STANDARDISATION OF SHADE REQUIREMENT IN *Dendrobium*

By

SHERON FERNANDEZ

THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DEPARTMENT OF POMOLOGY AND FLORICULTURE
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DECLARATION

I hereby declare that this thesis entitled **"Standardisation of shade requirement in *Dendrobium*"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
14.12.2001

SHERON FERNANDEZ

CERTIFICATE

Certified that this thesis, entitled **"Standardisation of shade requirement in *Dendrobium*"** is a record of research work done independently by **Miss. Sheron Fernandez** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Dr. A. Sobhana
Chairperson, Advisory Committee
Assistant Professor
Department of Pomology and Floriculture
College of Horticulture
Vellanikkara, Thrissur

Vellanikkara
14.12.2001

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Miss. Sheron Fernandez,** a candidate for the degree of **Master of Science in Horticulture** with major in **Pomology and Floriculture,** agree that the thesis entitled **"Standardisation of shade requirement in *Dendrobium*"** may be submitted by Miss. Sheron Fernandez, in partial fulfilment of the requirements for the degree.

31/1/02

Dr. A. Sobhana
(Chairperson, Advisory Committee)
Assistant Professor
Department of Pomology and Floriculture
College of Horticulture
Vellanikkara, Thrissur

31 01 02

Dr. P.K. Rajeevan
(Member, Advisory Committee)
Associate Professor & Head
Department of Pomology and Floriculture
College of Horticulture
Vellanikkara, Thrissur

31/1/02

Dr. A. Suma
(Member, Advisory Committee)
Associate Professor
Banana Research Station, Kannara
Kerala Agricultural University
Thrissur

31/1/02

Dr. E.K. Lalitha Bai
(Member, Advisory Committee)
Associate Professor
Department of Agrometeorology
College of Horticulture
Vellanikkara, Thrissur

31/1/2002

EXTERNAL EXAMINER
Dr.Jayaprasad K.V.
Associate Professor
Department of Horticulture
University of Agricultural Sciences
Bangalore

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*Affectionately Dedicated
to my beloved
Daddy and Mummy*

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

INTRODUCTION

Orchids, a charming group of flowering plants, with their flowers exhibiting an incredible range of diversity in size, shape, form, fragrance, colour and beauty, are well known all over the world for their horticultural value, especially for their keeping quality. These pampered plants are doyen among the ornamentals and have contributed significantly to the international trade in cut-flowers and potted plants.

Orchids comprise the largest family of flowering plants. Taxonomically, they belong to the family Orchidaceae coming under the monocotyledons, with 600-800 genera and 25,000-35,000 species. Majority of the orchids known in cultivation are natives of tropical countries and occur in their greatest diversity in humid tropical forests of south and central America, India, Sri Lanka, Myanmar, South China, Thailand, Malaysia, Brazil, Philippines, New Guinea, Australia etc. Nearly 14 per cent of the orchid species known today are represented in India. Among these, *Dendrobium* is one of the major groups cultivated here. They are the gem orchids known for their diverse morphological features and beautiful flowers.

The orchid industry in India is still in its infancy. Some growers in Sikkim, West Bengal and Kerala have started organised orchid cultivation. In Kerala, cultivation of orchids was started by a few growers in Thiruvananthapuram district as early as 1970's. It is only very recently that commercial cultivation on scientific basis has started in Kerala (Chadha, 1992). According to the Federation of Indian Floricultural Association (1997), about 14 lakh orchids are cultivated in the state. Of these, dendrobiums occupy more than 90 per cent of cultivated orchids. Some of the commonly cultivated hybrids include Sonia 17, Sonia 28, Sonia Bom Jo, Renappa, Kasem White, Emma White etc.

Kerala is identified as one of the few places in the world where sophisticated infra structure is not required for orchid cultivation. More than 30 hybrids of *Dendrobium* are under commercial cultivation in Kerala. These hybrids differ widely not only with respect to the morphological features of plants and flower spikes but also in their response to the various external factors. The practices being adopted here, require slight changes in order to exploit the available agro-climatic conditions (Rajeevan, 1997).

The floriculture world is highly competitive and quality conscious. A perusal of the existing floriculture scenario of Kerala reveals that one of the obvious constraints for the development of the orchid industry is poor infra-structure for plant production in laboratory and field (Seeni and Bejoy, 1997). When the requirement of infra structure is focussed upon, regulation of light is proved to be a key to the successful commercial cultivation of this genus, since they are shade loving orchids. Optimum light intensity is highly essential for the proper growth, timely flowering and production of quality spikes.

In this context, a study was undertaken in *Dendrobium* var. Sonia Bom Jo and Renappa, with the following objectives:

- Influence of shade on growth parameters and flowering
- Influence of shade on pigment content
- Influence of shade on nutrient uptake by the plant
- Influence of shade on post harvest characters

Review of Literature

2. REVIEW OF LITERATURE

Orchid industry in Kerala has obtained commercialization very recently. The state is considered as agro-ecologically congenial for the cultivation of orchids but commercial production requires slight modification of growing conditions, to meet with international market. Efforts have been made in this chapter to review the available information for the effect of environmental factors mainly light and humidity, on growth performance of orchids.

Considering light as an important factor for growth, researches are being carried out to establish a fast growth production system in orchids (Ichihashi, 1990). Light quality affects plants, morphologically, biochemically and physiologically through its action on phytochromes and other pigments associated with light-mediated regulation of biological processes (Lopez- Juez *et al.*, 1990).

2.1 Light requirement in orchids

Available light is one of the critical factors which influences plant responses. Several workers have reported on the light requirement of the major genera of orchids.

Sessler (1978) outlined the light needs of major orchid genera and pointed out that those which needed greater illumination for flowering were *Cattleya* and *Oncidium* (2000 to 4000 ft-c), *Cymbidium* and *Dendrobium* (3000 ft-c) and the Miltonia (2000 to 3000 ft-c). While Sheehan and Sheehan (1979) reported that optimum light requirement for *Phelaenopsis* is 1500 ft-c. Likewise, Bose and Yadav (1986) reported that illumination levels ranging from 2,400 to 3,600 ft-c were needed for *Arachnis* and its hybrids, *Dendrobium, Oncidium* and *Vanda,* with a temperature of 18°C to 21°C and a relative humidity of 70 per cent. In temperate climates, supplementary illumination was found to be beneficial for flowering.

Baker and Baker (1993) have described with details of origin and habitat, climatic conditions, cultural recommendations and flowering seasons in the northern and southern hemispheres, of various species of *Miltoniopsis*. Baker and Baker (1995) further reported that *Paphiopedilum armeniacum* is healthiest in rather bright, diffused light of about 1,800 to 2,500 ft-c intensity. According to Ertelt (1995), the initiation of flower spikes in *Peristeria elata* was found to occur with cultivation in moderate to high light i.e., 2000 ft-c during summer and 1800 ft-c in winter.

Reports by Thomas (1996) indicated that *Odontoglossum haryanum* is benefitted by 60-70 per cent shade and found to grow well with summer and winter night temperatures of 21-12°C and 18-15°C, respectively. According to Wood (1996), the genus *Epigeneium,* which is closely related to *Dendrobium,* was found to flower profusely in a green house condition with 60 per cent shade, R.H. maintained at about 85 per cent, falling to 75 per cent by midafternoon and having a minimum night temperature of 17°C and day minima of 20°C and 22°C in winter and summer, respectively.

Yoneda and Sasaki (1978) observed an adverse effect on growth and flowering of *Epidendrum radicans* grown under more than 50 per cent shade.

2.2 Light, temperature and their control

Light, temperature and humidity go hand in hand to bring about good growing conditions for orchids (Sessler, 1978). In the case of orchids, the duration and intensity of light affect the short term functions of metabolism and long term processes of growth and flowering.

Early investigations on supplementary illumination of tropical genera grown under greenhouse conditions revealed beneficial effects with manipulation of light intensities (Walker and Abernathie, 1964; Baer, 1971). In the natural stands of terrestrials like *Liparis lilifolia, Habenaria clavellata* and *Isotria medeoloides*, light was observed to be a critical factor with respect to flowering and seed production than vegetative growth (Stuckey, 1967). According to Sandford (1974), light together with moisture availability were reported to be responsible for the positioning of epiphytes in different vertical levels in the aerial environment. Purseglove (1975) detailed the cultivation of orchids in humid tropics. Gordon (1989a, 1989b and 1989c) observed the varying light conditions under which *Phalaenopsis* cultivars are grown. He stated that light intensity was the chief factor, setting the pace of others such as nutrition, temperature and humidity.

To control light, providing shade was found as an effecitve mechanism in tropical condition. Sessler (1978) opined that in summer, the greenhouse must be shaded for a longer period, so that the rise in temperature of the plants themselves is usually due to the warmth outside and not to the sunlight. Since light is necessary for growth, the shading must only provide relief from the sun's heat and never to eliminate all the light.

There are evidences supporting the effectiveness of temperature on orchid growth. Lee and Lee (1993) observed that high temperatures (20-30°C) enhanced the outgrowth of vegetative shoots, the formation of flower buds, and the development and anthesis of flowers in *Cymbidium ensifolium*.

Adverse effect of temperature was also observed by Park *et al.* (1998), based on the studies on *Platycodon grandiflorus*. Fresh and dry mass, and leaf area at flowering increased with decreasing temperature. Time to flowering from sowing was earliest at high temperatures.

Arditti (1979) observed that rain induced cooling initiates flower development and anthesis in *Dendrobium crumenatum* and some other *Dendrobium* species. The induction of flowers by cooling is an indication that they are sensitive to slight variations in temperature.

Literature reveals that monopodials belonging to the genera *Arachnis, Aranda, Aranthera, Renanthera* and *Vanda* are grown in the tropics under partial to full sunlight while *Dendrobium* is grown under varying amounts of lath shade. Reports from Sri Lanka by Hagen (1976) indicated that *Dendrobium phalaenopsis* types were grown under 40 per cent shade, *Ceratobium* types in zero shade (full sunlight) and intermediate types under 20 per cent shade. In several terrestrials and epiphytes too, growing outdoors under partial shade was found to be satisfactory (Rao and Mohanan, 1986). While Bose and Yadav (1986), Abraham and Vatsala (1981) and Yadav and Bose (1986) too confirmed the prevalence of outdoor cultivation for the high light intensity requiring monopodials and cultivation in pots under shade for the sympodials.

For accelerating flowering, Laeliocattleyas were potted and transferred to a greenhouse bench with 50 per cent shade, minimum night temperature of 10 and 21°C and maximum temperatures of 24 and 35°C in winter and summer, respectively (Adelbery and Darling, 1993). While Baker and Baker (1995) pointed out that warm growing epiphytes experiencing 13°C minimum temperature in winter and 32-35°C maximum temperature in the summer were given moderate light levels of 2000 to 4000 ft-c.

Cruz (1993) and Bridley (1993) have emphasised the importance of the use of plastic shading for cut flower production including orchids. Rault (1988) corroborates this by pointing out that basic requirement of shading in the humid tropical regions is to provide an 'umbrella effect', while a rainshelter can act as a perfect compromise between ventilation and protection from the heavy rains.

Coudroy (1987) in an attempt to measure global radiation inside a polyethylene film covered greenhouse showed that just 70 per cent of the external daily sunlight reaches the plants after transmission through the film.

2.3 Photosynthetic effects

Photosynthesis is one of the most temperature sensitive aspects of growth along with light. The temperature sensitivity of photosynthesis was most closely related to that of the quantum yield of photosystem II driven electron transport and some photo synthetic enzymes, such as ribulose-S-phosphate kinase (Jones, 1983).

Arditti (1982) with sufficient support of literature stated that thick leaved orchids have CAM pathway and a direct relationship exists between stomatal opening and CO_2 fixation in the dark. Studies of Khoo and Hew (1999) also revealed the existence of Crassulacean acid metabolism in *Dendrobium*.

Based on the studies on CAM *Dendrobium* cv. Sonia by He *et al.* (1998) for the response of leaves and flowers to high light and high temperature conditions, it was observed that severe damage occurred in flowers at 38°C than at 28°C under a higher photon flux density (PFD) of 1500 μmol $m^{-2}S^{-1}$.

In *Cattleya*, Lacey (1981) reported that peak photosynthetic efficiency at 20°C was at 10,000 lux and that shading was necessary to maintain the illumination at 10,000 lux. While Wang (1995) reported that *Phalaenopsis* cv. Joseph Hampton, required a photosynthetic photon flux (PPF) of 160 μmol $m^{-2}S^{-1}$ for 12 hrs daily and at 20/15°C day/night air temperature and began spiking in an average of 28 days.

However, Lootens and Heursel (1998) have observed in *Phalaenopsis* hybrids a decreased CO_2 uptake with increasing night temperatures, which in turn may be caused by a higher respiration rate. They even observed that a difference of 5°C between day and night temperatures during the vegetative growth period probably does not induce flowering.

For the orchid cut flower industry, the flower is the economic part. The harvestable yield is the result of carbondioxide fixation and the subsequent allocation of fixed carbon and other assimilates into economically important yield components. Information on assimilate partitioning between sources and sinks is essential for increasing the harvestable component of economically important plants (Gifford and Evans, 1981; Wardlaw, 1990; Farrar, 1992). While Neo (1993) stated that sucrose is the dominant form of reduced carbon transported in thick leaved orchids.

Hew *et al.* (1996) have highlighted some salient features of carbon partitioning in tropical orchids. They stated that inflorescence growth of orchids is primarily source limited, and pinpointed the need of increasing total biomass production as a strategy for increase in yield.

2.4 Influence on morphological characters

Light is one of the most important factors affecting growth. McKendrick (1996) observed that orchids could tolerate shade and stated that a decrease in photosynthetic photon fluence rates (PPFR) led to a decrease in dry weight, an increase in specific leaf area and elongation of the petioles.

Von Noordegraff (1968) had pointed out that in anthurium, a low temperature (< 20°C) associated with heavy shade, was found to slow down leaf growth, with small leaves, dark green in colour with thin long stalks and the plants were flaccid. Krizek and Lawson (1974) found that in controlled environments, higher light intensity and elevated temperatures greatly accelerated vegetative growth (three to four times) of *Cattleya* and *Phalaenopsis*. At an intensity of 3000 ft-c, a day temperature of 32°C and a night temperature of 29°C, an increase in leaf area, leaf elongation, lateral shoot production and growth of aeriel roots was observed. Kubota *et al*. (1993) have noticed an increase in plant dry weight, sugar content, nitrogen absorption, the number of expanded leaves, root number and length in *Phalaenopsis* under higher light intensities. Supporting this, Kititrakunyanun *et al.* (1999) have noticed that *Dendrobium cruentum* put forth best growth at higher light intensities. Plantlets grown under low light intensity had lower dry weight and higher chlorophyll contents than plantlets grown at the higher light intensity.

2.5 Stomatal studies

The size and distribution of stomata in plants are studied in relation to the response of plants to stress, light intensity, temperature, hormonal level and also as an indication of ploidy levels. According to Cutter (1978) the stomatal variability is a humidity related phenomenon, although the light intensity may be implicated. Pardosi *et al.* (1992) and Save *et al.* (1995) have reported the water relations, ABA levels and spectral reflectance of stomatal aperature of *Gerbera jamesonii* Botus.

2.6 Influence on flowering

Flowering in *Dendrobium* is influenced by the light intensities received by the plant.

Earliest reports are there about the effect of high light intensity on flower production (Montgomery and Laurie, 1944). Goh *et al.* (1982) reviewed the light induced responses of flowering in orchids and classified cultivated species and varieties based on their response to light. Trials with the terete leaved *Vanda* Miss Joaquim in Hawaii showed that light intensity is the main determinant of earliness or lateness in the commencement of flowering

(Murashige *et al.*, 1967). Flowering was the earliest under full exposure to sunlight. As available light was decreased, flowering was delayed.

Gerlach (1992) has quoted the flowering periodicity of several orchids including *Dendrobium* species (like *D. vsupelianum, D. biflorum, D. sladie*) as observed in a screen house, under approximate 50 per cent shade.

Based on the work on *Dendrobium* Sonia-16, Thekkayam (1996) reported that a progressive increase in the number of inflorescences produced was observed with increase in the light intensity. She observed that the number of inflorescences was greater under 75 per cent light than under 25 per cent light.

Von Noordegraff (1968) pointed out that in Anthurium, light followed by temperature, had the greatest effect on flower production. Poole and Mc Connel (1971) observed that in anthuriums, the largest number of flowers were produced with least shading, but flower quality was better under higher intensity of shade.

According to Sessler (1978), well developed, firm, long-lasting flowers with strong stems indicated that the light had been adequate throughout the growing period for orchids. Gordon (1989a) observed that the brighter light was involved in the flower induction process and would lead to heavier flower production in *Phalaenopsis*.

In orchid culture, the harvestable organ is flower, which is the sink of foremost concern. Wareing and Patrick (1975) observed that the growth of the inflorescence may be limited by the supply of assimilate (source-limited) or by the capacity of the inflorescence to import or use that assimilate (sink-limited). While again reports state that manipulations of assimilate supply by removal of competing sinks or changing light levels may be confounded by changes in correlative plant hormone signals (Patrick, 1988).

In many plants, it has been found that fruit and seed growth generally dominates the growth of vegetative tissues, but under source-limiting conditions, flowers are poor competitors for assimilates (Wardlaw, 1990). Hew *et al.* (1996) stated that source or sink limiting situations invariably change with plant ontogeny as well as environmental differences.

2.7 Influence on pigment content

2.7.1 Effects on chlorophyll content

Regarding the influence of shade on chlorophyll content, perusal of literature shows that the concentration of chlorophyll per unit weight of leaf increases with shading as reported in the case of plants like cocoa, tea, strawberry, bean, alfa-alfa etc.

Increase in chlorophyll content was noticed in the leaves of shaded cocoa plants (Evans and Murray, 1953 and Guers, 1971). Similar observations were made by Ramaswami (1960) and Venkataswami (1961) in the case of tea.

Chlorophyll content per unit weight of leaf was found to increase in plants grown at lower light intensities, but the chlorophyll content per unit area of leaf surface was very often less than the plants grown in the open (Bjorkman and Holmgren, 1963). Similar observations were made by Cooper and Qualls (1967) in the case of alfa-alfa, and Khossein (1970) in the case of bean plants. Radha (1979) observed that chlorophyll 'a', 'b' and 'total' content of leaves increased with the increased shade intensity in pineapple. While He *et al.* (1998) observed a lowered chlorophyll status in both leaves and flowers of *Dendrobium* cv. Sonia when exposed to full sunlight, indicative of 'chronic' photo inhibition.

Contrary to the earlier reports, in the case of cowpea, Higazi *et al.* (1975) observed that the concentration of total chlorophyll as well as its components 'a' and 'b' decreased by increased shade intensity. In wheat, Moursi *et al.* (1976) observed that all the pigments decreased significantly with increasing shade intensities, viz., 100, 60, 40 or 20 per cent full sunlight, but the ratio of chlorophyll a:b remained constant at all the shade intensities. While Acker (1989) stated that when plant has more than enough light for its photosynthetic needs, it becomes apparent to the human eye by a colour shift or by developing a red pigmentation.

2.7.2 Effect on anthocyanins

According to Griesbach (1983) the flower colour is due to 3 different pigments, viz., chlorophyll, flavanoids and carotenoids. Light intensity, temperature and even soil pH can affect flower colour. High light intensity and high temperature can cause the anthocyanins to break down leading to fading. While Islam *et al.* (1998) opined that the greenish yellow flowers of *alba* plants are without anthocyanins but with carotenoids and chlorophylls, whereas intensely purple ones contain high levels of anthocyanins.

Kuehnle *et al.* (1997) identified anthocyanidins in 28 *Dendrobium* species and hybrids, selected for analysis, based on colour and suitability in cut flower breeding. The colour range contained anthocyanins based on cyanidin, with peonidin occurring as a minor pigment. Anthocyanin concentrations ranged from 0.13 to 0.18 µmoles/g fresh weight in light lavender and peach and upto 3.66 µmoles/g fresh weight in brown.

2.8 Influence on nutrient uptake

In general, the mineral nutrient status of plants was found to improve under shading as in the case of apple, cocoa, spinach and tea. Kraybill (1922) observed higher contents of moisture and nitrogen in shaded apple leaves.

Regarding orchids, Lim *et al.* (1992) found that there was a preferential uptake of ammonium over nitrate. Uptake of nitrate was relatively low and increased with increase in light intensity or when the culture medium was supplemented with sucrose. Ammonium uptake was also affected by light intensity.

Orchids absorb nutrients through their foliage and roots. Sheehan (1966) reported that in *Cattleya,* phosphorus (like nitrogen, potassium and magnesium) was found to enter the plants through the foliage and that three year old roots were able to absorb and translocate ^{32}P as actively on one year old roots. Rahayu (1980) found that the absorption of phosphorus through the leaves was comparable to that through the root in *Phalaenopsis.*

However in *Cymbidium*, Hong *et al.* (1991) found that the uptake of ^{32}P by the root was directly proportional and that of urea was inversely proportional to the relative humidity of the growing environment. Moreover, orchids have built in mechanisms such as the velamen of the roots, additional pathways of photosynthesis (C.A.M.) and a greater leaf longevity and leaf thickness as adaptations to overcome moisture fluctuations in the environment (Benzing, 1986).

While comparing the effects of shade, Guers (1971) reported that cocoa leaves exposed to direct sunlight contained less moisture and nitrogen than shaded leaves. American Holly plant exhibited higher amounts of potassium and magnesium in leaf tissues when the plants were grown at 92 per cent shade (Fretz and Dunham, 1971).

Cantiliffe (1972) observed in spinach that the concentration of potassium in the tissue increased with reduction in the light intensity. Influential effects of shade has been noticed in the case of coffee, where Oladokum (1980) observed that shade significantly affected the nitrogen, phosphorus and potassium contents in plants. According to Wong and Wilson (1980), nitrogen accumulation in all the plant components of green-panic was markedly improved by shading. But the nitrogen yield of siratro in pure sword declined with shading. Lalithabai (1981) also reported that due to shading N, P and K contents increased in all the plants viz., colocasia, sweet potato, turmeric and ginger at different growth stages under varying levels of shade from 0 to 75 per cent (0, 25, 50 and 75%) shade.

Contradictory results were observed by Gopinathan (1981), where he found a higher percentage of N, P and K in cocoa plants grown under direct sunlight.

In *Dracaena sanderiana*, on the other hand, shade had little effect on the leaf nutrient content, except that high shade intensity increased potassium and magnesium, especially in young leaves (Rodriguez *et al.*, 1973). According to Radha (1979) the uptake pattern of major nutrients in pineapple was not greatly influenced by shading. Similar reports have been made by Swapna (1996) in *Philodendron wendlandi*, where the concentration of N, P and K in plants was not subjected to variations when different shade levels were provided.

2.9 The vase life of inflorescence

The longevity of orchid blooms add to their ornamental value. In orchids, the effect of light as such on cut flower longevity has not been reported. In other cut flowers like carnations and chrysanthemums, a rapid aging in the flowers produced during periods of low light intensity has been reported (Lancaster, 1974; Kofranek *et al.*, 1972). This was found to be directly related to their carbohydrate levels.

Ding *et al.* (1980) reported that the age of the inflorescence was correlated with the time taken for 30 per cent drop of the blooms. The younger inflorescence had a greater longevity than the older ones and those having a smaller size had a greater longevity than the larger ones when cut at 30 per cent full bloom stage. In the inflorescences cut at 50 per cent full bloom stage, size had no effect on the vase life.

One of the most important pre-harvest factors influencing the post harvest life of a cut flower is light, the effect of which is largely related to the accumulation of responsible substrates, mainly carbohydrates (Halery and Mayak, 1981).

In *Dendrobium nobile* cultivars, Suto *et al.* (1984) found that storage carbohydrates accumulated in the shoots after the emergence of the last leaf and during the elongation of the floral axis.

Clifford *et al.* (1992) reported that in *Aranda* Tay Swee Eng, assimilate supply to an inflorescence was not only from its subtending leaf but also from several leaves above and below it. The upper fully expanded leaves constituted the main additional source. Such an unrestricted assimilate supply was proposed to be indicative of minimal vascular restriction to assimilate movement.

Materials and Methods

3. MATERIALS AND METHODS

The study on "Standardisation of shade requirement in *Dendrobium*" was carried out in the orchidarium of All India Co-ordinated Floriculture Improvement Project in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara from October 2000 to September 2001.

The materials used and the methodology adopted for the investigation are dealt with in this chapter.

3.1 Location

Vellanikkara is situated at a latitude of 10°31' N and longitude of 76°13' E. The area lies 22.25 m above MSL.

3.2 Climate

The site enjoys a humid tropical climate with the maximum temperature varying from 27.2°C to 37.5°C and the minimum temperature from 19.8°C to 25.5°C during the period of investigation. The mean relative humidity varied from 59 per cent to 87 per cent. The total rainfall recorded during the period of investigation was 2250mm.

The weather parameters recorded during the period are presented in APPENDIX I.

3.3 Planting material

Sonia Bom Jo and Renappa, two popular varieties of *Dendrobium*, were used for the study. Hardened tissue culture plants of 3-4 cm size were planted in pots of 5.0 cm size using coconut husk, brick pieces and charcoal bits as growing media.

Plate 1. *Dendrobium* varieties used for the study

Sonia Bom Jo

Renappa

3.4 Treatment details

The effects of six levels of shade on *Dendrobium* var. Sonia Bom Jo and Renappa were studied.

No. of plants per treatment - 10

No. of replications - 4

Experimental design - Split plot in RBD

Treatments (Shade level)

T_1 - 25%, one level shading

T_2 - 35%, one level shading

T_3 - 50%, one level shading (control)

T_4 - 25%, two level shading

T_5 - 35%, two level shading

T_6 - 50%, two level shading

Shade nets for two level shading were provided such that the final shade level was 25 per cent, 35 per cent and 50 per cent. The lower shade net was removed and replaced with rainshelter during rainy season.

3.4.1 Cladding material

Shade nets - UV stabilized agro-shade nets

Rain shelter - UV stabilized polyethylene film of 70 GSM

3.4.2 Shade house design (Fig. 1)

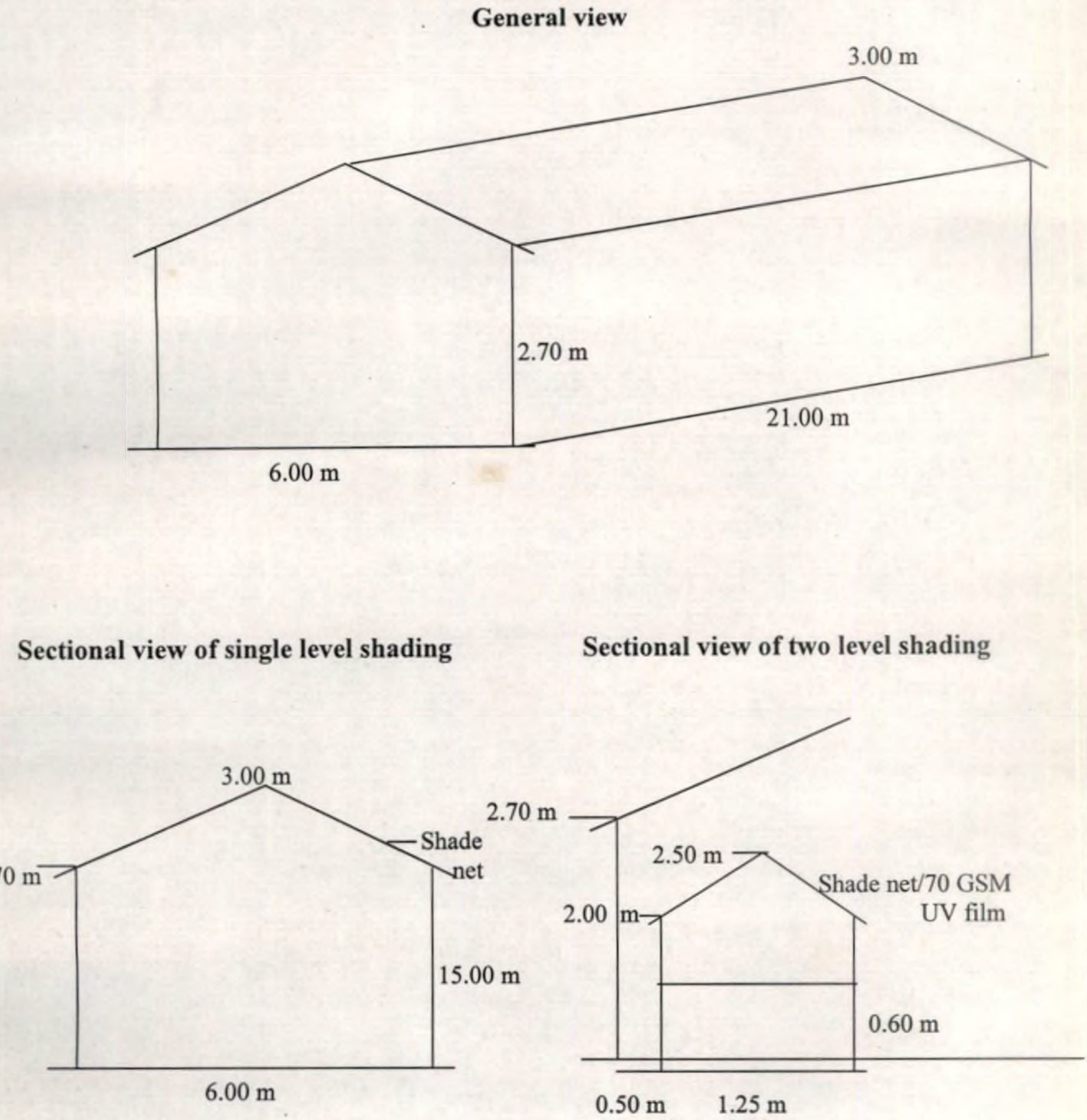
3.5 Cultural practices

Cultural practices were imposed uniformly for all treatment plants.

3.5.1 Inorganic nutrients and growth regulators

Major nutrients N, P and K at two different ratios were used for pre blooming and post blooming stages, separately at 0.2 per cent concentration, weekly twice as foliar spray (Swapna, 2000).

Fig. 1. Structural dimensions of the shade house



Pre blooming : NPK - 30:10:10

Post blooming : NPK - 10:20:20

Nutrient combinations were made using ammonium nitrate, orthophosphoric acid and potassium nitrate.

Growth regulator viz. Benzyl Adenine (BA) was given monthly as foliar spray at 200 ppm concentration during pre blooming stage and at 100 ppm concentration during the post blooming stage (Swapna, 2000).

3.5.2 Organic nutrients and plant protection measures

The plants were sprayed as per the recommendation of the package of practices of Kerala Agricultural University (KAU, 1996).

3.6 Observations

The following observations were taken from four plants each, from both the varieties in the treatment and mean values were recorded.

3.6.1 Growth parameters

Observations on the following plant characters were taken.

3.6.1.1 Plant height

The height of the plant was measured from the base of the tallest shoot to the last node at monthly intervals and expressed in 'cm'.

3.6.1.2 Side shoots

Number of side shoots per plant was counted and recorded.

3.6.1.3 Number of leaves

The total number of leaves were counted and recorded at monthly intervals.

3.6.1.4 Length, breadth and area of the leaf

The length and breadth of each leaf was recorded and the area of leaf was computed using the formula

$a = 2.78 + 0.688\ lb$ (Swapna, 2000)

where a = leaf area in cm^2

l = length of the leaf in cm

b = maximum width of the leaf in cm

3.6.1.5 Total leaf area per plant

The total leaf area was estimated from individual leaf area obtained at monthly intervals.

3.6.1.6 Internodal length

The length of the last developed internode from the mature shoot was taken and expressed in 'cm'.

3.6.1.7 Shoot girth

Girth of the biggest shoot was measured and expressed in 'cm'.

3.6.1.8 Frequency of stomata

A thin layer of *Quickfix* (a commercial adhesive) was applied on the lower surface of the leaves and the epidermal peelings were taken and mounted on a slide. Frequency was calculated as number of stomata per mm^2. Average of 10 fields were taken (Srivastava *et al.*, 1980).

3.6.1.9 Biomass production

Plant samples taken from each treatment was dried in a hot air oven at 70°C for 2-3 days until constant weight was obtained and the weight was expressed in 'g'.

3.7 Observations on flowering

Spike characters were observed as and when the spikes were produced.

3.7.1 Time taken for spike emergence

The time taken for the emergence of first spike in every treatment was recorded in days.

3.7.2 Days from spike emergence to opening of first floret

Time taken for the opening of first floret after spike emergence was recorded in days.

3.7.3 Efficiency of spike production

The total number of inflorescences produced in a plot was recorded, and expressed as the efficiency.

3.7.4 Length of spike, stalk and rachis

The length of the spike, length of flower stalk and length of rachis produced were recorded, mean values worked out and expressed in 'cm'.

3.7.5 Number of flowers per spike

The total number of flowers produced in each spike was recorded and averaged values were expressed as the number of flowers per spike.

3.7.6 Internodal length

Length between florets was recorded as internodal length and expressed in 'cm'.

3.7.7 Size of floret

Size of individual floret was recorded as length (vertically) and width (across) of the flower and expressed in 'cm'.

3.7.8 Longevity of spike on the plant

Duration between opening of the first floret and wilting of the last floret was recorded in days.

3.8 Post harvest characters

3.8.1 Fresh weight of the spike

Immediately after harvest the fresh weight of the spikes was taken and recorded in 'g'.

3.8.2 Days to wilting of first floret

Time taken from the harvest of the spike to wilting of the first floret was recorded in days.

3.9 Measurement of temperature and relative humidity

The microclimate parameters like ambient air temperature and relative humidity were measured using whirling psychrometer at one foot height from the canopy level.

3.10 Chemical analysis

3.10.1 Chlorophyll content

The chlorophyll content of the leaves was determined using Dimethyl sulphoxide (DMSO) (Shoaf and Livm, 1976).

The most recent, fully developed leaf was taken and cut into small pieces. Incubated the sample in 7.0 ml of DMSO at 65°C for 30 minutes. At the end of the incubation period the supernatent solution was decanted and the leaf tissue was discarded. The volume was made up to 10 ml with DMSO. The absorbance was read at 645 and 663 nm using DMSO as blank. Chlorophyll 'a', 'b 'and total ratio was calculated using the formula.

$$\text{Chlorophyll 'a'} = 12.7 (A_{663}) - 2.69 (A_{645}) \times \frac{V}{1000 \times W \times a} \quad (\text{mg g}^{-1} \text{ leaf wt.})$$

$$\text{Chlorophyll 'b'} = 22.9 (A_{645}) - 4.68 (A_{663}) \times \frac{V}{1000 \times W \times a} \quad (\text{mg g}^{-1} \text{ leaf wt.})$$

$$\text{Total chlorophyll} = 20.2 (A_{645}) + 8.02 (A_{663}) \times \frac{V}{1000 \times W \times a} \quad (\text{mg g}^{-1} \text{ leaf wt.})$$

where

A = absorbance at specific wave lengths 645 and 663 nm

V = Final volume of the chlorophyll extract (ml)

W = Fresh weight of the sample (g)

a = Path length of light (1 cm)

10.2 Anthocyanin content

The anthocyanin content of the flower was extracted with methanolic - HCl and the absorbance of the resultant extract was determined at maximum absorption of 525 nm (Sweon and Hills, 1959).

Fresh flowers were cut into small pieces and one gram of the sample was taken and blended in 10 ml of methanol. The extract was filtered and left over residue was ground using alcohol and the process was repeated 3-4 times. Extract was boiled in hot water till the total volume was reduced to 1-2 ml and volume made upto 25 ml with distilled water. One ml of this extract was taken in a test tube, added 3 ml of reagent B, 1 ml of reagent A and 1 ml of reagent C, incubated in dark for 15-20 minutes and the absorbance was measured at 525 nm.

Total anthocyanin content (mg/g sample) =

$$\frac{\text{Absorbance at 525 nm} \times \text{Volume made up of the extract used for colour measurement} \times \text{Total volume}}{\text{Volume of the extract used} \times \text{weight of the sample} \times 98.2}$$

98.2 - The molecular extinction coefficient for 1 μg/ml solution

3.10.3 Nutrient content

The dried plant samples were ground and chemically analysed for macronutrients as detailed below.

3.10.3.1 Total nitrogen

One gram of dried plant sample was digested using concentrated sulphuric acid and analysed for estimating nitrogen, colorimetrically using Nessler's reagent (Wolf, 1982).

3.10.3.2 Total phosphorus and total potassium

Dried plant sample was digested using diacid mixtures of nitric acid and perchloric acid and made upto 100 ml (Johnson and Ulrich, 1959).

Total phosphorus was determined colorimetrically by the Vanado molybdo phosphoric yellow colour method (Jackson, 1958). The yellow colour was read in Spectronic-20 at a wave length of 470 nm.

3.10.3.3 Total potassium

The total potassium content of the above extract was estimated using flame photometer (Jackson, 1958).

3.10.3.4 Nutrient uptake

The nutrient uptake was computed from the values of concentration of the nutrients and dry weight of the parts sampled, and expressed in 'mg'.

3.11 Statistical analyses

Statistical analyses was done using analysis of variance technique (Panse and Sukhatme, 1985). MSTATC and MS-Excel softwares were used for computation and analysis.

Results

4. RESULTS

The results of the experiment conducted to standardise the shade requirement for *Dendrobium* varieties Sonia Bom Jo and Renappa are presented in this chapter.

Results are presented under the following heads.

4.1 Growth parameters

Monthly observations on growth parameters of the varieties, Sonia Bom Jo and Renappa until the ninth month after planting are presented in Tables 1 to 6.

4.1.1 Plant height

The effect of shade on plant height at monthly intervals are presented in Table 1.

Shading affected plant height only at first, fifth, sixth and seventh month after planting. At one month after planting 25 per cent (T_4) and 35 per cent (T_5) two level shading were found superior compared to other treatments, eventhough maximum height was obtained for the former (5.61 cm). All the other treatments were on par, with the least for 25 per cent single level shading (T_1). Fifty per cent, two level shading (T_6) was better than 35 per cent (T_2) and 50 per cent (T_3) single level shading in increasing the plant height. Not much noticeable difference was observed between T_2 and T_3. When treatment comparison was made within variety Sonia Bom Jo, significant results were obtained. T_5 (6.67 cm) was distinctly superior to the other treatments. Treatments T_1, T_2, T_3 and T_6 were on par, while T_4 was better than these in increasing the height. In the case of Renappa, T_4 (5.913 cm) was significantly superior to the other treatments, while the remaining treatments were on par (Fig. 2a and 2b).

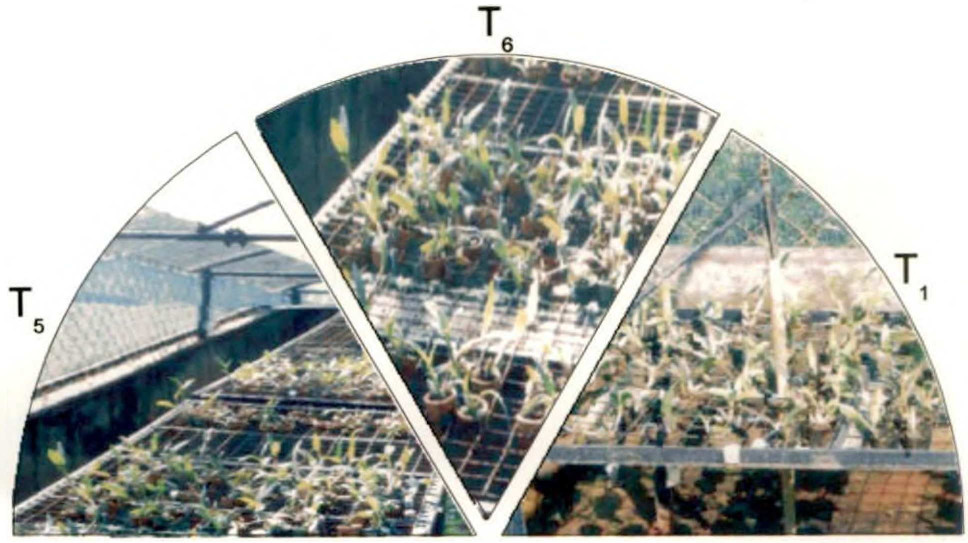


Plate 2. View of the experimental field at the stage of planting

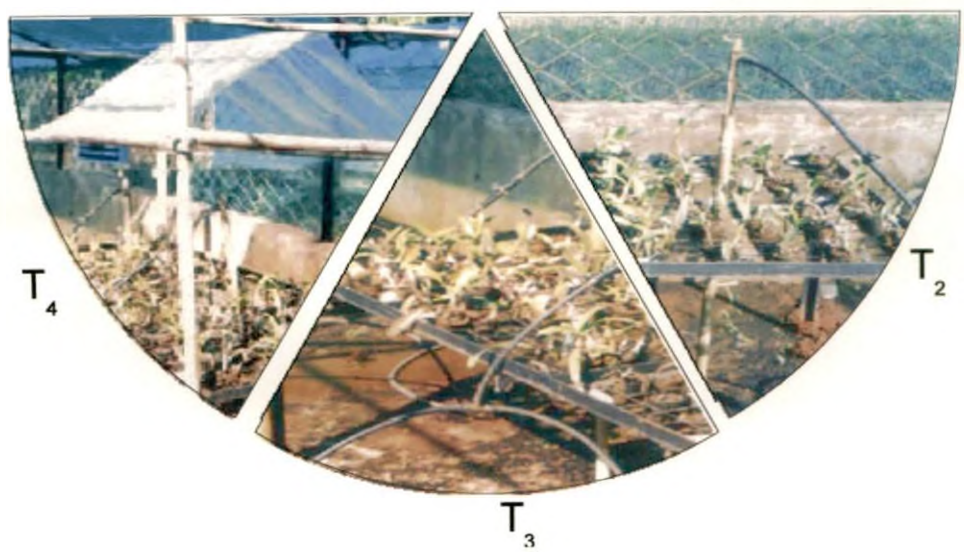


Table 1. Plant height in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatment	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 (25% - 1 level)	4.41	4.32	4.37	5.56	4.93	5.25	6.44	5.65	6.04	6.61	5.35	5.98	7.21	6.07	6.64
T_2 (35% - 1 level)	4.74	4.94	4.84	5.42	5.63	5.52	5.73	6.01	5.87	5.35	6.08	5.72	5.31	6.81	6.06
T_3 (50% - 1 level)	4.83	4.92	4.88	5.35	5.97	5.66	6.86	6.30	6.58	6.88	5.93	6.41	8.11	6.54	7.33
T_4 (25% - 2 level)	5.30	5.91	5.63	5.71	5.96	5.83	6.25	6.10	6.17	6.47	6.13	6.30	8.30	6.96	7.63
T_5 (35% - 2 level)	6.67	4.38	5.52	6.28	5.10	5.69	7.63	7.24	6.93	7.32	5.49	6.41	9.28	6.17	7.72
T_6 (50% - 2 level)	4.94	4.87	4.91	6.00	5.90	5.94	7.02	6.22	6.62	6.66	5.83	6.26	8.42	6.64	7.53
Mean	5.15	4.89		5.72	5.55		6.65	6.09		6.55	5.80		7.77	6.53	
SEm±	0.195			0.313			0.399			0.364			0.436		
CD^1	0.564			NS			NS			NS			NS		
SEm±	0.276			0.443			0.565			0.514			0.617		
CD^2	0.798			NS			NS			NS			1.782		

Treatment	6 MAP			7 MAP			8 MAP			9 MAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 (25% - 1 level)	8.70	6.20	7.46	10.02	7.32	8.67	10.86	8.75	9.85	11.00	8.52	9.76
T_2 (35% - 1 level)	7.35	7.20	7.26	9.00	6.05	7.52	9.75	10.52	10.14	10.09	9.57	9.83
T_3 (50% - 1 level)	9.36	8.10	8.75	11.50	8.98	10.24	12.87	10.11	11.49	13.56	10.19	11.88
T_4 (25% - 2 level)	9.67	8.10	8.90	9.89	9.33	9.61	11.51	9.78	10.64	12.10	10.78	11.44
T_5 (35% - 2 level)	9.75	7.80	8.79	10.39	9.78	10.09	11.39	10.78	11.09	11.72	10.40	11.06
T_6 (50% - 2 level)	9.60	7.70	8.66	11.43	10.52	10.98	10.80	12.54	11.67	11.98	12.98	12.48
Mean	9.07	7.53		10.37	8.66		11.20	10.41		11.74	10.41	
SEm±	0.432			0.606			0.695			0.820		
CD^1	1.248			1.75			NS			NS		
SEm±	0.611			0.857			0.983			1.160		
CD^2	NS			NS			NS			NS		

V_1 - Sonia Bom Jo; V_2 - Renappa; MAP - Months after planting
CD^1 (0.05) - For comparison of treatments
CD^2 (0.05) - For comparison of treatments within varieties

During the second, third and fourth months after planting, plant height did not show any varied significance as influenced by the treatments. But, a substantial increase in height was noted and the mean height ranged from 5.25 cm to 6.41 cm.

The data corresponding to plant height for the fifth month after planting, revealed that the variety Sonia Bom Jo showed significant results with the influence of shade. Treatments receiving more shade intensities such as 50 per cent - single level (T_3), 25 per cent, 35 per cent and 50 per cent - double level shading were statistically on par with each other with the mean height of 8.11 cm, 8.30 cm, 9.28 cm and 8.42 cm respectively. Thirty five per cent - single level shade recorded the least (5.31 cm). However, twenty five per cent - single level performed better than thirty five per cent - single level. The treatment effect was not much pronounced in variety Renappa during this month.

During the sixth month after planting, height of the plant reflected an appreciable significant variation. The peak summer showed an influential effect on plant height. Treatments receiving more shade gave substantial increase, where in T_3, T_4, T_5 and T_6 were superior and statistically on par. However, T_4 gave a better result (8.9 cm) than T_3, T_5 and T_6. T_2 recorded the least (7.26 cm) which was statistically on par with T_1.

Height of the plant made a progressive increase during seventh month and significantly superior results were obtained for treatments T_3, T_4, T_5 and T_6. Fifty per cent - double level shading was distinctly superior, which recorded a maximum height of 10.98 cm. The least recorded height was for thirty five per cent - single level (7.52 cm), while twenty five per cent single level performed better than T_2.

Fig. 2a. Plant height in *Dendrobium* var. 'Sonia Bom Jo' as influenced by different levels of shade

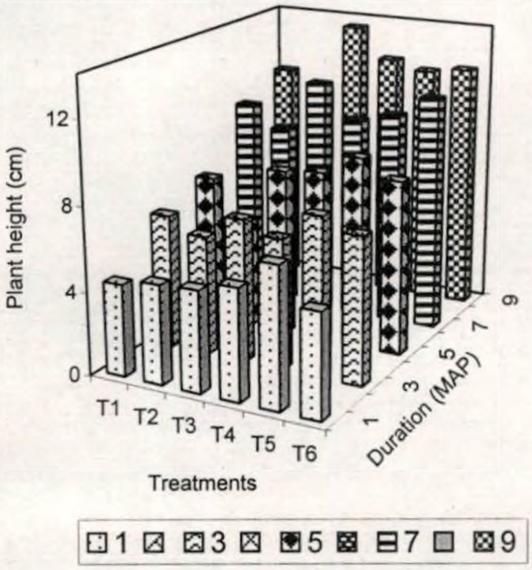
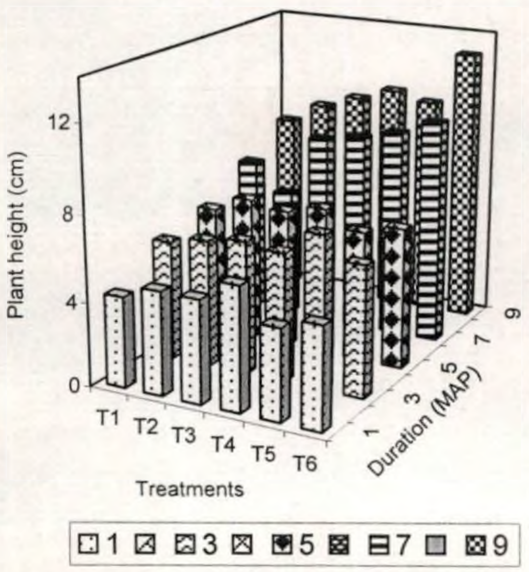


Fig. 2b. Plant height in *Dendrobium* var. 'Renappa' as influenced by different levels of shade



During the eighth and ninth month, not much varied significance was noticed in plant height, for the effect of treatments imposed, maximum height being 12.48 cm in 50 per cent double level shade.

4.1.2 Shoot production

Data regarding shoot production expressed as monthly mean are presented in Table 2.

The number of shoots produced one month after planting did not show much significant variation among treatments and the mean values obtained were around two in different treatments.

During the second month after planting a distinguishable variation was observed among treatments for the number of shoots produced. Thirty five per cent single level shading (T_2) and 35 (T_5) and 50 per cent (T_6) double level shading, were superior compared to others, however T_5 had highest production (2.00). T_2 was better than T_6 in shoot production. Twenty five per cent single level shading gave the least value compared to other treatments (1.44). Treatments receiving 50 per cent single level (T_5) shading and 25 per cent double level shading (T_4) gave intermediate results.

Shoot production for the third month after planting did not show any significant variation between treatments with the advancement of time.

During the fourth month after planting, the shoot number differed significantly and 35 per cent double level shading gave distinctly superior results with mean values of 2.28, while 35 per cent single level shading was inferior (1.78) compared to all the treatments. T_1, T_3, T_4 and T_6 gave intermediate results and were statistically on par.

Table 2. Shoot production in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatment	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 (25% - 1 level)	1.63	1.43	1.53	1.75	1.12	1.44	1.94	1.13	1.53	2.13	1.92	2.02	2.63	1.50	2.06
T_2 (35% - 1 level)	1.94	1.71	1.82	1.94	1.75	1.84	1.56	1.23	1.40	1.81	1.68	1.75	2.13	1.98	2.06
T_3 (50% - 1 level)	2.19	1.83	2.01	1.69	1.81	1.75	1.63	1.44	1.53	2.06	2.03	2.03	1.94	1.75	1.84
T_4 (25% - 2 level)	1.81	1.81	1.81	1.81	1.63	1.72	1.31	1.44	1.38	2.00	1.94	1.97	2.69	2.23	2.46
T_5 (35% - 2 level)	2.25	1.97	2.11	2.00	2.00	2.00	1.44	1.38	1.41	2.44	2.13	2.28	2.00	2.31	2.16
T_6 (50% - 2 level)	1.81	1.85	1.83	1.81	1.75	1.78	1.67	1.86	1.76	2.06	1.81	1.94	2.13	1.81	1.97
Mean	1.94	1.77		1.83	1.68		1.59	1.41		2.08	1.91		2.25	1.90	
SEm±	0.130			0.079			0.126			0.061			0.138		
CD^1	NS			0.228			NS			0.176			0.399		
SEm±	0.184			0.111			0.178			0.087			0.195		
CD^2	NS			NS			NS			NS			0.563		

Treatment	6 MAP			7 MAP			8 MAP			9 MAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 (25% - 1 level)	2.31	1.88	2.09	2.56	1.88	2.22	2.44	1.94	2.19	2.63	2.19	2.41
T_2 (35% - 1 level)	1.94	1.89	1.92	1.88	2.10	1.99	2.06	2.00	2.03	2.25	2.13	2.19
T_3 (50% - 1 level)	1.96	1.98	1.97	2.13	1.71	1.92	2.06	2.15	2.10	2.06	2.04	2.05
T_4 (25% - 2 level)	2.06	2.00	2.03	2.56	2.81	2.69	2.88	2.50	2.69	2.75	2.88	2.81
T_5 (35% - 2 level)	1.94	2.06	2.00	2.31	2.13	2.22	2.31	2.86	2.58	2.50	3.06	2.78
T_6 (50% - 2 level)	2.00	2.02	2.01	2.00	2.08	2.04	2.31	2.19	2.25	2.33	2.42	2.37
Mean	2.04	1.97		2.24	2.12		2.34	2.27		2.42	2.45	
SEm±	0.152			0.163			0.138			0.187		
CD^1	NS			0.471			0.399			0.540		
SEm±	0.214			0.231			0.195			0.264		
CD^2	NS			NS			NS			NS		

V_1 - Sonia Bom Jo; V_2 - Renappa; MAP - Months after planting
CD^1 (0.05) - For comparison of treatments
CD^2 (0.05) - For comparison of treatments within varieties

During the fifth month after planting, significant results were obtained between treatments and for treatments within varieties. Comparison of data on the effect of treatments indicated that T_1, T_4 and T_5 were superior to others and these three were statistically on par, even though 25 per cent double level shading gave the highest shoot production. The least results were obtained for those with highest shade intensity, nevertheless T_3 gave minimum shoot production. When treatment comparison is done within varieties, a distinct significance were observed for those with more light intensity, i.e., 25 per cent single level and 25 per cent, two level shading. Rest of the treatments were on par. In the case of Renappa, appreciable variation between treatments was not observed.

Appreciable difference in shoot production for the different treatments imposed was not observed after six months.

Seven months after planting, the number of shoots produced again gave significant results. T_4, T_5, and T_1 were statistically superior, eventhough the best results were obtained in T_4. T_1 and T_5 were on par in the case of shoot production. The number of shoots were least in T_3 which was statistically on par with T_2 and T_6. Treatment comparison done within the variety was ineffective.

The number of shoots produced differed significantly after eight months of planting. Distinctly superior result was obtained in treatments T_4 and T_5. Other treatments did not have any progressive effects on shoot production. Lowest number of shoots were obtained in T_2 compared to others. Treatments did not vary much within varieties.

Data for the ninth month after planting reveals substantial increase in shoot production for treatments T_1, T_4, T_5 and T_6. Best results were obtained in T_4 (2.81) and T_5 (2.78). T_3 had least shoot production with the mean value of 2.05. While within varieties, treatments did not show much significant variation.

4.1.3 Internodal length

Data showing the effect of different levels of shade treatments on internodal length are presented in Table 3.

When the internodal length for the first month after planting was considered, significant variation was observed between treatments, as well as for treatments within varieties. It was evident that treatments T_2, T_3, T_5 and T_6 were statistically on par with the highest shade treatment (T_6) expressing greatest internodal length (1.94 cm). Treatments T_1 expressed the least (1.15 cm) and T_4 gave intermediate results. When comparison of treatments was done within varieties, a similar trend was observed in Sonia Bom Jo. While in Renappa, T_6 and T_3 were superior to others. T_6 (50 per cent - double level shading) recorded the highest of all (1.76 cm). However, treatments T_1, T_2, T_4 and T_5 were on par with each other.

Shade had influenced the length of internode significantly after the second month. Treatments receiving more shade, viz., T_5 and T_6 gave evident results, T_6 (2.26 cm) having more length for internode than T_5 (2.13 cm). T_1 and T_2 had minimum internode length with T_1 showing least mean value (1.46 cm). T_3 and T_4 were on par with each other and gave intermediate results.

During the third month after planting the internodal length markedly differed in different shade levels, where a significant difference was noticed between treatments and for treatments within varieties. The internodal length observed was distinctly superior for the treatments with highest shade level i.e. 35 (T_5) per cent and 50 per cent (T_6) double level shading, however T_6 recorded highest (2.51 cm) compared to T_5. While the rest of the treatments were on par, with T_1 having the least (2.07 cm). The same trend was observed for treatment

Table 3. Internodal length in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatment	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 (25% - 1 level)	1.24	1.07	1.15	1.84	1.07	1.46	2.21	1.93	2.07	2.38	1.71	2.04	2.31	2.04	2.17
T_2 (35% - 1 level)	2.23	1.13	1.68	1.97	1.09	1.53	2.03	2.13	2.08	2.01	2.04	2.02	1.88	2.51	2.19
T_3 (50% - 1 level)	2.29	1.34	1.82	1.99	1.81	1.90	2.12	2.23	2.17	2.36	1.95	2.15	2.60	2.08	2.34
T_4 (25% - 2 level)	1.77	1.27	1.52	2.06	1.77	1.91	2.04	2.13	2.09	2.34	1.87	2.10	2.53	2.21	2.37
T_5 (35% - 2 level)	2.54	1.14	1.84	2.34	1.92	2.13	2.86	2.09	2.47	2.37	1.85	2.11	2.65	2.03	2.34
T_6 (50% - 2 level)	2.13	1.76	1.94	2.37	2.14	2.26	2.60	2.42	2.51	2.38	2.26	2.32	2.33	2.23	2.28
Mean	2.03	1.28		2.09	1.63		2.31	2.15		2.30	1.95		2.38	2.18	
SEm±	0.113			0.117			0.107			0.127			0.140		
CD^1	0.327			0.338			0.309			NS			NS		
SEm±	0.160			0.165			0.152			0.180			0.198		
CD^2	0.462			NS			0.439			NS			0.572		

Treatment	6 MAP			7 MAP			8 MAP			9 MAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 (25% - 1 level)	2.30	2.00	2.15	2.52	2.21	2.37	3.03	2.41	2.72	3.01	2.41	2.71
T_2 (35% - 1 level)	2.02	1.98	2.00	2.48	2.08	2.28	2.76	2.53	2.64	3.05	2.47	2.76
T_3 (50% - 1 level)	2.69	2.17	2.43	2.77	2.25	2.51	3.02	2.32	2.67	3.26	2.92	3.09
T_4 (25% - 2 level)	2.54	2.10	2.32	2.93	2.50	2.72	3.05	2.22	2.64	3.16	2.88	3.02
T_5 (35% - 2 level)	2.51	2.15	2.33	2.44	2.30	2.37	2.79	3.00	2.89	3.01	2.42	2.72
T_6 (50% - 2 level)	2.40	2.33	2.37	2.57	2.43	2.50	2.58	2.86	2.72	2.94	2.99	2.97
Mean	2.41	2.13		2.62	2.29		2.87	2.56		3.07	2.68	
SEm±	0.109			0.107			0.138			0.124		
CD^1	NS			NS			NS			NS		
SEm±	0.154			0.152			0.196			0.175		
CD^2	NS			NS			NS			NS		

V_1 - Sonia Bom Jo; V_2 - Renappa; MAP - Months after planting
CD^1 (0.05) - For comparison of treatments
CD^2 (0.05) - For comparison of treatments within varieties

comparison within Sonia Bom Jo, while in Renappa all the treatments were on par except T_1 with the least internodal length (1.93 cm).

Fourth month after planting, internodal length did not show any varied significance as influence by the treatments.

At five month stage, the treatments showed significant results within variety Sonia Bom Jo. T_1, T_3, T_4, T_5 and T_6 were outstanding and statistically on par, eventhough 35 per cent double level (2.65 cm) and 50 per cent single level (2.60 cm) performed better. Minimum increase in internodal length was noticed for 35 per cent and 25 per cent single level shading, where 35 per cent single level shading recorded the lowest value.

In the subsequent months, shade levels did not influence the internodal length, eventhough a progressive increase in length was observed, with advancing age of the plant.

4.1.4 Shoot girth

Data related to the girth of shoot as influenced by different treatments are presented in Table 4.

One month after planting, shoot girth expressed a significant variation between treatments, while, within varieties it was not significant. The girth was more for T_3 (3.08 cm) eventhough T_4 and T_5 were on par with T_3. The treatment T_1 had least girth (2.01 cm). Treatments T_2 and T_6 gave intermediate results and both of them were statistically similar.

The influence of shade on shoot girth was not significant in the second month after planting.

Table 4. Shoot girth in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatment	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 (25% - 1 level)	1.99	2.02	2.01	2.81	2.63	2.72	3.53	3.31	3.42	3.52	3.41	3.46	3.65	3.52	3.59
T_2 (35% - 1 level)	2.82	2.79	2.80	3.20	2.64	2.92	3.57	3.19	3.38	3.53	3.34	3.43	3.61	3.52	3.56
T_3 (50% - 1 level)	3.12	3.03	3.08	3.40	2.84	3.12	3.62	3.00	3.31	3.51	3.04	3.27	3.61	3.20	3.41
T_4 (25% - 2 level)	3.02	3.02	3.02	3.27	2.78	3.02	2.99	3.07	3.03	3.28	3.24	3.26	3.47	3.39	3.43
T_5 (35% - 2 level)	2.90	2.92	2.91	3.16	2.51	2.84	3.38	2.52	2.95	3.45	2.68	3.06	3.59	2.81	3.20
T_6 (50% - 2 level)	2.84	2.67	2.75	3.11	2.65	2.88	2.99	2.75	2.87	3.14	2.80	2.97	3.46	2.92	3.19
Mean	2.78	2.74		3.16	2.67		3.35	2.97		3.41	3.08		3.56	3.23	
SEm±	0.095			0.106			0.041			0.149			0.145		
CD^1	0.274			NS			0.406			NS			NS		
SEm±	0.134			0.078			0.199			0.211			0.204		
CD^2	NS			NS			NS			NS			NS		

Treatment	6 MAP			7 MAP			8 MAP			9 MAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 (25% - 1 level)	3.07	2.91	2.99	3.20	2.98	3.09	3.32	3.11	3.21	3.75	3.25	3.50
T_2 (35% - 1 level)	3.13	2.81	2.97	3.22	2.87	3.05	3.33	3.00	3.16	3.93	3.17	3.55
T_3 (50% - 1 level)	3.55	2.69	3.12	3.68	2.79	3.24	3.90	2.97	3.43	3.91	2.94	3.42
T_4 (25% - 2 level)	3.10	2.55	2.83	3.24	2.67	2.96	3.37	2.68	3.02	3.67	3.15	3.41
T_5 (35% - 2 level)	3.04	2.93	2.99	3.14	2.97	3.05	3.29	2.95	3.12	3.49	2.87	3.18
T_6 (50% - 2 level)	2.97	2.99	2.98	3.07	3.13	3.10	3.23	3.11	3.17	3.18	3.20	3.19
Mean	3.14	2.81		3.26	2.90		3.41	2.97		3.65	3.10	
SEm±	0.115			0.115			0.111			0.116		
CD^1	NS			NS			NS			NS		
SEm±	0.163			0.162			0.157			0.164		
CD^2	NS			NS			NS			NS		

V_1 - Sonia Bom Jo; V_2 - Renappa; MAP - Months after planting
CD^1 (0.05) - For comparison of treatments
CD^2 (0.05) - For comparison of treatments within varieties

The effect of treatments on shoot girth showed significant variation during the third month. The data revealed that, those treatments which received more height had more girth. Though the treatments T_1, T_2, T_3 and T_4 were statistically on par, those treatments receiving the maximum light intensity (25 per cent single level shading) was superior to all. T_2 recorded more shoot girth than T_3, while T_4 had the least. However, treatments T_5 and T_6 gave minimum girth compared to others and 50 per cent - double level (T_6) shading had least girth for the shoot among the treatments.

In the subsequent months the shoot girth did not give much significant variation for the various treatments imposed, eventhough a progressive increase in length was observed.

4.1.5 Leaf production

Data on the influence of different shade treatments on leaf production are presented in Table 5.

Leaf production for the first month after planting did not produce any appreciable difference for the various treatments imposed. The mean values varied around two.

During the second month after planting a significant variation in leaf number was noticed. Twenty five per cent double level (T_4) shading had highest leaf production with a mean value of 1.97. Fifty per cent single level (T_3) shading also gave outstanding results as the former (1.94). However, T_2, T_3, T_4 and T_5 were statistically on par. T_1 gave the lowest leaf production with the mean value of 1.64.

Leaf production during the third, fourth and fifth month after planting did not give much significant variation for the influence of treatments.

Table 5. Leaf production/plant in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatment	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 (25% - 1 level)	1.69	1.62	1.65	1.69	1.59	1.64	1.81	1.81	1.81	1.81	1.77	1.79	2.25	1.94	2.09
T_2 (35% - 1 level)	2.06	1.62	1.84	1.81	1.73	1.77	1.68	1.69	1.68	1.75	2.08	1.92	2.13	1.97	2.05
T_3 (50% - 1 level)	2.00	1.93	1.97	1.81	2.06	1.94	1.75	1.88	1.81	1.81	1.56	1.69	2.50	1.81	2.16
T_4 (25% - 2 level)	1.88	1.93	1.90	1.94	2.00	1.97	1.81	1.96	1.89	2.13	1.75	1.94	2.81	1.86	2.33
T_5 (35% - 2 level)	1.94	1.74	1.84	1.69	1.88	1.78	1.56	1.81	1.69	1.88	1.88	1.88	2.44	2.31	2.38
T_6 (50% - 2 level)	1.88	1.75	1.81	1.61	1.69	1.65	1.75	1.52	1.63	1.81	1.81	1.81	2.13	2.33	2.23
Mean	1.91	1.77		1.76	1.82		1.73	1.78		1.87	1.81		2.38	2.04	
SEm±	0.103			0.078			0.064			0.082			0.151		
CD^1	NS			0.225			NS			NS			NS		
SEm±	0.146			0.146			0.097			0.116			0.141		
CD^2	NS			NS			NS			NS			NS		

Treatment	6 MAP			7 MAP			8 MAP			9 MAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 (25% - 1 level)	2.44	2.31	2.38	3.06	3.31	3.19	3.25	3.31	3.28	3.19	2.75	2.97
T_2 (35% - 1 level)	2.38	2.44	2.41	3.38	3.12	3.25	3.19	3.50	3.34	2.88	3.50	3.19
T_3 (50% - 1 level)	2.38	2.52	2.45	3.38	2.98	3.18	3.25	3.44	3.34	2.94	3.13	3.03
T_4 (25% - 2 level)	2.31	2.94	2.63	3.00	3.00	3.00	3.13	3.69	3.41	2.81	3.19	3.00
T_5 (35% - 2 level)	2.56	3.13	2.84	3.38	4.13	3.75	3.44	3.94	3.69	3.38	3.50	3.44
T_6 (50% - 2 level)	2.94	2.50	2.72	3.75	4.27	4.01	3.63	4.00	3.81	3.25	3.54	3.40
Mean	2.50	2.64		3.32	3.47		3.31	3.65		3.07	3.27	
SEm±	0.105			0.147			0.154			0.161		
CD^1	0.303			0.425			NS			NS		
SEm±	0.148			0.208			0.217			0.228		
CD^2	0.427			NS			NS			NS		

V_1 - Sonia Bom Jo; V_2 - Renappa; MAP - Months after planting
CD^1 (0.05) - For comparison of treatments
CD^2 (0.05) - For comparison of treatments within varieties

During the sixth month after planting the leaf number per plant showed a significant variation which was markedly influenced by shade. Treatments imposed with double level shade were found outstanding compared to single shade levels. Of these, best results were obtained for 35 per cent double level shading (T_5) with a mean value of 2.84. T_6 was superior to T_4, eventhough all the three were statistically on par with each other. Single level shading showed an appreciable reduction and the least result (2.38) was obtained for T_1, while T_3 gave higher leaf production than T_1. When a comparison of treatments was done within variety a similar trend as above was noticed. In Sonia Bom Jo, the two level shade treatments T_5 and T_6 were superior compared to others, with, T_6 giving better result. While in Renappa, T_4 and T_5 of the double level shade group were outstanding with the highest leaf production for T_5. T_1 gave the least production of leaves.

Mean number of leaves produced was markedly influenced by shade after the seventh month. The treatments receiving more shade level had more leaves and outstanding results were obtained in 50 per cent double level shading, though it was statistically on par with 35 per cent double level shading. All the other treatments gave minimum leaf production. Within the variety, the treatments did not reflect any significant variation.

In the subsequent months, not much significant variation was observed in the number of leaves produced.

4.1.6 Leaf area per plant

Data pertaining to leaf area (cm^2) are expressed on monthly means in Table 6.

During the initial month after planting, a distinct significant variation was observed with reference to leaf area. Among the treatments, single level

Table 6. Leaf area per plant in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatment	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 (25% - 1 level)	12.30	12.34	12.32	18.62	18.69	18.65	23.37	24.57	23.97	19.47	20.08	19.77	28.91	22.10	25.51
T_2 (35% - 1 level)	19.67	20.40	20.03	18.58	18.55	18.57	18.68	24.91	21.80	16.77	25.70	21.23	29.97	29.29	29.63
T_3 (50% - 1 level)	27.29	26.65	26.97	21.87	23.75	22.81	22.17	21.71	21.94	19.93	17.50	18.71	37.86	18.70	28.28
T_4 (25% - 2 level)	18.57	18.40	18.48	21.44	22.18	21.81	20.70	23.78	22.24	22.73	20.65	21.69	42.31	22.62	32.46
T_5 (35% - 2 level)	20.76	20.65	20.70	18.56	20.73	19.65	21.88	21.35	21.61	25.17	21.45	23.31	40.81	28.74	34.77
T_6 (50% - 2 level)	20.22	19.83	20.02	17.34	19.11	18.23	19.38	17.40	18.39	21.00	20.55	20.77	35.98	31.01	33.50
Mean	19.80	19.71		19.40	20.50		21.03	22.29		20.84	20.99		35.97	25.41	
SEm±	0.985			1.293			1.547			1.518			2.630		
CD^1	2.845			NS			NS			NS			NS		
SEm±	1.393			1.827			2.187			2.147			3.719		
CD^2	NS			NS			NS			NS			NS		

Treatment	6 MAP			7 MAP			8 MAP			9 MAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1 (25% - 1 level)	38.46	27.61	33.03	49.18	46.26	47.72	55.74	50.66	53.20	62.39	47.77	55.08
T_2 (35% - 1 level)	33.91	33.36	33.64	52.73	43.81	48.27	56.16	60.53	58.34	54.31	56.97	55.64
T_3 (50% - 1 level)	40.34	34.85	37.59	59.69	45.06	52.37	63.14	51.81	57.47	63.46	54.74	59.10
T_4 (25% - 2 level)	41.72	42.17	41.95	55.62	45.26	50.44	59.91	51.50	55.70	55.05	56.86	55.95
T_5 (35% - 2 level)	48.69	50.94	49.82	52.40	65.62	59.01	67.80	65.45	66.62	67.37	61.82	64.59
T_6 (50% - 2 level)	52.67	42.76	47.72	67.65	73.07	70.36	69.35	83.10	76.23	73.79	80.17	76.98
Mean	42.63	38.61		56.21	53.18		62.02	60.51		62.73	59.72	
SEm±	2.761			4.173			3.91			4.57		
CD^1	7.974			12.05			11.29			13.20		
SEm±	3.904			5.902			5.536			6.469		
CD^2	NS			NS			NS			NS		

V_1 - Sonia Bom Jo; V_2 - Renappa; MAP - Months after planting
CD^1 (0.05) - For comparison of treatments
CD^2 (0.05) - For comparison of treatments within varieties

shading at 50 per cent level (T_3) gave superior results (26.97 cm^2) compared to all. While 25 per cent single level shading (T_1) gave minimum leaf area with a mean value of 12.32 cm^2. However, T_2, T_4, T_5 and T_6 were on par (Fig. 3a and 3b).

Shade levels did not effect the leaf area at second, third, fourth and fifth month stage of the plant.

Leaf area was markedly influenced by shade treatments after the sixth month. Double level shading gave outstanding significant results. T_4, T_5 and T_6 were statistically on par. Good results were obtained in T_6 too, with a leaf area of 47.72 cm^2. T_1 (25% single level shading) gave the least leaf area compared to all, eventhough T_1, T_2 and T_3 were statistically on par with each other.

Influential effects of shade were observed during the seventh month also. Fifty per cent double level shading was distinctly superior, eventhough it was statistically on par with T_5. A substantial reduction was observed in other treatments and least area was noted in T_1. However T_3 recorded more than T_2 and T_4.

Eighth month after planting gave significant results for the different treatments imposed. T_5 and T_6 were distinctly superior with an area of 66.62 cm^2 and 76.23 cm^2 respectively. The other treatments did not perform well and least area was noted for T_1 (53.20 cm^2). T_2 (58.34 cm^2) and T_3 (57.47 cm^2) were better than T_4 (55.7 cm^2) eventhough T_1, T_2, T_3 and T_4 were statistically on par with each other.

Distinctly superior results were obtained with the influence of shade during the ninth month. Thirty five per cent (T_5) and 50 per cent (T_6) double level shading were outstanding with a leaf area of 64.59 cm^2 and 76.98 cm^2, respectively. The other treatments such as T_1, T_2, T_3 and T_4 were statistically on

Fig. 3a. Leaf area in *Dendrobium* var. 'Sonia Bom Jo' as influenced by different levels of shade

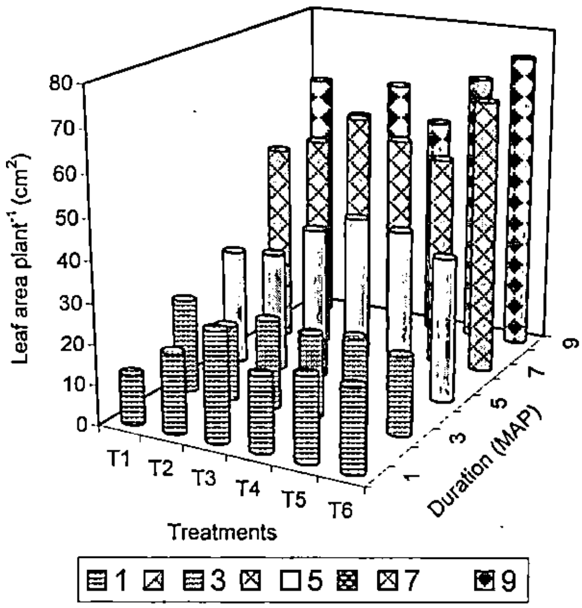
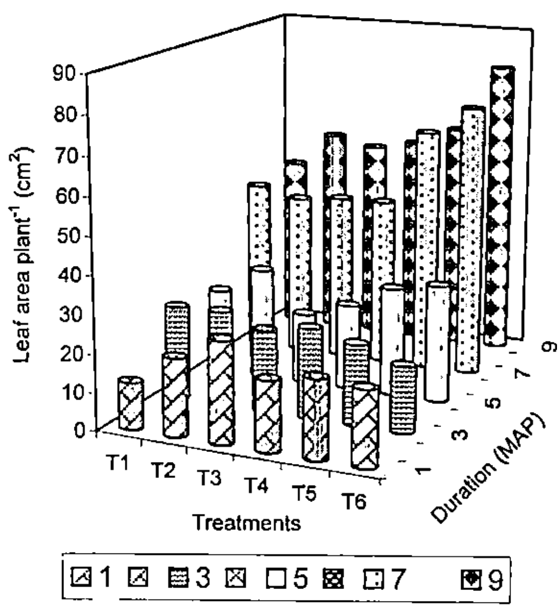


Fig. 3b. Leaf area in *Dendrobium* var. 'Renappa' as influenced by different levels of shade



par with each other, eventhough lowest values were obtained in T_1 (55.08 cm^2). Fifty per cent single level shading performed better compared to other three.

4.1.7 Frequency of stomata

The stomatal frequency did not show any varied significance as influenced by treatments. Number of stomata ranged between 386.1 and 555.8 per mm^2 (Table 7).

Table 7. Stomatal frequency in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	397.80	444.60	421.20
T_2 (35% - 1 level)	462.00	494.30	478.20
T_3 (50% - 1 level)	397.10	429.90	413.50
T_4 (25% - 2 level)	424.10	508.90	466.50
T_5 (35% - 2 level)	391.95	555.80	473.90
T_6 (50% - 2 level)	386.10	412.40	399.30
Mean	409.86	474.34	
SEm	2.066		
CD^1	NS		
SEm	2.300		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

4.1.8 Biomass production

Biomass production expressed in 'g' is presented in Table 8.

The dry matter production showed a significant variation for the different treatments imposed. The treatments provided with 50 per cent single level shading (T_3), 25 per cent (T_4) and 35 per cent (T_5), double level shading resulted in higher dry matter accumulation. However T_4 was superior to T_3 and T_5 with a biomass production of 5.86 g. The lowest biomass accumulation was observed for 35 per cent single level shading (3.86 g) and was statistically on par with T_1 and T_6 (Fig. 6).

Fig. 4. Biomass production in *Dendrobium* var. 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

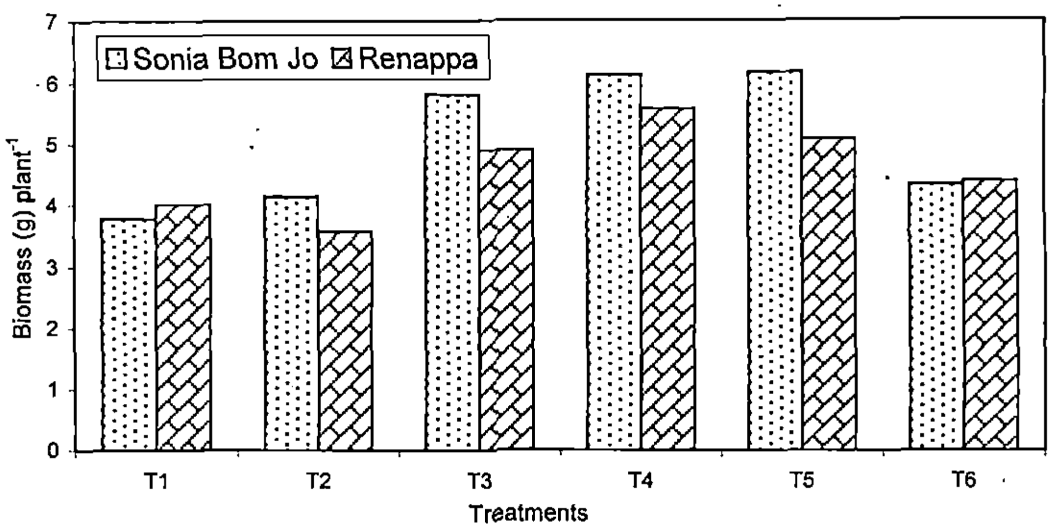


Fig. 5. Anthocyanin content in the flowers in *Dendrobium* var. 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

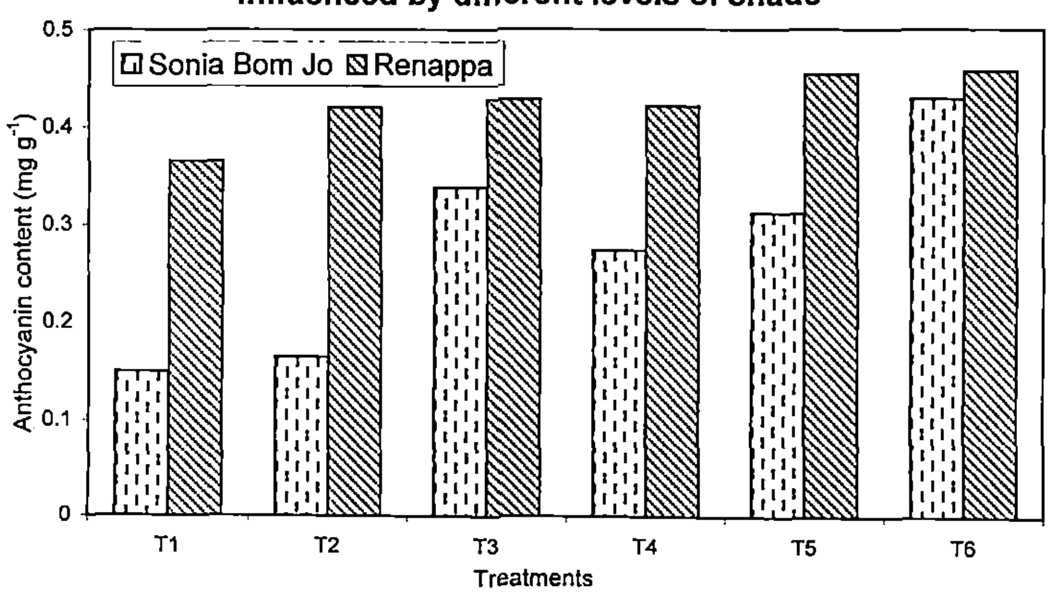


Table 8. Biomass production / Dry matter yield (g) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	3.78	4.01	3.90
T_2 (35% - 1 level)	4.14	3.58	3.86
T_3 (50% - 1 level)	5.82	4.91	5.36
T_4 (25% - 2 level)	6.13	5.58	5.86
T_5 (35% - 2 level)	6.17	5.09	5.63
T_6 (50% - 2 level)	4.35	4.41	4.38
Mean	5.07	4.60	
SEm	0.475		
CD^1	1.371		
SEm	0.271		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

4.2 Observations on flowering

Mean values of observations on flowering for eight months are presented in Tables 9 to 12.

4.2.1 Time taken for spike emergence

The different treatments imposed, significantly effected the time taken for emergence of first spike (Table 9). Earliness in flowering was observed for those treatments receiving more light conditions. In this regard, treatments T_1, T_2, T_4 and T_5 gave appreciable results and were statistically on par, however, 25 per cent single level shading (T_1) was the earliest to flower (148.13 days). While the days to first flowering were prolonged in treatments receiving more shade, viz. 50 per cent - single level (176.75 days) and 50 per cent - two level shading (177.38 days). The varieties responded similarly to the character, irrespective of the shade levels.

Table 9. Effect of different levels of shade on the time taken for spike emergence (mean days) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa'

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	148.50	147.75	148.13
T_2 (35% - 1 level)	151.50	152.50	152.0
T_3 (50% - 1 level)	175.50	178.0	176.75
T_4 (25% - 2 level)	156.00	159.00	157.50
T_5 (35% - 2 level)	162.75	176.25	169.50
T_6 (50% - 2 level)	176.50	178.25	177.38
Mean	161.79	165.29	
SEm	8.040		
CD^1	23.210		
SEm	11.370		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

4.2.2 Days from spike emergence to opening of first floret

The time taken for the opening of first floret after spike emergence did not show any significant variation, for the different treatments imposed (Table 10).

Table 10. Days from spike emergence to opening of first floret in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	33.83	38.00	35.92
T_2 (35% - 1 level)	35.75	32.00	33.88
T_3 (50% - 1 level)	33.25	32.38	32.81
T_4 (25% - 2 level)	33.25	33.25	33.25
T_5 (35% - 2 level)	36.25	38.88	37.56
T_6 (50% - 2 level)	35.04	41.67	38.36
Mean	34.56	36.03	
SEm	1.815		
CD^1	NS		
SEm	2.566		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

4.2.3 Efficiency of spike production

Pooled data for the efficiency of spike production revealed that 25 per cent, two level shading, 25 per cent and 50 per cent single level shading were significantly superior than others with efficiencies of 3.38, 3.00 and 2.75, respectively. While 35 per cent - single level shading recorded the lowest value and was statistically on par with 35 per cent and 50 per cent two level shading (Table 11, Fig. 4).

Table 11. Efficiency of spike production (%) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	3.00	2.50	2.75
T_2 (35% - 1 level)	2.25	2.00	2.13
T_3 (50% - 1 level)	3.00	3.00	3.00
T_4 (25% - 2 level)	3.25	3.50	3.38
T_5 (35% - 2 level)	2.75	2.50	2.63
T_6 (50% - 2 level)	2.50	2.75	2.63
Mean	2.79	2.71	
SEm	0.265		
CD^1	0.739		
SEm	0.252		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

4.2.4 Longevity of the spike on the plant

The longevity of the spike on the plant was markedly influenced by shade (Table 12). The pooled data reflects the superiority of shade, whereby the treatments T_3 and T_6 gave superior results, 59.75 and 59.85 days respectively. While the treatment with minimum shade retained the flowers for the least period (43.5 days), even though it was statistically on par with T_2 (45.75 days) and T_4 (47.79 days). The treatment resulted in retaining the spike for 53 days on the plant (Fig. 8).

Fig. 6. Efficiency of spike production (%) in *Dendrobium* var. 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

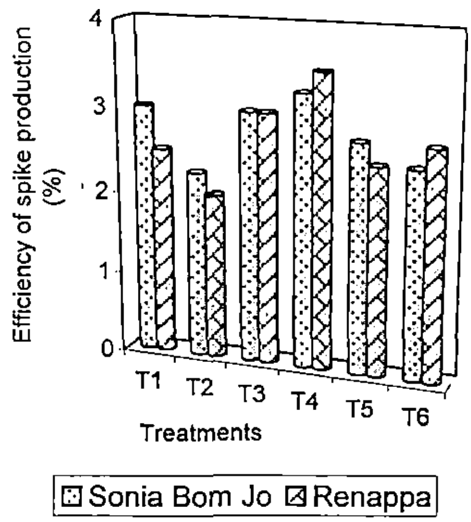


Fig. 7. Number of florets per spike in *Dendrobium* var. 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

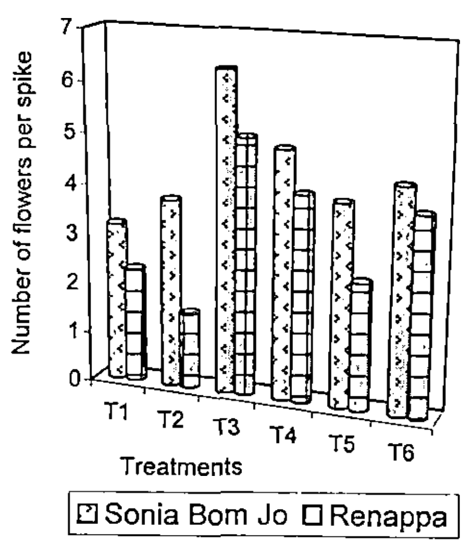


Fig. 8. Longevity of spike on the plant in *Dendrobium* var. 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

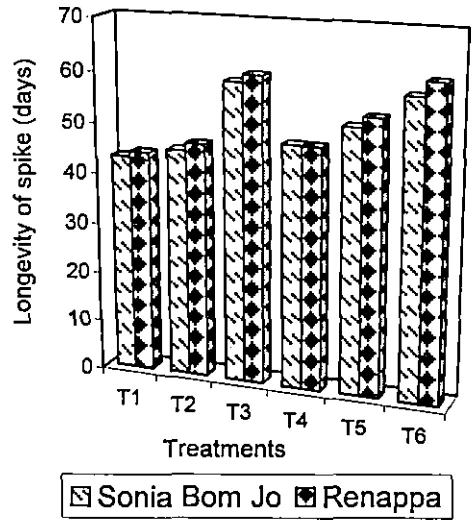


Fig. 9. Vase life of spikes in *Dendrobium* var. 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

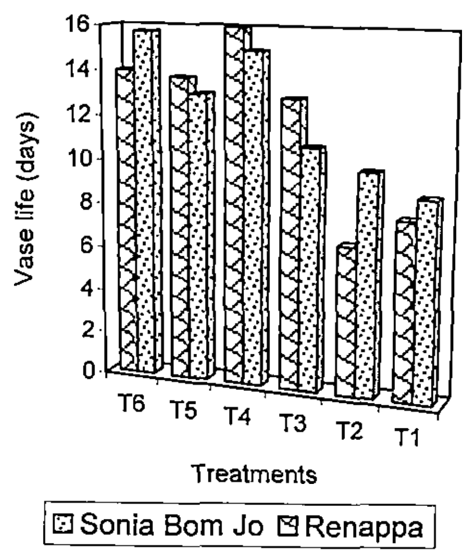


Table 12. Effect of different levels of shade on longevity of the spike on the plant (days) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa'

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	43.00	44.00	43.5
T_2 (35% - 1 level)	45.00	46.50	45.75
T_3 (50% - 1 level)	59.00	60.50	59.75
T_4 (25% - 2 level)	47.83	47.75	47.79
T_5 (35% - 2 level)	52.00	54.00	53.00
T_6 (50% - 2 level)	58.45	61.25	59.85
Mean	50.85	52.33	
SEm	2.367		
CD^1	6.830		
SEm	3.348		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

4.2.5 Length of the spike

The length of the spike differed significantly among treatments (Table 13). The longest spike was obtained in 50 per cent single level shading (24.86 cm) eventhough it was statistically on par with 35 per cent double level shading (21.48 cm). Least values were obtained in 25 per cent single level with a mean value of 13.47 cm. While intermediate results were obtained in T_2, T_4 and T_6, of these T_6 was superior. The treatments did not influence the performance of both the varieties in this respect.

Table 13. Length of the spike (cm) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	14.74	12.20	13.47
T_2 (35% - 1 level)	19.01	18.69	18.85
T_3 (50% - 1 level)	26.28	23.44	24.86
T_4 (25% - 2 level)	19.90	17.89	18.89
T_5 (35% - 2 level)	21.10	21.85	21.48
T_6 (50% - 2 level)	19.38	19.58	19.48
Mean	20.07	18.94	
SEm	1.651		
CD^1	4.770		
SEm	2.335		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

4.2.6 Length of the rachis

Shade levels imposed had significantly influence the flower bearing portion of the spike (Table 14). Superior results were obtained in T_3 (11.64 cm) and T_6 (11.88 cm) eventhough they were statistically on par with T_4 and T_5. Those treatments receiving higher light intensities resulted in lowest values viz. T_1 (5.41 cm) and T_6 (5.49 cm). The influence of treatment on the varieties did not result in any distinguishable difference.

Table 14. Length of the rachis (cm) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	6.3	4.53	5.41
T_2 (35% - 1 level)	6.41	4.58	5.49
T_3 (50% - 1 level)	13.00	10.27	11.64
T_4 (25% - 2 level)	10.6	10.13	10.36
T_5 (35% - 2 level)	10.73	10.83	10.78
T_6 (50% - 2 level)	12.45	11.3	11.88
Mean	9.92	8.60	
SEm	1.191		
CD^1	3.440		
SEm	1.684		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

4.2.7 Length of the inflorescence stalk

The inflorescence stalk length was not markedly influenced by shade, eventhough influence of shade was evident here too, with 50 per cent - single level and 50 per cent - double level shading giving superior results, while least values were obtained in 25 per cent single level shading (Table 15).

Table 15. Length of the inflorescence stalk (cm) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	9.23	9.35	9.29
T_2 (35% - 1 level)	11.64	10.74	11.19
T_3 (50% - 1 level)	14.08	12.78	13.43
T_4 (25% - 2 level)	12.46	11.63	12.04
T_5 (35% - 2 level)	12.83	12.35	12.59
T_6 (50% - 2 level)	13.23	12.40	12.81
Mean	12.24	11.54	
SEm	1.036		
CD^1	NS		
SEm	1.465		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

5.2.8 Internodal length

The length of the internode did not give any significant result (Table 16). Nevertheless, 50 per cent - single level shading (2.5 cm) along with 35 per cent (2.49) and 50 per cent (2.43) double level shading had more length for the internodes. The least value was obtained in 25 per cent single level (2.26 cm) shade.

Table 16. Internodal length of the spike (cm) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	2.22	2.30	2.26
T_2 (35% - 1 level)	2.40	2.31	2.36
T_3 (50% - 1 level)	1.55	2.45	2.50
T_4 (25% - 2 level)	2.37	2.23	2.30
T_5 (35% - 2 level)	2.51	2.47	2.49
T_6 (50% - 2 level)	2.41	2.44	2.43
Mean	2.41	2.37	
SEm	0.114		
CD^1	NS		
SEm	0.161		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

4.2.9 Number of florets per spike

Pooled data on the number of flowers produced per spike reflected that 50 per cent single level shading was distinctly superior to all other treatments imposed (5.7) (Table 17). Appreciable reduction was observed in T_4 and T_6 with mean values of 4.49 and 4.17 respectively. Flower production was less in T_1, T_2 and T_5. The treatment T_2 recorded the lowest mean value of 2.63 flowers per spike. Treatment did not effect the character in both the varieties (Fig. 5).

Table 17. Number of florets per spike in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	3.17	2.28	2.72
T_2 (35% - 1 level)	3.75	1.50	2.63
T_3 (50% - 1 level)	6.33	5.06	5.70
T_4 (25% - 2 level)	4.90	4.08	4.49
T_5 (35% - 2 level)	4.00	2.50	3.25
T_6 (50% - 2 level)	4.42	3.92	4.17
Mean	4.43	3.22	
SEm	0.415		
CD^1	1.198		
SEm	0.325		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

4.2.10 Length of the floret

The flower length recorded significantly higher values especially for treatments T_3, T_4 and T_6 with mean values of 6.47, 6.09 and 5.93 respectively. However maximum length was noticed in T_3 (6.47 cm). Other treatments such as T_1, T_2 and T_5 were comparatively inferior and statistically on par (Table 18).

4.2.11 Breadth of the floret

The major factor which determines the size of the floret viz. breadth also recorded concomitant results, eventhough T_3 was statistically superior

Plate 3. Treatment performance – one year after planting

T_1 (25%-single level shading)

T_2 (35%-single level shading)

T_3 (50%-single level shading)

T_4 (25%-two level shading)

T_5 (35%-two level shading)

T_6 (50%-two level shading)

Table 18. Size of the floret (length - cm) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	6.25	5.30	5.78
T_2 (35% - 1 level)	5.38	5.95	5.66
T_3 (50% - 1 level)	6.29	6.66	6.47
T_4 (25% - 2 level)	6.13	6.04	6.09
T_5 (35% - 2 level)	5.35	5.54	5.45
T_6 (50% - 2 level)	6.00	5.87	5.93
Mean	5.90	5.89	
SEm	0.213		
CD^1	0.615		
SEm	0.184		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

Table 19. Size of floret (breadth - cm) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	6.52	6.33	6.42
T_2 (35% - 1 level)	6.12	6.12	6.12
T_3 (50% - 1 level)	7.16	7.38	7.27
T_4 (25% - 2 level)	7.06	6.39	6.72
T_5 (35% - 2 level)	6.09	5.99	6.04
T_6 (50% - 2 level)	6.68	6.51	6.60
Mean	6.60	6.45	
SEm	0.130		
CD1	0.375		
SEm	0.191		
CD2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

(7.27 cm) than all others. While significantly lower values was recorded in T_1, T_2 and T_5. Within varieties, not much variation was observed (Table 19).

4.3 Observations of pigment content

4.3.1 Chlorophyll content

Chlorophyll 'a'

Estimation of chlorophyll 'a' revealed that shade leaves contained significantly higher amounts than others (Table 20). This was evident in T_5 and T_6 with mean values 3.87 and 4.03, respectively. While T_1, T_2, T_3 and T_4 were statistically low in chlorophyll 'a' content eventhough the lowest value w observed in T_1 (2.67). Comparison of treatments within varieties was insignificant.

Table 20. Chlorophyll 'a' content (mg g-1) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T1 (25% - 1 level)	3.03	2.32	2.67
T2 (35% - 1 level)	2.73	3.23	2.98
T3 (50% - 1 level)	3.12	2.52	2.82
T4 (25% - 2 level)	3.09	3.23	3.16
T5 (35% - 2 level)	3.53	4.20	3.87
T_6 (50% - 2 level)	4.41	3.66	4.03
Mean	3.32	3.19	
SEm	0.232		
CD[1]	0.670		
SEm	0.223		
CD[2]	NS		

CD[1] (0.05) – For comparison of treatments
CD[2] (0.05) – For comparison of treatments within varieties

Chlorophyll 'b'

Concomitant results were obtained during the estimation of chlorophyll 'b' also (Table 21). Thirty five per cent double level (2.86) and 50 per cent - double level (2.79) shading gave higher chlorophyll 'b' content. Similar trend as in chlorophyll 'a' was also observed here, with the lowest values for T_1 (1.72).

Table 21. Chlorophyll 'b' content (mg g^{-1}) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	1.52	1.93	1.72
T_2 (35% - 1 level)	1.92	2.04	2.98
T_3 (50% - 1 level)	2.01	1.73	1.87
T_4 (25% - 2 level)	1.73	1.73	1.73
T_5 (35% - 2 level)	2.68	3.03	2.86
T_6 (50% - 2 level)	2.98	2.61	2.79
Mean	2.14	2.18	
SEm	0.169		
CD^1	0.488		
SEm	0.204		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

Total chlorophyll content

Data pertaining to the influence of shade on total chlorophyll content followed a subsequent increase with shade levels (Table 22). Total chlorophyll estimated was highest for T_5 (2.89) and was statistically on par with T_6 (2.86). However, T_1 recorded a lowest value of 1.77 and the treatments T_2, T_3 and T_4 were on par.

Table 22. Total chlorophyll content (mg g^{-1}) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	1.63	1.92	1.77
T_2 (35% - 1 level)	1.96	2.11	2.03
T_3 (50% - 1 level)	2.08	1.76	1.92
T_4 (25% - 2 level)	1.83	2.06	1.95
T_5 (35% - 2 level)	2.71	3.08	2.89
T_6 (50% - 2 level)	3.05	2.67	2.86
Mean	2.21	2.67	
SEm	0.168		
CD^1	0.485		
SEm	0.201		
CD^2	NS		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

Chlorophyll a/b ratio

The chlorophyll a/b ratio did not show any significant variation as influenced by the different treatments imposed (Table 23).

Table 23. Chlorophyll a/b ratio in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	0.31	0.48	0.39
T_2 (35% - 1 level)	0.41	0.37	0.39
T_3 (50% - 1 level)	0.37	0.41	0.39
T_4 (25% - 2 level)	0.33	0.36	0.35
T_5 (35% - 2 level)	0.44	0.42	0.43
T_6 (50% - 2 level)	0.40	0.41	0.41
Mean	0.38	0.41	
SEm	0.064		
CD^1	NS		
SEm	0.025		
CD^2	0.072		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

4.3.2 Anthocyanin content

The major floral pigment - anthocyanin gave conclusive results for the effect of shade. Anthocyanin content gave significant variation between treatments, as well as for treatments within varieties (Table 24).

Table 24. Anthocyanin content (mg g^{-1}) in the flowers of *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T1 (25% - 1 level)	0.150	0.365	0.258
T2 (35% - 1 level)	0.165	0.420	0.293
T3 (50% - 1 level)	0.338	0.428	0.383
T4 (25% - 2 level)	0.273	0.421	0.347
T5 (35% - 2 level)	0.312	0.454	0.383
T6 (50% - 2 level)	0.429	0.457	0.443
Mean	0.278	0.424	
SEm		0.001	
CD1		0.003	
SEm		0.001	
CD2		0.003	

CD1 – For comparison of treatments
CD2 – For comparison of treatments within varieties

Within treatments 50 per cent double level shading gave highly superior values (0.443) and confirmed that it was statistically superior to others. Subsequent fall in anthocyanin content was observed with reduction in shade intensity. Treatments T_3 and T_5 were statistically on par (0.383). While T_4 recorded an anthocyanin content of 0.347 however least pigmentation was found in T_1 (0.258). T_2 (0.293) gave better results than T_1 (Fig. 7).

When treatment comparison was done within variety-Sonia Bom Jo, a similar trend was observed with distinctly superior values for T_6 (0.429). The other treatments recorded anthocyanin content in diminishing order viz. T_3, T_5, T_4, T_2 respectively. The least content was observed in T_1 (0.150). In the case of Renappa, both T_5 and T_6 were statistically outstanding eventhough T_6 was superior of the two. T_1 gave the lowest value, while T_2 and T_4 were better than T_1.

4.4 Observations on post harvest characters

4.4.1 Fresh weight of the spike

In orchid culture, the economic important part is the spike (Table 25). When the fresh weight of the harvested spikes were taken, a significantly higher results were noticed among the treatments and also between varieties. Among the treatments, 50 per cent single level shading gave significantly heavier spikes than others (16.41 g). Next best result was obtained in 25 per cent double level shading (15.89 g) which was superior to 50 per cent - double level shading (14.36 g). Twenty five per cent - single level shading gave the lowest spike weight (11.09 g). Thirty five per cent single level performed better (13.64 g) results than 35 per cent - double level shading.

Within variety Sonia Bom Jo superior results were obtained in 25 per cent - double level shading (18.73 g). While 50 per cent single level shading gave comparatively better results than 50 per cent - double level. Compared to all the treatments 35 per cent - single level shading resulted in lowest values (10.35 g).

Table 25. Fresh weight (g) of the spikes of *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	10.94	11.24	11.09
T_2 (35% - 1 level)	10.35	16.92	13.64
T_3 (50% - 1 level)	16.91	15.91	16.41
T_4 (25% - 2 level)	18.73	13.05	15.89
T_5 (35% - 2 level)	14.25	12.05	13.15
T_6 (50% - 2 level)	16.88	11.84	14.36
Mean	14.68	13.50	
SEm		0.007	
CD^1		0.029	
SEm		0.010	
CD^2		0.029	

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

When treatment comparisons were done within variety Renappa, 35 per cent - single level shading gave outstanding results (16.92 g) with minimum recorded values for 25 per cent - single level shading. All the treatments were significantly different between themselves with 50 per cent - single level, 25, 35 and 50 per cent - double level recording 15.91 g, 13.05 g, 12.05 and 11.84 g respectively.

4.4.2 Days to wilting of the first floret

The longevity of the orchid bloom can be noted in terms of the days taken for wilting of the first floret (Table 26). Considerable variations were observed between treatments, with significantly superior results in 25 per cent (15.50 days) and 50 per cent (14.88 days), two level shading. Reduced longevity of the spike was noted in 25 per cent and 35 per cent single levels. Thirty five per cent double level shading (13.4 days) was superior to 50 per cent - single level shading, taking intermediate values with much significant variation (Fig. 9).

Table 26. Vase life of the spikes of *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade (Days to wilting of the first floret)

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	9.00	8.03	8.51
T_2 (35% - 1 level)	10.02	6.75	8.38
T_3 (50% - 1 level)	10.95	13.00	11.96
T_4 (25% - 2 level)	15.00	16.00	15.50
T_5 (35% - 2 level)	13.05	13.75	13.40
T_6 (50% - 2 level)	15.75	14.00	14.875
Mean	12.30	11.92	
SEm	0.225		
CD^1	0.650		
SEm	0.318		
CD^2	0.918		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

Significant difference was noticed within variety Sonia Bom Jo too, with 25 per cent and 50 per cent, two level shading giving significantly superior results of 15.00 and 15.75 respectively. The next best was the treatment provided with 25 per cent double level shading. Twenty five per cent - single level shading performed the least in the vase with mean values of 9 days. Thirty five per cent and 50 per cent single level shading performed much better than the former one. Within the variety Renappa much outstanding results were observed in 25 per cent, two level shading (16.00 days). Thirty five per cent and 50 per cent, two level shading were the next best and significantly on par with each other. While 50 per cent and 25 per cent, single level gave mean values of 13.00 and 8.03 days respectively. The least recorded results were produced by 35 per cent single level shading (6.75 days).

4.5 Nutrient content

4.5.1 Total nitrogen

Total nitrogen content present in the plant sample expressed in percentage are presented in Table 27.

Table 27. Total nitrogen content (%) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	0.06	0.25	0.15
T_2 (35% - 1 level)	0.15	0.97	0.56
T_3 (50% - 1 level)	1.59	1.29	1.44
T_4 (25% - 2 level)	0.96	0.14	0.55
T_5 (35% - 2 level)	1.18	1.46	1.32
T_6 (50% - 2 level)	1.21	1.85	1.53
Mean	0.86	0.99	
SEm	0.090		
CD^1	0.260		
SEm	0.130		
CD^2	0.375		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

Conclusive results for the effect of shade was observed with much significant variation between treatments as well as that within varieties. Distinctly superior results were obtained for 50 per cent single level shading (T_3) as well as 35 (T_5) per cent and 50 per cent (T_6) double level shading. However, T_6 (1.53) was superior to T_3 and T_5. The least nitrogen content was observed for 25 per cent single level (T_1) shading (0.15). Thirty five per cent single level (T_2) and 25 per cent (T_4) double level shading produced nitrogen content of 0.56 per cent and 0.55 per cent and were statistically on par with each other.

Treatment variation within variety Sonia Bom Jo noted higher nitrogen content in T_3 and T_6, where T_3 (1.59) was superior to T_6 (1.21). The least nitrogen content was observed for T_1 with mean value of 0.06. Content of nitrogen was also less for T_2 (0.15) and was statistically on par with T_1. In the case of Renappa highest nitrogen content was for T_6 (1.85). Fairly higher content was observed for T_3 and T_5 with 1.29 and 1.46 per cent respectively. The content of nitrogen was less for T_1 and T_4.

4.5.2 Total phosphorus

Total phosphorus content present in the plant sample expressed as percentage are presented in Table 28.

Analysis of the total phosphorus content revealed that 25 per cent single level shading (T_1), along with 35 per cent (T_5) and 50 per cent (T_6) double level shading were significantly superior. The least phosphorus content was observed for 25 per cent double level shading (0.09), which was statistically on par with that in 35 per cent and 50 per cent, single level shading. In variety Sonia Bom Jo outstanding results were obtained in T_1 and T_6, where T_6 (0.20) was superior to T_1 (01.15). The least phosphorus content was noted for T_4 and was statistically on par with T_2, T_3 and T_5. In the case of Renappa highest 'P' content was observed for T_5 (0.22%) The least content of phosphorus was noted in T_4 (0.10%) which was statistically on par with T_1, T_2, T_3 and T_6.

Table 28. Total phosphorus content (%) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	0.15	0.13	0.14
T_2 (35% - 1 level)	0.10	0.12	0.11
T_3 (50% - 1 level)	0.10	0.11	0.11
T_4 (25% - 2 level)	0.07	0.10	0.09
T_5 (35% - 2 level)	0.11	0.22	0.16
T_6 (50% - 2 level)	0.20	0.14	0.17
Mean	0.12	0.14	
SEm		0.011	
CD^1		0.032	
SEm		0.016	
CD^2		0.046	

CD^1 (0.05) – For comparison of treatments

CD^2 (0.05) – For comparison of treatments within varieties

4.5.3 Total potassium

Data pertaining to the total potassium content expressed as 'percentage' are presented in Table 29.

Table 29. Total potassium content (%) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	1.29	1.50	1.39
T_2 (35% - 1 level)	1.39	1.90	1.64
T_3 (50% - 1 level)	1.25	1.50	1.38
T_4 (25% - 2 level)	1.35	1.35	1.35
T_5 (35% - 2 level)	1.30	1.80	1.55
T_6 (50% - 2 level)	1.45	1.50	1.48
Mean	1.34	1.59	
SEm	0.305		
CD^1	0.101		
SEm	0.049		
CD^2	0.141		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

Estimation of potassium content revealed that 35 per cent single level shading (T_2) and 35 per cent double level shading (T_5) gave outstanding results wherein T_2 (1.64) was superior to T_5 (1.55). T_4 had the least content of potassium (1.35) eventhough it was statistically on par with T_1, T_3 and T_6.

Within variety Sonia Bom Jo distinctly superior results were obtained for T_2, T_4, T_5 and T_6. T_6 noted highest (1.45) potassium content. The least content of potassium was observed in T_3 (1.25), though it was statistically on par with T_1 (1.29). In the case of Renappa superior results were obtained for T_2 and T_5, where T_2 had highest potassium content (1.9). The least potassium content was observed for T_4, with a mean value of 1.35.

4.6 Nutrient uptake

The data pertaining to the nutrient uptake are presented in Tables 30 to 32.

4.6.1 Uptake of nitrogen

Uptake of nitrogen expressed in mg $plant^{-1}$ is presented in Table 30.

Table 30. Nutrient uptake - Nitrogen (mg plant^{-1}) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	1.80	5.23	3.51
T_2 (35% - 1 level)	6.67	18.91	12.79
T_3 (50% - 1 level)	62.97	24.74	43.86
T_4 (25% - 2 level)	28.71	2.68	15.69
T_5 (35% - 2 level)	24.47	34.91	29.69
T_6 (50% - 2 level)	31.12	72.48	51.80
Mean	25.96	26.49	
SEm	4.501		
CD^1	12.99		
SEm	6.366		
CD^2	18.38		

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

Nitrogen content showed a significant variation for the different treatments imposed. Fifty per cent double level and 50 per cent single level shading were outstanding with significantly superior results of 51.80 and 43.86 (mg plant^{-1}) respectively. The least nitrogen content was for 25 per cent single level shading (3.51), even though it was statistically on par with 35 per cent and 50 per cent single level shading. Thirty five per cent double level shading was intermediate of these.

Treatment variation within variety Sonia Bom Jo gave maximum nitrogen uptake in 50 per cent single level shading (62.97). The least nitrogen uptake was noted in 25 per cent single level shading (1.8 mg plant^{-1}). In the case of Renappa highest uptake of nitrogen was observed for 50 per cent double level (72.48 mg plant^{-1}) shading. However, treatments receiving more light intensity, gave less uptake of nitrogen viz. 25 per cent, 35 per cent single level shading and 25 per cent double level shading.

4.6.2 Uptake of phosphorus

Uptake of phosphorus expressed in 'mg plant^{-1}' is presented in Table 31.

Table 31. Nutrient uptake - Phosphorus (mg plant^{-1}) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	4.40	2.69	3.55
T_2 (35% - 1 level)	4.30	2.19	3.25
T_3 (50% - 1 level)	4.52	2.07	3.30
T_4 (25% - 2 level)	1.80	2.00	1.90
T_5 (35% - 2 level)	2.29	5.43	3.86
T_6 (50% - 2 level)	5.40	5.50	5.45
Mean	3.79	3.31	
SEm		0.519	
CD^1		1.500	
SEm		0.733	
CD^2		2.120	

CD^1 (0.05) – For comparison of treatments
CD^2 (0.05) – For comparison of treatments within varieties

Estimation of phosphorus uptake revealed that 50 per cent double level shading gave maximum when comparison was done within treatments, as well as for treatment comparison within varieties. However, it was statistically on par with 25 per cent, 35 per cent and 50 per cent single level shading in the case of Sonia Bom Jo. The least phosphorus uptake was noticed in 25 per cent double level shading in all the cases.

4.6.3 Uptake of potassium

Potassium uptake expressed in 'mg plant^{-1}' is presented in Table 32.

Potassium uptake was maximum in 35 per cent single level shading (49.87), however it was statistically on par with 50 per cent single (39.66) and double (47.80) levels of shade. The least potassium uptake was observed in 25 per cent double level shading (33.49). In variety Sonia Bom Jo highest uptake was noted in 35 per cent single level shading even though it was statistically on par with 50 per cent single level shading. All the other treatments had less uptake of potassium and were on par with each other. In the case of variety Renappa, 50 per cent double level had maximum uptake (58.09) even though it was statistically on par with 35 per cent double levels of shade. All other treatments were statistically on par, with less uptake of potassium.

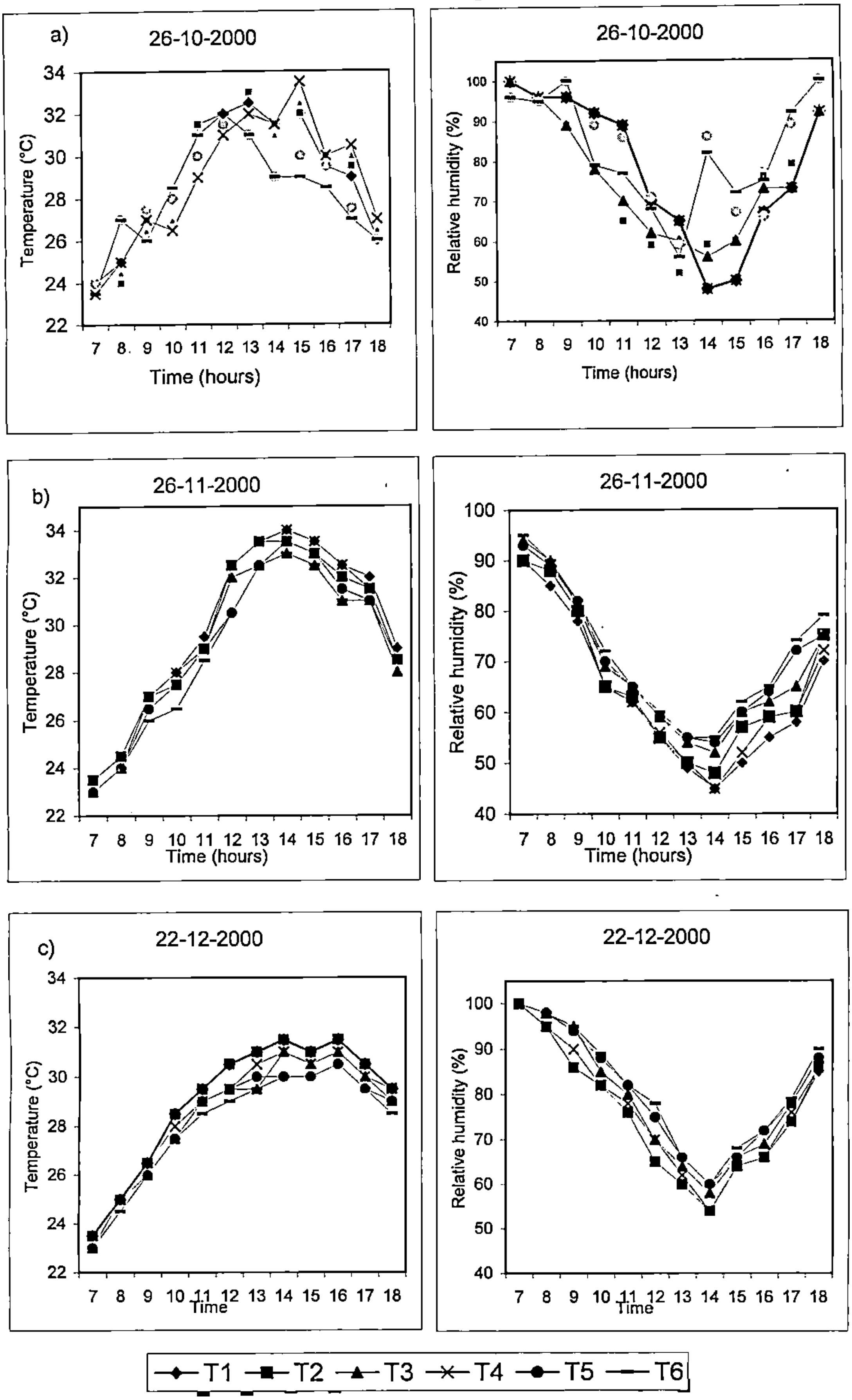
Table 32. Nutrient uptake - Potassium (mg plant^{-1}) in *Dendrobium* varieties 'Sonia Bom Jo' and 'Renappa' as influenced by different levels of shade

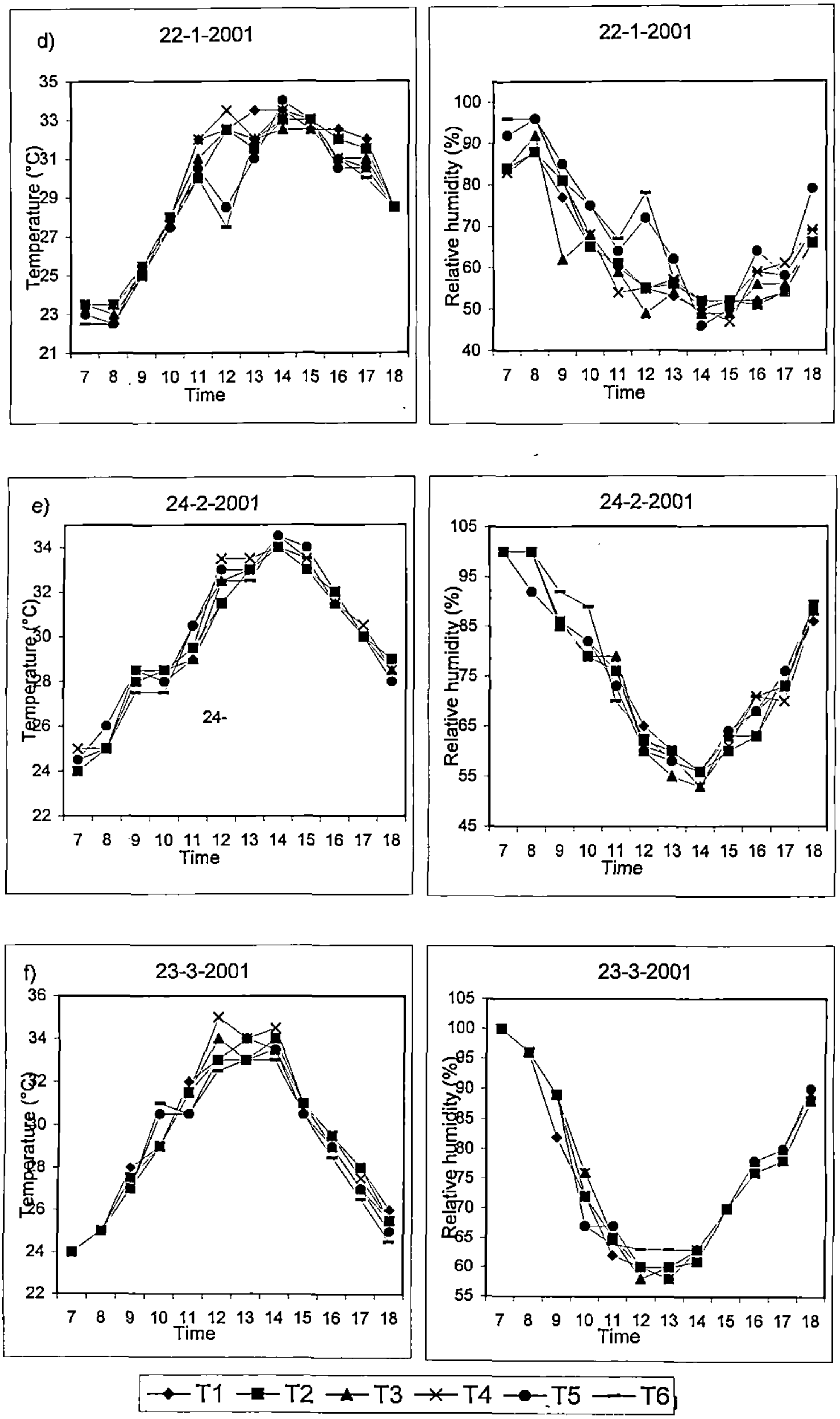
Treatments	Sonia Bom Jo	Renappa	Mean
T_1 (25% - 1 level)	38.93	30.98	34.95
T_2 (35% - 1 level)	62.65	37.10	49.87
T_3 (50% - 1 level)	51.20	28.13	39.66
T_4 (25% - 2 level)	40.33	26.66	33.49
T_5 (35% - 2 level)	28.11	42.62	35.37
T_6 (50% - 2 level)	37.51	58.09	47.80
Mean	43.12	37.26	
SEm	3.95		
CD^1	11.41		
SEm	5.59		
CD^2	16.14		

CD^1 (0.05) – For comparison of treatments

CD^2 (0.05) – For comparison of treatments within varieties

Fig. 10 (a - l). Temperature and relative humidity profiles as influenced by different levels of shade during the period of experimentation

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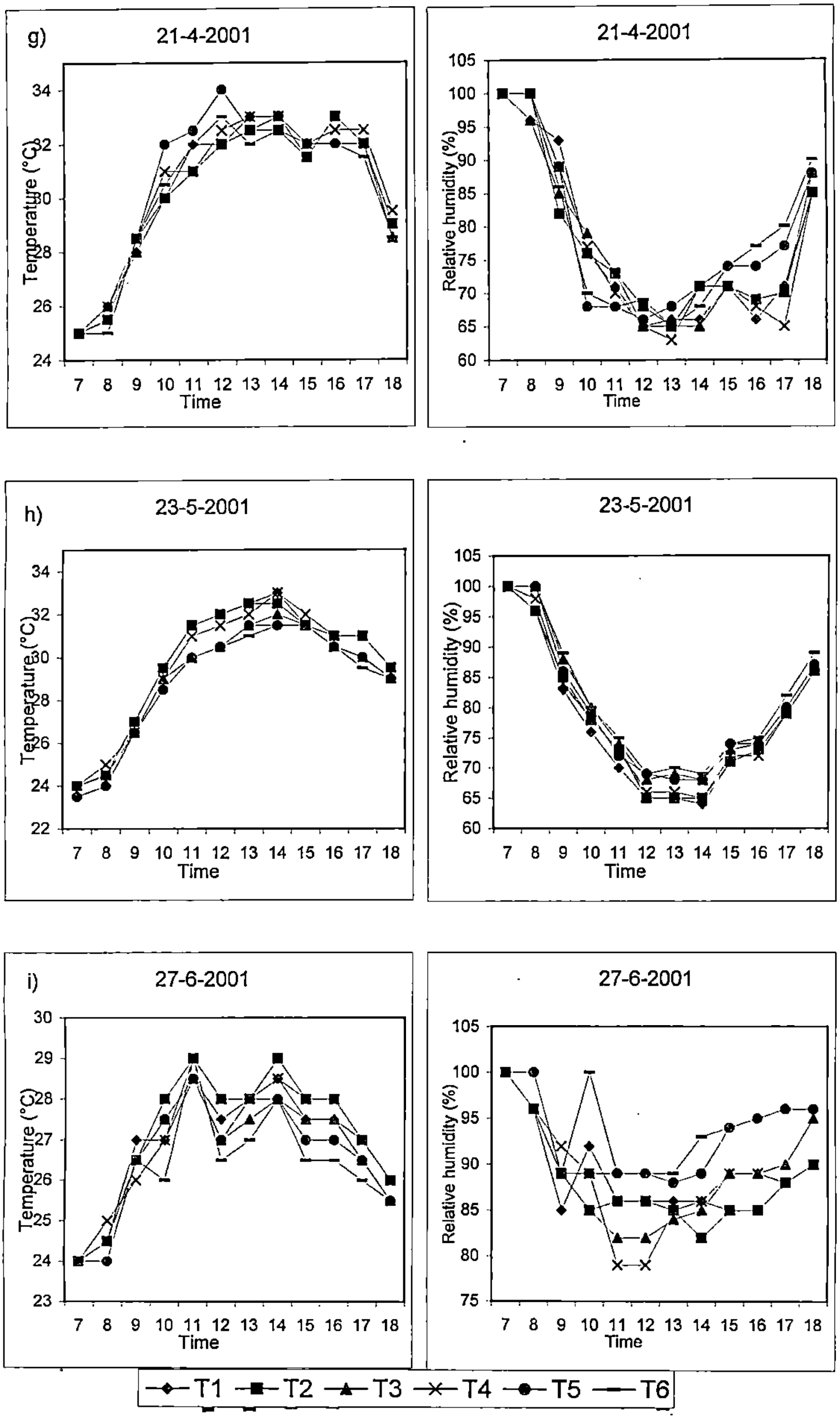
22-1-2001
Temperature (°C)
Time
22-1-2001
Relative humidity (%)
Time
e)
24-2-2001
Temperature (°C)
24-
Time
24-2-2001
Relative humidity (%)
Time
f)
23-3-2001
Temperature (°C)
Time
23-3-2001
Relative humidity (%)
Time
T1
T2
T3
T4
T5
T6


g)
21-4-2001
Temperature (°C)
Time
21-4-2001
Relative humidity (%)
Time
h)
23-5-2001
Temperature (°C)
Time
23-5-2001
Relative humidity (%)
Time
i)
27-6-2001
Temperature (°C)
Time
27-6-2001
Relative humidity (%)
Time
T1
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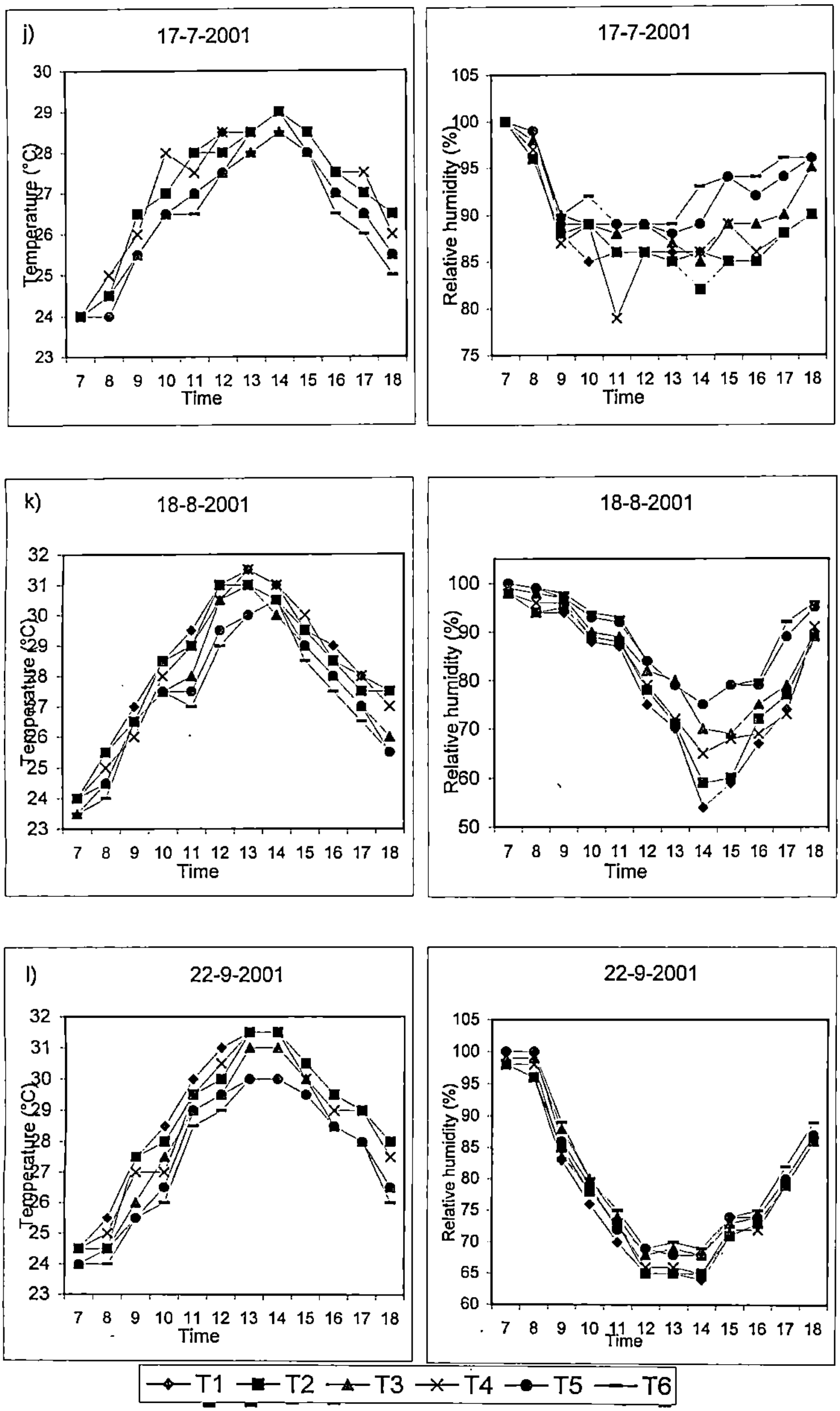
T3
T4
T5
T6


j)
17-7-2001
Temperature (°C)
Time
17-7-2001
Relative humidity (%)
Time
k)
18-8-2001
Temperature (°C)
Time
18-8-2001
Relative humidity (%)
Time
l)
22-9-2001
Temperature (°C)
Time
22-9-2001
Relative humidity (%)
Time
T1
T2
T3
T4
T5
T6

Discussion

5. DISCUSSION

The growth and development of any crop is highly influenced by the climatic factors and light is one among them. Most of the dendrobiums require warm green house with shading from direct sunshine. In commercial practice, it is grown under partial shade. The intensity of light affects the morphological characters, flower production and quality of flowers. Light intensity is an important factor regulating the bloom count. Hence the present study takes into account the suitable range of shade to be provided for effective growth and spike production. The results generated from the study are discussed in this chapter.

5.1 Influence of shade on growth parameters

The overall influence of shade during vegetative growth can be assessed by parameters such as plant height, shoot production, internodal length, shoot girth, leaf production and leaf area.

Plant height was significantly influenced by shade which was prominent during the peak summer months.

During the initial months, influence of different shade levels on plant height was not much evident, which could be due to the time taken for acclimatization. While, during the peak summer months, those treatments receiving more shade intensity put forth more height. Remarkable increase was noticed in treatments with 35 per cent and 50 per cent (both at double level shading) and 50 per cent single level shading. The plant height was considerably less in intense light conditions. These results are in conformity with the reports of Von Noordegraff (1968), Leffering (1975) Stamps *et al.* (1995) and Thekkayam (1996).

Plants exhibit basically two responses to shade. The "shade avoiders" generally tend to redirect their development in shade such that the internode extension is favoured at the expense of leaf development, thereby allowing the young leaves to be kept out of shade (Smith, 1982). So the possible reason for increase in height under higher shade intensity is the response to reductions in the total fluence rate (constant spectrum). Reduced light levels might have caused increased stem extension as a shade avoidance reaction, as in other plants.

The influence of shade on shoot production was highly significant during the entire period of vegetative growth. During the first month after planting, there was not much variation in shoot production as the rate of growth was slow. While in the subsequent months, the number of shoots produced was more, especially for those with more light intensity. The conclusion was based on the results obtained during the second, fourth, fifth, seventh, eighth and ninth month after planting. Twenty five per cent single level shading as well as 25 per cent and 35 per cent double level shading produced more shoots during these months.

Beneficial effects of light on shoot production was also observed by Thekkeyam (1996) with more number of shoots under 75 per cent light in *Dendrobium* var Sonia. Under more light condition, there is more production of photo assimilates thus leading to more shoot production. A biochemical interpretation of the result is made by Kapoor (1989). In light condition photo oxidation of auxin occurs and IAA oxidase enzyme inhibits the basipetal transport of auxin. This may favour a high cytokinin - auxin ratio, which may be responsible for higher shoot production.

The length of the internode had influential effects of shade especially during the initial period of vegetative growth, i.e., upto five months. Internodal length was high for treatments subjected to more shade intensities viz. 50 per cent single level shading, 35 per cent and 50 per cent double level shading with more length during most of the initial months. Since flowering had started, not much significant variation in the length of internode was observed among treatments.

These findings can be well explained based on the report of Kendrick and Frankland (1976) who found that extension growth is inversely related to the Pfr/Pr ratio (phytochrome) maintained. Higher light intensities inhibit cell extension by promoting cell maturation.

The number of leaves produced per plant throughout the experimental period was significantly influenced by shade. During the first month of planting, leaf production was insignificant. Varied production of leaf was noticed till January. Thereafter a profound influence of shade was noticed during the entire period of observation. Higher leaf production was noticed in double level shading mainly 35 per cent and 50 per cent shade levels. Temperature and relative humidity fluctuations were not prominent in double shade levels of 35 and 50 per cent which reduced the leaf fall in these treatments. These results agree to the findings of Rajeevan (1997) done in dendrobiums under Kerala condition.

Similar reports are there on other crops too. Based on the studies on cocoa, Hardy (1958) had reported a better growth performance and leaf production under shade than in the open because of regulation of leaf production by certain auxins. The auxin concentration, according to him, at full direct sunlight decreases because of photo oxidation. Another possible explanation could be in agreement with Smith (1982) who reported that, shade tolerators adopt an alternative strategic response, which comprises of a transition to a highly conservative utilization of resources, commonly accompanied by structural and biochemical changes which enhances the efficiency of photosynthetic energy transduction and reduced respiratory losses.

The shade treatments had a direct influence on leaf area during the summer season. Highest leaf area was noticed for 50 per cent double level shading which was much reflected during sixth, seventh, eighth and ninth months after planting. Similar reports have been made by Gopinathan (1981), Mc Kendrick (1996), Thekkayam (1996) and Salvi (1997).

The area of the leaf surface that intercepts solar radiation is the most important factor. Leaves produced in heavy shade are much larger and attain much length because of loosened mesophylls and elongated epidermal cells. Increase in leaf area of plants is also reported to be the immediate perceptible morphological adaptation generally associated with low intensities of light both in shade tolerant and shade intolerant species.

These findings confirm the reports of Smith (1982) that, the response of 'shade tolerators' leads to highly conservative utilization of resources, commonly accompanied by enhancement of photosynthetic energy, with an increase in leaf length and breadth, thereby increase in leaf area, for more photosynthesis. With decline in shade intensity considerable decrease in length and breadth of leaves was observed.

Biomass production is the net result of active vegetative growth and optimum resource utilization for which shade had an influential effect. The results indicate a significantly higher biomass production in 25 per cent and 35 per cent double level shading, viz., 5.86 g and 5.63 g, respectively. Apparently good results were obtained in fifty per cent single level shading with a dry weight of 5.36 g.

Similar results with increased plant dry weight under higher light intensities were reported by Kubota *et al.* 1993) and Kititrakunyanun *et al.* (1999). At intense shade levels, light became the dominant limiting factor as expected and dry matter accumulation decreased substantially.

5.2 Effect of shade on flowering

Flowering is the end result of physiological processes, biochemical sequences and gene action with the whole system responding to the influence of environmental stimuli and the passage of time. The flowering responses observed in this study endorse the beneficial effect of higher light intensities on the flowering of tropical species as reported by Murashige *et al.* (1967) and Goh and Arditti (1981).

One of the most beneficial effects of light was observed in the earliness in the commencement of flowering. Flowering was earlier in the treatment receiving highest light condition, viz., 25 per cent single level shading with a mean value of 148.13 days. A progressive delay in spike emergence was observed in the other treatments where the maximum delay was noticed in 50 per cent double level shading (177.38 days). This corroborates with the opinions of Murashige *et al.* (1967); Ding *et al.* (1980); Goh and Arditti (1981), Smith (1982); Gorden (1989a); Thekkayam (1996) and Salvi (1997).

The results can be well explained based on the findings of Wardlaw (1990). Information on assimilate partitioning shows that under source limiting conditions, flowers are poor competitors for assimilates. This may be the probable reason for less spike production and delay in spike production under 50 per cent double level shading. The length of the spike produced was maximum under 50 per cent single level shading with a mean value of 24.86 cm. Length of the rachis was maximum under 50 per cent double level shading with a value of 11.88 cm. In general length of the spike as well as that of rachis were higher in treatments receiving high shade condition. This may be due to a response to reductions in the total fluence rates (constant spectrum), where the extension growth is inversely related to the Pfr/Pr ratio.

The total bloom count is a critical factor in the commercial cultivation of orchids. Here light intensity acts as a key factor in regulating the efficiency of spike production. Efficient spike production was observed in 25 per cent double level as well as 25 per cent and 50 per cent single level shading. But when the average number of flowers per spike was observed 50 per cent single level shading gave the highest average of 5.7. High temperature and high light intensity produced wilting of some florets within the spike. High temperature and rapid fluctuations in humidity are a common cause of bud drop seen in orchids. This could be the reason for reduced florets per spike in highly illuminated treatments. Similar trend had been observed in the size of the florets also.

5.3 Effect on pigment content

Light intensity influences plant growth through photosynthesis. Chlorophyll 'a' influences the photosynthetic efficiency which in turn helps in efficient carbon assimilation, which reflects on better growth and better spike formation. Reported evidences show that the concentration of chlorophyll per unit weight of leaf increases with shading. Similarly, varying light intensities also influence flower colour which in turn determines the flower quality.

In the present study there was a clear trend of decrease in chlorophyll content with the decreasing intensity of shade. Higher chlorophyll content (a, b and total) was noted for intense shade treatments, viz., 50 per cent and 35 per cent double level shading. No such trends were observed for chlorophyll a/b ratio. Similar results were also reported by some of the earlier workers in different crops viz., cocoa (Guers, 1971); pineapple (Radha, 1979); coconut intercrops (Lalithabai, 1981) etc. Chlorophyll content was found to increase proportionally with shade levels as noticed in *Dracaena* (Conover and Poole, 1975) and *Philodendron* (Swapna, 1996).

Chlorophyll 'b' is formed from chlorophyll 'a' in the dark by thermochemical reaction. The illumination allows labeling of chlorophyll 'a', but it is not necessary for transformation of chlorophyll 'a' into chlorophyll 'b'. The balance between formation and degradation determines the amount present in the leaves. It is more reasonable to assume that chlorophyll 'a' and 'b' are formed concurrently from some common precursor, than to assume that chlorophyll 'b' is formed from chlorophyll 'a'. The reaction is probably an oxidation and the acting enzymes are controlled by a specific gene. Chlorophyll biosynthesis is centred in the plastids (Shlyk, 1971). This fact supports the present finding with respect to the content of chlorophyll 'a', 'b' and 'total' in the orchid leaves. Increased chlorophyll content in shaded leaves is attributed in avoiding light deficiency and to trap whatever light available by decreasing reflection and transmission of incident light (Boardman, 1977). However, reduced chlorophyll content observed in intense light condition is an indicative of chronic photo inhibition (He *et al.*, 1998).

Based on the visual observations a red pigmentation was noticed for the leaves exposed to higher light intensities, viz., 25 and 35 per cent single level shading, and also in 25 per cent double level shading. According to Acker (1989), if a plant has more than enough light for its photosynthetic needs, it will narrow its spectral absorption range and start rejecting (or reflecting) light at the edges of its useful range. This becomes apparent to the human eye by a colour shift, either to yellow or more red. Similar observations were also made by Radha *et al.* (1994) in sunplants of the orchid group.

Anthocyanin content

Different shade levels had influenced the anthocyanin content significantly. Fifty per cent double level shading gave the highest level of anthocyanin content and the least content was noticed for 25 per cent single level shading. A progressive increase in anthocyanin was noticed with increase in shade intensity. The result obtained is in conformity with the report of Griesbach (1983), who opined that environmental factors like light intensity and temperature had a great influence on flower colour. High light intensity and high temperature can cause the break down of anthocyanin leading to fading of flowers.

5.4 Influence of shade on vase life of orchid spike

Pre harvest and post harvest factors influence the longevity of cut flowers. One of the factors which play a major role in regulating the vase life of a cut flower is the carbohydrate supply. Cut flower longevity is also curtailed by ethylene.

Results reveal that fresh weight of the spike was maximum under 50 per cent single level shading (16.41 g). Twenty five per cent double level shading also produced heavier spikes of 15.89 g. The number of florets was more in 50 per cent single level shading which contributed to the weight of the spike. While the inflorescence stalk thickness contributed much to the fresh weight, in the other two treatments.

Vase life, which was recorded as the days from harvest to wilting of the first floret, gave highest value in 25 per cent single level shading (15.50 days). Within the variety Sonia Bom Jo longevity of the spike was more, both in 25 per cent and 50 per cent double level shadings. However, longevity was maximum in 25 per cent double level shading in variety Renappa (16 days).

According to Halery and Mayak (1981), one of the most important pre harvest factors influencing the post harvest life of a cut flower is light, the effect of which is largely related to the accumulation of respirable substrates, mainly carbohydrates. α-amylase is involved in the hydrolysis of carbohydrates on perception of light. Light mediated α-amylase production could thus be an important step in the formation of an active sink to draw materials from the rest of the plant. Longevity of the spike on the plant reflects that, treatments with minimum shade retained the flowers for the least period viz., 25 per cent single level shading (43.5 days) which was statistically on par with 35 per cent single and 25 per cent double levels of shade. Longevity was more in 50 per cent single (59.75 days) and double levels (59.85 days) of shade.

Studies on the responses of the leaves and flowers to high light and temperature on CAM *Dendrobium* cv.Sonia by He *et al.*(1998)observed that severe damage occurred in flowers at 38^0C than at 28^0C under a higher PFD of 1500 $\mu molm^{-2}S^{-1}$. Increased ethylene production in strong light was noticed by Gregg (1977) and Gregg (1984).

High temperature would increase fatty acid metabolism which leads to a subsequent increase in respiration rate and an ultimate increase in ethylene production. Peroxidase enzymes are activated and this enzyme has been shown to be involved in ethylene synthesis. Ethylene thus shortens the life of orchid flowers under strong light condition in field (Arditti, 1979).

Ding *et al.* (1980) observed that those having a smaller size had a greater longevity than the larger ones. This could be the reason for greater shelf life noticed in 50 per cent double level shading, where the floret size (length and breadth) was generally less.

5.5 Influence on nutrient content

Analysis of the nutrient content indicates an influential effect of shade. Nitrogen content was significantly higher under 50 per cent single level, 35 per cent and 50 per cent double level shading. Similar trend was observed in the uptake of nitrogen too.

The results can be confirmed through the studies on shade made by various workers in different crops, where they observed higher uptake of nitrogen under shaded condition (Guers, 1971, Oladokum, 1980; Wong and Wilson, 1980; Lalithabai, 1981 and Salvi, 1997). This clearly shows that light not only has a controlling influence on ion transport in leaves, by providing the energy for active transport across cellular membrane, but also affects ionic movements through activation of the phytochrome system. The optimum light intensity required by the plant favours these reactions.

The phosphorus content was high under 25 per cent single level shading along with 35 per cent and 50 per cent double level shading. The highest content was observed in 50 per cent double level shading (0.17%) and the least in 25 per cent double level shading (0.09%). Here the higher 'P' content was observed for treatments with less dry matter production. Twenty five per cent double level shading had produced maximum biomass for which 'P' content was the least. Therefore it is natural to assume that it can be due to dilution effect.

Estimation of potassium content revealed that 35 per cent single level shading and 35 per cent double level shading gave outstanding results. This is in conformity with Gopinathan (1981) where he observed a higher percentage of 'K' in cocoa plants grown under direct sunlight. These findings are in agreement with that of Lauchli (1972) that light enhanced the rate of K^+ absorption by corn leaf tissue, where the role of light might be to provide the energy for the enhanced uptake of K^+ through synthesis of ATP in cyclic photo phosphorylation.

The results clearly shows that intense shade condition is required for *Dendrobium* during vegetative growth period viz. 50 per cent double levels of shade had maximum height, internodal length, number of leaves and leaf area. Thereafter, with the initiation of flowering, light had an influential role. During flowering period 50 per cent single and 25 per cent double levels of shade put forth outstanding performance. Earliness and efficiency of spike production was maximum in 25 per cent double shade level and had maximum life in the vase. But the number of florets per spike, length of the spike, the length and breadth of individual florets etc. were maximum in 50 per cent single shade level. Anthocyanin content was more in this compared to 25 per cent double level. So when the flower quality is assessed 50 per cent single performed better.

Summary

6. SUMMARY

An experiment was conducted during October 2000 to September 2001 in the orchidarium of All India Co-ordinated Floriculture Improvement Project in the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Thrissur to standardise the shade requirement for *Dendrobium*. The study was undertaken in varieties Sonia Bom Jo and Renappa to assess the influence of shade on the growth and flowering and to standardise the optimum requirement of shade for maximum flowering. The salient findings of the study are summarised below:

1. The height of the plant was significantly influenced by shade. During the peak summer months, those treatments receiving more shade intensity putforth more height, eventhough influence of shade was not much evident during the initial months after planting. Remarkable increase was noticed in treatments with 35 per cent and 50 per cent (both double level shading) and 50 per cent single level shading. Maximum plant height was obtained for 50 per cent double level shading (12.48 cm).
2. Shade had a significant role in shoot production, especially during second, fourth, fifth, seventh, eighth and ninth month after planting. Twenty five per cent single level as well as, 25 and 35 per cent double levels of shade gave higher shoot production during these months. In general better shoot production was observed in treatments receiving more light.
3. The length of the internode had influential effects of shade especially during the initial period of vegetative growth i.e. the initial five months of planting. Internode length was more for treatments subjected to more shade intensities. Fifty per cent double level shading had maximum length during most of the initial months. After flowering not much significant variation in the length of internode was observed.

4. Shoot growth was not significantly affected by the various treatments imposed during most of the period under study.

5. The number of leaves produced per plant throughout the experimental period was significantly influenced by shade. Higher leaf production was noticed in double level shading mainly at 35 and 50 per cent shade levels with mean values of 3.44 and 3.40, respectively.

6. The light intensity treatments had a direct influence on leaf area especially during the summer season. Highest leaf area was noted for 50 per cent double level shading which was much reflected during sixth (42.76 cm^2), seventh (70.36 cm^2), eighth (76.23 cm^2) and ninth (76.98 cm^2) month after planting.

7. Significant superiority in dry matter accumulation was observed for treatments provided with 50 per cent single level shading as well as 25 per cent and 35 per cent double level shading. Twenty five per cent double level shading recorded the highest biomass production of 5.86 g.

8. Earliness in flowering was observed for those treatments receiving more light conditions. Twenty five per cent single level shading was the earliest to flower of the group (148.13 days). While the days to first flowering prolonged in treatments receiving more shade viz. 50 per cent single level (176.75 days) and 50 per cent two level shading (177.38 days).

9. Longevity of the spike on the plant was more in 50 per cent single (59.75 days) and double (59.85 days) levels of shade. The treatment with minimum shade retained the flowers for the least period (43.5 days).

10. Length of the spike and length of the rachis differed significantly among treatments. The longest spike was obtained in 50 per cent single level shading (24.86 cm), while the length of the rachis was maximum in 50 per cent double level shading (11.88 cm). The length of the inflorescence stalk and internode did not give significant results.

11. Fifty per cent single level shading was distinctly superior to all other treatments with a mean value of 5.7, for the number of flowers produced per spike. Maximum length of the floret was noticed in 50 per cent single level shading (6.47 cm), and the same had maximum breadth too (7.27 cm).

12. Pooled data for the efficiency of spike production revealed that 25 per cent double level, 25 and 50 per cent single level shading were outstanding. However maximum production was noticed in 25 per cent double level shading.

13. When the fresh weight of the harvested spikes were taken, heaviest spikes were obtained under 50 per cent single level shading (16.41 g). Heavy spikes were also obtained in 25 per cent double level shading (15.89 g).

14. Vase life was significantly higher in 25 per cent (15.50 days) and 50 per cent (14.88 days) double levels of shade. Reduced longevity was noted in 25 per cent and 35 per cent single levels.

15. Anthocyanin content analysed in flowers gave slightly superior values (0.443) in 50 per cent double level shading. Fall in anthocyanin content was observed with reduction in shade intensity.

16. The total chlorophyll and its components 'a' and 'b' were significantly influenced by the different shade levels. Highest content of chlorophyll 'a' was obtained in 50 per cent double level shading (4.03), while chlorophyll 'b' was maximum in 35 per cent double level shading (2.86). Total chlorophyll estimated was highest for 35 per cent double level shading (2.89) and was statistically on par with 50 per cent double level of shade (2.86).

17. Nutrient content within the plant was significantly influenced by different levels of shade. Total nitrogen content was maximum in 50 per cent double level shading (1.53%) eventhough significantly higher 'N' content was observed in 50 per cent single level shading (1.44%) and 35 per cent double level shading (1.32%). Total phosphorus content was maximum under

50 per cent double level shading (0.17%). Thirty five per cent single levels of shade had maximum potassium content (1.64%).

18. Nutrient uptake within the plant showed similar trend as nutrient content. Fifty per cent double and single level shading gave significantly superior results of 51.80 and 43.86 (mg $plant^{-1}$) respectively. Phosphorus uptake was maximum in 50 per cent double level shading (3.86 mg $plant^{-1}$). In the case of potassium uptake maximum was obtained in 35 per cent single level shading (49.87), however it was statistically on par with 50 per cent single (39.66) and double (47.80) levels of shade.

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* Originals not seen

APPENDIX

Weekly distribution of weather parameters during the experiment

(October - 2000 to September - 2001)

Month	Week	Temperature (°C)		Relative Humidity (%)		Rainfall	Mean
		Maximum	Minimum	Morning	Evening	(mm)	sunshine
2000 October	1	28.9	22.0	92	79	3.2	3.2
	2	30.9	22.1	91	65	18.1	7.1
	3	30.6	23.6	92	72	160.8	3.7
	4	31.7	19.8	90	58	6.8	7.4
November	1	33.4	23.0	73	47	0	8.3
	2	32.5	24.1	67	48	0	7.7
	3	36.6	23.9	82	64	23.1	3.1
	4	31.1	20.8	86	60	5.4	6.2
December	1	31.1	23.3	69	53	0	8.5
	2	31.1	21.2	65	36	0	9.7
	3	31.5	22.6	67	43	0	7.3
	4	30.7	21.4	75	55	8	6.8
2001 January	1	32.1	23.1	80	49	0	8.4
	2	37.5	22.9	75	40	0	9.0
	3	32.6	23.0	63	34	0	8.8
	4	33.5	23.4	69	39	0	8.1
	5	31.9	23.3	77	52	12.2	4.3
February	1	34.3	22.1	81	44	0	7.7
	2	34.9	22.4	82	37	0	9.1
	3	35.1	23.5	90	52	0	8.7
	4	35.2	23.7	85	49	0	8.7
March	1	35.0	23.5	89	57	2.2	8.1
	2	35.2	23.4	88	57	0	8.6
	3	34.3	24.2	85	54	0	7.2
	4	34.3	25.2	87	54	2.2	8.0
April	1	35.7	25.3	85	62	7.1	6.3
	2	33.1	23.4	90	64	190.6	5.3
	3	33.7	24.8	89	65	44.0	8.4
	4	34.3	25.5	90	63	1.4	6.3
	5	33.5	25.4	78	65	13.0	6.0
May	1	33.0	25.5	88	62	Nil	7.1
	2	32.8	25.0	89	64	18.1	8.4
	3	31.4	23.5	91	76	102.9	4.7
	4	30.8	23.7	92	71	44.8	4.7
June	1	29.0	22.0	95	81	185.5	1.5
	2	28.0	23.1	94	83	265.8	1.7
	3	29.7	23.3	95	80	146.2	2.8
	4	29.3	22.9	93	78	61.7	2.0
July	1	28.7	22.7	94	83	284.7	1.3
	2	28.9	22.5	94	93	109.1	2.1
	3	30.2	23.2	90	66	10.4	4.3
	4	28.3	22.6	93	79	62.7	1.8
	5	27.2	22.3	94	83	54.2	0.8
August	1	29.9	23.5	95	72	37.4	4.8
	2	29.0	23.1	95	81	105.4	2.2
	3	30.1	23.2	94	72	52.6	3.8
	4	30.3	23.5	93	70	12.4	6.7
September	1	31.8	23.2	91	57	2.5	8.2
	2	31.7	23.5	90	61	Nil	6.6
	3	30.8	23.5	88	69	10.2	4.5
	4	28.8	22.3	94	80	193.4	1.6

STANDARDISATION OF SHADE REQUIREMENT IN *Dendrobium*

By

SHERON FERNANDEZ

ABSTRACT OF THE THESIS

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DEPARTMENT OF POMOLOGY AND FLORICULTURE

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR-680 656

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ABSTRACT

An experiment was carried out in the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Thrissur, during 2000-2001, to standardize the shade requirement for *Dendrobium* variety Sonia Bom Jo and Renappa. The effect of different levels of shade on the morphological characters, flower production and quality of flowers were assessed.

Results revealed that the different levels of shade significantly influenced the morphological characters of the plant, viz., plant height, shoot production, internodal length, leaf production and leaf area. Maximum plant height was obtained for fifty per cent double level shading. With respect to shoot production, 25 and 35 per cent double levels of shade performed better. The length of the internode was maximum for 50 per cent double level shading. Highest leaf production was noticed in 35 per cent double level shading which was statistically on par with 50 per cent double level of shade.

Flower quality and flower production were markedly influenced by shade. Earliness in flowering was observed for those treatments receiving more light condition. Twenty five per cent single level shading was the earliest to flower in the group, while the longevity of the spike on the plant was more in 50 per cent single and double levels of shade. Vase life was significantly high in 25 per cent (15.50 days) and 50 per cent (14.88 days) double levels of shade. Longest spike was obtained in 50 per cent single level shading, while the length of the rachis was maximum in 50 per cent double level shading. Fifty per cent single level shading was distinctly superior to all other treatments with respect to the number of flowers per spike. Maximum spike production was noticed in 25 per cent double level shading. Anthocyanin content in flowers was found maximum under 50 per cent double level shading.