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Growth, Flowering and Yield of Maize (*Zea Mays* L.) as Affected by Plant Growth Regulators and Variety in Yola Adamawa State Nigeria

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Abstract

The world is faced with rising demand of maize for food, animal feeds and industrial needs, and the production could not meet up with these increased demands due to low yield obtained in farmer field as a result of poor varietal selection and non-use of plant growth regulators. The field experiments were conducted at the Department of Crop Production and Horticulture Teaching and Research Farm, Modibbo Adama University Yola, Adamawa state Nigeria during 2019, 2020 and 2021 rainy seasons to evaluate the effects of varieties and plant growth regulators on the growth, flowering and yield of maize (Zea mays L.). The treatments consisted of three varieties of maize (M12M, SAMMAZ-37 and Admiral Improved Seeds) and seven plant growth regulators (Cytokinins, Super-gro, Growth force, Boostract, Nanomix, Vitalon and Water as control). The treatments were laid out in a split plot design with three replications. Maize varieties were assigned to the main plot and plant growth regulators to sub plot. Data were collected on establishment count, number of leaves, days to 50 % tasseling, days to 50 % silking and grain yield. Data collected were subjected to analysis of variance using statistical analysis software (SAS) system version 9.1 and least significant difference was used to separate the means at 5 % level of probability. The results indicated that varieties had significant effects on establishment count, number of leaves and number of days to 50 % tasseling, while plant growth regulators significantly affect number of leaves, days to 50 % tasseling, days to 50% silking and grains yield. Higher grains yield (5.23 tones ha^{-1}) was obtained in variety M12M, while cytokinins recorded the highest grains yield of 5.73 tones ha^{-1} though statistically similar with other growth regulators except with vitalon, and control recorded the least (4.06tones ha^{-1}). There were no significant interactions between the varieties and plant growth regulators in all the parameters measured. For higher grains yield, variety M12M and Cytokinins were found to be promising and are hereby recommended as the best variety and plant growth regulators respectively for farmers to adopt in the study area.

Background of the Study

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). 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 hits 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. Nigeria averaged production volume is about 11million MT making it the 2nd largest producer in the continent, after South Africa with 16millionMT and Ethiopia the 3rd with 8.4millionMT (FAO, 2011). However, FAOSTAT (2021) reported that Nigeria is the largest producer of maize in Africa with about 11 million MT followed by South Africa, Egypt and Ethiopia.

The local demand in Nigeria is as high as 13 million MT excluding exports leaving a deficit of over 2 million MT (FOASTAT, 2021). 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, 2021). 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). Maize production in Nigeria is limited by several factors including inadequate use of improve varieties, poor soil fertility management, ignorant of selecting proper varieties and none use of plant growth regulators for maize production that can give maximum yield. The above challenges are justification for a need to improve yields by making agriculture more efficient, profitable and sustainable, particularly for small holders.

Objective of the Study

The broad objectives of the study are to evaluate the effects of plant growth regulators and variety on the growth, flowering and yield of maize in the study area; while the specific objectives are to determine the best plant growth regulators and varieties that can give minimum number of days to flowering with 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 28^0C and rainfall of 700mm-1000mm (Adebayo and Tukur, 2020).

Treatments and Experimental Design

The treatments consisted of three maize varieties (M12M, SAMMAZ-37 and Admiral Improved Seed) and seven (7) Plant Growth Regulators (PGRs): (Cytokinins, 0.4%, Super-gro, Brassinolide 0.01 %, Boostract, Nanomix, Vitalon 2000 and Water as a control). The treatments were laid out in split plot design replicated three times. The gross plot size is 4.5mx3m (13.5m^2) and net plot size is 3mx2 m (6 m^2). Maize varieties were assigned to the main plots and plant growth regulators to sub-plots.

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), brassinolide 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 was diluted per knapsack of clean water). And the control plots received no plant growth regulators were sprayed with water.

Data Collection

The following data were collected:

1. Establishment count (%)
2. Number of leaves per plant
3. Number of days to 50 % tasseling
4. Number of Days to 50 % silking
5. Grain yield (kg ha^{-1}).

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 (2008). Mean values were separated using the least significant difference (LSD) at 0.05 level of probability.

Results

Effect of Variety and Plant Growth Regulators on establishment count (%) of Maize (*Zea mays* L.) during 2019, 2020 and 2021 Growing Seasons

The result of the effects of variety and plant growth regulators on establishment count (%) of maize during 2019, 2020 and 2021 is presented in table 2. Effect of variety on the establishment count was only significant ($p \leq 0.05$) in 2019. SAMMAZ-37 recorded the highest establishment count of 72.06 % which is statistically the same with M12M (70.26 %) and the least establishment count of 68.40 % was record in Admiral Improved Seed. Effect plant of growth regulators was not significant ($P > 0.05$) on establishment count during the three years of study and there was no significant ($P > 0.05$) interaction between variety and growth regulators on establishment count of maize during the period of the study.

Effect of Variety and Plant Growth Regulators on Number of Leaves Plant^{-1} of Maize (*Zea mays* L) in Yola during 2019, 2020 and 2021 Growing Seasons

The results on the effect of variety and plant growth regulators on number of leaves per plant of maize in 2019, 2020 and 2021 is presented in Table 1. The result showed that effect of variety on number of leaves per plant of maize was significant ($p \leq 0.05$) at 2 WAS and highly significant ($p \leq 0.001$) at 4 WAS in 2019, significantly ($p \leq 0.05$) at 12 WAS in 2020 and 4 WAS in 2021. In 2019 at 2 WAS, Admiral Improved Seed recorded the highest number of leaves (4.93) per plant while SAMMAZ-37 recorded the least (2.78) which are at par with M12M variety (2.80). At 4 WAS, SAMMAZ-37 recorded the highest number of leaves (5.32) and statistically similar with M12M variety (5.25) while Admiral Improved Seed recorded the least (4.85). In 2020 12 WAS, Admiral Improved Seed recorded the highest number of leaves (11.13) which is statistically similar with SAMMAZ-37 (10.78) while M12M variety recorded the least (10.41). In 2021 4 WAS, SAMMAZ-37 recorded the highest number of leaves (9.36) which is statistically similar with M12M variety (8.80) while Admiral Improved Seed recorded the least (8.25).

However, effect of plant growth regulators was significant ($p \geq 0.05$) at 2 WAS in 2019, significant at 4 WAS in 2020 and highly significant ($p \leq 0.001$) at all the sampled period of 2021 except at 8 WAS. In 2019 4 WAS, application of Super-gro recorded the highest number of 4.04 leaves which is statistically similar with all the rest of the plant growth regulators and control recorded the least (2.33). In 2020 at 4 WAS, application of Vitalon recorded the highest number of 5.53 leaves which is also statistically similar with all the rest of the plant growth regulators and control recorded the least (4.71). In 2021 at 2 WAS, application of Cytokinins recorded the highest number of leaves per plant (5.28) though statistically similar with all the rest of the plant growth regulators and control recorded the least (4.56). At 4 WAS, application of Vitalon recorded the highest number of leaves (9.20) which is also at par with all the rest of the plant growth regulators and control recorded the least (7.88). At 6 WAS, Cytokinins recorded the highest number of leaves per plant (11.69) which is also statistically similar with all the rest of the similar except with Nanomix (10.82), and control recorded the least (9.51). Similarly, at 10 and 12 WAS application of Cytokinins recorded the highest number of leaves per plant (14.22 and

14.76) which are also similar statistically with all the rest of the similar and control recorded the least (12.07 and 12.38). There was no significant ($p \geq 0.05$) interaction between the varieties and plant growth regulators on number of leaves per plant of maize during the period of the study.

Effect of Variety and Plant Growth Regulators on Number of Days to 50 % Tasseling of Maize (*Zea mays* L) in Yola during 2019, 2020 and 2021 Growing Seasons

The result of the effects of variety and plant growth regulators on number of days to 50 % tasseling of maize during 2019, 2020 and 2021 growing seasons is presented in Table 2. Effect of variety on number of days to 50 % tasseling was highly significant ($p \leq 0.01$) in 2021. SAMMAZ-37recorded the least number of days to 50% tasseling (60.43) while Admiral Improved Seeds recorded the highest mean value of 63.66 days which is statistically the same with M12M (63.38 days). Effect of plant growth regulators on number of days to 50% tasseling was highly significant ($p \leq 0.01$) in 2019. Application of Super-gro recorded the least number of days to 50 % tasseling (57.11) while control recorded the highest number (59.33) days to 50% tasseling. There was no significant ($p > 0.05$) interaction between variety and plant growth regulators on number of days to 50 % tasseling in Yola during the period of study.

Effect of Variety and Plant Growth Regulators on Number of Days to 50 % Silking of Maize (*Zea mays* L) in Yola during 2019, 2020 and 2021 Growing Seasons

The result of the effects of variety and plant growth regulators on number of days to 50 % silking of maize in 2019, 2020 and 2021 growing seasons is presented in Table 2. Varietal differences did not significantly ($p>0.05$) affect number of days to 50 % silking. However, effect of plant growth regulators was significant ($p \leq 0.05$) in 2019. Application of Super-gro recorded the least number of days to 50 % silking (61.11) which are at par with the rest of the plant growth regulators and control recorded the highest number of days (63.11). There was no significant ($p > 0.05$) interaction observed between variety and growth regulators on number of days to 50% silking.

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.

The result of the effects of variety and plant growth regulators on grains yield (kg ha^{-1}) of maize in Yola during 2019, 2020 and 2021growing seasons is presented in Table 2. Effect of variety was 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}) and 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 (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.

Discussion

Effect of Variety and Plant Growth Regulators on the Growth Parameters of Maize

The highest number of shoot population (establishment count) recordedonSAMMAZ-37 and M12M varieties over Admiral Improve Seed could be due their variability and adaptation to the environment. Babaji *et al*. (2012) also noted that hybrids maize responded differently to population density as well as soil and environmental conditions. And the none significant effect of plant growth regulators on establishment count is in contrast with findings of Santos and Vieira (2005) who recorded an increase in seedling emergence (%) with the application of plant growth regulators on *Gossypium hirsutum*.

The none consistence of either of the varieties to be dominant over another on number of leaves could be associated with their genetic makeup and favorable climatic conditions during the growth of the crops which provide optimum conditions for maize crops that enable them performed to their maximum. This result is in line with the findings of Kareem *et al*. (2020) who reported that the genetic makeup of each variety had more influence on the parameters than the treatments. The significant influence of all the plant growth regulators over the control on number of leave per plant could be due to the roles of these plant growth regulators in cell division and elongation. Stimulant like Boostract, Super-gro and Vitalon contain humic substance and nitrogen compound (Kocira *et al*., 2018). And the fertilizer also contains natural energy acids and their derivatives in a biologically active form (Mandava *et al*., 1979). Cytokinins influences cell division and shoot formation, it also helps delay aging of tissues (Taiz and Zeiger, 2010) while Brassinolide help to stimulate cell division and elongation, resistance to stress and xylem differentiation (Wikipedia, 2018).

Effect of Varieties and Plant Growth Regulators on Phenological Parameters of Maize

The significant effect of SAMMAZ-37 variety on number of days to 50 % tasseling over M12M and Admiral Improve Seed could be due its genetic makeup which indicated that variability existed among species. This was in line with the findings of Agbogidi and Ofuoko (2005) who reported that, plants respond differently to environmental factors based on their genetic make-up and their adaptation capability, which indicates that variability, existed among species. Marfo-Ahenkora*et al*. (2023); Kisaka (2014) and Kpoto (2012) also reported similar findings and admitted that the influence of phenological parameters indicated that hybrids, open pollinated varieties and local inbreed lines have varying days for phenological trait. Contrary to the findings of Kareem *et al*. (2017) who did not observe any significant effect of varieties on number of days to tasseling and silking. The minimum number of days obtained in the application of plant growth regulators over the control could be due to the positive role of plant growth regulators to induced plant to attain minimum number of days to flowering. Taiz and Zeiger (2010) also reported that application of plant growth regulators helps to promote early flowering. Application of Vitalon helps to increase return bloom (Mandava, 1979). The non-significant effect of variety on number of days to 50 % silking could also be due to genetic constituent of the maize varieties used. Kareem *et al*. (2017) also did not observed any significant effect of variety on number of days to 50 % silking. And the significant effect of plant growth regulators over the control on minimum number of days to 50 % silking were earlier reported by Taiz and Zeiger (2010).

Effect of Plant Growth Regulators and Variety on Grain Yield of Maize

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 local 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 grain yield of maize with the application of bio stimulant when compared to the control. Significant higher grain yield was also observed in the application of plant growth regulators over the control by Qandeel *et al*. (2020). The non-significant interaction between the varieties and plant growth regulators on all the parameters 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 these variables:

Conclusion and Recommendations

From the foregoing, it could be concluded that both plant growth regulators and variety significantly influenced the flowering, growth and grains yield of maize with variety M12M and Cytokinins performed better among the varieties and plant growth regulators.

Based on the results obtained from this study, the following recommendations were made.

1. Adaption of M12M variety for its high growth and grain yield.
2. Application of Cytokinins on maize production for its maximum growth and grain yield in the study area.

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

	2019						2020						2021					
Treatments	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS
Varieties																		
M12M	2.80	5.25	7.60	9.71	11.41	12.51	2.24	5.20	8.13	10.87	10.66	10.41	4.98	8.80	10.84	13.40	13.66	14.09
Sammaz-37	2.78	5.32	10.40	9.73	11.58	12.68	4.93	5.40	7.93	10.04	10.67	10.78	5.40	9.36	11.49	19.00	13.98	14.69
Admiral	4.93	4.85	7.00	9.41	11.17	12.41	5.07	5.26	8.14	10.13	10.80	11.13	4.91	8.25	10.72	13.20	13.26	14.14
P of F	0.020	0.009	0.410	0.311	0.327	0.664	0.568	0.845	0.781	0.797	0.163	0.026	0.25	0.06	0.310	0.396	0.287	0.377
LSD	1.676	0.3150	5.610	0.4737	0.547	0.607	0.7426	0.9647	0.9055	1.084	0.1826	0.482	0.75	0.87	1.2760	11.82	1.0808	1.1592
PGRs																		
Cytokinins	3.78	5.11	14.80	9.56	11.50	12.73	5.04	5.47	8.16	10.51	10.62	10.87	5.28	9.18	11.69	13.70	14.22	14.76
Super-gro	4.04	5.20	7..50	9.84	11.70	12.82	5.20	5.36	8.33	10.93	11.00	11.82	5.16	9.16	11.11	13.60	13.82	14.58
Brassinolide	3.48	5.29	7.40	9.77	11.50	12.54	5.18	5.24	8.22	10.82	10.67	10.89	5.04	8.64	11.10	13.60	13.76	14.62
Boostract	3.61	5.33	7.30	9.67	11.42	12.67	5.04	5.29	7.80	10.64	10.76	10.87	5.24	8.70	11.22	13.70	14.00	14.58
Nanomix	3.74	4.96	7.20	9.31	11.24	12.16	5.16	5.40	7.84	10.36	10.78	10.93	5.11	8.87	10.87	13.20	13.53	14.22
Vitalon	3.54	5.02	7.20	9.51	11.62	12.39	4.89	5.53	7.78	10.62	10.89	11.09	5.27	9.20	11.62	13.80	14.02	15.00
Control	2.33	5.07	6.90	9.67	10.73	12.40	5.04	4.71	8.36	10.13	10.62	10.64	4.56	7.88	9.51	24.70	12.07	12.38
P of F	0.045	0.779	0.488	0.884	0.371	0.592	0.769	0.028	0.475	0.683	0.831	0.312	0.001	0.001	0.001	0.590	0.001	0.001
LSD	0.959	0.594	9.010	0.895	0.907	0.800	0.419	0.474	0.752	0.852	0.591	0.592	0.312	0.535	0.543	13.630	0.695	0.595
Va. x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

PGRs = Plant growth regulators, NS = Not significant

Table 2: Effect of Plant Growth Regulators and Variety on Establishment Count, Phenological and Grain Yield of Maize (*Zea mays* L.) in Yola during 2019, 2020 and 2021 Growing Seasons

	Establishment count (%)			Days to 50 % tasseling			Days to 50 % silking			Grin yield (kg ha^{-1})		
Treatments	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
Varieties												
M12M	2.80	89.20	97.27	57.95	57.76	63.38	61.86	61.76	63.38	5536	5239	5348
Sammaz-37	2.78	80.80	97.88	57.52	56.84	60.43	61.52	60.71	60.43	5328	4034	5074
Admiral	4.93	87.80	97.67	57.86	57.24	63.66	61.57	61.10	63.60	5163	3903	5185
P of F	0.020	0.216	0.905	0.478	0.504	0.007	0.598	0.413	0.145	0.077	0.050	0.683
LSD	1.676	11.57	3.768	0.749	1.412	0.822	0.721	1.974	3.897	408.8	407.4	436.9
PGRs												
Cytokinins	3.78	91.90	98.38	57.33	56.22	61.89	61.44	60.67	61.89	5770	3832	5734
Super-gro	4.04	79.30	97.24	57.11	57.78	62.22	61.11	61.56	62.22	5290	4092	5576
Brassinolide	3.48	86.40	97.44	57.44	57.22	62.44	61.44	61.22	62.44	5423	3837	5274
Boostract	3.61	89.20	97.29	58.00	57.44	63.00	61.78	61.33	63.00	5346	4065	5439
Nanomix	3.74	85.60	97.19	57.67	57.78	62.33	61.44	61.78	62.33	5387	3982	5481
Vitalon	3.54	78.80	98.24	57.56	57.00	62.71	61.22	60.67	62.71	5123	3865	4852
Control	2.33	90.40	97.44	59.33	57.56	62.82	63.11	61.11	62.82	4825	3480	4058
P of F	0.045	0.095	0.870	0.015	0.310	0.182	0.051	0.413	0.633	0.107	0.393	0.001
LSD	0.959	10.53	2.220	0.101	1.412	1.188	1.210	1.176	1.292	591.2	619.3	739.1
Interaction												
Var. x PGRs	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

PGRs= Plant Growth Regulators, NS= Not Significant