Original Research Article

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Influence of Plant Growth Regulators on Rooting of Stem Cuttings in Jamun (*Syzygium cumini* L. Skeels)

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ABSTRACT

Vegetative propagation of Jamun (*Syzygium cumini* L. Skeels) through cutting is the most convenient and the cheapest method to obtain true to type plants in considerably lesser time. In the present study, effect of various concentration of PGR's on the rooting ability of different types of stem cuttings of jamun was assessed at College of Horticulture, University of Horticultural sciences, Navanagar, Bagalkot (Karnataka) India. The experiment was laid out in Factorial Completely Randomized Design. There was significant differences among treatments in various shoot and root parameters recorded. The hardwood cuttings and rootex (commercial formulation) were significantly best with respect to most of the shoot and root parameters. In the interaction of treatments, number of days taken for sprout initiation was found early in T₂₁ (Hardwood cutting and Rootex, 8.65days), the highest number of sprouts (12.05), number of leaves per cutting (9.15) and length of shoots (8.64 cm) at 30, 60 and 90 DAP, sprouting percentage (29.90), fresh weight of cuttings (21.47g), dry weight of cuttings (14.25g), number of primary and secondary roots (57.60), length of longest root (16.85cm), and rooting percentage (35.40) at 90 DAP was more in interaction T₂₁ (Hard wood cutting and rootex). Overall, T₂₁ having interaction of hard wood cutting and rootex was shown superior results as compared to other treatments.

Keywords

Jamun, rooting,
stem cutting, PGRs,
vegetative
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Introduction

The Jamun (*Syzygium cumini* L. Skeels) commonly known as Indian blackberry, Java plum, Jambu, black plum and Jambul belongs

to family Myrtaceae are important evergreen beautiful tree, native to India. *S. cumini* is an emerging fruit crop of the twenty-first century. The fruit contains various pharmacological active phytochemicals such as alkaloids, fatty

acids, steroids and tannins. The fruit is also known as diabetic-fighter because of its hypoglycemic properties. The dried alcoholic extract of jamun seeds has the potential to reduce blood sugar and glycosuria. The plants raised by seed takes long period to flower and bear fruits. Seed propagated plant bears fruits of variable size and quality. The percentage of germination and seed longevity of jamun is eight per cent and three week respectively. (Roberts, 1983). Therefore vegetative propagation is utmost desirable to propagate true to type plants. Propagation by cuttings is the most convenient and cheap method of obtaining a fully developed stronger tree in considerably less time. Auxin has varying degree of effectiveness in promoting adventitious roots in stem cuttings of many species. It has been suggested that auxin promotes growth of avena coleoptile by induction of hydrogen ion secretion and cell wall acidification (Cleland, 1973).

Furthermore, Tripathi and Shukla (2004) reported that the maximum rooting percentage in pomegranate cutting was recorded under 1000 ppm PHB + 5000 ppm IBA and the maximum number of root per cutting was also recorded under 1000 ppm PHB + 5000 ppm IBA. The research work on rooting of jamun cuttings is very limited. Keeping these points in view the present study was conducted to study the influence of PGRs on success of rooting ability of different types of stem cuttings of jamun.

Materials and Methods

The experiment was conducted at College of horticulture, University of Horticultural sciences, Navanagar, Bagalkot (Karnataka) India. The experiment was laid out in Factorial completely randomized design. There were seven treatments of different PGR combination. Each treatment was replicated twice.

Preparation of cuttings

Jamun (*Syzygium cumini* L. Skeels) stem cuttings were taken from well-developed disease free mother plants.

The cuttings were 15 cm long, containing about 4 to 5 buds. In the present study three types of stem cuttings were taken, which are as follows:

Hard-wood cuttings: The branches of pencil thickness from the past season growth having an age of seven to nine months were selected from the mother plant. All the leaves were removed by using secateurs. The length of the cuttings were retained about 15 to 20 cm.

Semi-hardwood cuttings: The branches of pencil thickness from the past season growth having an age of seven to nine months were selected.

The length of the stem cuttings were 15 cm. few top leaves were retained in the cuttings.

Shoot tip cuttings: These are the fast growing soft tips of stems, usually taken from four to five months old shoots having a length of 15 cm, including the terminal bud.

A slanting cut was given at the upper side and a flat cut was given at the lower end of the cutting.

Preparation of growth regulator

The cuttings was treated with growth regulators by quick dip method and for this a required amount of growth regulator was weighed and dissolved in 0.2 N NaOH and then the volume was made up to 1 litre using distilled water and the cutting was dipped in solution for 2 minutes (Ayesha and Thippesha, 2018) and planted in portrays containing cocopeat as media.

Selection of treatments

Factor A (Seven growth regulators levels)

G₁ IBA 2,000 ppm, G₂ IBA 3,000 ppm, G₃ IBA 4,000 ppm, G₄ IBA 2,000+ PHB 750 ppm G₅ IBA 3,000 + PHB (P- Hydroxy benzoic Acid) 750 ppm, G₆ IBA 4,000+ PHB 750 ppm and G₇ Rootex (commercial formulation for rooting) and Factor B (Three types of cuttings)- C₁ Hardwood cuttings, C₂ Semi Hardwood cuttings and C₃ Shoot tips Cuttings.

Induction of treatments

Factor A and Factor B were combined and 21 treatments obtained are as follows; T₁. C₁ Hardwood cuttings + G₁ IBA 2,000 ppm, T₂. C₂ Semi-hardwood cutting + G₁ IBA 2,000 ppm, T₃. C₃ Shoot-tip cutting+ G₁ IBA 2,000 ppm, T₄. C₁ Hardwood cuttings + G₂ IBA 3,000 ppm, T₅. C₂ Semi-hardwood cutting + G₂ IBA 3,000 ppm, T₆. C₃ Shoot-tip cutting + G₂ IBA 3,000 ppm, T₇. C₁ Hardwood cuttings + G₃ IBA 4,000 ppm, T₈. C₂ Semi-hardwood cutting + G₃ IBA 4,000 ppm, T₉. C₃ Shoot-tip cutting+ G₃ IBA 4,000 ppm, T₁₀. C₁ Hardwood cuttings + G₄ IBA 2,000 + PHB 750 ppm, T₁₁. C₂ Semi-hardwood cutting + G₄ IBA 2,000 + PHB 750 ppm, T₁₂. C₃ Shoot-tip cutting + G₄ IBA 2,000 + PHB 750 ppm, T₁₃. C₁ Hardwood cuttings + G₅ IBA 3,000 + PHB 750 ppm, T₁₄. C₂ Semi-hardwood cutting + G₅ IBA 3,000 + PHB 750 ppm, T₁₅. C₃ Shoot-tip cutting + G₅ IBA 3,000 + PHB 750 ppm, T₁₆. C₁ Hardwood cuttings + G₆ IBA 4,000 + PHB 750 ppm, T₁₇. C₂ Semi-hardwood cutting + G₆ IBA 4,000 + PHB 750 ppm, T₁₈. C₃ Shoot-tip cutting + G₆ IBA 4,000 + PHB 750 ppm, T₁₉. C₁ Hardwood cuttings + G₇ Rootex, T₂₀. C₂ Semi-hardwood cutting + G₇ Rootex and T₂₁. C₃ Shoot-tip cutting + G₇ Rootex.

Observations

The observations taken were days taken for sprout initiation, sprouting percentage, number

of sprouts, number of leaves and length of shoots at 30, 60 and 90 days after planting and fresh weight of cuttings, dry weight of cuttings, number of primary and secondary roots, length of longest root, and rooting percentage at 90 Days after planting.

Dry weight (g)

After the fresh weight was taken, the jamun cuttings was taken in the butter paper bags. Tagging was done to individual paper bags according to the treatments to avoid mechanical mixture. After that, the tagged paper bags were put in the hot air oven at 100°F for few days until the mass gets constant.

Statistical analysis

The data recorded for all the parameters was statistically analysed (ANOVA) by following the completely randomized design (CRD) at 5% level of significance. The analysis has been done in Web Agri-Stat Package (WASP 2.0) developed by ICAR Research Complex, Goa.

Results and Discussion

Effect on days taken for sprout initiation

The numbers of days taken for sprout initiation in jamun stem cuttings was significantly influenced by various levels growth regulators and type of cuttings and their interactions. Shoot-tip cuttings (11.46 days) were early than others and rootex (11.20 days) was the best in early sprout initiation compared to other propagation conditions (Table 1). In the interaction, the minimum number of days of 8.65 was recorded for sprouting initiation in T₂₁ (C₃ Shoot-tip cutting + G₇ Rootex), which was on par with T₉ (C₃ Shoot-tip cutting+ G₃ IBA 4,000 ppm) and T₁₈ (C₃ Shoot-tip cutting + G₆ IBA 4,000 + PHB

750 ppm) with 9.50 and 9.70 days respectively (Table 3). The maximum number of days (15.50) taken for sprout initiation was recorded in treatment T₁- C₂. Semi-hardwood cutting + G₁ IBA 2,000 ppm. Earliest sprouting of cutting may be due to prevention of down-word translocation of carbohydrate and accumulation of higher level of endogenous and exogenous auxins and also due to the exogenous application of auxin which hydrolysis starch into sugars. This is needed to a greater extent for the production of new cells and for increased respiratory activity in the regeneration tissue at the time of initiation of new root primordial (Bhattacharjee and Thimmappa, 1993). Similar results were also reported by Hussain *et al.*, (2016) in sweet lime and Kumar *et al.*, (2004) in sweet lime.

Effect on number of sprouts per cutting

In the present study growth regulators and type of cuttings and their combinations exhibited significant effect on average number of sprouts per cutting. Highest number of sprouts was recorded in hardwood cuttings (9.79, 8.29 and 5.11) and rootex (9.49, 8.49 and 5.90) as compared to other type of cuttings and PGR's at 30, 60, and 90 days after planting, respectively (Table 1). In the interaction, the maximum number of sprouts per cutting (12.05, 10.05 and 6.10) was recorded in T₁₉- C₁- Hardwood cuttings + G7 Rootex. Whereas, the minimum number of sprouts per cutting (5.91- T₃- C₃ Shoot-tip cutting + G₁ IBA 2,000 ppm, 5.41- T₃- C₃ Shoot-tip cutting + G₁ IBA 2,000 ppm and 3.90-T₁₅- C₃ Shoot-tip cutting + G₅ IBA 3,000 + PHB 750 ppm) was recorded at 30, 60 and 90 days after planting, respectively (Table 3). Increase in sprouting percentage in hardwood cuttings may be due to better utilization of stored carbohydrate, nitrogen and other factor with the aid of growth regulator. Rootex treated cuttings had more sprouts per cutting

as it was adhered with the cut end of the cuttings for a prolonged period. Similar results were also reported by Siddiqui and Hussain (2007) in *Ficus* and Tripathi and Shukla (2004) in pomegranate.

Effect on percent sprouted cuttings

In the present study growth regulators and type of cuttings and their combinations exhibited significant effect on sprout percentage. Highest percentage of sprouting was recorded in the hardwood cuttings (12.68 %) compared to other type of cuttings and rootex (16.19%) was best condition to record highest sprouting compared to other conditions (Table 1). In the interaction, the highest sprouting percentage was recorded in treatment T₁₉ (C₁ Hardwood cuttings + G7 Rootex) with 29.90 per cent whereas lowest sprouting percentage was observed in treatment T₁₂ (C₃ Shoot-tip cutting + G₄ IBA 2,000 + PHB 750 ppm) with 2.31 per cent (Table 3). Increase in sprouting percentage in hardwood cuttings may be due to better utilization of stored carbohydrate, nitrogen and other factor with the aid of growth regulator. Similar results were also reported by Bastos *et al.*, (2006) in litchi, Siddiqui and Hussain (2007) in *Ficus* and Hussain *et al.*, (2016) in sweet lime.

Effect on number of leaves per cutting

In the present study growth regulators and type of cuttings and their combinations exhibited significant effect on average number of leaves per cutting. Highest number of leaves was recorded in hardwood cuttings (4.76, 6.73 and 7.72) and rootex (5.29, 7.46 and 8.19) as compared to other type of cuttings and PGR's at 30, 60, and 90 days after planting, respectively (Table 1). In the interaction, the maximum number of leaves per cutting (5.68, 8.15 and 9.15) was recorded in T₁₉ (C₁ Hardwood cuttings + G7 Rootex) as

presented in (Table.3). Whereas, the minimum number of leaves per cutting of (3.05- T₁₅ - C₃ Shoot-tip cutting + G₅ IBA 3,000 + PHB 750 ppm, 4.12- T₁₂- C₃ Shoot-tip cutting + G₄ IBA 2,000 + PHB 750 ppm and 5.12- T₁₂- C₃ Shoot-tip cutting + G₄ IBA 2,000 + PHB 750 ppm) was recorded at 30, 60 and 90 days after planting, respectively (Table 1). Increase in number of leaves might be due to effect of exogenous and endogenous auxin. Rootex treated cuttings had more leaves per cutting as it was adhered with the cut end of the cuttings for a prolonged period. Similar results were also reported by Gurjar and Patel (2006) in pomegranate, Singh *et al.*, (2016) in phalsa and Hussain *et al.*, (2016) in sweet lime.

Effect on shoot length

In the present study growth regulators and type of cuttings and their combinations exhibited significant effect on average shoot length. Highest shoot length was recorded in hardwood cuttings (4.66, 5.93 and 5.11cm) and rootex (6.25, 7.62 and 7.93cm) as compared to other type of cuttings and PGR's at 30, 60, and 90 days after planting, respectively (Table 2). In the interaction, the maximum shoot length (6.45cm- T₂₀- C₂ Semi-hardwood cutting + G7 Rootex, 8.15cm- T₁₉ - C₁ Hardwood cuttings + G7 Rootex and 8.54cm- T₁₉ -C₁ Hardwood cuttings + G7 Rootex) was recorded at 30, 60 and 90 days after planting, respectively.

The minimum length of shoot (2.15cm- T₃ -C₃ Shoot-tip cutting + G₁ IBA 2,000 ppm, 3.85cm- T₁₀ -C₁ Hardwood cuttings + G₄ IBA 2,000 + PHB 750 ppm and 4.95cm- T₁₀ -C₁ Hardwood cuttings + G₄ IBA 2,000 + PHB 750 ppm) at 30, 60 and 90 days after planting, respectively (Table.3).The length of shoots had got increased due to development of primary roots at 60 and 90 DAP as compared to 30 days which enhanced better uptake of nutrients like nitrogen from media for

vegetative growth. These results were in accordance with that of Tripathi and Shukla (2004) in pomegranate and Ahmad *et al.*, (2016) in dragon fruit.

Effect on fresh weight

In the present study growth regulators and type of cuttings and their combinations exhibited significant effect on average fresh weight of cuttings. The maximum fresh weight of cuttings was recorded in hardwood cuttings (17.90g) and rootex (19.69g) as compared to other types of cuttings and PGR's at 30, 60 and 90 days after planting, respectively (Table 2). Hardwood cuttings were produced more fresh weight as compared to other types of cutting as the diameter was more in case of hardwood cuttings.

In the interaction, the highest fresh weight at 90 DAP was recorded in the treatment T₁₉ (C₁ Hardwood cuttings + G7 Rootex) with 21.47g, which was on par with T₇ (C₁ Hardwood cuttings + G₃ IBA 4,000 ppm) with 20.70 g whereas, the lowest fresh weight was recorded in T₁₅ (C₃ Shoot-tip cutting + G₅ IBA 3,000 + PHB 750 ppm) with 13.42g (Table 4). These results were in accordance with that of Mehta *et al.*, (2018) in pomegranate, Filho *et al.*, (2009) in citrumello and Ahmad *et al.*, (2016) in dragon fruit.

Effect on dry weight

In the present study growth regulators and type of cuttings and their combinations exhibited significant effect on average dry weight of cuttings. The maximum dry weight of cuttings was recorded in hardwood cuttings (11.83g) and rootex (11.34g) as compared to other types of cuttings and PGR's at 30, 60 and 90 days after planting, respectively (Table 2). In the interaction, highest average dry weight had been recorded in the hardwood as the diameter of cuttings were more.

Table.1 Effect of types of cuttings and PGRs on shoot parameters in jamun

Factor	Days taken for sprout initiation	Percentage of sprouted cuttings	Number of sprouts per cutting			Number of leaves per cutting		
			30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
C ₁	14.29	12.68	9.79	8.29	5.11	4.76	6.73	7.72
C ₂	12.91	5.84	8.05	7.04	4.98	4.31	6.07	6.96
C ₃	11.46	4.86	6.85	6.32	4.75	4.08	5.52	6.46
SEm ± (Cutting)	0.17	0.20	0.11	0.10	0.09	0.06	0.08	0.17
CD (0.05) (Cutting)	0.51	0.57	0.33	0.29	0.25	0.18	0.25	0.49
G ₁	13.63	3.86	7.83	6.82	4.65	4.09	6.18	7.15
G ₂	13.52	4.23	8.34	7.32	5.00	4.08	5.28	6.28
G ₃	11.68	10.31	8.52	7.52	5.34	4.98	6.99	7.82
G ₄	14.00	5.10	7.56	6.50	4.30	3.92	5.04	6.07
G ₅	14.27	5.02	7.48	6.48	4.17	3.55	5.23	6.26
G ₆	11.90	9.84	8.41	7.40	5.27	4.77	6.56	7.56
G ₇	11.20	16.19	9.49	8.49	5.90	5.29	7.46	8.19
SEm ± (PGR)	0.27	0.30	0.17	0.15	0.13	0.09	0.13	0.25
CD (0.05) (PGR)	0.78	0.88	0.50	0.44	0.38	0.28	0.37	0.75

*Significant at 5 percent level; C₁ Hardwood cuttings, C₂ Semi-hardwood cutting, C₃ Shot-tip cutting, G₁ IBA 2,000 ppm, G₂ IBA 3,000 ppm, G₃ IBA 4,000 ppm, G₄ IBA 2,000 + PHB 750 ppm, G₅ IBA 3,000 + PHB 750 ppm, G₆ IBA 4,000 + PHB 750 ppm and G₇ Rootex

Table.2 Effect of types of cuttings and PGRs on shoot and root parameters in jamun

Factor	Shoot length (cm)			Fresh weight (g)	Dry weight (g)	Number of primary and secondary roots	Longest root length (cm)	Percentage of rooted cuttings
	30 DAP	60 DAP	90 DAP					
C ₁	4.66	5.93	6.75	17.90	11.83	50.18	15.55	27.71
C ₂	4.37	5.53	5.85	16.58	9.60	48.81	12.66	14.01
C ₃	4.10	5.31	6.54	15.64	7.86	45.69	9.01	9.39
SEm ± (Cutting)	0.08	0.09	0.14	0.23	0.15	0.74	0.17	0.42
CD (0.05) (Cutting)	0.23	0.25	0.42	0.67	0.43	2.18	0.49	1.24
G ₁	2.93	4.36	5.35	15.12	9.25	39.38	10.65	15.88
G ₂	3.41	4.65	5.58	16.41	9.45	48.51	11.79	16.50
G ₃	5.97	7.33	7.79	18.55	10.51	52.92	13.81	18.62
G ₄	3.00	4.07	5.05	14.39	8.60	42.78	11.64	14.50
G ₅	3.40	4.33	5.43	15.23	9.00	46.00	11.70	15.43
G ₆	5.65	6.79	7.52	17.56	10.18	52.65	12.99	17.45
G ₇	6.25	7.62	7.93	19.69	11.34	55.35	14.28	20.90
SEm ± (PGR)	0.12	0.13	0.22	0.35	0.22	1.13	0.25	0.64
CD (0.05) (PGR)	0.35	0.38	0.64	1.02	0.66	3.33	0.75	1.89

*Significant at 5 percent level

Table.3 Effect of Interaction of type of cutting and PGRs on shoot parameters in jamun

S. No.	Treatment details	Days taken for sprout initiation	Percentage of Sprouted cuttings	Number of Sprouts per cutting			Number of leaves per cutting			Shoot length (cm)		
				30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
1	T ₁ - C ₁ G ₁	15.50	4.20	9.35	7.85	4.85	4.54	6.03	7.18	3.45	4.30	5.10
2	T ₂ - C ₂ G ₁	13.00	4.15	7.66	6.66	4.65	3.72	5.29	6.06	3.20	4.70	5.75
3	T ₃ - C ₃ G ₁	12.40	3.22	6.50	5.96	4.45	4.03	7.23	8.23	2.15	4.08	5.20
4	T ₄ - C ₁ G ₂	14.00	4.65	9.45	7.95	5.20	4.38	6.29	7.33	4.00	5.30	6.20
5	T ₅ - C ₂ G ₂	13.75	4.50	8.00	7.00	5.00	4.03	5.30	6.25	3.29	4.40	5.25
6	T ₆ - C ₃ G ₂	12.80	3.55	7.56	7.01	4.80	3.84	4.26	5.26	2.95	4.24	5.29
7	T ₇ - C ₁ G ₃	13.50	16.00	9.75	8.25	5.20	5.00	7.30	7.88	6.10	7.90	8.43
8	T ₈ - C ₂ G ₃	12.03	7.95	8.50	7.50	5.50	5.28	7.34	8.34	6.15	7.25	6.65
9	T ₉ - C ₃ G ₃	9.50	6.98	7.31	6.81	5.31	4.67	6.33	7.24	5.67	6.84	8.30
10	T ₁₀ - C ₁ G ₄	15.00	9.70	9.04	7.51	4.50	4.43	5.89	7.00	2.90	3.85	4.95
11	T ₁₁ - C ₂ G ₄	13.65	3.30	7.40	6.30	4.30	3.80	5.10	6.10	3.00	4.35	5.09
12	T ₁₂ - C ₃ G ₄	13.35	2.31	6.23	5.70	4.10	3.54	4.12	5.12	3.10	4.01	5.12
13	T ₁₃ - C ₁ G ₅	15.00	9.25	8.91	7.41	4.40	4.33	6.26	7.32	3.75	4.50	5.55
14	T ₁₄ - C ₂ G ₅	14.00	3.40	7.61	6.61	4.20	3.28	5.19	6.18	3.15	4.25	5.00
15	T ₁₅ - C ₃ G ₅	13.80	2.40	5.91	5.41	3.90	3.05	4.26	5.30	3.30	4.23	5.75
16	T ₁₆ - C ₁ G ₆	14.00	15.05	10.01	8.51	5.50	4.95	7.18	8.18	6.10	7.55	8.39
17	T ₁₇ - C ₂ G ₆	12.00	7.70	8.31	7.31	5.30	4.80	6.66	7.66	5.35	6.29	6.45
18	T ₁₈ - C ₃ G ₆	9.70	6.77	6.92	6.37	5.00	4.55	5.84	6.84	5.51	6.54	7.72
19	T ₁₉ - C ₁ G ₇	13.00	29.90	12.05	10.55	6.10	5.68	8.15	9.15	6.30	8.15	8.64
20	T ₂₀ - C ₂ G ₇	11.95	9.85	8.90	7.90	5.90	5.29	7.65	8.16	6.45	7.45	6.74
21	T ₂₁ - C ₃ G ₇	8.65	8.83	7.53	7.01	5.70	4.90	6.59	7.28	6.00	7.25	8.41
SEm ±		0.46	0.29	0.21	0.17	0.23	0.16	0.22	0.44	0.21	0.23	0.38
CD (0.05)		1.36*	0.87*	0.62*	0.50*	0.66*	0.48*	0.65*	1.29*	0.60*	0.67*	1.11*

*Significant at 5 percent level; C₁-Hardwood cuttings, C₂- Semi hardwood cuttings, C- Shoot-tip cuttings, G₁-2000ppm IBA, G₂- 3000ppm IBA, G₃. 4000ppm IBA, G₄. IBA 2,000 + PHB 750 ppm, G₅. IBA 3,000 + PHB 750 ppm, G₆. 4,000 + PHB 750 ppm and G₇. Rootex

Table.4 Effect of Interaction of type of cutting and PGRs on root parameters in jamun

S. No.	Treatment Details	Fresh weight (gram)	Dry weight (gram)	Number of primary and secondary roots	Length of longest root (cm)	Percentage of rooted cuttings
1	T ₁ - C ₁ G ₁	15.50	10.30	42.15	13.05	26.85
2	T ₂ - C ₂ G ₁	14.63	9.85	39.75	11.14	12.15
3	T ₃ - C ₃ G ₁	15.24	7.60	36.25	7.76	8.65
4	T ₄ - C ₁ G ₂	18.17	12.11	42.93	15.05	26.60
5	T ₅ - C ₂ G ₂	16.68	9.06	52.99	12.04	13.95
6	T ₆ - C ₃ G ₂	14.40	7.20	49.60	8.27	8.95
7	T ₇ - C ₁ G ₃	20.70	12.36	56.88	16.22	30.70
8	T ₈ - C ₂ G ₃	17.42	10.33	52.20	14.24	14.10
9	T ₉ - C ₃ G ₃	17.53	8.85	49.68	10.98	11.05
10	T ₁₀ - C ₁ G ₄	15.28	10.48	45.60	15.40	20.95
11	T ₁₁ - C ₂ G ₄	14.16	8.23	42.70	12.37	13.95
12	T ₁₂ - C ₃ G ₄	13.73	7.09	40.04	7.16	8.60
13	T ₁₃ - C ₁ G ₅	15.67	11.14	49.46	15.74	24.35
14	T ₁₄ - C ₂ G ₅	16.60	9.15	46.00	11.14	13.90
15	T ₁₅ - C ₃ G ₅	13.42	6.71	42.55	8.23	8.05
16	T ₁₆ - C ₁ G ₆	18.52	12.15	56.65	16.56	29.15
17	T ₁₇ - C ₂ G ₆	17.07	9.75	52.60	13.04	14.20
18	T ₁₈ - C ₃ G ₆	17.10	8.65	48.70	9.39	9.00
19	T ₁₉ - C ₁ G ₇	21.47	14.25	57.60	16.85	35.40
20	T ₂₀ - C ₂ G ₇	19.50	10.83	55.45	14.69	15.85
21	T ₂₁ - C ₃ G ₇	18.10	8.93	52.99	11.29	11.45
SEm ±		0.66	0.39	1.96	0.44	1.12
CD (0.05)		1.77*	1.14*	5.76*	1.30*	3.28*

*Significant at 5 percent level

The highest dry weight at 90 DAP was recorded in the treatment T₁₉ (C₁ Hardwood cuttings + G₇ Rootex) with 14.25g, followed by T₇ (C₁ Hardwood cuttings + G₃ IBA 4,000 ppm) with 12.36 g whereas, the lowest fresh weight was recorded in T₁₅ (C₃ Shoot-tip cutting + G₅ IBA 3,000 + PHB 750 ppm) with 6.71g (Table 4).

These results were in accordance with that of Gurjar and Patel (2006) in pomegranate, Sardoei (2014) in guava and Ahmad *et al.*, (2016) in dragon fruit.

Effect on number of primary and secondary root

In the present study growth regulators and type of cuttings and their combinations exhibited significant effect on average number of primary and secondary roots. Number of primary and secondary roots was more in the hardwood cuttings (50.18) and rootex (55.35) treated cuttings compared to others (Table 2). In the interaction, the highest number of primary and secondary roots per cutting had been recorded in T₁₉ (C₁ Hardwood cuttings + G₇ Rootex) with 57.60, which is on par with T₇ (C₁ Hardwood

cuttings + G₃ IBA 4,000 ppm) with 56.88 whereas, the lowest number of roots was observed in the treatment T₃ (C₃ Shoot-tip cutting+ G₁ IBA 2,000 ppm) of about 36.25 roots (Table 4).

Number of primary and secondary roots was more in the hardwood cuttings as the dry matter of cuttings were more. These results were in accordance with that of Bastos *et al.*, (2006) in litchi, Akakpo *et al.*, (2014) in sheanut tree and Singh *et al.*, (2013) in pant lemon.

Effect on length of longest root

In the present study growth regulators and type of cuttings and their combinations exhibited significant effect on length of longest root (Table 2). Overall, the longest length of primary root was recorded in the hardwood cutting and rootex treated plants.

It might be due to an auxin application has been found to enhance the histological features like formation of callus, tissue and differentiation of vascular tissue and also due to the assimilation and translocation of auxins compound in rooted cutting. In the interaction, Length of longest root was more in the hardwood cuttings (15.55cm) and rootex (14.28cm) treated cuttings compared to others (Table 4). The highest length of longest root per cutting was recorded in T₁₉ (C₁ Hardwood cuttings + G₇ Rootex) with 16.85cm whereas, the lowest length of primary roots was observed in the treatment T₁₂ (C₃ Shoot-tip cutting + G₄ IBA 2,000 + PHB 750 ppm) with 7.16 cm (Table 4). These results were in accordance with that of Galavi *et al.*, (2013) in Grape, Akakpo *et al.*, (2014) in sheanut tree, Mehta *et al.*, (2018) in pomegranate and Singh *et al.*, (2019) pant lemon.

Percentage of rooted cuttings

In the present study growth regulators and

type of cuttings and their combinations exhibited significant effect on percentage of rooted cuttings. Percentage of rooted cuttings was more in the hardwood cuttings (27.71) and rootex (20.90) treated cuttings compared to others (Table 2). Overall, highest percentage of rooting was recorded in the hardwood cuttings compared to other type of cuttings and rootex was best growth regulator to record highest rooting compared to other conditions.

It might be due to the rapid hydrolysis of polysaccharides stored in stem cuttings into physiologically active sugars which provide energy to meristematic tissues and activate the root primordia to initiate formation of more number of roots in stem cuttings. In the interaction, the highest rooting percentage was recorded in treatment T₁₉ (C₁ Hardwood cuttings + G₇ Rootex) with 35.40 per cent whereas, the lowest rooting percentage was observed in treatment T₁₅ (C₃ Shoot-tip cutting + G₅ IBA 3,000 + PHB 750 ppm) with 8.05 per cent (Table 4).

These results were in accordance with that of Filho *et al.*, (2009) in citrumello, Karimi *et al.*, (2012) in Pomegranate, Akakpo *et al.*, (2014) in sheanut tree and Mehta *et al.*, (2018) in pomegranate.

The hardwood cutting in combination with rootex was superior to show more shooting and rooting parameters in jamun. The results would be very useful in standardization of an efficient protocol for multiplication of jamun through cuttings.

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