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Gibberellic acid (GA_3) can shorten the grafting cycle through enhanced seedling growth and biomass in cashew (*Anacardium occidentale* L.)

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Abstract

Due to the slow growth of cashew seedlings, nurserymen and growers have to wait for more time for taking up softwood grafting operations to market or planting them. The use of growth regulators has resulted in a shortening of propagation time in many fruit crops. Therefore, the nursery experiment was conducted to study the effect of foliar spray of GA_3 and NAA on the growth and biomass of cashew seedlings. Five treatments *viz.*, control and foliar application of GA_3 @ 50 ppm, GA_3 @ 100 ppm, NAA @ 50 ppm and NAA @ 100 ppm were replicated four times in completely randomized design. Growth regulators were sprayed on 10 days old seedlings of cashew cultivar Vengurla-4. Cashew seedlings sprayed with GA_3 @ 100 ppm recorded highest shoot length, seedling length and girth, leaf numbers, shoot fresh weight and shoot dry weight. However, spraying of NAA @ 100 ppm recorded maximum root length and highest root fresh weight and root dry weight. Irrespective of the treatments, most of the seedling growth parameters increased as days progressed. Post germination sprays with GA_3 @ 100 ppm can be effectively employed for increasing the seedling growth of cashew which would help in producing healthy seedlings in a short period for advancing the grafting operations and in turn reduce the duration of propagation as well as the cost of seedling production.

Keywords: Cashew, foliar spray, growth regulators, seedling growth, Vengurla-4

Introduction

Cashew (*Anacardium occidentale* L), belonging to the family Anacardiaceae, is an important commercial plantation crop in India. This crop is widely cultivated in India, Brazil, South East Asia, and other tropical African countries. India was the first country to exploit the international trade of cashew nuts at the beginning of the 20th Century. During 2013-14, India netted rupees 5095 crores as foreign exchange by exporting 1.20 lakh tonnes of processed cashew kernel (NHB, 2014). Edible and nutritious cashew kernel contains fat (47%), protein (21%), carbohydrate (22%), dietary fibre (1.3%), minerals and vitamins. Cashew kernel is free from cholesterol, contains oleic acid, which reduces blood cholesterol and linoleic acid which lowers serum LDL. The current raw cashew nuts production of 7.5 lakh tonnes from 10.1 lakh ha area cannot suffice the demand of processors which stands at 14 lakh tonnes per year (NHB, 2014). The present low productivity of 0.74 tonnes per hectare is mainly attributable to the use of non-descript varieties, low-quality planting materials, non-adaption of recommended package of practices, a lower percentage of perfect flowers, low fruit setting and fruit retention (Lakshmipathi *et al.*, 2017).

The use of growth regulators has resulted in improving growth and yield in different fruit crops (Bisht *et al.*, 2018). Growth regulators like GA_3 (Gibberellic acid) and NAA (Naphthalene acetic acid) play a vital role in plant growth and development through increased cell division and cell enlargement, greater translocation of

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photosynthates and mineral elements in plants. Improvement of seed germination and seedling vigour are the essential prerequisites for vegetative propagation of tree crops. Since cashew is commercially propagated through softwood grafting, the extent of germination, increased vigour and the time taken for acquiring sufficient softwood growth will determine the success of propagation. Due to the slow growth of cashew seedlings, the growers/nurserymen have to wait for more time for taking up grafting operations to market them or plant them. Under normal conditions, cashew seedlings take about 60 days to reach graftable height (Lakshmipathi *et al*., 2013). Seed germination and emergence have been improved in many crops with the help of seed treatment (osmo-priming). Soaking of cashew nuts in growth regulators like GA_3 is known to enhance germination and seedling vigour (Lakshmipathi *et al*., 2013). Ram and Litz (2009) reported that to attain good germination, stones of mango were soaked in 20 to 200 ppm GA_3 for 24 to 48 hours or sprayed with 50 to 300 ppm GA_3. Synchronization and rapid seedling emergence are the commonly reported benefits of osmo-priming (Mohamed *et al*., 2010; Chauhan *et al*., 2018). This is particularly important for a crop like a cashew which is commercially propagated through softwood grafting, wherein early attainability of seedling height and girth can reduce the cycle of propagation. No information is available, so far, on the foliar spray effect of growth regulators in cashew seedlings. Hence, the investigation was carried out to determine the effectiveness of post-germination foliar spray of GA_3 and NAA on vegetative growth and biomass of cashew (var. Vengurla-4) seedlings for shortening the grafting cycle for the benefit of nurserymen and growers.

Materials and methods

Experimental location and treatment details

A nursery experiment was conducted at ICAR-Directorate of Cashew Research, Puttur, Karnataka during 2012 to study the effect of post-germination application with GA_3 and NAA on growth of cashew seedlings with five treatments *viz.*, control (T_1), GA_3 at 50 ppm (T_2), GA_3 at 100 ppm (T_3), NAA at 50 ppm (T_4) and NAA at 100 ppm (T_5). The experiment was carried out in a completely randomized design (CRD) with four replications. The experimental site was situated in a cashew growing belt, had typical lateritic soils of the west coast, located 87 m above MSL at 12.77° N latitude and 75.22° E longitude. The climate was hot and humid throughout the year with a mean yearly rainfall of 3,500 mm, distributed predominantly from June to September. The mean twelve-monthly temperature was 27.6 °C and the mean maximum and minimum temperatures were 36 °C and 20 °C, respectively.

Plant materials and data collection

Seeds of uniform age, size, and weight of cashew cultivar Vengurla-4 were used for the experiment. Seeds were sown with stalk end facing upwards in black coloured polythene bags of 25 cm x 15 cm size, filled with a potting mixture containing equal quantities of sand, red soil and well rotten farmyard manure. Growth regulators were sprayed to on? the 10 days old cashew seedlings. Observations on various seedling growth parameters were recorded at 30, 60, 90 and 120 days after sowing. Observations were recorded at different days to ascertain the rate of upsurge in various parameters over a period of time. The length of the shoot was measured from the ground surface to the tip of the growing point. Leaves on each cashew seedlings were counted and measured. Stem girth was measured at 10 cm above the soil surface. At 30, 60, 90 and 120 DAS, seedlings were removed to determine their length, fresh and dry, shoot and root weight. The roots of the seedlings after removal were washed completely with tap water. The seedlings were dried in an oven at 65 °C for 48 h to determine the biomass of seedlings.

Statistical analysis

Data generated from the experimental plots were scrutinized using SAS 9.3 (SAS Institute Inc, 2011). Analysis of variance was performed using the SAS PROC ANOVA procedure. Means were separated using Fisher's protected least significant difference (LSD) test at a probability level of $p<0.05$.

Results and discussion

Shoot and root length

The maximum shoot height was recorded with the application of GA_3 @ 100 ppm (Table 1). An increase in shoot length due to application of Ga_3

Table 1. Effect of post germination foliar spray of GA_3 and NAA on shoot and root length of cashew seedlings

Treatment (T)	School length (cm)				Root length (cm)			
	Days after sowing (DAS)				Days after sowing (DAS)			
	30	60	90	120	30	60	90	120
Control	24.95^{E}	32.40^{D}	38.05^{E}	48.70^{E}	10.20^{E}	14.20^{E}	15.05^{D}	17.50^{D}
GA_3 @ 50 ppm	35.10^{B}	41.43^{B}	46.18^{B}	59.48^{B}	12.15^{D}	19.20^{D}	22.28^{C}	26.30^{C}
GA_3 @ 100 ppm	38.30^{A}	46.68^{A}	58.50^{A}	75.60^{A}	15.00^{C}	28.30^{C}	31.80^{B}	39.05^{B}
NAA @ 50 ppm	28.45^{D}	37.55^{C}	42.80^{D}	53.00^{D}	18.20^{B}	28.70^{B}	34.28^{B}	42.23^{AB}
NAA @ 100 ppm	31.30^{C}	38.53^{C}	44.85^{C}	56.23^{C}	20.10^{A}	35.03^{A}	39.65^{A}	45.08^{A}
Mean	31.62	39.32	46.08	58.60	15.13	25.09	28.61	34.03
S. Em	0.16	0.58	0.29	0.95	0.64	0.15	2.12	2.33
LSD at 5%	0.35	1.27	0.64	2.07	1.39	0.33	4.62	5.07

Values with different alphabets are significantly different

@100 ppm makes the seedlings ready for early grafting (30-45 days) than control (60-75 days) and NAA spray. Under normal conditions, cashew seedlings take about 60-75 days to reach graftable height (35 cm). Irrespective of the treatments, the length of shoot increased as days progressed. An increase in shoot length with GA_3 might be due to increase in both cell division and internodal elongation in higher plants with gibberellic acid application which in turn promote stem and shoot elongation (Hartmann *et al*., 2002; Harris *et al.,* 2004; Hopkins and Huner, 2004). Shanmugavelu (1985) reported that the most striking response of Ga_3 on cashew is on stem elongation. The number and length of cells in the cortex and pith regions were influenced by GA_3 treatment. Therefore, it appears that the stem elongation is predominantly due to cell elongation supplemented with cell division in the cortex and pith region. Mohamed *et al*. (2010) also reported that the application of GA_3 on citrus rootstocks increased the stem height. Similarly, maximal shoot lengths were recorded in maize (Afzal *et al*., 2002), onion (Yarnia and Tabrizi, 2012), rice (Watanabe *et al*., 2007), tomato (Bakrim *et al*., 2007), and loquat (El-Dengawy, 2005) seeds treated with $GA_{3.}$

It was observed that seedlings sprayed with NAA @ 50 ppm recorded maximum root length followed by NAA @ 100 ppm, GA_3 @ 50 ppm, GA_3 @ 100 ppm and control (Table 1). Root length significantly increased over number of days. The root length of all the seedlings sprayed with GA_3 and NAA was increased compared to control. The highest (20.10 cm) and lowest (10.20 cm) root length was recorded in the seedlings sprayed with NAA @ 100 ppm and unsprayed seedlings (control), respectively at 30 DAS. Irrespective of treatments, the length of the root increased with the increasing number of days. Shanmugavelu (1985) and Lakshmipathi *et al*. (2013) also reported that the highest root length was recorded in NAA @ 100 ppm treatment over the control. Since auxins have a role in root production, the present result, where NAA was associated with increased root length, is well justified. Subash *et al*. (2015) reported that the application of GA_3 recorded maximum root and shoot length compared to IAA and control in sesame.

Seedling length and girth

The highest seedling length (53.60 cm) was associated with GA_3 @ 100 ppm followed by NAA @ 100 ppm (51.63 cm), while lowest seedling length (35.55 cm) was associated with control at 30 DAS (Table 2). A similar trend was observed at 60, 90 and 120 days after sowing also. All the seedlings sprayed with GA_3 and NAA recorded increased seedling length as compared to control. The role of GA_3 in promoting shoot elongation through cell division and cell elongation is well established in higher plants (Hartman *et al.,* 2002; Harris *et al*., 2004; Hopkins and Huner, 2004). GA_3 was found to be more effective in promoting seedling growth of corn and soybean than kinetin (Wang *et al*., 1996). GA_3 application increases Masson pine seed germination and seedling vigor by supporting seed respiration or decreasing the ABA level and stimulating IAA and GA (1) biosynthesis (Zhao and Jiang, 2014). Various levels of GA_3 and NAA application significantly increased the girth of seedlings (Table 2). Seedling girth increased significantly over the number of days growth. All the seedlings sprayed with GA_3 and NAA increased the girth compared to control. The highest (2.38 cm) and lowest (2.13 cm) girth were recorded in the seedlings sprayed by GA_3 @ 100 ppm and unsprayed seedlings (control) respectively at 30 DAS. Similar kind of results were also reported by Shanmugavelu (1985) and Lakshmipathi *et al*. (2013) in cashew, Shabon (2010) in mango, Burns *et al*. (1966) in avocado, Gholap *et al*. (2000) in aonla, Al-Imam (2007) in pistachio seeds and Wang *et al*. (1996) in corn and soybean, where GA_3 increased the seedling height and diameter. The graftable seedling girth of 2.5 cm was attained one month earlier with GA_3 application than control.

Number of leaves

At 120 days after sowing, seedlings sprayed with GA_3 @ 100 ppm recorded maximum number of leaves followed by GA_3 @ 50 ppm, NAA @ 50 ppm, NAA @ 100 ppm and control (Table 3). Leaf numbers per seedling increased significantly over the number of days irrespective of treatments. All the seedlings sprayed with GA_3 and NAA had a higher number of leaves as compared to control.

The highest and lowest number of leaves was 21 and 12 recorded by the seedlings sprayed with GA_3 @ 100 ppm and unsprayed seedlings (control), respectively at 30 DAS. Shabon (2010) reported that mango seeds treated with GA_3 @ 200 ppm for 48 hours increased the number of leaves in the seedlings. Osmopriming or pre-soaking of cashew seeds with GA_3 @ 200 for 48 hours increased the number of leaves (Lakshmipathi *et al*., 2013).

Table 2. Effect of post germination foliar spray of GA_3 and NAA on seedling length and girth of cashew seedlings

Treatment (T)	Seedling length (cm)				Seedling girth (cm)			
	Days after sowing (DAS)				Days after sowing (DAS)			
	30	60	90	120	30	60	90	120
Control	35.55^{D}	46.60^{E}	53.48^{E}	66.53^{E}	2.13^{B}	2.38^{D}	2.41^{C}	2.40^{E}
GA_3 @ 50 ppm	47.58^{C}	60.63^{D}	68.48^{D}	85.65^{D}	2.33^{A}	2.61^{B}	3.00^{A}	3.10^{B}
GA_3 @ 100 ppm	53.60^{A}	74.98^{A}	92.88^{A}	114.93^{A}	2.38^{A}	2.91^{A}	3.15^{A}	3.28^{A}
NAA @ 50 ppm	47.13^{C}	65.65^{C}	77.05^{C}	93.83^{C}	2.28^{A}	2.50^{C}	2.60^{BC}	2.73^{D}
NAA @ 100 ppm	51.63^{B}	73.65^{B}	79.95^{B}	101.55^{B}	2.38^{A}	2.60^{B}	2.80^{AB}	2.90^{C}
Mean	47.10	64.30	74.37	92.50	2.30	2.60	2.79	2.88
S. Em	0.39	0.35	0.38	0.19	0.06	0.04	0.17	0.05
LSD at 5%	0.85	0.76	0.82	0.42	0.13	0.09	0.36	0.10

Values with different alphabets are significantly different

Table 3. Effect of post germination foliar spray of GA_3 and NAA on number of leaves of cashew seedlings

Treatment (T)	Number of leaves			
	Days after sowing (DAS)			
	30	60	90	120
Control	12.00^{D}	16.00^{C}	19.00^{C}	20.00^{D}
GA_3 @ 50 ppm	18.00^{B}	19.00^{B}	23.00^{B}	25.00^{B}
GA_3 @ 100 ppm	21.00^{A}	25.00^{A}	28.00^{A}	29.00^{A}
NAA @ 50 ppm	16.00^{C}	19.00^{B}	22.00^{B}	23.00^{C}
NAA @ 100 ppm	18.00^{B}	19.00^{B}	20.00^{C}	21.00^{D}
Mean	17.00	19.60	22.40	23.60
Sem	0.61	0.63	0.52	0.63
LSD at 5%	1.32	1.38	1.13	1.38

Values with different alphabets are significantly different

Fresh and dry weight of shoot

Irrespective of treatments, fresh and dry weight of shoot increased significantly over the number of days (Table 4). At 120 DAS, seedlings sprayed with GA_3 @ 100 ppm recorded the highest fresh and dry weight of shoot followed by GA_3 @ 50 ppm, NAA @ 50 ppm and NAA @ 100 ppm while, control recorded the least shoot fresh and dry weight. All the seedlings sprayed with GA_3 and NAA recorded higher fresh and dry weight as compared to control. Irrespective of the treatments, as days progressed, the weight of the shoot increased. The increased weight of shoot was mainly attributed to enhanced germination, early seedling emergence, and better seedling growth. This can also be attributed to the increase in the overall assimilation and redistribution of materials within the plant (Shanmugavelu, 1985). A significant increase in shoot dry weights of pistachio seedlings occurred under 24 hours seed soaking period and with increasing GA_3 level as reported by Al-Imam (2007). Application of GA_3 was found to be beneficial to the seedlings growth and dry matter accumulation in tomato (Yang, 2017; Vendruscolo *et al.*, 2016) and corn (Hamza and Ali, 2017).

Table 4. Effect of post germination foliar spray of GA_3 and NAA on fresh and dry weight of shoot of cashew seedlings

Treatment (T)	Fresh weight of shoot (g)				Dry weight of shoot (g)			
	Days after sowing (DAS)				Days after sowing (DAS)			
	30	60	90	120	30	60	90	120
Control	10.80^{D}	15.50^{D}	28.05^{E}	39.00^{D}	2.45^{D}	5.10^{C}	8.10^{E}	14.20^{D}
Ga_3 @ 50 ppm	20.20^{B}	19.60^{B}	40.50^{B}	52.00^{B}	8.60^{B}	10.00^{B}	5.10^{B}	26.30^{B}
GA_3 @ 100 ppm	30.10^{A}	41.00^{A}	52.50^{A}	65.10^{A}	13.50^{A}	18.10^{A}	22.40^{A}	31.00^{A}
NAA @ 50 ppm	11.50^{D}	16.00^{CD}	30.50^{D}	38.40^{D}	3.00^{CD}	4.40^{C}	10.20^{D}	14.40^{D}
NAA @ 100 ppm	14.60^{C}	17.00^{C}	35.60^{C}	44.20^{C}	4.00^{C}	5.50^{C}	12.80^{C}	16.10^{C}
Mean	17.44	21.82	37.43	47.74	6.31	8.62	13.72	20.40
S.Em	0.52	0.63	0.63	0.52	0.50	0.63	0.52	0.55
LSD at 5%	1.13	1.38	1.38	1.13	1.09	1.38	1.13	1.19

Values with different alphabets are significantly different

Table 5. Effect of post germination foliar spray of GA_3 and NAA on fresh and dry weight of root of cashew seedlings

Treatment (T)	Fresh weight of root (g)				Dry weight of root (g)			
	Days after sowing (DAS)				Days after sowing (DAS)			
	30	60	90	120	30	60	90	120
Control	6.10^{CD}	8.10^{E}	10.50^{E}	12.80^{E}	1.50^{C}	2.50^{D}	2.37^{E}	2.95^{D}
GA_3 @ 50 ppm	5.45^{D}	12.50^{D}	14.20^{D}	17.10^{D}	1.60^{C}	3.13^{C}	3.40^{D}	4.60^{C}
GA_3 @ 100 ppm	7.50^{C}	14.80^{C}	17.80^{C}	21.90^{C}	2.20^{B}	3.50^{BC}	3.90^{C}	5.00^{B}
NAA @ 50 ppm	12.10^{B}	19.50^{B}	25.20^{B}	30.80^{B}	2.80^{A}	3.90^{AB}	4.41^{B}	2.90^{D}
NAA @ 100 ppm	18.40^{A}	22.60^{A}	27.50^{A}	34.90^{A}	2.90^{A}	4.05^{A}	5.25^{A}	6.80^{A}
Mean	9.91	15.50	19.04	23.50	2.20	3.42	3.87	4.45
S.Em	0.79	0.52	0.63	0.52	0.21	0.23	0.16	0.13
LSD at 5%	1.72	1.13	1.38	1.13	0.45	0.50	0.35	0.29

Values with different alphabets are significantly different

Fresh and dry root weight

Highly significant differences were recorded among the treatments at 120 days after sowing with respect to fresh and dry root weights. All the seedlings sprayed with GA_3 and NAA had higher fresh and dry root weight (Table 5). The highest (18.40 g) and lowest (5.45 g) root fresh weight were recorded in the seedlings sprayed with NAA @ 100 ppm and unsprayed seedlings (control), respectively, at 30 DAS. Similarly, the highest (2.90 g) and lowest (1.50 g) root dry weight were recorded in the seedlings sprayed with NAA @ 100 ppm and unsprayed seedlings (control), respectively, at 30 DAS. The highest rate of increase in root fresh weight was associated with NAA @ 50 ppm followed by NAA @ 100 ppm, GA_3 @ 100 ppm, GA_3 @ 50 ppm and control at 120 DAS. The increase in fresh and dry root weight might be attributed to the increase in assimilation and reallocation of materials inside the plant (Shanmugavelu, 1985). Further, NAA, being an auxin, is well known for the role in rooting. Foliar spray of GA_3 reduced the fresh and dry root weight in cashew seedlings. Tadeo *et al*. (1997) indicated that GA_3 decreased the root weight and decreased all parameters connected to radial enlargement in citrus plants. Moreover, the influence of GA_3 on root growth is not direct, by means of its influence on the growth of the aerial part, because of the action exerted by GA_3 on cell elongation (Tanimoto, 1990).

Conclusion

Seedlings sprayed with GA_3 @ 100 ppm recorded the maximum leaf area, shoot length, number of leaves, shoot fresh and dry weight and seedling girth, indicating that GA_3 @ 100 ppm can be effectively employed as post-germination spray for increasing the seedling growth of cashew which would help in producing healthy seedlings in a short period for advancing grafting operations and ultimately reduce the duration of propagation as well as inputs and cost for seedling production.

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