PERFORMANCE OF PHALAENOPSIS ORCHIDS UNDER VARYING SHADE LEVELS

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Thesis submitted in partial fulfillment of the requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2008

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DECLARATION

I here by declare that this thesis entitled "**Performance of Phalaenopsis orchids under varying shade levels**" 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 of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Performance of Phalaenopsis orchids under varying shade levels**" is a bonafide record of research work done independently by Ms. Pavithra .C.G. (2005-12-103) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Dedicated to

LORD KRISHNA
&
MY ACHAN AND AMMA

ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude and unforgettable indebtedness to:

God Almighty for the blessings that he showers upon my life and for giving me the courage to persue this endeavour to completion.

Dr. T. Sabina George, Professor, Department of Pomology and Floriculture and Chairperson of the Advisory Committee for her immense help, inspiration, constant mental support, prayers and encouragement.

Dr. C.S. Jayachandran Nair, Professor and Head, Department of Pomology and Floriculture for his inspiring guidance, valuable suggestions and critical supervision through out the study and preparation of the thesis.

Dr. V.L. Sheela, Professor, Department of Pomology and Floriculture for her sincere help, valid opinions and kind treatment throughout the courser of study and preparation of the thesis.

Dr. Vijayaraghava Kumar, Professor, Department of Agrl. Statistics and Computer Science for their whole hearted cooperation, timely help and valuable suggestions during the course of investigation.

Mr. C.E. Ajithkumar, Senior programmer, Department of Agrl. Statistics for his sincere help in statistical analysis of the data.

The faculty and staff of the Department of Pomology and Floriculture who have helped in one way or the other during the course of the study.

Kerala Agricultural University for granting the junior research fellowship.

My dear friends Lekshmi, Veena, Princy and Sadaf for their constant cooperation during the course of the study and preparation of the thesis.

My dear achan, amma, shari, smitha, sir, sisters, brother in law and ammomma for the unbound love, support and encouragement without which this work would not have been successfully completed.

Pavithra. C.G

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Introduction

1. INTRODUCTION

Orchids, the most beautiful flowers in god's creation, comprise a unique group of plants. Taxonomically, they represent the most highly evolved family among monocotyledons with 600 to 800 genera and 25,000 to 35,000 species. Orchids exhibit an incredible range of diversity in size, shape and color of their flowers. Orchids constitute an order of royalty in the world of ornamental plants and they are of immense horticultural importance (Kaushik, 1983).Orchids are known for their bewitchingly beautiful flowers with long lasting shelf life which fetch a very high price in the international market.

Fortunately, our country has all the potentials for development of a successful orchid industry on a scientific basis. In North India, the major orchid growing states are Sikkim, Arunachal Pradesh, and Himachal Pradesh. In South India, Kerala with high humidity and low temperature accompanied by good rainfall, has the congenial climate for commercial orchid cultivation. The important commercial orchids grown for cut-flower production in Kerala are *Aranthera, Aranda, Arachnis, Mokara, Dendrobium* and *Oncidium.*

Phalaenopsis, the fabulous moth orchids are recognized as the most beautiful flowers among orchids. Their long arching sprays of long lasting blooms are very popular throughout the world. They are grown in large quantities for cutflower trade in Taiwan, Thailand, United States, Hong Kong, Mainland China, Vietnam, The Philippines, South Korea, and Australia. It is a shade loving orchid. However, the cultural requirements are yet to be standardized.

One of the critical factors identified for successful growing of orchids is light. Determining the most suitable shade level for early vegetative growth of orchids is important as it influences the pre flowering period, flower induction and flower production. The present work was thus taken up with a view to assess the performance of three Phalaenopsis cultivars under varying shade levels and to determine the most suitable shade level for early vegetative growth of hardened plants.

Review of Literature

2. REVIEW OF LITERATURE

Orchids with flowers of exquisite beauty and variety of patterns belong to the family Orchidaceae. Today orchids such as *Cymbidium, Dendrobium, Oncidium* and *Phalaenopsis* are marketed globally and the orchid industry has contributed substantially to the economy of many ASEAN countries (Hew, 1994). *Phalaenopsis* is one of the most popular orchids commercially grown in the world. It is a remarkable epiphytic orchid, the species and hybrids of which do not show large growth, occupy less space but their flowers are magnificent and long lasting. Several hybrids of this genus grow well and flower profusely through out the year under the favourable agro climatic conditions of Kerala.The growth and development of crop plants are influenced by the solar energy harvested by them. In shade loving plants, light intensity influences various growth parameters, photosynthesis, chlorophyll content and other attributes (Hart, 1988). Some of the important research work on orchids and other crop plants are described in this chapter.

2.1 LIGHT AND SHADE EFFECTS

The growth and development of crop at anytime is determined by the solar energy intercepted and harnessed by the leaves. Shade influences vegetative characters, photosynthesis, chlorophyll content etc.

Available light and the nutrient regime followed are the two critical factors which influence plant responses. Early investigations on supplementary illumination of tropical orchid genera grown under green house conditions revealed beneficial effects with manipulation of light intensities (Sessler, 1978).

Sheehan & Sheehan (1974) reported that the optimum requirement of light for *Paphiopedilum* in general varied between 1800 and 2400 foot candles while *Phalaenopsis* shows satisfactory growth and flowering at 1500 foot candles light intensity.

The light requirements of epiphytic orchids varied considerably depending on their native habitat. Some could be grown in full sun; while others required varying degrees of shade (Purseglove, 1975).

Ross (1976) brought out the effect of light intensity on growth of house plants. The plants grown in full sun appeared stunted with stiff branches and sparse foliage but were tall and lanky with abundant foliage as shade increased.

Poole and Seeley (1977) noted that fluorescent light sources were better than high intensity discharge lamp and green house light for the growth of *Cattleya, Cymbidium* and *Phalaenopsis.*

In *Phalaenopsis*, light intensity should have been preferably fairly low. It varied from 1000 foot candles in the green house to 600 foot candles in the indoors, since phalaenopsis required less light than most other orchids. Although they were warm growing orchids, phalaenopsis did not like their warmth from the hot rays of the sun. Infact too much sunlight tends to burn the leaves. It is the atmosphere around them that must be warm. Some shading was always needed. However, during their active growing season, which came during the the summer, they could stand a bit more light, although nowhere near the amount cattleyas, could stand. In any case, *Phalaenopsis* leaves should have been firm. If they were too soft, a little more light was given to them from time to time (Sessler, 1978).

Full sunlight was detrimental to the growth of begonia. The leaves developed scorched marks on the margins. The best growth of begonia plants was obtained under 50% day light (Aasha, 1986).

Bose and Yadav (1989) reported that the light requirement of *Phalaenopsis* was 1500 foot candles. It was a shade loving orchid. It could not tolerate direct exposure to tropical full sun and they would have been scorched with in hours if exposed to strong mid day sun directly. High intensity discharge lamp and natural green house were required for *Phalaenopsis*.

Considering light as an important factor for growth, researchers are being carried out to establish a fast growth production system in orchids by Ichisashi (1990).

George and Mohanakumaran (1999) found that in sympodial orchids, the periodic functions of vegetative growth and flowering were dependant to a great extent on the cultural environment in which they were grown. Available light and the nutrient regime followed are the two critical factors which influenced plant responses.

For *Phalaenopsis* , a shade loving CAM orchid , the day and night time carbondioxide fixation increase with increasing light intensity in the day up to 130 micromoles/ m2/ sec (Hew et al., 2003).

Varghese (2005) reported that in *Phalaenopsis*, the growing period should have been in green house with 70-80% shade. For intense flowering in Kerala, the plants should have been transferred to areas where more light was available.

2.1.1 Influence of shade level on number of roots

Orchids depending up on their habit have different kinds of roots. Epiphytic and most lithophytic orchids had clinging roots for attachment to the tree or rock on which they grew , absorbing roots which penetrated the humus collected on the bark and aerial roots which hung free in the air aided in the absorption of moisture and to a lesser extent, food materials .

Dyeus and Knudson (1957) reported that the velamen absorbed moisture from the atmosphere but they were incapable of transmitting it into the interior of the root.

Root production was of extreme importance for the survival and growth of plants, orchids were not an exception. Compared to the roots found in field condition, the invitro roots of cauliflower plantlets were non –functional because they had poor vascular connection with the shoot which resulted in restricted water transfer from roots to shoot (Grout and Aston, 1977).

Debergh and Macne (1981) reported that invitro roots of ornamental plants died after transplanting to green house and delayed the plant growth.

Gent (1986) reported that root formation in tomato was stimulated at high irradiance, and relative growth rate (RGR) was also found to be high at high irradiance.

In study of stock plant etiolation and stem banding, stem cuttings of upright European horn bean(*Carpinus betulus* L. *fastigata)* were taken at two week intervals over four months following bud break and rooted under intermittent mist for 30 days. Stock plants were grown in a glass green house with 0, 50, 75, 95 percent shade on for 15 days. The highest rooting percentage and the greatest root counts and lengths were observed under 95% shade (Maynard and Bassuck, 1992).

Fakuoka et al. (1996) conducted a study on the effect of shading in cabbage seedlings on their physiological processes and rooting ability after transplanting and was observed that the rate of photosynthesis and root respiration declined in shaded condition.

Aerial roots of epiphytic orchids are characterized by a green tip whilst the remainder part of the root is covered with velamen. Root production for the monopodial orchids is at regular intervals near the nodal region along the stem axis and up to three roots may be produced at each node. Generally orchid roots can be divided into several distinct layers; velamen, cortex (exodermis and endodermis) and stele. A unique feature of the aerial root is the presence of velamen which covers the whole root except at the tip. Lying beneath the velamen and exodermis is the chloroplast containing cortex. A highly specialized layer of cells, the exodermis lies between the cortex and the velamen.The exodermis consists of two components small and dense cytoplasmic passage cells that are evenly dispersed among the larger, elongated and more vacuolated with thick walls (Hew et al., 2003).

The photosynthetic efficiency of aerial roots in leafy orchids had attracted considerable attention although the gas exchange pattern of aerial roots in leafy orchid was different from that of the leaf. Aerial root lost its chlorophyll and become branched when penetrated in to the mulch (Hew et al., 2003).

2.1.2 Influence of shade level on root length

In conifers, root and bud growth were usually inhibited by low light intensities and this could lead to reduction in assimilate flow to the root system (Nelson, 1964).

In an experiment on studying the effect of defoliation, shading and competition on spotted knapweed (*Centaurea maculosa* lam.) the foliage ,root and crown growth increased significantly when plants received full sunlight, rather than 50% shade (Kennet et al., 1992).

2.1.3 Influence of shade level on root thickness

Aerial roots of epiphytic orchids are characterized by a green tip whilst the remainder part of the root is covered with velamen. Root production for the monopodial orchids is at regular intervals near the nodal region along the stem axis and up to three roots may be produced at each node. Generally orchid roots can be divided into several distinct layers; velamen, cortex (exodermis and endodermis) and stele. A unique feature of the aerial root is the presence of velamen which covers the whole root except at the tip. Lying beneath the velamen and exodermis is the chloroplast containing cortex. A highly specialized layer of cells, the exodermis lies between the cortex and the velamen.The exodermis consists of two components small and dense cytoplasmic passage cells that are evenly dispersed among the larger, elongated and more vacuolated with thick walls (Hew et al., 2003).

In a study on the effects on growth in super-elevated (1%) CO_2 in terms of photosynthetic capability and carbohydrate production were studied in an epiphytic CAM (Crassulacean acid metabolism) orchid plantlet, *Mokara* Yellow. The growth of the plantlets was greatly enhanced after growing for 3 months at 1% CO_2 compared with the control plantlets (0.035% CO_2). CO_2 enrichment produced more than a 2-fold increase in dry matter production. The enhanced root growth at 1% CO_2 led to a higher root:shoot ratio. The increased photosynthetic capacity and enhanced growth of the epiphytic roots under CO_2 enrichment would facilitate the generation of more photoassimilates and acquisition of essential resources, thereby increasing the survival rate of orchid plantlets under stressful field conditions (Gouk et al., 1999).

2.1.4 Influence of shade level on number of shoots and offshoots

In an experiment on studying the response of Dendrobium orchid cultivar Sonia 16 to varying light intensities and nutrient regimes , the number of shoots was greater in the plants under 75% light and 50% light at 10 MAP. Shoot number was low in the plants under 25 % light (George et al., 1999).

2.1.5 Influence of shade level on shoot length

Shoot length differences in plants grown under open and in different shade levels were reported in soyabean (Allen, 1975) and in ginger (Aclan and Quisumbing, 1976).

Ross (1976) brought out the effect of light intensity on growth of house plants. The plants which were grown in full sun appeared stunted with stiff branches, sparse foliage but were tall and lanky with abundant foliage as shade increased.

Tarila et al. (1977) reported that high light intensity reduced plant height in cowpea. Positive influence of shade on plant height was reported on groundnut(George,1982),tomato(Kamaruddin,1983),wingedbean(Sorenson,1984),cassava (Ramanujam et al.,1984; Sreekumar et al.,1988), sweet red pepper(Rylski and Spingelman,1986),broad bean(Xia, 1987), rice(Jadhav, 1987;Singh et al., 1988), passion fruit(Menzel and Simpson, 1988) and in colocasia(Prameela,1990) and Pillai(1990) in clocimum.

In plants like cowpea, black gram and colocasia, plant height was unaffected by shading. However a negative effect on height was observed in red gram (George, 1982).

High light intensity was found to give rise to shorter but very strong stems in *Datura candida* (Acosta et.al., 1983).Cooper (1996) in his attempt to find out the response of birds foot terfoil and alfa- alfa to various levels of shade (51, 76 & 92% shade) found that plant height was decreasing proportionately with increasing levels of shade.

Dustan and Turner (1984) suggested that inorder to minimize the shock to the micropropagated plantlets during acclimatization; light intensity should be kept low at first and then increased gradually.

In shade loving ornamental aroids, decreasing light intensity was reported to favour plant height. In *Syngonium podophyllum* , plants grown under 80 % shade were taller than those grown under 47 % shade (Chase and Poole, 1987) and in anthurium, plant height was found to increase with increasing shade (Lalithabhai, 1981).

Plant height was found to increase in ginger when the shade intensity was increased from zero to 75% (Susanvarghese, 1989; Jayachandran et al., 1991; Ancy, 1992; Babu, 1993).

2.1.6 Influence of shade level on internodal length

The shade environment produced in agro forestry practices affects the morphology, anatomy and chemical composition of intercropped forages.Internodal length and leaf area increased for plants grown in shade compared to those grown in full sun (Lin et al., 2001).

In a study on the effect of far-red light on the growth of the second internode in *Helianthus annuus* L. The internodes of helianthus plants grew at faster rates that were exposed to supplementary far-red light (Garrison and Briggs, 1975).

2.1.7 Influence of shade level on rate of shoot elongation

In a study on the effects of greenhouse climate and plant density on external quality of chrysanthemum (*Chrysanthemum morifolium*), higher light intensity has a positive effect on several external quality aspects of chrysanthemum and resulted in longer stems and more lateral branches (Carvalho and Heuvelink, 2001).

2.1.8 Influence of shade level on number of leaves

Aclan and Quisumbing (1976) reported that reduced numbers of leaves per tiller in ginger were noticed when grown under full sunlight compared to different levels of shade.

Lee et al. (1985) studied the effect of light intensity on the surface morphology of invitro developed leaves of sweet gum. Compact and larger mesophyll cells and high stomatal density was more in the leaves grown under high light intensity.

The leaf number and size of leaf of Amaranthus species were found to be greater at the medium than at higher levels of shade (Simbolon and Sutarno, 1986).

In sweet potato, leaf number and leaf size increased as leaf number declined in response to higher shade levels, thus leaf areas were similar in all treatments (Laura et al., 1986).

The clove seedlings kept under shade produced more number of leaves than seedlings exposed to sun (Venkataramanan and Govindappa, 1987).

Sreekumari et al. (1988) reported that in cassava the leaf size and leaf longevity increased and leaf number decreased when grown under shade in coconut garden.

In a shade study at Vellayani, Ancy Joseph (1992) observed maximum number of leaves per plant in ginger under 25% shade at all the growth stages and the lowest number of leaves were recorded at 75% shade.

In an experiment on studying the comparison of chlorophyll content, water loss and anatomical features of leaves of the normal, invitrocultured and hardened dendrobium hybrid plantlets, a reduction in the size of the guard cells, subsidiary cells, and chlorophyll content were observed. The green house grown plantlets had characteristic intermediate in the above characters between those of normal and TC plantlets (Anita, 2000).

2.1.9 Influence of shade level on length of leaves

Krisek and Lawson (1974) in a study on the effect of high light intensity and elevated temperature on growth of *Cattleya* and *Phalaenopsis* observed that temperature was more a limiting factor than light intensity for growth of both the orchids. At high light intensity, elevated temperature and frequent fertilization, cattleya plants produced 3-4 times the amount of leaf elongation on lateral shoots and 2-3 times as many lateral shoots than plants grown under conventional green house condition.

2.1.10Influence of shade level on Width of leaves

Anita (2000) reported comparison regarding the leaf anatomy,stomatal size, stomatal count, chlorophyll content between the leaf tissues of invitro culture and green house grown plants of a *Dendrobium* hybrid *Dendrobium* Sonia-17.Leaves of invitro grown plants were smaller and thinner and have a less compactly arranged mesophyll cells than the acclimatized plants. Normal leaves i.e. leaves from green house grown plants were larger and thicker and the ground tissue was compactly arranged.

In a study on the effects of photon flux density on the morphology, photosynthesis and growth of a CAM orchid, *Doritaenopsis* during post-micro propagation acclimatization, the plantlets were transferred to three different photosynthetic photon flux densities for four months, i.e. ‘low light’ (175), ‘ intermediate light’ (270) and ‘high light’ (450 μ mol m^{-2} s^{-1}). For most of the growth parameters measured i.e. leaf length, leaf area, leaf width, chlorophyll *a*/*b* ratio, were greater at 270 μ mol m^{-2} s^{-1}. The only exception was leaf thickness, which was increased more under high light levels. Results showed that the survival of *Doritaenopsis* plantlets was greatest (90%) in low light and intermediate light (89%) compared with only (73%) at high light (Jeon, 2005).

2.1.11 Influence of shade level on Leaf area

Vinson (1923) studied the effects of shading on geranium and reported larger leaf area under shaded conditions.

In bird’s foot trefoil, there was a decrease in leaf area under conditions of moderate shading (McKee, 1962).

Leaf area per plant of red clover was found to increase under conditions of moderate shading (McKee, 1962).

Panikar et al. (1969) observed an increase of 15.1 and 17.6 percent in the length and breadth of leaves in tobacco under shade compared to unshaded plants.

Yoshida (1972) found that 70% shade was optimum for anthurium plantlets which resulted in an increase of photosynthetic rate with increase in leaf area index.

Ross (1976) brought out the effect of light intensity on growth of house plants. The plants grown in full sun appeared stunted with stiff branches, sparse foliage but were tall and lanky with abundant foliage as shade increased.

In rice, leaf area development was reduced due to low light intensity (Venkateswaralu and Srinivasan, 1978).

Full sunlight was detrimental to the growth of begonia. The leaves developed scorched marks on the margins. The best growth of plants was obtained under 50% day light (Aasha, 1986).

Gratani et al (1987) found that leaf area of sun leaves (upper layer) was lower than that of shade ones with in beach crown.

Salisbury and Ross (1992) reported that light was an important factor for leaf expansion.

In an experiment in studying the effect of shade and mulch on the yield of ginger, maximum leaf area was produced under 25% shade and minimum leaf area was produced under open condition at 120 and 180 DAP
(Babu ,1993).

Shaheen et al. (1995) observed a reduction in fresh weight, dry weight and total chlorophyll content at higher shade level in seedlings of some vegetables grown under plastic houses at different levels of light intensity.

Galyuon et al. (1996) observed a reduction in total leaf area plant under full sunlight but leaf thickness, specific leaf weight and stomatal density was increased in an experiment on studying the effect of irradiance level on cocoa, its growth and leaf adaptation.

A direct influence of light intensities on the leaf area of *Dendrobium* Sonia-16 was observed during the early stages at 3 and 4 month after planting. The light intensity of 25% resulted in a greater leaf area than 50% light intensity at 3 and 4 month after planting. The leaf area under 25% light intensity was greater than under both 50% and 75% light (George, 1999).

2.1.12 Influence of shade level on leaf thickness

Leaf morphology was strongly influenced by light levels during development. A comparative study on light and shade on leaflets of common flowering plant *Vicia americana* revealed striking differences in leaflet form, size and thickness (Cormack, 1955).

Fails et al. (1982) observed that in *Ficus benjamina* plants, shade grown leaves were larger, thinner, flatter and darker green than the sun grown leaves.

In a study on the light acclimation in citrus leaves, citrus plants were grown in different light situations like full sunlight, 50 and 90 % shade. Those grown in full sunlight had the highest leaf thickness and the lowest thickness was reported on 90% shade (Syvertsen and Smit, 1984).

In a pot trial on beans (*Phaseolus vulgaris*) grown at different light intensities has shown that leaf thickness increased with increased light intensity (Silva et al., 1984).

Different cultivars of cranberry grown at four light levels, simulating levels, naturally occurring in the plant canopy in the field, showed that leaf thickness was reduced substantially with increased shading (Stang et al., 1985).

In dicots, shade leaves were typically larger in area but thinner than sun leaves (Salisburry and Ross, 1992).

Leaves of orchids are variable in shapes, sizes and thickness.Generally,orchid leaves can be divided in to 2 types based on leaf thickness; thin leaved or thick leaved.Both thin and thick leaved orchids lack stomata on the upper epidermis.Thin leaved orchids have higher density of stomata on the lower epidermis in comparison to thick leaved orchids((Hew et al., 2003).

2.1.13 Influence of shade level on leaf pigmentation and leaf sheath colour

Rooted cuttings of the tropical epiphyte *Ficus benjamina* L., were grown in a shaded environment that excluded approximately 50% of the natural photosynthetically active irradiance (890 µmol m^{-2} s^{-1}) for 4 months. Established plants were transferred and grown for 10 months under a range of irradiance levels with daily average maxima varying from a full-sun environment to 20% full sun (100%−1735; 50%−890; 40%−695; and 20%−303 μmol $m^{-2}s^{-1}$). Chlorophyll,carotenoid and soluble protein content increased in ficus leaves as irradiance level decreased (Lance and Guy, 1992).

2.1.14 Influence of shade level on number of stomata and shape of stomata

Marin et al. (1988) reported that the shape of stomata in persistent leaves changed from round to normal elliptical during acclimatization.

In majority of the dendrobes, stomata possess 4-6 subsidiary cells (Kaushik, 1983; Khasim and Mohana Rao, 1989) but in the present sps (D. *jenkinsii*) they had only 2 subsidiary cells which was a characteristic feature of vandoid tribes (Williams, 1979).

Isiah and Rao (1992) studied the anatomy of dendrobium and reported that the leaves were hypostomatal with paracyclic stomata and they possessed large and compound marginal vascular bundles.

Pack and Jun (1995) reported that in 33 orchids, the stomata were mainly confirmed to the abaxial side of leaves except in *Blitilla striata*.

Leaves of orchids are variable in shapes, sizes and thickness. Generally, orchid leaves can be divided in to 2 types based on leaf thickness; thin leaved or thick leaved. Both thin and thick leaved orchids lack stomata on the upper epidermis .Thin leaved orchids have higher density of stomata on the lower epidermis in comparison to thick leaved orchids((Hew et al., 2003).

2.1.15 Influence of shade level on Chlorophyll content

Shirley (1929) reported that shaded leaves generally had an enhanced chlorophyll level per unit weight.

Seybold and Egle (1937) observed increased chlorophyll 'b' content in the leaves of plants grown under low light intensity.

In fruit crops, concentration of chlorophyll per unit area or weight of leaves increased with increase in light intensity (Gardner et al., 1952).

An increased chlorophyll content with increased shade level was reported by Evans and Murran (1953) in cocoa; Radha (1979) in colocasia; Bhat and Ramanujam (1975) in cotton; George (1982) in groundnut; Sorenson (1984) in winged beans; Anderson et.al. (1985) in tobacco; Singh (1988) in potato and Prameela (1990) in colocasia.

Yoshida (1972) found that 70% shade was optimum for anthurium plantlets resulting in an increase of photosynthetic rate with increase in leaf area index.

Instances where the chlorophyll content was unaffected by shading were also observed in crops like chick pea (Pandey et al., 1980) and kiwi fruit (Grant and Ryng, 1984).

Donnelly and Vidaver (1984) found that the amount of chlorophyll a and chlorophyll b were significantly higher in the newly produced leaves of the transplants than in the leaves of the invitro cultured plantlets of red rasp berry.

An inverse relationship of shade and chlorophyll content had been reported in peanut (Rao and Mithra, 1988) and maize (Bhutani et al., 1989).

Farquhar et al. (1989) studied that during photosynthesis, green plants preferentially took up the lighter of two naturally occurring isotopes of carbon (^{12}C and ^{13}C).

Susan Varghese(1989) and George (1992) found that chlorophyll and its fraction (chlorophyll 'a' and chlorophyll'b') of ginger increased steadily with increasing levels of shade at Vellanikkara ,Trichur. In a shade study at Vellayani, Thiruvananthapuram, Ancy joseph(1992) observed the same trend with respect to chlorophyll content.

The chlorophyll contents of tea shoots grown in the shade of trees were significantly higher than those from unshaded plots (Mahanta and Baruah, 1992).

Photosynthesis of the C_3 orchid, Oncidium Goldiana had been studied at four different stages of development, bud stage (youngest),plantlet stage, unsheathing stage and pseudobulb stage (oldest).Leaf photosynthesis changed as the leaves aged. Similarly the capacity for CAM appeared to change with leaf age (Hew et al., 2003).

Shaheen et al. (1995) observed a reduction in fresh weight, dry weight and total chlorophyll content at higher shade level in seedlings of some vegetables grown under plastic houses at different levels of light intensity.

Leonardi (1996) studied the effect of shading on greenhouse pepper and observed that shading reduced chlorophyll content, photosynthetic rate as well as the rate of respiration.

Alex (1996) reported that with decreasing intensity of shade, there was a decrease in chlorophyll content of *Philodendron wendlandi* when the effect of shade alone is considered.

Nii and Kurowia (1998) studied that the anatomical changes including chloroplast structures in peach leaves under different light conditions and found that chlorophyll content per unit leaf area increased with shading. Shade leaf chloroplasts were larger and rich in thylakoids, where sun leaf chloroplasts showed poorly stacked grana.

The concentrations of chlorophyll a, chlorophyll b, chlorophyll a + b decreased significantly in germinating and growing cattleya seedlings under red, yellow green and blue lights as compared to those living under white light. The chlorophyll content was relatively higher under red and blue light in these seedlings (Salam et al., 2000).

Materials and Methods

3. MATERIALS AND METHODS

An investigation was carried out to assess the performance of *Phalaenopsis* orchids under varying shade levels and to determine the most suitable shade level for early vegetative growth of hardened plants.Three experiments were conducted during 2006-2007 at the Department of Pomology and Floriculture, College of Agriculture, Vellayani,Thiruvanathapuram under the Kerala Agricultural University. The materials and methods used for the study are described in this chapter

3.1 MATERIALS UTILISED FOR STUDY

3.1.1 Variety

The following three commercially grown cultivars of *Phalaenopsis* orchids were used as the experimental material. The cultivars (V) are Hsin (V_1), Luchia Pink (V_2) and Brother Girl (V_3).

3.1.2 Planting Material

Eight month old hardened tissue cultured plantlets were used as the planting material.

3.2 METHOD

Pot culture was the cultivation method adopted. The selected varieties were established in orchid pots with charcoal, as the medium. For the three experiments, shade(S) was provided with black high density polyethylene shade net calibrated for 25 per cent, (S_1) 50 per cent (S_2) and 75 per cent (S_3) shade. General view of the experimental plot is given in plate1, 2 and 3.

3.2.1 EXPERIMENTAL DETAILS

Particulars	Experiment 1	Experiment 2	Experiment 3
Shade	25%(S_1)	50%(S_2)	75%(S_3)
Experimental Design	CRD	CRD	CRD
Replications	5	5	5
Treatments	3 cultivars	3 cultivars	
No. of Plants	15	15	15
Duration	12 months	12 months	12 months

3.2.2 Planting

The plantlets maintained in charcoal and husk medium in plastic cups were transferred to orchid pots containing charcoal as the medium.

3.2.3 Nutrient Application

A nutrient mixture (green care orchid food) containing NPK 13:27:27 @ 0.4 % was given as foliar spray daily. The plants were irrigated once on all rainless days and the frequency was increased to two during the summer months.

3.2.4 Plant Protection

Bio control agent *Pseudomonas fluorescence* @ 20 g per litre was given as a whole plant spray at weekly intervals from April 2007 onwards. Prophylactic application of Bavistin (0 .1 %) was carried out at monthly intervals.

S_1

Plate 1. General view of the experiment under 25% shade

S_2

Plate 2. General view of the experiment under 50% shade

S_3

Plate 3. General view of the experiment under 75% shade

3.3 OBSERVATIONS RECORDED

The following biometric observations were recorded from all the plants at fortnightly intervals for the three experiments during the period of investigation.

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3.3.1 Number of roots

The numbers of roots growing into the medium and just visible per plant were recorded and the mean was calculated.

3.3.2 Length of roots (cm)

The length of roots that were visible and measurable were taken at fortnightly intervals and the mean calculated.

3.3.3 Thickness of roots (cm)

The maximum thickness of roots that were visible was measured at their middle portion and the mean calculated.

3.3.4 Number of shoots and offshoots

The number of shoots and offshoots other than the main shoot produced after planting were recorded.

3.3.5 Length of shoot (cm)

The length of main shoot was measured from the base of the plant to the tip of the topmost leaf and the mean calculated.

3.3.6 Girth of shoot (cm)

The maximum girth of the main shoot was measured at their middle and the mean calculated.

3.3.7 Internodal length of shoots (cm)

The distances between two adjacent nodes of the main shoot were taken and the mean was calculated and expressed in centimeters.

3.3.8 Rate of shoot elongation

The difference between the final shoot length and the initial shoot length divided by total fortnights was measured and expressed in centimeters.

3.3.9 Number of leaves

The total number of leaves produced by each plant was counted and the mean calculated.

3.3.10 Length of leaves (cm)

Lengths of the leaves were measured from the base to the tip in centimeters and the mean calculated.

3.3.11 Width of leaves (cm)

The maximum width of leaves was measured at their middle portion and the mean calculated.

3.3.12 Leaf area (cm^2)

The maximum length and breadth of all the leaves on the plant was measured in centimeter at fortnightly intervals and the total leaf area (cm^2) was computed using a constant (K) derived from a sample of stratified leaves which was equal to 0.75 for V_1, 0.66 for V_2 and 0.71 for V_3.
Leaf area = Kx length x breadth.

3.3.13 Leaf shape

The shape of fully opened mature leaves was recorded for each cultivar at fortnightly intervals.

3.3.14 Leaf thickness (µm)

Leaf thickness was measured by taking the section of a fully opened leaf using a micrometer and was measured in microns.

3.3.15 Leaf pigmentation

The leaf was observed for presence or absence of pigmented streaks and the colour of leaf were recorded.

3.3.16 Leaf sheath colour

The leaf sheath was observed for presence or absence of pigmented streaks and the colour of the leaf sheath were recorded.

3.3.17 Chlorophyll content

Photosynthetic pigments namely chlorophyll a and chlorophyll b was estimated by the following methods as described by Arnon (1949).

A representative sample of 100 mg of leaf tissue was weighed, chopped and added to 5 ml of DMSO solution and kept over night. The absorbance of the extract was measured at 663 and 645nm using spectrophotometer. The amount of pigments was calculated using the following formulae and expressed as mg of pigment per g of fresh leaf weight.

Chlorophyll a = {[12.7(OD at 663) - 2.69 (OD at 645)]* V} / W*1000

Chlorophyll b = {[22.9(OD at 645) - 4.68(OD at 660)]* V} / W*1000

3.3.18 Stomatal distribution on upper and lower surface of the leaves (per mm^2)

Stomata were counted both on the adaxial and abaxial surface by putting a thin film of quick fix over randomly selected leaves .The film was removed after few minutes and the numbers of stomatal impressions were counted using a microscope. The number of stomata per unit area was calculated and the mean recorded (Taylor et al., 1997)

3.3.19 Shape of stomata

The shape of stomata on the upper and lower surface of the leaves was recorded and their photographs were taken under microscope of 40x magnification.

3.4 STATISTICAL ANALYSIS

Analysis of the experiments was carried out. Pooled analysis of the experiments and their interpretations were done as per Panse and Sukhatme (1985).

Results

4. RESULTS

The results of the experiments conducted on the standardization of suitable shade levels for hardened tissue cultured plantlets of three *Phalaenopsis* orchids are presented in this chapter.

Vegetative characters such as number of roots, length of roots, thickness of roots, number of shoots and off shoots, length of shoots, shoot girth, internodal length of shoots, rate of shoot elongation, number of leaves, Length and width of leaves, leaf area, leaf shape, leaf thickness, leaf pigmentation and leaf sheath colour were recorded at fortnightly intervals.Stomatal distribution and shape of stomata were recorded at monthly intervals. Chlorophyll content (both a and b) were recorded at the end of field experimentation.

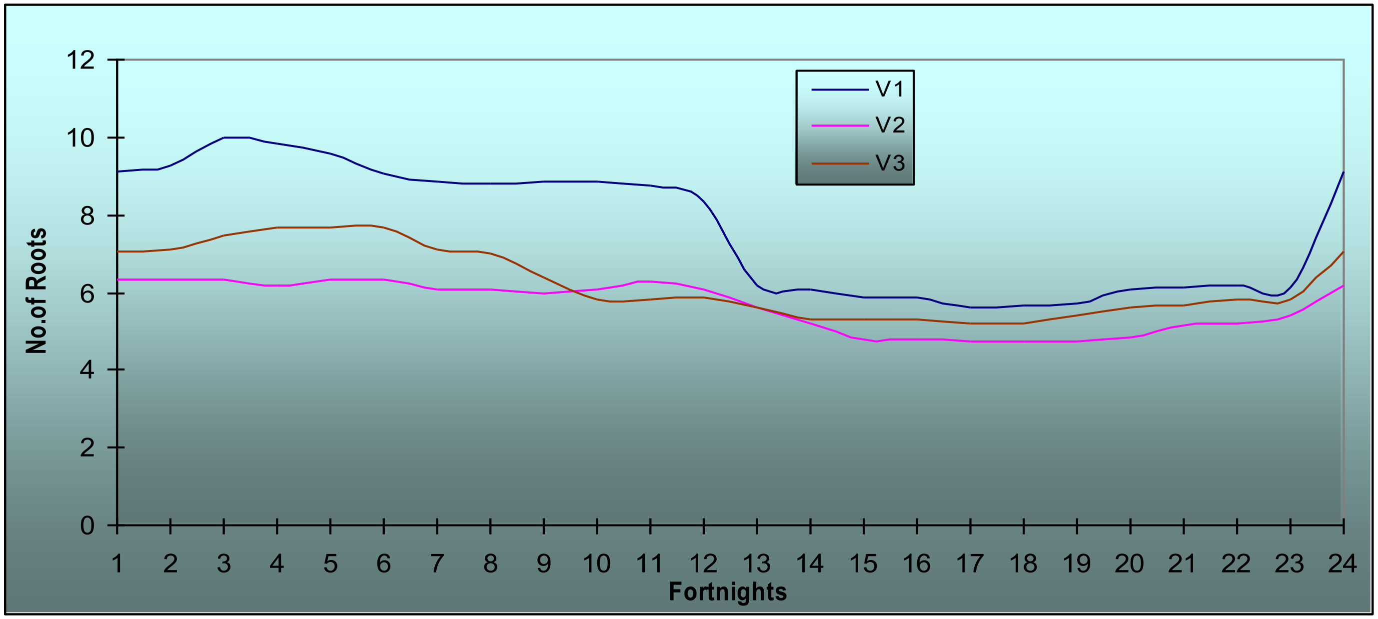
4.1 Vegetative Characters

4.1.1 Number of roots (Table1, fig.1 and fig.2)

Significant differences between cultivars in the number of roots produced were observed from the first fortnight to the 12th fortnight (November 2006 to fortnight of April 2007) after planting. From the 13th to the 23rd fortnight, (May 2007 to October 2007) cultivar differences in root number were not significant. During the first fortnight, *Phalaenopsis* Hsin (V_1) was superior to *Phalaenopsis* Luchia Pink (V_2) and *Phalaenopsis* Brother Girl (V_3). *Phalaenopsis* Hsin (V_1) was found to have significantly greater number of roots from the first fortnight to the 12th fortnight (8.33 to 10) than *Phalaenopsis* Luchia Pink(V_2) or *Phalaenopsis* Brother Girl(V_3) having root numbers ranging from 6.00 to 6.33 and 5.80 to 7.66 respectively. From the 13th to the 23rd fortnight, number of roots did not differ significantly in the three cultivars. However during

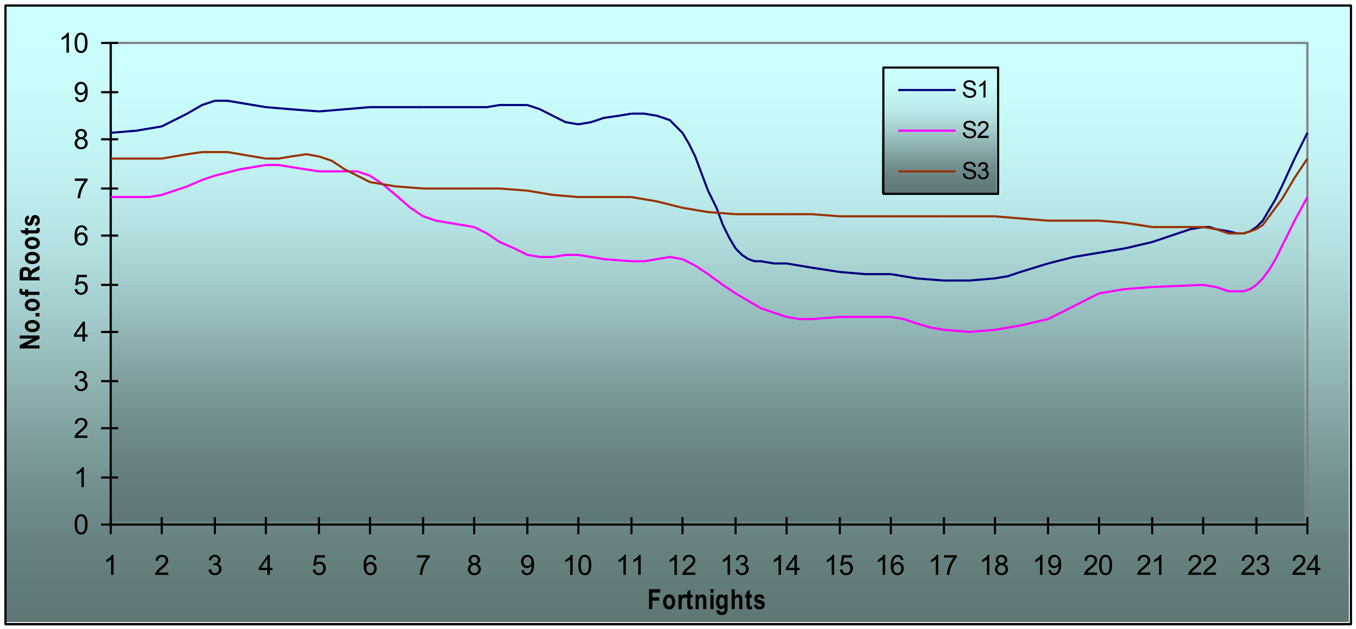
Table 1. Effect of shade on number of roots in *Phalaenopsis* orchids

FN	V1				V2				V3				shade			CD		
	S1	S2	S3	Pooled	S1	S2	S3	Pooled	S1	S2	S3	Pooled	S1	S2	S3	V	S	VxS
1	10.80	7.60	9.00	9.13	6.40	6.20	6.40	6.33	7.20	6.60	7.40	7.06	8.13	6.80	7.60	1.60	NS	NS
2	11.20	7.60	9.00	9.26	6.40	6.20	6.40	6.33	7.20	6.80	7.40	7.13	8.26	6.86	7.60	1.54	NS	NS
3	12.20	8.40	9.40	10.00	6.40	6.20	6.40	6.33	7.80	7.20	7.40	7.46	8.80	7.26	7.73	1.50	NS	NS
4	11.80	8.80	9.00	9.86	6.20	6.00	6.40	6.20	8.00	7.60	7.40	7.66	8.66	7.46	7.60	1.44	NS	NS
5	11.20	8.40	9.20	9.60	6.60	6.00	6.40	6.33	8.00	7.60	7.40	7.66	8.66	7.33	7.66	1.43	NS	NS
6	11.20	8.20	7.60	9.06	6.60	6.00	6.40	6.33	8.00	7.60	7.40	7.66	8.66	7.26	7.13	1.35	NS	NS
7	11.40	8.00	7.20	8.86	6.60	5.40	6.20	6.06	8.00	5.80	7.60	7.13	8.66	6.40	7.00	1.17	1.17	NS
8	11.60	7.60	7.20	8.80	6.60	5.40	6.20	6.06	7.80	5.60	7.60	7.00	8.66	6.20	7.00	1.16	1.16	2.02
9	11.60	7.60	7.20	8.86	6.60	5.40	6.00	6.00	7.80	3.80	7.60	6.40	8.73	5.60	6.93	1.25	1.25	2.18
10	11.80	7.60	7.20	8.86	6.40	5.40	6.40	6.06	6.80	3.80	6.80	5.80	8.33	5.60	6.80	1.27	1.27	2.21
11	11.80	7.20	7.20	8.73	7.00	5.40	6.40	6.26	6.80	3.80	6.80	5.80	8.53	5.46	6.80	1.43	1.43	NS
12	10.60	7.20	7.20	8.33	7.00	5.40	5.80	6.06	6.80	4.00	6.80	5.86	8.13	5.53	6.60	1.55	1.55	NS
13	8.20	5.40	7.20	6.20	5.60	5.40	5.80	5.60	6.40	4.00	6.40	5.60	5.73	4.80	6.46	NS	NS	NS
14	6.00	5.20	7.40	6.06	4.80	5.00	5.80	5.20	6.00	3.60	6.40	5.33	5.40	4.33	6.46	NS	1.32	NS
15	5.60	5.20	7.20	5.86	4.60	4.20	5.60	4.80	6.00	3.60	6.40	5.33	5.26	4.33	6.40	NS	1.25	NS
16	5.20	5.20	7.20	5.86	4.60	4.20	5.60	4.80	6.00	3.60	6.40	5.33	5.20	4.33	6.40	NS	1.25	NS
17	5.20	4.40	7.20	5.60	4.40	4.20	5.60	4.73	5.60	3.60	6.40	5.20	5.06	4.06	6.40	NS	1.14	NS
18	5.20	4.40	7.20	5.66	4.40	4.20	5.60	4.73	5.60	3.60	6.40	5.20	5.13	4.06	6.40	NS	1.14	NS
19	5.40	4.60	7.00	5.73	4.40	4.20	5.60	4.73	6.00	3.80	6.40	5.40	5.40	4.26	6.33	NS	1.21	NS
20	5.60	5.40	7.00	6.06	4.60	4.40	5.60	4.86	6.20	4.20	6.40	5.60	5.66	4.80	6.33	NS	NS	NS
21	5.80	5.40	7.00	6.13	5.00	4.80	5.60	5.13	6.40	4.40	6.20	5.66	5.86	4.93	6.20	NS	NS	NS
22	6.00	5.60	7.00	6.20	5.20	5.00	5.40	5.20	6.80	4.40	6.20	5.80	6.20	5.00	6.20	NS	NS	NS
23	6.00	5.60	6.80	6.13	5.80	5.00	5.40	5.40	6.80	4.40	6.20	5.80	6.20	5.00	6.13	NS	NS	NS
24	6.00	7.60	9.00	9.13	5.80	5.00	5.40	6.20	7.20	6.60	7.40	7.06	8.13	6.80	7.60	1.60	NS	NS



V_1 – *Phalaenopsis* Hsin
V_2 – *Phalaenopsis* Luchia Pink
V_3 – *Phalaenopsis* Brother Girl

Fig 1. Cultivar differences on number of roots in *Phalaenopsis* orchids



S_1– 25% shade
S_2– 50% shade
S_3– 75% shade

Fig 2. Effect of shade on number of roots in *Phalaenopsis* orchids

the 24th fortnight, *Phalaenopsis* Hsin (V_1) was found to record significantly greater root number (9.13) than V_2 (6.2) or V_3 (7.06).

Effect of shade on number of roots produced at fortnightly intervals in the three cultivars was not significant from the first to the 6th fortnight. However from the seventh to the 12th fortnight (February 2007 to April 2007) and 14th to the 19th fortnight (May 2007 to August 2007),shade effects significantly influenced the number of roots produced. From the 7th to the 12th fortnight ,all the cultivars recorded significantly greater root number(8.13 to 8.73) under 25% shade (S_1) when compared to 50% shade (S_2).From the 14th to the 19th fortnight,75% shade (S_3) was found to be more conducive for root production in the cultivars than 50% shade (S_2). From the 20th to the 23rd fortnight , shade effects were not found to significantly influence the number of roots. However at the 24th fortnight (October 2007), more number of roots was significantly produced under 25% shade than under 50% shade (S_2).

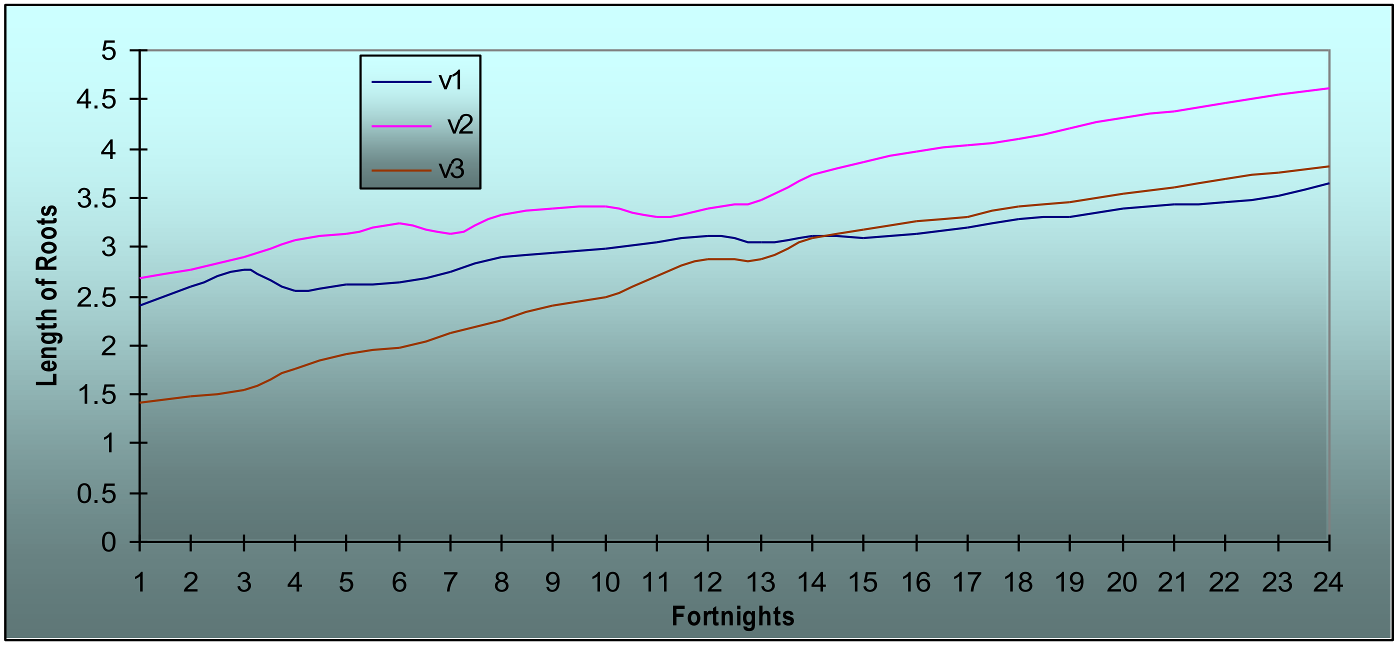
Interaction between cultivars and shade effects influenced root production from the 8th fortnight to the 10th fortnight (February 2007 to March 2007). During the 8th fortnight, *Phalaenopsis* Hsin (V_1) had significantly greater number of roots (11.6) under 25% shade than under 50% and 75% shade than the *Phalaenopsis* Luchia Pink or *Phalaenopsis* Brother Girl under 25%, 50% or 75% shade. *Phalaenopsis* Luchia Pink had significantly lesser number of roots under 50% shade than *Phalaenopsis* Hsin or plants of all the three cultivars grown under 25% shade.

4.1.2. Length of roots (Table 2, fig.3 and fig.4)

Significant difference between the cultivars in the root length was observed from the first to the 10th fortnight (November 2006 to March 2007) after planting. From the 11th fortnight to the 19th fortnight, cultivar differences in root

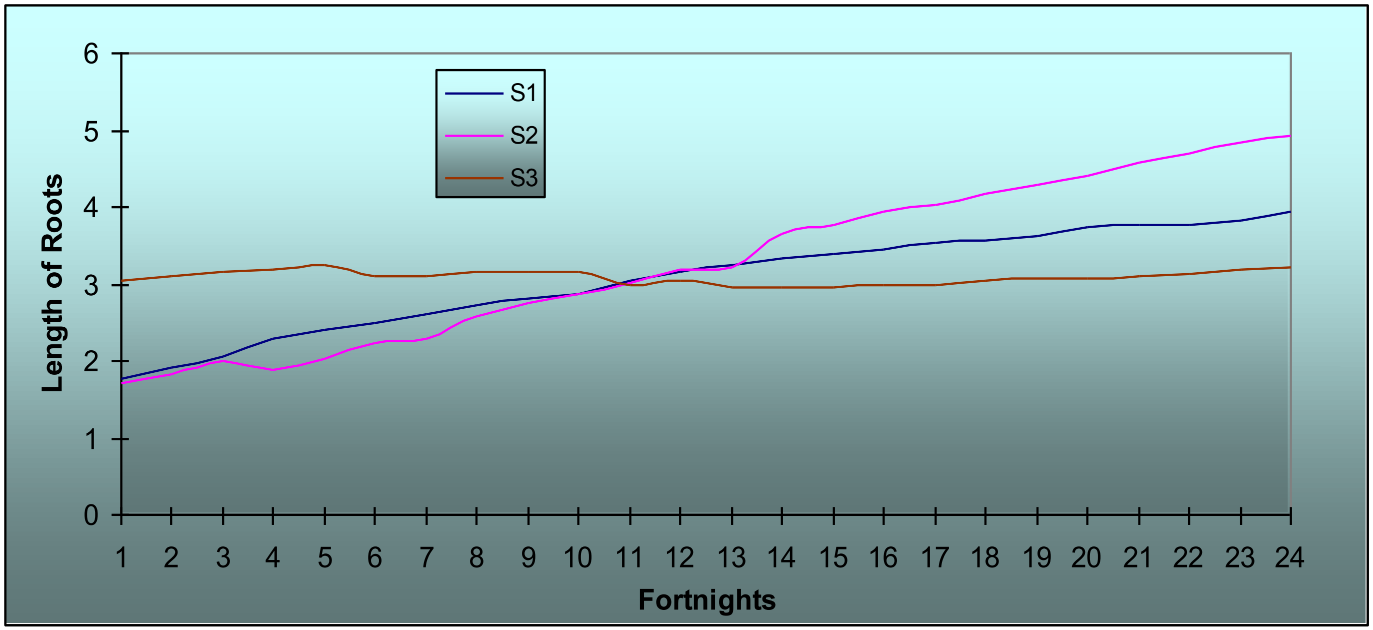
Table 2. Effect of shade on length of roots (cm) in *Phalaenopsis* orchid

FN	V_1				V_2				V_3				shade			CD		
	S_1	S_2	S_3	Pooled	S_1	S_2	S_3	Pooled	S_1	S_2	S_3	Pooled	S_1	S_2	S_3	V	S	VxS
1	1.89	2.26	3.08	2.41	1.98	1.96	4.12	2.68	1.42	0.90	1.94	1.42	1.76	1.70	3.04	0.69	0.69	NS
2	2.11	2.46	3.20	2.59	2.12	2.02	4.16	2.76	1.48	0.91	1.98	1.48	1.90	1.82	3.11	0.67	0.67	NS
3	2.49	2.58	3.24	2.77	2.22	2.24	1.26	2.90	1.48	1.16	2.00	1.54	2.06	1.99	3.16	0.67	0.67	NS
4	2.66	1.74	3.30	2.56	2.30	2.54	4.30	3.07	1.92	1.34	2.02	1.76	2.29	1.87	3.20	0.49	0.49	0.85
5	2.72	1.78	3.36	2.62	2.44	2.68	4.30	3.14	2.04	1.62	2.08	1.91	2.40	2.02	3.24	0.50	0.50	0.87
6	2.76	2.00	3.14	2.63	2.54	2.86	4.30	3.23	2.22	1.84	1.88	1.98	2.50	2.23	3.10	0.50	0.50	0.87
7	2.84	2.22	3.16	2.74	2.64	2.50	4.30	3.14	2.34	2.16	1.88	2.12	2.60	2.29	3.11	0.51	0.51	0.89
8	2.88	2.58	3.24	2.90	2.84	2.78	4.36	3.32	2.46	2.42	1.92	2.26	2.72	2.59	3.17	0.52	NS	0.90
9	2.96	2.72	3.16	2.94	2.92	2.84	4.38	3.38	2.58	2.70	1.92	2.40	2.82	2.75	3.15	0.57	NS	0.99
10	3.02	2.76	3.18	2.98	3.00	2.90	4.38	3.42	2.58	2.98	1.94	2.50	2.86	2.88	3.16	0.62	NS	1.08
11	3.10	2.84	3.22	3.05	3.14	3.00	3.80	3.31	2.90	3.24	1.96	2.70	3.04	3.02	2.99	NS	NS	NS
12	3.18	2.88	3.28	3.11	3.28	3.08	3.82	3.39	3.02	3.58	2.02	2.87	3.16	3.18	3.04	NS	NS	NS
13	3.22	2.90	3.04	3.05	3.46	3.18	3.82	3.48	3.06	3.58	2.02	2.88	3.24	3.22	2.96	NS	NS	NS
14	3.28	3.04	3.04	3.12	3.60	3.82	3.82	3.74	3.14	4.08	2.02	3.08	3.34	3.64	2.96	NS	NS	NS
15	3.34	3.02	2.88	3.08	3.72	3.98	3.88	3.86	3.16	4.30	2.10	3.18	3.40	3.76	2.95	NS	NS	NS
16	3.36	3.14	2.90	3.13	3.80	4.20	3.90	3.96	3.20	4.46	2.14	3.26	3.45	3.93	2.98	NS	0.73	NS
17	3.46	3.26	2.90	3.20	3.90	4.30	3.90	4.03	3.26	4.54	2.14	3.31	3.54	4.03	2.98	NS	0.77	NS
18	3.48	3.36	3.00	3.28	3.94	4.46	3.92	4.10	3.30	4.70	2.24	3.41	3.57	4.17	3.05	NS	0.78	NS
19	3.48	3.42	3.02	3.30	4.04	4.66	3.94	4.21	3.34	4.78	2.26	3.46	3.62	4.28	3.07	NS	0.79	NS
20	3.60	3.54	3.04	3.39	4.16	4.84	3.94	4.31	3.44	4.90	2.28	3.54	3.73	4.42	3.08	0.78	0.78	NS
21	3.60	3.66	3.06	3.44	4.22	4.98	3.96	4.38	3.46	5.10	2.28	3.61	3.76	4.58	3.10	0.79	0.79	NS
22	3.64	3.70	3.06	3.46	4.24	5.14	4.00	4.46	3.48	5.28	2.34	3.70	3.78	4.70	3.13	0.79	0.79	NS
23	3.70	3.78	3.12	3.53	4.32	5.34	4.04	4.56	3.50	5.38	2.42	3.76	3.84	4.83	3.19	0.80	0.8	NS
24	3.88	3.86	3.18	3.64	4.38	5.46	4.04	4.62	3.56	5.46	2.46	3.82	3.94	4.92	3.22	0.82	0.82	NS



V_1 – *Phalaenopsis* Hsin
V_2 – *Phalaenopsis* Luchia Pink
V_3 – *Phalaenopsis* Brother Girl

Fig 3. Cultivar differences on length of roots (cm) in *Phalaenopsis* orchids



S_1– 25% shade
S_2– 50% shade
S_3– 75% shade

Fig 4. Effect of shade on length of roots (cm) in *Phalaenopsis* orchids

length were not significant. Thereafter from the 20th to the 24th fortnight significant difference between cultivars in the root length was observed. From the first to the 8th fortnight, *Phalaenopsis* Brother Girl recorded significantly lesser root length when compared to *Phalaenopsis* Hsin and *Phalaenopsis* Luchia Pink. However at the 9th to the 10th fortnight, *Phalaenopsis* Luchia Pink recorded significantly greater root length when compared to *Phalaenopsis* Brother Girl. And from the 20th to the 24th fortnight, *Phalaenopsis* Luchia Pink recorded significantly greater root length when compared to *Phalaenopsis* Brother Girl and *Phalaenopsis* Hsin.

Effect of shade on length of roots produced at fortnightly intervals in three cultivars was significant from the first to the 6th fortnight (November 2006 to January 2007). All the cultivars recorded significantly greater root length (3.04 to 3.24 cm) under 75% shade when compared to 25% and 50% shade. However from the 8th to the 15th fortnight (February 2007 to June 2007), effect of shade on length of roots was not significant.Thereafter from the 16th to the 24th fortnight (June 2007 to October 2007), 50% shade was found to be more conducive for greater root growth in the cultivars than 75% shade.

Interaction between cultivars and shade effects influenced root length. During the 4th to the 9th fortnight,(December 2006 to March 2007), *Phalaenopsis* Luchia Pink had significantly greater root length under 50% shade than under 25% and 75% shade and also had significantly greater root length than *Phalaenopsis* Brother Girl and *Phalaenopsis* Hsin under 25%, 50% and 75% shade.

4.1.3. Thickness of roots (Table 3)

The cultivars did not differ significantly in thickness of roots when observed from the first to the 21st fortnight (November 2006 to September 2007) after planting. However from the 22nd to the 24th fortnight, significant differences

Table 3. Effect of shade on thickness of roots (cm) in *Phalaenopsis* orchid

FN	V1				V2				V3				shade			CD		
	S_1	S_2	S_3	Pooled	S_1	S_2	S_3	Pooled	S_1	S_2	S_3	Pooled	S_1	S_2	S_3	V	S	VxS
1	0.30	0.34	0.36	0.33	0.36	0.22	0.36	0.31	0.30	0.30	0.32	0.30	0.32	0.28	0.34	NS	NS	NS
2	0.30	0.34	0.36	0.33	0.36	0.22	0.36	0.31	0.30	0.30	0.32	0.30	0.32	0.28	0.34	NS	NS	NS
3	0.30	0.36	0.36	0.34	0.38	0.24	0.38	0.33	0.30	0.30	0.32	0.30	0.32	0.30	0.35	NS	NS	NS
4	0.34	0.30	0.36	0.33	0.38	0.26	0.38	0.34	0.32	0.32	0.34	0.32	0.34	0.29	0.36	NS	NS	NS
5	0.34	0.30	0.38	0.34	0.40	0.30	0.38	0.36	0.34	0.34	0.34	0.34	0.36	0.31	0.36	NS	NS	NS
6	0.36	0.30	0.36	0.34	0.40	0.30	0.40	0.36	0.36	0.34	0.32	0.34	0.37	0.31	0.36	NS	NS	NS
7	0.36	0.34	0.38	0.36	0.42	0.36	0.40	0.39	0.38	0.36	0.32	0.35	0.38	0.35	0.36	NS	NS	NS
8	0.38	0.34	0.36	0.36	0.44	0.38	0.44	0.42	0.38	0.36	0.36	0.36	0.40	0.36	0.38	NS	NS	NS
9	0.42	0.34	0.36	0.37	0.46	0.38	0.44	0.42	0.38	0.38	0.36	0.37	0.42	0.36	0.38	NS	NS	NS
10	0.44	0.32	0.36	0.37	0.48	0.36	0.44	0.42	0.38	0.38	0.34	0.36	0.43	0.35	0.38	NS	0.05	NS
11	0.44	0.34	0.36	0.38	0.48	0.38	0.40	0.42	0.40	0.40	0.34	0.38	0.44	0.37	0.36	NS	0.06	NS
12	0.44	0.32	0.34	0.36	0.48	0.40	0.42	0.43	0.40	0.44	0.34	0.39	0.44	0.38	0.36	NS	NS	NS
13	0.44	0.32	0.36	0.37	0.48	0.40	0.42	0.43	0.42	0.46	0.34	0.40	0.44	0.39	0.37	NS	NS	NS
14	0.46	0.36	0.36	0.39	0.48	0.40	0.44	0.44	0.42	0.46	0.36	0.41	0.45	0.40	0.38	NS	NS	NS
15	0.46	0.36	0.36	0.39	0.48	0.42	0.46	0.45	0.42	0.48	0.38	0.42	0.45	0.42	0.40	NS	NS	NS
16	0.46	0.36	0.36	0.39	0.48	0.42	0.46	0.45	0.42	0.48	0.40	0.43	0.45	0.42	0.40	NS	NS	NS
17	0.48	0.36	0.36	0.40	0.48	0.42	0.48	0.46	0.42	0.48	0.40	0.43	0.46	0.42	0.41	NS	NS	0.08
18	0.48	0.36	0.40	0.41	0.48	0.42	0.48	0.46	0.46	0.48	0.40	0.44	0.47	0.42	0.42	NS	NS	NS
19	0.48	0.36	0.40	0.41	0.48	0.42	0.48	0.46	0.46	0.48	0.42	0.45	0.47	0.42	0.43	NS	NS	NS
20	0.50	0.38	0.42	0.43	0.48	0.42	0.48	0.46	0.48	0.48	0.44	0.46	0.48	0.42	0.44	NS	NS	NS
21	0.50	0.42	0.42	0.44	0.50	0.46	0.48	0.48	0.48	0.48	0.48	0.48	0.49	0.45	0.46	NS	NS	NS
22	0.50	0.42	0.42	0.44	0.50	0.46	0.50	0.48	0.50	0.48	0.48	0.48	0.50	0.45	0.46	0.03	0.03	NS
23	0.50	0.42	0.44	0.45	0.50	0.48	0.52	0.50	0.50	0.48	0.48	0.48	0.50	0.46	0.48	0.03	NS	NS
24	0.50	0.42	0.44	0.45	0.50	0.50	0.54	0.51	0.50	0.48	0.48	0.48	0.50	0.46	0.48	0.03	NS	NS

between cultivars in the thickness of roots were observed. At the 22nd fortnight, *Phalaenopsis* Hsin recorded lesser root thickness (0.44 to 0.45cm) than *Phalaenopsis* Luchia Pink and *Phalaenopsis* Brother Girl having root thickness ranging from 0.48 to 0.51 cm and 0.48 cm respectively. However at the 23rd and 24th fortnight, *Phalaenopsis* Luchia Pink was found to have significantly greater root thickness (0.50 to 0.51cm) than *Phalaenopsis* Brother Girl and *Phalaenopsis* Hsin in which the root thickness ranged from 0.45 cm and 0 .48 cm respectively.

Effect of shade on thickness of roots (cm) produced at fortnightly intervals in three cultivars of *Phalaenopsis* orchids was not significant from the first fortnight to the 9th fortnight and from the 12th to the 21st fortnight. However from the 10th to the 11th fortnight and the 22nd fortnight, (March-April 2007 to October 2007) shade effects significantly influenced the thickness of roots produced. From the 10th to the 11th fortnight and at the 22nd fortnight, (March-April 2007 to October 2007) 25% shade was found to be more conducive for greater root thickness in the cultivars than 50% shade. However at the 23rd and the 24th fortnight, effect of shade on thickness of roots was not significant.

Interaction between cultivars and shade influenced root thickness during the 17th fortnight. All the three Phalaenopsis cultivars had significantly greater root thickness under 25%, 50% and 75% shade. *Phalaenopsis* Hsin recorded significantly lesser root thickness under 50% shade than under 25% and 75% shade and also had lesser root thickness than all of the three cultivars grown under 25% , 50% and 75% shade.

4.1.4. Number of shoots and off shoots

Significant difference between cultivars in number of shoots and off shoots was observed from the 10th to the 24th fortnight after planting. During the period, *Phalaenopsis* Luchia Pink recorded more number of shoots and off shoots when compared to those produced by *Phalaenopsis* Hsin and *Phalaenopsis* Brother Girl.

Effect of shade on number of shoots and off shoots produced at fortnightly intervals in the cultivars was significant from the 10th to the 24th fortnight (March 2007 to November 2007) after planting. However during the period *Phalaenopsis* Luchia Pink recorded significantly more number of shoots and off shoots under 50% shade when compared to 25% and 75% shade.

4.1.5. Length of shoots (Table 4)

Significant differences between the cultivars in the length of the shoots produced were observed from the first to the 11th fortnight after planting. However from the 12th to the 24th fortnight, cultivar differences in shoot length were not significant. During the first to the 11th fortnight, *Phalaenopsis* Hsin recorded significantly greater shoot length (1.51 to 1.76 cm) than *Phalaenopsis* Luchia Pink or *Phalaenopsis* Brother Girl having shoot length ranging from 0.86 to 1.24 cm and 0.94 to 1.30 cm respectively.

Effect of shade on length of shoots produced at fortnightly intervals in the cultivars was not significant from the first to the 5th fortnight (November 2006 to January 2007). During the 6th fortnight and the 7th fortnight (January 2007 to February 2007), all the cultivars recorded significantly greater shoot length (1.48 to 1.54 cm) under 50% shade (S1) when compared to 25% and 50% shade. However at the 9th, 12th, 17th and 21st fortnight (March 2007,April 2007, July 2007 and October 2007), the cultivars recorded significantly greater shoot length (1.65 to 2.24 cm) under 50% shade than under 25% or 50% shade.

Interaction between cultivars and shade effects on shoot length was not significant from the first to the 24th fortnight after planting.

Table 4. Effect of shade on length of shoots (cm) in *Phalaenopsis* orchid

FN	V_1				V_2				V_3				shade			CD		
	S_1	S_2	S_3	Pooled	S_1	S_2	S_3	Pooled	S_1	S_2	S_3	Pooled	S_1	S_2	S_3	V	S	VxS
1	1.50	1.48	1.56	1.51	0.80	1.04	0.74	0.86	0.94	1.10	0.78	0.94	1.08	1.20	1.02	0.33	NS	NS
2	1.50	1.52	1.56	1.52	0.80	1.10	0.74	0.88	0.94	1.10	0.78	0.94	1.08	1.24	1.02	0.32	NS	NS
3	1.50	1.62	1.58	1.56	0.80	1.14	0.74	0.89	0.96	1.10	0.78	0.94	1.08	1.28	1.03	0.31	NS	NS
4	1.50	1.62	1.58	1.60	0.80	1.2	0.74	0.91	1.00	1.18	0.78	0.98	1.10	1.33	1.03	0.30	NS	NS
5	1.52	1.74	1.58	1.61	0.80	1.34	0.78	0.97	1.00	1.24	0.88	1.04	1.10	1.44	1.08	0.32	NS	NS
6	1.56	1.76	1.60	1.64	0.80	1.34	0.80	0.98	1.00	1.36	0.90	1.08	1.12	1.48	1.10	0.33	0.33	NS
7	1.60	1.78	1.62	1.66	0.80	1.48	0.82	1.03	1.10	1.36	0.90	1.12	1.16	1.54	1.11	0.35	0.35	NS
8	1.60	1.82	1.62	1.68	0.82	1.54	0.88	1.08	1.10	1.36	0.94	1.13	1.17	1.57	1.14	0.38	NS	NS
9	1.68	1.82	1.64	1.71	0.82	1.64	0.90	1.12	1.12	1.50	0.98	1.20	1.20	1.65	1.17	0.39	0.39	NS
10	1.72	1.84	1.68	1.74	0.90	1.78	0.96	1.21	1.18	1.52	1.16	1.28	1.26	1.71	1.26	0.41	NS	NS
11	1.72	1.90	1.68	1.76	0.94	1.82	0.98	1.24	1.20	1.52	1.20	1.30	1.28	1.74	1.28	0.42	NS	NS
12	1.76	1.92	1.70	1.79	0.96	1.86	1.00	1.27	1.30	1.68	1.24	1.40	1.34	1.82	1.31	NS	0.43	NS
13	1.78	1.92	1.70	1.80	1.00	1.96	1.06	1.34	1.36	1.74	1.38	1.49	1.38	1.87	1.38	NS	NS	NS
14	1.82	1.98	1.74	1.84	1.04	2.02	1.06	1.37	1.42	1.84	1.38	1.54	1.42	1.94	1.39	NS	0.48	NS
15	1.82	2.02	1.74	1.86	1.08	2.02	1.16	1.42	1.46	1.92	1.46	1.61	1.45	1.98	1.45	NS	NS	NS
16	1.82	2.02	1.74	1.86	1.08	2.06	1.18	1.44	1.50	1.96	1.54	1.66	1.46	2.01	1.48	NS	NS	NS
17	1.90	2.06	1.78	1.91	1.08	2.10	1.18	1.45	1.50	2.00	1.54	1.68	1.49	2.05	1.50	NS	0.50	NS
18	1.96	2.08	1.88	1.97	1.16	2.10	1.22	1.49	1.62	2.06	1.62	1.76	1.58	2.08	1.57	NS	NS	NS
19	1.96	2.08	1.88	1.97	1.18	2.16	1.34	1.56	1.68	2.18	1.68	1.84	1.60	2.14	1.63	NS	NS	NS
20	1.96	2.08	1.92	1.98	1.24	2.16	1.36	1.58	1.70	2.18	1.68	1.85	1.63	2.14	1.65	NS	NS	NS
21	2.02	2.22	1.92	2.05	1.28	2.22	1.38	1.62	1.76	2.30	1.70	1.92	1.68	2.24	1.66	NS	0.51	NS
22	2.10	2.22	1.96	2.09	1.40	2.22	1.42	1.68	1.88	2.32	1.72	1.97	1.79	2.25	1.70	NS	NS	NS
23	2.10	2.24	2.00	2.11	1.40	2.24	1.42	1.68	1.90	2.36	1.76	2.00	1.80	2.28	1.72	NS	NS	NS
24	2.20	2.26	2.00	2.16	1.46	2.28	1.46	1.73	2.00	2.46	1.78	2.08	1.89	2.33	1.74	NS	NS	NS

4.1.6. Shoot girth (Table 5)

Significant differences between cultivars in the shoot girth were observed from the first to the 6th fortnight after planting. However from the 7th fortnight to the 24th fortnight, cultivar differences in shoot girth were not significant. During the first to the 4th fortnight, *Phalaenopsis* Hsin recorded significantly greater shoot girth (0.68 to 0.70 cm) when compared to *Phalaenopsis* Luchia Pink and *Phalaenopsis* Brother Girl which had shoot girth ranging from 0.49 to 0.51cm and 0.54 to 0.58 cm respectively. However at the 5th and the 6th fortnight, *Phalaenopsi*s Hsin recorded significantly greater shoot girth (0.72 to 0.76 cm) than *Phalaenopsi*s Luchia Pink having shoot girth ranging from 0.54 to 0.55 cm respectively.

Effect of shade on shoot girth at fortnightly intervals in three cultivars was not significant from the first fortnight to the 9th fortnight. However from the 10th to the 24th fortnight (March 2007 to November 2007), shade effects significantly influenced the shoot girth. During the 10th to the 24th fortnight, all the cultivars recorded significantly greater shoot girth (0.82 to 1.30 cm) under 50% shade when compared to 25 % shade (0.6 to 0.94 cm).

Interaction between cultivars and shade effects on shoot girth was not significant from the first to the 24th fortnight after planting.

4.1.7. Internodal length of shoots (Table 6, fig.5)

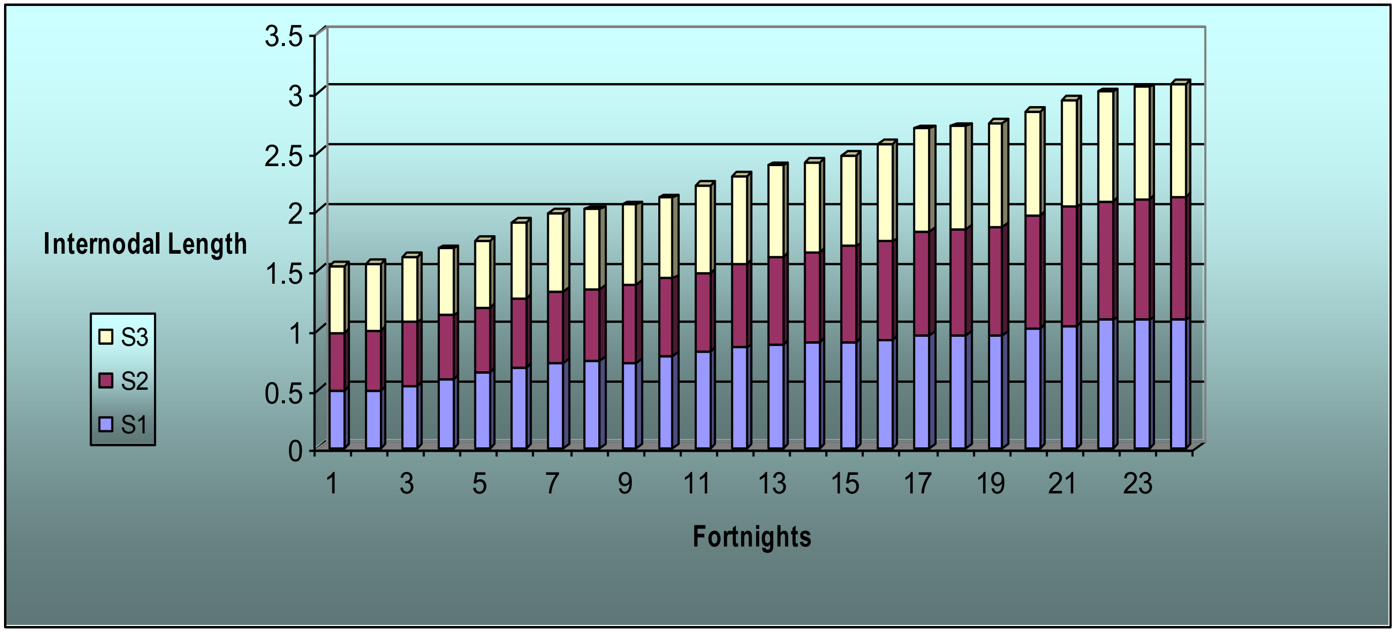
Significant differences between cultivars in internodal length were observed from the first fortnight to the 24th fortnight after planting. During the period, *Phalaenopsis* Hsin recorded significantly greater internodal length (0.76 to 1.37cm) than *Phalaenopsis* Luchia Pink and *Phalaenopsis* Brother Girl (0.36 to 0.81 cm and 0.40 to 0 .89 cm) respectively.

Table 5. Effect of shade on shoot girth (cm) in *Phalaenopsis* orchid

FN	V_1				V_2				V_3				shade			CD		
	S_1	S_2	S_3	Pooled	S_1	S_2	S_3	Pooled	S_1	S_2	S_3	Pooled	S_1	S_2	S_3	V	S	VxS
1	0.62	0.82	0.62	0.68	0.54	0.46	0.44	0.49	0.46	0.46	0.70	0.54	0.54	0.58	0.58	0.12	NS	0.22
2	0.62	0.82	0.62	0.68	0.54	0.46	0.48	0.49	0.46	0.46	0.70	0.54	0.54	0.58	0.60	0.12	NS	NS
3	0.64	0.82	0.62	0.69	0.54	0.48	0.48	0.50	0.46	0.50	0.70	0.55	0.54	0.6	0.60	0.12	NS	NS
4	0.64	0.84	0.62	0.70	0.54	0.48	0.52	0.51	0.48	0.54	0.74	0.58	0.55	0.62	0.62	0.12	NS	NS
5	0.64	0.88	0.66	0.72	0.56	0.56	0.52	0.54	0.52	0.58	0.74	0.61	0.57	0.67	0.64	0.13	NS	NS
6	0.64	0.98	0.66	0.76	0.56	0.56	0.54	0.55	0.54	0.64	0.76	0.64	0.58	0.72	0.65	0.13	NS	NS
7	0.64	0.98	0.68	0.76	0.60	0.64	0.54	0.59	0.56	0.64	0.78	0.66	0.60	0.75	0.66	NS	NS	NS
8	0.64	1.00	0.70	0.78	0.60	0.66	0.54	0.60	0.58	0.70	0.86	0.71	0.60	0.78	0.70	NS	NS	NS
9	0.66	1.00	0.70	0.78	0.62	0.70	0.72	0.68	0.58	0.70	0.86	0.71	0.62	0.80	0.76	NS	NS	NS
10	0.66	1.04	0.74	0.81	0.52	0.72	0.76	0.66	0.62	0.70	0.86	0.72	0.60	0.82	0.78	NS	0.16	NS
11	0.74	1.06	0.74	0.84	0.52	0.78	0.76	0.68	0.68	0.76	0.90	0.78	0.64	0.86	0.80	NS	0.17	NS
12	0.74	1.12	0.76	0.87	0.58	0.84	0.78	0.73	0.70	0.94	0.96	0.86	0.67	0.96	0.83	NS	0.19	NS
13	0.74	1.12	0.88	0.91	0.60	0.84	0.78	0.74	0.72	0.94	0.96	0.87	0.68	0.96	0.87	NS	0.19	NS
14	0.78	1.12	0.88	0.92	0.60	0.96	0.78	0.78	0.74	0.94	0.96	0.88	0.70	1.00	0.87	NS	0.19	NS
15	0.78	1.18	0.88	0.94	0.60	1.04	0.86	0.83	0.76	0.98	1.02	0.92	0.71	1.06	0.92	NS	0.21	NS
16	0.78	1.18	0.90	0.95	0.60	1.08	0.92	0.86	0.80	0.98	1.06	0.94	0.72	1.08	0.96	NS	0.20	NS
17	0.84	1.26	0.94	1.01	0.62	1.12	0.96	0.90	0.82	1.02	1.06	0.96	0.76	1.13	0.98	NS	0.21	NS
18	0.86	1.28	1.06	1.06	0.64	1.18	0.96	0.92	0.82	1.06	1.06	0.98	0.77	1.17	1.02	NS	0.21	NS
19	0.86	1.30	1.06	1.07	0.68	1.18	1.02	0.96	0.90	1.06	1.06	1.00	0.81	1.18	1.04	NS	0.21	NS
20	0.90	1.30	1.06	1.08	0.72	1.22	1.02	0.98	0.94	1.08	1.12	1.04	0.85	1.20	1.06	NS	0.22	NS
21	0.92	1.32	1.06	1.10	0.72	1.28	1.02	1.00	0.98	1.10	1.20	1.09	0.87	1.23	1.09	NS	0.22	NS
22	0.96	1.34	1.06	1.12	0.74	1.30	1.06	1.03	1.02	1.10	1.20	1.10	0.90	1.24	1.10	NS	0.23	NS
23	0.98	1.36	1.06	1.13	0.76	1.34	1.06	1.05	1.02	1.16	1.20	1.12	0.92	1.28	1.10	NS	0.23	NS
24	0.98	1.36	1.06	1.13	0.76	1.38	1.06	1.06	1.08	1.16	1.22	1.15	0.94	1.30	1.11	NS	0.25	NS

Table 6. Effect of shade on internodal length of shoots (cm) in *Phalaenopsis* orchid

FN	V1				V2				V3				shade			CD		
	S1	S2	S3	Pooled	S1	S2	S3	Pooled	S1	S2	S3	Pooled	S1	S2	S3	V	S	VxS
1	0.72	0.56	1.02	0.76	0.36	0.42	0.32	0.36	0.40	0.48	0.34	0.40	0.49	0.48	0.56	0.13	NS	0.23
2	0.72	0.62	1.02	0.78	0.36	0.44	0.32	0.37	0.40	0.48	0.34	0.40	0.49	0.51	0.56	0.13	NS	0.23
3	0.72	0.66	1.02	0.80	0.36	0.46	0.32	0.38	0.52	0.48	0.34	0.44	0.53	0.53	0.56	0.15	NS	0.27
4	0.84	0.66	1.02	0.84	0.36	0.50	0.32	0.39	0.56	0.48	0.34	0.46	0.58	0.54	0.56	0.15	NS	0.27
5	0.88	0.66	1.02	0.85	0.48	0.52	0.32	0.44	0.58	0.48	0.34	0.46	0.64	0.55	0.56	0.16	NS	NS
6	0.88	0.68	1.22	0.92	0.56	0.52	0.32	0.46	0.60	0.54	0.38	0.50	0.68	0.58	0.64	0.16	NS	0.28
7	0.92	0.72	1.22	0.95	0.60	0.58	0.34	0.50	0.66	0.54	0.40	0.53	0.72	0.61	0.65	0.15	NS	0.26
8	0.92	0.72	1.22	0.95	0.62	0.58	0.36	0.52	0.68	0.54	0.40	0.54	0.74	0.61	0.66	0.15	NS	0.26
9	0.94	0.74	1.22	0.96	0.58	0.64	0.40	0.54	0.68	0.58	0.40	0.55	0.73	0.65	0.67	0.15	NS	0.27
10	0.96	0.74	1.22	0.97	0.62	0.64	0.40	0.55	0.78	0.58	0.44	0.60	0.78	0.65	0.68	0.16	NS	0.27
11	1.04	0.76	1.34	1.04	0.62	0.64	0.42	0.56	0.80	0.60	0.46	0.62	0.82	0.66	0.74	0.16	NS	0.28
12	1.08	0.78	1.34	1.06	0.64	0.70	0.42	0.58	0.84	0.64	0.46	0.64	0.85	0.70	0.74	0.17	NS	0.30
13	1.10	0.82	1.40	1.10	0.64	0.74	0.42	0.60	0.90	0.68	0.46	0.68	0.88	0.74	0.76	0.19	NS	0.33
14	1.14	0.82	1.40	1.12	0.64	0.76	0.44	0.61	0.90	0.70	0.46	0.68	0.89	0.76	0.76	0.19	NS	0.33
15	1.14	0.86	1.40	1.13	0.64	0.84	0.44	0.64	0.92	0.72	0.48	0.70	0.90	0.80	0.77	0.19	NS	0.33
16	1.14	0.86	1.40	1.13	0.70	0.88	0.58	0.72	0.94	0.72	0.50	0.72	0.92	0.82	0.82	0.20	NS	0.35
17	1.18	0.96	1.50	1.21	0.70	0.92	0.58	0.73	0.98	0.76	0.50	0.74	0.95	0.88	0.86	0.20	NS	0.35
18	1.20	1.00	1.50	1.23	0.70	0.92	0.58	0.73	1.00	0.76	0.50	0.75	0.96	0.89	0.86	0.20	NS	0.35
19	1.20	1.02	1.50	1.24	0.70	0.96	0.58	0.74	1.00	0.76	0.54	0.76	0.96	0.91	0.87	0.20	NS	0.35
20	1.26	1.02	1.52	1.26	0.74	0.98	0.60	0.77	1.06	0.82	0.54	0.80	1.02	0.94	0.88	0.20	NS	0.35
21	1.30	1.08	1.54	1.30	0.78	1.04	0.60	0.8	1.06	0.86	0.56	0.82	1.04	0.99	0.90	0.20	NS	0.35
22	1.36	1.10	1.60	1.35	0.78	1.06	0.60	0.81	1.10	0.86	0.58	0.84	1.08	1.00	0.92	0.22	NS	0.39
23	1.36	1.12	1.60	1.36	0.78	1.06	0.60	0.81	1.10	0.90	0.62	0.87	1.08	1.02	0.94	0.22	NS	0.39
24	1.36	1.14	1.62	1.37	0.78	1.06	0.60	0.81	1.12	0.92	0.64	0.89	1.08	1.04	0.95	0.22	NS	0.39



S_1– 25% shade
S_2– 50% shade
S_3– 75% shade

Fig 5. Effect of shade on internodal length of shoots (cm) in *Phalaenopsis* orchids

Effect of shade on internodal length of shoots recorded at fortnightly intervals in the three cultivars was not significant from the first to the 24th fortnight after planting.

Interaction between cultivars and shade levels significantly influenced internodal length of shoots from the first fortnight to the 4th fortnight. Thereafter at the 5th fortnight, interaction between cultivars and shade levels was not significant. However from the 6th to the 24th fortnight, interaction between cultivars and shade was significant. From the first fortnight to the 4th fortnight, and from the 6th to the 24th fortnight, *Phalaenopsis* Hsin recorded significantly greater internodal length (0.48 to 0 .54 cm) under 75% shade than under 50% shade and 25% shade and the cultivars Luchia Pink, Brother Girl and Hsin under 25% and 50% shade.

4.1.8. Rate of shoot elongation (Table 7)

Significant differences were not observed in rate of shoot elongation between cultivars or shade levels.

Leaf characteristics

As leaf growth of the cultivars was poor under 75% shade, analysis of observations on leaf characteristics such as leaf length, width, thickness and number of stomata on upper and lower surface under 25% shade and 50% shade was done and the results were interpreted.

4.1.9. Number of leaves (Table 8)

Significant differences in number of leaves were not observed in the cultivars from the first to the 24th fortnight after planting.

Table 7.Effect of shade on rate of shoot elongation in *Phalaenopsis* orchids

FN	S1				S2				S3			
	V1	**V2**	**V3**	**CD**	**V1**	**V2**	**V3**	**CD**	**V1**	**V2**	**V3**	**CD**
1	0.02	0.03	0.04	NS	0.03	0.04	0.05	NS	0.01	0.03	0.04	NS
2	0.02	0.02	0.04	NS	0.02	0.04	0.05	NS	0.01	0.03	0.04	NS
3	0.02	0.02	0.04	NS	0.02	0.04	0.05	NS	0.01	0.03	0.04	NS
4	0.02	0.02	0.04	NS	0.02	0.04	0.05	NS	0.01	0.03	0.04	NS
5	0.02	0.02	0.04	NS	0.02	0.04	0.05	NS	0.01	0.03	0.03	NS
6	0.02	0.02	0.04	NS	0.02	0.04	0.04	NS	0.01	0.02	0.03	NS
7	0.02	0.02	0.04	NS	0.02	0.03	0.04	NS	0.01	0.02	0.03	NS
8	0.02	0.02	0.04	NS	0.02	0.03	0.06	NS	0.01	0.02	0.03	NS
9	0.02	0.02	0.04	NS	0.02	0.02	0.05	NS	0.01	0.02	0.03	NS
10	0.02	0.02	0.03	NS	0.02	0.02	0.05	NS	0.01	0.02	0.03	NS
11	0.02	0.01	0.03	NS	0.01	0.02	0.05	NS	0.01	0.02	0.03	NS
12	0.01	0.01	0.03	NS	0.01	0.02	0.04	NS	0.01	0.02	0.02	NS
13	0.01	0.01	0.03	NS	0.01	0.01	0.04	NS	0.01	0.02	0.02	NS
14	0.01	0.01	0.03	NS	0.01	0.01	0.03	NS	0.01	0.02	0.02	NS
15	0.01	0.01	0.02	NS	0.01	0.01	0.02	NS	0.01	0.02	0.02	NS
16	0.01	0.01	0.02	NS	0.01	0.01	0.02	NS	0.01	0.02	0.01	NS
17	0.01	0.01	0.02	NS	0.01	0.01	0.02	NS	0.01	0.02	0.01	NS
18	0.01	0.01	0.02	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01	NS

Table 8. Effect of shade on number of leaves in *Phalaenopsis* orchid

FN	V_1			V_2			V_3			shade		CD		
	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	V	S	VxS
1	2.40	3.40	2.90	2.00	2.60	2.30	1.60	3.40	2.50	2.00	3.13	NS	0.72	1.24
2	2.40	3.40	2.90	2.00	2.60	2.30	1.80	3.40	2.60	2.06	3.13	NS	0.71	NS
3	2.40	3.40	2.90	2.00	2.60	2.30	1.80	3.40	2.60	2.06	3.13	NS	0.71	NS
4	2.20	3.40	2.80	2.00	2.60	2.30	1.80	3.40	2.60	2.00	3.13	NS	0.70	NS
5	2.00	3.40	2.70	1.80	2.60	2.20	1.80	3.40	2.60	1.86	3.13	NS	0.70	NS
6	2.00	3.40	2.70	1.80	2.60	2.20	2.00	3.40	2.70	1.93	3.13	NS	0.72	NS
7	2.00	3.40	2.70	1.80	2.60	2.20	2.00	3.60	2.80	1.93	3.20	NS	0.84	NS
8	2.00	3.40	2.70	1.80	2.80	2.30	2.00	3.60	2.80	1.93	3.26	NS	0.84	NS
9	2.00	3.40	2.70	1.80	2.80	2.30	2.00	3.40	2.70	1.93	3.20	NS	0.87	NS
10	2.00	3.40	2.70	1.80	2.80	2.30	2.00	3.20	2.60	1.93	3.13	NS	0.91	NS
11	2.00	3.40	2.70	1.80	2.80	2.30	2.20	3.20	2.70	2.00	3.13	NS	0.92	NS
12	2.00	3.40	2.70	1.80	2.80	2.30	2.20	3.20	2.70	2.00	3.10	NS	0.92	NS
13	2.40	3.40	2.90	1.80	2.80	2.30	2.40	3.20	2.80	2.20	3.13	NS	NS	NS
14	2.40	3.40	2.90	1.80	2.80	2.30	2.40	3.40	2.90	2.20	3.20	NS	0.92	NS
15	2.60	3.40	3.00	1.80	2.60	2.20	2.80	3.40	3.10	2.40	3.13	NS	NS	NS
16	2.60	3.40	3.00	1.80	2.60	2.20	2.80	3.40	3.10	2.40	3.13	NS	NS	NS
17	2.60	3.40	3.00	1.80	2.80	2.30	2.80	3.40	3.10	2.40	3.20	NS	NS	NS
18	2.60	3.40	3.00	1.80	2.80	2.30	2.80	3.40	3.10	2.40	3.20	NS	NS	NS
19	2.60	3.60	3.10	1.80	2.80	2.30	2.80	3.40	3.10	2.40	3.26	NS	NS	NS
20	2.60	3.60	3.10	1.80	2.80	2.30	2.80	3.40	3.10	2.40	3.26	NS	NS	NS
21	2.60	3.60	3.10	1.80	2.80	2.40	2.80	3.40	3.10	2.40	3.26	NS	NS	NS
22	2.60	3.60	3.10	1.80	2.80	2.30	2.80	3.40	3.10	2.40	3.26	NS	NS	NS
23	2.60	3.60	3.10	1.80	3.00	2.40	2.80	3.40	3.10	2.40	3.33	NS	NS	NS
24	2.60	3.60	3.10	1.80	3.00	2.40	2.80	3.40	3.10	2.4o	3.33	NS	NS	NS

Effects of shade on number of leaves produced at fortnightly intervals in the three cultivars were significant from the first fortnight to the 12^{th} fortnight and at the 14^{th} fortnight after planting. However at the 13^{th} fortnight and 15^{th} to the 24^{th} fortnight after planting, shade effects on number of leaves were not significant. During the 1^{st} to the 12^{th} fortnight and at the 14^{th} fortnight, all the cultivars recorded significantly more number of leaves (3.1 to 3.26) under 50% shade compared to 25% shade.

Interaction between cultivars and shade effects on number of leaves was not significant from the first to the 24^{th} fortnight after planting.

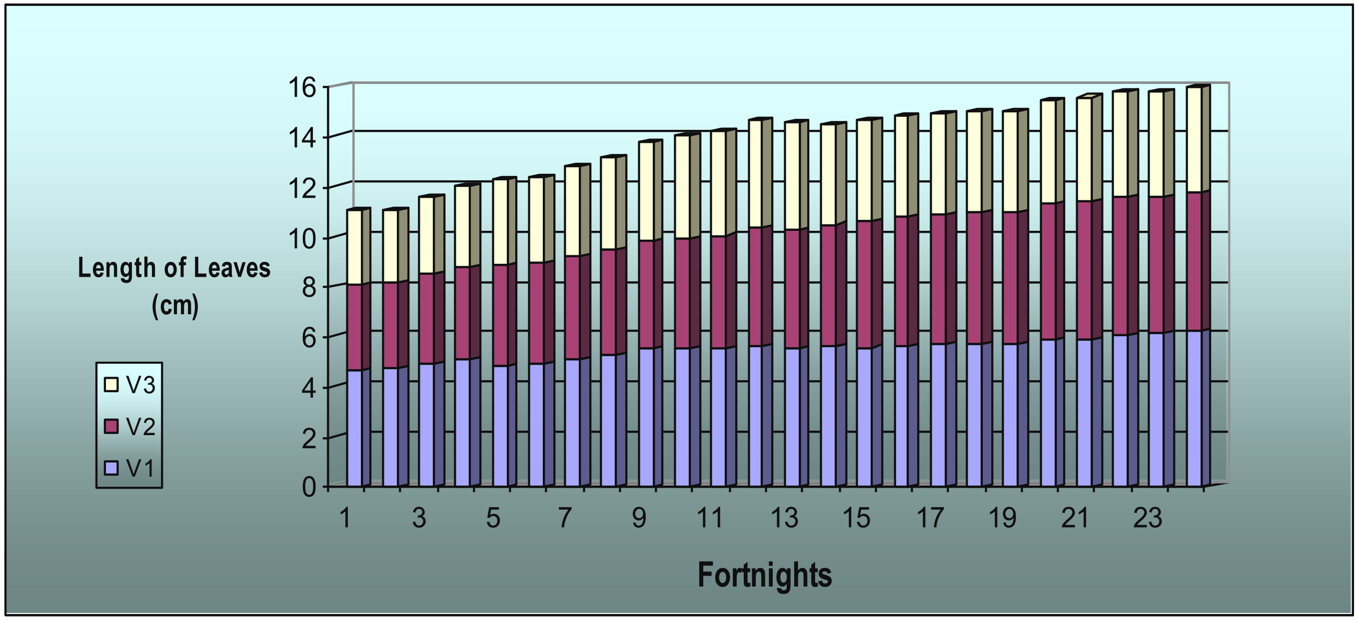
4.1.10. Length of leaves (Table 9, fig.6 and fig.7)

Cultivar difference in length of leaves was not significant from the first fortnight to the 15^{th} fortnight after planting. However from the 16^{th} to the 24^{th} fortnight after planting, significant differences between cultivars in length of leaves were observed. From the 16^{th} to the 19^{th} fortnight, *Phalaenopsis* Hsin had greater length of leaves (5.59 to 5.71 cm) than *Phalaenopsis* Brother Girl (4.02 to 4.07 cm).However from the 20^{th} to the 24^{th} fortnight, *Phalaenopsis* Brother Girl recorded significantly lesser length of leaves (1.96 to 1.24 cm) than *Phalaenopsis* Hsin and *Phalaenopsis* Luchia Pink (5.84 to 6.17 cm and 5.43 to 5.59 cm) respectively.

Effect of shade on length of leaves recorded at fortnightly intervals was significant from the first fortnight to the 11^{th} fortnight and at 13^{th} and 15^{th} fortnight (November 2006 to April 2007 and at May 2007 to June 2007).During the periods, all the cultivars recorded significantly greater leaf length (4.45 to 5.46 cm) under 50% shade when compared to 25% shade. However from the 16^{th} to the 24^{th} fortnight, shade effects were not found to significantly influence the length of the leaves.

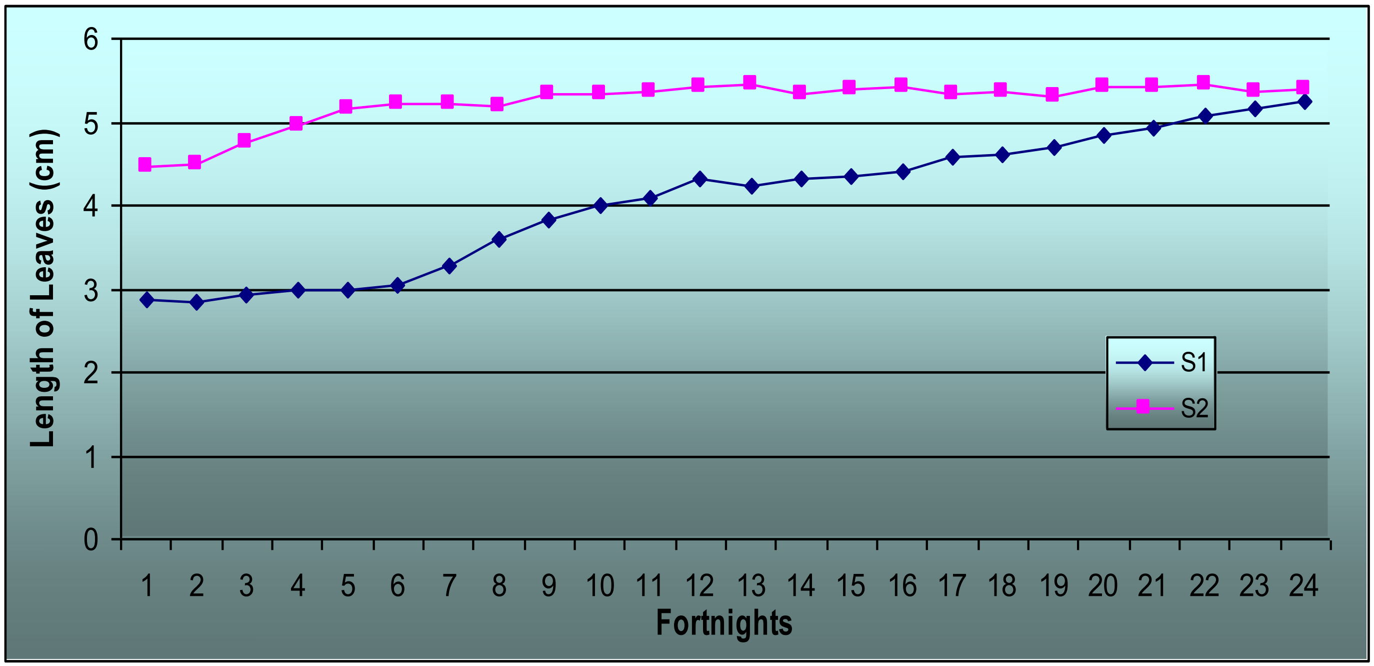
Table 9. Effect of shade on length of leaves (cm) in *Phalaenopsis* orchid

FN	V_1			V_2			V_3			shade		CD		
	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	V	S	VxS
1	3.76	5.46	4.61	2.56	4.32	3.44	2.34	3.58	2.96	2.88	4.45	NS	1.25	NS
2	3.88	5.46	4.67	2.58	4.36	3.47	2.08	3.64	2.86	2.84	4.48	NS	1.24	NS
3	3.94	5.88	4.91	2.62	4.50	3.56	2.20	3.90	3.05	2.92	4.76	NS	1.25	NS
4	4.14	6.00	5.07	2.66	4.72	3.69	2.22	4.18	3.20	3.00	4.96	NS	1.27	NS
5	3.36	6.24	4.80	3.24	4.90	4.07	2.34	4.36	3.35	2.98	5.16	NS	1.37	NS
6	3.50	6.30	4.90	3.06	4.98	4.02	2.54	4.36	3.45	3.03	5.21	NS	1.40	NS
7	3.86	6.30	5.08	3.18	5.00	4.09	2.80	4.36	3.58	3.28	5.22	NS	1.34	NS
8	4.18	6.32	5.25	3.56	4.82	4.19	3.06	4.40	3.73	3.60	5.18	NS	1.29	NS
9	4.40	6.56	5.48	3.74	4.86	4.30	3.38	4.58	3.98	3.84	5.33	NS	1.24	NS
10	4.56	6.42	5.49	3.90	4.90	4.40	3.58	4.68	4.13	4.01	5.33	NS	1.22	NS
11	4.60	6.44	5.52	4.08	4.92	4.50	3.62	4.74	4.18	4.10	5.36	NS	1.21	NS
12	4.74	6.46	5.60	4.42	4.98	4.70	3.80	4.86	4.33	4.32	5.43	NS	NS	NS
13	4.48	6.48	5.48	4.54	5.02	4.78	3.70	4.88	4.29	4.24	5.46	NS	1.14	NS
14	4.60	6.52	5.56	4.70	5.10	4.90	3.70	4.36	4.03	4.33	5.32	NS	NS	NS
15	4.52	6.56	5.54	4.88	5.26	5.07	3.62	4.38	4.00	4.34	5.40	NS	1.05	NS
16	4.64	6.54	5.59	4.98	5.30	5.14	3.66	4.42	4.04	4.42	5.42	1.24	NS	NS
17	4.78	6.58	5.68	5.38	5.04	5.21	3.62	4.42	4.02	4.59	5.34	1.26	NS	NS
18	4.84	6.58	5.71	5.38	5.04	5.21	3.64	4.44	4.04	4.62	5.35	1.23	NS	NS
19	4.94	6.40	5.67	5.50	5.04	5.27	3.66	4.48	4.07	4.70	5.30	1.25	NS	NS
20	5.16	6.52	5.84	5.66	5.20	5.43	3.74	4.52	4.13	4.85	5.41	1.24	NS	NS
21	5.26	6.52	5.89	5.82	5.22	5.52	3.74	4.54	4.14	4.94	5.42	1.21	NS	NS
22	5.44	6.56	6.00	5.94	5.24	5.59	3.82	4.54	4.18	5.06	5.44	1.20	NS	NS
23	5.58	6.60	6.09	6.06	4.92	5.49	3.82	4.54	4.18	5.15	5.35	1.16	NS	NS
24	5.70	6.64	6.17	6.20	4.94	5.57	3.90	4.56	4.23	5.26	5.38	1.17	NS	NS



V_1 – *Phalaenopsis* Hsin
V_2 – *Phalaenopsis* Luchia Pink
V_3 – *Phalaenopsis* Brother Girl

Fig 6. Cultivar differences on length of leaves (cm) in *Phalaenopsis* orchids



S$_1$– 25% shade
S$_2$– 50% shade

Fig 7. Effect of shade on length of leaves (cm) in *Phalaenopsis* orchids

Interaction between cultivars and shade levels influencing the length of leaves was not significant from the first fortnight to the 24th fortnight after planting.

4.1.11. Width of leaves (Table 10, fig.8 and fig.9)

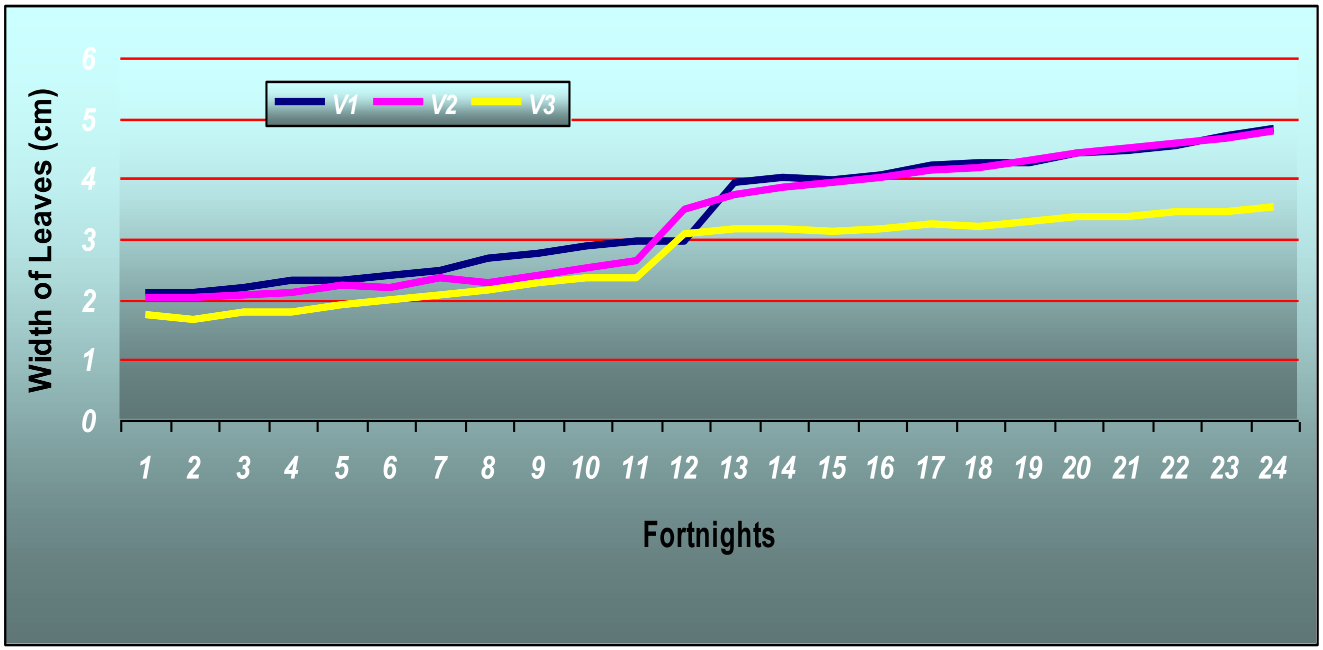
Cultivar differences in width of leaves were not significant from the first to the 20th fortnight after planting. However from the 21st to the 24th fortnight, significant differences between the cultivars in the width of leaves were observed. During the period, *Phalaenopsis* Brother Girl recorded significantly lesser leaf width (3.37 to 3.51 cm) than *Phalaenopsis* Hsin and *Phalaenopsis* Luchia Pink which recorded leaf width ranging from 4.52 to 4.77 cm and 4.46 to 4.82 cm respectively.

Effect of shade on width of leaves recorded at fortnightly intervals in the three cultivars was significant from the first to the 9th fortnight, at 11th fortnight (November 2006 to March 2007, April 2007). During the period, 50% shade was found to be more conducive for greater leaf width in the cultivars than under 25% shade. At the 10th and 12th fortnight, shade effects were not found to significantly influence the width of leaves (November 2006 to March 2007,April 2007 to May 2007).However from the 13th to the 24th fortnight,(May 2007 to November 2007) 25% shade was found to be more conducive for greater leaf width production in the cultivars than 50% shade.

Interaction between cultivars and shade on leaf width was not significant from the first fortnight to the 24th fortnight after planting.

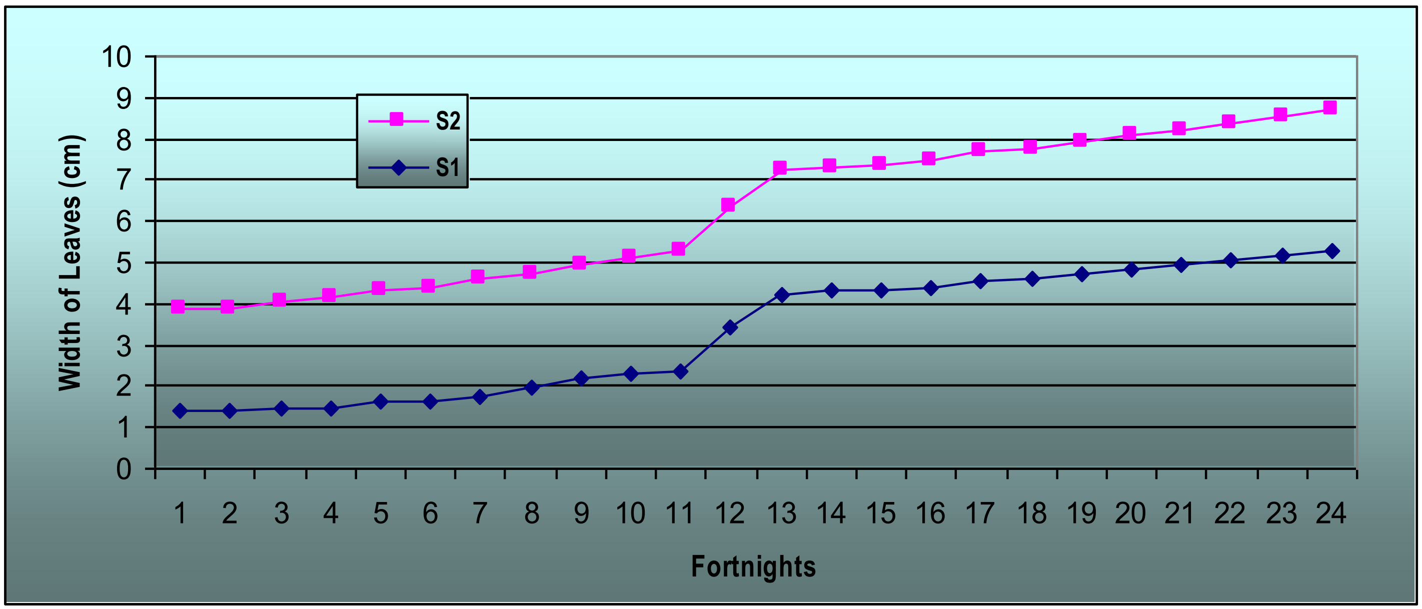
Table 10. Effect of shade on width of leaves (cm) in *Phalaenopsis* orchid

FN	V_1			V_2			V_3			shade		CD		
	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	V	S	VxS
1	1.36	2.82	2.09	1.60	2.46	2.03	1.32	2.16	1.74	1.42	2.48	NS	0.63	NS
2	1.40	2.82	2.11	1.60	2.46	2.03	1.16	2.16	1.66	1.38	2.48	NS	0.61	NS
3	1.50	2.86	2.18	1.62	2.54	2.08	1.26	2.28	1.77	1.46	2.56	NS	0.62	NS
4	1.54	3.08	2.31	1.66	2.58	2.12	1.22	2.38	1.80	1.47	2.68	NS	0.62	NS
5	1.54	3.08	2.31	1.88	2.60	2.24	1.42	2.40	1.91	1.61	2.69	NS	0.68	NS
6	1.66	3.10	2.38	1.74	2.66	2.20	1.48	2.48	1.98	1.62	2.74	NS	0.68	NS
7	1.86	3.10	2.48	1.82	2.88	2.35	1.62	2.50	2.06	1.76	2.82	NS	0.66	NS
8	2.22	3.14	2.68	1.96	2.60	2.28	1.74	2.56	2.15	1.97	2.76	NS	0.61	NS
9	2.38	3.14	2.76	2.22	2.60	2.41	1.94	2.62	2.28	2.18	2.78	NS	0.59	NS
10	2.58	3.16	2.87	2.34	2.66	2.50	2.02	2.68	2.35	2.31	2.83	NS	NS	NS
11	2.66	3.22	2.94	2.50	2.80	2.65	1.94	2.78	2.36	2.36	2.93	NS	0.53	NS
12	2.70	3.22	2.96	4.14	2.80	3.47	3.36	2.82	3.09	3.40	2.94	NS	NS	NS
13	4.50	3.36	3.93	4.54	2.94	3.74	3.56	2.78	3.17	4.20	3.02	NS	0.98	NS
14	4.62	3.38	4.00	4.70	2.98	3.84	3.66	2.68	3.17	4.32	3.01	NS	0.92	NS
15	4.52	3.42	3.97	4.88	3.02	3.95	3.56	2.72	3.14	4.32	3.05	NS	0.91	NS
16	4.64	3.48	4.06	4.98	3.08	4.03	3.60	2.76	3.18	4.40	3.10	NS	0.88	NS
17	4.78	3.66	4.22	5.22	3.06	4.14	3.62	2.84	3.23	4.54	3.18	NS	0.87	NS
18	4.84	3.68	4.26	5.32	3.06	4.19	3.64	2.80	3.22	4.60	3.18	NS	0.87	NS
19	4.94	3.60	4.27	5.50	3.10	4.30	3.66	2.90	3.28	4.70	3.20	NS	0.85	NS
20	5.16	3.66	4.41	5.66	3.18	4.42	3.74	2.96	3.35	4.85	3.26	NS	0.83	NS
21	5.26	3.66	4.46	5.82	3.22	4.52	3.74	3.00	3.37	4.94	3.29	1.00	0.82	NS
22	5.44	3.68	4.56	5.94	3.22	4.58	3.82	3.04	3.43	5.06	3.31	0.99	0.81	NS
23	5.58	3.86	4.72	6.06	3.28	4.67	3.82	3.10	3.46	5.15	3.41	0.97	0.79	NS
24	5.70	3.94	4.82	6.20	3.34	4.77	3.90	3.12	3.51	5.26	3.46	0.97	0.79	NS



V_1 – *Phalaenopsis* Hsin
V_2 – *Phalaenopsis* Luchia Pink
V_3 – *Phalaenopsis* Brother Girl

Fig 8. Cultivar differences on width of leaves (cm) in *Phalaenopsis* orchids



S_1– 25% shade
S_2– 50% shade

Fig 9. Effect of shade on width of leaves (cm) in *Phalaenopsis* orchids

4.1.12. Leaf area (Table 11)

Cultivar differences in leaf area were not significant from the 1st to the 22nd fortnight. However at the 23rd and 24th fortnight after planting (October 2007), significant differences between cultivars in leaf area were observed. During the period, *Phalaenopsis* Hsin recorded significantly greater leaf area (29.00 to 30.04 cm^2) than *Phalaenopsis* Luchia Pink and *Phalaenopsis* Brother Girl which recorded leaf area ranging from 27.33 to 28.44 cm^2 and 15.39 to 15.75 cm^2)respectively.

Effect of shade on leaf area produced at fortnightly intervals was significant from the first to the 9th fortnight (November 2006 to March 2007) and from the 22nd to the 24th fortnight (September 2007 to October 2007).During the period, all the cultivars recorded significantly greater leaf area (11.35 to 19.30 cm^2) under 50% shade when compared to 25% shade. However from the 10th to the 22nd fortnight, shade effects on leaf area were not significant.

Interaction between cultivars and shade on leaf area was not significant from the 1st to the 24th fortnight after planting.

4.1.13. Leaf shape

Phalaenopsis Hsin and *Phalaenopsis* Luchia Pink were found to have more or less round shaped leaves. *Phalaenopsis* Brother Girl was found to have elongate shaped leaves.

4.1.14. Leaf thickness (Table 12)

Significant differences between cultivars in the leaf thickness were observed from the first fortnight to the 24th fortnight after planting. During the

Table 11. Effect of shade on leaf area (cm^2) in *Phalaenopsis* orchid

FN	V1			V2			V3			shade		CD		
	S1	S2	Pooled	S1	S2	Pooled	S1	S2	Pooled	S1	S2	V	S	VxS
1	6.26	15.38	10.82	6.37	10.53	8.45	4.75	8.14	6.45	5.79	11.35	NS	1.27	NS
2	6.51	15.38	10.94	6.38	10.61	8.49	3.89	8.30	6.10	5.59	11.43	NS	3.70	NS
3	7.01	16.86	11.94	6.43	11.29	8.86	4.39	9.39	6.89	5.95	12.51	NS	3.86	NS
4	7.56	18.61	13.09	6.54	12.04	9.29	4.25	10.54	7.39	6.11	13.73	NS	4.08	NS
5	6.82	19.34	13.08	9.24	12.61	10.93	5.00	11.08	8.04	7.02	14.34	NS	5.20	NS
6	7.37	19.66	13.51	8.74	13.13	10.93	5.36	11.47	8.41	7.16	14.75	NS	5.46	NS
7	8.37	19.66	14.01	9.07	14.52	11.79	5.92	11.54	8.73	7.78	15.24	NS	5.58	NS
8	9.71	19.96	14.83	9.91	12.54	11.23	6.59	11.95	9.27	8.74	14.81	NS	5.50	NS
9	10.78	20.68	15.73	10.70	12.65	11.67	7.77	12.82	10.30	9.75	15.38	NS	5.56	NS
10	11.90	20.41	16.15	11.42	13.04	12.23	8.21	13.53	10.87	10.51	15.66	NS	NS	NS
11	12.35	20.84	16.59	12.20	13.86	13.03	7.78	14.33	11.06	10.78	16.34	NS	NS	NS
12	1.2.87	20.91	16.89	22.87	14.03	18.45	13.61	14.82	14.22	16.45	16.59	NS	NS	NS
13	21.99	21.89	21.94	24.67	14.82	19.75	14.42	14.51	14.47	20.36	17.07	NS	NS	NS
14	22.84	22.14	22.49	25.71	15.24	20.47	14.68	12.48	13.58	21.08	16.62	NS	NS	NS
15	21.80	22.52	22.16	27.11	15.99	21.55	14.37	12.75	13.56	21.09	17.09	NS	NS	NS
16	22.89	22.91	22.90	27.84	16.41	22.13	14.55	12.95	13.75	21.76	17.42	NS	NS	NS
17	24.27	24.18	24.22	30.79	15.63	23.21	14.59	13.29	13.94	23.22	17.70	NS	NS	NS
18	24.69	24.32	24.51	31.13	15.63	23.38	14.80	13.26	14.03	23.54	17.74	NS	NS	NS
19	25.72	23.34	24.53	32.46	15.81	24.13	14.95	13.81	14.38	24.38	17.65	NS	NS	NS
20	27.97	24.17	26.07	34.22	16.69	25.45	15.41	14.20	14.8	25.87	18.35	NS	NS	NS
21	28.92	24.17	26.55	35.87	16.93	26.40	15.41	14.45	14.93	26.73	18.52	NS	NS	NS
22	30.90	24.43	27.66	37.17	16.99	27.08	15.95	14.59	15.27	28.00	18.67	NS	9.05	NS
23	32.24	25.77	29.00	38.60	16.05	27.33	15.95	14.83	15.39	28.93	18.88	10.83	8.84	NS
24	33.68	26.41	30.04	40.37	16.51	28.44	16.51	14.99	15.75	30.18	19.30	11.05	9.02	NS

Table 12. Effect of shade on leaf thickness (μm) in *Phalaenopsis* orchid

FN	V_1			V_2			V_3			Shade		CD		
	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	V	S	VxS
1	113.0	112.0	112.5	107.4	105.8	106.6	114.0	112.0	113.0	111.4	109.9	0.92	0.75	NS
2	113.0	112.0	112.5	107.4	105.8	106.6	113.8	112.0	112.9	111.4	109.9	0.93	0.76	NS
3	113.0	112.0	112.5	107.2	105.8	106.5	114.2	112.2	113.2	111.4	110.0	0.94	0.77	NS
4	113.2	113.0	113.1	107.2	106.8	107.0	113.8	113.0	113.4	111.4	110.9	0.86	NS	NS
5	113.2	113.0	113.1	107.2	106.8	107.0	113.8	113.0	113.4	111.4	110.9	0.86	NS	NS
6	113.2	113.0	113.1	107.2	107.0	107.1	113.8	113.0	113.4	111.4	111.0	0.89	NS	NS
7	113.4	113.2	113..3	107.0	107.2	107.1	113.8	112.8	113.3	111.4	111.1	1.00	NS	NS
8	113.4	113.2	113..3	107.2	107.0	107.1	113.8	112.8	113.3	111.4	111.1	0.96	NS	NS
9	112.8	113.4	113.1	107.2	107.0	107.1	114.0	112.8	113.4	111.3	111.0	1.12	NS	NS
10	112.8	113.4	113.1	107.2	107.0	107.1	114.0	112.8	113.4	111.3	111.0	1.12	NS	NS
11	112.8	113.4	113.1	107.2	107.0	107.1	113.4	112.8	113.1	111.1	111.1	1.23	NS	NS
12	112.8	113.4	113.1	107.2	107.2	107.2	114.0	112.8	113.4	111.3	111.1	1.16	NS	NS
13	112.0	113.8	112.9	107.2	107.6	107.4	113.6	113.0	113.3	110.9	111.4	1.30	NS	NS
14	112.2	113.8	113.0	107.4	107.6	107.5	112.4	112.0	112.2	110.6	111.1	1.44	NS	NS
15	112.0	113.8	112.9	107.4	107.8	107.6	112.4	112.0	112.2	110.6	111.2	1.53	NS	NS
16	111.6	113.8	112.7	107.4	107.8	107.6	112.4	112.0	112.2	110.4	111.2	1.47	NS	NS
17	111.6	113.8	112.7	107.4	107.6	107.5	112.4	112.2	112.3	110.46	111.2	1.38	NS	NS
18	111.6	114.0	112.8	107.4	107.8	107.6	112.4	112.2	112.3	110.4	111.3	1.42	NS	NS
19	111.8	114.0	112.9	107.6	108.0	107.8	112.4	112.2	112.3	110.6	111.4	1.48	NS	NS
20	111.8	114.0	112.9	107.6	108.0	107.8	112.4	108.0	110.2	110.6	110.0	1.39	NS	1.97
21	112.2	114.2	113.2	107.6	108.8	108.2	112.4	112.8	112.6	110.7	111.9	1.61	NS	NS
22	112.2	114.4	113.3	107.8	108.8	108.3	112.4	112.8	112.6	110.8	112.0	1.54	NS	NS
23	112.2	114.4	113.3	107.8	108.6	108.2	112.4	113.0	112.7	110.8	112.0	1.47	NS	NS
24	112.2	114.4	113.3	107.8	109.0	108.4	112.8	113.2	113.0	110.9	112.2	1.48	1.21	NS

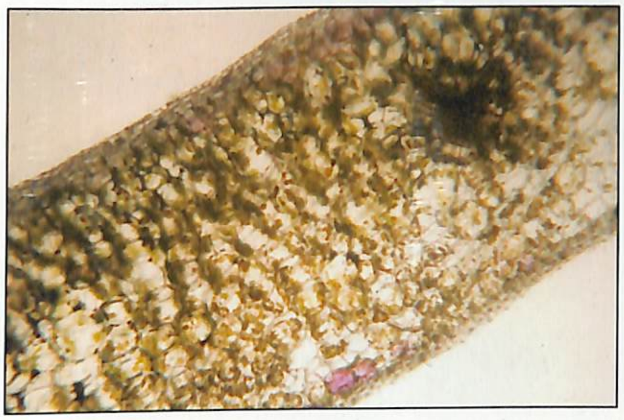
period, *Phalaenopsis* Luchia Pink recorded significantly lesser leaf thickness (106.5 to 108.4µm) than *Phalaenopsis* Hsin and *Phalaenopsis* Brother Girl which recorded leaf thickness ranging from 112.5 to 113.3µm and 110.2 to 113.4µm respectively.

Effect of shade on leaf thickness in the cultivars was significant from the first to the 3rd fortnight (November 2006 to December 2007).During the period, all the cultivars recorded significantly greater leaf thickness under 25% shade than under 50% shade. However from the 4th to the 23rd fortnight, shade effect on leaf thickness was not significant. But at the 24th fortnight, (November 2007) all the cultivars recorded significantly greater leaf thickness under 50% shade than under 25% shade.

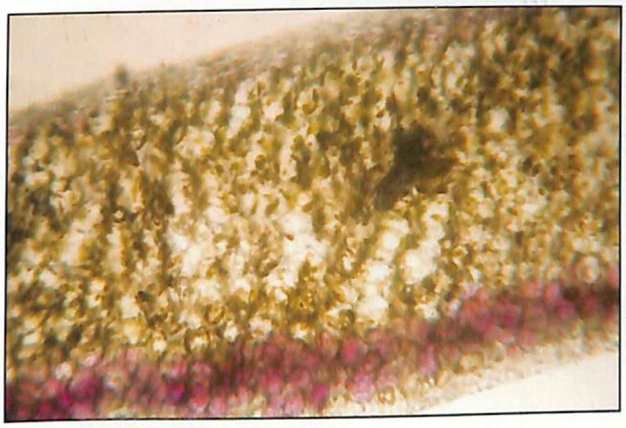
Interaction between cultivars and shade effects on leaf thickness was not significant from the 1st to the 19th fortnight and from the 21st to the 24th fortnight. However at the 20th fortnight (August 2007), interaction between cultivars and shade effects was significant and *Phalaenopsis* Hsin had significantly greater leaf thickness under 50% shade than under 25% shade and also greater leaf thickness than *Phalaenopsis* Luchia Pink or *Phalaenopsis* Brother Girl under 25% and 50% shade. *Phalaenopsis* Luchia Pink had significantly lesser leaf thickness under 25% shade than *Phalaenopsis* Hsin and *Phalaenopsis* Brother Girl under the same shade level or *Phalaenopsis* Hsin and *Phalaenopsis* Luchia Pink plants grown under 50% shade.

4.1.15 Leaf Pigmentation and Leaf Sheath colour

Phalaenopsis Hsin was found to have green and slight pink pigmentation on the leaves. *Phalaenopsis* Luchia Pink was to found have two layers of pink coloured pigmentation other than green pigmentation on the leaves. *Phalaenopsis* Brother Girl was found to have green pigmentation only.



V_1



V_2

V_3

Plate 4. Cultivar differences on leaf pigmentation

V_1

V_2

V_3

Plate 5. Cultivar differences on leaf sheath colour

Phalaenopsis Hsin was found to have purple coloured leaf sheath. *Phalaenopsis* Luchia Pink was found have more dark purple coloured leaf sheath. *Phalaenopsis* Brother Girl was found have green coloured leaf sheath.

4.1.16. Chlorophyll content (a and b) (Table 13 and Table 14)

Significant difference between the cultivars on the chlorophyll content (a) was observed during the 24th fortnight (October 2007).During the period, *Phalaenopsis* Hsin recorded lesser chlorophyll content (a) (0.26) compared to *Phalaenopsis* Luchia Pink and *Phalaenopsis* Brother Girl having chlorophyll content (a) ranging from 0.37 to 0.39.

Significant difference between the cultivars on the chlorophyll content (b) was observed during the 24th fortnight (October 2007). During the period, *Phalaenopsis* Hsin recorded lesser chlorophyll content (a) (0.35) compared to *Phalaenopsis* Luchia Pink and *Phalaenopsis* Brother Girl having chlorophyll content (a) ranging from 0.37 to 0.39.

Effect of shade on chlorophyll content in the three cultivars was significant during the 24th fortnight (October 2007). During the period, all the cultivars recorded significantly more chlorophyll content (a and b) under 25% shade than under 50% shade.

Interaction between cultivars and shade effects influences chlorophyll content during the 24th fortnight (October 2007). During the period, Phalaenopsis Brother Girl had significantly more chlorophyll content under 50% shade than 25% shade and the *Phalaenopsis* Hsin recorded significantly lesser chlorophyll content under 50% shade than 25% shade.

Table 13.Effect of shade on chlorophyll content (a) in *Phalaenopsis* orchids

FN	V1			V2			V3			Shade		CD		
	S1	S2	Pooled	S1	S2	Pooled	S1	S2	Pooled	S1	S2	V	S	VXS
24	0.28	0.23	0.26	0.42	0.33	0.37	0.35	0.43	0.39	0.35	0.33	0.008	0.007	0.004

Table 14.Effect of shade on chlorophyll content (b) in *Phalaenopsis* orchids

FN	V1			V2			V3			Shade		CD		
	S1	S2	Pooled	S1	S2	Pooled	S1	S2	Pooled	S1	S2	V	S	VXS
24	0.36	0.33	0.35	0.62	0.52	0.57	0.52	0.61	0.56	0.50	0.49	0.008	0.006	0.01

4.1.17. Number of stomata on the upper surface of the leaves (Table 15, fig.10 and fig.11)

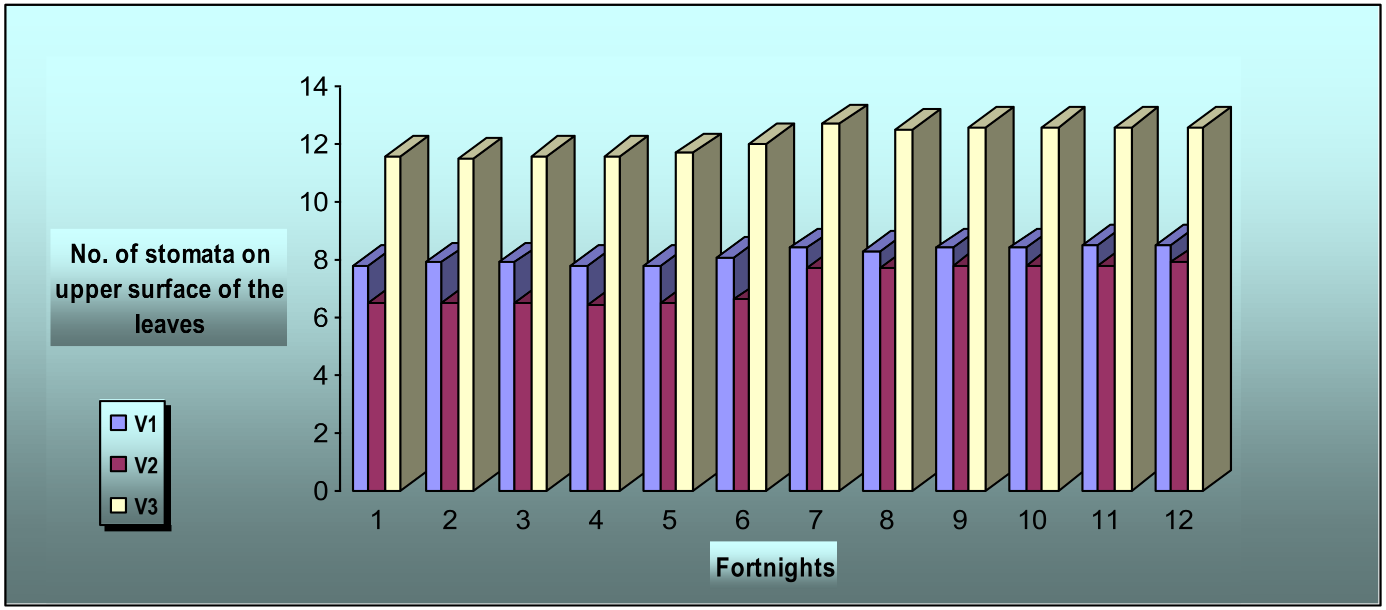
Significant difference between the *Phalaenopsis* cultivars was found in the number of stomata on the upper surface observed from the first to the 23rd fortnight (November 2006 to October 2007) after planting. During the first to the 12th fortnight (November 2006 to April 2007), *Phalaenopsis* Brother Girl was found to have significantly greater number of stomata on the upper surface (11.6 per mm^2) than *Phalaenopsis* Hsin and *Phalaenopsis* Luchia Pink which had stomatal numbers ranging from 7.8 to 8.5 and 6.5 to 7.9 per mm^2 respectively. However from the 13th to the 23rd fortnight (May 2007 to October 2007), *Phalaenopsis* Brother Girl was found to have significantly more stomatal number on upper surface (12.5 to 12.7 per mm^2) than *Phalaenopsis* Luchia Pink and *Phalaenopsis* Hsin having stomatal number ranging from 7.7 to 7.9 per mm^2 and 8.3 to 8.5 per mm^2 respectively.

Effect of shade on number of stomata on upper surface was significant from the first to the 9th fortnight (November 2006 to March 2007).However during the 11th fortnight (April 2007), the shade effects were not significant. Then from the 13th to the 23rd fortnight (May 2007 to October 2007), effect of shade on number of stomata on the upper surface was significant and all the cultivars recorded significantly more stomatal number on upper surface under 25% shade than 50% shade.

Interaction between cultivars and shade on stomatal count on the upper surface of the leaves was significant from the first to the 5th fortnight (November 2006 to January 2007) after planting. Thereafter at the 7th fortnight and the 9th fortnight (February 2007 and March 2007), effects on number of stomata on the upper surface was not significant. However at the 11th fortnight (April 2007), effect on number of stomata on the upper surface was significant. Thereafter from

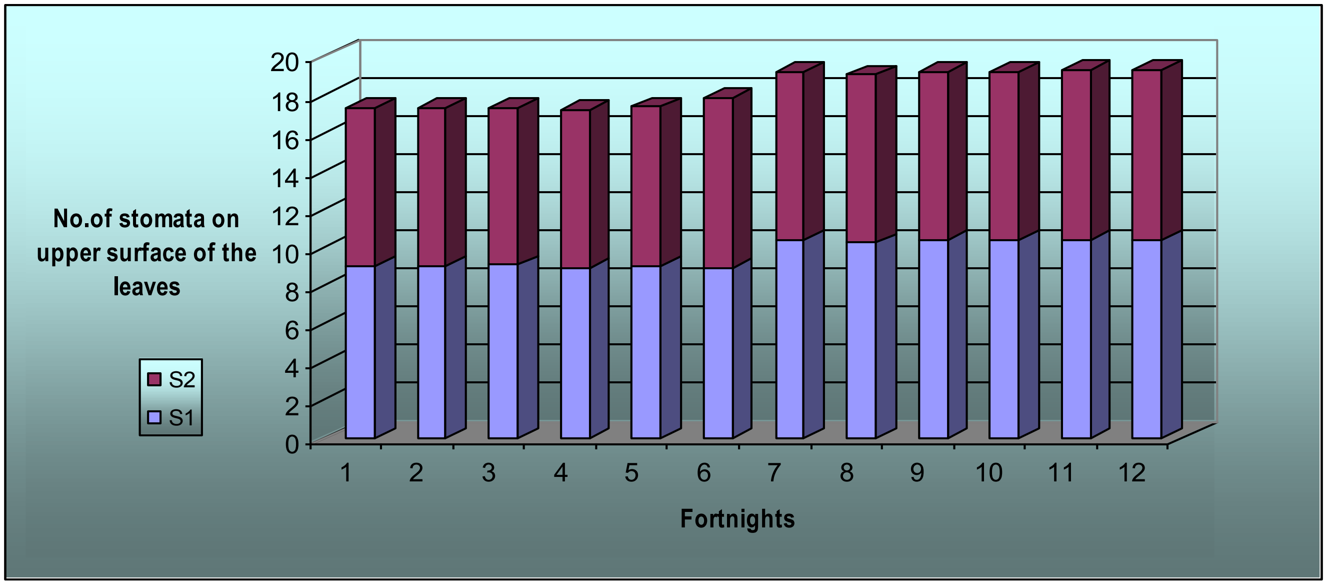
Table 15. Effect of shade on number of stomata (upper) in *Phalaenopsis* orchid

FN	V_1			V_2			V_3			shade		CD		
	S_1	S_2	Pooled	S_1	S_2	Pooled	S1	S2	Pooled	S_1	S_2	V	S	VxS
1	8.6	7.0	7.8	6.8	6.2	6.5	11.6	11.6	11.6	9.00	8.26	0.57	0.46	0.80
3	8.8	7.0	7.9	6.8	6.2	6.5	11.4	11.6	11.5	9.00	8.26	0.67	0.55	0.95
5	8.8	7.0	7.9	6.8	6.2	6.5	11.6	11.6	11.6	9.06	8.26	0.67	0.55	0.95
7	8.6	7.0	7.8	6.6	6.2	6.4	11.6	11.6	11.6	8.93	8.26	0.69	0.56	NS
9	8.6	7.0	7.8	6.6	6.4	6.5	11.8	11.6	11.7	9.00	8.33	0.69	0.56	NS
11	8.6	7.6	8.1	6.6	6.6	6.6	11.6	12.4	12.0	8.93	8.86	0.68	NS	0.96
13	9.2	7.6	8.4	8.8	6.6	7.7	13.0	12.4	12.7	10.33	8.86	0.78	0.63	NS
15	9.0	7.6	8.3	8.8	6.6	7.7	12.8	12.2	12.5	10.20	8.80	0.81	0.66	NS
17	9.2	7.6	8.4	9.0	6.6	7.8	12.8	12.4	12.6	10.33	8.86	0.82	0.67	NS
19	9.2	7.6	8.4	9.0	6.6	7.8	12.8	12.4	12.6	10.33	8.86	0.82	0.67	NS
21	9.4	7.6	8.5	9.0	6.6	7.8	12.8	12.4	12.6	10.40	8.86	0.79	0.64	1.11
23	9.4	7.6	8.5	9.0	6.8	7.9	12.8	12.4	12.6	10.40	8.90	0.82	0.67	NS



V_1 – *Phalaenopsis* Hsin
V_2 – *Phalaenopsis* Luchia Pink
V_3 – *Phalaenopsis* Brother Girl

Fig 10. Cultivar differences on number of stomata on upper surface of the leaves (per mm^2) in *Phalaenopsis* orchids



S_1– 25% shade
S_2– 50% shade

Fig 11. Effect of shade on number of stomata on upper surface of the leaves (per mm^2) in *Phalaenopsis* orchids

the 13th to the 19th fortnight and at the 23rd fortnight (May 2007 to August 2007 and October 2007), effects on number of stomata on the upper surface was not significant .During the first to the 5th fortnight and at the 11th and the 21st fortnight, *Phalaenopsis* Brother Girl had significantly greater stomatal number on upper surface under 25% and 50% shade than *Phalaenopsis* Hsin and *Phalaenopsis* Luchia Pink under 25 % or 50% shade.

4.1.18. Number of stomata on the lower surface of the leaves (Table 16, fig.12 and fig.13)

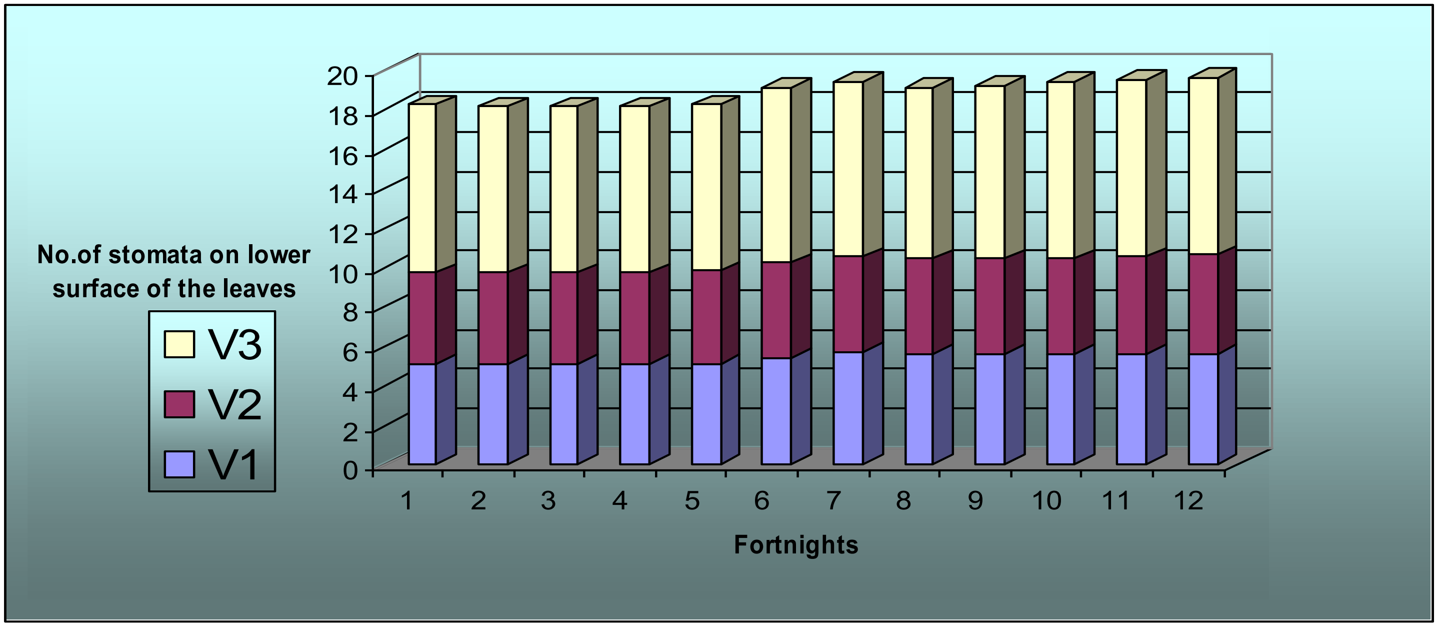
Significant difference between cultivars on the number of stomata on the lower surface of the leaves from the first fortnight to the 23rd fortnight (November 2006 to October 2007). During the period, *Phalaenopsis* Brother Girl recorded significantly more stomatal number (8.4 to 9 per mm^2) than *Phalaenopsis* Hsin and *Phalaenopsis* Luchia Pink which recorded stomatal numbers ranging from 5.1 to 5.6 and 4.6 to 5.0 per mm^2 respectively.

Effect of shade on number of stomata on the lower surface in the three cultivars was significant from the first to the 23rd fortnight (November 2006 to November 2007) after planting. During the period, the cultivars recorded significantly more stomatal number (8.26 to 8.93per mm2) on lower surface under 25% shade than under 50% shade.

Interaction between cultivars and shade effects on number of stomata on the lower surface was significant. From the first to the 23rd fortnight, *Phalaenopsis* Brother Girl had significantly greater stomatal number on the lower surface under 25% shade than under 50% shade. It was also greater than that of *Phalaenopsis* Luchia Pink and *Phalaenopsis* Hsin under 25% and 50% shade. *Phalaenopsis* Luchia Pink had significantly lesser stomatal number on the lower surface under 50% shade than *Phalaenopsis* Hsin and *Phalaenopsis* Brother Girl

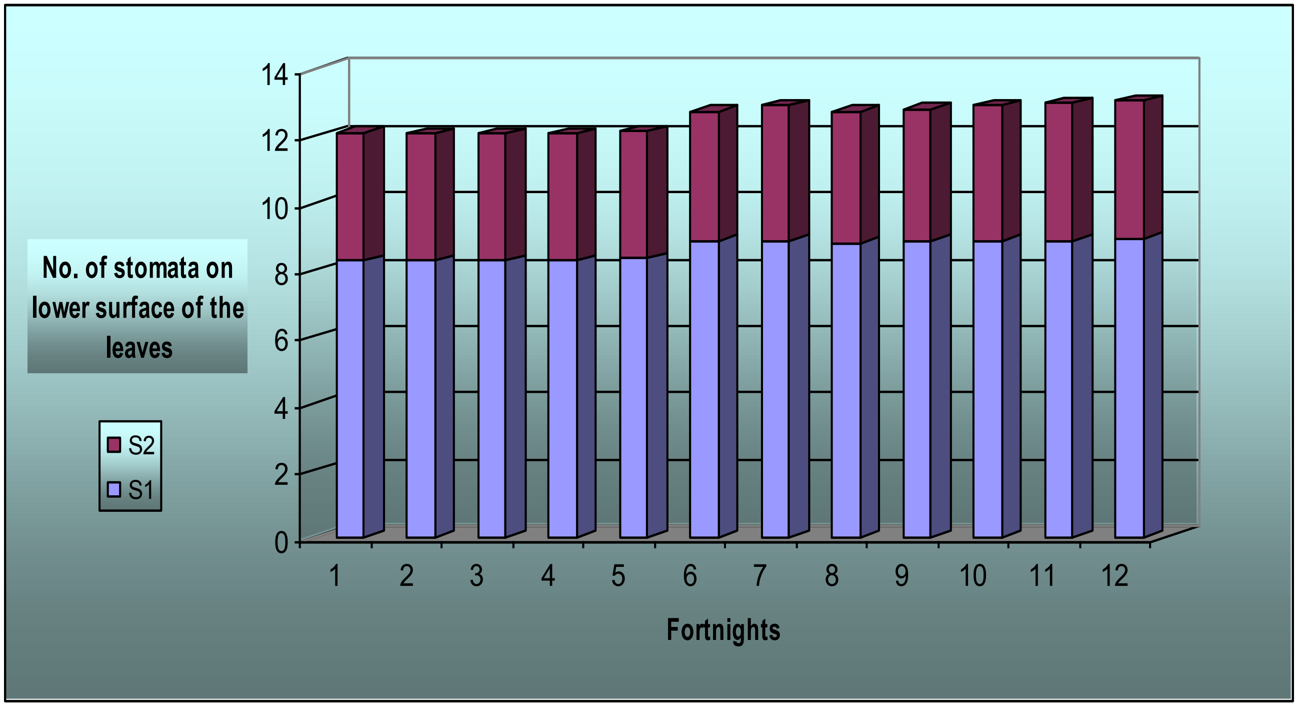
Table 16. Effect of shade on number of stomata (lower) in *Phalaenopsis* orchid

FN	V_1			V_2			V_3			shade		CD		
	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	V	S	VxS
1	4.2	3.2	5.1	3.6	3.0	4.6	7.2	5.4	8.5	8.26	3.86	0.82	0.67	1.16
3	4.2	3.2	5.1	3.6	3.0	4.6	7.2	5.2	8.4	8.26	3.80	0.51	0.42	0.73
5	4.2	3.2	5.1	3.8	3.0	4.6	7.2	5.2	8.4	8.26	3.80	0.51	0.42	0.73
7	4.6	3.2	5.1	4.2	3.0	4.6	7.8	5.2	8.4	8.26	3.80	0.51	0.42	0.73
9	4.6	3.2	5.1	4.2	3.0	4.7	7.8	5.2	8.4	8.33	3.80	0.53	0.43	0.75
11	4.6	3.2	5.4	4.2	3.0	4.8	7.6	5.4	8.9	8.86	3.86	0.58	0.47	0.82
13	4.4	3.8	5.7	4.2	3.0	4.8	7.8	5.4	8.9	8.86	4.06	0.58	0.47	0.82
15	5.0	3.6	5.6	4.6	3.0	4.8	7.8	5.2	8.7	8.80	3.93	0.57	0.46	0.80
17	5.0	3.6	5.6	4.6	3.0	4.8	7.8	5.2	8.8	8.86	3.93	0.51	0.42	0.73
19	5.0	3.6	5.6	4.6	3.0	4.8	7.8	5.6	9.0	8.86	4.06	0.53	0.43	0.75
21	5.0	3.6	5.6	4.8	3.2	4.9	8.0	5.6	9.0	8.86	4.13	0.55	0.45	0.79
23	5.0	3.6	5.6	4.8	3.2	5.0	8.0	5.6	9.0	8.93	4.13	0.60	0.49	0.85



V_1 – *Phalaenopsis* Hsin
V_2 – *Phalaenopsis* Luchia Pink
V_3 – *Phalaenopsis* Brother Girl

Fig 12. Cultivar differences on number of stomata on lower surface of the leaves (per mm^2) in *Phalaenopsis* orchids



S_1– 25% shade
S_2– 50% shade

Fig 13. Effect of shade on number of stomata on lower surface of the leaves (per mm^2) in *Phalaenopsis* orchids

under the same shade level or *Phalaenopsis* Hsin, Phalaenopsis Brother Girl and *Phalaenopsis* Luchia Pink under 25 % shade.

4.1.19. Shape of Stomata

All the three *Phalaenopsis* cultivars were found to have round shaped stomata on upper and lower surface of the leaves.

Discussion

5. DISCUSSION

The investigation was undertaken with the objective of assessing the performance of hardened tissue cultured *Phalaenopsis* plants under varying shade levels and to determine the most suitable shade level for their early vegetative growth. Three commercially grown cultivars of *Phalaenopsis* orchids of eight months age after deflasking were used as the planting material. The cultivars were *Phalaenopsis* Hsin (V_1), *Phalaenopsis* Luchia Pink (V_2) and *Phalaenopsis* Brother Girl (V_3). Three experiments were laid out under three shade levels *i.e.* 25% (S_1), 50% (S_2) and 75% (S_3) shade. The results obtained are discussed in this chapter.

Effect of shade and cultivar differences on root characteristics, shoot characteristics and leaf characteristics of hardened plants and anatomical characteristics such as leaf thickness, stomatal count on the upper and lower surfaces of the leaves and the chlorophyll content of the leaves were observed. Purseglove (1975) reported light requirements of epiphytic orchids and similar effects have also been reported in begonia plants grown under 50 % shade (Aasha, 1986).

Cultivar differences and shade effects were found to influence root characteristics such as production of number of roots. Greater number of roots was recorded by the *Phalaenopsis* Hsin during the1st to the 12th fortnight (November 2006 to April 2007). The number of roots in *Phalaenopsis* Hsin under 25 % shade ranged from 5.20 to 12.20 and was found to be maximum at the 3rd

fortnight (December 2006) and thereafter decreased and then increased steadily. The number of roots in *Phalaenopsis* Hsin under 50% shade ranged from 4.40 to 8.80 and in *Phalaenopsis* Hsin under 75% shade, number of roots ranged from 6.80 to 9.40.The most suitable shade level for greater number of roots was found to be 25% shade during the 7th to the 12th fortnight (February 2007 to April 2007) and at the 24th fortnight (October 2007) and 75% shade was also found to be conducive for more root production during the 14th to the 19th fortnight (May 2007 to August 2007). Similar effects on greatest root counts were reported in European horn bean by Maynard and Bassuck (1992).

Cultivar differences were found to influence the length of the roots. Greater root length was recorded by the *Phalaenopsis* Luchia Pink during the 9th and 10th fortnight (March 2007) and from the 20th to the 24th fortnight (August 2007 to October 2007). Highest root length was recorded by the *Phalaenopsis* Luchia Pink during the 24th fortnight (October 2007). The length of the roots in *Phalaenopsis* Luchia Pink under 25% shade ranged from 1.98 to 4.38 cm and the length of the roots in *Phalaenopsis* Luchia Pink under 50% shade ranged from 1.96 to 5.46 cm and in *Phalaenopsis* Luchia Pink under 75% shade, the length of the roots ranged from 3.80 to 4.38 cm. The most suitable shade level for greater length of roots was found to be 50% shade during the 16th to the 24th fortnight (June 2007 to October 2007) and 75% shade were also found to be conducive for more root length during the first to the 6th fortnight (November 2006 to January 2007). These results are in agreement with that reported by Nelson (1964), Kennet et al (1992).

The thickness of roots was influenced by the cultivar differences and the shade effects. Higher root thickness was recorded by the *Phalaenopsis* Luchia Pink during the 23rd and 24th fortnight (October 2007). Highest root thickness was recorded by the *Phalaenopsis* Luchia Pink during the 24th fortnight (October 2007). The thickness of the roots in *Phalaenopsis* Luchia Pink under 25% shade ranged from 0.36 to 0.50 cm and was found to be maximum at the 20th to the 24th fortnight (August 2007 to October 2007) and under 50% shade, the root thickness ranged from 0.22 to 0.50 cm and under 75% shade, the root thickness ranged from 0.36 to 0.54 cm.The most suitable shade level for all the three cultivars for greater root thickness was found to be 25% during the 10th, 11th and 22nd fortnight (March –April 2007 and September 2007).

Greater shoot length was recorded by the *Phalaenopsis* Hsin during the first to the 11th fortnight (November 2006 to April 2007). The length of the shoots in *Phalaenopsis* Hsin under 25% shade ranged from 1.50 to 2.20 cm and under 50% shade, shoot length ranged from 1.48 to 2.26 cm and under 75% shade, the length of the shoots ranged from1.56 to 2.00 cm .The most suitable shade level for greater shoot length for all the three cultivars was found to be 50% during the 6th,7th, 9th,12th,17th and 21st fortnight (January 2007 to March 2007, April 2007, July and September 2007). Similar effects on shoot length under high light intensity were observed in crops such as birds terfoil (Cooper, 1996) and Alfa Alfa and red gram (George, 1982).

Rate of shoot elongation was not influenced by shade effects or cultivar differences.

Highest shoot girth was recorded by the *Phalaenopsis* Hsin during the first to the 6th fortnight (November 2006 to January 2007). Shoot girth in *Phalaenopsis* Hsin under 25% shade ranged from 0.62 to 0.98 cm and ranged from 0.82 to 1.36 cm and 0.62 to 1.06 cm under 50% and 75% shade respectively. The most suitable shade for the greater shoot girth was found to be 50% during the 10th to the 24th fortnight (March 2007 to October 2007).

Greater internodal length of the shoots were recorded by the *Phalaenopsis* Hsin during the first to the 24th fortnight (November 2006 to 0ctober 2007). Internodal length of the shoots in *Phalaenopsis* Hsin under 25% shade ranged from 0.72 to 1.36 cm and 0.56 to 1.14 cm and 1.02 to1.62 cm under 50% and 75% shade respectively. The internodal length of the shoots was not influenced by the shade effects.

Cultivar differences and shade effects were not found to be influence the rate of shoot elongation during the first to the 24th fortnight (November 2006 to 0ctober 2007).

Cultivar differences were not found to be influence the number of leaves during the first to the 24th fortnight. The most suitable shade for greater number of leaves for all the three cultivars were found to be 50% during the 1st to the 12th fortnight and at the 14th fortnight (November 2006 to April 2007, May 2007).

The number of leaves in Amaranthus species was found to be greatest at the medium shade (Simbolon and Sutarno, 1986).

Greater length of the leaves was recorded by the *Phalaenopsis* Hsin during the16th to the 19th fortnight (June 2007 to August 2007). Length of the leaves of *Phalaenopsis* Hsin ranged from 3.76 to 5.70 cm and 5.40 to 6.64 cmunder 25% and 50% shade respectively. The most suitable shade level for greater length of the leaves was found to be 50% during the 1st to the 11th fortnight, 13th and 15th fortnight (November 2006 to April 2007 and May 2007 to June 2007).

The width of the leaves was influenced by cultivar differences and the shade effects. Higher width of the leaves was recorded by *Phalaenopsis* Hsin during the 21st to the 24th fortnight (September 2007 to 0ctober 2007). The width of the leaves of *Phalaenopsis* Hsin ranged from 1.36 to 5.70 cm and 2.82 to 3.94 cm under 25% and 50% shade respectively. The width of the leaves of *Phalaenopsis* Luchia Pink ranged from 1.60 to 6.20 cm and 2.46 to 3.34 cm under 25% and 50% shade respectively. The most suitable shade level for greater width of the leaves was found to be 50% during the 1st to the 9th fortnight, 11th and 13th fortnight (November 2006 to March 2007,April 2007 and May 2007) and 25 % shade was also found to be more conducive for greater width of the leaves during the 13th to the 24th fortnight (May 2007 to October 2007). These results are in agreement with that reported by Jeon (2005).

The leaf area was influenced by the cultivars differences and the shade effects. Greater leaf area was recorded by the *Phalaenopsis* Hsin during the 23rd and 24th fortnight after planting (October 2007). The leaf area of *Phalaenopsis* Hsin ranged from 6.26 to 33.68 cm^2 and 15.38 to 26.41 cm^2 under 25% and 50% shade respectively The most suitable shade level for greater leaf area was found to be 50% shade during the 22nd to 24th fortnight (September 2007 to October 2007).

Phalaenopsis Hsin and *Phalaenopsis* Luchia Pink were found to have more or less round shaped leaves. *Phalaenopsis* Brother Girl was found to have elongate shaped leaves.

The thickness of the leaves was influenced by the cultivar differences and the shade effects. Higher leaf thickness was recorded by the *Phalaenopsis* Brother Girl during the first fortnight to the 24th fortnight (November 2006 to 0ctober 2007). The thickness of the leaves of *Phalaenopsis* Brother Girl ranged from 112.4 µm to 114.2 µm and 108 µm to 113.2 µm under 25% and 50% shade respectively. The thickness of the leaves of *Phalaenopsis* Hsin ranged from 111.6 µm to 113.4 µm and 112 µm to 114.4 µm under 25% and 50% shade respectively. The thickness of the leaves of *Phalaenopsis* Luchia Pink ranged from 107.0 to 107.8 µm and 105.8 to 109.0 µm under 25% and 50% shade respectively. The most suitable shade level for greater thickness of the leaves was found to be 25% during the first to the 3rd fortnight (November 2006 to December 2006) and at the 24th fortnight (October 2007). These results are in agreement with that reported by Fails et al., (1982), Smit (1984) and Silva et al., (1984).

Phalaenopsis Hsin was found to have green and slight pink pigmentation on the leaves. *Phalaenopsis* Luchia Pink was to found have two layers of pink coloured pigmentation other than green pigmentation on the leaves. *Phalaenopsis* Brother Girl was found to have green pigmentation only. *Phalaenopsis* Hsin was found to have purple coloured leaf sheath. *Phalaenopsis* Luchia Pink was found have more dark purple coloured leaf sheath. *Phalaenopsis* Brother Girl was found have green coloured leaf sheath.

The chlorophyll content (a) of the leaves was found to be influenced by cultivar differences and the shade effects. Greater chlorophyll content (a) was recorded by the *Phalaenopsis* Brother Girl. The chlorophyll content (a) of the leaves in *Phalaenopsis* Brother Girl were 0.35 and 0.43 under 25% and 50% shade respectively and in *Phalaenopsis* Luchia Pink, the chlorophyll content (a) were 0.42 and 0.33 under 25% and 50% shade respectively and in *Phalaenopsis* Hsin, the chlorophyll content (a) were 0.28 and 0.23 under 25% and 50% shade respectively. The most suitable shade level for greater chlorophyll content (a) was found to be 25%. Seybold and Egle(1937) observed an inverse relationship of shade and chlorophyll content had been reported in peanut(Rao and Mithra,1988)and maize(Bhutani et al.,1989).

The chlorophyll content (b) of the leaves was found to be influenced by cultivar differences and the shade effects. Greater chlorophyll content (b) was recorded by the *Phalaenopsis* Luchia Pink. The chlorophyll content (b) of the leaves in *Phalaenopsis* Luchia Pink were 0.62 and 0.52 under 25% and 50% shade respectively and in *Phalaenopsis* Brother Girl, the chlorophyll content (b) were 0.52 and 0.61 under 25% and 50% shade respectively and in *Phalaenopsis* Hsin, the chlorophyll content (a) were 0.36 and 0.33 under 25% and 50% shade respectively. The most suitable shade level for greater chlorophyll content (b) was found to be 25%. Seybold and Egle (1937) observed an inverse relationship of shade and chlorophyll content had been reported in peanut (Rao and Mithra, 1988) and maize (Bhutani et al., 1989).

The number of stomata on the upper surface of the leaves was influenced by the cultivar differences and the shade effects. Higher number of stomata on the upper surface of the leaves was recorded by *Phalaenopsis* Brother Girl during the first to the 23^{rd} fortnight. The number of stomata on the upper surface of the leaves of *Phalaenopsis* Brother Girl ranged from 11.4 to 13.0 per mm^2 and 11.6 to 12.4 per mm^2 under 25% and 50% shade respectively. The number of stomata on the upper surface of the leaves of *Phalaenopsis* Hsin ranged from 8.60 to 9.4 per mm^2 and 7.0 to 7.6 per mm^2 under 25% and 50% shade respectively and the stomatal count on the upper surface of the leaves of *Phalaenopsis* Luchia Pink ranged from 6.6 to 9.0 per mm^2 and 6.2 to 6.8 per mm^2 under 25% and 50% shade respectively. The most suitable shade level for greater number of stomata on the upper surface of the leaves was found to be 25% during the 1^{st} to the 23^{rd}

fortnight after planting. (November 2006 to October 2007). Pack and Jun reported that in 33 orchids, the stomata were mainly confirmed to the abaxial side of the leaves except *Blitilla striata.*

The number of stomata on the lower surface of the leaves was influenced by the cultivar differences and the shade effects. Higher number of stomata on the lower surface of the leaves was recorded by *Phalaenopsis* Brother Girl during the first to the 23rd fortnight. The number of stomata on the lower surface of the leaves of *Phalaenopsis* Brother Girl ranged from 7.2 to 8.0 per mm^2 and 5.2 to 5.6 per mm^2 under 25% and 50% shade respectively. The number of stomata on the lower surface of the leaves of *Phalaenopsis* Hsin ranged from 4.2 to 5.0 per mm^2 and 3.2 to 3.6 per mm^2 under 25% and 50% shade respectively and in *Phalaenopsis* Luchia Pink, stomatal count ranged from 3.6 to 4.8 per mm^2 and 3.0 to 3.2 per mm^2 under 25% and 50% shade respectively. The most suitable shade level for greater number of stomata on the lower surface of the leaves was found to be 25% during the 1st to the 23rd fortnight after planting. (November 2006 to October 2007).

All the three *Phalaenopsis* cultivars were found to have round shaped stomata on upper and lower surface of the leaves.

Effect of cultivar differences observed in the study have shown that significantly greater number of roots, shoot length, shoot girth, internodal length of shoots, length and width of the leaves could be observed in the *Phalaenopsis* Hsin. Shade effects observed in the study have shown that greater root length, shoot length, shoot girth, number of leaves, length and width of the leaves could be observed under 50% shade.

Interaction between cultivar and shade effects were observed to influence the number of roots, length and thickness of roots, internodal length of shoots, leaf thickness, number of stomata on the upper and lower surface of the leaves and chlorophyll content.

Phalaenopsis Hsin was found to be the best cultivar for obtaining greater number of roots, shoot length, and shoot girth, internodal length, length and width of the leaves. The most suitable shade level conducive for root thickness, shoot length, shoot girth, number of leaves, length and width of the leaves was found to be 50%. Thus, the *Phalaenopsis* Hsin under 50% shade can be recommended for good early performance of hardened plants in Kerala.

Summary

6. SUMMARY

An investigation was carried out at the Department of Pomology and Floriculture, College of Agriculture, Vellayani, Thiruvananthapuram during 2006-2007 with view to assess the performance of *Phalaenopsis* cultivars under varying shade levels and to determine the most suitable shade level for early vegetative growth of hardened plants. The following three commercially grown cultivars of *Phalaenopsis* orchids were used as the planting material. The cultivars are are Hsin(V_1),LuchiaPink (V_2) and Brother Girl(V_3).For the three experiments, shade was provided with black high density polyethylene shade net calibrated for 25% (S_1), 50% (S_2) and 75% (S_3) shade. The results of the experiments obtained are summarized below.

Cultivar differences and shade effects influenced the plant growth, shoot and leaf morphology and physiological and anatomical characteristics of the hardened plants.

Greater number of roots was recorded by *Phalaenopsis* Hsin (V_1) during the first to 12th fortnight. The number of roots in *Phalaenopsis* Hsin under 25% shade ranged from 5.2 to 12.2 and was found to be maximum at the 3rd fortnight (December 2006).

The most suitable shade level for greater number of roots was found to be 25% shade during the 7th to the 12th fortnight (February 2007 to April 2007)and at the 24th fortnight and 75% shade was also found to be conducive for more root production during the 14th to the 19th fortnight (May 2007 to August 2007).

Greater root length was recorded by the *Phalaenopsis* Luchia Pink (V_2) during the 9th and the 10th fortnight (March 2007) and from the 20th to the 24th fortnight (August 2007 to October 2007). Highest root length was recorded by the *Phalaenopsis* Luchia Pink during the 24th fortnight (October 2007). The length of the roots in *Phalaenopsis* Luchia Pink under 50% shade ranged from 1.96 to 5.46 cm.

The most suitable shade level for greater length of roots was found to be 50% shade during the 16th to the 24th fortnight(June 2007 to October 2007) and 75% shade were also found to be conducive for more root length during the first to the 6th fortnight(November 2006 to January 2007).

Higher root thickness was recorded by the *Phalaenopsis* Luchia Pink (V_2) during the 23rd and 24th fortnight (October 2007). Highest root thickness was recorded by the *Phalaenopsis* Luchia Pink during the 24th fortnight (October 2007). The thickness of the roots in *Phalaenopsis* Luchia Pink under 25% shade ranged from 0.36 to 0.50 cm and was found to be maximum at the 20th to the 24th fortnight (August 2007 to October 2007).

The most suitable shade level for greater root thickness was found to be 25% during the 10th, 11th and 22nd fortnight (March –April 2007 and September 2007).

Greater shoot length was recorded by the *Phalaenopsis* Hsin during the first to the 11th fortnight (November 2006 to April 2007).The shoot length in *Phalaenopsis* Hsin ranged from 1.48 to 2.26 cm under 50% shade.

The most suitable shade level for greater shoot length for all the three cultivars was found to be 50% during the 6th,7th, 9th,12th,17th and 21st fortnight (January 2007 to March 2007, April 2007, July and September 2007).

Greater shoot girth was recorded by the *Phalaenopsis* Hsin during the first to the 6th fortnight (November 2006 to January 2007). The shoot girth in *Phalaenopsis* Hsin ranged from 0.82 to 1.36 cm under 50% shade.

The most suitable shade for the greater shoot girth was found to be 50% during the 10th to the 24th fortnight (March 2007 to October 2007).

Greater internodal length of the shoots were recorded by *Phalaenopsis* Hsin during the first to the 24th fortnight (November 2006 to 0ctober 2007).The internodal length of the shoots of *Phalaenopsis* Hsin ranged from 1.02 to1.62 cm.The internodal length of the shoots was not influenced by the shade effects.

Cultivar differences were not found to be influence the number of leaves during the first to the 24th fortnight. The most suitable shade for greater number of leaves for all the three cultivars were found to be 50% during the 1st to the 12th fortnight and at the 14th fortnight (November 2006 to April 2007, May 2007).

Greater length of the leaves was recorded by the *Phalaenopsis* Hsin during the 16th to the 19th fortnight (June 2007 to August 2007).The length of the leaves of *Phalaenopsis* Hsin ranged from 5.40 to 6.64 cm under 50% shade.

The most suitable shade level for greater length of the leaves was found to be 50% (S_2) during the 1st to the 11th fortnight, 13th and15th fortnight (November 2006 to April 2007 and May 2007 to June 2007).

Higher width of the leaves was recorded by *Phalaenopsis* Hsin during the 21st to the 24th fortnight (September 2007 to 0ctober 2007). The width of the leaves of *Phalaenopsis* Hsin ranged from 2.82 to 3.94 cm under 50% shade.

The most suitable shade level for greater width of the leaves was found to be 50% during the 1st to the 9th fortnight, 11th fortnight and 13th fortnight (November 2006 to March 2007, April 2007 and May 2007).

Greater leaf area was recorded by the *Phalaenopsis* Hsin during the 23rd and 24th fortnight after planting (October 2007). The leaf area of *Phalaenopsis* Hsin ranged from 15.38 to 26.41 cm^2 under 50% shade.

The most suitable shade level for greater leaf area was found to be 50% shade during the 22nd to 24th fortnight (September 2007 to October 2007).

Phalaenopsis Hsin and *Phalaenopsis* Luchia Pink were found to have more or less round shaped leaves. *Phalaenopsis* Brother Girl was found to have elongate shaped leaves.

Higher leaf thickness was recorded by the *Phalaenopsis* Brother Girl during the first fortnight to the 24th fortnight (November 2006 to 0ctober 2007).The thickness of the leaves of *Phalaenopsis* Brother Girl ranged from 112.4 µm to 114.2 µm under 25% shade.

The most suitable shade level for greater thickness of the leaves was found to be 25% during the first to the 3rd fortnight (November 2006 to December 2006) and at the 24th fortnight (October 2007).

Phalaenopsis Hsin was found to have green and slight pink pigmentation on the leaves. *Phalaenopsis* Luchia Pink was to found have two layers of pink coloured pigmentation other than green pigmentation on the leaves. *Phalaenopsis* Brother Girl was found to have green pigmentation only. *Phalaenopsis* Hsin was found to have purple coloured leaf sheath. *Phalaenopsis* Luchia Pink was found have more dark purple coloured leaf sheath. *Phalaenopsis* Brother Girl was found have green coloured leaf sheath.

Greater chlorophyll a content in the leaves was recorded by the *Phalaenopsis* Brother Girl. .The chlorophyll a content of the leaves of *Phalaenopsis* Brother Girl was 0.35.

The most suitable shade level for greater chlorophyll a content of the leaves was found to be 25%.

Greater chlorophyll b content in the leaves was recorded by the *Phalaenopsis* Luchia Pink. The chlorophyll b content of the leaves of *Phalaenopsis* Luchia Pink was 0.62.

The most suitable shade level for greater chlorophyll b content was found to be 25%.

Higher number of stomata on the upper surface of the leaves was recorded by the *Phalaenopsis* Brother Girl during the first to the 23rd fortnight. The number of stomata on the upper surface of the leaves of *Phalaenopsis* Brother Girl ranged from 11.4 to 13.0 per mm^2 under 25% shade.

The most suitable shade level for greater number of stomata on the upper surface of the leaves was found to be 25% during the 1st to the 23rd fortnight after planting. (November 2006 to October 2007).

Higher number of stomata on the lower surface of the leaves was recorded by the *Phalaenopsis* Brother Girl during the first to the 23rd fortnight. The number of stomata on the lower surface of the leaves of *Phalaenopsis* Brother Girl ranged from 7.2 to 8.0 per mm^2 under 25% shade.

The most suitable shade level for greater number of stomata on the lower surface of the leaves was found to be 25% during the 1st to the 23rd fortnight after planting. (November 2006 to October 2007).

Interaction between cultivars and shade effects resulted in greater number of roots *in Phalaenopsis* Hsin under 25 % shade during the 8th fortnight.

Interaction between cultivars and shade effects resulted in greater root length in *Phalaenopsis* Luchia pink under 50 % shade during the 4th to the 9th fortnight (December 2006 to March 2007).

Interaction between cultivars and shade effects resulted in greater production of thicker roots in all the three *Phalaenopsis* cultivars under the three shades during the 17th fortnight.

Interaction between cultivars and shade effects on shoot length was not significant from the first to the 24th fortnight after planting.

Interaction between and shade effects on shoot girth was not significant from the first to the 24th fortnight after planting.

Interaction between cultivars and shade effects resulted in greater internodal length of the shoots in *Phalaenopsis* Hsin under 75% shade during the 1st to the 4^{th} fortnight and from the 6^{th} to the 24^{th} fortnight.

Interaction between cultivars and shade effects on rate of shoot elongation was not significant from the first to the 24^{th} fortnight after planting.

Interaction between cultivars and shade effects resulted in greater leaf thickness in *Phalaenopsis* Hsin under 50% shade during the 20^{th}fortnight.

Interaction between cultivars and shade effects resulted in greater chlorophyll content (a) in *Phalaenopsis* Brother Girl under 50% shade at the end of field experimentation.

Interaction between cultivars and shade effects resulted in greater chlorophyll content (b) in *Phalaenopsis* Luchia Pink under 25% shade at the end of field experimentation.

Interaction between cultivars and shade effects resulted in greater number of stomata on the upper surface of the leaves in *Phalaenopsis* Brother Girl under 25% shade during the 1^{st} to the 5^{th} fortnight and at the 11^{th} and 21^{st} fortnight.

Interaction between cultivars and shade effects resulted in greater number of stomata on the lower surface of the leaves in *Phalaenopsis* Brother Girl under 25% shade during the 1^{st} to the 23^{rd} fortnight.

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PERFORMANCE OF PHALAENOPSIS ORCHIDS UNDER VARYING SHADE LEVELS

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Abstract of the
thesis submitted in partial fulfillment of the requirement
for the degree of

Master of Science in Horticulture

Faculty of Agriculture
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2008

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ABSTRACT

Orchids, the most beautiful flowers in god's creation, belongs to the family Orchidaceae. *Phalaenopsis* called the 'Moth Orchids' are recognised as the most beautiful flowers among orchids. Their long arching sprays of long lasting blooms are very popular throughout the world. One of the critical factors identified for successful growing of orchids is light. Determining the most suitable shade level for early vegetative growth of orchids is important as it influences the pre-flowering period, flower induction and flower production. The present work was thus taken up with a view to assess the performance of three *Phalaenopsis* cultivars under varying shade levels and to determine the most suitable shade level for early vegetative growth of hardened plants.

The experiment was carried out at the Department of Pomology and Floriculture , College of Agriculture, Vellayani during 2006 -2007 with a view to assess the performance of *Phalaenopsis* orchids under varying shade levels and to determine the most suitable shade level for early vegetative growth of hardened plants. The following three commercially grown cultivars of *Phalaenopsis* orchids were used as the experimental material. The cultivars are *Phalaenopsis* Hsin, *Phalaenopsis* Luchia Pink and *Phalaenopsis* Brother Girl. For the three experiments, shade was provided with black high density polyethylene shade net calibrated for 25 %, 50 % and 75 % shade.

Effect of shade and cultivar differences influenced the plant growth, shoot and leaf morphology and physiological and anatomical characteristics of the hardened plants.

Among the cultivars, *Phalaenopsis* Hsin was found to be the best cultivar for obtaining greater number of roots, shoot length, shoot girth, internodal length, length and width of the leaves. *Phalaenopsis* Brother Girl was found to be the best cultivar for maximum leaf thickness and number of stomata on upper and

lower surface of the leaves. *Phalaenopsis* Luchia Pink was found to be the best cultivar for greater root length and root thickness.

The most suitable shade level conducive for shoot length, shoot girth, number of leaves, length and width of the leaves was found to be 50%.

The most suitable shade level for greater number of roots, root thickness, thickness of leaves and chlorophyll (b) leaves was found to be 25%

The interaction between shade and cultivar differences were also found to influence the performance of hardened plants.