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Research Paper

Vegetative Growth Analysis of *Hibiscus sabdariffa* L. (Roselle) Treated with some Plant Growth Substances

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Roselle (*Hibiscus sabdariffa* L.) is a multifunctional plant whose calyx is commonly used for production of indigenous drink called "zobo" in Nigeria. This study was conducted to assess effect of single treatment of 50, 100, 200 mg/l of Gibberellic Acid (GA_3), Indole Acetic Acid (IAA), 6-Benzylaminopurine (BAP), Naphthalene Acetic Acid (NAA) and 10, 15 and 20 % coconut water on vegetative growth of the plants. Also, effect of combination of 50 mg/L GA_3 +10 % coconut water, 100 mg/L GA_3 + 15 % coconut water, 200 mg/L GA_3 + 20 % coconut water, 50 mg/L GA_3 + 50 mg/L IAA, 100 mg/L GA_3 + 100 mg/L IAA, 200 mg/L GA_3 + 200 mg/L IAA, 50 mg/L GA_3 + 50 mg/L NAA, 100 mg/L GA_3 + 100 mg/L NAA, 200 mg/L GA_3 + 200 mg/L NAA were used. Caffeic acids of 50, 100 and 200 mg/L were evaluated in a completely randomized design. Water served as control. Relative water content (RWC), Relative growth rate (RGR), Net assimilation rate (NAR) and Leaf area ratio (LAR) of the plant investigated were also determined. Data were analyzed using one-way ANOVA and means were separated using Duncan's Multiple Range Test at $p < 0.05$. Results showed that highest number of leaves (39.6), leaf area (83.2 cm^2) and stem diameter (0.37 mm) were recorded in *H. sabdariffa* sprayed with 20% coconut water. Also, highest RGR (0.67 gg^{-1} $week^{-1}$) was recorded in *H. sabdariffa* spared with 200 mg/L GA_3 and LAR (7541.2 cm^2 g^{-1}) in the plant treated with 200 mg/L Caffeic acid while highest NAR (0.3 gg^{-1} $week^{-1}$) was recorded in the plants sprayed with combine hormone treatment (200 mg/LGA3+200 mg/LNAA). In conclusion, single hormonal treatments were the best in improving vegetative parameters of *H. sabdariffa* .

Key words: *Hibiscus sabdariffa,* vegetative growth, growth substance, relative water content, net assimilation rate, leaf area ratio

INTRODUCTION

Roselle *(Hibiscus sabdariffa* L.) is an annual herbaceous shrub belonging to the malvaceae family. It is grown in tropical climates for its fleshy calyx and leaves (Bahaeldeen et al., 2012). In Egypt, India, Mali, Malaysia, Nigeria and Sudan, the plant was reported to contain high amount of protein, dietary fibre, lipids and mineral (Fatoumata et al., 2011; Balogun and Olatidoye, 2012).

Studies of Mohamad et al. (2002), Ojewumi and Kadiri, (2013) showed that juice from the calyx of the plant has hypoglycemic properties due to presence of secondary metabolites, vitamin C and antioxidants. Similarly, parts of the plant have been reported to be useful in trado-medical system as digestive agent, purgative and diuretic among others (Osuntogun and Aboaba, 2004). Also, despite the multipurpose relevance of *H. sabdariffa*, vegetative characters of the plants are always affected by pests, leading to poor growth and low yield of the plant most especially in the south west of Nigeria.

As efforts towards improvement of the vegetative growth parameters of this plant, many works have documented stimulatory effects of growth regulators such as indole-3-acetic acid (IAA), gibberellic acid (GA_3) on the growth and yield of vegetables including *H. sabdariffa* (Kadiri et al. 2016: Mostafa et al., 2005; Kadiri et al., 1997) but the price of many of these hormones could not be afforded by farmers, hence substitute or combination of the synthetic hormones and natural hormones (phyto hormones) is being advocated therefore, this study was

conducted to investigate responses of seeds and seedlings of *H. sabdariffa* to various concentrations and combination of growth substances.

MATERIALS AND METHODS

Seed collection, viability and germination text

Seeds of *H. sabdariffa* were purchased from local farmers at Suleja market, Abuja after which they were tested for viability according to the method of the International Seed Testing Association (ISTA, 1976). The variability of the seeds was determined using this mathematical relationship:

$$\text{Percentage viability} = \frac{\text{total number of seeds germinated}}{\text{initial total number of seeds}} x\ 100 \quad (1)$$

Collection and preparation of soil

Sandy soil was collected at 20 cm depth, sieved to remove pebble and stones and there after dispensed into dark polythene bags for planting.

Soil pH determination

20 ml of distilled water was added to 20 g of sieved air dried soil in a 50 ml beaker. It was allowed to settle for 30 min and stirred occasionally with a glass rod. The pH meter was standardized by dipping its electrode into buffers of pH4 and pH9, and later dipped into a partly settled suspension and the reading on the pH meter (6.54) was obtained.

Experimental site and seedlings lay out

Seedlings of *H. sabdariffa* were raised using perforated black polythene bag of 37 x 31 cm in the screen house of teaching and research botanical garden, Federal University of Agriculture, Abeokuta, Ogun State. The polythene bags were arranged using Complete Randomized Design (CRD). Seedlings were thinned to three per polythene bag after emergence.

Treatments

Foliage of the seedlings of the plant were sprayed separately with single 10 %, 15 % and 20 % coconut water, 50 mg/L, 100 mg/L and 200 mg/L GA_3, 50 mg/L, 100 mg/L 200 mg/L IAA, 50 mg/L 100 mg/L and 200 mg/L NAA, 50 mg/L, l00 m g/L, 200 mg/L BAP, 50 mg/L acid, l00 mg/L, and 200 mg/L Caffeic acid. Combined hormone treatments such as 50 mg/L GA3 + 10 % Coconut water, l00 mg/L GA3 + 15 % Coconut water, 200 mg!L GA3 + 20% Coconut water, 5Omg/L GA3 + 50 mg!L IAA, l00 mg/L GA3 + 100 mg/L IAA, 200 mg/L GA3 + 200 mg/L IAA, 50 mg/L GA3+ 50 mg/L NAA, 100 mg/L GA3+ 100 mg/LNAA, 200rngL GA3+ 200mg/L NAA were also tried while distilled water was used as the control.

H. sabdarffa was harvested at 2, 4, 6, 8 and 10 weeks after planting and agronomic parameters such as dry weight, number of leaves, leaf area and stem diameter were determined according to the method of (Kadiri, 1999) while plant height, relative growth rate, net assimilation rate and leaf area ratio were determined according to the method adopted by Fawibe et al. (2014).

$$PGR = \frac{loge\ W2 - \log e\ W1}{t2 - t1} \quad (2)$$

Where: w2 and w1 = dry weights of plant at initial and final
t1= Time of initial measurement, t2 time of final measurement

$$NAR = \frac{W2 - W1}{A2 - A1} . \frac{\log e\, A2 - loge\, A1}{t2 - t1} \quad (3)$$

Where: A2 and A1 = Leaf Area at Time (t_2 and t_1)
w2 and w1= Dry weights of plant at Time (t2 and ti)
t1 = Time of initial measurement, t2 = Time of final measurement

$$LAR = \frac{LA}{LW1} . \frac{LA2}{LW2} \quad (4)$$

Where: LA1 and LA2 Leaf area
Lw1and Lw2 = Dry weights of leaves

Statistical analysis

The data was subjected to Analysis of Variance (ANOVA) and means were separated using Duncan Multiple Range Test (DMRT) at $p< 0.05$.

RESULTS AND DISCUSSION

Table 1 showed that height of *H sabdarffa* sprayed with 200 mg/L singly was significant ($p < 0.05$) higher compared with height of the plant sprayed with other single hormones and control separately across 2, 4, 6, 8 and 10 weeks after planting. Highest height of *H sabdarffa* (57.00 cm) was recorded in *H sabdarffa* sprayed with 200 mg/LGA_3 at 10 weeks after planting.

Also, effect of single hormone treatment of relative growth rate, net assimilation rate, leaf area ratio, leaf relative water content, leaf area and stem diameter showed significant differences ($p < 0.0\ 5$). Relative growth rate (0.67) and net assimilation rate (0.038) were

Table 1. Plant height (cm) of Roselle (*H. sabdariffa*) given single treatment at 2, 4, 6, 8, and 10 weeks after planting.

Single Hormonal Treatment	Weeks after planting (WAP)				
	2	4	6	8	10
10% Coconut water	16.40 ± 0.62^{a}	19.20 ± 0.44^{a}	22.00 ± 1.01^{a}	26.70 ± 1.20^{cd}	46.00 ± 1.54^{bc}
15% Coconut water	13.74 ± 0.62^{bc}	15.52 ± 0.43^{bed}	18.50 ± 1.04^{bed}	24.90 ± 1.21^{de}	27.90 ± 1.62^{fgh}
20% Coconut water	15.30 ± 0.61^{ab}	15.30 ± 0.42^{bed}	22.40 ± 1.50^{a}	32.80 ± 1.17^{ab}	49.00 ± 1.67b
50 mg/L GA_3	15.20 ± 0.60^{ab}	18.18 ± 0.42^{ab}	21.80 ± 1.20^{bc}	30.40 ± 1.43^{bc}	34.80 ± 1.76^{ef}
100 mg/L GA_3	13.40 ± 0.60^{bc}	16.40 ± 0.40^{cd}	19.20 ± 1.45^{bed}	26.00 ± 1.12^{cd}	32.50 ± 1.08^{efg}
200 mg/L GA_3	14.20 ± 0.64^{abc}	16.96 ± 0.41^{cd}	20.60 ± 1.35^{bc}	33.10 ± 1.58^{a}	57.00 ± 1.56^{a}
50 mg/L NAA	10.28 ± 0.63^{ef}	14.90 ± 0.43^{d}	21.10 ± 1.08^{bc}	31.80 ± 1.06^{bc}	41.00 ± 1.68^{cd}
100 mg/L NAA	10.80 ± 0.62^{ef}	14.20 ± 0.42^{d}	18.00 ± 1.55^{d}	32.20 ± 1.09^{ab}	39.20 ± 1.39^{cde}
200 mg/L NAA	10.72 ± 0.60^{ef}	14.80 ± 0.41^{d}	19.20 ± 1.87^{d}	27.20 ± 1.21^{cd}	40.20 ± 106^{cd}
50 mg/L IAA	10.84 ± 0.60^{ef}	12.56 ± 0.42^{de}	15.00 ± 1.33^{e}	25.60 ± 1.10^{cde}	29.40 ± 1.21^{fgh}
100 mg/L IAA	10.82 ± 0.60^{ef}	14.00 ± 0.41^{cd}	16.66 ± 1.34^{de}	25.90 ± 1.08^{cde}	32.10 ± 1.45^{efg}
200 mg/L IAA	12.00 ± 0.64^{bed}	14.74 ± 0.42^{cde}	17.70 ± 1.22^{de}	26.40 ± 1.33^{cd}	32.40 ± 1.56^{efg}
50 mg/L BAP	13.00 ± 0.64^{bed}	17.24 ± 0.40^{def}	20.20 ± 1.21^{bc}	28.20 ± 1.09^{bcd}	37.40 ± 1.35^{cde}
100 mg/L BAP	13.00 ± 0.62^{bed}	15.80 ± 0.42^{bed}	21.60 ± 1.45^{bc}	33.80 ± 1.56^{a}	47.00 ± 1.46^{bc}
200 mg/L BAP	10.66 ± 0.62^{ef}	14.50 ± 0.44^{d}	18.90 ± 1.32^{bed}	32.00 ± 1.33^{ab}	43.00 ± 1.63^{cd}
Distilled water (Control)	13.10±0.60^{bed}	14.48±0.11^{d}	17.40±1.21^{de}	26.31±1.48 ^{cd}	28.11±1.27^{fgh}

Means followed by the same letters on the same column are not significantly different according to Duncan Multiple Range Test at 5% probability. GA_3 = Gibberellic Acid; NAA= Naphthalene Acetic Acid; IAA= Indole Acetic Acid; BAP=6-Benzyl-amino purine.

Table 2. RGR (gg^{-1} $week^{-1}$), NAR (gcm^{2-} $week^{-1}$) and LAR (cm^2 g^{-1}) of *H. sabdariffa* given single and combined hormone treatments at 2, 4, 6, 8, and 10 weeks after planting.

Single Hormonal Treatment	RGR	NAR	LAR
10% Coconut water	0.592 ± 0.21^{c}	0.026 ± 0.02^{bc}	4219.1 ± 0.20^{fgh}
15% Coconut water	0.603 ± 0.18^{b}	0.026 ± 0.01^{bc}	4183.0 ± 0.24^{fghi}
20% Coconut water	0.651 ± 0.11^{ab}	0.035 ± 0.08^{ab}	4044.4 ± 0.11^{i}
50 mg/L GA_3	0.532 ± 0.18^{cd}	0.028 ± 0.011^{bc}	5323.1 ± 0.18^{def}
100 mg/L GA_3	0.590 ± 0.23^{c}	0.032 ± 0.01^{ab}	4260.9 ± 0.27^{ijk}
200 mg/L GA_3	0.673 ± 0.01^{a}	0.038 ± 0.01^{a}	4095.0 ± 0.14^{i}
50 mg/L NAA	0.500 ± 0.13^{cde}	0.035 ± 0.20^{ab}	5664.3 ± 0.18^{cde}
100 mg/L NAA	0.482 ± 0.22^{de}	0.030 ± 0.02^{bc}	4788.3 ± 0.45^{fg}
200 mg/L NAA	0.455 ± 0.16^{de}	0.027 ± 0.02^{bc}	5455.0 ± 0.33^{cde}
50 mg/L IAA	0.527 ± 0.20^{cde}	0.026 ± 0.01^{bc}	4953.3 ± 0.38^{fg}
100 mg/L IAA	0.493 ± 0.18^{de}	0.021 ± 0.02^{bcd}	5523.4 ± 0.22^{cde}
200 mg/L IAA	0.502 ± 0.22^{cde}	0.021 ± 0.1^{bcd}	5740.1 ± 0.10^{cde}
50 mg/L BAP	0.395 ± 0.16^{f}	0.024 ± 0.04^{bcd}	5001.8 ± 0.29^{def}
100 mg/L BAP	0.504 ± 0.33^{cde}	0.027 ± 0.06^{bc}	5841.3 ± 0.43^{cde}
200 mg/L BAP	0.477 ± 0.19^{de}	0.026 ± 0.01^{bc}	5505.4 ± 0.13^{de}

Means followed by the same letters on the same column are not significantly different according to DMRT at 5% probability. RGR= Relative growth rate, NAR= Net assimilation rate and LAR= Leaf area ratio.

significantly ($p < 0.05$) higher in *H. sabdariffa* treated with 200 mg/LGA_3 while leaf area ration (5841.3 cm^2 g^{-1}) was significantly ($p < 0.05$) in the plant sprayed with 100mg/L BAP (Table 2). Similarly, leaf area (83.2 cm^2) and leaf relative water content (81.9 %) were significantly ($p < 0.05$) higher in *H. sabdariffa* sprayed with 20 % coconut water and 200mg/L GA_3 and 50 mg/L IAA respectively. while stem diameter (0.37 mm) was significantly($p < 0.05$) higher in in *H. sabdariffa* treated with 20 % coconut water at 10 weeks after planting (Tables 3-5). This observation agrees with submission of Kadiri, (1999); Youssef and Talaat, (1998) and Abdel-Rahim *el al.* (2000) who opined that coconut water is a rich source of kinetin and that foliar application of kinetin increased volatile oil percentage and oil yield per plant in lavender and Datura seeds respectively. Also the effect of GA_3 either singly or in combinations could suggest that GA_3 at 200 mg/L enhances promotion agronomic parameters in plant investigated. Similar observation was reported by Kadiri et al**.** (2016) who opined that agronomic characters were influenced by 200 ppm GA_3 application. In the same trend, the observation is in agreement with findings of

Table 3. Plant height (cm) of Roselle (*H. sabdariffa*) given single treatment at 2, 4, 6, 8, and 10 weeks after planting.

Single Hormonal Treatment	WEEKS AFTER PLANTING (WAP)				
	2	4	6	8	10
10% Coconut water	21.60 ± 1.55^{a}	32.00 ± 1.55^{a}	49.60 ± 1.80^{a}	61.20 ± 1.76^{b}	61.20 ± 1.54^{cd}
15% Coconut water	19.60 ± 1.55^{bc}	28.00 ± 1.86^{bc}	40.40 ± 1.75^{b}	58.40 ± 1.61^{c}	63.60 ± 1.55^{cd}
20% Coconut water	19.20 ± 1.79^{ab}	28.00 ± 1.44^{bc}	39.20 ± 1.49^{bc}	59.60 ± 1.46^{c}	83.20 ± 1.40^{a}
50 mg/L GA_3	20.00 ± 1.02^{ab}	29.20 ± 1.04^{b}	41.60 ± 1.55^{b}	64.40 ± 1.73^{a}	71.60 ± 1.09^{b}
100 mg/L GA_3	18.80 ± 1.43^{bc}	27.20 ± 1.54^{bcd}	36.80 ± 1.73^{bcd}	62.00 ± 1.54^{b}	68.80 ± 1.55^{c}
200 mg/L GA_3	20.00 ± 1.09^{ab}	27.60 ± 1.75^{bcd}	34.60 ± 1.45^{cde}	51.20 ± 1.56^{cd}	73.00 ± 1.66^{b}
50 mg/L NAA	18.40 ± 1.92^{bc}	23.20 ± 1.21^{cd}	24.60 ± 1.657^{j}	37.20 ± 1.73^{abc}	56.20 ± 1.43^{ef}
100 mg/L NAA	18.80 ± 1.47^{bc}	25.20 ± 1.75^{bcd}	35.20 ± 1.30^{bcd}	41.40 ± 1.65^{de}	58.20 ± 1.53^{ef}
200 mg/L NAA	19.60 ± 1.71^{ab}	24.00 ± 1.51^{cd}	28.60 ± 1.63^{gh}	38.80 ± 1.65^{abc}	55.00 ± 1.63^{ef}
50 mg/L IAA	19.20 ± 1.64^{ab}	28.00 ± 1.50^{bc}	34.00 ± 1.50^{cde}	42.40 ± 1.81^{de}	67.40 ± 1.09^{c}
100 mg/L IAA	19.60 ± 1.54^{ab}	24.40 ± 1.40^{cd}	31.20 ± 1.73^{cdef}	40.40 ± 1.81^{de}	66.80 ± 1.65^{c}
200 mg/L IAA	20.40 ± 1.44^{ab}	23.60 ± 1.67^{cd}	27.60 ± 1.40^{ghi}	38.40 ± 1.56^{def}	53.60 ± 1.83^{ef}
50 mg/L BAP	19.20 ± 1.67^{ab}	23.00 ± 1.03^{cd}	38.00 ± 1.22^{bc}	55.00 ± 1.67^{c}	60.80 ± 1.54^{cd}
100 mg/L BAP	18.00 ± 1.43^{bc}	22.40 ± 1.546^{e}	35.60 ± 1.44^{bcd}	55.40 ± 1.09^{c}	67.00 ± 1.67^{def}
200 mg/L BAP	18.60 ± 1.43^{bc}	30.40 ± 1.87^{ab}	40.40 ± 1.44^{b}	53.00 ± 1.56^{cd}	70.80 ± 1.89^{b}
Distilled water (control)	19.40±1.11^{ab}	27.11±0.9^{bcd}	39.60±1.21^{bc}	49.60±1.30^{cd}	71.20 ±1.62^{b}

Means followed by the same letters on the same column are not significantly different according to Duncan Multiple Range Test at 5% probability, GA_3 = Gibberellic Acid; NAA= Naphthalene Acetic Acid; IAA= Indole Acetic Acid; BAP=6-Benzyl-amino purine.

Table 4. Leaf relative water contents (%) of *H. sabdariffa* single and combined hormone treatments at 2, 4, 6, 8, and 10 weeks after planting.

Single Hormonal Treatment	WEEKS AFTER PLANTING (WAP)			
	4	6	8	10
10% Coconut water	46.50 ± 1.31^{de}	58.5 ± 1.674^{bc}	59.60 ± 1.21^{bc}	59.80 ± 1.85^{bc}
15% Coconut water	54.30 ± 1.16^{ab}	60.7 ± 1.218^{bc}	64.50 ± 1.59^{b}	66.90 ± 1.34^{bc}
20% Coconut water	49.20 ± 1.31^{bc}	53.7 ± 1.346^{cd}	55.80 ± 1.31^{bc}	55.80 ± 1.21^{bc}
50 mg/L GA_3	50.10 ± 1.21^{ab}	52.9 ± 1.173^{cd}	55.80 ± 1.29^{bc}	59.80 ± 1.30^{bc}
100 mg/L GA_3	36.40 ± 1.16^{cd}	38.2 ± 1.332^{def}	40.00 ± 1.24^{cd}	40.50 ± 1.52^{bcd}
200 mg/L GA_3	64.90 ± 1.45^{a}	70.5 ± 1.590^{b}	76.50 ± 1.21^{a}	81.90 ± 1.67^{a}
50 mg/L NAA	25.00 ± 1.27^{ef}	29.5 ± 1.435^{efg}	31.00 ± 1.42^{e}	34.80 ± 1.31^{de}
100 mg/L NAA	48.10 ± 1.53^{bc}	50.5 ± 1.333^{cd}	56.20 ± 1.123^{bc}	58.50 ± 1.44^{bc}
200 mg/L NAA	42.40 ± 1.84^{cd}	48.4 ± 1.631^{cde}	50.50 ± 1.24^{bc}	53.30 ± 1.20^{bcd}
50 mg/L IAA	69.20 ± 1.32^{a}	73.7 ± 1.451^{a}	75.40 ± 1.25^{a}	81.90 ± 1.404^{a}
100 mg/L IAA	50.20 ± 1.90^{def}	54.9 ± 1.235^{cd}	56.70 ± 1.31^{e}	58.50 ± 1.20^{bc}
200 mg/L IAA	36.30 ± 1.64^{cd}	40.1 ± 1.204^{def}	41.90 ± 1.29^{cd}	43.50 ± 1.20^{bcd}
50 mg/L BAP	34.20 ± 1.36^{cd}	37.6 ± 1.264^{def}	40.20 ± 1.21^{cd}	43.70 ± 1.31^{bcd}
100 mg/L BAP	30.10 ± 1.21^{c}	35.3 ± 1.234^{bc}	38.80 ± 1.37^{de}	40.80 ± 1.32^{cd}
200 mg/L BAP	25.50 ± 1.30^{ef}	28.9 ± 1.563^{efg}	30.70 ± 1.67^{e}	33.80 ± 1.42^{de}
Distilled water (control)	25.70±1.60^{ef}	35.4±1.11^{bc}	31.60± 0.26^{e}	42.60±1.61^{bcd}

Means followed by the same letters on the same column are not significantly different according to Duncan Multiple Range Test at 5% probability. GA_3 = Gibberellic Acid; NAA= Naphthalene Acetic Acid; IAA= Indole Acetic Acid; BAP=6-Benzyl-amino purine.

other researchers who postulated that spraying of GA_3 stimulated production of flowers in lettuce and increased significantly growth of bean and leaf length of lettuce (Metzger, 1988; Yildirim et al*.,* 2007; Thomas et al*.,* 2009; Tiwari et al., 2011; Mona et al*.,* 2013; Mondal et al*.,* 2013; Mukhtar, 2008; Fadimu et al., 2012).

Combined hormone treatments showed significant increase ($p < 0.05$) on *H, sabdariffa* investigated.

Further studies on the result showed that height (35.2 cm) of the plant treated with combination of 200 mg/L GA3 + 200 mg/L IAA was significant increase ($p < 0.05$) followed by height of the plant treated (34.9 cm) sprayed with 50mg/L GA3 + 10% Coconut water. Increase in the growth of *H. sabdarffa* seedlings with time can be attributed to the roles of phytohormones as growth promoter via physiological and biochemical processes (Kediri et al*.,* 1997).

Combinations of the hormones produced significant difference ($p < 0.05$) on the vegetative parameters of the plant. 200 mg/L GA_3 + 200 mg/L IAA produced highest height (35.20 cm), number of leaves (39.6), leaf area, (72.60) and stem diameter (0.31mm) compare with single

Table 5. Stem diameter (mm) of Roselle (*H. sabdariffa*) given single and combined hormone treatments at 2, 4, 6, 8, and 10 weeks after planting.

Single Hormonal Treatment	Weeks after planting (WAP)				
	2	4	6	8	10
10% Coconut water	0.07 ± 0.018^{a}	0.09 ± 0.01^{bc}	0.12 ± 0.08^{bc}	0.19 ± 0.04^{bc}	0.36 ± 0.03^{a}
15% Coconut water	0.06 ± 0.034^{ab}	0.07 ± 0.05^{bcd}	0.11 ± 0.04^{cd}	0.15 ± 0.02^{cd}	0.27 ± 0.03^{bcde}
20% Coconut water	0.07 ± 0.043^{a}	0.03 ± 0.01^{a}	0.16 ± 0.03^{a}	0.22 ± 0.013^{a}	0.37 ± 0.01^{a}
50 mg/L GA_3	0.05 ± 0.074^{bc}	0.07 ± 0.03^{cde}	0.10 ± 0.05^{d}	0.19 ± 0.02^{cd}	0.27 ± 0.05^{bcde}
100 mg/L GA_3	0.06 ± 0.043^{ab}	0.08 ± 0.01^{bc}	0.12 ± 0.01^{bc}	0.15 ± 0.02^{cd}	0.25 ± 0.04^{bcde}
200 mg/L GA_3	0.05 ± 0.065^{bc}	0.08 ± 0.04^{bc}	0.12 ± 0.03^{bc}	0.21 ± 0.03^{ab}	0.36 ± 0.05^{a}
50 mg/L NAA	0.06 ± 0.082^{ab}	0.08 ± 0.02^{bc}	0.13 ± 0.02^{bc}	0.21 ± 0.02^{ab}	0.31 ± 0.01^{abcd}
100 mg/L NAA	0.05 ± 0.042^{c}	0.08 ± 0.05^{bcd}	0.11 ± 0.03^{cd}	0.22 ± 0.03^{a}	0.28 ± 0.02^{bcde}
200 mg/L NAA	0.06 ± 0.017^{bc}	0.07 ± 0.02^{bcd}	0.11 ± 0.06^{cd}	0.19 ± 0.04^{bc}	0.36 ± 0.05^{a}
50 mg/L IAA	0.05 ± 0.073^{c}	0.06 ± 0.01^{cde}	0.08 ± 0.04^{de}	0.14 ± 0.04^{cd}	0.24 ± 0.02^{cde}
100 mg/L IAA	0.05 ± 0.082^{c}	0.08 ± 0.01^{bcd}	0.11 ± 0.01^{cd}	0.17 ± 0.02^{bcd}	0.25 ± 0.02^{bcde}
200 mg/L IAA	0.06 ± 0.032^{bc}	0.07 ± 0.05^{cde}	0.10 ± 0.04^{d}	0.16 ± 0.03^{cd}	0.28 ± 0.03^{bcde}
50 mg/L BAP	0.06 ± 0.009^{bc}	0.06 ± 0.03^{cde}	0.10 ± 0.08^{d}	0.19 ± 0.03^{bc}	0.31 ± 0.02^{abcd}
100 mg/L BAP	0.05 ± 0.032^{bc}	0.06 ± 0.04^{cde}	0.11 ± 0.01^{cd}	0.22 ± 0.021^{a}	0.34 ± 0.04^{abcd}
200 mg/L BAP	0.06 ± 0.02^{ab}	0.10 ± 0.01^{ab}	0.15 ± 0.02^{b}	0.20 ± 0.03^{ab}	0.31 ± 0.02^{abcd}
Distilled water (control)	0.06±0.01^{ab}	0.08±0.02^{bcd}	0.12±0.01^{bc}	0.21±0.01^{bc}	0.29±0.03^{bcde}

Means followed by the same letters on the same column are not significantly different according to Duncan Multiple Range Test at 5% probability. GA_3 = Gibberellic Acid; NAA= Naphthalene Acetic Acid; IAA= Indole Acetic Acid; BAP=6-Benzyl-amino purine.

Table 6. Plant height (cm) of Roselle (*H. sabdariffa*) given combined treatment at 2, 4, 6, 8, and 10 weeks after planting.

Combined Hormonal Treatment	Weeks after planting (WAP)				
	2	4	6	8	10
50mg/LGA_3 + 10% Coconut water	12.14 ± 0.76^{a}	15.14 ± 0.40^{a}	21.4 ± 0.31^{a}	28.6 ± 0.77^{ab}	34.90 ± 0.30^{ab}
100mg/L$GA_3$15% Coconut water	12.24 ± 0.21^{a}	12.24 ± 0.21^{a}	19.5 ± 0.40^{bc}	27.4 ± 0.45^{ab}	30.04 ± 0.49^{c}
200mg/L$GA_3$20% Coconut water	12.30 ± 0.45^{a}	12.30 ± 0.45^{a}	18.0 ± 0.55^{bc}	27.6 ± 0.64^{ab}	33.30 ± 0.54^{b}
50mg/LGA_3 + 50 mg/L NAA	8.20 ± 0.25^{de}	8.20 ± 0.25^{de}	15.8 ± 0.84^{cd}	23.4 ± 0.40^{ab}	27.60 ± 0.60^{cd}
100 mg/L GA_3 + 100 mg/L NAA	11.04 ± 0.61^{ab}	11.04 ± 0.61^{ab}	18.0 ± 0.28^{bc}	25.0 ± 0.40^{ab}	31.92 ± 0.50^{bc}
200 mg/L GA_3 + 200MG/L NAA	10.00 ± 0.09^{bc}	10.00 ± 0.09^{bc}	15.4 ± 0.40^{cd}	23.6 ± 0.54^{bc}	25.80 ± 0.49^{cd}
50mg/LGA_3 + 50 mg/L IAA	10.60 ± 0.43^{bc}	10.60 ± 0.43^{bc}	20.0 ± 0.35^{ab}	27.8 ± 0.65^{ab}	33.90 ± 0.66^{b}
100mg/LGA_3 + 100mg/L IAA	10.40 ± 0.32^{bc}	10.40 ± 0.32^{bc}	17.8 ± 0.47^{bcd}	23.4 ± 0.74^{bc}	31.40 ± 0.83^{bc}
200mg/LGA_3 + 200 mg/L IAA	10.60 ± 0.27^{bc}	10.60 ± 0.27^{bc}	17.2 ± 0.62^{bcd}	29.2 ± 0.43^{a}	35.20 ± 0.40^{a}
50mg/L Caffeic acid	7.90 ± 0.56^{de}	7.90 ± 0.56^{de}	10.5 ± 0.89^{e}	11.5 ± 0.33^{d}	27.20 ± 0.56^{cd}
100mg/L Caffeic acid	9.30 ± 0.34^{d}	9.30 ± 0.34^{d}	12.7 ± 0.54^{de}	13.5 ± 0.83^{d}	20.78 ± 0.36^{e}
200mg/L Caffeic acid	7.00 ± 0.53^{e}	7.00 ± 0.53^{e}	13.3 ± 0.47^{de}	13.8 ± 0.49^{d}	22.00 ± 0.54^{e}
Distilled water (Control)	7.60 ± 0.67^{de}	7.60 ± 0.67^{de}	13.2 ± 0.77^{de}	24.0 ± 0.43^{bc}	30.60 ± 0.22^{c}

Means followed by the same letters on the same column are not significantly different according to Duncan Multiple Range Test at 5% probability GA_3 = Gibberellic Acid; NAA= Naphthalene Acetic Acid and IAA= Indole Acetic Acid, and BAP=6-Benzyl-amino purine.

and control (Tables 6-9). This observation could suggest better synergetic effect of the hormones when they are used in combined form thereby leading to better physiological performance of the hormones than when used in single form. Similar observation was reported by kadiri (1999).

The leaf area in *H. sabdarffa* seedlings treated with 20 % coconut water, 200 mg/L GA_3 and 50 mg/L GA_3 showed that the growth rate of plants is dependent on the efficiency of the leaf area. This means that the seedlings with the phytohormones treatments are more effective than both the inhibitor and the control. This is in line with the work of Fawibe et al. (2014) who postulated that the smaller the leaf area ratio, the more effective the leaf area.

Highest leaves relative water contents (76.2%) was recorded in *H. sabdariffa* sprayed with combinations 50 mg/L GA_3 + 10 % Coconut water (Table 10), relative growth rate (0.62 gg $^{-1}$ week^{-1}) in *H. sabdariffa* sprayed with 50 mg/L GA_3 + 10 % Coconut water, net assimilation rate (0.038 gcm $^{-2}$ week^{-1}) in the plant sprayed with 200 mg/LGA3 + 200 mg/L NAA while highest leaf area ratio (7541.2 cm ^{2}g $^{-1}$ was recorded in the plant sprayed with 200 mg/L Caffeic acid (Table 11).

The increase in the stem diameter could be due to consistent watering and application of some of the plant hormones. This result is in agreement with the work of Fadimu et al. (2012**)** and Agboola et al. (2004) who suggested that stem girth of *Spondias mombin* increased significantly with application of plant hormones, growth

Table 7. Number of leaves of *H. sabdariffa* given single and combined hormone treatments at 2, 4, 6, 8, and 10 weeks after planting.

Single Hormonal Treatment	Weeks after planting (WAP)				
	2	4	6	8	10
10% Coconut water	6.60 ± 1.42^{ab}	6.80 ± 1.37^{bc}	8.00 ± 1.90^{bc}	12.4 ± 1.30^{cde}	12.40 ± 1.12^{efg}
15% Coconut water	6.20 ± 1.4^{ab}	7.80 ± 1.12^{ab}	9.20 ± 1.83^{bc}	9.80 ± 1.22^{defg}	15.40 ± 1.40^{def}
20% Coconut water	4.80 ± 1.38^{c}	8.00 ± 1.33^{a}	10.6 ± 1.32^{ab}	14.8 ± 1.55^{bc}	39.60 ± 1.34^{a}
50 mg/L GA_3	7.40 ± 1.44^{a}	7.60 ± 1.54^{ab}	10.2 ± 1.44^{ab}	13.0 ± 1.34^{bcd}	17.40 ± 1.22^{cdef}
100 mg/L GA_3	5.20 ± 1.65^{abc}	6.40 ± 1.34^{bc}	8.40 ± 1.336^{ab}	10.0 ± 1.23^{cdef}	18.6 ± 1.55^{cdef}
200 mg/L GA_3	4.60 ± 1.53^{c}	6.60 ± 1.76^{bc}	9.40 ± 1.62^{bc}	12.4 ± 1.55^{cde}	26.4 ± 1.44^{b}
50 mg/L NAA	5.80 ± 1.63^{abc}	6.60 ± 1.26^{bc}	10.4 ± 1.22^{ab}	21.0 ± 1.64^{a}	24.8 ± 1.35^{bc}
100 mg/L NAA	4.80 ± 1.33^{c}	7.20 ± 1.44^{ab}	8.40 ± 1.55^{ab}	13.6 ± 1.53^{bcd}	24.4 ± 1.22^{bc}
200 mg/L NAA	7.00 ± 1.44^{a}	8.20 ± 1.22^{a}	9.40 ± 1.20^{ab}	13.2 ± 1.33^{bcd}	16.6 ± 1.33^{cdef}
50 mg/L IAA	6.20 ± 1.33^{ab}	6.40 ± 1.63^{bc}	6.20 ± 1.11^{d}	10.0 ± 1.73^{cdef}	16.8 ± 1.21^{cdef}
100 mg/L IAA	6.20 ± 1.29^{ab}	6.80 ± 1.32^{bc}	9.20 ± 1.31^{ab}	10.8 ± 1.32^{cdef}	14.6 ± 1.73^{defg}
200 mg/L IAA	4.40 ± 1.27^{c}	7.00 ± 1.53^{ab}	9.00 ± 1.22^{ab}	10.6 ± 1.36^{cdef}	19.4 ± 1.33^{cde}
50 mg/L BAP	6.40 ± 1.73^{ab}	6.00 ± 1.21^{bc}	11.2 ± 1.43^{a}	12.6 ± 1.52^{cde}	20.2 ± 1.438^{cd}
100 mg/L BAP	5.20 ± 1.44^{abcd}	7.80 ± 1.44^{bc}	9.20 ± 1.44^{ab}	14.2 ± 1.43^{bcd}	25.2 ± 1.38^{fg}
200 mg/L BAP	5.00 ± 1.44^{abc}	7.00 ± 1.44^{abc}	8.60 ± 1.43^{ab}	15.6 ± 1.48^{d}	25.8 ± 1.48^{bc}
Distilled water (control)	5.1±00.28^{abcd}	7.00±1.20^{ab}	10.3±1.11^{ab}	13.3±1.44^{bcd}	25.6±1.01^{bc}

Means followed by the same letters on the same column are not significantly different according to Duncan Multiple Range Test at 5% probability. GA_3 = Gibberellic Acid; NAA= Naphthalene Acetic Acid; IAA= Indole Acetic Acid; BAP=6-Benzyl-amino purine.

Table 8. Relative leaf area (cm^2) of Roselle (*H. sabdariffa*) given combined treatment at 2, 4, 6, 8, and 10 weeks after planting.

Combined Hormonal Treatment	Weeks after planting (WAP)				
	2	4	6	8	10
50mg/LGA_3 + 10% Coconut water	18.60 ± 1.23^{bc}	22.20 ± 1.55^{e}	27.60 ± 1,74^{a}	41.20 ± 1.54^{bc}	62.40 ± 1.54^{b}
100mg/L$GA_3$15% Coconut water	18.40 ± 1.40^{bc}	23.60 ± 1.33^{cd}	32.00 ± 1.55^{cd}	44.40 ± 1.82^{bc}	58.80 ± 1.91^{bc}
200mg/L$GA_3$20% Coconut water	18.60 ± 1.51^{ab}	31.00 ± 1.65^{a}	42.20 ± 1.87^{b}	47.80 ± 1.52^{b}	53.20 ± 1.72^{cd}
50mg/LGA_3 + 50 mg/L NAA	19.60 ± 1.33^{ab}	29.60 ± 1.532^{abc}	37.20 ± 1.65^{c}	45.20 ± 1.22^{bc}	60.40 ± 1.43^{b}
100 mg/L GA_3 + 100 mg/L NAA	17.80 ± 1.89^{c}	24.40 ± 1.11^{cd}	29.20 ± 1.43^{abc}	40.60 ± 1.75^{cd}	55.60 ± 1.87^{bcd}
200 mg/L GA_3 + 200MG/L NAA	18.40 ± 1.78^{bc}	25.00 ± 1.33^{bc}	32.40 ± 1.70^{cd}	42.40 ± 1.43^{bc}	54.60 ± 1.82^{cd}
50mg/LGA_3 + 50 mg/L IAA	18.40 ± 1.43^{bc}	22.40 ± 1.56^{e}	27.40 ± 1.32^{cde}	34.40 ± 1.65^{de}	42.40 ± 1.63^{def}
100mg/LGA_3 + 100mg/L IAA	19.40 ± 1.t65^{ab}	26.60 ± 1.21^{bc}	37.20 ± 1.50^{c}	44.00 ± 1.33^{bc}	50.80 ± 1.63^{cd}
200mg/LGA_3 + 200 mg/L IAA	20.40 ± 1.32^{a}	30.00 ± 1.89^{ab}	53.60 ± 1.23^{a}	62.00 ± 1.87^{a}	72.60 ± 1.20^{a}
50mg/L Caffeic acid	18.60 ± 1.62^{bc}	25.20 ± 1.54^{bc}	33.20 ± 1.41^{cd}	37.60 ± 1.44^{d}	40.80 ± 1.03^{f}
100mg/L Caffeic acid	19.20 ± 1.01^{ab}	24.80 ± 1.87^{cd}	32.60 ± 1.43^{cd}	34.20 ± 1.32^{de}	38.00 ± 1.89^{fg}
200mg/L Caffeic acid	17.60 ± 1.97^{c}	24.40 ± 1.43^{cd}	28.60 ± 1.09^{cde}	32.80 ± 1.54^{c}	33.80 ± 1.64^{g}
Distilled water (Control)	18.80 ± 1.54^{bc}	24.00 ± 1.65^{cd}	28.80 ± 1.34^{a}	33.00 ± 1.67^{de}	41.60 ± 1.54^{f}

Means followed by the same letters on the same column are not significantly different according to Duncan Multiple Range Test at 5% probability. GA_3 = Gibberellic Acid; NAA= Naphthalene Acetic Acid and IAA= Indole Acetic Acid, and BAP=6-Benzyl-amino purine.

Table 9. Stem diameter (mm) of *H. sabdariffa* plants given single and combined hormone treatment at 2, 4, 6, 8, and 10 weeks after planting.

Combined Hormonal Treatment	Weeks after planting (WAP)				
	2	4	6	8	10
50mg/LGA_3 + 10% Coconut water	0.05 ± 0.06^{a}	0.06 ± 0.02^{bcd}	0.100 ± 0.06^{bcd}	0.154 ± 0.02^{cde}	0.27 ± 0.04^{cd}
100mg/L$GA_3$15% Coconut water	0.05 ± 0.04^{a}	0.06 ± 0.01^{bcd}	0.09 ± 0.03^{bcd}	0.168 ± 0.03^{cd}	0.27± 0.01^{cd}
200mg/L$GA_3$20% Coconut water	0.06 ± 0.03^{a}	0.07 ± 0.05^{bcd}	0.11 ± 0.02^{abc}	0.176 ± 0.03^{bc}	0.27 ± 0.04^{cde}
50mg/LGA_3 + 50 mg/L NAA	0.05 ± 0.09^{a}	0.08 ± 0.03^{a}	0.13 ± 0.03^{a}	0.178 ± 0.07^{bc}	0.24 ± 0.01^{de}
100 mg/L GA_3 + 100 mg/L NAA	0.05 ± 0.03^{a}	0.07 ± 0.09^{ab}	0.11 ± 0.03^{cde}	0.190 ± 0.01^{bc}	0.300 ± 0.03^{b}
200 mg/L GA_3 + 200MG/L NAA	0.05 ± 0.01^{a}	0.05 ± 0.01^{de}	0.07 ± 0.01^{abc}	0.152 ± 0.06^{cde}	0.21 ± 0.04^{de}
50mg/LGA_3 + 50 mg/L IAA	0.05 ± 0.02^{a}	0.07 ± 0.02^{bcd}	0.10 ± 0.05^{abc}	0.158 ± 0.03^{cde}	0.19 ± 0.08^{e}
100mg/LGA_3 + 100mg/L IAA	0.05 ± 0.02^{a}	0.07 ± 0.01^{bcd}	0.10 ± 0.04^{abc}	0.168 ± 0.01^{cd}	0.29 ± 0.02^{b}
200mg/LGA_3 + 200 mg/L IAA	0.05 ± 0.02^{a}	0.07 ± 0.02^{bcd}	0.11 ± 0.07^{ab}	0.232 ± 0.01^{a}	0.31 ± 0.04^{a}
50mg/L Caffeic acid	0.05 0.03^{a}	0.05 ± 0.02^{cde}	0.06 ± 0.01^{et}	0.098 ± 0.01^{t}	0.15 ± 0.03^{t}
100mg/L Caffeic acid	0.06 ± 0.02^{ab}	0.06 ± 0.03^{cde}	0.07 ± 0.03^{def}	0.104 ± 0.04^{ef}	0.16 ± 0.04^{ef}
200mg/L Caffeic acid	0.05 ± 0.01^{a}	0.06 ± 0.03^{cde}	0.08 ± 0.05^{det}	0.092 ± 0.02^{t}	0.17 ± 0.01^{et}
Distilled water (Control)	0.05 ± 0.06^{a}	0.04 ± 0.05^{t}	0.05 ± 0.01^{t}	0.118 ± 0.04^{et}	0.19 ± 0.05^{e}

Means followed by the same letters on the same column are not significantly different according to Duncan Multiple Range Test at 5% probability. GA_3 = Gibberellic Acid; NAA= Naphthalene Acetic Acid and IAA= Indole Acetic Acid, and BAP=6-Benzyl-amino purine.

Table 10. leaf relative water contents (%) of *H. sabdariffa* plants given single and combined hormone treatment at 2, 4, 6, 8, and 10 weeks after planting.

Combined Hormonal Treatment	Weeks after planting (WAP)			
	4	6	8	10
50mg/LGA$_3$ + 10% Coconut water	59.10 ± 1.20^{a}	69.90 ± 1.39^{a}	73.70 ± 1.33^{a}	76.20 ± 1.3^{a}
100mg/LGA$_3$15% Coconut water	44.60 ± 1.31^{ab}	47.80± 1.46^{bc}	48.30 ± 1.32^{cd}	52.0 ± 1.67^{cd}
200mg/LGA$_3$20% Coconut water	27.00 ± 1.55^{cd}	30.20 ± 1.22^{cd}	34.40 ± 1.42^{def}	35.7 0± 1.22^{f}
50mg/LGA$_3$ + 50 mg/L NAA	28.40 ± 1.42^{cd}	30.80 ± 1.44^{cd}	32.60 ± 1.45^{def}	36.50 ± 1.33^{f}
100 mg/L GA$_3$ + 100 mg/L NAA	27.90 ± 1.23^{cd}	31.50 ± 1.19^{cd}	36.50 ± 1.33^{def}	38.60 ± 1.442^{f}
200 mg/L GA$_3$ + 200MG/L NAA	41.10 ± 1.75^{ab}	45.20 ± 1.29^{bc}	47.80 ± 1.22^{cd}	49.40 ± 1.23^{def}
50mg/LGA$_3$ + 50 mg/L IAA	60.30 ± 1.22^{a}	64.60 ± 1.38^{b}	64.60 ± 1.38^{b}	66.90 ± 1.44^{bcd}
100mg/LGA$_3$ + 100mg/L IAA	42.70 ± 1.37^{ab}	45.00 ± 1.21^{bc}	47.30 ± 1.27^{cd}	49.40 ± 1.98^{def}
200mg/LGA$_3$ + 200 mg/L IAA	30.00 ± 1.44^{c}	32.20 ± 1.32^{bc}	34.70 ± 1.54^{def}	35.70 ± 1.26^{f}
50mg/L Caffeic acid	20.20 ± 1.51^{e}	23.70 ± 1.22^{e}	25.50 ± 1.32^{f}	25.50 ± 1.45^{g}
100mg/L Caffeic acid	25.50 ± 1.43^{de}	30.00 ± 1.44^{cd}	33.20 ± 1.21^{def}	33.80 ± 1.56^{f}
200mg/L Caffeic acid	23.40 ± 1.26^{e}	25.10 ± 1.21^{e}	27.90 ± 1.85^{ef}	28.30 ± 1.29^{g}
Distilled water (Control)	36.50± 1.47^{bc}	39.90 ± 1.30^{c}	41.80 ± 1.28^{cd}	43.20 ± 1.49^{ef}

Means followed by the same letters on the same column are not significantly different according to Duncan Multiple Range Test at 5% probability. GA_3 = Gibberellic Acid; NAA= Naphthalene Acetic Acid and IAA= Indole Acetic Acid, and BAP=6-Benzyl-amino purine.

Table 11. RGR (gg^{-1} week^{-1}) and NAR (gcm$^{2-1}$ week^{-1}) and LAR (cm^{2} g^{-1}) of *H. sabdariffa* given single and combined hormone treatments at 2, 4, 6, 8, and 10 weeks after planting.

Combined Hormonal Treatments	RGR	NAR	LAR
50 mg/LGA$_3$ + 10% Coconut water	0.62 ± 0.22^{a}	0.28 ± 0.01^{b}	5401.20 ± 0.35^{de}
100 mg/LGA$_3$15% Coconut water	0.56 ± 0.11^{ab}	0.20 ± 0.01^{bc}	6625.10 ± 0.28^{b}
200 mg/LGA$_3$20% Coconut water	0.49 ± 0.11^{cd}	0.22 ± 0.18^{bc}	6200.80 ± 0.36^{bc}
50 mg/LGA$_3$ + 50 mg/L NAA	0.56 ± 0.16^{ab}	0.20 ± 0.16^{bc}	5873.30 ± 0.24^{cd}
100 mg/L GA$_3$ + 100 mg/L NAA	0.60 ± 0.21^{a}	0.23 ± 0.11^{bc}	5441.10 ± 0.18^{de}
200 mg/L GA$_3$ + 200MG/L NAA	0.59 ± 0.18^{ab}	0.30 ± 0.14^{a}	6066.70 ± 0.20^{bc}
50 mg/LGA$_3$ + 50 mg/L IAA	0.49 ± 0.16^{cd}	0.25 ± 0.16^{b}	5935.40 ± 0.45^{cd}
100 mg/LGA$_3$ + 100mg/L IAA	0.47 ± 0.20^{cd}	0.26 ± 0.12^{b}	6322.20 ± 0.18^{bc}
200 mg/LGA$_3$ + 200 mg/L IAA	0.39 ± 0.18^{bcd}	0.22 ± 0.14^{bc}	5537.10 ± 0.24^{cd}
50mg/L Caffeic acid	0.31 ± 0.21^{cdef}	0.21 ± 0.02^{cd}	6546.30 ± 0.71^{b}
100 mg/L Caffeic acid	0.33 ± 0.20^{cde}	0.02 ± 0.18^{d}	6899.00 ± 0.30^{b}
200 mg/L Caffeic acid	0.29 ± 0.18^{f}	0.02 ± 0.19^{bc}	7541.20 ± 0.20^{a}
Distilled water (Control)	0.42 ± 0.16^{cd}	0.02 ± 0.24^{bc}	6311.00 ± 0.45^{bc}

Means followed by the same letters on the same column are not significantly different according to DMRT at 5% probability. RGR= Relative growth rate, NAR= Net assimilation rate and LAR= Leaf area ratio.

rate of plants depends on the effectiveness of the leaf area and that the leaf is the major assimilatory surface in plants. The high relative water content (RWC) in *H.sabdariffa* treated with 200 mg/L GA_3 and 50 mg/L IAA could be because water is a medium used for transportation of mineral nutrient and other complex substances manufactured within the plant as well as point of equilibrium of salts and other dissolved products in plants.

Conclusion

The study revealed that single hormone improved better the vegetative parameters of *H. sabdariffa* than combined hormone treatment and that 20% coconut water and 200 mg/L GA_3 were the most effective growth promoters, therefore, they are recommended for cultivation of *H. sabdariffa.*

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