



Morphological Features Growth and Development of *Dendrobium* sp. Orchid as Influenced by Nutrient Spray

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Abstract

The experiment was conducted to see the effect of nutrient spray on morphophysiological feature and growth of three orchid varieties namely *Dendrobium* Red Bull, *D. Kasim Gold* and *D White 5 N*. Results revealed that the morphophysiological and growth attributes significantly varied among the cultivars. *D. Red Bull* showed the highest plant height, leaf length, leaf area and stem diameter among the varieties. *D. White 5 N* was superior in leaf number and total leaf area and *D. Kasim Gold* was superior in leaf area index and leaf width to the other varieties. On the other hand, the trend of increasing in leaf length, leaf width, leaf area index, leaf number, leaf area and total leaf area was the highest for N:P:K as 10:25:30. Plant height and stem diameter was maximum for N:P:K as 15:20:20. In conclusion, low level of nitrogen and high level of phosphorus and potassium was suitable for leaf length, leaf width, leaf area index, leaf number, leaf area and total leaf area while high level of nitrogen and low level of potassium was suitable for plant height and stem diameter.

Key words: Fertilizer, Production protocol, Spray solution standardization

Introduction

Among all the flowering plants, orchids are fascinating and excellent items for garden and can be grown in beds, pots, baskets, split halves of bamboo pieces etc. Orchids have occupied top position among the flowering plants valued for cut flowers as well as pot plants. They exhibit an incredible range of diversity in size, shape and color of their flowers. They are famous for their longer lasting and beauty which fetch a very high price from the international market. They account for 27% of global cut flower production in terms of value. Brazilian Cattleyas, Japanese Phalaenopsis, Indian Dench-obiunis, *Cymbidilunis* and *Vandas* have played a major role in the development of modern orchid industry in the world (Singh, 1986). In many countries, orchid industry plays an important role as a source of foreign exchange. World-trade in floriculture today has a turnover of about 7,662,924 thousand US dollars involving more than 140 countries (Manilal and Sathish, 2006).

In Bangladesh, the environmental conditions required for the survival and culture of orchid are adequately favourable throughout the year. Various species of wild orchids are abundantly distributed in the country both in forest and non-forest areas (Chowdhury, 1975). Export potential of orchids from Bangladesh has a bright prospect in future.

Fertilizer application is effective for better growth and flower production in commercial cultivation of *Dendrobium* sp. A complete fertilizer mixture might

have an N-P-K ratio of 20-20-20 per liter of water to be applied as spray. These numbers describe the percentage of elemental nitrogen (N) and the oxides of phosphorus (P) and potassium (K). A growing orchid clone at sapling stage needs higher nitrogen and lower P and K. In course of growing, demand of P and K increases. At flowering stage low level of nitrogen helps to flowering. Therefore, fertilizer application as spray should be considered wisely. However, there is no available information on fertilizer application as spray in *Dendrobium* sp. in Bangladesh. To establish a production protocol at farmers level, the present study was designed to standardize a suitable fertilizer formulation contained N, P, and K at appropriate concentration to be sprayed in *Dendrobium* sp. orchids for their optimal growth, development and commercial production.

Materials and methods

Material collection

The seedlings of Orchid plants (*Dendrobium* Red Bull, *Dendrobium* Kasim Gold and *Dendrobium* white 5 N) were collected from Dipta Orchid Ltd. Dulma, Enayetpur, Fulbaria, Mymensingh. The age of Clone was about six months. These clones were separated from mother plant and cultured for six months with coconut shell as supporting material.

Experimental procedure

The experiment was laid out in Completely Randomized Block Design (RCBD) with 12 treatments and each treatment was replicated three times. The cultivars were treated with spray

formulations prepared by mixing Urea, Tripple Super Phosphate (TSP) and Muriate of Potash (MP) maintaining N, P and K at different ratio (Table 1). Formulation was prepared by following the thumb rule of BARI where total amount of fertilizer was 700 g in 172 liter water recommended for use as spray. The different ratios of N, P and K in spray nutrient

formulation applied from December, 2009 to June, 2010. The formulation used in present research contained different ratio of N, P and K. The ratio was changed over growth stage of orchid. Spray formulation used in early stages contained higher N and gradually reduced in later stages where P and K were increased.

Table 1. Composition of spray formulation

Name of formulation	Total urea, TSP and MP 70 gm per 17.2 liter water at N : P : K ratio			
F ₀ (Control)	0.0	0.0	0.0	0.0
F ₁	15:20:25	20:20:25	20:25:30	10:30:25
F ₂	10:15:20	15:20:25	10:25: 25	10:25:30
F ₃	5:15:10	10:15:10	10:20:15	15:20:20
Duration of spray	December 15 to January 30	January 31 to March 15	March 16 to April 30	May 01 to June 15

% of N, P and K in Urea, TSP and MP is 46.0, 60.0 and 48.0 respectively. In each times fresh formulation was prepared and sprayed once weekly with a hand sprayer in the afternoon. Watering was done 2 times per day by a water cane. To provide dappled shade, a shade was made by bamboo fence.

Data collection

Experimental data, such as, plant height (cm), leaf number, leaf length (cm), leaf wide (cm), leaf area (cm²), total leaf area (cm²), leaf area index (LAI) and stem diameter (cm) were recorded.

Anatomical investigation

To investigate the general anatomical structure of root, stem and leaf, a thin (about 10 μM) section was prepared from fresh plant material using sharp blade. The thin sections were stained in 1.0% safranin and mounted on slide. A cover sleep was set on thin section and observed under microscope with high resolution, progressive scan digital camera system (Model Olympus BX 41 and camera DP 20) and photos were taken.

Statistical analysis

All collected data were analyzed by following the analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan’s Multiple Range Test (DMRT) (Gomez and Gomez, 1984) using a computer operated programme named MSTAT-C (Russel, 1986).

Results and discussion

Plant Height

The plant height varied significantly among the three varieties of orchids namely *Dendrobium* Red Bull (V₁), *D. Kasim Gold* (V₂) and *D. White 5 N* (V₃). At 45 DAP, plant height of V₁, V₂ and V₃ was 30.25 cm, 12.5 cm, and 26.03cm, respectively. At 90 DAP, plant height increased to 35.91 cm, 15.78 and 29.75 cm, respectively. Plant height of V₁, V₂ and V₃ reached at 42.02, 19.03 and 35.18 cm, respectively after 135 days. The maximum plant height of *D. Red Bull* and *D. White 5 N* was 47.95 cm and 39.51 cm, respectively and the height of *D. Kasim Gold* was comparatively lower (23.99 cm) at 120 DAP (Table 2). Plant height increased progressively with the advancement of culture period. It revealed that the plant height of *D. Red Bull* and *D. White 5 N* increased rapidly than *D. Kasim Gold*.

Different treatments of spray formulation have the significant effects on plant height. At 45 DAP, maximum plant height 23.43 cm was recorded in F₁ and minimum 21.83 cm in F₂. At 90 DAP and 135 DAP, maximum plant height 28.06 and 34.7 cm was recorded in F₃ and minimum 25.44 and 27.02 cm in F₀, respectively. At 180 DAP, the maximum plant height 40.91 cm was recorded in F₃ and minimum

28.34 cm in F₀ (Table 3). Plant height increased slowly in control and rapidly in F₂ which indicated that different nutrients as spray formulation had significant effect on plant height.

The combined effect of variety and treatments on plant height was significant. Maximum plant height 30.5 cm was recorded in V₁F₁ and minimum 10.5 cm was in V₂F₂ at 45 DAP. Maximum plant height 37.03 cm and 45.33 cm was recorded in V₁F₂ and V₁F₃ and minimum 14.36 cm and 15.43 cm was recorded in V₂F₀ respectively, at 90 DAP and 135 DAP. The maximum plant height 52.06 cm was recorded in V₁F₃ and minimum 16.53 cm was recorded in V₂F₀ at 180 DAP (Table 4).

Individual leaf area

The individual leaf area of a plant varied significantly among the varieties. The Leaf area of *Dendrobium* Red Bull, *D. Kasim Gold* and *D. White 5 N* ranged from 40.44-48.45 cm², 25.05- 33.73 cm² and 30.32-39.48 cm², respectively over growing period. The *D. Red Bull* showed the maximum leaf area 40.44 cm² and *D. Kasim Gold* showed the minimum leaf area 25.05 cm² at 45 DAP. At 90 DAP and 135 DAP, the highest leaf area was respectively 41.99 cm² and 45.13 cm² in *D. Red Bull* and the lowest was respectively 27.42 cm² and 30.14cm² in *D. Kasim Gold* At 180 DAP, the leaf area of *D. Red Bull*, *D. Kasim Gold* and *D. White 5 N* was 48.45 · 33.73 and

was 39.48 cm², respectively (Table 2). The leaf area was higher in V₁ than V₂ and V₃.

Different nutrient as spray formulation resulted the maximum leaf area 34.78 cm² for F₁ and minimum 29.94 cm² for F₀ after 45days culture. Maximum leaf area was 37.26 cm² for F₁ and minimum 30.37 cm² recorded for F₀ at 90 DAP (Table 3). After 135 and 180 days culture, maximum leaf area was recorded 39.64 cm² and 46.66 cm² for F₂ and minimum 30.66 cm² and 30.85cm² for F₀ (control).The trend of leaf area increment as vegetative growth was rapid for F₃. During initial growing stage N concentration was increased and later stage P and K concentration was increased. Results revealed that combined effect of N, P, and K in spray nutrients increased leaf area.

The leaf area varied significantly due to the interaction effect between variety and treatments. At 45 DAP, highest leaf area 43.54 cm² was recorded in V₁F₁ and lowest 22.12 cm² was in V₂F₂. At 90 DAP, the leaf area ranged from 24.68 cm²-45.42 cm² in V₂F₂ and V₁F₃, respectively. At 135 DAP and 180 DAP the highest values were 54.48 cm² and 64.31 cm² in V₁F₃ and the lowest were 26.14 cm² and 26.28 cm² recorded in V₁F₃ and V₂F₀, respectively (Table 4). The variation in leaf area might occur due to the variation in number of leaves and their expansion. The result obtained from the present study is consistent with the results of Sharma and Haloi (2001) who stated that variation in leaf area might be attributed to the difference in number of leaves.

Table 2. Main effect of variety on plant height and leaf area

Variety	Plant Height (cm) at DAP				Leaf area (cm) at DAP			
	45	90	135	180	45	90	135	180
V ₁	30.25 a	35.91 a	42.02 a	47.95 a	40.44 a	41.99 a	45.13 a	48.45 a
V ₂	12.5 c	15.78 c	19.03 c	23.99 b	25.05 b	27.42 b	30.14 c	33.73 c
V ₃	26.03 b	29.75 b	35.18 b	39.51 a	30.32 b	32.91 b	36.2 b	39.48 b
LSD _(0.05)	2.12	2.01	2	2.43	5.51	5.67	5.53	5.21
CV (%)	10.95	8.78	7.39	6.97	20.40	19.65	17.61	15.18

V₁= *Dendrobium* Red Bull, V₂= *D. Kasim Gold* and V₃= *D. White 5 N*

Table 3. Main effect of spray formulation on plant height and leaf area

Formulations	Plant Height (cm) at DAP				Leaf area (cm) at DAP			
	45	90	135	180	45	90	135	180
F ₀	23.08 a	25.44 b	27.02 b	28.34 c	29.94 a	30.37 a	30.66 b	30.85 b
F ₁	23.43 a	27.92 a	33.85 a	40.20 ab	34.78 a	37.26 a	40.24 a	43.18 a
F ₂	21.83 a	27.17 ab	32.74 a	39.15 b	30.88 a	33.33 a	39.64 ab	46.66 a
F ₃	22.76 a	28.06 a	34.70 a	40.91 a	32.15 a	35.46 a	37.09 a	42.76 a
LSD _(0.05)	2.45	2.33	0.77	2.13	6.36	6.55	6.39	6.01
CV (%)	10.95	8.78	7.39	6.97	20.40	19.65	17.61	15.18

F₀ = Control, F₁ = Spray Formulation 1, F₂ = Spray Formulation 2 and F₃ = Spray Formulation 3

Table 4. Combined effect of variety to spray formulation on plant height and leaf area

Variety x formulation	Plant Height (cm) at DAP				Leaf area (cm) at DAP			
	45	90	135	180	45	90	135	180
V ₁ F ₀	30.06 a	33.50 ab	35.33 b	37.00 c	35.76 abcd	36.26 abc	36.67 bcd	36.94 bcde
V ₁ F ₁	30.50 a	36.10 a	42.60 a	51.43 a	43.54 a	45.13 a	45.66 ab	46.44 b
V ₁ F ₂	30.00 a	37.03 a	44.83 a	51.30 a	39.29 abc	41.15 ab	43.70 ab	46.11 b
V ₁ F ₃	29.83 a	37.0 a	45.33 a	52.06 a	43.17 ab	45.42 a	54.48 a	64.31 a
V ₂ F ₀	13.50 c	14.36 d	15.43 f	16.53 f	25.50 de	25.95 c	26.14 d	26.28 e
V ₂ F ₁	14.73 c	18.10 d	22.46 d	28.13 de	30.21 cde	33.24 abc	36.86 bcd	39.07 bcd
V ₂ F ₂	10.50 c	14.50 d	17.96 ef	24.80 e	22.12 e	24.68 c	27.93 cd	36.70 bcde
V ₂ F ₃	11.30 c	16.16 d	20.26 de	26.50 e	22.37 e	25.82 c	29.63 cd	32.86 cde
V ₃ F ₀	26.90 ab	28.46 c	30.30 c	31.50 d	28.55 cde	28.92 bc	29.17 cd	29.33 de
V ₃ F ₁	25.06 b	29.56 bc	36.50 b	41.03 bc	30.61 cde	33.42 abc	38.19 bcd	44.04 bc
V ₃ F ₂	25.00 b	30.00 bc	35.43 b	41.36 bc	31.22 bcde	34.17 abc	38.28 bcd	41.73 bc
V ₃ F ₃	27.16 ab	31.00 bc	38.50 b	44.16 b	30.92 cde	35.15 abc	39.16 bc	42.81 bc
LSD _(0.05)	4.25	4.03	4.01	4.38	11.03	11.35	11.08	10.42
CV (%)	10.95	8.78	7.39	6.97	20.40	19.65	17.61	15.18

V₁ = *Dendrobium* Red Bull, V₂ = *D. Kasim* Gold and V₃ = *D. White* 5 N

F₀ = Control, F₁ = Spray Formulation 1, F₂ = Spray Formulation 2 and F₃ = Spray Formulation 3

Leaf number

The number of leaves per plant was statistically significant at 45, 90,135,180 DAP. At 45 DAP, the average leaf number of V₁, V₂ and V₃ were 3.5, 3.66 and 4.33, respectively. At 90 DAP and 135 DAP the average number of leaves per plant was 3.83, 3.91, 4.25 and 4.91, 4.66, 5.25 for V₁, V₂ and V₃, respectively. Finally the average number of leaves per plant was 5.16, 4.75 and 5.41 in V₁, V₂ and V₃, respectively after 180 days culture (Table 5).

At 45 DAP, the highest number of leaf per plant was 4.0 for F₂ and the lowest was 3.67 for F₀. With the increase of age to 90 DAP, the number of leaf attained to 4.22 for F₁ and the lowest was 3.77 for F₀. At 135 DAP, the highest number of leaf was 5.44 for F₂ and the lowest was 3.77 for F₀. After 180 days, the highest number was 5.55 and the lowest was 4.0 for F₀ (Table 6). Thus leaf number was relatively lower in all level of nutrients. Report of Singh and Kohli (1999) is in agreement to the present results regarding number of leaf per plant.

Leaf number varied significantly due to the interaction effects between variety and treatments. At 45 DAP, the highest number was 4.66 and lowest was 3.0 in V₃F₃ and V₂F₀, respectively. The highest leaf number at 90, 135, 180 DAP was 4.66, 6.33 and 6.66 for V₃F₃ and V₁F₃, respectively. The lowest leaf number at 90,135, 180 DAP was 3.06, 3.66 and 3.66, respectively, for V₂F₀ (Table 7). The number of leaf in a plant primarily controlled by genetic makeup and secondarily by culture and management nutritional status is also an important factor for number of leaf plant.

Total leaf area

The total leaf area was significantly affected by varieties. At 45 DAP, the total leaf area of *D. Red*

Bull, D. Kasim Gold and *D. White 5 N* was 114.60 cm², 80.91 cm² and 122.99 cm², respectively. At 90 DAP, the average total leaf area increased to 120.81 cm², 83.51 cm² and 132.34 cm² respectively for those three varieties. Finally at 180 DAP average total leaf area reached at 137.82 cm², 103.28 cm² and 157.85 cm² in those three varieties respectively (Table 5).

Leaf area varied due to spray formulation. After 45 days culture the maximum average total leaf area was 119.17 cm² for F₂ and the minimum was 87.13 cm² for control (F₀). At 90 DAP, maximum total leaf area was 127.50 cm² for F₂ and minimum was 90.48 cm² for control (F₀). Leaf area gradually increases due to age of the plants. At 180 DAP, the maximum average total leaf area was 167.27 cm² in F₂ and the minimum was 95.88 cm² in F₀ (Table 6). Data revealed that trend of leaf area increment was relatively higher in F₂. In all treatments, average total leaf area raised in later growth stage might be full growth of plants. Balance in spray formulation suitable for vegetative growth might also be responsible for leaf growth.

Total leaf area varied significantly by the interaction effects between variety and formulation. At 45 DAP, the highest total leaf area was 134.80 cm² in V₃F₂ and lowest was 60.36 cm² in V₂F₀. At 90 DAP, the highest was 147.8 cm² and lowest was 63.61 cm² in V₃F₁ and V₂F₀, respectively. At 135 DAP, the highest was 168.6 cm² and the lowest was 65.13 cm² in V₃F₂ and V₂F₀, respectively. V₃F₂ and V₂F₀ also showed highest 191.83 cm² and the lowest 66.66 cm² total leaf area, respectively at 180 DAP (Table 7). The variation in leaf area might occur due to the variation in number of leaves and their expansion. The result obtained from the present study is in consistence with the results of Sharma and Haloi (2001) who stated that variation in leaf area might be attributed to the difference in number of leaves.

Table 5. Main effect of variety on leaf number and total leaf area

Variety	Leaf No at DAP				Total Leaf area (cm ²) at DAP			
	45	90	135	180	45	90	135	180
V ₁	3.50 b	3.83 a	4.91 a	5.16 a	114.60 a	120.81 a	128.67 a	137.82 b
V ₂	3.66 ab	3.91 a	4.66 a	4.75 a	80.91 b	83.51 b	89.00 b	103.28 c
V ₃	4.33 a	4.25 a	5.25 a	5.41 a	122.99 a	132.34 a	143.72 a	157.85 a
LSD _(0.05)	0.77	0.75	0.58	0.64	19.51	18.84	17.65	12.96
CV (%)	23.92	22.30	14.05	15.01	21.70	19.83	17.31	11.51

V₁ = *Dendrobium Red Bull*, V₂ = *D. Kasim Gold* and V₃ = *D. White 5 N*

Table 6. Main effect of nutrients as spray formulation on leaf number and total leaf area

Formulations	Leaf No at DAP				Total Leaf area (cm ²) at DAP			
	45	90	135	180	45	90	135	180
F ₀	3.67 a	3.77 a	3.77 b	4.00 b	87.13 b	90.48 b	92.92 c	95.00 d
F ₁	3.77 a	4.22 a	5.22 a	5.44 a	116.49 a	122.54 a	132.98 ab	145.88 b
F ₂	4.00 a	4.00 a	5.44 a	5.55 a	119.17 a	127.50 a	140.87 a	167.27 a
F ₃	3.77 a	4.00 a	5.33 a	5.44 a	101.87 ab	108.37 ab	115.10 b	123.78 c
LSD _(0.05)	0.89	0.87	0.67	0.74	22.52	21.75	20.38	20.5
CV (%)	23.92	22.30	14.05	15.01	21.70	19.83	17.31	11.51

F₀= Control, F₁=Spray Formulation 1, F₂= Spray Formulation 2 and F₃= Spray Formulation 3

Table 7. Combined effect of variety to spray formulation on leaf number and total leaf area

Variety x formulation	Leaf No at DAP at DAP				Total Leaf area (cm ²) at DAP			
	45	90	135	180	45	90	135	180
V ₁ F ₀	4.00 a	4.00 a	4.00 e	4.00 de	103.46 ab	107.23 abc	109.36 bc	110.80 de
V ₁ F ₁	3.33 a	4.33 a	4.66 cde	5.00 bcde	112.00a	119.11 ab	131.51 ab	147.00 c
V ₁ F ₂	3.33 a	3.33 a	4.66 bcde	5.00 bcde	128.45 a	134.83 ab	143.43 ab	157.40 bc
V ₁ F ₃	3.33 a	3.66 a	6.33 a	6.66 a	114.50 a	122.10 ab	130.40 ab	136.10 cd
V ₂ F ₀	3.0 a	3.06 a	3.66 e	3.66 e	60.36 c	63.61 d	65.13 d	66.66 f
V ₂ F ₁	3.66 a	4.00 a	5.00 bcde	5.33 abcd	104.92 ab	100.73 bcd	106.26 bc	110.10 de
V ₂ F ₂	4.33 a	4.33 a	5.66 abc	5.66 abc	94.27 abc	100.13 bcd	110.60 bc	152.60 c
V ₂ F ₃	3.33 a	3.66 a	4.33 de	4.33 cde	64.09 bc	69.56 cd	74.03 cd	83.76 ef
V ₃ F ₀	4.00 a	3.66 a	3.66 e	4.33 ade	97.58 abc	100.60 bcd	104.26 bc	107.53 e
V ₃ F ₁	4.33 a	4.33 a	6.00 ab	6.00 ab	132.54 a	147.80 a	161.16 a	180.56 ab
V ₃ F ₂	4.33 a	4.33 a	6.00 ab	6.00 ab	134.80 a	147.54 a	168.60 a	191.83 a
V ₃ F ₃	4.66 a	4.66 a	5.33 abcd	5.33 abcd	127.04 a	133.45 ab	140.86 ab	151.50 c
LSD _(0.05)	1.55	1.51	1.176	1.298	39.01	37.68	35.31	25.93
CV (%)	23.92	22.30	14.05	15.01	21.70	19.83	17.31	11.51

V₁= *Dendrobium* Red Bull, V₂= *D. Kasim* Gold and V₃= *D. White* 5 N

F₀= Control, F₁=Spray Formulation 1, F₂= Spray Formulation 2 and F₃= Spray Formulation 3

Leaf area index

Leaf Area Index (LAI) recorded at different growth stages i.e. 45 DAP, 90 DAP, 135 DAP and 180 DAP was significantly varied among the three varieties. The average leaf area index of V₁, V₂ and V₃ were 3.99, 4.54 and 4.43, respectively at 45 DAP. Similar trend was observed at 90 DAP. The average leaf area index of V₁, V₂ and V₃ were 4.34, 4.71 and 4.55, respectively. At 135 and 180 DAP these were 4.68, 4.88, 4.75 and 5.0, 5.05, 4.49 in V₁, V₂ and V₃, respectively (Table 8). Among the three varieties the leaf area index was higher in V₁ followed by V₂ and V₃.

At 45 DAP, the highest leaf area index was 4.64 in F₀ and the lowest was 3.88 in F₃. At 90 DAP, the highest leaf area index was 4.75 in F₀ and the lowest was 4.20 in F₃. At 135 DAP, the highest leaf area index was 4.91 and the lowest was 4.56 in F₂ and F₃, respectively. At 180 DAP, the highest was 5.19 and the lowest was 4.86 in F₂ and F₃, respectively (Table 9). Data showed that rate of increasing of leaf area index was more in F₂. The variation in leaf area index might occur due to the variation in number of leaves and their expansion. The results obtained from the present study was in consistence with the result of Sharma and Haloi (2001) who stated that variation in leaf area index might be attributed to the change in leaf number. The results obtained from the present study is also supported by Chandra and Das (2000).

The leaf area index varied by the interaction effect of variety to formulation. At 45 DAP, the maximum leaf area index was 5.27 in V₃F₀ and minimum was 3.75 in V₁F₀. At 90, 135 and 180 DAP the highest leaf area index were 5.28, 5.31, 5.45 and the lowest were 3.95, 4.17, 4.32, respectively in V₃F₀, V₃F₀, V₂F₂ and V₂F₃, V₂F₃, V₁F₀ (Table 10).

Leaf length

Average leaf length recorded at 45, 90, 135 and 180 DAP varied significantly among the varieties. The average leaf length of V₁, V₂ and V₃ were 13.73 cm, 6.06 cm and 12.34 cm, respectively at 45 DAP. At 90 DAP, the average leaf length of V₁, V₂ and V₃ were 13.86 cm, 6.66 cm and 13.03 cm, respectively. At 135 DAP and 180 DAP the plants showed the average leaf length 14.76 cm, 7.04 cm, 13.83 cm and 15.40 cm, 7.29 cm, 14.75 cm in V₁, V₂ and V₃, respectively (Table 8). It was observed during the whole period of the experiment that the leaf length was relatively higher in V₁ and V₂ than V₃. Therefore, it is concluded that *D. Red Bull* (V₁) and *D. White 5 N* (V₃) may be superior to *D. Kasim Gold* (V₂) in respect of leaf length.

At 45 DAP, the highest leaf length was 11.40 cm in F₂ and the lowest was 10.10 cm in F₀. At 90 DAP, the maximum leaf length was 11.58 cm in F₂ and the minimum was 10.74 cm in F₀. At 135 DAP, the maximum leaf length was 12.62 cm in F₂ and minimum was 10.94 cm in F₀. At 180 DAP, the maximum leaf length was 13.01 cm in F₂ and minimum was 11.25 cm in F₀ (Table 9). Leaf length increased at slow rate with the advancement of culture period. The spray nutrients containing N, P and K have little effects on leaf length. In every case, the lowest leaf length was observed in F₀ and the highest in F₂.

The interaction effect of variety to formulation on leaf length was significant. At 45 DAP, the highest leaf length was 14.24 cm in V₁F₃ and the lowest was 4.99 cm in V₂F₃. At 90 DAP, the highest leaf length was 14.58 cm in V₁F₃ and the lowest was 5.37 cm in V₂F₃. At 135 DAP, the highest leaf length was 15.53 cm in V₁F₃ and the lowest was 5.81 cm in V₂F₃. At 180 DAP, the highest leaf length was 16.53 cm in V₁F₃ and the lowest was 6.25 cm in V₂F₃ (Table 10).

Table 8. Main effect of variety on leaf area index and leaf length

Variety	Leaf Area Index (LAI) at DAP				Leaf Length (cm) at DAP			
	45	90	135	180	45	90	135	180
V ₁	3.99 a	4.34 a	4.68 a	5.00 a	13.73 a	13.86 a	14.76 a	15.40 a
V ₂	4.54 a	4.71 a	4.88 a	5.05 a	6.06 c	6.66 b	7.04 b	7.29 b
V ₃	4.43 a	4.55 a	4.75 a	4.94 a	12.34 b	13.03 a	13.83 a	14.75 a
LSD _(0.05)	0.65	0.70	0.69	0.68	1.02	0.91	0.99	1.01
CV (%)	17.86	18.33	17.19	16.11	11.26	9.61	9.86	9.58

V₁ = *Dendrobium Red Bull*, V₂ = *D. Kasim Gold* and V₃ = *D. White 5 N*

Table 9. Main effect of spray formulation on leaf area index and leaf length

Formulations	Leaf Area Index at DAP				Leaf Length (cm) at DAP			
	45	90	135	180	45	90	135	180
F ₀	4.64 a	4.75 a	4.83 a	4.89 a	10.10 b	10.74 a	10.94 b	11.25 b
F ₁	4.33 a	4.50 a	4.77 a	5.05 a	10.85 ab	11.45 a	12.12 ab	12.69 a
F ₂	4.42 a	4.68 a	4.94 a	5.19 a	11.40 a	11.58 a	12.62 a	13.01 a
F ₃	3.88 a	4.20 a	4.56 a	4.86 a	10.50 ab	10.94 a	11.83 ab	12.98 a
LSD _(0.05)	0.75	0.81	0.80	0.78	1.18	1.05	1.14	1.16
CV (%)	17.86	18.33	17.19	16.11	11.26	9.61	9.86	9.58

F₀ = Control, F₁ = Spray Formulation 1, F₂ = Spray Formulation 2 and F₃ = Spray Formulation 3

Table 10. Interaction effect of variety to spray formulation on leaf area index and leaf length

Variety x formulation	Leaf Area Index at DAP				Leaf Length at DAP			
	45	90	135	180	45	90	135	180
V ₁ F ₀	3.75 ab	4.00 a	4.18 a	4.32 a	12.79 ab	12.87 ab	13.02 b	13.28 b
V ₁ F ₁	3.95 ab	4.12 a	4.45 a	4.80 a	14.18 a	14.27 ab	15.22 a	16.08 a
V ₁ F ₂	4.33 ab	4.73 a	5.08 a	5.43 a	13.74 ab	13.72 ab	15.26 a	15.71 a
V ₁ F ₃	3.94 ab	4.49 a	5.02 a	5.44 a	14.24 a	14.58 a	15.53 a	16.53 a
V ₂ F ₀	4.91 ab	4.96 a	4.99 a	5.01 a	5.82 cd	6.88 cd	7.02 cd	7.11 c
V ₂ F ₁	4.73 ab	4.90 a	5.13 a	5.40 a	6.10 cd	6.86 cd	7.12 cd	7.47 c
V ₂ F ₂	4.78 ab	5.04 a	5.23 a	5.45 a	7.36 c	7.51 c	8.21 c	8.35 c
V ₂ F ₃	3.73 b	3.95 a	4.17 a	4.34 a	4.99 d	5.37 d	5.81 d	6.25 c
V ₃ F ₀	5.27 a	5.28 a	5.31 a	5.33 a	11.69 b	12.47 a	12.77 b	13.38 b
V ₃ F ₁	4.32 ab	4.49 a	4.74 a	4.94 a	12.28 ab	13.23 ab	14.02 ab	14.51 ab
V ₃ F ₂	4.16 ab	4.28 a	4.50 a	4.69 a	13.12 ab	13.52 ab	14.38 ab	14.96 ab
V ₃ F ₃	3.97 ab	4.16 a	4.47 a	4.82 a	12.27 ab	12.89 ab	14.15 ab	16.16 a
LSD _(0.05)	1.30	1.40	1.39	1.36	2.04	1.82	1.98	2.02
CV (%)	17.86	18.33	17.19	16.11	11.26	9.61	9.86	9.58

V₁ = *Dendrobium* Red Bull, V₂ = *D. Kasim* Gold and V₃ = *D. White* 5 N

F₀ = Control, F₁ = Spray Formulation 1, F₂ = Spray Formulation 2 and F₃ = Spray Formulation 3

Stem diameter

Varietal effect on stem diameter varied significantly. In *D. Red Bull*, the average stem diameter per plant was 1.42 cm, 1.53 cm, 1.60 cm, 1.60 cm at 45, 90, 135 and 180 DAP, respectively. In *D. Kasim Gold*, the values were 1.01 cm, 1.12 cm, 1.24 cm and 1.26 cm at 45, 90, 135 and 180, DAP respectively. In *D. White 5 N* the values were 1.11 cm, 1.15 cm, 1.32 cm and 1.36 cm at 45, 90, 135 and 180 DAP, respectively (Table 11).

The stem diameter varied due to the effect of formulation. The maximum stem diameter showed in F_3 were 1.31 cm, 1.40 cm, 1.55 cm and 1.56 cm at 45, 90, 135 and 180 DAP, respectively (Table 12). Spray nutrients containing N, P and K have little effect on stem diameter.

The interaction effect of variety to formulation on stem diameter varied significantly. At 45 DAP, the highest stem diameter was 1.50 cm and the lowest was 0.93 cm in V_1F_1 and V_2F_2 , respectively. At 90 DAP, the highest was 1.64 cm and the lowest was 1.06 cm in V_1F_1 and V_2F_2 , respectively. At 135 DAP, the highest was 1.7 cm and the lowest was 1.06 cm in V_1F_1 and V_3F_0 , respectively. At 180 DAP, the highest was 1.7 cm and the lowest was 1.06 cm in V_1F_1 and V_3F_0 , respectively (Table 13).

Leaf width

Leaf width recorded at 45, 90, 135 and 180 DAP varied among the varieties. At 45 DAP, the maximum leaf width was 3.51 cm in V_2 and minimum was 2.45 cm in V_3 . At 90 DAP, the maximum leaf width was 3.69 cm in V_2 and minimum was 2.56 cm in V_3 . At 135 DAP, the maximum leaf width was 3.83 cm in V_2 and minimum was 2.92 cm in V_3 . At 180 DAP, the maximum leaf width was 4.16 cm in V_2 and minimum was 3.17 cm in V_3 . Thus, V_2 was superior to V_1 and V_3 in respect of leaf width (Table 11).

At 45 DAP, the highest leaf width was 3.07 cm in F_3 and the lowest was 2.87 cm in F_2 . At 90 DAP, the highest leaf width was 3.13 cm in F_1 and the lowest was 3.01 cm in F_2 . At 135 DAP, the highest leaf width was 3.48 cm in F_3 and the lowest was 3.10 cm in F_0 . At 180 DAP, the highest leaf width was 3.86 cm in F_2 and the lowest was 3.14 cm in F_0 (Table 12).

Leaf width varied significantly due to interaction effect of variety to formulation. At 45 DAP, the highest leaf width was 3.68 cm in V_2F_3 and the lowest was 2.38 cm in V_3F_2 . At 90 DAP, the highest leaf width was 3.85 cm in V_2F_3 and the lowest was 2.52 cm in V_3F_2 . At 135DAP, the highest leaf width was 3.97 cm in V_2F_3 and the lowest was 2.71 cm in V_3F_0 (Table 13). At 180 DAP, the highest leaf width was 4.63 cm in V_2F_2 and the lowest was 2.71 cm in V_3F_0 .

Table 11. Main effect of variety on stem diameter and leaf width

Variety	Stem Diameter (cm) at DAP				Leaf width (cm) at DAP			
	45	90	135	180	45	90	135	180
V_1	1.42 a	1.53 a	1.60 a	1.60 a	2.94 b	2.97 b	3.31 b	3.42 b
V_2	1.01 b	1.12 b	1.24 b	1.26 b	3.51 a	3.69 a	3.83 a	4.16 a
V_3	1.11 b	1.15 b	1.32 b	1.36 b	2.45 c	2.56 c	2.92 c	3.17 b
LSD _(0.05)	0.15	0.15	0.13	0.13	0.38	0.37	0.37	0.35
CV (%)	15.80	14.71	11.64	11.19	15.13	14.39	13.33	11.53

$V_1 = Dendrobium$ Red Bull, $V_2 = D.$ Kasim Gold and $V_3 = D.$ White 5 N

Table 12. Main effect of spray formulation on stem diameter and leaf width

Formulations	Stem Diameter (cm) at DAP				Leaf width (cm) at DAP			
	45	90	135	180	45	90	135	180
F_0	1.14 a	1.18 b	1.21 c	1.21 b	2.91 a	3.03 a	3.10 a	3.14 b
F_1	1.16 a	1.25 ab	1.42 ab	1.47 a	3.02 a	3.13 a	3.43 a	3.67 a
F_2	1.12 a	1.23 ab	1.37 b	1.40 a	2.87 a	3.01 a	3.40 a	3.86 a
F_3	1.31 a	1.40 a	1.55 a	1.56 a	3.07 a	3.12 a	3.48 a	3.65 a
LSD _(0.05)	0.18	0.18	0.15	0.15	0.43	0.43	0.43	0.40
CV (%)	15.80	14.71	11.64	11.19	15.13	14.39	13.33	11.53

$F_0 =$ Control, $F_1 =$ Spray Formulation 1, $F_2 =$ Spray Formulation 2 and $F_3 =$ Spray Formulation 3

Table 13. Interaction effect of variety to spray formulation on stem diameter and leaf width

Variety x formulation	Stem Diameter (cm) at DAP				Leaf wide (cm) at DAP			
	45	90	135	180	45	90	135	180
V ₁ F ₀	1.43 ab	1.46 abc	1.46 abcd	1.46 abcd	2.76 bcd	2.80 cd	2.88 bc	2.88 de
V ₁ F ₁	1.50 a	1.64 a	1.70 a	1.70 a	3.06 abcd	3.11 abcd	3.55 abc	3.73 bc
V ₁ F ₂	1.33 abc	1.46 abc	1.58 abc	1.60 abc	2.91 abcd	3.05 abcd	3.25 abc	3.38 bcde
V ₁ F ₃	1.43 ab	1.56 ab	1.66 ab	1.66 ab	3.02 abcd	2.93 bcd	3.55 abc	3.69 bc
V ₂ F ₀	1.00 cd	1.10 de	1.10 e	1.10 ef	3.55 ab	3.70 ab	3.71 ab	3.83 bc
V ₂ F ₁	1.03 cd	1.10 de	1.26 de	1.33 cdef	3.51 ab	3.75 ab	3.84 a	4.11 ab
V ₂ F ₂	0.93 d	1.06 de	1.23 de	1.23 def	3.32 abc	3.47 abc	3.79 a	4.63 a
V ₂ F ₃	1.10 bcd	1.25 bcde	1.36 bcde	1.40 abcde	3.68 a	3.85 a	3.97 a	4.05 ab
V ₃ F ₀	1.00 cd	1.00 e	1.06 e	1.06 f	2.42 d	2.59 d	2.71 c	2.71 e
V ₃ F ₁	0.96 d	1.03 e	1.30 cde	1.40 abcde	2.50 cd	2.54 d	2.90 bc	3.17 cde
V ₃ F ₂	1.10 bcd	1.16 cde	1.30 cde	1.36 abcde	2.38 d	2.52 d	3.16 abc	3.58 bcd
V ₃ F ₃	1.40 ab	1.40 abcd	1.61 ab	1.61 abc	2.51 cd	2.58 d	2.92 bc	3.21 cde
LSD _(0.05)	0.31	0.31	0.27	0.26	0.76	0.74	0.75	0.70
CV (%)	15.80	14.71	11.64	11.19	15.13	14.39	13.33	11.53

V₁ = *Dendrobium* Red Bull, V₂ = *D. Kasim Gold* and V₃ = *D. White 5 N*

F₀ = Control, F₁ = Spray Formulation 1, F₂ = Spray Formulation 2 and F₃ = Spray Formulation 3

Conclusions

Morphological features as influenced by various nutrient solution sprays of three cultivars of *Dendrobium* sp. were stated clearly in this study. It was concluded from the experiment that *D. Red Bull* is superior to the other two varieties. While nutrient formulation 2 (F₂) may be considered as the suitable for vegetative growth of *Dendrobium* sp.

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