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RESEARCH PAPER

Influence of plant growth promoters and growing systems on physiological parameters of *Dendrobium* cv. EARSAKUL

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Abstract : The study was carried out to investigate the influence of plant growth promoters and systems of growing on physiological parameters of *Dendrobium* cv. EARSAKUL. The main objective was to assess the response of combination of nutrients, plant growth regulators and plant growth promoting root endophyte (PGPRE) in two age groups of *Dendrobium* cv. EARSAKUL plants (six month old and three year old at planting time) under three growing systems *viz.,* two level shade house (S_1), top ventilated polyhouse (S_2) and fan and pad system (S_3). Results revealed that leaf area (29.99 m^2), relative growth rate (0.013 g g^{-1} day^{-1}) and number of stomata (41.14) were highest in six month old plants, whereas, dry matter production (20.92 g $plant^{-1}$) and crop growth rate (0.148 g m^{-2} day^{-1}) were highest in three year old plants in the treatment POP + OM + VW + PGPRE + bone meal + GR (T_4). Dry matter production (14.27 g $plant^{-1}$), crop growth rate (0.131 g m^{-2} day^{-1}), rate of photosynthesis (6.36 µmol CO_2 m^{-2} s^{-1}) and transpiration rate (6.56 µmol m^{-2} s^{-1}) during day time were highest in the treatment POP + OM + VW + PGPRE + bone meal (T_3) in six month old plants. Among the systems of growing, maximum values for physiological parameters were recorded in top ventilated polyhouse. The interaction of plant growth promoters and systems of growing had significant effect on physiological parameters.

Key Words : *Dendrobium* cv. EARSAKUL, Inorganic nutrients, Plant growth promoting root endophyte (*Piriformospora indica*), Growing systems, Physiological parameters

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INTRODUCTION

Among the orchid genera, *Dendrobium* is a very complex and extremely large genus widely used in the commercially cut flower production. It is the second largest genus in the family with nearly 1600 species, is one of the commercially important species. Most *Dendrobium* species are epiphytic and are from tropical and sub-tropical regions. It is a popular genus for cut flower production. Many growers in the states of Kerala, Tamil Nadu and Coastal Karnataka are cultivating *Dendrobium* on a commercial scale.

In *Dendrobium* cv. EARSAKUL, among the physiological parameters, higher leaf area was resulted by the package of practices of KAU + organic mixture + *Piriformospora indica* + vermiwash + bone meal (Dhinesh, 2009). Many orchids are planted under shade since high light affects both vegetative and reproductive tissues. However, plants grown continuously under low light may suffer from a reduction in the rate of photosynthesis and reduction in growth rate (Khoo *et al.,* 1997). Leaf area is a more direct indication of photosynthetic efficiency of a plant. In *Dendrobium*, it is more so, because, being an epiphytic plant, nutrition is little through the growing

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media. Instead, foliar spray is the common practice for supplying nutrients where increased leaf area favours increased absorption. Total leaf area showed an increase with the increase in nutrient concentration (Swapna, 2000).

Light intensity influences plant growth through photosynthesis. Good vegetative growth is an indication of the photosynthetic ability of plants. The photosynthetic rate of *Cymbidium sinense* is low and ranges between 2.0 and 2.6 µmol CO_2 m^{-2} s^{-1} which is about 1/5 that of most of C_3 plants. There is no difference in the photosynthetic rates of one-and two-year-old leaves, and the rate declines significantly in three-year–old leaves (Ye *et al.*, 1992). Samasya (2000) reported that *Dendrobium* Sonia 17 plants subjected to 50 per cent light intensity and less than 70 per cent relative humidity exhibited lesser transpiration rate.

The major constraints encountered in *Dendrobium* orchid cultivation are growing conditions, long pre blooming period and susceptibility to pest and diseases. It is envisaged that growing tropical orchids for cut flower production and potted plants will benefit from the recent advances in plant physiology and biotechnology. For the orchid industry, producing an improved hybrid, through conventional breeding or genetic engineering, is only the beginning. Optimization of the production processes and ensuring a quality product for the market is equally important. To achieve this goal, a good basic understanding of orchid physiology is essential to solve key physiological issues. However, we lack information on the rate of photosynthesis and transpiration of tropical orchids under green house cultivation, particularly at a commercial level. This information is crucial in the optimization of the growth and yield of orchids in commercial farms.

Keeping in view all these problems, the present investigation on influence of plant growth promoters and systems of growing on physiological parameters of *Dendrobium* cv. EARSAKUL" was planned.

MATERIAL AND METHODS

The experiments were carried out at the orchidarium of All India Co-ordinated Floriculture Improvement Project (AICFIP) in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Thrissur, Kerala. Studies were conducted over a period from April 2011 to March 2013 in three types of growing systems *viz.*, two level shade house (S_1), top ventilated polyhouse (S_2) and fan and pad system (S_3). Commercially cultivated orchid hybrid variety *Dendrobium* cv. EARSAKUL was used for the study. Plants having two stages of growth *viz.*, six month and three year old plants were used (at planting time). Plants were grown under 50 per cent shade in two level shade house (size : 21.00× 6.00×3.50×2.00 m, top one layer shade net, lower one layer poly film 200 micron with misting system), top ventilated polyhouse (size: 21.00×6.00×3.50×2.00 m, poly film 200 micron covering with shade net and misting system) and in 75 per cent shade in fan and pad system (size : 12.50×8.00×6.00×4.00 m, poly film 200 micron covering, UV stabilized shade net with fan and pad for cooling system). The major nutrients N : P_2O_5 : K_2O at two different ratios, *viz.*, 3:1:1 and 1:2:2 @ 0.2 per cent were applied as foliar sprays during vegetative and flowering stages, respectively. The frequency of application was weekly twice. Nutrient combinations were made using ammonium nitrate, ortho-phosphoric acid and potassium nitrate.

The treatments consists of T_1- POP recommendations of KAU (foliar feeding with fertilizer mixture of N : P_2O_5 : K_2O 3:1:1 during vegetative period and 1:2:2 during flowering period @ 0.2 per cent, spraying at weekly twice as ammonium nitrate, ortho-phosphoric acid and potassium nitrate, respectively), T_2- POP + PGPRE (the fungal culture of *Piriformospora indica* was mixed with vermiculite @ 1 g per 100 g of vermiculite and applied near the root zone at the time of planting) + bone meal (15 g per plant applied near root zone at the time of planting), T_3- POP + OM (bone meal, neem cake and ground nut cake 100 g each, soaked in water for 3-4 days and diluted to 10-15 times with water, filtered and sprayed over plants at 15 days interval) + vermiwash (diluted to 3 % and sprayed at 15 days interval) + PGPRE + bone meal, T_4- POP + OM + VW + PGPRE + bone meal + GR (BA 50 mg l^{-1} and GA_3 10 mg l^{-1} sprayed at monthly intervals), T_5- 10:20:10 NPK + GR and T_6- NPK + GR + OM + VW + PGPRE + bone meal. The experiment was laid out in Completely Randomized Design comprising six treatments, three replications and five plants per treatment for recording observations.

The observations on physiological parameters were recorded and methodology followed as detailed below.

Leaf area :

The length and breadth of leaf was measured and the area of leaf was computed by using the following regression equation developed as part of the present study (R^2).

Leaf area (a) = - 25.857 + 8.95 × breadth + 2.184 × length

Chlorophyll content :

The chlorophyll content of the leaves was determined using 80 per cent acetone (Porra, 2002). The most recent, fully developed leaf was taken and cut into small pieces (100 mg), the leaf sample pieces digested in 10 ml acetone and ground well using mortar and pestle. Then ground material was poured into centrifuge tube and centrifuged at 5000 rpm for 10 minutes. The supernatent solution was poured into vial (cuvette). The absorbance was read at 646.6 nm and 663.6 nm using distilled water as blank with spectrophotometer. Chlorophyll a, b and total chlorophyll was calculated using the formula, and expressed in mg g^{-1} fresh weight.

Chlorophyll a = 12.25 ($A_{663.6}$) – 2.55 ($A_{646.6}$) × 10 ml acetone / 100 mg leaf tissue

Chlorophyll b = 20.31 ($A_{646.6}$) – 4.91 ($A_{663.6}$) × 10 ml acetone / 100 mg leaf tissue

Total chlorophyll = 17.76 ($A_{646.6}$) + 7.34 ($A_{663.6}$) × 10 ml acetone / 100 mg leaf tissue.

Relative growth rate :

Relative growth rate (RGR) is the rate of increase in dry weight per unit time expressed in g^{-1} day. It is calculated by the formula suggested by Blackman (1919) :

$$\mathbf{RGR} = \frac{\mathbf{Loge\,W_2 - Loge\,W_2}}{\mathbf{(t_2 - t_1)}}$$

where, W_1 and W_2 are the dry weight of the whole plant at time t_1 and t_2, respectively.

Net assimilation rate :

Net assimilation rate (NAR) refers to the change in dry weight of the plant per unit leaf area per unit time. NAR can be determined by measuring plant dry weight and leaf area periodically during the growth and is commonly expressed in g m^{-2} day^{-1} (Williams, 1946) :

$$\mathbf{NAR} = \frac{\mathbf{W_2 - W_1}}{\mathbf{(LA_2 - LA_1)}} \times \frac{\mathbf{Loge\,W_2 - Loge\,W_1}}{\mathbf{t_2 - t_1}}$$

where, LA_1 and LA_2 are the leaf area of plant and W_1 and W_2 are the whole plant dry weight at time t_1 and t_2, respectively.

Crop growth rate :

Crop growth rate (CGR) was calculated using the formula of Yaduraju and Ahuja (1996) and expressed in g m^{-2} day^{-1} :

$$\mathbf{CGR} = \frac{\mathbf{W_2 - W_1}}{\mathbf{T_2 - T_1}}$$

Dry matter production :

Pseudo stems, leaves and roots of the uprooted plants were dried to a constant weight at 70^0C – 80^0C in a hot air oven. The sum of the dry weights of component parts gave total dry matter production and expressed as g $plant^{-1}$.

Stomatal characters :

Stomatal impressions were taken at three different areas using glue (quick fix). The number of stomata per square millimeter of microscopic field (0.11 mm^2) was counted and recorded as per square millimeter (number of stomata / 0.11 mm^2).

Diffusive resistance :

Diffusive resistance of the leaf was measured using Infra Red Gas Analyzer (IRGA) and expressed as S cm^{-1}.

Rate of photosynthesis :

Photosynthetic rate of the leaf was recorded by using Infra red gas analyzer (IRGA) during the night (6 pm to 11 pm) and expressed as µmol CO_2 m^{-2} s^{-1}.

Rate of transpiration :

Transpiration rate of the leaf was recorded by using Infra red gas analyzer (IRGA) during the night (6 pm to 11 pm) and day time also and expressed as µmol m^{-2} s^{-1}.

The observation on photosynthetic rate was measured on the second leaf of the current shoot (Chang *et al.*, 2010) and data on photosynthesis, rate of transpiration during night and day was recorded by using IRGA (Infra red gas analyzer) at six months after planting in both the stages of plants. The experimental data were analyzed by the ANOVA (Analysis of variance technique) (Panse and Sukhatme, 1985). MSTATC and MS-Excel software were used for computation of data.

RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Leaf area :

Data made available in the Tables 1 and 2 revealed that the combination of POP + OM + VW + PGPRE + bone meal + GR recorded significantly higher leaf area irrespective of the age of the plants (29.99 cm^2, 30.58 cm^2). These results might be attributed that the leaf area was determined by a number of leaves per plant. Similar results were reported by Dhinesh (2009) and Sugapriya *et al.* (2012) in *Dendrobium*.

Among system of growing, top ventilated polyhouse had maximum influence on leaf area in six month old plants (28.92 cm^2). The increase in leaf number resulted in increase in leaf area (or) increase in leaf area can be attributed to increase in leaf number.

The combination of POP + OM + VW + PGPRE + bone meal and top ventilated polyhouse in six month old plants (34.41 cm^2), POP + OM + VW + PGPRE + bone meal + GR and two level shade house in three year old plants recorded significantly higher leaf area (32.73 cm^2). In six month old plants, the *P. indica* would influence the production of more number of leaves per plant which in turn enhance the leaf area in top ventilated polyhouse with the condition of high temperature, high light intensity and low relative humidity (Fig. 1, 2 and 3). Foliar feeding of organic manures may also the reason for highest leaf area. Whereas in three year old plants, the effect of *P. indica* and growth regulators would influence the production of more number of leaves which ultimately resulted in more leaf area.

Dry matter production :

The plant growth promoter POP + OM + VW + PGPRE + bone meal in six month old plants (14.27 g $plant^{-1}$), POP + OM + VW + PGPRE + bone meal + GR in three year old plants recorded significantly higher DMP (20.92 g $plant^{-1}$) (Table 1

Table 1 : Influence of plant growth promoters (T), growing systems (S) and T × S interaction on physiological parameters in six month old plants of *Dendrobium* cv. EARSAKUL

Treatments	Leaf area (cm^2)				Dry matter production (g $plant^{-1}$)				Crop growth rate (g m^{-2} day^{-1})				Relative growth rate (g g^{-1} day^{-1})			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	19.26	26.88	28.73	25.03	5.38	9.27	7.93	7.53	0.076	0.104	0.089	0.090	0.009	0.010	0.007	0.009
T_2	23.71	29.66	28.94	27.43	7.10	12.43	6.92	8.82	0.067	0.107	0.080	0.085	0.012	0.012	0.009	0.011
T_3	24.85	34.41	28.95	29.33	13.93	16.07	12.80	14.27	0.169	0.130	0.093	0.131	0.011	0.011	0.008	0.010
T_4	31.25	30.46	28.27	29.99	6.72	15.47	6.12	9.43	0.084	0.116	0.075	0.091	0.018	0.013	0.019	0.013
T_5	21.49	27.42	16.51	21.81	5.10	10.25	6.93	7.43	0.071	0.085	0.079	0.078	0.008	0.009	0.007	0.008
T_6	23.25	25.72	18.23	22.06	14.80	8.05	7.98	10.28	0.179	0.147	0.011	0.125	0.007	0.008	0.006	0.007
Mean	23.97	28.92	24.94		8.84	11.92	8.11		0.107	0.115	0.078		0.010	0.010	0.008	
C.D. (P=0.05)	T: 2.71				T: 1.95				T: 0.040				T: 0.003			
	S: 1.91				S: 1.38				S: 0.028				S: NS			
	T × S: 4.69				T × S: 3.38				T × S: 0.069				T × S: 0.005			

Treatments	Net assimilation rate (g m^{-2} day^{-1})				Number of stomata				Rate of photosynthesis (µmol CO_2 m^{-2} s^{-1})				Rate of transpiration (night) (µmol m^{-2} s^{-1})				Rate of transpiration (day) (µmol m^{-2} s^{-1})			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	0.004	0.009	0.004	0.006	34.32	31.80	28.26	31.46	4.24	8.86	3.73	5.61	0.14	0.23	0.11	0.16	1.73	4.40	3.15	3.09
T_2	0.006	0.009	0.004	0.006	31.80	44.92	39.38	38.70	4.83	6.10	3.49	4.81	0.16	0.45	0.18	0.26	3.81	5.27	3.11	4.06
T_3	0.007	0.009	0.005	0.007	34.82	34.33	39.38	36.17	4.94	9.73	4.41	6.36	0.14	0.23	0.10	0.16	8.83	7.77	3.09	6.56
T_4	0.009	0.009	0.006	0.008	40.33	41.38	41.72	41.14	3.62	6.01	3.26	4.29	0.21	0.46	0.07	0.25	3.88	5.39	3.24	4.17
T_5	0.006	0.006	0.003	0.005	28.55	37.85	38.35	34.91	2.48	6.90	3.88	4.42	0.10	0.37	0.12	0.19	4.46	9.19	2.47	5.37
T_6	0.004	0.011	0.002	0.006	32.29	39.36	43.00	38.21	4.20	3.58	2.58	3.45	0.15	0.14	0.15	0.15	2.41	3.95	2.96	3.10
Mean	0.006	0.009	0.004		33.68	38.27	38.34		4.05	6.86	3.55		0.15	0.32	0.12		4.18	6.00	3.00	
CD	T: NS				T: 3.41				T: 1.72				T: 0.032				T: 1.29			
(P=0.05)	S: 0.002				S: 2.41				S: 1.21				S: 0.023				S: 0.91			
	T × S: 0.007				T × S: 5.91				T × S: 2.98				T × S: 0.056				T × S:2.23			

NS = Non-significant

Table 2 : Influence of plant growth promoters (T), growing systems (S) and T × S interaction on physiological parameters in three year old plants of *Dendrobium* cv. EARSAKUL

Treatments	Leaf area (cm^2)				Dry matter production (g $plant^{-1}$)				Crop growth rate (g m^{-2} day^{-1})				Relative growth rate (g g^{-1} day^{-1})			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	20.72	25.66	18.66	22.36	6.76	8.46	6.93	7.38	0.105	0.106	0.090	0.100	0.016	0.011	0.008	0.011
T_2	25.43	27.52	24.01	26.13	12.33	13.33	9.66	11.77	0.092	0.108	0.065	0.088	0.014	0.013	0.010	0.012
T_3	25.05	31.41	31.53	27.17	17.66	24.33	12.30	18.09	0.156	0.122	0.091	0.123	0.012	0.012	0.009	0.011
T_4	32.73	26.30	23.80	30.58	22.33	26.66	13.76	20.92	0.180	0.159	0.104	0.148	0.011	0.015	0.014	0.012
T_5	22.15	19.36	23.48	21.22	7.88	11.78	8.88	9.51	0.098	0.128	0.086	0.104	0.010	0.010	0.007	0.009
T_6	18.84	20.81	20.81	19.49	15.25	16.16	11.81	14.41	0.117	0.114	0.100	0.110	0.039	0.009	0.007	0.018
Mean	24.15	25.18	24.14		13.70	16.78	10.56		0.125	0.123	0.089		0.017	0.012	0.008	
C.D.	T: 2.28				T: 1.64				T: 0.033				T: NS			
(P = 0.05)	S: NS				S: 1.16				S: 0.023				S: NS			
	T × S: 3.96				T × S: 2.84				T × S: 0.057				T × S: 0.021			

Treatments	Net assimilation rate (g m^{-2} day^{-1})				Number of stomata				Rate of photosynthesis (µmol CO_2 m^{-2} s^{-1})				Rate of transpiration (Night) (µmol m^{-2} s^{-1})				Rate of transpiration (day time) (µmol m^{-2} s^{-1})			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	0.011	0.007	0.004	0.007	32.79	34.80	37.35	34.98	3.72	5.92	4.49	4.71	0.12	0.09	0.26	0.15	2.40	2.33	3.56	2.76
T_2	0.013	0.012	0.003	0.009	40.39	37.33	38.33	38.68	3.78	3.58	3.22	3.53	0.19	0.12	0.04	0.12	3.88	6.15	3.28	4.44
T_3	0.012	0.010	0.004	0.009	38.37	38.86	42.36	39.86	3.71	3.63	4.93	4.09	0.15	0.09	0.05	0.10	3.14	6.71	2.64	4.16
T_4	0.007	0.014	0.005	0.009	30.33	44.92	39.85	38.36	2.82	3.51	8.72	5.01	0.22	0.06	0.29	0.19	7.20	1.42	1.96	3.53
T_5	0.009	0.014	0.004	0.009	34.32	37.85	36.33	36.16	2.87	2.96	6.58	4.14	0.11	0.20	0.23	0.17	4.05	0.57	3.10	2.57
T_6	0.028	0.017	0.004	0.016	35.83	38.86	39.38	38.02	2.95	3.98	3.26	3.40	0.16	0.06	0.22	0.14	8.73	3.06	3.40	5.06
Mean	0.013	0.012	0.004		35.34	38.77	38.93		3.30	3.93	5.20		0.16	0.10	0.18		4.90	3.37	2.98	
C.D.	T: NS				T: 3.22				T: NS				T: NS				T: 0.81			
(P = 0.05)	S: 0.007				S: 2.28				S: 1.84				S: NS				S: 0.57			
	T × S: 0.017				T × S: 5.57				T × S: 4.51				T × S: 0.301				T × S: 1.41			

NS = Non-significant

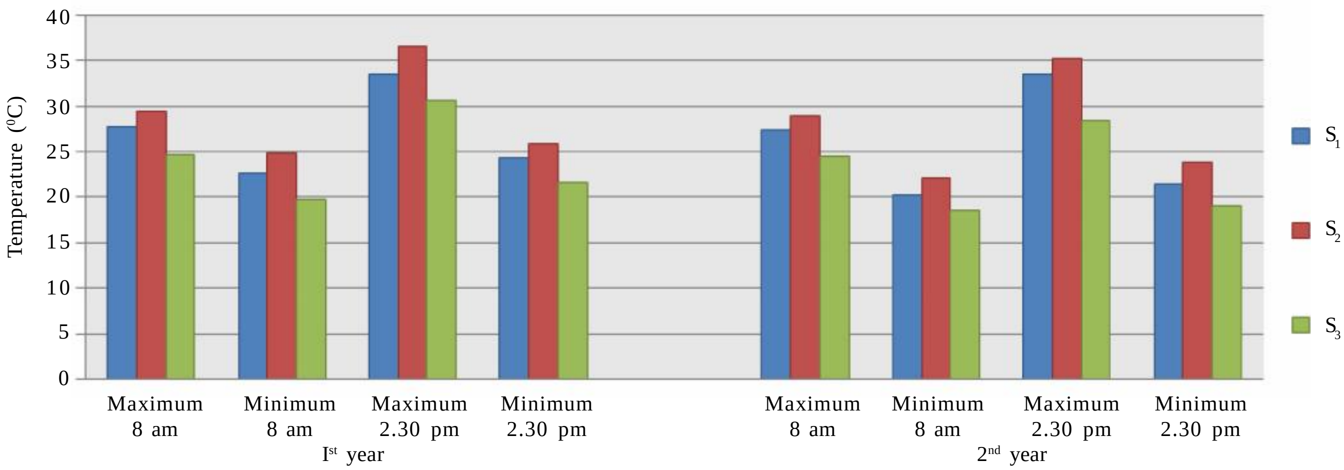

Fig. 1 : Yearly mean temperature (^{0}C) in different growing systems

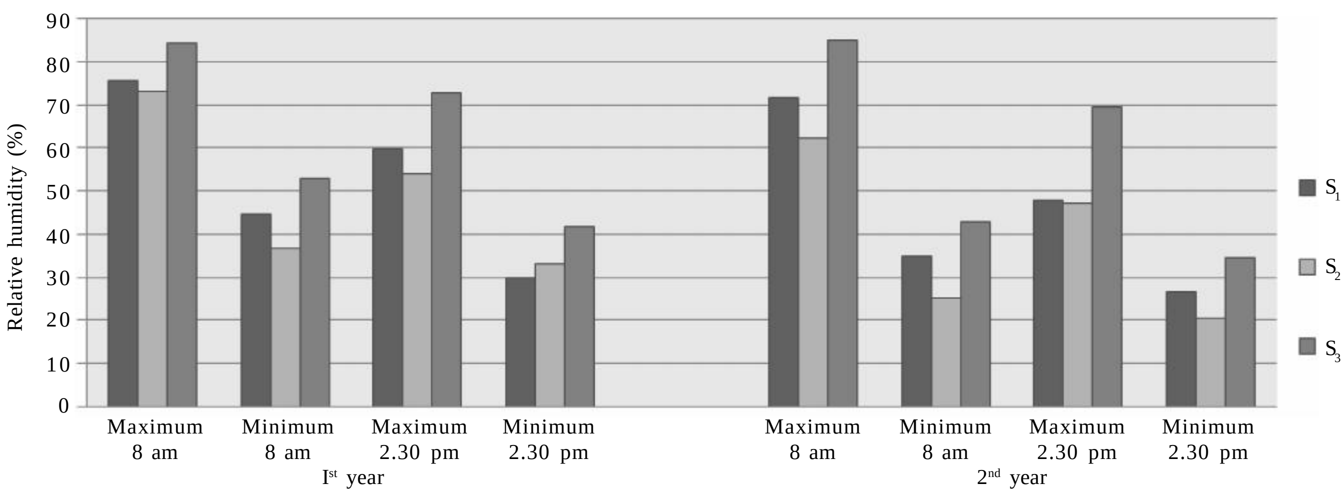

Fig. 2 : Yearly mean relative humidity (%) in different growing systems

Fig. 3 : Yearly mean light intensity (lux) inside and outside of the growing systems

and 2). These findings might be due to plant height and number of shoots per plant were more in the treatment POP + OM + VW + PGPRE + bone meal for six month old plants whereas, the number of leaves per plant, leaf area was more in the treatment POP + OM + VW + PGPRE + bone meal + GR. This might be the reason for more DMP observed in those treatments in six month old and three year old plants, respectively.

Top ventilated polyhouse had maximum influence on DMP irrespective of age of the plants (11.92 g plant^{-1}, 16.78 g plant^{-1}). The plant height, number of leaves, number of shoots and leaf area were maximum in top ventilated polyhouse which might have resulted in increased DMP in plants grown under top ventilated polyhouse. These findings are in conformity with the results obtained by Fernandez (2001) in *Dendrobium*.

In T×S interaction, the combination of POP + OM + VW + PGPRE + bone meal and top ventilated polyhouse in six month old plants (16.07 g plant^{-1}) and POP + OM + VW + PGPRE + bone meal + GR and top ventilated polyhouse in three year old plants recorded higher DMP (26.66 g plant^{-1}). These results are in conformity with earlier results of plant growth promoters and systems of growing on DMP.

Crop growth rate :

The input combination POP + OM + VW + PGPRE + bone meal in six month old plants (0.131 g m^{-2} day^{-1}), POP + OM + VW + PGPRE + bone meal + GR in three year old plants (0.148 g^{-2} day^{-1}) recorded significantly higher CGR (Tables 1 and 2). The CGR is the proportion of dry matter production and time period of growth. The results of DMP also proved that POP + OM + VW + PGPRE + bone meal in six month old and POP + OM + VW + PGPRE + bone meal + GR in three year old plants recorded more DMP. A similar trend was also observed in the case of CGR. Highest CGR was recorded in those plants which received POP + *P. indica*. This is in accordance with the findings of Dhinesh (2009) in *Dendrobium*.

Top ventilated polyhouse in six month old plants (0.115 g^{-2} day^{-1}) and two level shade house in three year old plants recorded maximum CGR (0.125 g m^{-2} day^{-1}). These findings are in line with the reports of Samasya (2000) in *Dendrobium*.

The combination of NPK + GR + OM + VW + PGPRE + bone meal and two level shade house in six month old plants (0.169 g m^{-2} day^{-1}), POP + OM + VW + PGPRE + bone meal + GR and two level shade house in three year old plants recorded higher CGR (0.180 g m^{-2} day^{-1}). The treatments NPK + GR + PGPRE + OM + VW + bone meal and POP + PGPRE + OM + VW + bone meal + GR under the environmental condition of two level shade house could resulted in high CGR.

Relative growth rate :

Among the various treatments, POP + OM + VW + PGPRE + bone meal + GR recorded significantly higher RGR in six month old plants (0.013 g g^{-1} day^{-1}) (Table 1). Since, the six month plants were in active growth phase, it was significantly showing the unit increasing DMP. This may lead to increase in RGR. The result in the present study is parallel with the findings of Dhinesh (2009) in *Dendrobium*.

Growing systems had no significant effect on RGR in both stages of plants.

In T×S interaction, POP + OM + VW + PGPRE + bone meal + GR and fan and pad system in six month old plants (0.019 g g^{-1} day^{-1}), NPK + GR + OM + VW + PGPRE + bone meal and two level shade house in three year old plants recorded maximum RGR (0.039 g g^{-1} day^{-1}). Under fan and pad system, a uniform environmental condition with high relative humidity may facilitating the maximum RGR in six month old plants which are in active growth stage, whereas in three year old plants, NPK + GR + OM + VW + PGPRE + bone meal combination was performing well under two level shade house in increasing RGR.

Table 3 : Influence of plant growth promoters (T), growing systems (S) and T × S interaction on diffusive resistance and chlorophyll content in six month old plants of *Dendrobium* cv. EARSAKUL

Treatments	Diffusive resistance (S cm^{-1})				Chlorophyll a (mg g^{-1} leaf weight)				Chlorophyll b (mg g^{-1} leaf weight)				Total chlorophyll (mg g^{-1} leaf weight)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	11.33	4.47	4.07	6.62	0.22	0.19	0.17	0.19	0.28	0.10	0.09	0.16	0.50	0.30	0.26	0.34
T_2	13.24	7.04	8.82	9.70	0.21	0.25	0.21	0.22	0.51	0.12	0.09	0.24	0.73	0.37	0.30	0.47
T_3	5.76	9.86	6.21	7.28	0.22	0.22	0.22	0.22	0.50	0.16	0.01	0.22	0.71	0.38	0.23	0.44
T_4	8.30	8.36	8.61	8.42	0.21	0.19	0.18	0.19	0.75	0.10	0.04	0.30	0.96	0.29	0.22	0.49
T_5	11.12	8.68	10.29	10.03	0.08	0.22	0.15	0.18	0.49	0.09	0.07	0.22	0.57	0.31	0.23	0.41
T_6	16.17	12.51	12.29	13.66	0.25	0.18	0.22	0.22	0.29	0.09	0.04	0.14	0.53	0.27	0.26	0.36
Mean	10.98	8.48	8.38		0.21	0.21	0.19		0.47	0.10	0.06		0.68	0.32	0.24	
C.D.	T: 2.31				T: NS				T: NS				T: NS			
(P=0.05)	S: 1.63				S: NS				S: 0.11				S: 0.11			
	T × S: 4.00				T × S: 0.12				T × S: 0.28				T × S: 0.27			

NS = Non-significant

Net assimilation rate :

Treatments had no significant influence on NAR at both stages of plant growth. Among systems of growing, top ventilated polyhouse in six month old plants and two level shade house in three year old plants recorded higher NAR (Tables 1 and 2). The combination of NPK + GR + OM + VW + PGPRE + bone meal had more influence on NAR in top ventilated polyhouse in six month old plants (0.011 g m^{-2} day^{-1}) and two level shade house in three year old plants (0.028 g m^{-2} day^{-1}). The interaction effect was clearly suggesting the results of plant growth promoters and systems of growing in independent cases on NAR.

Number of stomata :

The data recorded on number of stomata are presented in Tables 1 and 2 indicated that the plant growth promoter POP + OM + VW + PGPRE + bone meal + GR in six month old plants and POP + OM + VW + PGPRE + bone meal in three year old plants recoded higher number of stomata (41.14, 39.86). The number of leaves per plant in six month old plants might be high due to influence of growth regulators. Whereas in three year old plants, the individual leaf area were more. This could be the result of more number of stomata due to increasing number of leaves and larger area of the leaves in six month old and three year old plants. Similar observations were reported in *Dendrobium* by Yukawa *et al.* (1992).

The fan and pad system recorded higher number of stomata in both the stages of plants (38.34, 38.93). Under fan and pad system, the uniform environmental conditions were maintained throughout the growth phase of the plants. This might be the adaptations for maintaining the physiological processes of the plants.

Data showed the interaction of POP + PGPRE + bone meal and top ventilated polyhouse in six month old plants (44.92), POP + OM + VW + PGPRE + bone meal + GR and top ventilated polyhouse in three year old plants had more influence on number of stomata (44.92). This might be due to the fact that in top ventilated polyhouse, the favourable environmental conditions would have influenced the number of stomata in the leaves of both stages of plants.

Rate of photosynthesis :

An examination of the data in the Tables 1 and 2 showed that the combination of POP + OM + VW + PGPRE + bone meal in six month old plants recorded significantly higher rate of photosynthesis (6.36 µmol CO_2 m^{-2} s^{-1}). The positive effect of POP + OM + VW + PGPRE + bone meal in increasing DMP and CGR were recorded in earlier results which indicated that higher the rate of photosynthesis would increase the food reserves which subsequently increased DMP and CGR.

Top ventilated polyhouse in six month old plants and fan and pad system in three year old plants recorded highest photosynthetic rate (6.86 µmol CO_2 m^{-2} s^{-1}, 5.20 µmol CO_2 m^{-2} s^{-1}). This could be explained by the fact that the six month old plants were in active growth stage. Under top ventilated polyhouse system, high temperature (Fig. 1) and high light intensity (Fig. 3) resulted in higher rate of photosynthesis, whereas in three year old plants, uniform environmental conditions of fan and pad system resulted in higher rate of photosynthesis.

The combination of POP + OM + VW + PGPRE + bone meal and top ventilated polyhouse in six month old plants (9.73 µmol CO_2 m^{-2} s^{-1}), POP + OM + VW + PGPRE + bone meal + GR and fan pad system in three year old plants recorded maximum rate of photosynthesis (8.72 µmol CO_2 m^{-2} s^{-1}). The interaction results in the six month old plants conformed the earlier results in independent observations, whereas in three year old plants, the treatment POP + OM + VW + PGPRE + bone meal + GR was performed well under fan and pad system for recording highest photosynthetic rate.

Transpiration rate at night time :

The treatment POP + PGPRE + bone meal in six month old plants recorded highest rate of transpiration during night

Table 4 : Influence of plant growth promoters (T), growing systems (S) and T × S interaction on diffusive resistance and chlorophyll content in three year old plants of *Dendrobium* cv. EARSAKUL

Treatments	Diffusive resistance (S cm^{-1})				Chlorophyll a (mg g^{-1} leaf wt.)				Chlorophyll b (mg g^{-1} leaf wt.)				Total chlorophyll (mg g^{-1} wt.)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	16.00	17.03	6.65	13.23	0.14	0.29	0.08	0.17	0.18	0.13	0.11	0.14	0.32	0.42	0.19	0.31
T_2	10.72	9.23	8.49	9.48	0.12	0.27	0.10	0.16	0.15	0.12	0.13	0.13	0.27	0.39	0.23	0.30
T_3	21.27	8.10	11.32	13.56	0.09	0.40	0.12	0.20	0.20	0.20	0.09	0.15	0.28	0.60	0.22	0.35
T_4	12.60	22.80	14.90	16.77	0.15	0.29	0.08	0.17	0.17	0.14	0.11	0.14	0.32	0.43	0.19	0.31
T_5	13.55	34.81	7.16	18.51	0.19	0.30	0.09	0.18	0.28	0.14	0.14	0.19	0.47	0.44	0.22	0.37
T_6	6.07	17.83	9.93	11.28	0.11	0.31	0.09	0.17	0.25	0.08	0.10	0.14	0.36	0.39	0.19	0.31
Mean	13.37	18.30	9.74		0.13	0.31	0.09		0.20	0.13	0.11		0.33	0.44	0.20	
C.D.	T: 5.57				T: NS				T: 0.05				T: NS			
(P=0.05)	S: 3.94				S: 0.05				S: 0.03				S: 0.06			
	T × S: 9.66				T × S: 0.11				T × S: 0.09				T × S: 0.17			

NS=Non-significant

(Table 1). The *P. indica* and plant growth promoters access to more growth and more water and hence promoted higher rate of transpiration.

Among systems of growing, top ventilated polyhouse recorded highest rate of transpiration in six month old plants (0.32 µmol m^{-2} s^{-1}). This could be due to higher temperature, lower relative humidity (Fig. 1 and 2) would resulted in gradient in vapour pressure deficit resulting in higher rate of transpiration. The results in the present study were parallel with the findings of Nagoaka *et al.* (1984) and Samasya (2000) in *Dendrobium*.

In interaction, the combination of POP + OM + VW + PGPRE + bone meal + GR and top ventilated polyhouse in six month old plants (0.46 µmol m^{-2} s^{-1}), POP + OM + VW + PGPRE + bone meal + GR and fan and pad system in three year old plants recorded highest transpiration rate during night time (0.29 µmol m^{-2} s^{-1}). This might be due to reason that positive influences of plant growth promoter's favours for better growth of the plants *i.e.* number of leaves per plant, leaf area, number of stomata were higher in earlier results. Higher temperature and lower relative humidity prevailing in side top ventilated polyhouse favour for higher transpiration rate in six month old plants.

Transpiration rate at day time :

A perusal of the data from Tables 1 and 2 revealed that the combination of POP + OM + VW + PGPRE + bone meal in six month old plants and NPK + GR + OM + VW + PGPRE + bone meal in three year old plants recorded significantly higher rate of transpiration during day time. This might be due to positive influence of all applied plant growth promoters favour for luxurious growth of the plants there by resulted in increased rate of transpiration during day time and *i.e.* the indication for healthy growth of the plants.

Among systems of growing, top ventilated polyhouse in six month old plants and two level shade house in three year old plants recorded maximum rate of transpiration during day time (6.00, 4.90 µmol m^{-2} s^{-1}). The reasons for highest transpiration rate under top ventilated polyhouse are higher temperature, high light intensity and low relative humidity (Fig. 1, 2 and 3). In high light intensity, the water present in mesophyll cells diffuses rapidly resulting in increase in humidity of internal air and this increases the rate of transpiration (Cho and Kwack, 1996). In three year old plants also, the environmental conditions prevailing in two level shade house would have influenced higher rate of transpiration during day time.

The combination of NPK + GR and top ventilated polyhouse in six month old plants (9.19 µmol m^{-2} s^{-1}), NPK + GR + OM + VW + PGPRE + bone meal and two level shade house in three year old plants recorded significantly highest rate of transpiration during day time (8.73 µmol m^{-2} s^{-1}).

Diffusive resistance :

The input NPK + GR + OM + VW + PGPRE + bone meal in six month old plants (13.66 S cm^{-1}) and NPK + GR in three year old plants recorded significantly higher diffusive resistance (18.51 S cm^{-1}) (Table 3 and 4). It is evident that the rate of transpiration during day time was low in earlier results in the treatment NPK + GR + OM + VW + PGPRE + bone meal in six month old plants (Table 1) and NPK + GR in three year old plants (Table 2). The rate of transpiration is lower and the diffusive resistance was generally higher. This is most likely because of the lower water absorption by the plants. These results are in conformity with the findings of Stancato *et al.* (2002) in *Cattleya*.

Two level shade house in six month old plants and top ventilated polyhouse in three year old plants recorded higher diffusive resistance (10.98 S cm^{-1}, 18.30 S cm^{-1}). The favourable environmental conditions of the systems which might have resulted in higher diffusive resistance in two level shade house and top ventilated polyhouse.

The combination of NPK + GR + OM + VW + PGPRE + bone meal and two level shade house in six month old plants, NPK + GR and top ventilated polyhouse in three year old plants had significant influence on diffusive resistance (Table 4). This might be due to the influence of plant growth promoters and systems of growing influenced diffusive resistance.

Chlorophyll content :

The effect of treatments on chlorophyll 'a' content was not significant in both stages of plants. Top ventilated polyhouse had significant influence on chlorophyll 'a' content in three year old plants (Table 4). The combination of NPK + GR + OM + VW + PGPRE + bone meal and two level shade house in six month old plants (0.25 mg g^{-1} leaf weight), POP + OM + VW + PGPRE + bone meal and top ventilated polyhouse in three year old plants recorded significantly higher chlorophyll 'a' content (0.40 mg g^{-1} leaf weight).

The treatment NPK + GR recorded significantly higher chlorophyll 'b' content in three year old plants (0.19 mg g^{-1} leaf weight). Among systems of growing, two level shade house had maximum influence on chlorophyll 'b' content irrespective of the age of the plants (Tables 3 and 4). The combination of POP + OM + VW + PGPRE + bone meal + GR (0.75 mg g^{-1} leaf weight) and NPK + GR responding more influence on chlorophyll 'b' content in two level shade house in both stages of the plants.

The ratio of chlorophyll 'a' to chlorophyll 'b' in the chloroplast is normally 3:1. It is known that the chlorophyll a to b ratio is higher in high-light growth conditions than in low - light growth conditions (*i.e.* more chlorophyll b in shade plants). Chlorophyll 'b' absorbs light at different wavelengths than chlorophyll 'a' and extends the range of light that could be used for photosynthesis.

It is inferred that, application of different plant growth promoters had no significant effect on total chlorophyll content in both stages of plants (Tables 3 and 4). The application of plant growth promoters did not showed variation on total chlorophyll content of leaves. Two level shade house in six month old plants and top ventilated polyhouse in three year old plants recorded significantly higher total chlorophyll content. The reason might be explained that due to favourable weather conditions in the systems, the growth of the plants is luxurious because of the higher total chlorophyll content. The combination of POP + OM + VW + PGPRE + bone meal + GR and two level shade house in six month old plants, POP + OM + VW + PGPRE + bone meal and top ventilated polyhouse in three year old plants recorded significantly higher total chlorophyll content (Table 4). This is explained that, when there is a higher total chlorophyll content and naturally higher the plant growth, higher rate of photosynthesis, more transpiration occur as per previous results and hence the result for higher total chlorophyll content in the leaves. The amount of chlorophyll present had a direct relationship with the rate of photosynthesis because it is the pigment which is photoreceptive and is directly involved in trapping the light energy. Similar type of observations was also made by Suthar (2010).

From the above investigation, it is concluded that plant growth promoters POP + OM + VW + PGPRE + bone meal + GR and top ventilated polyhouse (T_4S_2) had maximum influence on physiological parameters like leaf area, DMP, CGR and RGR. The association of *P. indica* in root system of *Dendrobium* cv. EARSAKUL was highly significant and the *P. indica* fungus enhances higher root absorption and facilitates the growth parameters significantly.

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