RESEARCH ARTICLE

Response of IBA and NAA on Shoot Development in Stem Cuttings of Dragon Fruit [*Hylocereus undatus* (Haworth) Britton & Rose]

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Abstract

A study was conducted during 2019-2020 for a response of IBA and NAA on shoot development in stem cuttings of Dragon fruit. The plants can be propagated through both sexual means, such as seeds, and asexual methods, like stem cutting. Sexually propagated seedlings require more than three years to bear fruit. While some species of dragon fruit may naturally root and shoot without the need for exogenous auxin treatment, the majority do not readily develop roots and shoots, necessitating specific propagation techniques.The study aimed to standardize the different types of growth regulators and their concentrations, aiming to determine their positive correlation with the rooting and shooting percentages of dragon fruit stem cuttings. The experiment was conducted using a randomized block design comprising nine treatments and three replications. Stem cuttings of dragon fruit treated with IBA, NAA, and their combinations demonstrated that the minimum number of days taken for sprouting (8.10), best-sprouting percentage of shoots (51.13%), number of sprouts per cutting (2.05), sprout length (14.45 cm), diameter of the shoot (3.35 mm), average number of spines per areoles (4.15), fresh weight of shoot (52.6 g), and dry weight of shoot (10.48 g) were recorded in cuttings treated with IBA 4000 PPM. This was likely due to the stimulatory effects of exogenously applied auxin (IBA) on the initiation of new shoot tips in stem cuttings as compared to NAA.

Keywords: Rooting, Shooting, Stem cutting, Auxins, IBA.

Highlights

- Dragon fruit is a promising new profitable exotic tropical fruit crop. In the last two decades, it has attracted great attention from farmers as well as consumers due to its high content of essential nutrients and potential economic value.
- Stem-cutting propagated plants produce an economic yield after the first year of planting in comparison to sexually propagated seedlings, which require more than three years for bearing.
- The dragon fruit pulp is rich in nutrients like proteins, soluble sugar, and minerals such as magnesium, potassium, and calcium, along with different bioactive compounds.
- IBA 4000 ppm gave better results as compared to NAA alone or in combination (NAA+ IBA) concerning rooting and shooting parameters of dragon fruit.
- Dragon fruit has been investigated to have therapeutic benefits, particularly the red-fleshed varieties, which have high antioxidant contents. Hence, this research provides a comprehensive overview of the response of IBA and NAA on shoot development in stem cuttings of dragon fruit.

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Introduction

Dragon fruit [*Hylocereus undatus L.* (Haworth) Britton & Rose] is widely known as Pitaya or Kamalam, belonging to the family Cactaceae and having chromosome number 2n = 22. It is believed to have originated in the tropical and subtropical forest regions of Mexico and Central South America. It has gained great attention on a global scale as both an ornamental plant and a fruit crop. In India, dragon fruit is considered an exotic fruit, and its cultivation has expanded very rapidly due to its high economic value. As a perennial climber with rapid growth, dragon fruit requires vertical support to grow. The stem is a succulent vine with numerous branches. Each segment is composed of three to five ribs, or wavy wings, one to three spines, or spineless, and is typically covered with fragrant nocturnal white flowers. The flowers arise from areoles along with the lower to upper branches. Sections of dragon fruit stems develop aerial roots that cling to the support to climb and maintain the plant's upright position. The fruit is a globular form with red, pink, or yellow skin that is covered in green scales. The flesh of the fruit is white or red in color and contains many tiny,

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soft, black seeds. The whole dragon fruit pulp is rich in nutrients like proteins, soluble sugars and minerals such as magnesium, potassium, and calcium, along with different bioactive compounds (Tran *et al.,* 2015). The pulp color is red due to the presence of betalains, a water-soluble nitrogen-containing compound with potential antioxidant properties (Stintzing*et al.,* 2003). Dragon fruit has been investigated to have therapeutic benefits, particularly the red-fleshed varieties, which have high antioxidant contents (Ruzlan*et al.,*2010) and are protective for diabetes, cough, cholesterol, high blood pressure, and high blood sugar, and prevent cancer and congenital glaucoma (Abd Hadi *et al.,* 2016). Either sexual or asexual methods, such as stem cutting, can be used to reproduce dragon fruit. In comparison to plants propagated through stem cuttings, a crop propagated through seedlings will require three to four additional years to reach maturity. As it possesses all the desirable traits of a mother plant, dragon fruit is the simplest, most affordable, and most practical method of vegetative propagation. There is very little information on how to grow root and shoot development from dragon fruit trees using IBA, NAA, and their combinations. The experiment is therefore carried out to determine the impact of growth regulators and their mixtures on the rooting and shooting of stem cuttings.

Materials and Methods

The present investigation was carried out during the year 2019–2020 in a low-cost polyhouse at the Horticulture Research Farm, Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Lucknow, U.P., India. The site is located at 26.7633° N latitude and 80.9279° E longitude with an altitude of 121 m above mean sea level. The experimental site experiences a humid subtropical climate characterized by mild, dry winters from mid-November to February and hot, dry summers from late March to June. The experiment was arranged in a randomized block design, consisting of nine treatments and three replication viz., T1-control (dipped in normal water), T2-IBA (2000 ppm), T3-IBA (4000 ppm), T4-NAA (200 ppm), T5-NAA (400 ppm), T6-IBA (2000 ppm) + NAA (200 ppm), T7-IBA (2000 ppm) + NAA (400 ppm), T8-IBA (4000 ppm) + NAA (200 ppm), T9-IBA (4000 ppm) + NAA (400 ppm). The treated cuttings were planted in poly bags filled with a mixture of soil, sand and farmyard manure (FYM) in a ratio of 2:1:1. To facilitate rooting, one basal node was submerged in the medium. The planted poly bags were placed within an affordable polyethylene-covered structure for the rooting and shooting phases.

Observations were recorded on the number of days taken for sprouting, percentage sprouting of shoots per cutting, number of sprouts per cutting, sprout length and shoot length (cm), the diameter of the shoot (mm), average number of spines or areoles, fresh weight of the shoot (g) and dry weight of the shoot (g) from selected tag cuttings from each replication.

Statistical analysis of experimental data

The experimental data collected on various parameters during the investigation were statistically analyzed using analysis of variance (ANOVA) for the randomized block design (RBD) according to Fisher and Yates (1963). In cases where the F-test indicated significance in comparing the means of two treatments, critical differences (C.D. at 5%) were calculated. Pearson correlation coefficients and principal component analysis (PCA) were calculated for all traits under different concentrations and combinations of hormones.

Result and Discussion

Growth Parameters

Number of days taken for sprouting

The minimum number of days required for first sprouting was found (Table 1) (8.10) in cuttings treated with IBA 4000 ppm, while the maximum number of days was found in control (15.33). Sprouting could be attributed to the enhanced utilization of reserve carbohydrates, nitrogen, and other nutrients stored in the stem by activation of hydrolytic enzymes due to the exogenous application of IBA (Chandramouli, 2001) in *Bursera penicillate*. Similar findings were reported by Shirol and

Table 1: Effect of IBA, NAA and their combination on shoot parameters of dragon fruit *Hylocereus undatus*

Treatments	*Number of days taken for sprouting (days)*	*Percent sprouting of shoots per stem cutting (%)*		*No. sprouts per stem cutting*			*Sprout and shoot length of stem cuttings (cm)*		
		30DAP	*60DAP*	*30DAP*	*60DAP*	*90DAP*	*30DAP*	*60DAP*	*90DAP*
T_1	15.33	10.00	17.75	0.33	1.11	1.45	1.05	1.35	2.80
T_2	9.96	33.33	49.43	0.67	1.52	2.01	2.40	5.49	10.89
T_3	8.10	34.01	51.13	0.84	1.56	2.05	2.49	7.02	14.45
T_4	12.50	19.95	28.63	0.55	1.26	1.68	1.73	3.41	8.35
T_5	13.00	24.12	36.65	0.61	1.42	1.80	1.48	3.89	8.21
T_6	12.33	18.16	29.25	0.59	1.31	1.69	1.39	3.76	8.19
T_7	12.83	17.90	28.95	0.56	1.26	1.60	1.41	4.01	8.75
T_8	10.85	28.01	30.81	0.52	1.20	1.51	1.60	3.99	8.90
T_9	9.90	19.92	28.13	0.49	1.19	1.50	1.78	4.25	8.82
S. Em. (±)	0.30	0.68	0.97	0.01	0.03	0.04	0.05	0.12	0.25
C.D @ 5%	0.91	2.03	2.91	0.04	0.10	0.13	0.14	0.36	0.77

Patil (1992) in ixora, Srivastava *et al.,* (2005) in Kiwi fruit, and Muhammad *et al.,* (2009) in Ber.

Percentage sprouting of shoots per cuttings

The rate of sprouting and the percentage of shoots per stem cutting of Dragon fruit increased along with the dose of growth regulators. The Maximum percentage of sprouting was recorded (Table 1) at IBA 4000 ppm (34.01 and 51.13%), which was a decline from IBA 2000 ppm (33.33 and 49.43%), NAA (400 ppm) (24.12 and 36.65%), and the minimum was recorded in untreated soil (10.00 and 17.75) at 30 and 60 days after planting. Percentage sprouting is envisaged that auxin might have induced a stimulus for the regeneration of roots by promoting hydrolysis, mobilization, and utilization of nutritional reserves in the region of root and shoot formation (Nanda, 1975). This result is also well supported by Swetha (2005) in lavender.

Number of sprouts per cutting

The number of sprouts per cutting was significantly increased, along with the concentration of auxins. The maximum number of sprouts per cutting (0.84, 1.56, and 2.05) was observed (Table 1) in IBA at 4000 ppm, and the minimum number of sprouts per cutting (0.33, 1.11, and 1.45) was observed in control at 30, 60, and 90 days after planting, respectively. The cuttings treated with IBA 4000 ppm recorded a greater number of sprouts per cutting as compared to the rest of the treatments. The number of sprouts increased due to the favorable enhancement of physiological functions in the cuttings at this concentration. Early sprouting and an increase in the number of sprouts might be due to better utilization of stored carbohydrates, nitrogen, and other factors with the aid of growth regulators (Chandramouli, 2001). These results are in harmony with the outcomes of Pervaiz *et al*. (2007) in barbados cherry, Araujo *et al*. (2010) in wild passion fruit, Damar (2013) in pomegranate, and Singh *et al*. (2013) in lemon.

Sprout length and shoot length

There was maximum variation in shoot length recorded (Table 1) at IBA 4000 ppm concentration (2.49, 7.02, and 14.45 cm) at 30, 60, and 90 days after planting. However, the minimum length of sprouts (1.05, 1.35, and 2.80 cm) at 30, 60, and 90 days, respectively, were recorded in the control plants.Siddiqui and Hussain (2007) suggested that better rooting helps enhance nutrient uptake, which ultimately influences shoot length.

Diameter of shoot per cutting

The diameter of the shoot per cutting gets increased according to concentration and the highest dependent manner. The highest dose of IBA showed a positive impact compared to the control, in which results revealed that the maximum diameter of shoot per cutting (2.30, 2.98, and 3.35 cm) was observed in 4000 ppm of IBA, while the minimum diameter of shoot per cutting (1.03, 1.40, and 1.46 cm at 30, 60, and 90 days after planting, respectively) was recorded (Table 2) in the control. The maximum number of shoots per cutting observed with optimal IBA treatments could be attributed to improved root growth. This enhanced root development likely facilitated the absorption and translocation of nutrients from the nursery soil, actively participating in various metabolic processes within the plant (Singh 2001).

Fresh weight of shoot (g)

The rate of fresh weight of shoots collinearly increases in treatment-dependent manners. The maximum fresh weight of the shoot was found at IBA 4000 ppm (52.60 g), which slowly declined with lower concentrations of IBA 2000 ppm (48.26 g) (Table 2). However, the lower fresh weight was recorded as a control (25.40 g). Among the treatments, the application of IBA at 4000 ppm recorded the maximum shoot fresh weight. This phenomenon could be attributed to the effects of IBA, which induce early sprouting, an augmentation in the number of leaves and leaf area, and the establishment of a well-developed shoot system. A simple result was found by Stancato *et al.,* (2003) in *Rhipsalis*, Seran and Thiresh (2015), and Rahad*et al.,* (2016) in dragon fruit.

Dry weight of shoot (g)

Among all treatments, the maximum dry weight of the shoots per cutting was recorded at IBA 4000 ppm (4.84, 7.50, and 10.48 g) 30, 60, and 90 days after planting, as furnished in (Table 2). The lowest dry weight of the shoot was seen in cuttings dipped in

Table 2: Effect of IBA, NAA, and their combination on shoot parameters of *H. undatus*

Treatments	*Diameter of shoot per cuttings (mm)*			*Fresh weight of shoot (g)*			*Dry weight of shoot (g)*			*Number of spines per areole*		
	30DAP	*60DAP*	*90DAP*	*30DAP*	*60DAP*	*90DAP*	*30DAP*	*60DAP*	*90DAP*	*30DAP*	*60DAP*	*90DAP*
T_1	1.03	1.4	1.46	9.6	19.52	25.4	1.94	3.75	6.9	3.34	3.65	3.8
T_2	1.99	2.9	3.09	13.1	22.54	48.26	3.9	6.8	9.99	3.54	3.99	4.1
T_3	2.3	2.98	3.35	14.9	24.2	52.6	4.84	7.5	10.48	3.82	4.05	4.15
T_4	1.57	2.65	3.28	12.63	20.2	37.51	3.21	5.74	9.6	3.66	4	3.89
T_5	1.68	2.86	3.37	12.8	20.92	38.02	3.48	6.01	9	3.68	3.99	3.89
T_6	1.69	2.7	3.3	12.1	20.12	47.91	3.08	6.51	9.08	3.7	3.89	4.01
T_7	1.6	2.64	3.24	11.96	19.98	47.23	3.01	5.99	9.01	3.72	3.9	4
T_8	1.46	2.29	3.01	12.62	21.33	39.91	3.4	5.83	9.5	3.8	3.89	3.99
T_9	1.42	2.18	3	12.49	21.01	39.09	3.33	5.77	9.12	3.65	3.89	3.99
S. Em. (±)	0.04	0.06	0.08	0.34	0.57	1.12	0.09	0.16	0.25	N/S	N/S	N/S
C.D @ 5%	0.13	0.20	0.24	1.01	1.71	3.36	0.28	0.48	0.74	0.09	0.10	0.10

tap water (T_1) (6.90g). The shoot dry matter clearly demonstrates the earliness in sprouting, the increase in the number of leaves and leaf area, and the higher shoot fresh weight. Shukla and Bist (1994) in Pear, Shirol and Patil (1992) in Ixora, and Deb *et al.,* (2009) in Lemon cuttings.

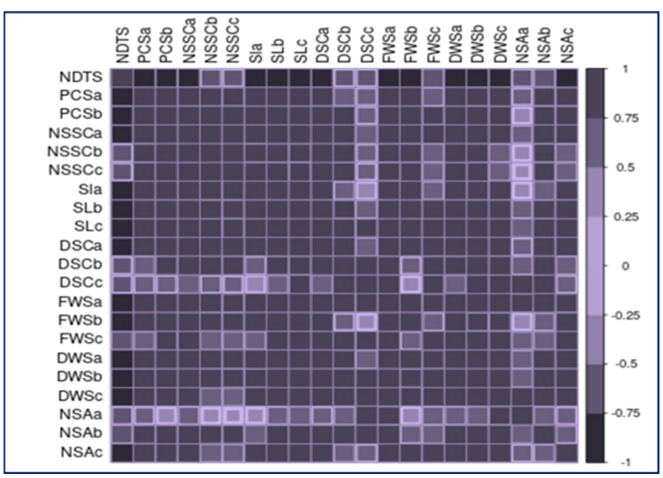
Number of spines per areole

The number of spines per areole was found to be non-significant. Among all treatments with control, the maximum number of spines per areole found at IBA 4000 ppm (3.82, 4.05, and 4.15) at 30, 60, and 90 days after planting was recorded in the cuttings treated with IBA 4000 ppm days after planting, while the minimum number of spines per areole was recorded (Table 2) in control (3.34, 3.65, and 3.80 cm) at 30, 60, and 90 days after planting. Ha *et al.,* (2014) also found that there was no significant variation in spines per areoles.

Correlation analysis of IBA and NAA and their combination on shoot parameters in dragon fruit

Multivariate analysis of vegetative parameters

Pearson correlation coefficient analysis was performed on the shoot sprout, growth, and development of dragon fruit under different concentrations of IBA and NAA (Fig. 1). The data (Table 3) indicated that the number of days taken for sprouting was highly negatively correlated to the percentage sprouting of shoots per cutting (r = -0.84*), the number of sprouts per cutting (r = -0.755*), sprout length and shoot length (r = -0.893**), the diameter of the shoot per cutting (r = -0.758*), and the dry weight of the shoot (P = 0.98*). However, the percentage sprouting of shoots per cutting is highly positively and significantly correlated to the number of sprouts per cutting length of shoot (r = 0.934***) and the number of sprouts per cutting (0.832**). The fresh weight of the shoot positively correlated with the average number. of spines (r = 0.685*) and the dry weight of the shoot



NDTS=Number of days taken for sprouts PCS= Percentage of cuttings sprouted (%), NSSC=Numbers of sprouts per stem cutting, SL= Sprout/ shoot length, DSC= Diameter of shoot per cutting, FWS= Fresh weight of shoot, DWS=Dry weight of shoot NSA=Number of spines per areoles;a,b,c = 30,60,90 (days)

Fig 1: Correlation matrix depicting the relationship among of IBA and NAA and their combination on shoot parameters in dragon fruit

Table 3: Extracted Eigenvalues and correlation values for IBA and NAA influence the shoot growth of dragon fruit cutting attributes with the first three principal components

Variables	*Principles components*		
	PC1	*PC2*	*PC3*
Extracted Eigenvalues	17.227	1.62	1.057
Explained variance (%)	82.032	5.036	1.314
Cumulative variance (%)	82.032	94.782	98.834
Vegetative and reproductive attributes			
NDTS	4.353	19.755	4.531
PCSa	4.78	1.045	0.005
PCSb	5.106	1.638	0.016
NSSCa	5.462	2.192	8.614
NSSCb	4.541	13.757	2.269
NSSCc	4.242	15.871	0.167
Sla	4.613	1.585	17.657
SLb	5.553	1.818	0.272
SLc	5.611	2.031	0.167
DSCa	5.456	2.904	1.643
DSCb	4.443	12.804	1.646
DSCc	3.457	1.508	4.708
FWSa	5.436	0.822	1.439
FWSb	4.42	3.891	9.053
FWSc	4.436	0.016	0.751
DWSa	5.556	1.001	3.106
DWSb	5.449	0.146	0.221
DWSc	5.195	1.116	10.007
NSAa	2.654	7.261	26.721
ANSb	4.682	3.152	4.826
ANSb.1	4.555	5.683	2.182

(r = -0.9***). The dry weight of the shoot was negatively correlated with the number of days taken for sprouting (r = -0.811**).

Principal component analysis

The structure of a data set is studied using principal components analysis (PCA), a statistical method for multivariate analysis, to identify the processes influencing the scores of the variables present in the data. The biplot (Fig. 2) clearly indicated the variation of data on the physical growth of the shoot with the number of treatments. Out of nine PCs observed, three PCs were reported to be significantly different due to an Eigenvalue greater than 1, which contributed to 98.834 and was not significant for the study (Table 3), which contributed 98.834 of the total variation. About 20 traits were illustrated throughout the range of ordinary, and the length of the vector indicated the contribution of characters.

The overlapping of dry weight of the shoot and fresh weight of the shoot number of sprouts per cuttings are showed a high degree of positive correlation. Furthermore, most traits are coming from groups one and two, such as treatments T_2,

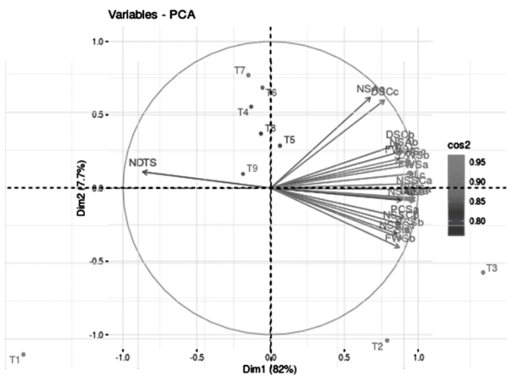


Fig. 2: Principal component analysis (PCA) of growth attributes of dragon fruit (*H. undatus*)

T_3, and T_5. However, the number of days taken for sprouting is highly negatively correlated with the fresh weight of the shoot and other traits, which come in groups (4th). The third group also indicates a positive correlation with most traits except the number of days taken for sprouting. The distribution of treatments across various segments of each biplot indicates a substantially dissimilar treatment effect concerning the variability obtained in the studied attributes. Among all, T_5 are highly indicative traits compared to other clusters.

Conclusion

In this study, we discovered the best types and concentrations of growth regulators for successfully growing dragon fruit from stem cuttings. We found that using IBA 4000 ppm produced the best results for rooting and shooting, followed by IBA 2000 ppm. These findings suggest that using stem cuttings is a reliable and cost-effective method for the commercial production of dragon fruit planting materials.

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Author's Contributions

LP & SP- conceptualized and wrote the manuscripts; KKS & DHD- language edited the manuscript; S. Pathak finalized the final manuscript.

All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there are no conflicts of interest related to this article.

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