berglund, T., Wallstrom, A., Nguyen, T.V., Laurell, C. and Ohlsson, A.B. (2017). Nicotinamide; antioxidative and DNA hypomethylation effects in plant cells. Plant Physiology Biochemistry, 118, p.551-560. *Journal of plaphy.* 2017.07.023.

Bulgari, R. and Cocetta, G. (2015). Biostimulants and crop responses: A review. *Biological Agriculture and Horticulture*.;31:1-17. DOI: 10.1080/01448765.2014.964649

Colla, R. L. da, S., Lima, S. F., Vendruscolo, E. P., Secco, V.A., Piati, G.L., Santos, O.F.D and Abreu, M.S. (2021). Does foliar nicotinamide application affect second-crop corn (*Zea mays*)? Revista de la Facultad de Ciencias Agrarias - UNCuyo, (53):64-70, https://doi.org/10.48162/rev.39.040.

Couto, C.A. and Peixoto, C.P. (2012). Ação da cinetina, ácido indolbutírico e ácido giberélico na emergência do girassol sob estresse por alumínio. Comunicata Scientiae, 3:206-209.

Du, J. P. (2019). The science of plant biostimulants—A bibliographic analysis, Ad hoc Study Report. 2012. Brussels: European Commission. Available from: http://hdl.handle.net/2268/169257 [Accessed: 25-04]

Dujardin, P. (2015). Plant stimulants, definition, concept, main categories and regulation. *Sciences Horticulture*. Vol.194, pp.3-14.

FAOSTAT (2012). Food and Agricultural Organization, FAOSTAT. Retrieved October 6, 2015 from http://Faostat.fao.org.

FAO (2011). Food and Agricultural Organization, FAOSTAT. Retrieved October 6, 2015 from http://Faostat.fao.org.

Frasca, L.L. De, M., Nascente, A.S., Lanna, A.C., Carvalho, M.C.S. and Costa, G.G. (2020). Bioestimulantes no crescimento vegetal e desempenho agronômico do feijão comum de ciclo superprecoce. Revista Agrarian, 13, p.27-41, https://doi.org/10.30612/agrarian.v13i47.8571.

Gomez, K.A. and Gomez, A.A. (1984). *Statistical procedure for Agricultural Research*. Second edition Wiley-Inter Science Publication. New York. 680.

Hasan, R.M., Rahman, R.M., Hasan, K.A., Poul, K.S. and Alam, J.A.H.M. (2018). Effect of variety and spacing on the yield performance of maize (*Zea mays* L.) in old Brahmaputra floodplain area of Bangladesh. *Archives of Agriculture and Environmental Science* 3(3): 270-274.

Iken, J.E. and Amusa, A. (2004). Maize Research and production in Nigeria. *African Journal of Biotechnology*, 3(6): 302-307.

Jules, J., Robert, W.S., Frank, W.N. and Varnon, W.R. (1981). Plant science. *An introduction to world crops*. W.H. Freeman and Co. New York p.55-64, 162-192.

Kareem, I., Taiwo, S.O., Kareem, S.A., Oladosu, Y., Eifediyi, E.K., Abdulmaliq, S.Y., Alasinrin, S.Y., Adekola, O.F. and Olalekan, K.K. (2020). Growth and yield of two maize varieties under the influence of plant ensity and NPK fertilization. *Journal of apllieid scince, environment and management*, 24 (3) 531-536.

Kareem, O.B., Jawando, E.K., Eifediyi, W.B. and Oladosu, Y. (2017). Improvement of growth and yield of maize (*Zea mays* L.) by poultry manure, maize variety and plant population. *Cercetari Agronomic in Moldova*, (172):51-64.

Kirkland, J.B. and Meyer-Ficca, M. L. (2018). Niacin. Advances in Food and Nutrition Research. .83, p.83-149. https://doi.org/10.1016/bs.afnr.2017.11.003.

Kocira, A., Swieca, M., Kocira, S, Zlotek, U. and Jackubczyk, A. (2018). Enhancement of yield, Nutritional and Nutraceutical properties of two common bean cultivars following the application of seaweed extract. *Saudi Journal Biology Science*, (25):563-571.

Latime, J.G. and Scoggins, H. (2010). Virginia cooperative Extension Publication 430-103, pp 1-40.

Layek, J., Das, A. and Ramkrushna, G.I. (2016). Effects of seaweed sapon germination, growth and productivity of maize, in North Eastern Himalayas. *Indian Journal of agronomy*, 61, pp 354-359.

Marfo-Ahenkora, E., Taah, K.J., Owusu, D.E. and Asere-Bediako, E. (2023). On-farm experimentation with improved maize seed and soil amendments in Southern Ghana: productivity effects in small holder farm. *Hindwi International Journal of Agronomy*. 2023. Article IDD 1882121, 16 pages.

Nigeria Seed Portal Initiative. (2020). Retrieved September, 8 2010.

Neill, E.M., Byrd, M.C. Billman, R., Brandizzi, T.F. and Stapleton, A.E. (2019). Plant growth regulators interact with elevated temperature to alter heat stress signaling via the Unfolded Protein Response in Maize Science Rep, 9: 10392.

Oliveira, F.A., Medeiros, J.F, Cunha. R.C, Souza, M.W.L. and Lima, L.A. (2016), Uso de bioestimulante como agente amenizador do estresse salino na cultura do milho pipoca. Revista Ciência Agronômica.;47:307-315. DOI: 10.5935/1806-6690.20160036

Panfili, I., Bartucca, M.L., Marrolo, G., Povero, G. and Buono, D.D. (2019). Application of a plant biostimulants to improve maize (*Zea mays*) tolerance to Merolachlor. *Journal of Agricultural Food Chemistry*, (67):12164-12171.

Peleg, Z. and Blumwald, E. (2011). Hormone balance and abiotic stress tolerance in crop plants. *Current opinion in plant biology*, 14(3): 290- 295.

Qandeel, M., Jabbar, A., Haidar, F.U., Virk, A.L. and Ain, N.U. (2020). Effect of plant growth regulators and dates planting on spring maize production under Agro-Climatic conditions of Faisalabad, Pakistan. *Pakistan Journal of Agriculture, Agricultural Engineering and Vetinary Science,* 36 (2): 120-128.

Rademacher, W. (2015). Plant growth regulators: Backgrounds and uses in plant production *Journal of Plant Growth Regulators*, 34: 845–72.

SAS, (2000). User's Guide, Statistics, Version 9.2 Edition. Statistical Analysis Software Institute, Inc., Cary, NC

Stone, P.J., Sorensen, I.B. and Jamieson, P.D. (1999). Effect of soil temperature on phenology, canopy development, biomass and yield of maize in a cool temperate climate. *Field Crops Research*, 63:169-178.

Spitzer, T., Míša, P., Bílovský, B. and Kazda, J. (2015). Management of Maize stand height using growth regulators, 51: 223–30

Trivadi, K., Amand, K.G., Kubavat, D., Kumar, R., Vaghela, P. and Ghosh, A.C. (2017). Crop stage selection is vital to elicit optimal response of maize to seaweed biostimulant application. *Journal of applied physiology*, (29): 2135-2144.

Vendruscolo, E.P., Lima, S. and De, F. (2021). The *Azospirillum* genus and the cultivation of vegetables. A review.

Biotechnology, Agronomy and Society and Environment, 24, p.236-246, https://doi.org/10.25518/1780-4507.19175.

Yakhin, O.I. and Lubyanov, A.A. (2017). Biostimulants in plant science: A global perspective. *Frontiers in Plant Science*, (7):1-32.

Yaronskaya, E. and Vershilovskaya, I. (2006). Cytokinin effects on tetrapyr role biosynthesis and photosynthetic activity in barley seedlings. Planta.;224:700-709

Zhang, F., Zhao, P., Shan, W., Gong, Y., Jian, Q. and Pan, C. (2012). Development of a method for the Analysis of four plant Growth.