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Growth Response of West Indian Cherry (*Malpighia glabra* L.) to Various Cutting Types, Monthly Variations and IBA Treatments

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ABSTRACT

Background: The West Indian Cherry, a tropical fruit crop, is notable for its exceptionally high vitamin C content. While it can be propagated through seeds, the germination rate is relatively low. Therefore, efforts were made to propagate it using stem cuttings, a popular method of vegetative propagation due to its rapidity, simplicity and cost-effectiveness.

Methods: Experiments were conducted from June to September using different concentrations of Indole-3-butyric acid (IBA) (1500 ppm, 2500 ppm and a control) on two types of cuttings: softwood and semi-hardwood.

Result: The best rooting and shooting results were observed with semi-hardwood cuttings treated with 1500 ppm IBA during the first fortnight of August. This method is recommended for nurseries and farmers to achieve faster and more successful propagation of the West Indian Cherry.

Key words: Climate, Cuttings, IBA, Propagation, Rooting, Types of cutting, West Indian cherry.

INTRODUCTION

The West Indian cherry (*Malpighia glabra* L.), also known as Barbados cherry or Acerola, is a tropical fruit species belonging to the Malphigiaceae family. Though it likely originated in southern Mexico, Central and South America, it is now cultivated in various tropical and subtropical regions across Asia. In India, it is cultivated in some parts of Tamil Nadu and Kerala due to its tropical humid climate. The fruit is packed with many health benefits like nutrients and unique antioxidants and it can be also considered as a medicinal tree. According to Kirker *et al.* (2021), a 100 g edible portion of West Indian cherry fruit contains 2000 to 4000 mg of vitamin C. Its unique antioxidant properties are attributed to its high content of ascorbic acid, carotenoids, flavonoids and anthocyanins (Prakash and Baskaran, 2018). The plant itself is a large, bushy type that can grow between 3 to 6 meters in height (Dey *et al*., 2018), characterized by spreading and drooping branches and a short trunk.

Fruit is small and it can be consumed whole or in a juicy form. It has been found to possess anti-cancer and anti-inflammatory properties and is also effective in reducing the risk of heart disease (Samim *et al*., 2021). The nutritional composition per 100 g of the edible portion of West Indian cherry fruit includes energy (59 Kcal), protein (0.68-1.8 g), carbohydrates (6.9-14 g), vitamin A (408-1000 I.U), vitamin B1 (0.024-0.4 mg), vitamin B_2 (0.039-0.079 mg), vitamin B3 (0.34-0.53 mg), vitamin C (1644 mg), iron (0.17-1.2 mg), phosphorus (16.2-36 mg), calcium (8.2-34 mg), fiber (0.6-1.2 g) and fat (0.18 - 0.1 g) (Dusman *et al*., 2012).

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West Indian cherry can be propagated through seeds, though the germination rate is very low due to the presence of non-viable embryos. Tripathi *et al.* (2022) reported that a lower germination percentage (35%) was recorded in West Indian cherry. It is commercially propagated through air layering, grafting and budding using growth regulators, which need skilled labor (Samim *et al*., 2021). Among the methods, cutting is the most popular form of vegetative propagation since it is rapid, simple, inexpensive and doesn't require specific techniques like other ways do. Hence, nurserymen have found that propagation is the simplest, most cost-effective and practical approach. Propagation by stem cuttings is the simplest and most convenient method, but earlier studies on propagation of West Indian cherry cuttings have given only poor to moderate success in rooting and establishment of the rooted cuttings. Enhanced rooting in fruit crop stem cuttings can be achieved only through the application of growth regulators such as IBA (Indole-3-butyric acid) and NAA (Naphthalene Acetic Acid), along with appropriate rooting media since they regulate the formation of both roots and shoots. Well maintained plants start to bear fruits three years after planting about 1.5-2 kg/plant in the initial and 4-5 kg/ plant after 5th year (Singh, 2006). Jackson and Pennock (1958) reported that 420 plants per hectare can accommodated in the spacing of 4.9×4.9m which yields about 22 tonnes of fruits.

The type of cuttings, prevailing climatic conditions in a particular region and the concentration of rooting hormones will influence the success rate. Therefore, research was conducted to rapidly multiply West Indian cherries to bring maximum success in the cuttings-based mode of propagation in Coimbatore region.

MATERIALS AND METHODS

The present study was conducted on the "Growth response of West Indian cherry (*Malpighia glabra* L.) to various cutting types, monthly variations and IBA treatments" during 2022-2023 at North farm, Division of Horticulture, The School of Agricultural Sciences, Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu, India. Softwood and semi-hardwood cuttings of uniform thickness, free from pests and diseases, were chosen from mother trees kept in the orchard at Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu. Following IBA treatment, the cuttings were planted in polybags filled with a 1:1:1 potting mixture of red soil, sand and FYM (Farmyard Manure). The cuttings, which had three to four nodes each, were made from the one-year-old shoot of a nine-year-old tree. The leaves were removed from uniform (15 cm) cuttings and a section of the stem was clipped toward the ends of each node. Both softwood and semi hardwood cuttings were taken from branches that were in current season growth (softwood) and those that were less than one year old (semi-hardwood). To improve the surface area for roots, a diagonal incision was made toward the basal part of the cuttings. The FRBD (Factorial Randomized Block Design) was used to set up the experiment. Twenty-four treatments included growth regulators, time and their combination. For every treatment, a total of 15 cuttings were obtained in 3 replications. The experiment was conducted during June - September of 2022. The basal portion of selected cuttings was treated with IBA. The details of the treatment were given in the Table 1.

Indole-3-butyric acid was dissolved (1.5 g and 2.5 g) in 1000 ml of distilled water to achieve the necessary concentrations of 1500 ppm and 2500 ppm, respectively. The chemical was initially dissolved in a small quantity of ethanol and then distilled water was added to adjust the total volume to 1000 ml. The basal portions (3-4 cm) of the cuttings were immersed in IBA solutions (1500 and 2500 ppm) for 30 seconds. The treated cuttings were then planted in polybags filled with rooting media.

The chlorophyll content index was recorded by using Spade meter. The observations were recorded after transferring to the polybags. The leaves were selected randomly from the tagged cuttings. The total nitrogen content in the sample was estimated with the help of Kel plus equipment through Micro-Kjeldhal method (Anonymous, 1970). The total carbohydrate was estimated by Anthrone method (Hedge and Hofreiter, 1962). The C: N ratio was calculated as the ratio of carbohydrates (%) to that of nitrogen (%) obtained by dry weight basis. And the meteorological data were recorded during the experiment (Fig 1).

RESULTS AND DISCUSSION

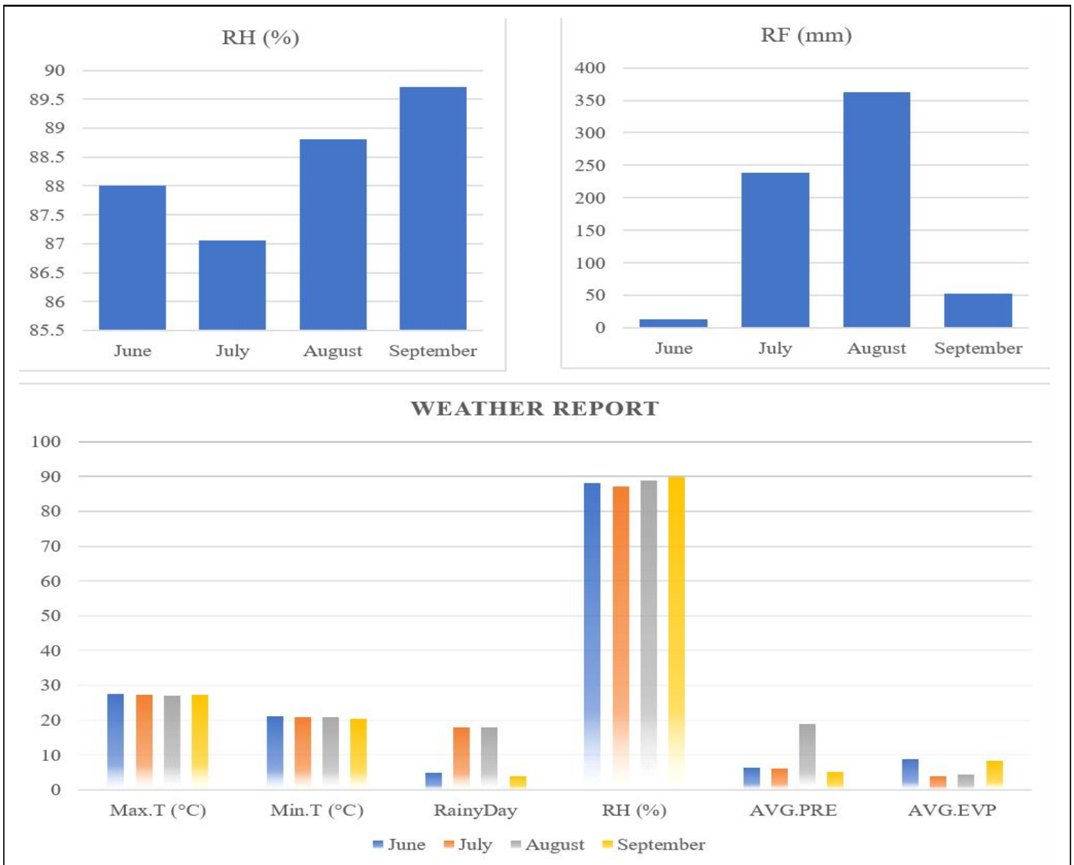
Impact of the timing of cuttings, IBA concentrations, cutting types and their interactions on rooting characteristics

Regarding the timing of cuttings, the highest rooting percentages (30.06%), number of roots per cutting (13.87), root length per cutting (9.17 cm), number of primary roots per cutting (6.09) and number of secondary roots per cutting (6.60) were achieved with cuttings taken during the first fortnight of August (A_3). This could be attributed to the climatic conditions prevalent in August (Fig 1). During this period, the plant remains in its active development phase, which aids rooting by enhancing metabolic activity and nutrient flow. Among the different IBA concentrations, the highest rooting percentage (33.49%), number of roots per cutting (15.56), root length per cutting (9.53 cm), number of primary roots per cutting (5.63) and number of secondary

Table 1: Treatment details.

Components	Stages	Symbol
Period	The first fortnight of June	A_1
	The first fortnight of July	A_2
	The first fortnight of August	A_3
	The first fortnight of September	A_4
Phytohormone (Indole-3-butyric acid)	Control (No phytohormone)	B_1
	Indole-3-butyric acid (1500 ppm)	B_2
	Indole-3-butyric acid (2500 ppm)	B_3
Cutting techniques	Softwood cutting	D_1
	Semi-hardwood cutting	D_2

roots per cutting (7.67) were observed with the B_2 (1500 ppm IBA) treatment. Maninderdeep and Singh, 2022 reported that application of IBA influence the rooting of cuttings. This effect might be due to auxin's action, which enhances cell elongation and division in a suitable environment by facilitating the hydrolysis and transfer of carbohydrates and nitrogenous substances near the base of cuttings (Hartmann *et al*., 2007). At 1500 ppm, IBA provides the optimal balance for promoting root initiation while minimizing potential toxicity. Higher concentrations may damage roots or inhibit their emergence, whereas lower concentrations may not trigger the necessary hormonal responses. Studies have shown that IBA at 1500 ppm significantly increases primary and secondary root lengths. This concentration promotes better root architecture, which is crucial for the better performance of cuttings (Singh and Attri, 2000). For the types of cuttings used, the highest rooting percentage (45.08%), number of roots per cutting (18.28), root length per cutting (7.78 cm), number of primary roots per cutting (5.99) and number of secondary roots per cutting (8.19) were recorded with D_2 (semi-hardwood) cuttings (Table 2). Semi-hardwood cuttings are more likely to root successfully compared to fully hardwood or softwood cuttings. This may be due to the mature wood in semi-hardwood cuttings, which likely contains substantial carbohydrate and sugar reserves. The presence of a large number of leaves is largely dependent on favourable weather conditions (Gray and Brady, 2016). The interaction between the timing of cuttings, IBA concentrations and types of cuttings had a significant impact on the percentage of rooted cuttings. The highest mean values and better root characteristics were recorded under the combination of cuttings taken during the first fortnight of August (A_3), treated with 1500 ppm IBA (B_2) and using semi-hardwood cuttings (D_2) (Table 3). The interplay of these factors likely established the optimal conditions for root initiation and development at the 45 and 90 DAC. This might be because taking cuttings during the first fortnight of August (A_3) may have provided optimal environmental conditions, such as suitable temperature and humidity, which are crucial for successful rooting. Additionally, the application of 1500 ppm IBA (B_2) might have enhanced root formation by providing the necessary hormonal stimulus. Auxin, whether naturally occurring



Max. T – maximum temperature, Min. T – minimum temperature, AVG. PRE – average precipitation, AVG. EVP – average evaporation

Fig 1: Weather data recorded during the study period.

within the plant or applied externally, plays a crucial role in root formation, particularly in the development of root cell primordia and on the stem (Hartmann *et al*., 2007). Lastly, the use of semi-hardwood cuttings (D_2) could have provided a balance between maturity and flexibility, enabling successful root establishment. Kaur and Singh, 2022 also observed that the interaction of IBA and time of cuttings taken influence the rooting of cutting. Babaie *et al*., 2014 reported that IBA concentration and time of cuttings taken, plays major role in rooting of cuttings and the better result was found in the cuttings taken during the early September in *Ficus binnendijkii*.

Impact of the timing of cuttings, IBA concentration, cutting types and their interactions on shooting parameters

Regarding the timing of cuttings, the first sprouting occurred in the shortest duration (17.28 days), with the highest number of shoots per cutting (3.63), number of leaves per cutting (30.18) and shoot length per cutting (10.92 cm) during the first fortnight of August (A_3). This may be due to conditions that help maintain the moisture balance necessary for shoot growth. August often coincides with the rainy season, reducing the need for manual watering and providing natural irrigation (Fig 1). This consistent moisture availability supports improved root and shoot development. For IBA concentrations, the quickest first sprouting (16.54 days), highest sprouting percentage (33.02%), number of shoots per cutting (3.69), number of leaves per cutting (29.32) and shoot length per cutting (11.45 cm) were observed with the B_2 (1500 ppm IBA) treatment. IBA, a synthetic auxin, promotes root initiation, which is crucial for shoot growth. By encouraging root formation, IBA ensures that cuttings have a strong foundation for developing new shoots. It helps maintain the hormonal balance within the cuttings, allowing roots and shoots to grow together harmoniously. This balance ensures efficient nutrient and energy use for the development of both roots and shoots (Ashok *et al*., 2020). Samim *et al*., 2021 reported that 5000ppm of IBA gave the better result in West Indian cherry cuttings but here the better result was observed in 1500ppm which reduces the quantity of IBA required for West Indian cherry propagation. Among the types of cuttings, the fastest first sprouting (14.57 days), highest sprouting percentage (33.02%), number of shoots per cutting (3.69), number of leaves per cutting (29.32) and shoot length per cutting (14.07 cm) were recorded with D_2 (semi-hardwood) cuttings (Table 4). These cuttings possess a more developed vascular system compared to softwood cuttings, which helps reduce water loss and maintain turgor pressure. Additionally, the increased number of leaves can enhance the rate of photosynthesis. These outcomes can be attributed to the cuttings' well-developed root systems, which likely promote shoot growth by ensuring sufficient water and nutrients are mobilized from the substrate or soil to the developing apices. Consequently, the newly emerging shoots grow more rapidly (Pratima and Rana, 2011). The interaction of

Table 2: Impact of the timing (months) of cuttings, IBA concentrations and cutting types on root parameters.

Treatments	90 DAC	45 DAC	90 DAC	45 DAC	90 DAC	45 DAC	90 DAC	45 DAC	90 DAC
	Percentage of cuttings rooted	Number of roots per cuttings		Length of the root (cm)		Number of primary roots		Number of secondary roots	
				Time of cuttings taken (T)					
A_1	20.17^{a}	4.36^{a}	10.57^{a}	4.36^{a}	6.77^{a}	1.84^{a}	3.29^{a}	2.37^{a}	4.39^{a}
A_2	24.06^{b}	5.76^{b}	11.86^{b}	4.71^{b}	7.38^{b}	2.53^{b}	4.16^{b}	2.72^{b}	5.05^{b}
A_3	30.06^{c}	6.87^{c}	13.87^{c}	5.47^{c}	9.17^{c}	3.43^{c}	6.09^{c}	3.24^{c}	6.60^{c}
A_4	28.72^{d}	6.33^{d}	13.76^{c}	5.05^{d}	8.39^{d}	2.66^{d}	5.03^{d}	3.16^{d}	5.85^{d}
SE. d	0.52	0.11	0.16	0.07	0.11	0.03	0.04	0.05	0.09
CD @ 5 %	1.05	0.22	0.32	0.14	0.23	0.06	0.09	0.10	0.18
				IBA concentrations (S)					
B_1	18.27^{a}	3.01^{a}	10.14^{a}	3.61^{a}	6.11^{a}	2.05^{a}	3.63^{a}	1.79^{a}	3.32^{a}
B_2	33.49^{b}	8.98^{b}	15.56^{b}	6.16^{b}	9.53^{b}	3.19^{b}	5.63^{b}	3.82^{b}	7.67^{b}
B_3	25.50^{c}	5.50^{c}	11.84^{c}	4.93^{c}	8.14^{c}	2.61^{c}	4.67^{c}	3.01^{c}	5.42^{c}
SE. d	0.45	0.09	0.13	0.06	0.10	0.02	0.04	0.08	0.07
CD @ 5 %	0.91	0.19	0.32	0.1	0.20	0.05	0.08	0.04	0.15
				Types of cuttings (C)					
D_1	6.43^{a}	2.89^{a}	6.74^{a}	2.26^{a}	6.77^{a}	1.72^{a}	3.30^{a}	1.27^{a}	2.75^{a}
D_2	45.08^{b}	8.77^{b}	18.28^{b}	7.54^{b}	17.38^{b}	3.51^{b}	5.99^{b}	4.47^{b}	8.19^{b}
SE. d	0.37	0.07	0.11	0.05	0.08	0.02	0.03	0.03	0.06
CD @ 5 %	0.74	0.15	0.22	0.10	0.16	0.04	0.06	0.07	0.13

DAC- Days after cutting.

time of cuttings taken, IBA concentrations and types of cutting was significant on days taken for first sprouting (Table 5). The lowest number of days taken for first sprouting (11.17 days), the highest sprouting percentage (58.33 %), number of shoots per cutting (5.00), number of leaves per cutting (46.06) and length of the shoot per cuttings (18.47 cm) were found under $A_3B_2D_2$ (first fortnight of August + 1500 ppm IBA + semi hardwood cutting). The findings from the experiment demonstrate the influence of the timing of cuttings taken, IBA concentrations and types of cutting on various aspects of the sprouting and further growth process. These findings highlight the significance of accounting for the combined effects of cutting timing, IBA concentrations and cutting types in propagation practices. These results suggest that these factors create an environment conducive of root development, sprouting of shoot and subsequent growth of the cuttings. These findings are in agreement with the findings of Singh and Bahadur (2015) in phalsa. This may be due to the increased hydrolysis of carbohydrates during the time of cuttings taken resulted in high success percentage of rooted cuttings.

Impact of the timing of cuttings, IBA concentrations, types of cuttings and their interactions on biochemical parameters

Among different time of cuttings taken the highest chlorophyll content (1.57 g/m^2), the lowest nitrogen content (0.73%), carbohydrate content (5.52%) and the highest C:N ratio (7.56) were recorded when cuttings taken during the first fortnight of August (A_3). In case of different IBA concentrations, the highest chlorophyll content (1.57 g/m^2), the lowest nitrogen content (0.69%), carbohydrate content (5.28%) and the highest C:N ratio (7.65) was observed under B_2 (1500 ppm IBA) treatment. In relation to the types of cutting used, the highest chlorophyll content (1.71 g/m^2), the lowest nitrogen content (0.66%), carbohydrate content (5.19%) and the highest C:N ratio (7.86) were observed under D_2 (Semi hardwood) treatment. The interaction between the timing of cuttings, IBA concentrations and types of cuttings significantly affected chlorophyll content. The highest chlorophyll content (1.81 g/m^2), the lowest nitrogen content (0.50%), carbohydrate content (5.09%) and the highest C:N ratio (8.78) were observed with the combination

Table 3: Interaction effect of the timing (months) of cuttings, IBA concentrations and types of cuttings on root parameters.

Treatments	90 DAC	45DAC	90 DAC	45 DAC	90 DAC	45 DAC	90 DAC	45 DAC	90 DAC
	Percentage of cuttings rooted	Number of roots per cuttings		Length of the root (cm)		Number of primary roots		Number of secondary roots	
$A_1B_1D_1$	2.3	1.55	3.78	1.25	2.34	1.01	1.41	1.04	1.7
$A_1B_1D_2$	30	3.67	12.36	5.12	8.12	2.14	3.33	2.34	4.11
$A_1B_2D_1$	6.1	3.12	6.31	2.56	3.87	1.45	2.84	1.21	2.23
$A_1B_2D_2$	41.67	8.7	21.56	8.11	12.75	2.82	5.76	4.56	9.43
$A_1B_3D_1$	4.3	2.56	5.11	2.15	3.09	1.22	2.02	1.34	2.42
$A_1B_3D_2$	36.67	6.57	14.31	6.99	10.45	2.45	4.41	3.77	6.48
$A_2B_1D_1$	3.2	2.13	4.81	1.48	2.97	1.25	1.89	1.23	1.92
$A_2B_1D_2$	32.3	3.84	14.11	5.65	9.33	2.78	4.27	2.45	4.11
$A_2B_2D_1$	7.3	3.52	7.48	2.74	4.01	1.72	3.69	1.19	2.91
$A_2B_2D_2$	51.67	14.5	22.81	8.84	13.12	4.25	6.21	5.89	10.78
$A_2B_3D_1$	4.9	3.41	6.23	2.36	3.55	1.55	2.88	1.36	3.52
$A_2B_3D_2$	45	7.21	15.74	7.23	11.32	3.67	6.05	4.21	7.11
$A_3B_1D_1$	4.1	2.42	6.87	1.87	3.19	1.72	3.73	1.34	2.47
$A_3B_1D_2$	33.4	4.17	15.67	6.08	10.11	3.33	6.25	2.56	5.27
$A_3B_2D_1$	13.4	3.9	9.81	2.98	4.67	2.71	5.84	1.25	3.67
$A_3B_2D_2$	72	18.32	24.67	11.37	17.85	5.98	8.78	7.78	15.65
$A_3B_3D_1$	6.5	3.13	8.89	2.65	3.97	2.73	4.57	1.34	3.28
$A_3B_3D_2$	51	9.32	17.35	7.89	15.23	4.12	7.39	5.21	9.26
$A_4B_1D_1$	5.3	2.21	5.56	1.67	3.04	1.33	2.52	1.05	2.34
$A_4B_1D_2$	35.6	4.13	17.98	5.78	9.79	2.87	5.68	2.37	4.67
$A_4B_2D_1$	12.5	3.68	8.76	2.87	4.24	2.54	4.63	1.32	3.54
$A_4B_2D_2$	63.33	16.13	23.12	9.83	15.78	4.05	7.32	7.38	13.22
$A_4B_3D_1$	7.3	3.09	7.37	2.54	3.77	1.42	3.62	1.63	3.11
$A_4B_3D_2$	48.33	8.74	19.78	7.65	13.76	3.76	6.46	5.21	8.23
SE. d	1.28	0.27	0.39	0.17	0.29	0.07	0.11	0.12	0.22
CD @ 5 %	2.58	0.54	0.78	0.35	0.58	0.14	0.23	0.24	0.45

DAC- Days after cutting.

Table 4: Impact of the timing (months) of cuttings, IBA concentrations and cutting types on shoot parameters.

Treatments	Days taken for first sprouting	Sprouting percentage	Number of shoots per cutting		Number of leaves per cutting		Length of the shoot (cm)	
	90 DAC	90 DAC	45 DAC	90 DAC	45 DAC	90 DAC	45 DAC	90 DAC
Time of cuttings taken (T)								
A_1	18.84^{a}	23.32^{a}	1.66^{a}	2.83^{a}	13.20^{a}	25.25^{a}	4.04^{a}	8.36^{a}
A_2	18.35^{b}	27.02^{b}	2.01^{b}	3.34^{b}	14.67^{b}	26.39^{b}	4.60^{b}	9.28^{b}
A_3	17.28^{c}	30.27^{c}	2.08^{c}	3.63^{c}	18.26^{c}	30.18^{c}	5.80^{c}	10.92^{c}
A_4	17.66^{d}	28.62^{d}	1.90^{d}	3.41^{d}	15.99^{d}	28.57^{d}	5.17^{d}	9.95^{d}
SE. d	0.09	0.36	0.01	0.04	0.17	0.17	0.06	0.07
CD @ 5%	0.18	0.73	0.02	0.08	0.35	0.35	0.12	0.16
IBA concentrations (S)								
B_1	19.52^{a}	22.56^{a}	1.56^{a}	2.81^{a}	13.43^{a}	25.74^{a}	3.98^{a}	8.23^{a}
B_2	16.54^{b}	33.02^{b}	2.16^{b}	3.69^{b}	16.14^{b}	29.32^{b}	5.86^{b}	11.45^{b}
B_3	18.03^{c}	26.73^{c}	2.02^{c}	3.41^{c}	17.02^{c}	27.73^{c}	4.87^{c}	9.21^{c}
SE. d	0.08	0.31	0.01	0.03	0.15	0.15	0.05	0.06
CD @ 5%	0.16	0.63	0.02	0.07	0.31	0.30	0.10	0.13
Types of cuttings (C)								
D_1	21.50^{a}	13.98^{a}	1.56^{a}	2.46^{a}	9.38^{a}	13.82^{a}	2.64^{a}	5.18^{a}
D_2	14.57^{b}	40.89^{b}	2.27^{b}	4.14^{b}	21.68^{b}	41.37^{b}	7.16^{b}	14.07^{b}
SE. d	0.06	0.25	0.009	0.03	0.12	0.12	0.04	0.05
CD @ 5%	0.13	0.52	0.018	0.06	0.25	0.25	0.08	0.11

DAC- Days after cutting.

Table 5: Interaction effects of the timing (months) of cuttings, IBA concentrations and types of cuttings on shoot parameters.

Treatments	Days taken for sprouting	Sprouting percentage	Number of shoots per cuttings		Number of leaves per cutting		Length of the shoot (cm)	
	90 DAC	90 DAC	45 DAC	90 DAC	45 DAC	90 DAC	45 DAC	90 DAC
$A_1B_1D_1$	23.10	11.2	1.21	1.64	5.21	9.99	1.28	2.96
$A_1B_1D_2$	17.11	29.45	1.67	3.06	18.79	36.26	5.23	11.34
$A_1B_2D_1$	21.45	13.33	1.34	2.17	6.45	12.64	2.31	5.43
$A_1B_2D_2$	13.87	41.23	2.45	4.21	22.73	41.54	7.01	14.34
$A_1B_3D_1$	22.32	12.11	1.45	2.07	6.36	12.64	2.11	4.21
$A_1B_3D_2$	15.21	35.67	1.86	3.87	19.69	38.44	6.32	11.90
$A_2B_1D_1$	22.94	12.67	1.48	1.88	5.81	10.91	1.67	3.92
$A_2B_1D_2$	16.88	31.82	1.65	3.56	19.05	37.98	5.91	11.88
$A_2B_2D_1$	20.32	14.33	1.71	2.73	8.14	14.56	2.82	6.48
$A_2B_2D_2$	13.45	49.67	2.83	4.89	24.61	41.85	7.78	15.65
$A_2B_3D_1$	21.64	14.33	1.62	2.76	7.55	12.88	2.56	4.89
$A_2B_3D_2$	14.87	39.33	2.77	4.23	22.86	40.18	6.89	12.88
$A_3B_1D_1$	21.87	14.33	1.62	2.79	9.51	14.69	2.76	4.89
$A_3B_1D_2$	15.91	34.67	1.78	3.73	20.12	42.13	6.64	13.86
$A_3B_2D_1$	19.76	16.67	1.82	2.99	8.87	17.00	3.94	7.35
$A_3B_2D_2$	11.17	58.33	2.82	5.00	25.59	46.06	10.40	18.47
$A_3B_3D_1$	21.13	15	1.63	2.89	24.44	17.40	3.24	5.87
$A_3B_3D_2$	13.86	42.67	2.86	4.44	21.06	43.85	7.84	15.12
$A_4B_1D_1$	22.14	13.89	1.33	2.11	7.41	13.23	2.34	4.31
$A_4B_1D_2$	16.25	32.45	1.76	3.76	21.61	40.80	6.06	12.70
$A_4B_2D_1$	20.32	15.33	1.88	2.86	9.62	15.74	3.73	6.91
$A_4B_2D_2$	12.03	55.33	2.46	4.70	23.11	45.22	8.89	16.99
$A_4B_3D_1$	21.03	14.67	1.65	2.73	13.21	14.23	2.98	5.01
$A_4B_3D_2$	14.24	40.09	2.36	4.35	21.03	42.23	7.03	13.80
SE. d	0.22	0.89	0.03	0.10	0.43	0.43	0.15	0.19
CD @ 5 %	0.45	1.80	0.06	0.21	0.87	0.87	0.30	0.39

DAC- Days after cutting.

Table 6: Impact of the timing (month) of cuttings, IBA concentrations and types of cuttings on biochemical parameters.

Treatments	90 DAC Chlorophyll content of leaf (g/m^2)	90 DAC Carbohydrate content (%)	90 DAC Nitrogen content (%)	90 DAC C:N ratio
		Time of cuttings taken (T)		
A_1	1.45^a	5.72^a	0.79^a	7.24
A_2	1.49^b	5.66^b	0.76^b	7.45
A_3	1.57^c	5.52^c	0.73^c	7.56
A_4	1.52^d	5.55^d	0.74^d	7.50
SE. d	0.005	0.013	0.003	-
CD @ 5%	0.011	0.027	0.006	-
		IBA concentrations (S)		
B_1	1.43^a	5.93^a	0.81^a	7.32
B_2	1.57^b	5.28^b	0.69^b	7.65
B_3	1.52^b	5.63^c	0.76^c	7.40
SE. d	0.05	0.011	0.003	-
CD @ 5%	0.10	0.023	0.005	-
		Types of cuttings (C)		
D_1	1.30^a	6.04^a	0.85^a	7.10
D_2	1.71^b	5.19^b	0.66^b	7.86
SE. d	0.04	0.009	0.002	-
CD @ 5%	0.08	0.019	0.004	-

DAC- Days after cutting.

Table 7: Interaction effects of the timing (months) of cuttings, IBA concentrations and types of cuttings on biochemical parameters.

Treatments	90 DAC Chlorophyll content of leaf (g/m^2)	90 DAC Carbohydrate Content (%)	90 DAC Nitrogen content (%)	90 DAC C:N ratio
$A_1B_1D_1$	1.13	6.21	0.90	6.90
$A_1B_1D_2$	1.63	5.81	0.79	7.35
$A_1B_2D_1$	1.34	5.98	0.88	6.80
$A_1B_2D_2$	1.71	4.78	0.61	7.84
$A_1B_3D_1$	1.26	6.07	0.85	7.14
$A_1B_3D_2$	1.67	5.51	0.73	7.55
$A_2B_1D_1$	1.18	6.18	0.88	7.02
$A_2B_1D_2$	1.66	5.73	0.77	7.44
$A_2B_2D_1$	1.38	5.95	0.84	7.08
$A_2B_2D_2$	1.74	4.91	0.59	8.32
$A_2B_3D_1$	1.28	6.03	0.83	7.27
$A_2B_3D_2$	1.71	5.21	0.69	7.55
$A_3B_1D_1$	1.27	6.15	0.84	7.32
$A_3B_1D_2$	1.72	5.63	0.74	7.61
$A_3B_2D_1$	1.44	5.92	0.82	7.22
$A_3B_2D_2$	1.81	4.39	0.50	8.78
$A_3B_3D_1$	1.41	5.99	0.85	7.05
$A_3B_3D_2$	1.77	5.09	0.63	8.08
$A_4B_1D_1$	1.23	6.11	0.86	7.10
$A_4B_1D_2$	1.66	5.69	0.76	7.49
$A_4B_2D_1$	1.41	5.89	0.81	7.27
$A_4B_2D_2$	1.78	4.47	0.53	8.43
$A_4B_3D_1$	1.36	6.01	0.88	6.83
$A_4B_3D_2$	1.73	5.17	0.66	7.83
SE. d	0.01	0.03	0.007	-
CD @ 5%	0.02	0.06	0.015	-

DAC- Days after cutting.

of cuttings taken during the first fortnight of August (A_3), treated with 1500 ppm IBA (B_2) and using semi-hardwood cuttings (D_2) (Table 6). Chlorophyll content can vary during different growth stages of plants. It is typically higher during active growth and decreases as plants mature or enter senescence. Sufficient carbohydrate availability in leaves supports active growth and development, resulting in increased leaf expansion, shoot elongation and overall biomass accumulation. Monitoring carbohydrate content can provide insights into the growth potential of plants. Nitrogen is a primary driver of plant growth and biomass accumulation. It promotes cell division and elongation, leading to increased leaf expansion, shoot growth and overall plant size (Zayed *et al*., 2023). Significant differences among the treatments were observed for chlorophyll index, carbohydrate content, nitrogen content and C:N ratio among the treatments (Table 7). The ranges seen in the chlorophyll index (1.13 and 1.81), carbohydrate content (4.39 and 6.21%), nitrogen content (0.50 and 0.90 %) and the C:N ratio (6.90 and 8.78) were observed on 45th and 90th DAC. The best result was observed under the $A_3B_2D_2$ treatment, which involved taking cuttings during the first fortnight of August, applying 1500 ppm IBA and utilizing semi-hardwood cuttings. The observed variations in the physiological parameters can be attributed to the combined effects of different factors. Arsnolov (1976) reported that there will be the reduction of total carbohydrates as the enzyme activities *viz*., peroxidase and catalase rise in the process of producing reducing sugar from the complex starch form (Samim *et al*., 2021). Rooted cuttings with a higher number of leaves typically produce more photosynthates due to the presence of chlorophyll, a light-harvesting pigment. As the rooting process proceeds, nitrogen content present in the plant is reduced which in turn results in rooting in willow-leaved Justicia cuttings as reported by Basu and Ghosh (1974). Similar results were obtained by Kaur *et al.* (2002) in grapes; Sivaci and Yalcin (2006) in apple; Jadhav *et al.* (2007) in phalsa.

CONCLUSION

The study highlights that August and September provide optimal climatic conditions for taking cuttings to efficiently propagate West Indian cherry. The most successful rooting and shooting results were obtained with semi-hardwood cuttings treated with 1500 ppm IBA during the first fortnight of August. The best result (Rs. 13,500 per 1000 cuttings) was achieved with the $A_3B_2D_2$ treatment, which involved taking cuttings during the first fortnight of August, applying 1500 ppm IBA and using semi-hardwood cuttings, resulting in a benefit-cost ratio of 1:3.41. Consequently, it is recommended to use vegetative propagation through cuttings for nursery plant production of Barbados cherry, as this method is both effective and simple.

Conflict of interest

All authors declared that there is no conflict of interest.

REFERENCES

Anonymous (1970). Official Methods of Analysis of the "Association of Official Analytical Chemists", 11th Edition, Washington.

Arsnolov, M.A. (1976), Physiological changes occurring during root formation in lemon cuttings. Uzbekskii Biologicheskii Zhurnal. 5: 24-26.

Ashok, A. and Ravivarman, J. (2020). Stimulating capability of IBA on rooting in stem cuttings of *Pseuderanthemum carruthersii* var. atropurpureum. International Journal of Chemical Studies. 8(4): 2503-2505.

Babaie, H., Zarei, H., Nikdel, K. and Firoozjai, M.N. (2014). Effect of Different Concentrations of IBA and Time of Taking Cutting on Rooting, Growth and Survival of *Ficus binnendijkii* 'Amstel Queen' Cuttings. Notulae Scientia Biologicae. 6(2): 163-166.

Basu, R.N. and Ghosh, S.K. (1974), Effect of nitrogen nutrition of stock plants of *Justica gendarussa* L. on the rooting of cuttings. Journal of Horticultural Sciences. 49: 245-252.

Dey, K., Ghosh, A., Bauri, F.K., Bhowmick, N., Dey, A.N., Mishra, D.K. and Das, B.C. (2018). Barbados cherry: Agriculture, breeding, utilization and role in nutritional and economical security-A review. Agricultural Reviews. 39(2): 144-150. doi:10.18805/ag.R-1764.

Dusman, E., Da Silva Ferreira, M.F., Berti, A.P., Mariucci, R.G., Mantovani, M.S. and Vicentini, V.E. P. (2012). Investigation of cytotoxic and mutagenic effects of *Malpighia glabra* L. (Barbados cherry) fruit pulp and vitamin C on plant and animal test systems. Food Science and Technology. 32(2): 405-411.

Gray, S.B. and Brady, S.M. (2016). Plant developmental responses to climate change. Developmental Biology. 419(1): 64-77.

Hartmann, H.T., Kester, D.E., Davies, F.T. and Geneve, R.L. (2007). Plant Propagation Principles and Practices. Seventh Edition, Prentice Hall of India Pvt. Ltd., New Delhi.

Hedge, J.E. and Hofreiter, B.T (1962). Methods in Carbohydrate Chemistry. Academic Pres. 17(1): 420.

Jackson, G.C. and Pennock, W. (1958). Fruit and vitamin C production of five- and Six-Year-Old acerola trees. The Journal of Agriculture of the University of Puerto Rico. 42(3): 196-205.

Jadhav, A. (2007). Studies on propagation of phalsa (*Grewia subinaequalis*) by cuttings. Thesis submitted, University of Agricultural Sciences, Dharwad.

Kaur, G. and Singh, S. (2022).,Regeneration of Stem Cuttings of Pomegranate cv. Bhagwa as Influenced by PGR's and Planting Time. Agricultural Science Digest. 42(1): 32-37. doi: 1018 805/ag.D-5280.

Kaur, S., Cheema, S.S., Chhabra, B.R. and Talwar, K.K. (2002). Chemical induction of physiological changes during adventitious root formation and bud break in grapevine cuttings. Plant Growth Regulators. 37: 63-68.

Kirker., Constance L., Mary Newman. (2021). Cherry. Reaktion Books.

Maninderdeep and Singh, G. (2022). Study of IBA Containing Rooting Powder on Root Induction Behavior of Hardwood Cutting of Grape (*Vitis vinifera* L.). Indian Journal of Agricultural Research. 56(4): 389-395. doi: 10.18805/IJARe.A-5767.

Prakash, A. and Baskaran, R. (2018). Acerola, an untapped functional superfruit: a review on latest frontiers. Journal of Food Science and Technology/Journal of Food Science and Technology. 55(9): 3373-3384.

Pratima, P. and V.S. Rana. V.S. (2011). Effect of pre-conditioning treatments, IBA and collection time on the rooting of semi hardwood cuttings of kiwifruit, *Actinidia deliciosa* Chev. International Journal of Farming and Allied Sciences. 1(2): 30-36.

Samim, A.K, N., Shivakumar, N.B.S., M, N.G. (2021). Effect of IBA, NAA and their Combination on Rooting and Biochemical Parameters of Stem Cuttings in Barbados Cherry. International Journal for Research in Applied Sciences and Biotechnology. 8(5): 147-150.

Singh, A.K. and Bahadur, V. (2015). Effect of NAA and IBA on rooting and establishment of hard wood cutting in Phalsa (*Grewia subinaequalis* L.). The Allahabad Farmer. 2: 199-201.

Singh, D.R. (2006). West Indian Cherry ñ A lesser-known fruit for nutritional security. Natural Product Radiance. 5(5): 366-368.

Singh. D.B. and Attri, D. (2000). Effect of IBA on rooting in West Indian cherry (*Malpighia galbra* L.) cuttings. Journal of Applied Horticulture. 02(02): 134-135.

Sivaci, A. and Yalcin, I. (2006), Determination of physiological changes related to effects of exogenous Indole-Butyric-Acid and callus formation in some kinds of Apple (*Malus sylvestris* Miller) stem cuttings. Fen Bilimleri Dergisi. 27(2): 1-12.

Tripathi, P.C., Yogeesha, H.S. and Shetti, D.L. (2022). Standardization of propagation methods in minor wild fruit crops. Current Horticulture. 10(1): 32-36.

Zayed, O., Hewedy, O.A., Abdelmoteleb, A., Ali, M., Youssef, M.S., Roumia, A.F., Seymour, D. and Yuan, Z. (2023). Nitrogen journey in plants: from uptake to metabolism, stress response and microbe interaction. Biomolecules. 13(10): 14-43.