Growth Responses of Castor to Application of Selected Growth Regulators

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Abstract- A field study was conducted at the Teaching and Research Farm, University of Agriculture, Makurdi, in 2008 and 2009 cropping seasons. The objective was to determine the effects of six selected growth regulators viz: 2, 4-dichlorophenoxyacetic acid (2, 4-D), aluminum tetraflouride (AIF_4), fusicoccin, ethrel (2-chloroethyl phosphonic acid) – both at 200mg/L; coconut milk and potassium nitrate (KNO_3) at 15% each, on the growth of four castor accessions namely; LAF-4, LAF-11, AKW-5 and AKW-7. Observations on growth were recorded on leaf area index (LAI), absolute growth rate (AGR), net assimilation rate (NAR), number of leaves and plant height – all per plant at 4, 8, 12, 16, 20, 24 and 28 weeks after sowing. The technique of growth analysis described by Steel and Torrie was adopted for data collection. Results showed that all the growth parameters were significantly affected by growth regulators and castor accessions at all growth stages, and were higher when castor accession were treated with 15% of coconut milk. Castor accessions varied significantly in growth being higher in AKW-5 at early growth stages and LAF-4 at latter growth stages. The 15% of coconut milk and AKW-5 interaction produced significantly higher growth at 8 to 24 WAS than other growth regulators and castor accession interactions. AKW-5 showed greater growth response to application of 15% of coconut milk.

Index Terms- growth, responses, castor, application, growth regulators.

I. INTRODUCTION

Castor (Ricinus communis L.) a member of the family Euphorbiaceae is a tall glabrous indeterminate annual (Onwueme and Sinha, 1991[1]). Although castor plant has promising attributes either as an industrial or medicinal crop, the non extensive cultivation of this crop has tended to obscure its significance as a commerce commodity. In Nigeria, castor has so far remained unexplored and underexploited and very little is known about its cultivation. Thus it contributes little as a foreign exchange earner in Nigeria, and its production is below optimum level for industrial uses.

According to Hudson (1984[2]), growth, development and yield of crop plants, together with factors affecting them occupy a position of primary importance in crop production. He further reported that growth and development of crops are products of interplay between its genetic constitution and the environment. While the genetic make up of a crop is a fixed entity that delimits the extent to which that crop can develop and yield, the actual performance of the crop is regulated by the environment in which it grows.

Plant growth regulators act inside plant cells to stimulate or inhibit specific enzymes or enzyme systems and help regulate plant metabolism (Gianfagna, 1987[3]). Experience with 2, 4-D using the tobacco cell line cv Virginia Bright Italia (vB1-0) demonstrated that 2, 4-D promotes cell division at optimum dose of 10µm (Prisca and Nick, 2005[4]). Chen (2001[5]) noted that when 2, 4-D was administered as the only auxin, it was sufficient to maintain a high level of cell division. Field trials showed that by applying potassium nitrate, growth and grain yield as well as the protein content in the grains could be increased (Cakmak, 2003[6]). Single treatments of 10% and 15% of coconut milk resulted in significantly increased plant height, chlorophyll content and yield of Abelmoschus esculentus L., Hibiscus sabdariffa and Solanum gilo L. (Mukaila et al., 2005[7]). In a study on ethrel (2, chloroethyl phosphonic acid) application to tomato (Atta-Aly et al., 1994[8]), the period of cell division was extended up to 16-18 days as compared to that of control, which completed its cell division in 10-12 days. A large stimulation of growth of tobacco calluses by fusicoccin has been reported (De Witt, 1995[9]). Zhao et al., (2002[10]) observed that when both 2, 4-D and NAA were present, AIF_4 caused a strong stimulation of cell division and strong decrease of cell length.

There is dearth of information on the response of castor to growth regulators with respect to growth. The objective of this study was therefore, to determine the effects of some growth regulators on the growth of castor.

II. MATERIALS AND METHODS

Four castor accessions namely: LAF-4, LAF-11, AKW-5, AKW-7 and six growth regulators viz: 2,4-D (2,4-dichlorophenoxyacetic acid), fusicoccin, ethrel (2-chloroethyl phosphonic acid, aluminum tetraflouride AIF_4) – both at 200mg/L; coconut milk and potassium nitrate (KNO_3), at 15% each were used as treatments. Three castor seeds were sown per hill on the ridge and spaced 90cm x 50cm with a population density of 22, 222 plants per hectare. Thinning to one seedling per stand was done three weeks after sowing (WAS). The experiment was laid out in Randomized Complete Block Design with three replications. The gross plot size was 8m x 9.9m ($79.2m^2$) with net plot size of $7.2m^2$.

The plots were weeded manually twice, before and after flowering at 30 and 60 days intervals respectively. Split foliar application of growth regulators was done at 40 days after sowing and one week after flowering. The plants were sprayed fortnightly with Vetox 85 insecticide at the rate of 1.1kg chemical per 225 litres of water starting from 9 WAS to minimize insect damage by weevils, leaf rollers, grasshoppers and aphids.

Data on selected growth parameters collected from five randomly labelled plants from net plots were recorded at 4, 8, 12, 16, 20, 24 and 28 weeks after sowing and included the following:

(i) Leaf Area Index (LAI) = $\frac{LA}{GA}$

where:

LA = total leaf area in cm^2.

GA = area covered on ground in cm^2.

(ii) Absolute Growth Rate (AGR) = $\frac{W_2-W_1}{t_2 - t_1}$ $g/m^2/day$

where:

W_1 and W_2 = total dry weight of plant material in grams.

t_1 and t_2 = sampling times in weeks after sowing

(iii) Net Assimilation Rate (NAR) =

$$\frac{W_2-W_1}{A_2-A_1} \times \frac{\text{Log } A_2 - \text{Log } A_1}{t_2 - t_1} \text{ g/m}^2\text{/day}$$

where:

W_1, W_2 = total dry weight of plant (g)

A_1, A_2 = total leaf area (cm^2)

t_1, t_2 = sampling times (weeks after sowing).

The technique of growth analysis was adopted according to Steel and Torrie (1980[11]) and Hunt (1978[12]).

(iv) Plant height (cm)

(v) Number of leaves per plant.

Data collected were analyzed statistically using the Analysis of Variance Procedure described by Singh and Chaudhary, 1979[13]; Steel and Torrie, 1980[14]. Treatment effects were compared by the Fisher's Least Significant Difference Procedure (F-LSD) at 5% level of probability.

III. RESULTS

Leaf Area Index

Results on leaf area index (LAI) are presented in Table 1. LAI was significantly affected by growth regulators at all growth stages, and castor accessions at 8 to 16 WAS. LAI was higher when castor accessions were treated with 15% of coconut milk at 8 to 16 WAS (Table 1). Significant variation in LAI was observed among the four castor accessions with AKW-5 being higher in LAI at 8 to 16 WAS, and LAF-4 at 20 to 28 WAS. LAI increased steadily from 8 to 12 WAS (stage of maximum leaf expansion) and thereafter, decreased till 28 WAS with age of plant.

Growth regulator x castor accession interactions on LAI at 8, 12 and at 16 WAS were significant (Table 2). The 15% of coconut milk x LAF-4, LAF-11, AKW-5, AKW-7 interactions produced higher LAI at 8, 12 and 16 WAS followed by 200mg/L of AIF_4 x castor accession interactions at 12 WAS (Table 2).

Absolute Growth Rate

Absolute growth rate (AGR) was significantly influenced by growth regulators at 4 WAS to 28 WAS (Table 3). Higher AGR was observed under the stimulative influence of 15% of coconut milk. Castor accessions varied significantly in AGR, being higher in AKW-5 accession at 4, 8, 12, 24 and 28 WAS, and in LAF-4 at 16 and 20 WAS. Castor accessions produced steady increase in AGR up to 16 WAS, and thereafter, decreased till 28 WAS.

Significant growth regulator x castor accession interactions on AGR occurred at 12, 16 and 24 WAS (Table 4) with 15% of coconut milk x castor accession interactions being significantly higher than other growth regulator x castor accession interactions at 12, 16 and 24 WAS.

Net Assimilation Rate

Results summarized in Table 5 show that net assimilation rate (NAR) was significantly affected by growth regulators at all weeks after sowing (growth stages), and was higher under coconut milk treatment (15%). Table 5 shows variations in net assimilation rate with age of plant at different growth regulator applications. Net assimilation rate increased steadily from 4 WAS up to the stage of maximum leaf expansion (12 WAS) and thereafter, decreased up to 28 WAS. Net assimilation rate was significantly affected by castor accessions at 4, 12, 16 and 20 WAS except at 28 WAS, being higher with LAF-4 accession at 12, 16, 20 and 24 WAS; LAF-11 at 8 WAS, and AKW-5 at 4 WAS.

Growth regulator x castor accession interaction on net assimilation rate was significant at 4, 12, 16 and 20 WAS (Table 6). Coconut milk @ 15% x LAF-4, LAF-11, AKW-5 and AKW-7 interactions produced higher net assimilation rate (Table 6).

Number of Leaves Per Plant

Results on number of leaves (NOL) at 8 WAS corresponding with the ripe-to-flower stage, 12 WAS corresponding with the stage of maximum leaf expansion and panicle formation, 16 WAS corresponding with the capsule development stage, 20 to 24 WAS corresponding with the capsule drying stage, and 28 WAS corresponding with physiological maturity and final harvest stage are presented in Table 7. Growth regulators significantly affected number of leaves at 8 to 28 WAS. Coconut milk treated plants produced significantly higher number of leaves compared to other growth regulators. Number of leaves was higher at 12 WAS but reduced abruptly at 16 WAS until 28 WAS. Higher NOL occurred in AKW-5 at 8 to 16 WAS compared to other accessions, and in LAF-4 at 20 to 28 WAS compared to LAF-11, AKW-5 and AKW-7 castor accessions (Table 7).

Growth regulator x castor accession interaction on NOL was significant at 8 to 16 WAS (Table 8), and 20-28 WAS (Table 9). Castor accession x coconut milk interaction produced higher NOL followed by castor accession x aluminum tetraflouride at 8 to 16 WAS (Table 8).

Plant Height

Results on plant height (PH) at different times of sampling are summarized in Table 10. Height of castor plant was significantly affected by growth regulators at all the growth stages (weeks after sowing) and was higher when plants were sprayed with 15% of coconut milk. There was a steady increase in PH at 4 WAS, till 28 WAS. Plant height varied significantly among the four castor accessions. At each growth stage, AKW-5 plants were taller than others.

Growth regulator x castor accession interactions on PH were significant at 4, 8 and 12 WAS (Table 11); 20, 24 and 28 WAS (Table 12), with 15% of coconut milk x LAF-4 and AKW-5 interactions producing higher PH than other interactions.

IV. DISCUSSION

Leaf Area Index

Leaf area index is a measure of the photosynthetic activity of crop plants (Steel and Torrie, 1980[15]). There was a steady rise in leaf area index which reached maximum point at 12 WAS corresponding with the stage of maximum leaf expansion. The increase in leaf area index was essentially due to increase in the number of leaves. The higher leaf area index observed with coconut milk treated plants could be attributed to the positive stimulative influence of coconut milk under favourable environmental conditions. At 16 WAS till 28 WAS, there was an abrupt decline in leaf area index mainly due to proportional reduction in number of leaves with age of plant.

Absolute Growth Rate

Absolute growth rate increased steadily from 4 WAS to 16 WAS in all the castor accessions being higher with 15 % of coconut milk followed by 200mg/L of AIF_4 and 15% of KNO_3 due to increased production and translocation of assimilates (dry matter) to both vegetative and reproductive parts caused by growth regulators.

The subsequent decline in absolute growth rate from 20 to 28 WAS was probably due to a progressive decline in number of leaves and net assimilation rate which presumably led to a greater diversion of assimilates to the panicles than to the vegetative parts. Horseman et al (1986[16]) reported that absolute growth rate is associated with age of plant and decreases as plants approach physiological maturity.

Net Assimilation Rate

In all the four castor accessions (LAF-4, LAF-11, AKW-5 and AKW-7), the physiological effect of coconut milk was responsible for higher net assimilation rate that was observed. The higher net assimilation rate at early stages of growth appeared to follow the trend of rapid leaf expansion and increase in number of leaves observed at 12 WAS in Table 5. Net assimilation rate and leaf area index are correlated. The progressive decrease in net assimilation rate with age of plant (16 to 28 WAS) could be due to relatively slower rate of leaf development as leaves approached maximum size. Okezie et al. (1980[17]) reported that white yam grown in Southern Nigeria between May and October attained maximum net assimilation rate at 10 WAS which decreased thereafter, with increase in age of the crop. Ezedinma (1967[18]) reported significant seasonal drifts in net assimilation rate of cowpea even at an early age of one week after sowing.

Number of Leaves per Plant

The increase in the number of leaves with 15% of coconut milk (crude cytokinin) could be attributed to its stimulative effect (cell division) which led to proportional increase in the quantity of dry matter produced per unit time at optimum environmental conditions. Caers and Vending (1986[19]) reported that application of coconut milk in Solanum gilo promoted photosynthetic activity mainly by means of increase in leaf chlorophyll content and leaf number. Davis (1984[20]) showed that the quantity of dry matter produced per unit time is a function of the number and size of leaves per plant at optimum light intensity, light duration and soil moisture conditions.

The fewer number of leaves produced with other growth regulators was probably due to decline in their stimulative effect and hence decline in the quantity of dry matter produced.

Plant Height

It was observed that, type of growth regulator notwithstanding, castor plants grew steadily up to 28 WAS. The greater stimulative effect of 15% of coconut milk probably produced higher plant height observed at all growth stages in all the castor accessions.

The plant height pattern was found to agree with the normal sigmoid growth pattern for crop plants (Hunt, 1978[21]). Single treatments of 100mg/L of IAA, 100mg/L of GA_3 and 15% of coconut milk resulted in significantly increased plant height, chlorophyll contents and yield of Abelmoschus esculentus L., Hibiscus sabdariffa and Solanum gilo L. (Mukaila, et al., 2005[22]). Ethrel effectively reduced plant height and lodging when applied to crops (Brown, 1996[23]).

Based on these discussions, it could be concluded that, 15% of coconut milk which is a crude source of cytokinin (zeatin) exerted greater stimulative effect (cell division) which led to higher growth when compared to the stimulative effects of other growth regulators evaluated in this study.

AKW-5 showed greater growth response to application of growth regulators compared to other castor accessions.

Table 1. Effects of Growth Regulators and Castor Accessions on Leaf Area Index per Castor Plant at different times of Sampling in 2008 and 2009 (Combined Data).

Treatments	Weeks after sowing					
	8	12	16	20	24	28
Growth Regulators						
2, 4-D @ 200mg/L	2.64	3.83	0.14	0.04	0.02	0.01
Coconut milk @ 15%	4.22	7.88	0.27	0.07	0.04	0.02
AIF_4 @ 200mg/L	3.84	6.54	0.24	0.07	0.04	0.02
KNO_3 @ 15%	3.83	6.30	0.24	0.06	0.04	0.02
Fusicoccin @ 200mg/L	3.48	5.52	0.19	0.06	0.03	0.01
Ethrel @ 200mg/L	3.17	4.89	0.18	0.05	0.03	0.01
LSD (0.05)	0.09	0.15	0.03	0.007	0.004	0.003
Castor Accessions						
LAF-4	3.43	7.21	0.23	0.07	0.05	0.03
LAF-11	3.25	4.48	0.19	0.05	0.03	0.02
AKW-5	4.11	7.29	0.29	0.06	0.03	0.02
AKW-7	3.34	4.33	0.13	0.05	0.03	0.01
LSD (0.05)	0.07	0.13	0.02	0.006	0.003	0.003
Regulator x Accessions	*	*	*	NS	NS	NS

Key:

NS = Not Significant

Table 2. Growth Regulator x Castor Accession Interactions on Leaf Area Index at 8, 12 and 16 Weeks After Sowing in 2008 and 2009 (Combined Data).

	8 Weeks after sowing				12 Weeks after sowing				6 Weeks after sowing			
	Castor Accessions				Castor Accessions				Castor Accessions			
Growth Regulators	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**
2, 4-D @ 200mg/L	2.39	2.40	4.07	1.70	3.90	3.66	5.00	2.77	0.15	0.17	0.14	0.10
Coconut milk @ 15%	4.26	3.80	4.20	4.60	8.54	4.72	8.51	6.70	0.26	0.25	0.41	0.15
AIF_4 @ 200mg/L	3.60	3.70	4.11	3.96	8.24	4.71	7.90	4.70	0.24	0.19	0.38	0.14
KNO_3 @ 15%	3.50	3.73	4.10	4.00	8.10	4.71	7.90	4.50	0.25	0.20	0.36	0.13
Fusicoccin @ 200mg/L	3.42	3.00	409	3.40	7.45	3.92	6.83	3.89	0.23	0.18	0.23	0.12
Ethrel @ 200mg/L	3.38	2.84	4.07	2.40	7.05	3.70	5.40	3.40	0.22	0.17	0.20	0.12
LSD (0.05)	0.17				0.13				0.06			

Table 3. Effects of Growth Regulators and Castor Accessions on Absolute Growth Rate (G/M^2/Day) per Castor Plant at different times of Sampling in 2008 and 2009 (Combined Data).

	Weeks after sowing						
Treatments	4	8	12	16	20	24	28
Growth Regulators							
2, 4-D @ 200mg/L	1.89	3.88	34.20	61.73	13.40	3.10	1.25
Coconut milk @ 15%	2.14	4.33	38.93	69.09	14.85	3.48	1.39
AIF_4 @ 200mg/L	2.09	4.25	37.45	67.73	14.55	3.33	1.37
KNO_3 @ 15%	2.08	4.25	37.10	67.35	14.65	3.33	1.35
Fusicoccin @ 200mg/L	2.05	4.13	35.70	66.00	13.80	3.21	1.32
Ethrel @ 200mg/L	1.98	4.03	34.95	64.75	12.62	3.15	1.30
LSD (0.05)	0.16	0.31	0.47	0.65	1.02	0.06	0.04
Castor Accessions							
LAF-4	2.02	4.12	37.85	69.20	14.63	3.30	1.31
LAF-11	2.09	4.25	35.80	65.76	13.51	3.18	1.35
AKW-5	2.16	4.37	37.97	67.15	14.33	3.39	1.36
AKW-7	1.88	3.83	33.93	62.32	13.43	3.18	1.30
LSD (0.05)	0.13	0.25	0.38	0.53	0.83	0.05	0.03
Regulator x Accessions	NS	NS	*	*	NS	*	NS

Key:

NS = Not Significant

Table 4. Growth Regulator x Castor Accession Interactions on Absolute Growth Rate (G/M^2/Day) at 12, 16 and 24 Weeks After Sowing in 2008 and 2009 (Combined Data).

	12 Weeks after sowing				16 Weeks after sowing				24 Weeks after sowing			
	Castor Accessions				Castor Accessions				Castor Accessions			
Growth Regulators	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**
2, 4-D @ 200mg/L	35.40	34.00	35.00	32.40	64.30	62.90	60.40	59.30	3.20	3.10	3.10	3.00
Coconut milk @ 15%	40.70	38.00	40.80	36.20	72.20	68.17	71.00	65.00	3.50	3.40	3.60	3.40
AIF_4 @ 200mg/L	38.40	37.00	39.40	35.00	71.30	66.90	69.70	63.00	3.40	3.20	3.50	3.20
KNO_3 @ 15%	39.60	36.00	38.80	34.00	70.10	67.60	68.50	63.20	3.30	3.30	3.50	3.20
Fusicoccin @ 200mg/L	37.00	35.00	37.60	33.00	69.30	65.00	67.30	62.40	3.20	3.10	3.37	3.17
Ethrel @ 200mg/L	36.00	34.60	36.20	33.00	68.00	64.00	66.00	61.00	3.20	3.00	3.30	3.10
LSD (0.05)	0.94				1.31				0.13			

Table 5. Effects of Growth Regulators and Castor Accessions on Net Assimilation Rate (G/M^2/Day) per Castor Plant at different times of sampling in 2008 and 2009 (Combined Data).

	Weeks after sowing						
Treatments	4	8	12	16	20	24	28
Growth Regulators							
2, 4-D @ 200mg/L	0.13	0.43	41.33	32.00	1.62	0.83	0.37
Coconut milk @ 15%	0.30	0.58	47.75	37.50	2.10	1.03	0.51
AIF_4 @ 200mg/L	0.23	0.52	45.67	36.58	1.93	0.90	0.43
KNO_3 @ 15%	0.30	0.58	45.92	35.75	1.95	0.96	0.48
Fusicoccin @ 200mg/L	0.23	0.51	45.92	34.75	1.88	0.89	0.47
Ethrel @ 200mg/L	0.20	0.47	43.67	34.17	1.78	0.78	0.40
LSD (0.05)	0.01	0.05	0.59	0.60	0.06	0.06	0.06
Castor Accessions							
LAF-4	0.22	0.53	47.33	36.50	2.03	1.02	0.45
LAF-11	0.24	0.54	44.56	34.50	1.83	0.87	0.43
AKW-5	0.25	0.53	46.28	36.17	2.00	0.96	0.46
AKW-7	0.22	0.45	42.00	33.33	1.64	0.74	0.43
LSD (0.05)	0.007	0.04	0.48	0.49	0.05	0.05	NS
Regulator x Accessions	*	NS	*	*	*	NS	NS

Key:

NS = Not Significant

Table 6. Growth Regulator x Castor Accession Interactions on Net Assimilation Rate at 4, 12, 16 and 20 Weeks After Sowing in 2008 and 2009 (Combined Data).

	4 Weeks after Sowing				12 Weeks after sowing				16 Weeks after sowing				20 Weeks after sowing			
	Castor Accession				Castor Accession				Castor Accession				Castor Accession			
Growth Regulators	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**
2, 4-D @ 200mg/L	0.10	0.10	0.10	0.10	43.00	40.33	43.00	39.00	33.00	30.00	35.00	30.00	1.60	1.57	1.80	1.50
Coconut milk @ 15%	0.30	0.30	0.30	0.30	51.00	47.00	49.00	44.00	40.00	37.00	38.00	35.00	2.40	2.00	2.20	1.80
AIF_4 @ 200mg/L	0.20	0.30	0.20	0.20	46.00	45.67	48.00	43.00	38.00	36.33	36.00	36.00	2.10	1.90	2.00	1.70
KNO_3 @ 15%	0.30	0.30	0.30	0.30	49.00	44.67	47.00	43.00	37.00	35.00	37.00	34.00	2.20	1.90	2.10	1.60
Fusicoccin @ 200mg/L	0.20	0.20	0.30	0.20	50.00	45.67	46.00	42.00	35.67	34.33	36.00	33.00	2.00	1.80	2.00	1.70
Ethrel @ 200mg/L	0.20	0.20	0.20	0.20	45.00	44.00	44.67	41.00	35.33	34.33	35.00	32.00	1.87	1.80	1.90	1.57
LSD (0.05)	0.02				0.18				1.21				0.12			

Table 7. Effects of Growth Regulators and Castor Accessions on Number of Leaves per Castor Plant at different times of Sampling in 2008 and 2009 (Combined Data).

Weeks after sowing						
Treatments	8	12	16	20	24	28
Growth Regulators						
2, 4-D @ 200mg/L	15.50	21.75	16.25	13.25	10.50	7.75
Coconut milk @ 15%	25.25	37.25	31.00	27.25	24.00	19.92
AIF_4 @ 200mg/L	22.50	32.50	26.50	23.25	19.75	17.00
KNO_3 @ 15%	20.75	31.50	25.75	22.75	19.75	16.50
Fusicoccin @ 200mg/L	19.00	29.75	24.00	20.75	17.75	14.75
Ethrel @ 200mg/L	17.50	26.25	21.50	18.25	15.00	12.00
LSD (0.05)	0.90	1.13	0.80	0.84	0.68	0.71
Castor Accessions						
LAF-4	19.33	30.50	25.00	22.00	19.00	16.17
LAF-11	20.17	29.50	23.83	20.83	17.83	14.50
AKW-5	21.83	31.00	25.33	21.50	18.17	15.00
AKW-7	19.00	28.33	22.50	19.33	16.17	12.94
LSD (0.05)	0.73	0.92	0.65	0.69	0.55	0.58
Regulator x Accessions	*	*	*	*	*	*

Key:

NS = Not Significant

Table 8. Growth Regulators x Castor Accession Interaction on Number of Leaves at 8, 12 and 16 Weeks After Sowing in 2008 and 2009 (Combined Data).

	8 Weeks after sowing				12 Weeks after sowing				16 Weeks after sowing			
	Castor Accessions				Castor Accessions				Castor Accessions			
Growth Regulators	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**
2, 4-D @ 200mg/L	15.00	16.00	17.00	14.00	20.00	23.00	24.00	20.00	15.00	17.00	18.00	15.00
Coconut milk @ 15%	25.00	25.00	27.00	24.00	39.00	35.00	37.00	38.00	31.00	30.00	32.00	31.00
AIF_4 @ 200mg/L	21.00	23.00	24.00	22.00	32.00	32.00	34.00	32.00	28.00	26.00	27.00	25.00
KNO_3 @ 15%	19.00	21.00	23.00	20.00	33.00	30.00	30.00	30.00	27.00	25.00	27.00	24.00
Fusicoccin @ 200mg/L	18.00	19.00	21.00	18.00	31.00	30.00	30.00	28.00	25.00	24.00	25.00	22.00
Ethrel @ 200mg/L	18.00	17.00	19.00	16.00	28.00	27.00	28.00	22.00	24.00	21.00	23.00	18.00
LSD (0.05)	1.79				2.26				1.60			

Table 9. Growth Regulators x Castor Accession Interaction on Number of Leaves at 20, 24 and 28 Weeks After Sowing in 2008 and 2009 (Combined Data).

	20 Weeks after sowing				24 Weeks after sowing				28 Weeks after sowing			
	Castor Accessions				Castor Accessions				Castor Accessions			
Growth Regulators	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**
2, 4-D @ 200mg/L	13.00	14.00	14.00	12.00	10.00	11.00	12.00	9.00	8.00	8.00	9.00	6.00
Coconut milk @ 15%	27.00	27.00	28.00	27.00	24.00	24.00	25.00	23.00	20.00	20.00	21.00	19.00
AIF_4 @ 200mg/L	25.00	22.00	24.00	22.00	21.00	20.00	19.00	19.00	19.00	16.00	17.00	16.00
KNO_3 @ 15%	24.00	23.00	23.00	21.00	22.00	19.00	20.00	18.00	18.00	17.00	16.00	15.00
Fusicoccin @ 200mg/L	22.00	21.00	21.00	19.00	19.00	18.00	18.00	16.00	16.00	15.00	15.00	13.00
Ethrel @ 200mg/L	21.00	18.00	19.00	15.00	18.00	15.00	15.00	12.00	16.00	11.00	12.00	9.00
LSD (0.05)	1.68				1.35				1.42			

Table 10. Effects of Growth Regulators and Castor Accessions on Plant Height (CM) at different times of Sampling in 2008 and 2009 (Combined Data)

	Weeks after sowing						
Treatments	4	8	12	16	20	24	28
Growth Regulators							
2, 4-D @ 200mg/L	24.55	45.83	84.40	117.55	143.85	162.10	176.55
Coconut milk @ 15%	33.50	57.30	96.97	135.72	159.18	177.32	191.15
ALF_4 @ 200mg/L	30.95	55.35	92.38	133.25	156.25	175.99	189.75
KNO_3 @ 15%	30.42	54.78	93.65	131.30	156.63	174.52	189.13
Fusicoccin @ 200mg/L	29.30	51.30	90.00	129.27	153.85	172.42	186.50
Ethrel @ 200mg/L	27.50	48.50	87.65	126.02	150.53	168.75	183.50
LSD (0.05)	1.19	1.33	1.36	1.77	1.37	1.13	1.92
Castor Accessions							
LAF-4	37.67	58.75	95.02	127.78	156.75	175.53	191.50
LAF-11	22.15	49.20	87.57	127.46	153.83	171.67	179.52
AKW-5	38.50	59.75	95.78	133.17	158.25	176.05	194.03
AKW-7	19.17	41.00	85.00	127.00	144.68	164.17	179.33
LSD (0.05)	0.97	1.08	1.11	1.45	1.12	0.93	1.57

Key:

NS = Not Significant

Table 11. Growth Regulator x Castor Accession Interactions on Plant Height (CM) at 4, 8 and 12 Weeks After Sowing in 2008 and 2009 (Combined Data).

	4 weeks after sowing				8 Weeks after sowing				12 Weeks after sowing			
Growth Regulators	**Castor Accessions**				**Castor Accessions**				**Castor Accessions**			
	LAF-4	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**
2, 4-D@ 200mg/L	28.20	19.00	35.00	16.00	49.20	41.00	56.10	37.00	84.00	82.60	90.00	81.00
Coconut milk @ 15%	43.00	25.00	43.00	23.00	64.00	57.00	64.20	44.00	102.10	93.80	101.00	91.00
ALF @ 200mg/L	40.40	23.40	40.00	20.00	62.70	53.00	62.70	43.00	97.00	89.00	96.50	87.00
KNO_3 @ 15%	39.40	23.30	39.00	20.00	60.60	54.00	61.50	43.00	99.00	91.00	98.60	86.00
Fusicoccin @ 200mg/L	38.00	22.20	38.00	19.00	59.00	47.20	58.00	41.00	95.00	86.00	95.00	84.00
Ethrel @ 200mg/L	37.00	20.00	36.00	17.00	57.00	43.00	56.00	38.00	93.00	83.00	93.60	81.00
$LSD_{(0.05)}$	2.38				2.64				2.71			

Table 12. Growth Regulators x Castor Accession Interaction on Plant Height (CM) 20, 24 and 28 Weeks After Sowing in 2008 and 2009 (Combined Data).

	20 Weeks after sowing				24 Weeks after sowing				28 Weeks after sowing			
	Castor Accessions				Castor Accessions				Castor Accessions			
Growth Regulators	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**	**LAF-4**	**LAF-11**	**AKW-5**	**AKW-7**
2, 4-D@ 200mg/L	135.00	147.00	151.30	142.10	158.40	165.00	171.00	154.00	177.00	175.00	188.20	166.00
Coconut milk @ 15%	166.00	159.00	163.70	148.00	183.30	176.00	181.00	169.00	197.10	183.60	198.00	186.00
ALF_4 @ 200mg/L	163.00	156.00	160.00	146.00	181.67	175.00	179.30	168.00	196.00	182.00	196.00	185.00
KNO_3 @ 15%	161.00	158.00	161.50	146.00	179.10	174.00	178.00	167.00	195.00	181.50	196.50	184.00
Fusicoccin @ 200mg/L	159.40	154.00	158.00	144.00	177.70	172.00	175.00	165.00	193.00	179.00	194.00	180.00
Ethrel @ 200mg/L	156.10	149.00	155.00	142.00	173.00	168.00	172.00	162.00	191.00	176.00	192.00	175.00
LSD (0.05)		2.74				2.27				3.84		

REFERENCES

[1] Omwueme, I.C. and Sinha, T. D. (1991). Field Crop Production in Tropical Africa. Tech. Centre Agric. of Rural Crops. ACP-EEC Lome Convention. pp. 159-175.

[2] Hudson, J. P. (1984). Climate, plants and crop research. Span. J. Crop Sci. 27:3-8).

[3] Gianfagna, T. J. (1987). Effect of CCC on the morphology and growth potential of containerized silver birch seedlings, (14), 3:167-777.

[4] Prisca, C., and Nick, P. (2005). Auxin-dependent cell division and cell elongation. I-Naphthaleneacetic acid and 2, 4 – dichlorophenoxyacetic acid activate different pathways. Plant Physiol 2005; 137 (3) : 939-948.

[5] Chen, J. G. (2001). Dual auxin signialling pathways control cell elongation and division. J. Plant growth Regul 20:255-264.

[6] Cakmak, I. (2003). The role of potassium in alleviating detrimental effects of abiotic stresses in plants. In: Proceedings of the IPI Golden Jubilee Congress, October 8-10, 2002, Basel, Switzerland, pp. 325-343.

[7] Mukaila, A., Nitsch, J. P., and Rhodes, M. J. C. (2005). Growth factors in the tomato fruit. In "Plant Growth Regulation" 4th International conference on plant growth regulation, Yonkers, NY., 2003, Ames Iowa State Univ. press, pp 680-700.

[8] Atta-Aly, M. A., Brecht. J., Huber D. J. (1994). Ethylene feedback mechanisms in tomato And Strawberry fruit tissues. Postharvest Physiology, Pathology and Technologies for Horticulture Commodities: Recent Advances, Institute Agronomique & Veterinaire Hassan II, Agadir, Morocco.

[9] De Witt, P. J. G. M. (1995). Fungal avirulence genes and plant resistance genes: Unraveling the molecular basis of gene for gene interactions. Adv. Bot. Res. 21:148-177.

[10] Zhao, H., Hertel, R., Ishikawa, H., Evans, M. L. (2002). Species differences in ligand specification, elongation and auxin transport : comparing Zea and Vigna. Planta 216:293-301 (PubMed).

[11] Steel, G.D. and Torrie, J.H. (1980). Principles and Procedures of Statistics. Mc Graw Hill Book Company Inc. New York, pp.481.

[12] Hunt, R. (1978). Plant growth analysis. Studies in Biology No. 96. Mc Graw Hill Book Company, New York.

[13] Singh, R. K., and Chaudhary, B. D. (1979). Biometrical Methods in Quantitative Genetic Analysis. Kalyani Pub. N. Delhi, India. pp 39-78.

[14] Steel, G.D. and Torrie, J.H. (1980). Principles and Procedures of Statistics. Mc Graw Hill Book Company Inc. New York, pp.481.

[15] Steel, G.D. and Torrie, J.H. (1980). Principles and Procedures of Statistics. Mc Graw Hill Book Company Inc. New York, pp.481.

[16] Horseman, D. A., Harris, P. M., and Hanway, J. J. (1986). Response of cotton to planting dates under spacing conditions. Nature, London, 182:22-24.

[17] Okezie, C. E., Okonkwo, S. N. C., and Nweke, F. L. (1980). Growth pattern and growth analysis of the white Guinea yam raised from seed. Proceedings of the triennial Root Crops Symposium of the International Society for Tropical Root Crops, African Branch. 17-21 September, Ibadan In: Tropical root crops Research Strategies for the 1980s. pp. 180-188.

[18] Ezedinma, F.O.C. (1967). Seasonal variations in the growth of Cowpea (Vigna unguiculata L.) Walp.). seedlings in the humid tropical environment of Southern Nigeria. J. West Afr. Sci. Assoc. 12:45-49.

[19] Caers, M. and Vending, J. C. (1986). Benzyladenine effects on the development of the photosynthetic apparatus in Zea mays: studies on photosynthetic activity, enzymes and chloroplast ultrastructure. Physiol. Plant., 66:685-691.

[20] Davis, E. V. (1984). The effect of growth, temperature, light intensity and soil moisture Content on cotton yield. Netherlands. J. Agric. Sci. 13:212-221.

[21] Hunt, R. (1978). Plant growth analysis. Studies in Biology No. 96. Mc Graw Hill Book Company, New York.

[22] Mukaila, A., Nitsch, J. P., and Rhodes, M. J. C. (2005). Growth factors in the tomato fruit. In "Plant Growth Regulation" 4th International conference on plant growth regulation, Yonkers, NY., 2003, Ames Iowa State Univ. press, pp 680-700.

[23] Brown, B. (1996). Lodging. The Cereal Sentinal, University of Idaho. Cooperative Extension System, 10:2-4.

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