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Effect of plant growth regulators on the early growth of tissue cultured banana plants (cv. Grand Naine)

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ABSTRACT

The present study investigated the effects of several growth regulators on the early growth of banana plants (cv. Grand Naine) at Horticultural Farm, Department of Horticulture and Post-Harvest Technology, Institute of Agriculture, Visva-Bharti, Sriniketan, West Bengal, during 2021-2022. Six different combinations of two growth regulators, viz. GA_3 (100, 150 and 200 ppm) and NAA (50 and 100 ppm) were used in combination with a control treatment (no growth regulators) in three replications under a randomized block design. According to the final observation taken at 75 DAP, the maximum plant height (56.33 cm), number of leaves/plant (8.47), and pseudostem diameter (25.72 cm) were observed under T_5 (GA_3 @ 150 ppm + NAA @ 100 ppm). The greatest sizes with respect to total leaf length (36.71 cm), leaf lamina length (28.06 cm) and breadth were also observed under the same treatment. Thus, the performance of banana plants at an early stage was markedly influenced by the application of different growth regulators, and the combination of GA_3 @ 150 ppm and NAA @ 100 ppm was the most effective combination of plant growth regulators for improved growth and development of tissue-cultured banana plants.

Introduction

Banana, popularly known as "Kalpataru" (a plant with virtues), is one of the most important fruit crops grown in India. Bananas are used in different regions as staple foods owing to their rich and easily digestible carbohydrates. It is a rich source of vitamins and minerals such as calcium, magnesium, potassium, and phosphorus and has several medicinal properties. Botanically, it belongs to the family Musaceae. According to Simmonds and Shepherd (1955), Musaceae plants are strictly old and predominantly Asian. Edible banana plants are believed to have originated in hot tropical regions of Southeast Asia (Nayar, 2010). Bananas are popular fruits due to their low cost and great nutritional value. It is eaten fresh as table fruit, and mature green fruits are cooked. Banana plants are rich sources of carbohydrates and vitamins, particularly vitamin B. They are also high in potassium, phosphorus, calcium, and magnesium (Annon., 2019). The fruit is easy to digest and low in fat and cholesterol. Banana powder is used as the first baby food. When used frequently, it reduces the risk of heart disease and is advised for people suffering from high blood pressure, arthritis, ulcers, gastroenteritis, or renal illnesses. Banana is one of the most important fruit crops of tropical and subtropical states in India, namely, Tamil Nadu, Maharashtra, Gujarat, Andhra Pradesh, Karnataka West Bengal and Odisha. India's share of global banana production is 31.6%, which contributes to an agricultural GDP of 1.99% and a national productivity of 34.2 T/ha (Meenakshi and Prasad, 2022). In Eastern India, commercial banana cultivation occurs in West Bengal, Bihar, Odisha and Assam. In West Bengal, the banana growing belts are Hooghly, Nadia, and North 24 Parganas,

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and most of the varieties grown are Champa, Mortman, Dwarf Cavendish, Giant Governor, Kanthali, and Singapuri. Currently, tissue-cultured Grand Naine banana plants are becoming popular among banana growers in eastern India. The Grand Naine variety of banana plants is the most accepted international variety (Keelery, 2023). It is a tall statured plant and a heavy yielder with a long cylindrical bunch. On average, it produces bunches weighing 25 kg and may reach 32-35 kg, with 8-10 hands with 200-220 fruits/bunch. The length of the fruit is 15-21 cm, and the girth is 12-13 cm. However, compared with those of other banana varieties, the growth rate of tissue-cultured Grand Naine variety banana plants is very slow, with a long gestation period occurring during the initial phase despite good nutrient management (Kumar, 2006). Thus, growth promotion is required to reduce the length of gestation. Plant growth regulators are essential organic compounds that allow plants to grow in a better way and produce high-quality crops. Even though plants produce the majority of these nutrients, exogenous application of some of them in suitable amounts and concentrations may optimize productivity efficiency and yield characteristics. The application of auxins, particularly naphthalene acetic acid and gibberellins, e.g., GA_3, has been reported to play a major role in improving plant characteristics, e.g., plant height, number of leaves, and leaf size, and ultimately helps in holistic plant growth (Dayan *et al*., 2012; Davies, 2013; Deb *et al*., 2010; Digby and Wareing,1966; Rana *et al*., 2020). Although a considerable number of studies have been conducted by various scientists on the application of NAA and GA_3 to major horticultural crops (Deb *et al*., 2009; Saha *et al*., 2009), very few of them have been conducted on banana plants, particularly those in which NAA and GA3 are used to induce early plant growth. Thus, the present study aimed to investigate the synergistic effect of GA_3 and NAA on improving the growth of tissue-cultured banana plants (cv. Grand Naine) at early stages.

Material and Methods

Location of the experiment: The present investigation was carried out at Horticultural Farm, Department of Horticulture and Post-Harvest Technology, Institute of Agriculture, Visva-Bharti, Srinikatan, West Bengal (23°42’ N latitude and 87°40’30” E longitude, altitude of 40 m MSL, under a semiarid lateritic belt) during 2021-2022.

Planting and aftercare: The whole experiment was conducted in poly bags filled with a 10 kg mixture of soil, well rotten farmyard manure, and sand at a ratio of 4:2:1. Healthy, disease-free, and uniform-sized tissue-cultured banana saplings (cultivary cv. GrandNaine) were procured from Agro and Horticulture World, Jamalpur, PurbaBardhaman District, West Bengal. The banana plants were transplanted and fed nutrients at 15-day intervals as a foliar spray of urea @ 5 g/L water, followed by the application of urea @ 10 granules/plant and, again, the 3rd and 4th applications of the 10-26-26 N-P-K mixture @10 granules/plant.

Application of growth regulators and treatment details: Stock solutions of NAA and GA_3 were prepared at the required concentrations for each treatment by dissolving in ethyl alcohol. A total of three applications of NAA and GA_3 were applied at an interval of 20 days starting 20 days after planting (DAP), and every 3 days, a difference was maintained between the application of NAA and that of GA_3. The treatment combinations considered were as follows:

T_1: GA_3 @ 100 ppm + NAA @ 50 ppm,
T_2: GA_3 @ 150 ppm + NAA @ 50 ppm,
T_3: GA_3 @ 200 ppm + NAA @ 50 ppm,
T_4: GA_3 @ 100 ppm + NAA @ 100 ppm,
T_5: GA_3 @ 150 ppm + NAA @ 100 ppm,
T_6: GA_3 @ 200 ppm + NAA @ 100 ppm and
T_7: Control (only distilled water).

Recording observations: Observations of different plant growth parameters were recorded from banana plants under different treatments beginning 45 days after transplanting (DAP) at 15-day intervals, after which the mean was calculated. The plant height, number of leaves per plant, leaf lamina length, breadth, petiole length, and pseudostem girth were recorded with a meter scale and are expressed in centimeters. Root characteristics, such as the number of roots, length, and diameter, were measured only 75 days after planting by evaporating the banana plants from the media. The fresh weights (shoots and roots) of three randomly selected plants from each replication under each treatment were measured, after which the plants were dried under sun and subsequently oven-dried at 65°C for 12 hours. The

dry weight of the plants (shoot and root) was measured by an electronic balance, and the average was calculated in grams**.**

Statistical analysis: The data were analyzed according to the procedure for analysis of a completely randomized design (CRD) for seven treatments and three replications. The overall significance of differences among the treatments was tested using the critical difference (CD) test at a 5% level of significance, as suggested by Gomez and Gomez (1984).

Results and Discussion

The findings from the present investigation revealed the significant effect of growth regulator combinations on the normal growth of the plants.

Plant height

The maximum height of the tissue-cultured banana plants (Plate 1, Table 1, Figure 1) at 45 days (28.46 cm) was observed in T_5 (GA_3 @ 150 ppm + NAA @ 100 ppm), which was significantly similar to that in T2 (GA_3 @ 150 ppm + NAA @ 50 ppm). Similarly, at 60 DAP and 75 DAP, the maximum plant heights were 43.91 cm and 56.33 cm, respectively, in treatment T_5 (GA_3 @ 150 ppm+ NAA @ 100 ppm), and the minimum plant heights (30.05 cm and 44.13 cm) were recorded in treatments T_7 (control) and T_3 (GA_3 @ 200 ppm +NAA @ 50 ppm). The increase in plant height may be due to the positive influence of NAA on cell division, cell elongation and further growth. An increase in plant height might also be due to the application of gibberellic acid, which has a positive effect on plant growth. Singh *et al.* (2021) reported that the plant height of Gladiolus increased in response to the application of GA_3 in combination with NAA. Pahare and Das (2020) reported that the plant height of periwinkles increased in response to the application of NAA. Awan *et al.* (2015) found that the plant height of spinach improved in response to the application of NAA and BA. Pal *et al.* (2016) reported an increase in plant height in cucumber plants following the application of gibberellic acid and potassium. These findings are in agreement with the findings of the present study.

Plate 1: Effect of different concentrations of GA_3 and NAA on the early growth of banana plants at 75 DAP (cv. Grand Naine)

T_1: GA3@100 ppm + NAA@50 ppm

T_2: GA3@150 ppm + NAA@50 ppm

T_3: GA3@200 ppm + NAA@50 ppm

T_4: GA3@100 ppm + NAA@100 ppm

T_5: GA3@150 ppm + NAA@100 ppm

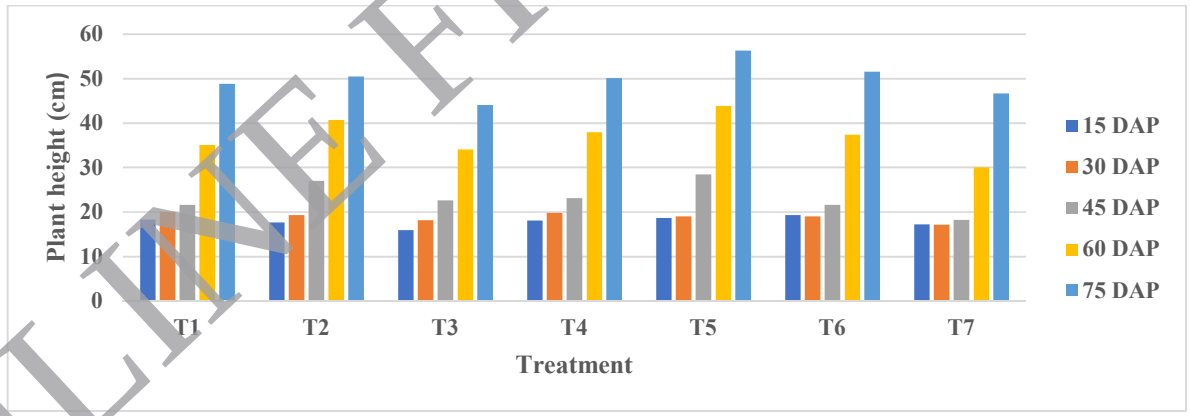
T_6: GA3@200 ppm NAA@100 ppm

T_7: Control (only distilled water)

Table 1: Effect of GA_3 and NAA on plant height, pseudostem girth and number of leaves of tissue-cultured banana plants (cv. Grand Naine) at the early growth stage

Treatments	Plant height (cm)			Pseudostem girth (cm)			Number of leaves		
	45 DAP	60 DAP	75 DAP	45 DAP	60 DAP	75 DAP	45 DAP	60 DAP	75 DAP
T_1	21.63^{c}	35.07^{c}	48.80^{b}	15.14^{a}	17.09	21.99^{cd}	5.89^{a}	6.53^{a}	7.67^{bc}
T_2	27.00^{ab}	40.67^{ab}	50.47^{b}	15.94^{a}	21.38^{ab}	24.44^{ab}	5.93^{a}	6.82^{a}	8.13^{ab}
T_3	22.69^{c}	34.05^{c}	44.13	14.53	18.96^{b}	22.03^{c}	5.47^{a}	6.13	7.33^{c}
T_4	23.15^{bc}	37.93^{bc}	50.13^{b}	14.67	19.89^{b}	21.74^{c}	5.93^{a}	6.07	7.54^{b}
T_5	28.46^{a}	43.91^{a}	56.33^{a}	15.13^{a}	21.82^{a}	25.72^{a}	5.90^{a}	6.24^{a}	8.47^{a}
T_6	21.59^{c}	37.40^{b}	51.60^{ab}	14.04	19.02	22.74^{c}	5.98^{a}	6.26^{a}	7.07^{c}
T_7	18.27	30.05	46.73	14.90	18.52	20.42	5.20	6.11	6.77
SE(m)	**4.23**	**4.92**	**5.08**	**0.35**	**0.45**	**0.47**	**0.21**	**0.22**	**0.24**
CD (0.05)	**1.40**	**1.62**	**1.69**	**1.05**	**1.35**	**1.41**	**0.64**	**0.68**	**0.75**

T_1: **GA3@100 ppm + NAA@50 ppm; T2: GA3@150 ppm + NAA@50 ppm; T3: GA3@200 ppm + NAA@50 ppm; T4: GA3@100 ppm + NAA@100 ppm; T5: GA3@150 ppm + NAA@100 ppm; T6: GA3@200 ppm + NAA@100 ppm; T7: Control (only distilled water). (a, b, c: means with the same letter are not significantly different).**



Figs. 1 Effects of different concentrations of GA_3 and NAA on the plant height and leaf length of banana plants at 75 DAP (cv. Grand Naine)

Number of leaves per plant: The influence of various concentrations of GA3 and NAA on the number of leaves of tissue-cultured banana plants (Table 1) was statistically significant. The maximum number of leaves 45 days after planting (5.98) on the banana plants was observed in treatmentT_6 (GA_3 @ 200 ppm + NAA @ 100 ppm), which was significantly different from those in treatment T_2 (GA_3 @ 150 ppm+ NAA @ 50 ppm) and T_4 (GA_3 @ 100 ppm+ NAA @ 100 ppm). The minimum number of leaves (5.20) was observed in the T_7 control plots. Similarly, at 60 DAP, the maximum number of leaves (6.82) was recorded in treatment T_2 (GA_3 @ 150 ppm + NAA @ 50 ppm), which was significantly similar to that in treatment T_1 GA_3 @ 100 ppm + NAA @ 50 ppm. The minimum number of leaves (6.07) was observed in T_4 (GA_3 @ 100 ppm + NAA @ 100 ppm). On the other hand, the maximum number of leaves per plant (8.47) at 75 DAP was obtained in treatmentT_5 (GA_3 @ 150 ppm + NAA @ 100 ppm), which was *on par* with that in treatment T_2 (GA_3 @ 150 ppm + NAA @ 50 ppm), and the minimum number of leaves per plant at 75 DAP (6.77) was recorded in the control treatment (T_7).The greater number of leaves produced in the present study might be attributed to the application of NAA and GA_3, as both are reported to have positive effects on the production of leaf primordia at the growing points of the plants. The application of gibberellins and NAA in combination increased the primary leaf production of *Phaseolus vulgaris* (Brock,1993) and mustard (Khan and Samiullah, 2003) in mustard. Thus, the findings of the present study are consistent with the findings of Brock (1993) and Khan and Samiullah (2003).

Pseudostem girth: The pseudostem girth of tissue-cultured banana plants was also influenced by different concentrations of plant growth regulators (GA_3 and NAA) (Table 1). The maximum stem diameter of the banana plant (15.94 cm) was recorded in treatment T_2 (GA_3 @ 150 ppm + NAA @ 50 ppm), which was significantly different from that in treatment T_1 (GA_3 @ 100 ppm + NAA @ 50 ppm) and T_5 (GA_3 @ 150 ppm + NAA @ 100 ppm). The maximum pseudostem girth (21.82 cm) of the banana plant was recorded in treatment T_5 (GA_3 @ 150 ppm + NAA @ 100 ppm) at 60 DAP, and the minimum (18.52 cm) was recorded in treatment T7 (control). There was a significant difference in the pseudostem girth of the banana plants at 75 days after transplanting, as the maximum stem diameter (25.72 mm) was observed for plants treated with T_5 ($GA_3$150 ppm+NAA@100 ppm), which was significantly similar to that of plants treated with T2 (GA3@150 ppm + NAA@50 ppm). The lowest pseudostem girth (20.42 mm) at 75 DAP was recorded in the control plots (T_7). An increase in the number of leaves in the present study triggered by the application of NAA and GA_3 resulted in a greater number of leaf bases, which ultimately produced a greater diameter of the pseudostems of the banana plants. An increase in the girth of soybean plants following the application of gibberellins and auxin was reported by Kothule *et al*. (2003). Shah *et al*. (2006) also reported that the application of gibberellic acid increased plant girth in black cumin plants.

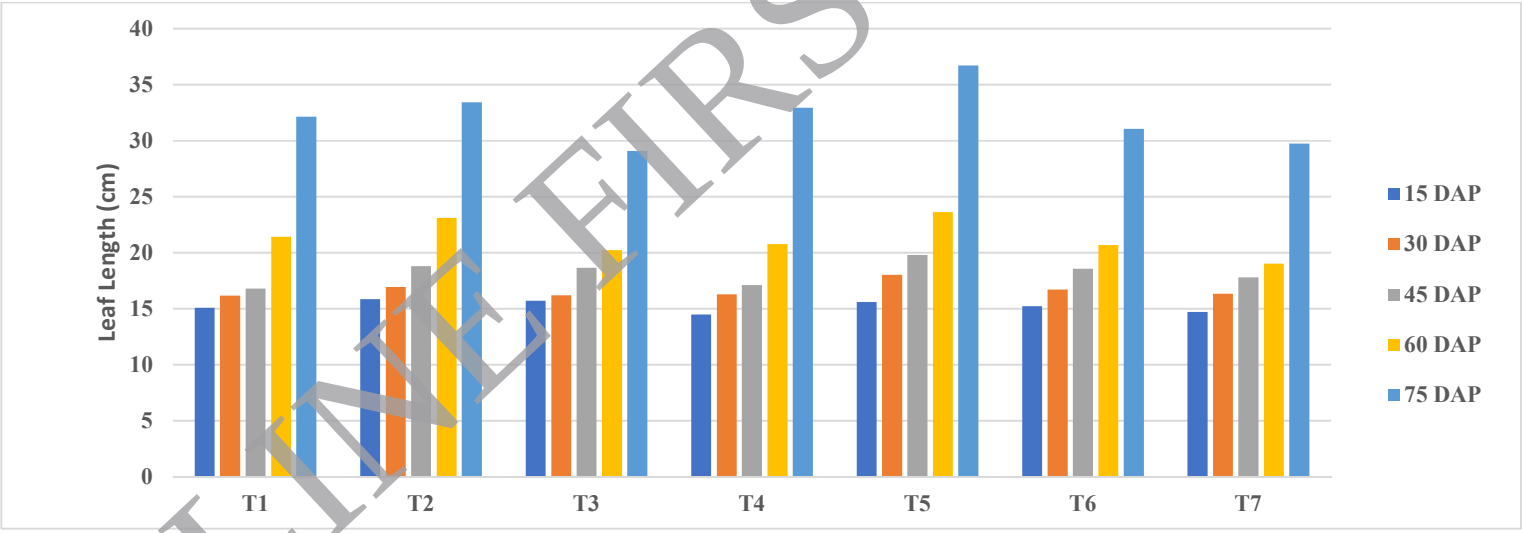
Leaf length with respect to the petiole: Significant variation in the leaf length of tissue-cultured banana plants was influenced by the combination of GA_3 and NAA (Table 2, Figure 2, plate 1), which varied from 29.09 cm to 36.71 cm at 75 days after planting. The maximum leaf length of the banana plants (19.81 cm) at 45 DAP was observed in treatment T_5 (GA_3 @ 150ppm + NAA @ 100ppm), which was significantly different from treatment T_2 (GA_3 @ 150 ppm + NAA @ 50 ppm), and the minimum leaf length (16.80 cm) was observed in T_1 (GA_3 @ 100 ppm + NAA @ 50 ppm). A similar trend was also recorded at 60 DAP. Again, the maximum leaf length (36.71 cm) at 75 DAP was recorded in T_5 (GA_3 150 ppm + NAA @ 100 ppm), which was significantly similar to that in T_2 (GA_3 @ 150 ppm + NAA @ 50 ppm). The increase in the leaf length of the banana plants in the present study following the application of NAA and GA_3 might be due to the growth-promoting activity of the plant hormones, particularly the enlargement of leaves. Guttiride and Thompson (1959) reported the positive role of GA_3 in increasing the leaf petiole length of strawberry plants, thereby increasing leaf length. Similar observations have been reported by Miceli *et al*. (2019) for lettuce.

Leaf lamina length: The maximum leaf lamina length of the tissue-cultured banana plants (Table 2, plate 1) was observed during the entire period of observation (45, 60 and 75 DAP) in treatment T_5 (GA_3 @ 150 ppm + NAA @ 100 ppm), at 17.77 cm, 22.38 cm and 28.06 cm, respectively. However, the

Table 2: Effect of GA_3 and NAA on the leaf length and leaf breadth of tissue-cultured banana plants (cv. Grand Naine) at the early growth stage

Treatments	Leaf length with petiole (cm)			Leaf lamina length (cm)			Leam lamina breadth (cm)		
	45 DAP	60 DAP	75 DAP	45 DAP	60 DAP	75 DAP	45 DAP	60 DAP	75 DAP
T_1	16.80	21.41^{a}	32.15^{b}	14.17	17.33^{c}	22.15	5.84	8.07	12.74^{abc}
T_2	18.81^{a}	23.13^{a}	33.43^{ab}	16.47^{ab}	19.80^{b}	26.67^{ab}	7.91^{a}	9.38^{ab}	13.01^{ab}
T_3	18.67	20.22^{a}	29.09	15.49^{a}	16.15	21.65	6.58	7.13	11.08
T_4	17.11^{a}	20.78	32.95^{b}	14.40	16.87^{c}	25.60^{bc}	5.97	8.53^{b}	11.37^{d}
T_5	19.81^{a}	23.61^{a}	36.71^{a}	17.77^{a}	22.38^{a}	28.06^{a}	7.27^{a}	9.89^{a}	13.13^{a}
T_6	18.58^{a}	20.71^{a}	31.07^{b}	13.98	16.79^{c}	22.61^{d}	7.13^{a}	8.80^{b}	11.19
T_7	17.81	19.03	29.75	12.70	16.24	21.66	5.62	7.85	11.32
SE(m)	**0.62**	**1.18**	**1.17**	**0.56**	**0.79**	**0.81**	**0.26**	**0.32**	**0.36**
CD (0.05)	**1.86**	**3.57**	**3.51**	**1.70**	**2.38**	**2.44**	**0.79**	**0.98**	**1.09**

T_1: GA3@100 ppm + NAA@50 ppm; T2: GA3@150 ppm + NAA@50 ppm; T3: GA3@200 ppm + NAA@50 ppm; T4: GA3@100 ppm + NAA@100 ppm; T5: GA3@150 ppm + NAA@100 ppm; T6: GA3@200 ppm + NAA@100 ppm; T7: Control (only distilled water). (a, b, c: means with the same letter are not significantly different).



Figs. 2. Effects of different concentrations of GA_3 and NAA on the plant height and leaf length of banana plants at 75 DAP (cv. Grand Naine)

leaf lamina length was significantly shorter than that in the T2 treatment (GA3 @ 150 ppm + NAA @ 50 ppm) at 45, 60 and 75 DAP. However, the minimum leaf lamina length was observed in T_7 (control) at 45 DAP, T_3 (GA_3 @ 200 + NAA @ 50 ppm) at 60 DAP and T_3 at 75 DAP.An increase in leaf lamina length caused by the application of gibberellic acid was also reported by Miceli *et al*. (2019) in the case of lettuce. Azuma *et al*. (1997) and Brock (1993) also reported similar results for floating rice and *Phaseolus vulgaris,* respectively, after the application of gibberellin. These findings support the results of the present study.

Leaf lamina breadth: The analysis of leaf lamina breadth data from tissue-cultured banana plants (Table 2, plate 1) revealed that the maximum breadth of the leaf lamina (7.91 cm) was found in treatment T_2 (GA_3 @ 150 ppm + NAA @ 50 ppm) at 45 DAP, which was closely followed by treatment T_5 (GA_3 @ 150 ppm + NAA @ 100 ppm). The minimum leaf breadth (5.62 cm) was observed in the T_7 treatment (control). Similarly, at 60 DAP, the maximum leaf breadth (9.89 cm) occurred in treatment T_5 (GA_3 @ 150 ppm + NAA @ 100 ppm), which was significantly similar to that in treatment T_2 (GA_3 @ 150 ppm + NAA @ 50 ppm). The minimum amount of leaf breath on the plant (7.13 cm) was observed in TreatmentT_3 (GA_3 @ 200 ppm + NAA @ 50 ppm). Again, the greatest leaf breadth (13.13 cm) was observed in treatment T_5 (GA_3 @ 150 ppm + NAA @ 100 ppm), which was close to that in T_2, and the minimum leaf breadth (11.08 cm) was recorded in treatment T_3 (GA_3 @ 200 ppm + NAA @ 50 ppm) at 75 days after planting. At the early stage of growth, most plants respond to the application of growth regulators. The increased leaf lamina breadth of the banana plants in the present study following the application of NAA and GA_3 might be attributed to enhanced growth promoted by plant hormones, particularly leaf enlargement. Lee (2003) reported that the use of GA_3 and NAA can increase the leaf size of many horticultural crop species. Basra (2000) noted an increase in the leaf size of bananas, strawberry plants and papaya plants in the early growth stage following the application of gibberellins. Thus, the findings of the present study are consistent with the abovementioned reports.

Root characteristics: All the root characteristics of tissue-cultured banana plants were observed 75 days after planting via the destructive method (Table 3). The number of roots is represented in Table 3, and the data per plant clearly show that the highest number of roots per plant (22.67) was recorded in the T_5 treatment (GA_3 @ 150 ppm + NAA 50 ppm), which was significantly similar to that in the T2 treatment (GA3 @ 150 ppm + NAA @ 50 ppm), and the minimum number of roots per plant (13.33) at 75 DAP was recorded in the T_1 treatment (GA_3 @ 100 ppm + NAA @ 50 ppm).The results of the statistical analysis of the length of the roots of tissue-cultured banana plants are presented in Table 3. The greatest length (36.87 cm) of the roots of the banana plants was recorded in the T_5 treatment (GA_3 @ 150 ppm + NAA @ 100 ppm), which was similar to that in the T2 treatment (GA_3 @ 150+ NAA @ 50 ppm), and the minimum length at 75 DAP (24.52 cm) was observed in the T_7 treatment (control).The average root diameter of the tissue-cultured banana plants (Table 3) under different growth regulator treatment combinations at 75 days after planting are presented in Table 3. The greatest diameter of the banana plant roots (5.77 mm) was recorded in the T_5 treatment (GA_3 @ 150 ppm + NAA @ 100 ppm), which was *on par* with the T_2 treatment (GA_3 @ 150 ppm + NAA @ 50 ppm). The minimum average root diameter of the banana plants (3.18 mm) at 75 DAP was recorded in the T7 treatment, i.e., the control treatment.The application of NAA may increase the number of roots on banana plants by increasing the number of root primordia produced, and the increase in root length might be due to the growth promotion triggered by the action of GA_3. Moreover, the apical dominance caused by the application of NAA might also have caused the greater length of the roots in the present study. The greatest length and diameter of the roots of the banana plants were recorded in the T_5 treatment (GA_3@150 ppm +NAA@100 ppm), which was the best treatment among all the treatments in the present study. Evans *et al*. (1980) reported increased growth of corn roots in terms of the number of roots, length and number of branches following the application of exogenous auxin. Aloni *et al*. (2006) described the positive role of cytokinin and auxin in shaping root architecture, regulating vascular differentiation, lateral root initiation, root apical dominance and root gravitropism in plants.

Fresh weight and dry weight of shoots and roots: The maximum fresh weight of shoots of tissue-cultured banana plants (172.67 g), as presented in Table 3 and Figure 3, was recorded in the T_5 treatment

Table 3: Effect of GA_3 and NAA on the root and shoot characteristics of tissue-cultured banana plants (cv. Grand Naine) at the early growth stage

Treatments	Number of roots	Root length (cm).	Root diameter (mm)	Fresh weight of shoot (g)	Fresh weight of roots (g)	Dry weight of shoot (g)	Dry weight of root (g)
T1	13.33	26.18	3.71	118.67	27.24	21.33	2.23
T2	21.41[a]	35.35[a]	5.13[ab]	165.33[ab]	34.51[a]	39.11[a]	3.54
T3	20.01[a]	28.41	4.67[b]	144.00[c]	28.61	34.33	2.37
T4	16.33	25.29	4.68[b]	132.33	23.63	26.00	2.12
T5	22.67[a]	36.87[a]	5.77[a]	172.67[a]	36.67[a]	41.67[a]	4.31[a]
T6	20.65[a]	29.64	4.57[b]	128.00	21.67	33.67	3.40
T7	17.53	24.52	3.18	113.00	26.34	20.67	1.97
SE(m)	**1.53**	**1.32**	**0.21**	**2.95**	**1.51**	**1.11**	**0.14**
CD (0.05)	**4.61**	**3.96**	**0.65**	**8.87**	**4.54**	**3.34**	**0.44**

Treatments: T_1: **GA3@100 ppm + NAA@50 ppm, T2: GA3@150 ppm + NAA@50 ppm, T3: GA3@200 ppm + NAA@50 ppm, T4: GA3@100 ppm + NAA@100 ppm, T5: GA3@150 ppm + NAA@100 ppm, T6: GA3@200 ppm + NAA@100 ppm and T7: Control (only distilled water). (a, b, c: means with the same letter are not significantly different).**

Fig. 3. Effects of different concentrations of GA_3 and NAA on the number of roots, length of the roots, and diameter and weight of the shoots and roots and on the dry weight of the shoots and roots of the banana plants at 75 DAP (cv. Grand Naine)

(GA_3 @ 150 ppm + NAA @ 100 ppm), which was *on par* with that in the T2 treatment (GA_3 @ 150 ppm + NAA @ 50 ppm), and the minimum fresh weight of shoots (113.0 g) was recorded in the T_7 treatment (control). The maximum fresh weight of the roots (36.67 g) was recorded in treatment T_5 (GA_3 @ 150 ppm + NAA @ 100 ppm), which was statistically similar to that in treatment T_2 (GA_3 @ 150 ppm + NAA @ 50 ppm), and the minimum fresh weight of the roots (21.61 g) at 75 DAP was recorded in T_6 (GA_3 @ 200 ppm + NAA @ 100 ppm).The statistical analysis of the dry weight of the shoots of tissue-cultured banana plants is presented in Table 3. A significant influence of growth regulators was observed, and the maximum dry weight of the shoot (41.67 g) was recorded in the T_5 treatment (GA_3 @ 150 ppm + NAA @ 100 ppm), which was statistically similar to that in the T2 treatment (GA_3 @ 150 + NAA @ 50 ppm), and the minimum dry weight of the shoot (20.67 g) of the banana plant at 75 DAP was recorded in the T_7 treatment (control). The data on the dry weight of the roots are presented in Table 3, and the influence of growth regulators on the dry weight of the roots was significant. The maximum dry weight of the roots of the banana plants (4.31 g) at 75 DAP was recorded in the T_5 treatment (GA_3 @ 150 ppm + NAA @ 100 ppm) (4.31 gm), followed by the T_2 treatment (GA_3 @ 150 ppm + NAA @ 50 ppm).Sugiura *et al.* (2016) reported enhanced dry matter accumulation in roots and shoots following the application of gibberellins and auxin. Again, the positive role of gibbrellin was described by the findings of an experiment by Sagiura *et al*. (2015) in the case of *Polygonum* and Zhang *et al*. (2017) in tomato. Mbandlwa *et al*. (2019) reported greater dry matter accumulation in sweet pepper plants following the exogenous application of gibberellins and auxin. Li *et al.* (2008) described the positive role of gibbrellin in the suberization of plant tissues and thereby in increasing dry matter accumulation in plants. Thus, the findings of the present study, which included an increase in dry matter content with the application of GA_3 and NAA, are consistent with the findings of the abovementioned scientists.

Conclusion

The findings of the present study indicated that the application of NAA and GA_3 significantly affects the early growth stage of tissue-cultured banana plants. Among the plant growth regulator combinations tested, T_5, i.e., GA_3@ 150 ppm along with NAA @ 100 ppm, was most effective at improving plant height, number of leaves, leaf length and breadth and pseudostem girth. The application of GA_3@150 ppm along with NAA@100 ppm also resulted in improved root growth and development in tissue-cultured banana plants. Hence, for improved growth and establishment of tissue-cultured banana plants (cv. Grand Naine), the foliar application of GA_3@150 ppm in combination with NAA@100 ppm at the initial stage of plant growth can be recommended for the Grand Naine variety of banana plants.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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