INFLUENCE OF PARTIAL SHADES ON MORPHO-PHYSIOLOGICAL CHARACTERISTICS OF POTTED ANTHURIUM

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CERTIFICATE

This is to certify that the thesis entitled ***"INFLUENCE OF PARTIAL SHADES ON MORPHO-PHYSIOLOGICAL CHARACTERISTICS OF POTTED ANTHURIUM"*** *submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in AGRICULTURAL BOTANY****, embodies the result of a piece of bonafide research work carried out by* ***MD. ZOHURUL KADIR RONI****, Registration No.* ***07-02390*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information received during the course of this investigation has been duly acknowledged.

Dated: June, 2014
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Alhamdulillah
All praise to Almighty Allah,
who is the source of life and strength of knowledge and wisdom

Dedicated to ---
Prof. A. Faiz Md. Jamal Uddin Ph. D

For my mysterious director who meant me that
Life is Beautiful

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The Author

Strength does not come from physical capacity.
It comes from indomitable will.

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ABSTRACT

A pot experiment was conducted to find out the morpho-physiological characteristics of anthurium under shade condition at Sher-e-Bangla Agricultural University, Dhaka, during the period from April 2013 to February 2014. Five anthurium varieties viz. V_1 (Pink anthurium), V_2 (White pink anthurium), V_3 (White anthurium), V_4 (Light anthurium) and V_5 (Green red anthurium) were grown under three light intensities (L_0, Control or full sun; L_1, 40% reduced light; L_2, 60% reduced light). The experiment was carried out in split-plot design with four replications. The highest plant height (34.4 cm) and flower stalk length (29.1 cm) were found from V_1, whereas the lowest was from V_5. Maximum spathe length (9.6 cm), spathe breadth (8.3 cm), number of flowers/plant (6.4) and highest vase life (26.7 days) were also found from V_3, while minimum results for these characters were obtained in V_5. Among the light intensities, maximum result of all attributes were recorded from L_2 (60% reduced light) whereas minimum in L_0. Results also revealed that leaf area and SPAD value were positive relation with anthurium flower yield. Maximum number of flowers (8.3) was obtained from V_3 under 60% reduced light and minimum in V_2 under full sunlight. Overall, V_3 (White anthurium) is the best variety for flowering and 60% reduced light was the most suitable shade condition for its cultivation. Combination of these two also produced the best results.

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ABBREVIATIONS AND ACCORONYMS

AEZ	=	Agro-ecological Zone
ANOVA	=	Analysis of Variance
Bot.	=	Botany
cm	=	Centimeter
CRD	=	Completely Randomized Design
CV	=	Coefficient Variance
DAT	=	Days after Transplanting
DMRT	=	Duncan’s Multiple Range Test
et al.,	=	And others
GA	=	Gibberellic Acid
Hort.	=	Horticulture
IAA	=	Indole Acetic Acid
i.e.	=	That is
J.	=	Journal
K	=	Potassium
LSD	=	Least Significance Difference
mm	=	Millimeter
N	=	Nitrogen
P	=	Phosphorous
R:FR	=	Red and Far red
RH	=	Relative Humidity
SAU	=	Sher-e-Bangla Agricultural University
Sci.	=	Science
Viz.	=	Namely
%	=	Percentage
(^{0})	=	Degree

CHAPTER I

INTRODUCTION

Anthurium (*Anthurium andraeanum* Linden*)* is one of the most beautiful ornamental plants, grown worldwide for its aesthetic value. It ranks ninth in the global flower trade and commands a respectable price both for its cut flower and whole plant (Islam *et al.*, 2013). It belongs to the family Araceae and is native of tropical zones of Central and South America. The name anthurium is derived from Greek '*anthos*' meaning flower and '*oura*' meaning tail referring to the spadix. Thus, anthurium is also known as 'tail flower'. It is a slow-growing perennial that requires shady and humid condition for growing as is found in tropical forests (Agasimani *et al.*, 2011).

The inflorescence of anthurium cut-flower comprises a spadix subtended by a modified leaf termed spathe borne on a long stalk (peduncle). The flower has a wide range of spathe colors viz., white, pink, pinkish white, red, reddish green, whitish green, cream, etc. There are also variation in the shape and firmness of the spathe varying from flat to cup-shaped and firm to floppy. Suitable variety of anthurium is very important for its higher return per unit and their beautification and attractive long lasting flower. In Bangladesh, anthurium is still in its infancy and not available in flower market. At present, anthurium is mostly grown in some small gardens and houses as a pot plant for interior decoration.

Anthurium can be grown in low light because it is a tropical shade plant. Therefore, it is necessary to consider an appropriate shade level of light in garden and household where anthurium is being grown. It is a well-established fact that anthurium plants do not thrive well under high light intensities and that some shade must be provided for its satisfactory growth and flowering (Hlatshwayo and Wahome, 2010).

The quality and quantity of diffused light is the most important factor influencing foliage plant performances under interior conditions. Light intensity can affect plant form, flowering, leaf size, and color in both herbaceous (Jeong *et al.*, 2009; Vendrame *et al.*, 2004) and woody species (Hampson *et al.*, 1996). Shade tolerant plants have both morphological and physiological adaptations that allow them to adapt in low-light conditions (Boardman, 1977). Plants can easily be susceptible to photosynthetic activity because net photosynthesis rate of shade plants is maximized in shade condition (Chen *et al.*, 2005). Interestingly, shade tolerant plants have low photosynthetic rate but they efficiently use light energy, that is why leaf area and chlorophyll content are found to increase significantly from sun plants (Boardman, 1977). Even, phenotypic response to light can vary within a species, suggesting that selection may allow for development of cultivars with enhanced shade tolerance (Siemann and Rogers, 2001).

In Bangladesh, there is a huge number of small gardens, apartments and others households where enough light is not available for anthurium cultivation. To serve this purpose, anthurium cultivars of higher yielding and shade tolerance should be introduced as indoor plants. Research works on shade tolerance of anthurium for indoor cultivation are very scanty in Bangladesh. However, indoor plants require bright, indirect light; tolerate 200-500 foot candles with active growth at 500-1000 foot candles and low light intensity favors vegetative development at the expense of flowering and fruiting (Daubenmire, 1974). So, research screening of anthurium variety should investigate for interior foliage and flower development under different light intensities in house condition as well as in field level.

Even though anthurium is grown by many growers in Bangladesh, there is no scientific information on the use of high yielding varieties, standardization of suitable variety to differentiate for flower quality, vase life, and shade tolerance.

Keeping above points in view, the present investigations were taken to evaluate suitable germplasm for vegetative growth and flowering, as well as performances in relation to different light intensities with the following

OBJECTIVES:

- ® To find out a suitable anthurium variety as indoor plant, and
- ® To determine the appropriate light intensity for flowering of anthurium

CHAPTER II
REVIEW OF LITERATURE

Anthurium is one of the most beautiful cut flower and foliage plants all over the world. Though new in Bangladesh, it has gained high demand for urban gardening and commercial market. Therefore, using reduced light or partial shading is a good technique to develop anthurium in urban areas. Herein, some of important and informative works have so far been done in home and abroad related to this experimentation have been presented in this chapter.

2.1 Varietal performance

Chen *et al.* (1999) evaluated two anthurium cultivars in interior condition under two light intensities: 16μmol.$m^{-2}s^{-1}$ (100 foot candles as low light) and 48μmol.$m^{-2}s^{-1}$ (300 foot candles as low light). Plant height and width, total number of buds, open flowers, new and senesced leaves were measured in interior rooms. Results showed that new leaves and average flower were best in low light conditions than high light. Plant quality remained excellent, leaves were dark green and shiny, flowers were colorful and long lasting.

An experiment was carried out by Bibi *et al.* (2012) in Peshawar. The experiment was consisted of providing shades (55 percent) and two tomato cultivars in comparison with control (full sun). Partial shade effects were studied on various growth parameters of tomato varieties. Maximum increase in plant height in partial shade and number of branches per plant was recorded in control. Fruit size was not affected significantly by shade. Partial shade applied in April and May significantly reduced the yield compared to that applied in June and full sun. On the basis of the results, shading tomato plants during summer was not recommended.

Kamemoto and Nakasone (1963) who recommended 13 variety for commercial cut flower production including Haga white, Nitta, Kaumana, Ozaki, Kansako No.1 and Hirose.

Elibox and Umaharan (2012) investigated 82 anthurium accessions grown in the Caribbean. Spadix color combinations than spathe color, cut flower and leaf parameters were evaluated with productivity and peduncle length having the smallest and largest range, respectively. The frequency distributions had skewed to the right for spathe length, spathe width, spathe size, spadix length, spadix diameter, leaf width, leaf size, and productivity and was normal for leaf length, spadix angle, peduncle length, petiole length, and spathe showiness. Accessions with wider leaves had longer leaves and longer petioles; those with longer spathes had wider spathes; and those with longer peduncles had correspondingly longer petioles. Spadix diameter showed moderate correlations with leaf parameters. In contrast of leaf length and width, leaf size, petiole length, peduncle length, and spadix diameter; spathe length, spathe width, spathe size, and spathe showiness; and productivity loaded on the first, second, and third component respectively.

Cultivar ‘Red Hot’ was a new interspecific hybrid pot plant developed by Henny (1999). The typical characteristics of this cultivar were leaves dark green, 18-20 cm long and 11-12 cm wide; spathes 6-7 cm long, 4-5 cm wide; spadix orange-red, 3-4 cm long and 5-6 cm wide. Plants reached marketable size in 11 months with quality rated between excellent and good.

Anthurium ‘Show Biz’ derived its flowering and growth habit from *A. amnicola* and *A. antioquiense*, both of which were involved in its pedigree. These species along with an accession of *A. andraeanum* G-79 led to development of four Mid-Florida Research and Education Center (MREC) hybrid selections, of which MREC 702 was crossed as female with Anthurium ‘Lady Jane’ giving rise to

‘Show Biz’. Size and flowering of anthurium ‘Show Biz’ grown for 10 months in 1.6-L pots under 125 $\mu mol \cdot m^{-2} s^{-1}$ maximum light intensity and natural photoperiod from November to August. Results showed the canopy height and width, leaf length and width and total number of flowering (Henny and Norman, 2001).

Henley and Robinson (1994) studied twenty-one cultivars of tissue cultured anthurium in 15.2 cm pot. Herein, plants had inflorescence counts which were low, less than 1.5/pot; medium, 1.5 to 3.0/pot and high, more than 3.0/pot. Results observed the plant foliage canopy height and width, leaf and inflorescence number, and color of leaves and inflorescence (spathe and spadix).

In a study, coir pith was tested in combination with different proportions of normal potting medium to find of their suitability as substrate for anthurium. In each growing media three levels of pH (4.5-5.5, 6.5-7.5) were maintained to determine the optimum range of pH for anthurium. The growth parameters like leaf area, number of levers, petiole length, petiole thickness and number of roots were maximum in 100% coir pith medium. The number of suckers per plant, fresh weight and dry weight were higher in T2 (75% coir pith + 25% normal potting medium) and T1 (100% coir pith) growing media when compared to other growing media treatments (Smitha, 1999).

Femina *et al.* (2006) conducted studies on four anthurium cultivars namely, Tropical, Pistache, Mauritius Orange and Passion, to ascertain the influence of four different types of growing structures on growth and quality of flowers. The treatments varied significantly showing the response of different cultivars and the growing systems. The low cost structure with UV stabilized shade net to divert 75% light intensity and UV stabilized polyethylene film (120 gsm) on top to provide protection from rainfall and sides covered with 25% of shade nets.

Cultivar 'Pistache' was the best in terms of plant spread (22.45 cm), leaf number (5.68) and leaf area (80.22 cm^2) and spathe angel (152.03^0) was in Aymara variety.

Evaluation of genotypes showed the presence of wide variation in shape of the leaf, length of the petiole, shape and color of spathe, thickness, length and color of spadix, nature of spadix, yield of the flower per plant per year and number of suckers produced per plant per year. Fifteen of the 28 genotypes showed nearly all the characters of the spathe that was desired for a good variety (Nirmala, 1996).

An experiment was conducted by Srinivasa and Reddy (2005) in Karnataka during 2001-02 to evaluate the performance of anthurium cultivars Hondura, Tinora, Senator, Tropical and Pasricha for cut flower production. The cultivars significantly influenced all the vegetative, physiological and flower parameters. Hondura was the most superior cultivar followed by Senator, Pasricha, Tinora and Tropical.

An experiment was conducted by Agasimani *et al.* (2011) to evaluate the performance and economics of anthuriums. Among the ten varieties tried, number of leaves (5.2), leaf length (18.4 cm), leaf breadth (14.8 cm) and leaf area (237.4 cm^2) was highest in variety "Esmeralda" compared to other varieties. More number of suckers (4.1) was found in variety Ivory. Floral characters like stalk length (39.4 cm), stalk diameter (6.8 mm) and girth (18.33 m), spathe length (15.7 cm), spadix length (8.2 cm), number of flowers per plant per year (9.3) and vase life (21 days) was highest in the variety Esmeralda.

Talia *et al*. (2003) conducted an experiment to evaluate the productivity and quality of six new cultivars *viz.,* Carnaval, Neon, Queen, Sante, Terra, and Vanilla, in soilless culture and under heated glasshouse conditions. Terra was the most productive with 9.4 cut flowers per plant, followed by Neon and Vanilla respectively with 7.3 and 7.0 flowers/plant; the least productive was Carnaval with 4.6 flowers. Regarding quality, Queen showed a bigger spathe with a mean length of 23 cm and a mean width of 18 cm, whereas Santè exhibited the smallest spathe (10 cm for both parameters, on average).

Hew *et al.* (1994) observed in three cultivars of anthurium (‘Jaya’, ‘Fla-range’, ‘Leonette’) flowers for circadian rhythm in CO_2 production. They reported that the rhythmicity was not affected by light, darkness, and detachment. Spadix respiration accounted for 90% of the total flower respiration. Rhythmicity in CO_2 production continued after spathe removal and increased the longevity of anthurium flower. Less pronounced rhythmicity was observed following spadix removal.

Islam *et al.* (2013) studied 5 varieties of anthurium viz., Caesar, Aymara, Ivory, Jewel, and Triticaca. Significant differences among cultivars were noted for all attributes evaluated. Variety ‘Triticaca’ had maximum stalk length and diameter, spathe length and breadth, spadix length, vase life and flowers per plant. Through present analysis it was noticed that, variety ‘Titicaca’ was exceedingly preferred because of its attractive flowers, excellent flower size, yield potentiality, and long shelf life.

Paull *et al.* (1985) monitored the physiological changes accompanying anthurium flower (*A. andraeanum* Andre) senescence with silver pulse treatment. In both treated and untreated flowers, respiration rate was low until senescence began 8 days after harvest. The rate of increase in respiration of silver treated flowers was half that of the controls. Ethylene production remained low throughout the postharvest life of the flowers. Ten days from harvest spathe color began to change from red to blue with no significant changes in the ratios of the anthocyanins. There was a significant increase in spathe tissue ammonium ion due, apparently, to protein breakdown which probably caused the increase in tissue pH. The concentration of tissue phenolics increased during senescence and could have intensified the color change by copigmentation. Flower senescence apparently was not due to a shortage of carbohydrates, though tissue starch levels did decline by about 25%. The ratio of free sugars in the stem, spathe and spadix remained constant with a slight decline in concentration during postharvest life. Senescence probably was caused by water stress due to stem plugging of undetermined nature.

An experiment was investigated by Agampodi and Jayawardena (2007), who revealed the effect of coconut water on vase life of anthuruim (white pink variety) cut flower. The flowers treated with 40, 50 and 60% fresh coconut water solutions as well as distilled water and 5% sucrose also used as control with 0.23% NaOCl as a biocide. The flower was assessed daily observation for browning, wilting and rotten stem bases. Vase life has been determined by the maturity level of spathe and spadix. The longest vase life (21 days) was found in 50% coconut water with 0.23% NaOCl compared to the control and other treatments.

According to Dufour and Guerin (2003), anthurium cultivation is becoming very important in global cut flowers production. Soilless and protected cultivation have been developed for 20 years in tropical countries in order to improve yields and flowers quality and to reduce phytosanitary problems. The size of the leaves and flowers increased from the first to the seventh leaf of the sympodial phase and to the seventh flower. The size of the peduncle and spathe of the first-formed flowers are too small to be sold in the best quality categories. It might be possible to make large flowers appear earlier by suppressing small flowers as soon as they emerge. However, low abaxial stomata which increase vase life. On the other hand, the suppression of the young leaf, i.e. the strongest sink in the plant, can accelerate the emergence of the next flower, but it reduces the leaf area, and hence the amount of assimilate for subsequent flowers.

Avila-Rostant *et al.* (2010) conducted six experiments involving 23 cultivars of anthurium to find out the relationship between vacuolar pH and spathe color, cultivar, developmental stage, spathe location, spathe surface differences, and time after harvest. There were no differences in pH between locations sampled on the spathe nor between the spathe surfaces provided and there were no differences in color intensity. The pH increased with vase life in two of three cultivars tested with pH values (Iwata *et al.*, 1985).

Shiva and Nair (2008) evaluated 14 anthurium cultivars under shade-net house in Andamans. Maximum number of suckers, leaves and plant height was recorded in Mirage. However, leaf size, leaf area, leaf dry weight and plant spread were found maximum in Honey. The cultivar, Wrinkled Orange registered maximum leaf fresh weight. Maximum number of flowers was obtained with Honey followed by Mauritius and Wrinkled Orange. The maximum spathe size was recorded in Mauritius followed by Honey. The cultivar Colarado produced maximum spadix length and number of coils per spadix, while Wrinkled Orange produced maximum peduncle length. The shelf-life of flower on plant was found longest in Wrinkled Orange followed by Honey.

Croat and Chavez (2008) evaluated ten new species of anthurium (Araceae) from Amazonian Peru. Nine of the species, *A. carpishense* Croat, *A. cerrateae* Croat & Lingán, *A.debilipeltatum* Croat, *A.josei*Croat, *A.linganii* Croat, *A.longissimilobum* Croat, *A. pradoense* Croat, *A. puberulum* Croat and Lingán, and *A. timplowmanii* Croat, are from a single area of high endemism in the southern Huallaga River Valley of Huánuco Department near Tingo María, and the area between Tingo María and La Divisora; and one species, *A. pulcachense* Croat, is endemic to an area in the middle Río Huallaga valley in San Martín, Peru.

In terms of anthurium (*Anthurium andraeanum* André), a native of tropical America, is a perennial plant that grows best under shaded, humid conditions. During the early development of the industry, shade was provided for anthuriums by tree ferns or other trees. Since then, many commercial nurseries have used polypropylene shade cloth along with supplemental irrigation to provide anthuriums with a favorable growing environment. However, studies conducted under shade house conditions have demonstrated that flower rejection by shippers can amount to as much as 50 percent of the total flowers harvested. The reasons for rejection commonly were diseases, and injuries caused by insects, environmental stresses, or mechanical means (Bushe *et al.,* 2004).

Khawlhring *et al.* (2012) stated the performance of anthurium as affected by shade conditions as well as the effects of different conventional nutrient sources on beds. Plantlets were collected from tissue culture technique to raising their adapted quality under artificial shade and natural tree shade. Beds were prepared by cocopeat, charcoal and vermicompost, which brought under the netlon shade (75%) and natural tree shade. NPK, biofetilizers, cattle manure, pig and poultry were supplied for better growth, as well as function of nutrient source made an interaction under shade of anthurium. That's why NPK and biofertilizer raised the plant height netlon shade compare to the consistent of cattle manure provided better results in plant height under natural tree shade.

According to Assis *et al.* (2011) evaluated the adaptation of anthurium cultivars as cut flowers in a subtropical area in north of Paraná State. The Apalai, Ianomami, Kinã, nK 102, Parakanã, Rubi, and Terena cultivars were cultivated in a nursery under 80% shade. The number of leaves and inflorescences, floral stem length,

length and width of inflorescences, and spadix length were evaluated. In addition, 'Parakanã' produced 11 inflorescences per plant, whereas the other cultivars produced seven to nine inflorescences per plant. The number of leaves produced per plant was: 'Ianomami', 25; 'Parakanã', 20; 'Apalai' and 'Terena', 15; 'Kinã' and 'Rubi', 11; and 'nK 102', 9. The Apalai, nK 102, Parakanã, and Rubi cultivars are the most recommended as cut flowers as a cut flower in this region.

According to Takahashi *et al.* (2009) evaluated of five cultivars of A. andraeanum, as vessel plant, in the northern region of Paraná State. The study was conducted at greenhouse with 80% of shade given by a black colored polypropylene screen. The following parameters were evaluated monthly: length of the petiole, number of leafs, width and length of spathes and length of the floral axis. The evaluations showed increases on the height of plants and in the number of leaves during the three years of cultivation. The cultivars 'Parakanã', 'Rubi', 'Terena' and 'Apalai' are showed more vegetative development and their cultivation can be recommended as vessel plant in the north of Paraná State.

2.2 Effect of light intensity

According to Jeong *et al.* (2009), the Ornamental Plant Germplasm Center (OPGC) evaluated the response of begonia species to different shade levels and to identify light intensities that favor the production and maintenance of quality begonia plants in greenhouses during summer. Plants of six begonia species were grown in a greenhouse in Columbus, either in full light (1000-1800 $\mu mol.m^{-2}.s^{-1}$) or shade-cloth tents providing three levels of shade (41, 62, and 76% of full sunlight in the greenhouse). Each plant was evaluated for the number of inflorescences, leaf greenness (SPAD readings), shoot length, leaf area, and shoot dry weight. Shade percentage for optimal growth and quality of *B. albopicta, B. echinosepala var. elongatifolia*, *B. holtonis, B. foliosa var. miniata*, and *B. 'Fuchsifoliosa'* plants was 62% and 76% for *B. cucullata* var. cucullata plants.

According to Vendrame *et al.* (2004) observed the New guinea impatiens (Impatiens hawkeri) (NGI) `Pure Beauty Rose' (PBR) and `Paradise Orchid' (PO) in full sun, 55% shade, or 73% shade and fertilized with a controlled-release fertilizer (CRF) incorporated at rates of 2, 4, 6, 8, 12, 16, 20, 24, 28 and 32 lb/yard3 of growing media (1.2, 2.4, 3.6, 4.7, 7.1, 9.5, 11.9, 14.2, 16.6, and 19.0 $kg \cdot m^{-3}$). For both cultivars, light intensity and fertilization rate interactions were different for shoot dry weight and flower number, but there was no difference in plant quality rating between the light levels. Shoot dry weight of PBR plants grown in full sun increased as CRF rate increased to 28 $lb/yard^3$ and then decreased, while shoot dry weight of plants grown with 55% and 73% shade increased as CRF rate increased to 20 and 16 $lb/yard^3$, respectively, with no further increases. Flower number of PBR plants grown in full sun, 55% shade and 73% shade increased as CRF rate increased to 24 $lb/yard^3$ and then decreased. Flower number of plants grown in 55% and 73% shade increased as CRF rate increased to 24 $lb/yard^3$ and then decreased.

Hampson and Azarenko (1996) studied to quantify the effect of shade on reproduction and photosynthetic rate in this shade-tolerant species of hazelnut. Shade cloth was used to exclude 30%, 47%, 63%, 73%, or 92% of ambient sunlight from whole `Ennis' and `Barcelona' trees from mid-May until harvest. Photosynthetic light response curves were obtained for leaves that had developed in full sunlight, deep inside the canopy of unshaded trees, or in 92% shade. Light-saturated net photosynthetic rates were 12.0, 6.1, and 9.3 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of CO_2 and dark respiration rates were 2.0, 1.1, and 0.7 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of CO_2, respectively, for the three light regimes. Area per leaf increased by 49% and chlorophyll concentration (dry weight basis) by 157% as shading increased from 0% to 92%. Shading to 92% reduced specific leaf weight (68%), stomatal density (30%), light compensation point (69%), and dark respiration rate (63%) compared to controls.

Shade was more detrimental to yield than flowering: yield per tree dropped by >80%, from 2.9 to 3.4 kg in full sun to 0.6 to 0.9 kg in 92% shade. Shade reduced yield primarily by decreasing nut number and secondarily by decreasing nut size. The incidence of several kernel defects increased as shade increased.

Siemann and Rogers (2001) observed the invasive plants were often more vigorous in their introduced ranges than in their native ranges. Invasive genotypes, especially those from recently colonized areas, were larger than native genotypes and more likely to produce seeds but had lower quality, poorly defended leaves. Our results demonstrate significant post-invasion genetic differences in an invasive plant species. Post-introduction adaptation by introduced plants may contribute to their invasive success and make it difficult to predict problem species. On the other hand, light the matters discussed include the relative importance of light quality and the effects of the atmosphere on light. Low light increased the vegetative growth and flowering (Daubenmire, 1974).

Investigation was done on the performance of Anthurium andreanum plant as affected by shade conditions as well as the effects of different conventional nutrient sources. Anthuriums were planted on beds containing a media of cocopeat, charcoal and vermicompost. The beds were constructed under two shade conditions, that is, shade house (netlon with 75% shade) and natural tree shade. Different sources of nutrients such as NPK, biofertilizers, cattle manure, pig and poultry manure were supplemented. Better performance in terms of consistent growth as well as taller plant heights were obtained from those grown under shade house. Under shade house, NPK and biofertilizer application resulted in best performance of plant height whereas cattle manure treatment resulted in tallest average plant height under tree shade.

A study was accomplished by Hlatshwayo and Wahome (2010) for production of carnation among different shade treatments along with 0 (no shading/control), 20, 40, 60 and 70% shading. Investigation of this experiment was varied in different treatments for carnation variety including bedding and cut flower for world market. The result showed that 70% shade was highest plant followed by control treatment. Control was lowest plant height in shade influencing investigation. Nevertheless, other vegetative growth effect was influenced by 20% shading to using black net. Black nets used for shade that findings were promoted in flowering and flower quality in carnation flower.

An investigation was conducted by Bibi *et al.* (2012) in Khyber to get better tomato varieties along with their vegetative attributes in shade condition (55 percentage). Observation of growth performance of tomato cultivars, it showed that plant height was the maximum in partial shade at different month wise. But maximum number of branches in control and, number of flower cluster as well as flower per cluster was also higher in control. Incase of this situation, partial shading and control treatments significantly interacted with each other. These interactions evaluated the growth and yield character. As far as month wise treatment of partial shade and control, it was clear that April and May months was not significant followed by the June month for yield.

Thangam and Thamburaj (2008) determined six and fourteen cultivars for growth, yield and quality test under the 50 percent shade under the agro shade net. Comparison of partial shade and open field in summer season, highest plant was recorded through under the partial shade. However, this result also stimulated the higher amount dry matter under shade condition. Survey of tomato genotype that fruit weight was better in shade, despite of biochemical compound tomato juice showed significant variation under shade and open field at their TSS, acidity, ascorbic acid and PH analysis. Yield and quality test of tomato cultivars observed for understanding the shade affect compared to open field.

Medney *et al.* (2009) conducted two experiments in Nile Delta, for investigating of sweet peeper growth through the effect of black and white insect-proof nets as a greenhouse cover, replacing the polythene sheets and reduce the cost of covering material under greenhouses. In greenhouse, interior environment was rich due to intensive environment by reducing temperature, relative humidity, wind speed and light intensity to protect insect, pest and another unwanted object. The findings of the experiment suggested that black net shaded greenhouse focused significant yield, where as white net shaded greenhouse showed the highest plant height, number of leaves per plant, leaf area index and total yield. Results also observed in winter season that plastic house allowed the highest yield and depreciated to the half of making cost ratio as covering nets.

A research was carried out by Murakami *et al*. (1997), the effects of covering materials to control plant growth by changing the red/far-red photon flux ratio (600–700/700–800nm) (R/FR) of daylight. In terms of growth, development and yield of (*Cucumis sativus* L. cv. Hokushin) and tomatoes (*Lycopersicon esculentum* Mill. cv. Saturn) was scrutinized with hydroponics production under greenhouse, while interception of FR or R was selected. Investigation was reported that R-interception promoted the early flowering for tomato, where as FR interception reduced the shorter stem length and internodes both in tomato and cucumber at the initial stage. Nevertheless, vegetative growth was significantly provoked by longer length and internodes, even there was earlier fruit harvesting and yield of fruit in both species, and especially more in cucumber. The investigation was also suggested that covering materials showed differences R:FR ratio which controlling vegetative growth, reproductive growth and improving morphological characteristics.

A study was accomplished by two different shading materials having 55% and 75% shade density, other one control (no shade). In terms of shade intensity for transparent of FR radiation (700-800 nm wavelength) and partially filter the visible radiation (light i.e. 400-700 nm wavelength) including red light (600-700nm wavelength) had substantial effects on different tomato lines in between their two shades and control, and it reported at low FR and R radiation increases vegetative growth. Summery of this study revealed that maximum plant height, leaf number, days to flowering days to fruiting, and fruit yield per plot were reported in 75% shade. Minimum of results were control. It was also found that shades and tomato had significant interaction in plant height, not in all vegetative characters (Khattak *et al.,* 2007).

Maize (Zea mays) plants are commercially grown at larger and typical distance, such as their arrangement creates a heterogeneous environment in which the plants receive higher red light (R) to far-red light (FR) ratios from the inter row spaces. Proportion of leaves increased at interrow space in DK696 and Exp980 retained leaf orientation. For leaves of DK696 showed low R to FR ratio signals, where as whereas Exp980 leaves remained unaffected though plant height was best and tiller number was low at low R to FR ratio. In this circumstance, low R/FR-simulating reported that mutual shading on leaves along with both two rows, because phytochrome- mediated responses to determine the best yield at low R/FR ratio (Maddoni *et al.,* 2002).

Mclaren and Smith (1978) studied on the growth and development of Rumex obtusifolius seedlings under simulated shade conditions, who examined both light quality and quantity. Simulation of shade condition, petiole elongation observed in under shade condition where as lower dry matter, lower leaf area and lower net assimilation rates in same condition. Physiology of light quality increase the relative photon flux, on other hand, these photon flux stimulated far-red ratio which induced phytochrome photoequilibria.

Germana *et al.* (2001) accomplished a study in Eastern Sicily on bio-agronomic effects of shading, with black and white net, young 'Primosole' mandarin plants compared with unshaded trees as control. photosynthetically active radiation (PAR) at 70% approximately diminished under black net shade along with lower soil, air and leaf temperature, and CO2 exchange rate (CER) water use efficiency (WUE) and quantum yield (QY) also increased in this shade condition. Opposite effects was founded by the white net at 30%. This reporting also suggested that the physiological study of black and white net shade induced far red in between vegetative growth, larger and darker green leaves, control showed lower flower production yielded less fruits.

Cookson (2006) found the leaf area expansion is affected by environmental conditions because of differences in cell number and/or cell size. Increases in the DNA content (ploidy) of a cell by endoreduplication are related to its size. The shading and water deficit treatments reduced final leaf area and cell number. These differences in cell size were unrelated to alterations of the endocycle, which was reduced by these treatments. The genetic modification of the extent of endoreduplication altered leaf growth responses to shading and water deficit. An increase in the extent of endoreduplication in a leaf rendered it more sensitive to the shade treatment but less sensitive to water deficit conditions. The link between the control of whole organ and individual cell expansion under different environmental conditions was demonstrated by the correlation between the plasticity of cell size and the changes in the duration of leaf expansion.

According to Woo and Wetzstein (2008), morphological and histological evaluations of cultures during induction and development conducted using light microscopy of sectioned material and scanning electron micrography. Histology of explant tissues indicates that plant regeneration of Georgia plume occurs through a shoot organogenesis pathway that involves the formation of actively dividing meristematic regions originating in subepidermal cell layers that proliferate to form protuberances on the explant surface. Numerous well-formed shoot apical meristems with leaf primordia are produced, as well as fused shoot-like structures. Elongated, embryo-like structures had various degrees of shoot apex development. Evaluations of serial sections found that they lacked a defined root apex, and that basal portions were composed of parenchymatous files of cells with a broad point of attachment to the parent tissue.

A greenhouse experiment was carried out by Stuefer and Huber (1998) who studied that the effects of changes in light quality and quantity on the growth, morphology and development of two stoloniferous Potentilla species. Individual plants were subjected to three light treatments: (1) full daylight (control); and two shade treatments, in which (2) light quantity (photon flux density) and (3) light spectral quality (red/far-red ratio) were changed independently. Natural shade comprises two basically different features, a reduction in light quantity (amount of radiation) and changes in the spectral light quality. Morphological parameters, biomass and clonal offspring production were measured at the end of the experiment. Morphological traits such as petiole length, leaf blade characteristics and investment patterns into spacers showed high degrees of shade-induced plasticity in both species. Light quality changes also positively affected biomass production via changes in leaf allocation.

Tsukaya *et al.* (2002) mentioned that shade-avoidance syndrome is characterized by the formation of elongated petioles and unexpanded leaf blades under low-intensity light. In this study, two-dimensional mutational analysis revealed that the gene for phytochrome B, PHYB, had opposing effects in the leaf petioles and leaf blades of Arabidopsis. Anatomical analysis revealed that the PHYB and ACL2 genes control the length of leaf petioles exclusively via control of the length of individual cells, while the GAI, GA1 and ROT3 genes appeared to control both the elongation and proliferation of petiole cells, in particular, under strong light.

According to Robson *et al.* (1993), the phytochrome-mediated shade avoidance syndrome have been measured in seedlings and mature plants of a wild-type and a hy3 mutant of Arabidopsis thaliana deficient in phytochrome B. Growth parameters were compared in plants grown in either white light (high red:far-red ratio) or white light plus added far-red (FR) light (low R:FR ratio). Wild-type Arabidopsis exhibited increased hypocotyl and petiole extension under a low, compared with a high, R:FR ratio. The hy3 mutant did not respond to low R:FR ratio by increase in hypocotyl or petiole length. Both leaf area and specific stem weight responses to low R:FR ratio also were unchanged in the ein mutant of *Brassica rapa*, known to be deficient in phytochrome B. The hypothesis is proposed that different phytochromes may be responsible for the regulation of extension growth and the regulation of lateral or radial expansion.

It was reported by Franklin and Whitelam (2005), phytochromes responses to the shade-avoidance plants. The regulation of shade-avoidance responses by endogenous and exogenous factors, and the molecular components involved in red to far-red ratio signal transduction. Especially, phytochrome-B is also regulation of shade-avoidance responses to petiole length. It was also found that increased cell number and cell length both contribute to shade induced elongation of petioles which enables stoloniferous plants to place their leaf lamina higher up in the canopy. Although petiole elongation is assumed to be beneficial, it may also imply costs in terms of decreased biomechanical stability.

Shade induced elongation changes the biomechanical properties of petioles and that the underlying mechanisms, cell division and cell elongation, differentially affect biomechanical properties. Hypothesis of this experiment also mentioned that shade induced changes of cell number and cell size differs among light environments (Huber *et al.*, 2008).

Weijschede *et al.* (2008) noticed in 34 genotypes of *Trifolium repens* under high light conditions and simulated canopy shade. Study aimed at quantifying the relative contributions of cell division and cell elongation to genotypic and plastic variation in petiole length of the stoloniferous herb T. repens from a mechanistic perspective, two developmental processes, cell division and cell elongation, are responsible for the length of a given petiole. Study also revealed a strong negative correlation between shade-induced changes in cell number and cell length: genotypes that responded to shading by increasing cell numbers hardly changed in cell length, and vice versa. Our results suggest that genotypic and phenotypic variation in petiole length results from a complex interplay between the developmental processes of cell elongation and cell division.

According to Chen *et al.* (1999) documented that how different cultivars perform interior condition. Anthurium cultivars, a true interior-flowering foliage plant, were evaluated in interior rooms under two light intensities: 16 µmol $m^{-2}S^{-1}$ (100 foot candles as low light) and 48 µmol $m^{-2}S^{-1}$ (300 foot candles as high light). Plant height and width, total number of buds, open flowers, new and senesced leaves were measured. Results showed that the monthly average numbers of new leaves produced from 1.2 to 5.4 under low light and flower also produce monthly.

Kriebitzsh *et al.* (1997) found that leaf numbers in Intsia palembanica and Hopea odorata were higher in shade than in full light. Contrasting experiment was accomplished with Seedlings of two indigenous tree species. The light levels were dense shade (25% of full sunlight), moderate shade (42% of full light), partial shade (65% of full light). The full (100%) sunlight acted as the control. Measurements were made of assimilation rate, transpiration rate, stomatal conductance and water use efficiency. Finally the seedlings were harvested and total dry weight, leaf area, specific leaf area and shoot/root ratio (SIR) were estimated. In both species leaf number, leaf area, seedling height, shoot/root ratio and specific leaf areas were greater under shade treatments than in full sunlight. Leaf number was higher in moderate and dense shade than in full sunlight and partial shade for the two species. The mean leaf number was 28 for P. fulva in full sunlight and 37 in dense shade. Seedlings of W. ugandensis gave a mean leaf number of 21 in full sunlight and 29 under dense shade (Theuri, 1999).

Evans and Poorter (2001) observed in 10 dicotyledonous C_3 species grown in photon irradiances of 200 and 1000 µmol $m^{-2}s^{-1}$ Photosynthesis, SLA and nitrogen partitioning within leaves was determined in two irradiances stage. Photosynthetic rate per unit leaf area measured under the growth irradiance was, on average, three times higher for high-light-grown plants than for those grown under low light, and two times higher when measured near light saturation. However, light-saturated photosynthetic rate per unit leaf dry mass was unaltered by growth irradiance because low-light plants had double the SLA. Nitrogen concentrations per unit leaf mass were constant between the two light treatments, but plants grown in low light partitioned a larger fraction of leaf nitrogen into light harvesting. Daily photosynthesis per unit leaf dry mass under low-light conditions was much more responsive to changes in SLA than to nitrogen partitioning. Under high light, sensitivity to nitrogen partitioning increased, but changes in SLA were still more important in low light.

Tropical forests, was complex matrix of microsite which varied dramatically the light availability in single plants. Photosynthetic active radiation (PAR) range established in less than 10 µmol $m^{-2}s^{-1}$ in closed-canopy understory of mature forests along with well over 1000 µmol $m^{-2}s^{-1}$. Among the environmental factors that influence plant growth and survival in tropical forests, light availability was likely to be the resource most frequently limiting growth, survival, and reproduction. Photosynthetic utilization of light was therefore a major component of the regeneration responses to chlorophyll in forest species within the larger context of forest dynamics and succession (Chazdon *et al.*, 1996).

According to Poorter and Najel (2000), the biomass allocation is very important for plant and it depends on species, ontogeny and environment. Subdivision biomass has three component- leaves, stems and roots. According meta analysis, environmental variable also allocates total biomass. The responses to light, nutrients and water agree with the (qualitative) prediction of the 'functional equilibrium' which permits to produce more biomass allocation under low rate of environmental factor like as light. The effects of light also differ to make more carbon grain and carbon losses per unit area. At low irradiance, chlorophyll content allocates relative growth rate through biomass production, but only low nutrient availability are changes at shifts in biomass allocation.

It is found by Björkman (1981) that growth of autotrophic plants was directly and dramatically influenced by the intensity of light the driving force of photosynthesis - which provides nearly all of the carbon and chemical energy needed for plant growth. Moreover, light intensity (quantum flux density) is perhaps the most conspicuous environmental variable with which plants must cope. Contrasting terrestrial habitats may differ by at least two orders of magnitude in the daily quantum flux available for photosynthesis.

Sims and Pearcy (1989) observed that photosynthetic acclimation to 5 light environments ranging from 2 to 60% full sun was determined in *Alocasia* *macrorrhiza*, a shade tolerant species from tropical forest understories. *Colocasia esculenta* is a cultivated species which occurs naturally in open marshy areas. Photosynthetic capacities of both species increased nearly 3 fold with increased photon flux density (PFD) which allow to vegetative growth along with leaves number. In a given environment, however, photosynthetic capacities of C. esculenta were double those of *A. macrorrhiza*. Respiration rates and estimated biochemical capacities increased in parallel to photosynthetic capacity.

An investigation was accomplished by Poorter and Evans (1998) with ten dicotyledonous species for comparing specific leaf area:leaf dry mass. Hydropoincs culture was used in controlled environment at two irradiances (200 and 1000 μmol $m^{-2}s^{-1}$). CO_2 and irradiance response curves of photosynthesis were measured followed by analysis of the chlorophyll, Rubisco, nitrate and total nitrogen contents of the leaves. Under low irradiance leaf area has allocated a larger fraction of organic nitrogen to thylakoids and Rubisco which generates new leaves.

Hikosaka and Terashima (1995) observed that leaf nitrogen content is fixed in sun and shade irradiance, the amount of nitrogen allocated to Calvin cycle enzymes and electron carriers increases with increasing irradiance, while that allocated to chlorophyll-protein complexes increases with decreasing irradiance. At photosystem II increases the light harvesting capacity through chlorophyll-protien with decreasing irradiance, which partitioning into ribulose bisphosphate carboxylase promote to increase total leaf nitrogen content. Total amount of nitrogen content and photosynthetic components reveal to show adaptive significance in different environment and contribute to form new leaf through efficient use of photosynthesis.

Bradshaw (1965) revealed in evolutionary significance of plasticity that phenotypic plasticity is related to the physiological plasticity of plants which regulate by genetic make up. Besides, different environmental condition also control plant genetic plasticity as way of this regulation meristematic activity helps to form different plant organ like leaf number, bud scales etc.

According to Jurik *et al.* (1982) described in a single genotype of wild strawberry, Fragaria virgnuiana Duchesne, which were grown with or without fertilizer in high (406 microeinsteins per square meter per second) and low (80 microeinsteins per square meter per second) light. High-light leaves were thicker than low-light leaves and had greater development of the mesophyll. But mesophyll cell had high capacity of net CO_2 exchange rate in low light, photosynthesis and transpiration ratio also show boundary layer resistance and low light exchanges resistance for developing leaf size in between leaf and environment.

Sprent (1969) investigated the effects of gibberellic acid (GA) and N-dimethylaminosuccinamic acid (B-9) on leaf growth in several pea cultivars. The relationships between the growth of a leaf and its subtending internode were examined. A general inverse relationship between growth of the two organs was found in untreated and GA-treated plants, and in B-9-treated plants grown at low light intensities. At high light intensities B-9 was inhibitory to both leaf and internode growth.

Kasperbauer (1971) determined within and below a canopy of field-grown burley tobacco (*Nicotiana tabacum* L. cv. Burley 21). The leaves transmitted much far red light relative to red and blue light. Thus, shaded leaves received more far red light, relative to red and blue, than was received by unshaded leaves. The far red-irradiated plants developed longer internodes, were lighter green in color, and had thinner leaves than the red-irradiated ones. Plants of both treatments had the same number of leaves on the main axis. However, the red-irradiated plants developed branches from axils of lower leaves.

Das (2010) documented on masters research work that light intensity was significantly effect on different gerbera cultivars. Two factors were considered in experiment: Factor A: light intensity: L_0, control; L_1, 40% reduced sunlight; L_2, 60% reduced sunlight and Factor B: Variety: C1, White colored flower; C2, Pink colored flower; C3, Light pink colored flower; C4, Yellow Colored flower and C5, Orange colored flower. Maximum plant height, leaf length and breath as well as flower was found in 40% reduced light intensity. Experiment was concluded that orange colored flower and 40% reduced light gave best result.

According to Kurepin *et al.* (2007) investigated the effects of the two primary components of shade light, a reduced red to far-red (R/FR) ratio and low photosynthetically active radiation (PAR), on the elongation of the youngest internode of sunflower seedlings. Reducing the R/FR ratio (by enrichment with FR) gave significant increases in gibberellin A1 (GA1) and indole-3-acetic acid (IAA) contents in both internodes and leaves. By implication, then, the leaf may be the major source of GAs and IAA, at least, for the rapidly elongating internode. Several other hormones were also assessed in leaves for plants grown under varying R/FR ratios and PARs.

Hampson and Azarenko (1996) designed the effect of shade on reproduction and photosynthetic rate in this shade-tolerant species in hazelnut (*Corylus avellana* L.) to exclude 30%, 47%, 63%, 73%, or 92% of ambient sunlight. Photosynthetic light response curves were obtained for leaves that had developed in full sunlight, deep inside the canopy of unshaded trees, or in 92% shade. Area per leaf increased by 49% and chlorophyll concentration (dry weight basis) by 157% as shading increased from 0% to 92%. Shading to 92% reduced specific leaf weight (68%), stomatal density (30%), light compensation point (69%), and dark respiration rate

(63%) compared to controls. Shade was more detrimental to yield than flowering. The incidence of several kernel defects increased as shade increased. Therefore, hazelnut leaves showed considerable capacity to adapt structurally and functionally to shade, but improving light penetration into the canopy would probably increase orchard productivity.

Kebrom *et al.* (2006) documented that phytochrome B (phy B) mutant plants display constitutive shade avoidance responses, including increased plant height and enhanced apical dominance. Buds are formed in the leaf axils of phyB-1; however, they enter into dormancy soon after their formation. The dormant state of phyB-1 buds is confirmed by the high level of expression of the SbDRM1 gene. So, phyB mediates the growth of axillary shoots in response to light signals in part by regulating the mRNA abundance of SbTB1. These results are confirmed by sucker or axillary bud development with supplemental far-red light that induces shade avoidance responses. On the other hand, development of independent roots on suckers was found to be greater with increasing light intensity from 25% to 100•‹/o of full sunlight (Sandberg and Schneider, 1953).

Adventitious shoots (suckers) from the roots of aspen (Populus treuloides Michx.) originated from newly initiated meristems, preexisting primordial or suppressed buds. Development of suckers suppressed by auxin, as way to suckers was probably initiated by cytokinin, which synthesized in root tips. An elongation of sucker remains totally dependent upon root carbohydrate reserves until it emerges at the soil surface and can carry on photosynthesis (Schier and Johnston, 1971).

Halliday and Fankhauser (2003) observed environment and plants are translating by environmental light signals. The phytochrome family of photoreceptors monitors cues such as day length or vegetative shade condition. Evidence is monitoring that hormones control many of these light-mediated changes and initiate root sucker. Toward this goal, phytochrome and the hormonal networks and explores their interactions.

An adventitious rooting is a quantitative genetic trait regulated by both environmental and endogenous factors. Super root mutant spontaneously makes adventitious roots, and the argonaute1 (ago1) mutants, which unlike super root are barely able to form adventitious roots. The defect in adventitious rooting observed in ago1 correlated with light hypersensitivity and the deregulation of auxin homeostasis specifically in the apical part of the seedlings. The characterization of an ARF17-overexpressing line showed that it produced fewer adventitious roots than the wild type and retained a lower expression of GH3 genes. Thus, results suggest that ARF17 could be a major regulator of adventitious rooting in Arabidopsis (Sorin *et al.*, 2005).

A study was accomplished by Perez-Casal *et al.* (1986) in two plants, *Paspalum dilatatum* and *Lolium multiflorum* at different densities which half was taken in red light and far red light at their bases by means of light-emitting diodes. Density reduced both the proportion of incident radiation intercepted per plant and the red/far-red ratio of the light at plant bases. In both species the enrichment with red light did not increase tillering of isolated plants. That means, densities of plants achieved the number of tillers due to high far red:red ratio in isolated plants.

Tillering responded to light quality in different phenological stages in grass *Eragrostis curvula*. In vegetative plants, tillering rates were higher in the low R/FR treatment when the plants in the high R/FR regime reached the reproductive stage, while the plants in the low R/FR regime remained vegetative. That result showed that far red:red light ratio assists the growth of tiller or apical meristem from soil (Wan and Sosebee, 1998).

According to Stanton *et al.* (2010) evaluated two native shrubs, *Spiraea alba* and *Spiraea tomentosa* in the field under six different light treatments: full sun; morning full sun; afternoon full sun; and 40%, 60%, and 80% shade with four geographical seed sources of each species. Provenance differences did exist for height, flowering, and leaf greenness. Growth, flowering, and canopy density were greater in full sun and 40% shade and least in 80% shade. Both species responded to shade with increased individual leaf area and higher specific leaf area. Relative leaf greenness decreased with shade in *S. tomentosa* but did not change in *S. alba*. These species could survive in deep shade, but based on growth and appearance, they were best suited to full sun or light shade in the landscape.

According to Uddin *et al.* (2012) revealed the different light intensities on growth and flower characteristics of Gerbera. 40% reduced sunlight is more effective on growth and flower production than 60% reduced or in full sunlight. Tallest, thickest peduncles and bigger flowers found with 40% reduced sunlight in comparison to control. Highest leaf area and maximum number of flowers per plant are documented from 40% light intensity. This study also observed that excessive sun light causes crown death and sun burn of leaf in gerbera production.

Srikrishnah *et al.* (2012) was conducted to determine the effects of three shade levels on leaf area and biomass production of three varieties of dracaena (Dracaena sanderiana L.) varieties were arranged in 50%, 70% and 80% shade levels. Significant interaction was found in between varieties of dracaena and the shade levels on leaf area and biomass production. The plants grown at 50% and 70% shade levels produced the highest leaf area and biomass than plants subjected to 80% shade. Biomass production was in accordance with the trend of variances for leaf area. Therefore, in this study it was also revealed that, very low irradiance also showed the lowest leaf area, due to the reduction of photosynthesis.

Hlatshwayo and Wahome (2010) documented that carnation has commercial value which determining the influence of shading on growth, yield and quality of carnation cut flowers. Five treatments i.e., 0 (no shading/control), 20, 40, 60 and 70% shading was included. The highest plants were obtained from carnations provided with 70% shading. The highest number of leaves per plant, leaf area and number of lateral shoots per plant were observed in plants provided with shading. Shade increased the stem length.

Medany *et al.* (2009) investigated the effect of black and white insect-proof nets as a greenhouse cover. Sweet pepper (Capsicum annuum L) cv. Reda F1 seedlings were used. The obtained results indicate that black net greenhouse gave significantly the highest early yield, while white net greenhouse gave significantly the highest plant height, number of leaves per plant, leaf area index and total yield compared to the other greenhouses. In the winter season, the highest yield was obtained in the plastic house.

Scuderi *et al.* (2008) observed the effect of shading levels influenced on growth and quality of weeping fig and croton which has kept in pots under 50, 70 and 90% shading level. Tested species has showed different growth rates linked to plant morphology and leaf characteristics. Weeping fig is more significant than in croton plants. Increases net photosynthesis under low PAR conditions (45 µmol m-2s-1) produce more leaf area and color of leaf variation was positively influenced by the highest shading level.

The dynamics of leaf production, rosette expansion, individual leaf area expansion and epidermal cell expansion were observed in Arabidopsis thaliana plants grown under two light intensities- 75% in the light treatment and 68% in the shade. It is well known that plant aerial development is affected by light intensity in terms of flowering, the length of stems and petioles, and the final individual leaf area.

Shade-induced changes in leaf development occur on a dynamic basis from the whole rosette level to that of the cells. The whole rosette leaf expansion rate was reduced by shading and leaf area was also increased by shading (Cookson and Granier, 2006).

Reich *et al.* (1998) determined the growth, biomass partitioning and morphology of seedlings of nine near-boreal tree species in high- and low-light greenhouse environment in shade. The species differ widely in shade tolerance, seed size and leaf life span. In low light, all species allocated proportionally more biomass to stems and less to roots, but the same to foliage, compared with the high-light environment. At a common size, all species had finer leaf morphology (higher specific leaf area, SLA) but coarser root morphology (lower specific root length, SRL) in low than high light. From a whole plant perspective, all species enhanced leaf area per unit plant mass (leaf area ratio, LAR) in low light and root length per unit plant mass (root length ratio, RLR) in high light.

According to Li *et al.* (2014), *Aeschynanthus longicaulis*, an understory plants , adapted in low light. High irradiance plant had significantly thicker leaves with smaller leaf area, length, width, and perimeter compared to the plants grown under low irradiance. Leaf color turned yellowish and the total chlorophyll decreased in high light, but low irradiance was high cholorophyll. The anthocyanin content of high irradiance leaves was doubles that of those under low irradiance. The plants under high irradiance had significantly lower net photosynthesis rate A_{max} (5.69 µmol $m^{-2}s^{-1}$) and light saturation point (367 µmol $m^{-2}s^{-1}$) and higher light compensation point (21.9 µmol $m^{-2}s^{-1}$). Maximum PPFD of 650 µmol $m^{-2}s^{-1}$ led to significant light stress and photoinhibition of *A. longicaulis*.
Wiginton and McMillan (1979) documented that sea grasses from various depths were grown under three light conditions. Light absorption readings of extracted pigments showed that total chlorophyll content is inversely related to reduced light

over the range from 35 to 200 μM $m^{-2}s^{-1}$. The ratio of chlorophyll a to chlorophyll b decreases in response to reduced light. There is a correlation of the maximum depth of the St. Croix seagrasses and the ratio of chlorophyll a to chlorophyll b is high in the greatest depth range, to −42 m, has the lowest ratio. Although light quality and sea bottom characteristics may play roles in the ultimate depth to which a seagrass may occur, photon flux density is suggested as a primary environmental determinant.

Dennison and Alberte (1982) were examined the photosynthetic responses of the temperate seagrass, *Zostera marina* L., by manipulations of photon flux density. Light-saturated photosynthetic rates, dark respiration rates, leaf chlorophyll content, chlorophyll a/b, PSU density, leaf area, specific leaf area, leaf turnover times and leaf production rates were determined at the end of three sets of 1- to 2-week experiments. One of the measured parameters were affected by the photon flux density manipulations at the shallow station; however, at the deep station leaf production rates were significantly reduced under the shading screen and chlorophyll a/b ratios were higher at the reflector.

Six light regime were used as full sunlight (100%), 50, 30, 20, 15, and 5% of full light. Plants survived under all light treatments, even below minimum light requirements of related seagrasses. High light shows smaller shoot, higher biomass and productivity, lower leaf nitrogen content, less chlorophyll and more ultraviolet light absorbing pigment than plants grown under low light conditions (<20% light). Nutrient limitation in high light was inferred by a growth maximum at 50% light level, increased root biomass and lower leaf nitrogen content in high light treatments (Abal *et al.,* 1994).

Lichtenthaler *et al.* (1981) studied a comparative research on the photosynthetic CO2-fixation rates, chlorophyll content, chloroplast ultrastructure and other leaf characteristics in sun and shade leaves of beech (Fagus sylvatica) and in high-light and low-light seedlings. As way to this condition, the chloroplast ultrastructure of shade-type chloroplasts (shade leaves, LL-leaves) is not only characterized by a much higher number of thylakoids per granum and a higher stacking degree of thylakoids, but also by broader grana than in sun-type chloroplasts (sun leaves, HL-leaves). Shade leaves and LL-leaves exhibit a higher maximum chlorophyll fluorescence and it takes more time for the fluorescence to decline to the steady state than in sun and HL-leaves. Moreover, low light efficiently capture and use of light energy and improvement chlorophyll concentration and decrease chlorophyll a/b ratio (Taiz and Zeiger, 2006).

Armitage (1991) revealed that various field-grown specialty cut-flower species were subjected to full sun or 55% or 67% shade treatments for 2 to 3 years. Plants grown in shade had longer flower stems than those grown in ambient irradiance; however, yield (flower stems per plant) was species-dependent. However, yield of Echinops ritro L. 'Taplow Blue', a perennial species, was higher in 55% shade than in ambient irradiance. Plants grown under 67% shade had the longest stems starting 3 weeks after the beginning of harvest and the difference persisted for an additional 4 weeks regardless of planting material. A quadratic decline of yield in three of four cultivars of Zantedeschia Spreng occurred as shade increased, but yield was similar for ambient and 55% shade.

It is well documented by Downs *et al.* (1957) the internodes of young seedlings of Pinto bean (*Phaseolus vulgaris* L.), increased under fluorescent lights. Consequently, plants that received no daily high-energy period of light did not elongate in response to far-red treatments unless given sugar solution through their severed hypocotyls. Moreover, elongation of internodes resulted primarily from light action on the internode itself, (a) by promotion with the correct amount of far-red energy and (b) by inhibition with the correct amount of red after initial saturation with far red, due to the active pigment being in the far-red-absorbing form and the rest in the red-absorbing form.

Pasian and Lieth (1989) measured the leaf net photosynthesis rates in 'Cara Mia' rose (*Rosa hybrida* L.) with different range of irradiance levels. With the four leaf ages measured, a non-rectangular hyperbola with physiologically meaningful parameters was found to adequately represent the photosynthetically active radiation (PAR) responses. Maximal net photosynthetic rates exhibited a convex pattern with temperature with an optimum between 30 and 37C. The PAR compensation and saturation point both increased with temperature. Maximum efficiency for photosynthesis for all species obtained only at low irradiance levels, but not in bright long day sunlight (Salisbury and Ross, 1991).

A study was accomplished by Peeraz-Casal (1993) stated that supplementary far-red light (FR) and reproductive shoot growth were investigated in *Triticum aestivum* L. plants grown under natural radiation. In terms of FR had no obvious effects on the date of floral initiation, low number of leaves and the rate of leaf appearance. The first internode to elongate was longer, and the first visible node appeared earlier in FR-treated plants. Consequently, the responses to FR provided during twilight were fully reversed by red light, indicating the involvement of phytochrome. The potential significance of stem-growth responses mediated by phytochrome for wheat crop performance is discussed.

Light intensity is considered a limiting factor in greenhouse rose production. Shading treatments (0, 25, 50, and 65% shading) on quality and chlorophyll content of cut rose (Rosa hybrida cv. Avalanche), under greenhouse conditions. The experiment was showed that shading significantly affected on bud sprouting, flowering stem fresh and dry weight and flowering stem diameter, so that earliest bud sprouting, highest flowering stem, fresh and dry weight and flowering stem diameter were observed in no shading treatment. However, shading had no significant effect on flowering stem length and leaf area, but specific leaf area increased with shading percentage increment at 65% shade. Results of total chlorophyll content as well as chlorophyll a and b showed a decrement with increasing of shading percentage (Dolatkhahi *et al.* 2013).

Singh and Srivastava (2008) evaluated 8 gerbera varieties to assess growth, flowering and yield parameters under low cost polyhouse and shade net (50 per cent) conditions at Model Floriculture Centre, of the university during 2007. Low cost polyhouse planting recorded significantly better growth and yield to shade net planting. Flower stalk length, diameter of flower, stalk diameter and yield of flower per square meter were more under low cost polyhouse conditions as compared to shade net conditions. The duration of flower, days taken to first floret opening and vase life were also more under low cost polyhouse conditions as compared to shade net conditions.

Ten gerbera (*Gerbera hybrid* Hort.) cultivars, new to the Indian cut flower industry, were cultivated under shade house and evaluated over a two-year period. Variations in the number of days until first harvest, flower yield and quality were particularly significant, with the variety Savannah out performing the rest. Savannah produced more average total yield of flowers per plant (17.7) and per m2 (101.7), with Fusion yielding the lowest (10.5 flowers per plant and 51.9 per m2). Flower quality parameters (diameter, stalk length and girth, and length of ray florets) were also consistently higher for Savannah, although Goliath produced significantly more ray florets than any of the other cultivars under shade condition (Mantur and Patil, 2012).

According to Runkle and Heins (2006) studied the photoperiod, light intensity, and light quality influence plant growth and development from seed germination to flowering. Hence, light quality, or the spectral distribution of light, can influence internode length, flower initiation, and flower development. Besides, light intensity can be described by instantaneous or cumulative (daily light integral, or DLI) measurements and influences photosynthesis and thus parameters of plant quality, e.g., branching, stem thickness, flower number, and flower size. It can also influence time to flower initiation. It revealed the various properties of light influence morphogenesis and flowering, with an emphasis on horticultural flowering.

Kubota *et al.* (2000) documented the effects of red- and far-red-rich spectral (R- and FR-rich) treatments on the growth, development, and morphological changes of Petunia under diurnal temperature alternations (DIF). Herein, R-rich treatment inhibited elongation of the main stem compared to the control and the FR-rich treatments. Positive DIF (high day/low night temperatures, P-DIF) promoted and negative DIF inhibited the main stem elongation and flowering in contrast with the control, however, flowering was not delayed by the R-rich treatment. On the other hand, the R-rich treatment under P-DIF further improved plant morphology by increasing the size and number of lateral shoots, growth of lateral shoots, and the number of flowers on these lateral shoots. Therefore, one can produce compact Petunia plants, i.e. a short, main stem but more lateral shoots, without interrupting the flowering process by creating R-rich environment with a photo-selective plastic film.

A study performed by Rajapakse *et al.* (1999), in contrast of plastic film with quality light for inner and outer environment. Quality light also performs as signaling to the plants and it has some photoreceptor i.e. phytochrome which act as signal transducers to the plants in inner environment of green house. Moreover, physiological like as photosynthesis and morphological i.e. plant height, stem thickness, responses by photomorphogenesis in green house plants. Interestingly, photomorphogenesis provides the phytochorme and cryptochorme pigments receptor in light control environment.

Influence of shading and pot color revealed on shoot growth of strawberry firetails (*Acalypha hispaniolae* Urb.) under 60% and 80% shading. According the study green and white pot was used in hanging basket. After that plant grown in under 60% shading had 10% longer shoots, 10% more shoot dry weight and 23% longer flowers compared to the white pots in same condition. Contrast of 60% shading had 48% larger flowers than 80% shading (Sevenson, 1993).

Middleton (2001) mentioned the suitable ornamental plants for shady and low-light dependant on environments, but understanding the adaptations of plants that essentially follow strategies of optimum use of available energy and of conservation of energy. Herein, shade adaptations included not only thinner leaves with relatively higher chlorophyll content per unit leaf volume but also lens-shaped epidermal cells. It also focused incoming light into and within the mesophyll, where as red abaxial cell layer reflected outgoing light back into the mesophyll; the greater allocation of available energy to defence-mechanisms against herbivory and flowers and fruit that are inconspicuous in size and colour. Many of the adaptations of shade-plants were a pronounced effect on their ornamental value, and can therefore also determine their physiological adaptations and growth requirement is important in the successful cultivation and sustained utilization of ornamental shade-plants.

According to Wang *et al.* (2007), improve light compose in the solar greenhouse, it supplied red, blue, UV-A and UV-B light in the solar greenhouse. There after, the effect of the different light quality investigated on the growth characteristics of cucumber growing in solar greenhouse. Being under different light quality (red, blue) the plant height, flower sprout differentiation and photosynthesis rate improved greatly, as for UV-A and UV-B the growth rate was lower compared with the control. When under UV-B light the stoma conduction, transpiration rate, and the CO_2 concentration between cells as well as the photosynthesis rate were decreased, at the same time the germinating rate, fresh and dry weight, plant height and flower differentiate number all were restrained distinctly; while the stoma density and thickness of cucumber leaf were increased greatly.

An investigation was accomplished by Zhao *et al.* (2012), observed the effects of shade on plant growth and flower quality on peony flower. Compared with sun exposure, shade decreased P. lactiflora photosynthetic capacity; light saturation point (LSP) and light compensation point (LCP) and increased the apparent quantum yield (AQY), mainly due to declined stomatal conduction (Gs). These decreases caused the soluble sugar, soluble protein and malondialdehyde (MDA) contents to decline, which led to delayed initial flowering date, prolonged flowering time, reduced flower fresh weight, increased flower diameter and faded flower color. These results could provide us with a theoretical basis for further application of *P. lactiflora* in the greening of urban spaces and an understanding of the mechanisms behind the changes induced by shade.

An experiment was carried out by Singh *et al.* (2005) in CCS Haryana Agricultural University. One month old rooted cuttings of Vasantika cultivar were transplanted in the month of August in 50 and 75% shade intensities along with open field conditions. Maximum plant height (78.00 cm) and stalk length (13.74 cm) were observed in 75% shade intensity, whereas maximum number of flowers (47.82) and flower yield (68.91 g) per plant were recorded in 50% shade intensity.

According to Munir *et al.* (2004) has studied the different light intensities (29%, 43%, 54%, 60% or 68%) along with control (no shade) on the flowering time and plant quality. A hyperbolic relationship is observed to estimate the total number of flower buds and flowers on a curvilinear relationship with light intensities. Growth parameters is related to the plant characteristics such as plant height, leaf area and plant fresh weight were improved under shading treatments at the expense of flowering time and number of flower buds. However, both linear and polynomial models applied assumed that cultivar Chimes White was equally sensitive to light intensity throughout development.

The control of flowering of Blandfordia grandiflora (Liliaceae) has been studied in wild populations in the coast of eastern Australia, namely Williamtown, Port Macquarie, Wooli and in seedlings in the laboratory. These locations encompass much of the geographic range of the species. Plant growth (fresh weight gain) was fastest with a temperature of $27/22^0$ Cand 50% shade compared with 0, 10 or 70%. In the laboratory, floral initiation could be induced in 3-year-old plants by subjecting them to a cold period of 4-6 weeks at temperatures between 2 and 8^0 C. Treatment at 10 ^{0}C did not induce flowering. The percentage flowering could be increased to 80% with 3-year-old plant material. Thus, the induction of flowering seems to require that plants reach a suitable size and then be vernalised, and supports with the other summer flowering bulbs from the same family (Goodwin *et al.*, 1995).

Thomas (2006) was observed the light to regulate flowering through the three main variables of quality, quantity, and duration. Intensive molecular genetic and genomic studies with the model plant Arabidopsis was given considerable insight into the mechanisms involved, particularly with regard to quality and photoperiod. Phytochromes and cryptochromes, the main photomorphogenetic photoreceptors, act to entrain and interact with a circadian rhythm of constans (CO) expression leading to transcription of the mobile floral integrator, flowering locus T (FT). Light quantity effects were likely to be linked either directly or indirectly to patterns of assimilate partitioning and resource utilization within the plant and flowering.

According to Friend *et al.* (1963) studied the effect of light intensity (200 to 2500 ft-c) on floral initiation by energy in the far-red (730 mμ). The rate of formation of leaf primordia was accelerated by increases in light intensity to a greater extent than floral initiation, so that the final leaf number on the main shoot was greatest for the plants grown at high light intensities. Between 10 and 25 °C an increase in temperature had similar effects on the rate of formation of leaf primordia and floral initiation. The final leaf number was lower at 30 °C than at 25 °C because leaf primordium formation was retarded. After floral initiation, the growth of the apical meristem was most rapid at 30 °C and 2500 ft-c, resulting in the earliest heading and anthesis.

An investigation was conducted by Halliday *et al.,* (1994) to the involvement of phytochrome B in the early-flowering response of Arabidopsis thaliana L. seedlings to low red:far-red (R/FR) ratio light conditions. In contrast of the phytochrome B-deficient in hy3 or hy2, seedlings show only a slight acceleration of flowering in response to low R/FR ratio. This additive effect clearly indicates the involvement of one or more phytochrome species in addition to phytochrome B in the flowering response as well as indicating the presence of some functional phytochrome B in hy2 seedlings. Seedlings are homozygous for the hy3 mutation and one of the fca, fwa, or co late-flowering mutations display a pronounced early-flowering response to low R/FR ratio. Thus, placing the hy^3 or hy^2 mutations into a late-flowering background has the effect of uncovering a flowering response to low R/FR ratio. Thus, the observed flowering responses to low R/FR ratio in phytochrome B-deficient mutants can be attributed to the action of at least one other phytochrome species.

Mayoli *et al.* (2009) conducted to determine the relationships between GA_3 and shade of ranunculus cutflower in relation to light intensity (LI). The fixed factors were four GA_3 levels (0, 100, 500, 1500 mg/L) and three shade levels (0%, 40% and 80% shade). Tuberous roots were soaked in the respective GA_3 solutions for 10 minutes followed by planting under the shaded plots. The relationship of time to flower formation with LI was negative linear in season 1 and positive linear in season 2. The relationships of flower stem length with LI and air temperature (AT) were negative linear. The relationships of flower buds per stem, flower stem diameter, flower head diameter and tuberous root fresh weight with either LI or AT were negative quadratic. Therefore, shade modifies both LI and temperature that then interact in influencing growth of GA3-treated ranunculus. About 40000 lux LI and moderate seasonal temperature, both prevailing under 40% shade are ideal for best growth of ranunculus and has no effect to produce flowering.

Rice-Evans *et al.* (1997) showed that many dietary polyphenolic constituents derived from plants are more effective antioxidants in vitro than vitamins E or C, and thus might contribute significantly to the protective effects in vivo. It is now possible to establish the antioxidant activities of plant-derived flavonoids in the aqueous and lipophilic phases, and to assess the extent to which the total antioxidant potentials of wine and tea can be accounted for by the activities of individual polyphenols for post harvest quality.

Dodd *et al.* (1997) was assessed in Syzygium moorei, a species with dark green juvenile leaves, Syzygium corynanthum, which has light green juvenile leaves, and two species with pink-red juvenile leaves. When measured at midday, dark-adapted Fv/Fm ratios of juvenile leaves gradually increased in all species as percentage of full leaf expansion (% FLE) increased. Courses of Fv/Fm on sunny days showed greater diurnal photoinhibition in green juvenile (c. 50% FLE) leaves of S. moorei (24%) and S. corynanthum (36%) than in mature leaves of the previous flush in these species (< 10%). Re-positioning juvenile leaves of S. wilsonii horizontally increased diurnal photo inhibition. Exposure of leaves to a standard mild photoinhibitory light treatment (30 min at 1000 umol $m^{-2}s^{-1}$) showed that juvenile leaves of all species had a lower percentage of high energy state quenching (qE) and a higher percentage of photoinhibitory quenching (ql) than mature leaves.

Gould *et al.* (2000) ascribed to anthocyanins in leaves can be performed as effectively by a number of other compounds phytoprotective pigments. Pigment concentrations and their histological distribution were surveyed for a sample of 1000 leaves from a forest population of Quintinia serrata, which displays natural polymorphism in leaf color. Anthocyanins were observed in almost all combinations of every leaf tissue, but were most commonly located in the vacuoles of photosynthetic cells. Red leaves contained two anthocyanins (Cy-3-glc and Cy-3-gal), epicuticular flavones, epidermal flavonols, hydroxycinnamic acids, chlorophylls, and carotenoids. Green leaves lacked anthocyanins, but had otherwise similar pigment profiles. Anthocyanins are most abundant in older leaves on trees under canopies with south - facing gaps. These data indicate that anthocyanins are associated with photosynthesis, but do not serve an auxiliary phytoprotective role. They may serve to protect shade-adapted chloroplasts from brief exposure to high intensity sunflecks.

Leffring (1975) conducted to improve yield under the following conditions of an automatical shading system outside the glasshouse the light intensity inside was at least 45% of the available light. Under these conditions both growth rate and the formation of lateral shoots increased the average flower production from 5 till 12 flowers per plant per year. Moreover, improved selection seems possible because a variation of 0 – 49 flowers per plant per year was found in the plant material. Normally a variation exists from 0-7 flowers per plant per year.

CHAPTER III

MATERIALS AND METHODS

This chapter demonstrates information regarding methodology that was exploited in accomplishment of the experiment. It encompasses a brief outline of the location of the experiment, climate conditions and the materials used for the experiment. It also flourishes the treatments of the experiment, data collection and data analysis procedures along with a report of general practice adopted during the experiment.

3.1 Experimental site

The experiment was accomplished in partially control environment at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during the period from July 2012 to September 2013. Location of the site is $23^{0}74'$ N latitude and $90^{0}35'$ E longitudes with an elevation of 8 meter from the sea level in the Agro-Ecological Zone of Madhupur Tract (AEZ No. 28).

3.2 Climatic conditions

The experimental site was conducted in a subtropical monsoon climatic zone, characterized by a heavy rainfall during the months from April to September (*Kharif* season) and a scantly rainfall during the rest of the year (*Rabi* season). Plenty of sunshine and moderately low temperatures prevail during October to March (*Rabi* season), which is suitable for anthurium (the test plant) growing in Bangladesh.

3.3 Plant materials

The anthurium plants were collected from a commercial nursery in July 2012 and then multiplied at SAU Horticultural farm and new plantlet were collected from their suckers.

3.4 Treatment

The experiment was carried out to detect the morpho-physiological activities of anthurium under shade conditions for both vegetative growth and flowering. There were two factors combination in this experiment. They were as follows :

Factor A: Verities

Five different varieties were used. These were –

i. Pink anthurium, V_1
ii. White pink anthurium, V_2
iii. White anthurium, V_3
iv. Light anthurium, V_4
v. Green red anthurium, V_5

Factor B: Light intensities

Three levels of light intensities were tested, as –

i. L_0- Light (100% light/ full sunlight)
ii. L_1- 40% reduced light (60% of the full sunlight)
iii. L_3- 60% reduced light (40% of the full sunlight)

Light intensity levels were maintained using black nylon (60 mesh) net (Black, 2003). The net was hanged out at 2.3 meters height with bamboo stick. A single layer net reduced 40% light intensity (approximately) and a double layer net was reduced (approximately) 60% light intensity. Light intensities were measured by a CEM DT-1301 Digital Lux and fc light meter (Shenzhen Everebest Manhinery Industry Co. Ltd., China).

3.5 Design and layout of the experiment

The experiment was carried out in splitplot design with four replications which comprise in 60 pots (Figure 1). A single plant was grown in a pot. The size of each pot was 25 cm (10 inches) in diameter and 20 cm (8 inches) in height.

3.6 Pot preparation

Earthen pots were filled up 5 days before planting. Pulverized coconut husk was mixed with small amount of soil (10:1) as growing media. Weeds and stubbles were completely removed and the soil was treated with lime and fungicide to keep the media free from pathogen.

3.7 Transplanting of plantlets

After preparation of the pots, 60 plantlets were assembled for transplanting. Anthurium plants were transplanted in the pot carefully, so that root and shoot crown were not damaged during transplanting.

3.8 Intercultural operations

Hand weeding was done in all pots as necessary. Old and diseased leaves were picked up from healthy plants every day when noticed. Watering was done at every alternate day. Every fortnight interval, anthurium were treated with ridomil @ 2g/L and Malathion @ 2g/L to control the pests and diseases at vegetative and flowering stages. In vegetative stage, Furadan 5G @ 3g/L was also applied to protect soil nematodes.

3.9 Flower harvesting

Flowers were harvested when the unfolding of the spathe was completed. It was harvested in the morning and was cut with long stalks of anthurium. The best time for harvest was when 1/3rd to 2/3rd of the true flowers on the spadix were open (Kamemoto, 1962). Slanting cut of flower was done with a sharp knife. The flowers were sorted out for grading from blemishes, black spot, discolored spathe, short stalk, as well as deformed shape, and on vase life.

3.10 Parameters studied

a) Vegetative characters

a. Plant height
b. Leaves palnt^{-1}
c. Suckers plant^{-1}
d. Length of petiole
e. Leaf length
f. Leaf breadth

b) Physiological characters

a. SPAD value
b. Leaf area

c) Flower characters

a. Stalk length
b. Stalk diameter
c. Spathe length
d. Spathe breadth
e. Spadix length
f. Spadix diameter
g. Candle position
h. Spathe angle
i. Vase life

d) Yield related

a. Flowers per plant

3.10.1 Plant height

Plant height was measured in centimeter (cm) through the measuring scale and data were taken at 20 days interval (Plate 2. a).

3.10.2 Length of petiole

Length of petiole was measured from the base of leaves. Data were taken at 20 days interval (Plate 2. a).

3.10.3 Leaves plant^{-1}

Leaves plant^{-1} were recorded at 20 days interval. Number of plant was not counted at 100 days after transplanting.

3.10.4 Leaf length

Length of leaf was counted from the base to the tip of leaf of fully opened leaves and expressed as centimeter (cm). Data were worked out up to 100 days after transplanting (Plate 2. a).

3.10.5 Leaf breadth

Breadth of leaves was measured at the center of leaf and expressed as centimeter (cm). Three open spread leaf in each plant were counted in every replication. Average data were worked out at 20 days interval (Plate 2. a).

3.10.6 Suckers plant^{-1}

Anthurium suckers grow from the base of the independent roots. The number of new sucker grown was counted in three plants of each replication.

3.10.7 Leaf area

Leaf area was recorded by CL-202 Leaf Area Meter, (USA) with non destructive method. Four mature leaves were used to determine mean value of leaf area. It was expressed in cm^2 and data were collected at three stages namely vegetative, reproductive and harvesting (Plate 2. d).

3.10.8 SPAD value

The mean of five readings from the portable chlorophyll meter (SPAD-502, Minolta, Japan) was obtained. The use of chlorophyll meter (SPAD) is non-destructive. Data were collected at three stages namely vegetative, reproductive and harvesting (Plate 2. e).

3.10.9 Flower Stalk length

The length of flower stalk was obtained from each flower. It was counted from the basement of emergence to the attachment of the spathe and recorded as centimeter. Data were worked out after flowering per plant and observed up to 100 days (Plate 2. a).

3.10.10 Flower stalk diameter

Diameters of flower stalk were measured using Digital Caliper-515 (DC-515) in millimeter (mm) (Plate 2. b).

3.10.11 Spathe length

Spathe length was measured from the base to tip of the spathe and recorded in centimeter.

3.10.12 Spathe breadth

A meter scale was used to record the breadth of spathe and conveyed in centimeter. Center of the spathe was worked out for spathe breadth.

3.10.13 Spadix length

The length of spadix was estimated from the base to tip of the spadix. Mean data were calculated in centimeter (cm).

3.10.14 Spadix width

The width of spadix was recorded using Digital Caliper-515 (DC-515) in millimeter (mm). The middle part of spadix was worked out (Plate 2. b).

3.10. 15 Candle position

Candle position is the orientation between spathe and spadix which was measured as an angle between the tip of spathe to the tip of spadix. It was recorded in degrees (^{0}). The data was recorded and average candle position was taken after blooming of flowers.

3.10.16 Spathe angle

Spathe angle is the placement between flower stalk and base of spathe which was recorded as an angle. Mean data was calculated as degree (^{0}) after flower blooming.

3.10.17 Vase life

Vase life of flowers was counted harvesting and kept under plastic bottles with the normal tap water. Daily observations were taken and the data was recorded in terms of number of days.

3.10.18 Flowers plant^{-1}

Number of flowers obtained per plant was recorded in each replication at the experiment duration.

3.11 Histological analysis

Five leaf petioles of anthurium grown under different light intensities were collected for histological studies. A 5 cm long and 4 mm diameter of petiole were taken from the midpoint with each petiole and fixed in neutral buffered formalin (NBF) for 24 h (Seago *et al.* 2000), then washed in abundant running water and dehydrated in a series of alcohol (10, 30, 50, 70, 90 and 100%) for 10 min at each concentration and embedded in a plastic petri dish. Then the petiole was cut in cross section by hand using steel blades. In order to make slides, sections were stained with 0.5% Toluidine blue color reagent for one minute. Then they were washed thoroughly in water. Finally, transverse sections were mounted between the slide and coverslip with 50% glycerin, and sealed with clear nail polish. Then the slides were observed under microscope attached to the image capture and photography system, and the corresponding micrometric scales were displayed (Plate 2. f).

3.12 Statistical analysis

Collected data were tabulated and analyzed in accordance with the objectives of the study using MSTAT-C computer package programme and difference between treatments was assessed by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1989).

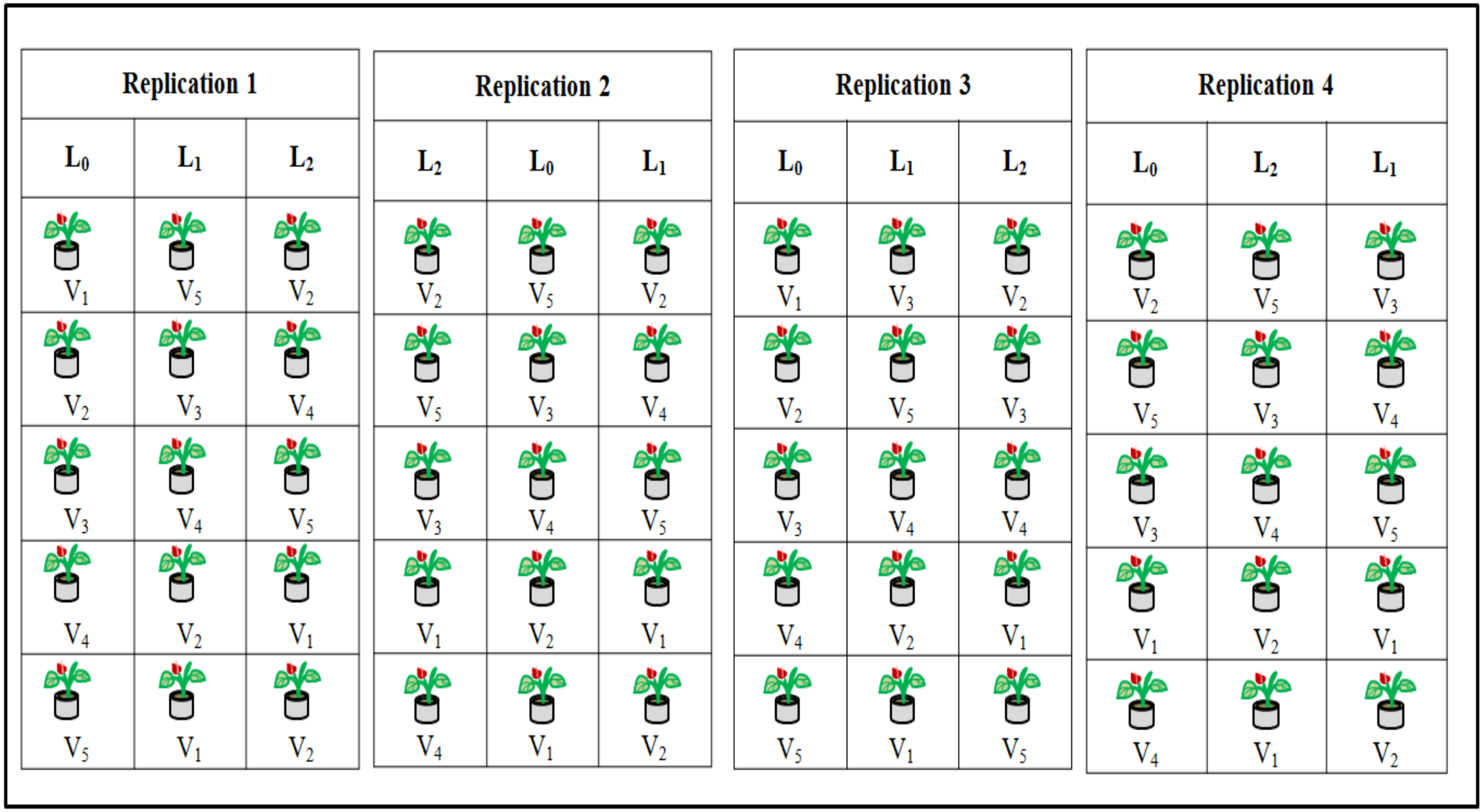
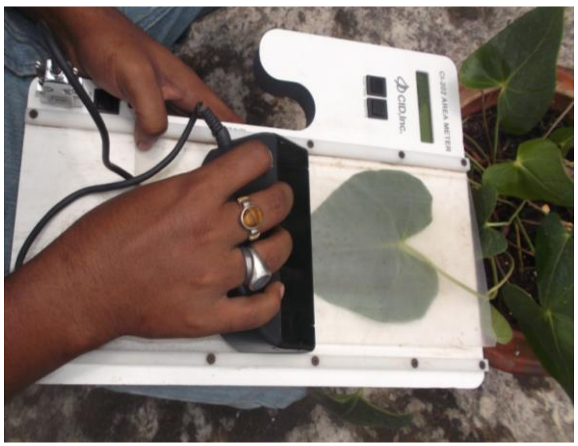
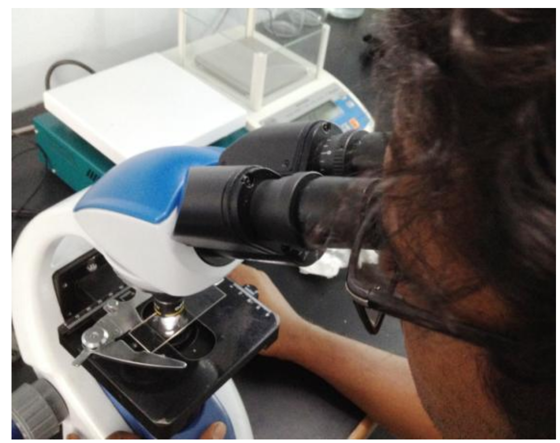


Fig. 1. Layout of the experiment

a. **b.** **c.**





d. **e.** **f.**

Plate. Photographs showing **a.** Measurement of plant height, petiole length, length and breadth of leaf using meter scale in cm; **b.** Flower stalk and spadix diameter measurement using Digital Caliper -515 (DC- 515) in millimeter (mm); **c.** Maintaining of light intensity using CEM DT- 1301 Digital Lux and fc light meter; **d.** Leaf area measurement using CL-202 Leaf Area Meter (USA) in cm^2; **e.** Measurement of chlorophyll using SPAD-502 chlorophyll Meter in (%); **f.** Histological observation of cell sizes under photonic microscope.

CHAPTER IV

RESULTS AND DISCUSSION

To pick out suitable Anthurium varieties for floricultural production, this piece of research work was accomplished under different light treatments in Bangladesh prospect. Contrasting attribute of varieties and reduced light treatments have been discussed and presented in this chapter. Illustration of this chapter has been focused by tables and figures to enhance their parallel and dissimilar character through discussion, comprehension and perceiving. Analysis of variance of all parameters has been shown in appendices.

Table 4.1 Morphological variations among the anthurium varieties laid out on the experiment (Photograph a-c)

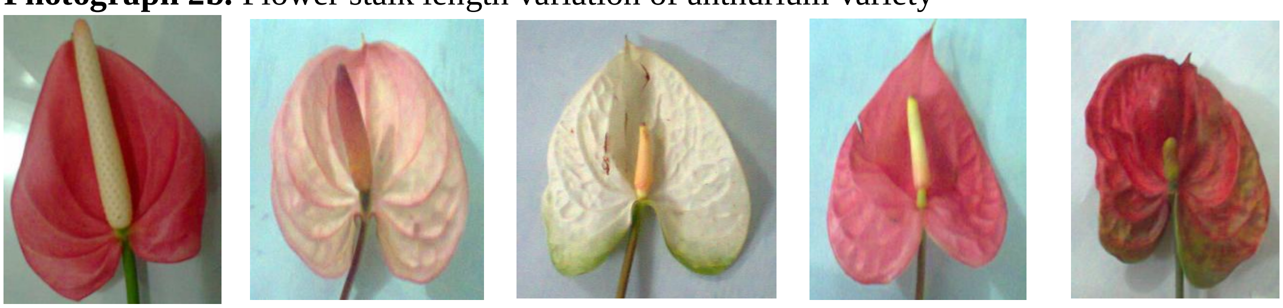
	Characteristics	Germplasms				
		V_1	V_2	V_3	V_4	V_5
1.	Plant foliage	High	Moderate	High	Moderate	Moderate
2.	Plant height	Tallest	Medium	Tallest	Medium	Shortest
3.	Petiole length	Longest	Longest	Medium	Medium	Smallest
4.	Leaf size	Large	Medium	Medium	Small	Small
5.	Leaf shape	Wide ovate	Ovate	Cordate	Hastate	Segitate
6.	Leaf margin	Wavy	Wavy	Continuous	Continuous	Continuous
7.	Sucker number	Maximum	Medium	Maximum	Medium	Minimum
8.	Time of flowering	Late	Early	Early	Late	Late
9.	Flower Stalk	Longest	Shortest	Moderate	Moderate	Shortest
10.	Spath size	Medium	Medium	Large	Medium	Medium
11.	Spadix size	Long	Medium	Medium	Medium	Short
12.	Spath color	Pinkish	Light pinkish	Whitish-green	Pinkish	Reddish-green
13.	Spadix color	Creamy	Pinkish	Light yellowish	Creamy	Greenish
14.	Flower vase life	Moderate	Shortest	Longest	Shortest	Shortest
15.	Flower number	Medium	Lower	Higher	Medium	Lower

V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium

V_1 V_2 V_3 V_4 V_5

Photograph 2a. Leaf variation of anthurium variety

Photograph 2b. Flower stalk length variation of anthurium variety



Photograph 2c. Spath and spadix color variation of anthurium variety

4.1 Plant height

Significant variation in plant height was observed with different varieties viz. V_1 (Pink anthurium), V_2 (White pink anthurium), V_3 (White anthurium), V_4 (Light pink anthurium) and V_5 (Green red anthurium) at different days after transplanting (Appendix I). Tallest plant height (34.4 cm) was obtained from V_1 (Pink anthurium) and shortest (20.9 cm) from V_5 (Figure 2). Genotype and environmental factors always steer their plant height even growth performance. Chen *et al.* (1999) obtained the performance of two anthurium cultivars on plant height under interior condition. Bibi *et al.* (2012) observed similar results on plant height of tomato cultivars under shade treatment.

Different light intensities were provoked variation in plant height among control (L_0), 40% reduced light (L_1) and 60% reduced light (L_2) treatments (Appendix I). Plant height was significantly different at 20, 40, 60, 80 and 100 days after transplanting (DAT). Highest plant height (29.4 cm) was observed in 60% reduced light (L_2) and Lowest (23.2 cm) was from control (L_0) (Figure 3). Due to the variation of treatments in Figure 3, it is clarified that plant height was slowly climbed in trend lines at mature stage. Khawlhring *et al.* (2012) stated that *Anthurium andranearum* in 75% shade house has significant relation for raising the plant height along with conventional nutrients.

Hlatshwayo and Wahome (2010) observed in carnation plant that shade treatment influenced the plant height. Partial shading enhance the plant height than full sunlight, which compared the plant growth under shade (Thangam and Thamburaj, 2008). Shade enhances the microclimate condition which reduces of temperature, relative humidity, wind speed and light intensity in shading area (Medany *et al.*, 2009), that means low light elevation of plant height. In case of 60% reduce light contributes to make the results in plant height of anthurium. Due to the reduction of red and far red light ratio present in low light and comparison of this low red and high far red light promotes the plant height (Murakami *et al.,* 1997). Germana *et al.* (2001) also supported the results that increasing of far red is responsible for vegetative growth. In terms of FR radiation in shade is 700-800 nm wavelength that partially filter in red light is 600-700 nm wavelength which reduces the R:FR ratio (Khattak *et al.,* 2007). Moreover, transverse section of same size petiole was also observed for identifying cell size in relation to different light intensity of anthurium plant height (Figure 1). In histological analysis, longer cell size was found in 60% reduced light than control and 40% reduced light. However, 40% reduced light also increased cell size. In case of diffused light, low red and far red light radiation is induced by the phytochrome, which stimulates the Indole acetic acid (IAA) and geibberiline in cell (Kurepin *et al.,* 2007), and ultimately plant height increase through cell size elongation (Maddonni *et al.,* 2002). Furthermore, cell size enlargement happen in low light condition due to the reduction of the number of endoreduplication cycles (Cookson, 2006). Finding of this investigation was also allowed by Mclaren and Smith (1978) and Woo and Wetzstein (2008).

Combinedly varieties and light intensities were significantly varied at combined effects with different DAT (Appendix I). Endpoint of the experiment, highest plant height (38.8 cm) was recorded at V_1L_2 as well as nearest highest (34.8 cm) was obtained $V_1L_1$from lowest, and lowest (17.8 cm) was obtained from V_5L_0 treatments (Table 1). Due to the genetical control, interaction of variety and shade treatments were statistically significance. Same results picked out in tomato cultivars and shade effects by Bibi *et al.* (2012), interaction of both treatments were significant. Khattak *et al.* (2007) also documented that interaction of tomato lines and light intensity was significance.

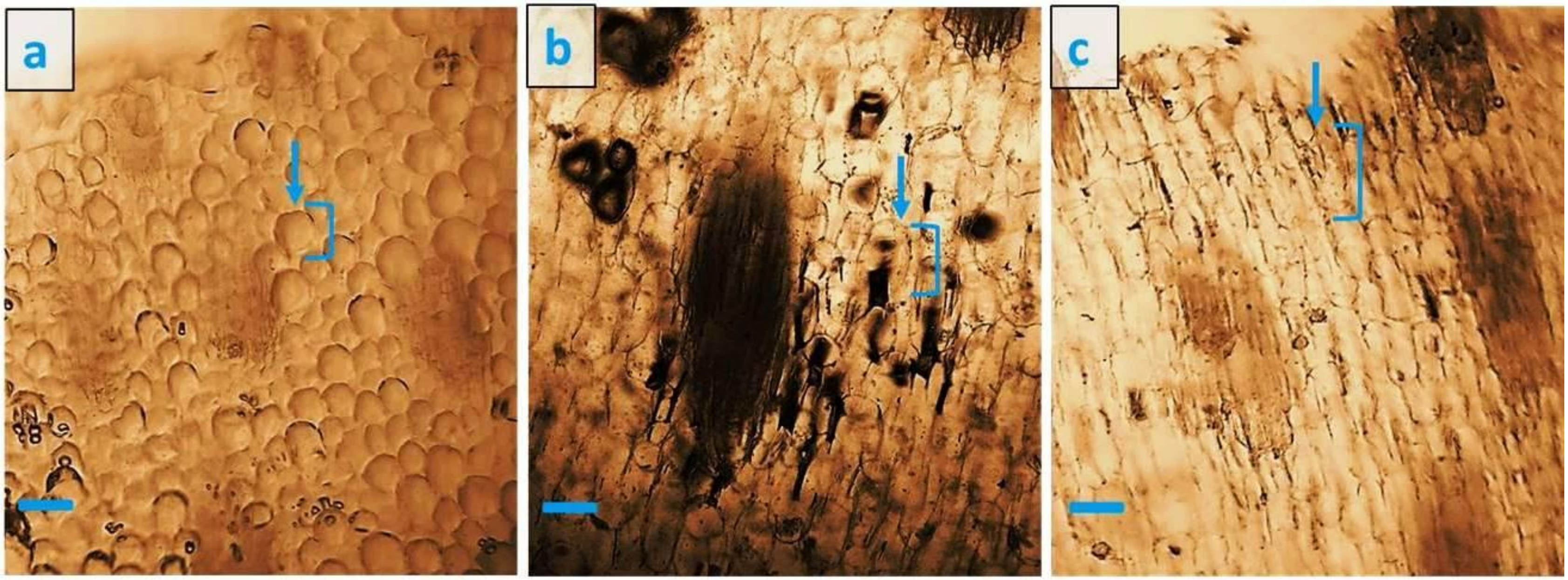


Figure 1. Photograph showing cross sectional view (Histological analysis) of petioles from Pink anthurium grown under (a) full sunlight, (b) 40% reduced light, and (c) 60% reduced light. Photographs were taken under a microscope with photographic outfit. Bar – 20µm in a, c and 25µm in b.

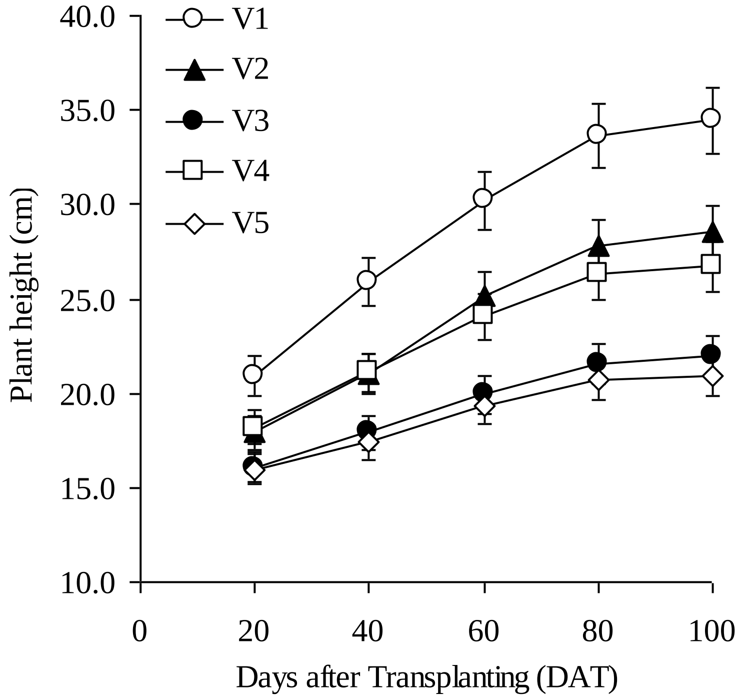


Figure 2. Plant height of anthurium varieties at different days after transplanting of anthurium (V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium)

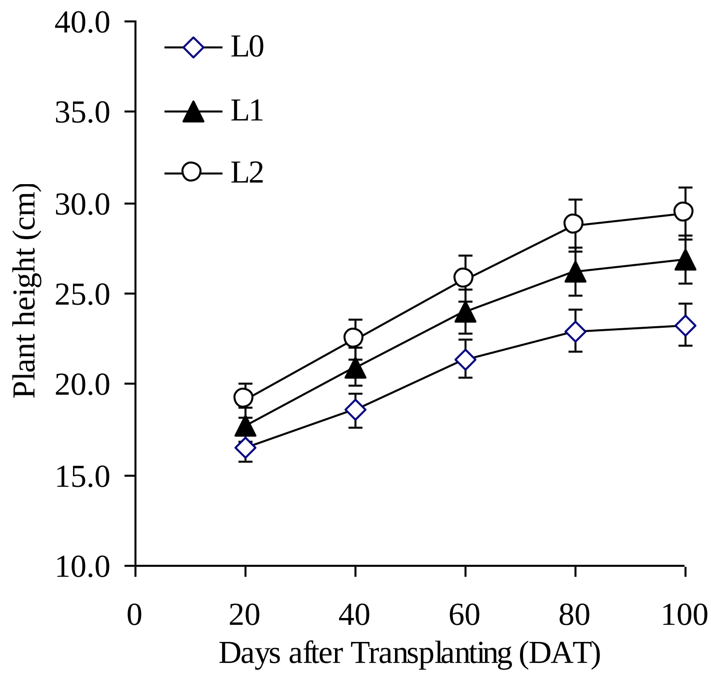


Figure 3. Plant height of anthurium under different light intensities at different days after transplanting (L_0, Control; L_1, 40% reduced light and L_2, 60% reduced light)

4.2 Petiole length

Variation in petiole length was statistically significant among different anthurium varieties at 20, 40, 60, 80 and 100 DAT (Appendix II). Highest petiole length (19.1 cm) was found from V_1 (Pink anthurium); where as lowest (13.6 cm) was from V_3 and V_4 (Figure 4). Results exhibited no significance difference in V_3 and V_5 at mature stage. Despite of this variation showed that petiole length was controlled by internal regulation of genetic characters. Kamemoto and Nakasone (1963) documented the 113 clones of anthurium and who recommended that the best thirteen cut variety depends on its long petiole length. Eliboxand and Umaharan (2012) also found the similar results on anthurium varieties.

Different light intensities were significantly sorted on petiole length of anthurium like control (L_0), 40% reduced light (L_1) and 60% reduced light (L_2) at 20, 40, 60, 80 and 100 DAT (Appendix II). Utmost petiole length (18.9 cm) was observed from 60% reduced light (L_2) and least (12.8 cm) were from control (L_0) (Figure 5). Variation of light quality and quantity induced the petiole length as well as growth and morphology of stolinfers Potentilla species increase in shade condition (Stuefer and Huber, 1998). Tsukaya *et al.* (2002) and Robson *et al.* (1993) mentioned on *Arabidopsis thaliana*, petiole length enhanced in low light condition.

However, to increase of petiole length is responsible on R:FR light in low light which relates the phytochrome (Tsukaya, 2002). In order to shade avoidance, phytochrome B promotes the petiole length in low light (Franklin and Whitelam, 2005 and Robson *et al.* 1993). As light pigment help to increase petiole length, morphological as well as physiological attribute change observed in plant cell. Under the low light cell number increase, as well as cell length promotes to increase the petiole length (Huber *et al.*, 2008 and Weijschede *et al.*, 2008).

Context of light intensities, 60% reduced light intensity promoted to petiole length among anthurium variety.

Interaction of variety and light intensities was statistically significant in combination effects of different varieties like V_1 (Pink anthurium), V_2 (White pink anthurium), V_3 (White anthurium), V_4 (Light pink anthurium) and V_5 (Green red anthurium) as well as light intensities viz. L_0 (Control), L_1 (40% reduced light) and L_2 (60% reduced light) at different days after transplanting (Appendix II). Higher petiole length (25.4 cm) was found from V_1L_2, as well as lower petiole length (11.2 cm) was showed from V_3L_0 behind the V_5L_0 (Table 1).

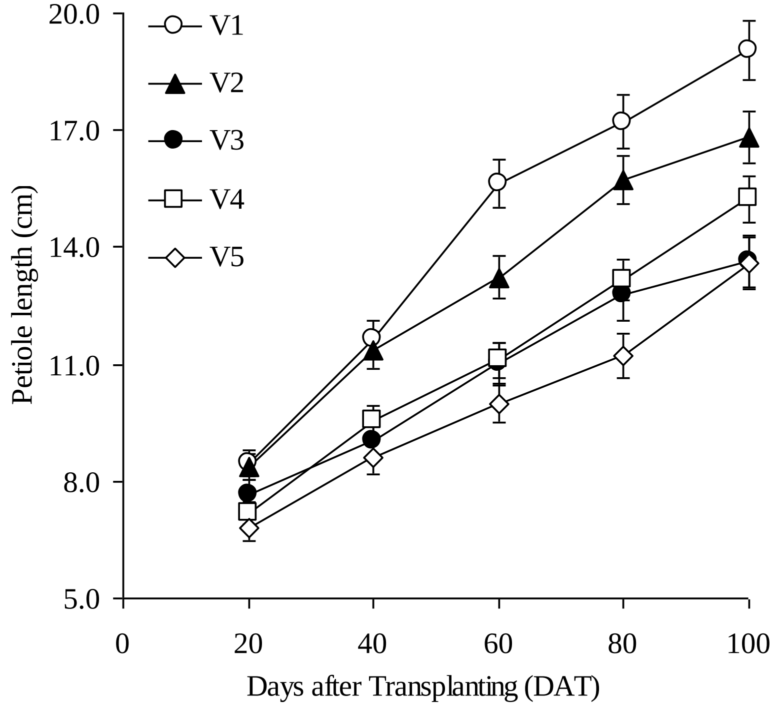


Figure 4. Petiole length of anthurium varieties at different days after transplanting of anthurium (V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium)

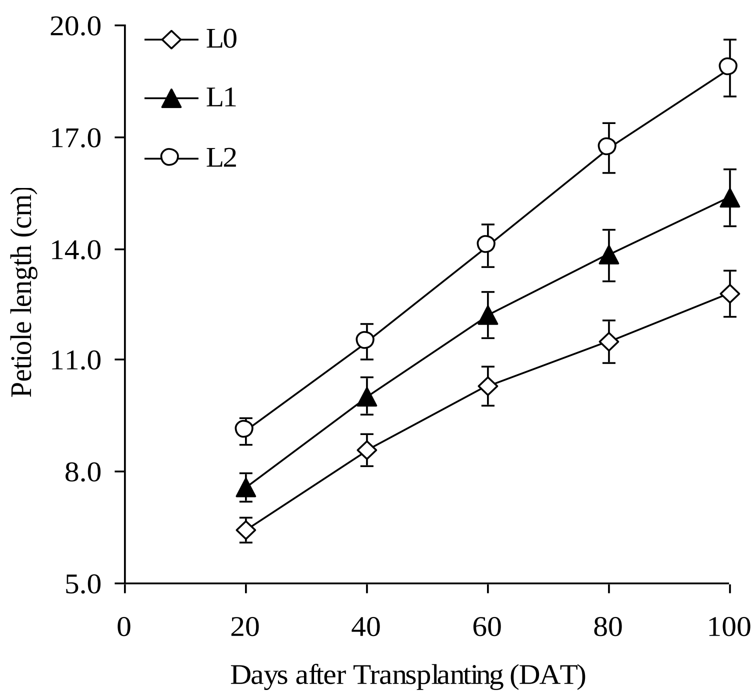


Figure 5. Petiole length of anthurium under different light intensities at different days after transplanting (L_0, Control; L_1, 40% reduced light and L_2, 60% reduced light)

4.3 Leaves plant^{-1}

Significant variation was found on number of leaves among the different varieties of anthurium at 20, 40, 60, 80 and 100 DAT (Appendix III). Maximum leaf number (17.7) was obtained from Pink anthurium (V_1) and minimum (13.7) was observed from V_5 (Figure 6). It was reported at final stage of experiment and observed the number of leaves increased in trend line at different DAT. Similar result was investigated in 21 potted anthurium under interior house by Henely and Robinson (1994).

The effects of light intensities in number of leaves were found statistically significant with different treatments like L_0 (Control), L_1 (40% reduced light) and L_2 (60% reduced light) at different DAT (Appendix III). Higher number of leaves (17.4) was observed from L_2 and lower (13.2) was from control (L_0) (Figure 7). Chen *et al.* (1999) observed the number of leaves (5.4) increased in potted anthurium with interior condition at low light. Supporting results also was obtained by Theuri (1999); Cookson and Granier (2006) and stated the number of leaf significantly increase at shading (65% shade) than full sunlight (Kriebitzsch *et al.*, 1997). On the other hand, light capturing ability is high in shade (Evans and Poorter, 2001) as well as combination of chlorophyll content is also high in low light compared to the sun (Chazdon *et al.*, 1996; Poorter and Nagel, 2000). As light capturing capacity is high in shade condition, and leaves show lower investment of growth biomass for respiration in low light condition (Björkman, 1981; Sims and Pearcy, 1989). For this situation, investment of Rubisco reflect the chlorophyll content and N ratio which promote to produce numbering of leaves (Hikosaka and Terashima, 1995; Poorter and Evans, 1998) and plasticity also shows genotype leaf function in different light irradiance for developing leaves (Bradshaw, 1965).

Number of leaves was significantly varied through combination effects of anthurium varieties (V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium) and light intensities (L_0, control; L_1, 40% reduced light and L_2, 60% reduced light) at different DAT (Appendices III). Highest number of leaves (21.0) was found from V_1L_2 where as lowest (11.9) was recorded from V_5L_0 at 100 days after transplanting (Table 1). Number of leaves was recorded at 100 DAT in table 1.

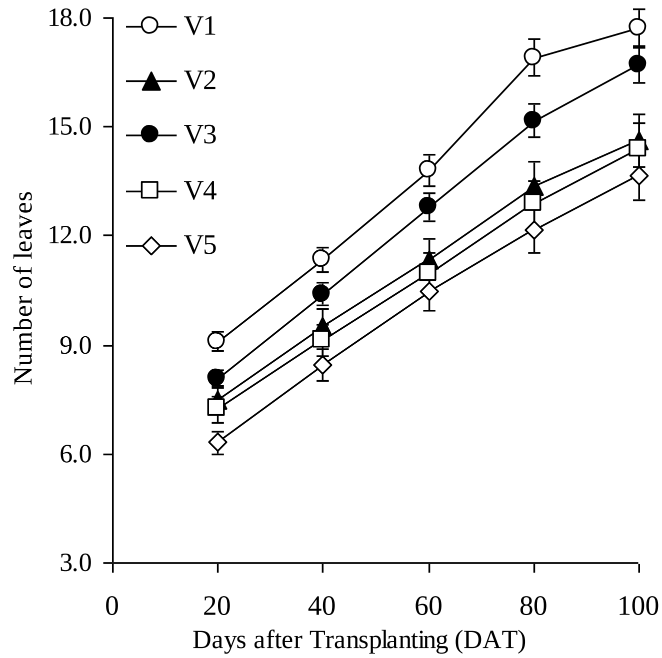


Figure 6. Number of leaves of anthurium varieties at different days after transplanting (V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium)

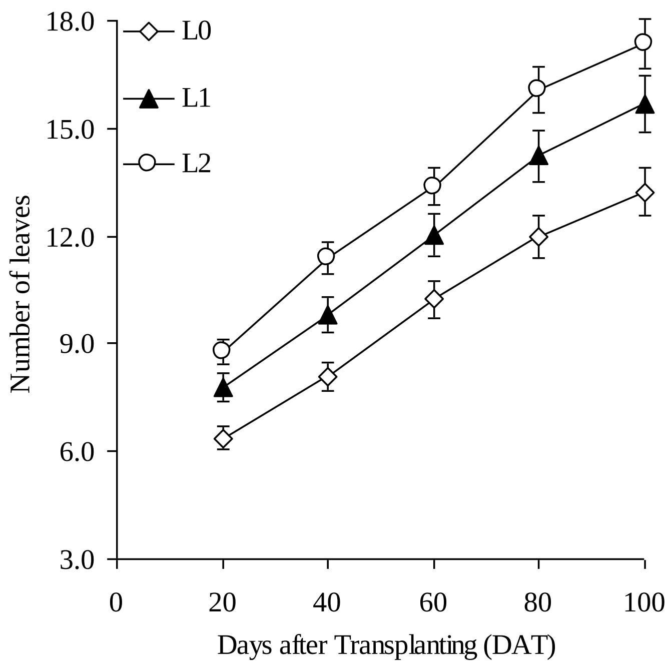


Figure 7. Number of leaves of anthurium under different light intensities at different days after transplanting (L_0, Control; L_1, 40% reduced light and L_2, 60% reduced light)

4.4 Leaf length

Leaf length showed significant variations with different anthurium varieties like V_1, V_2, V_3, V_4, and V_5 at different days after transplanting (Appendix IV). Highest leaf length (21.1 cm) was obtained from V_1 (Pink anthurium) and lowest (13.7) was from V_5 (Figure 8). Elibox and Umaharan (2012) observed the morpho-physiological study on leaf length in 82 accessions of anthurium.

Significant variation was exposed on length of leaf with different light intensities viz. L_0, L_1 and L_2 at different DAT (Appendix IV). Utmost result (19.3 cm) was remarked from L_2 and least leaf length (14.3 cm) was obtained from L_0 (Figure 9). Agasimani *et al.* (2011) documented the performance of anthurium under green house condition that length of leaf was significantly increased in shade condition. Relationship between gibberellic acid (GA) and N-dimethylaminosuccinamic acid (B-9) also promote leaf growth at low light intensity than direct sunlight (Sprent, 1969). On the other side, mesophyll cell have high capacity of net CO_2 exchange rate in low light (Jurik e*t al.,* 1982). Even, photosynthesis and transpiration ratio also show boundary layer resistance in low light which increases the size of leaf in relation to the environment (Jurik e*t al.,* 1982). Furthermore, biomass allocates more in shade leaves compared to the full sun light (Reich *et al.*, 1998). Nevertheless, shade leaves receives more far red light which evolves in shade, and far red have more blue light in relative to the red due to filtered light (Kasperbauer, 1971). For this case, differing red:far red ratio affects through photoreceptor phytochrome which is responsible for growth and can cause etiolation (increased internode length) (Kasperbauer, 1971) and leaf expansion.

Anthurium varieties and light intensities were significantly influenced on leaf length (cm) along with combination effects at different DAT (Appendices IV). V_1L_2 treatment reported the highest leaf length (24.7 cm), where as V_5L_0 was lowest (12.0 cm) (Table 1). Leaf length was counted at mature stage (Table 1).

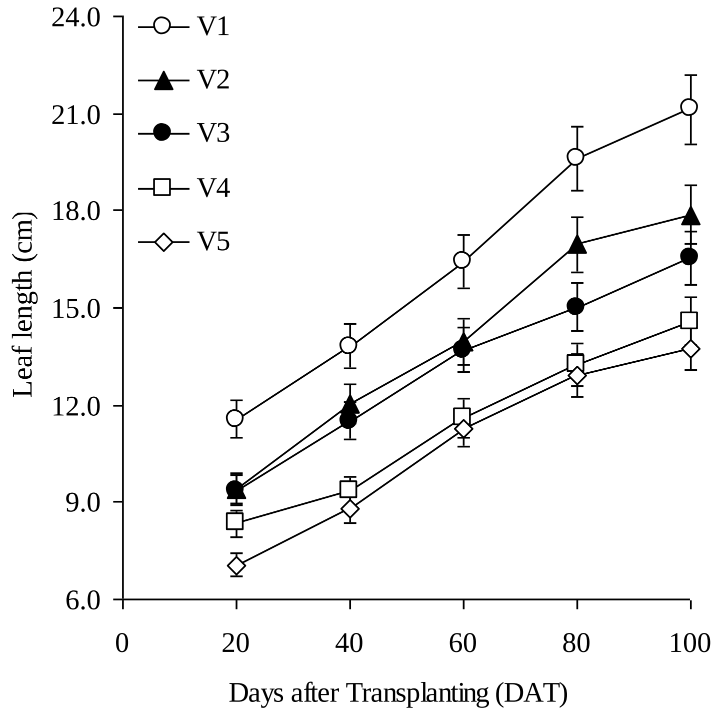


Figure 8. Leaf length of anthurium varieties at days after transplanting (V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium)

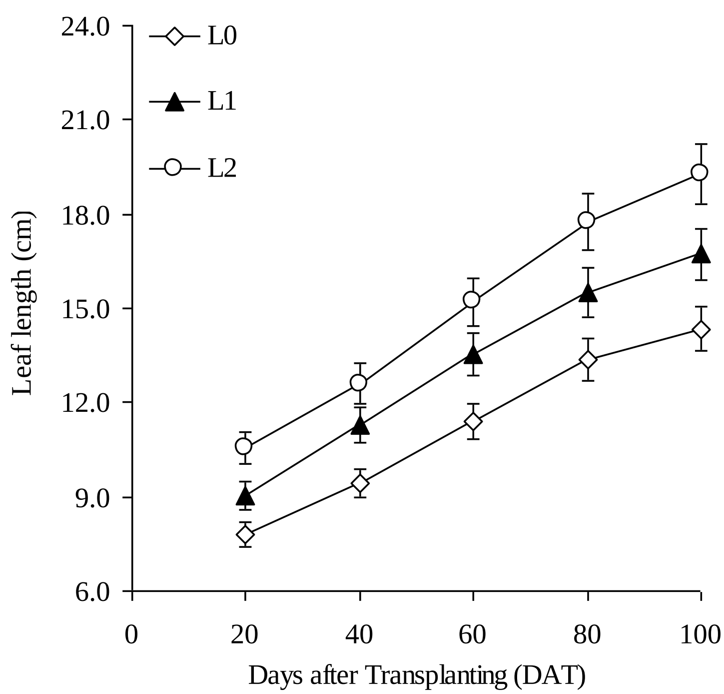


Figure 9. Leaf length of anthurium under different light intensities at different days after transplanting (L_0, Control; L_1, 40% reduced light and L_2, 60% reduced light)

4.5 Leaf breadth

Leaf breadth was significantly influenced with anthurium varieties viz. V_1, V_2, V_3, V_4, and V_5 at different days after transplanting (Appendix V). Maximum leaf breath (18.8 cm) was observed from V_1 and minimum (10.3 cm) was reported from V_5 (Figure 10). Henny (1999); Henny and Norman (2001) had reported similar results on leaf breath of anthuium cultivars who mentioned the difference in leaf breadth is a varietals trait as it is governed by the genetic make up and also due to ideal environmental conditions. Similar results also documented on 82 anthuirum accessions by Elibox and Umaharan (2012).

Light intensities were showed statistical variation on leaf breadth like L_0, Control; L_1, 40% reduced light and L_2, 60% reduced light along with 20, 40, 60, 80 and 100 DAT (Figure 15). Highest leaf breath (16.3 cm) was showed in L_2 and lowest (12.5 cm) from L_0 (Figure 11). Similar result was also documented by Das (2010) the effect of light intensity on potted gerbera and stated the leaf breadth influenced at low irradiance. In low light have low red:far red ratio (by enrichment of fr) and photosynthetically active radiation (PAR). Low red:far red ratio increases the GA and indole acetic acid (IAA) in shade condition because growth hormone and cytokinin significantly increase in high fr:r ratio in low light (Kurepin *et al.*, 2007). So, maximum size of leaf beathe is also considered to produce more photosynthetic activity in leaf. Hormones also help to develop leaves growth and photosynthetic activity under low red:far red ratio which is responsible elongates internode internode and leaves breadth (Kurepin *et al.*, 2007; Hampson and Azarenko, 1996).

In combination, statistical significance was observed on leaf breadth among varieties V_1, V_2, V_3, V_4 and V_5 as well as light treatments L_0, L_1, and L_2 at 20, 40, 60, 80 and 100 DAT respectively (Appendices V). Best combination effect (21.9

cm) was obtained from V_1L_2 and lowest (8.8 cm) was reported among V_5L_0 treatments (Table 1). Leaf breadth was recorded in mature stage (Table 1).

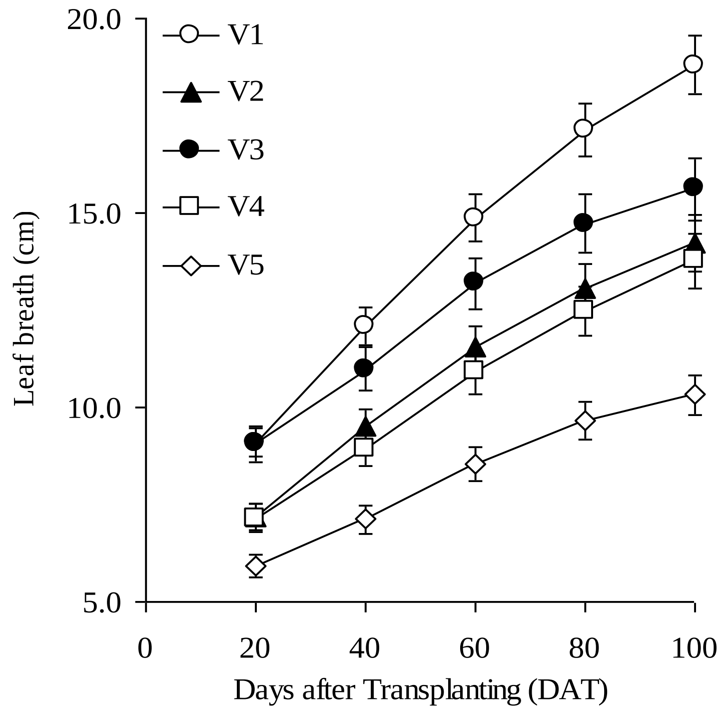


Figure 10. Leaf breadth of anthurium varieties at different days after transplanting (DAT) (V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium)

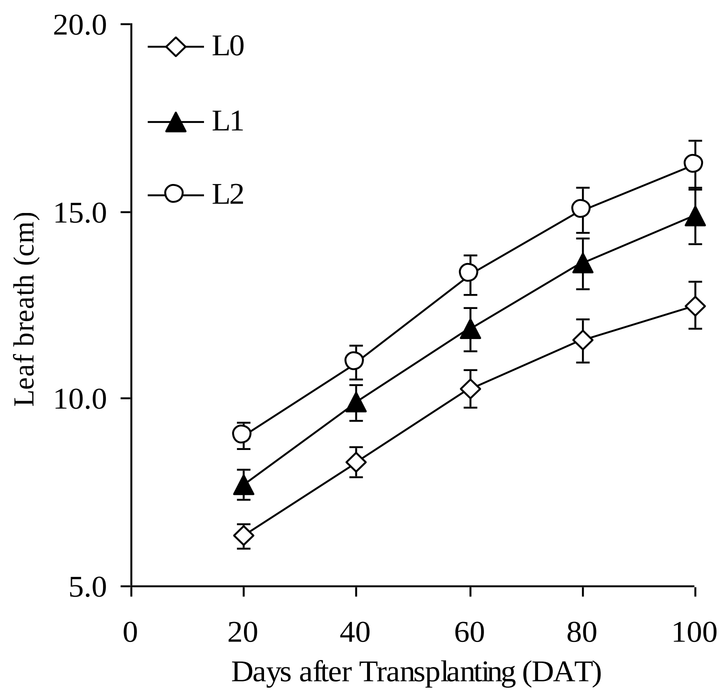


Figure 11. Leaf breadth of anthurium under different light intensities at different days after transplanting (DAT) (L_0, control; L_1, 40% reduced light and L_2, 60% reduced light)

Table 1. Combined effects of light intensities with varieties on growth related traits of different Anthurium[y]

Treatments[x]	Plant height at 100 DAT (cm)	Petiole length at 100 DAT (cm)	Number of leaves at 100 DAT	Leaf length at 100 DAT (cm)	Leaf breath at 100 DAT (cm)
$V_1 L_0$	29.9 cd	14.2 g	14.6 h	17.4 d	16.0 d
$V_1 L_1$	34.8 b	17.7 c	17.6 c	21.3 b	18.5 b
$V_1 L_2$	38.8 a	25.4 a	21.0 a	24.7 a	21.9 a
$V_2 L_0$	25.5 f	14.1 g	12.2 j	15.1 f	12.2 h
$V_2 L_1$	29.1 de	16.2 d	14.9 gh	17.5 d	14.7 ef
$V_2 L_2$	31.0 c	20.2 b	16.8 e	21.1 b	15.8 d
$V_3 L_0$	19.8 i	11.2 j	15.1 g	14.2 g	13.6 g
$V_3 L_1$	21.4 i	13.5 h	17.1 d	16.5 e	16.0 d
$V_3 L_2$	24.7 fg	16.3 d	18.1 b	18.9 c	17.2 c
$V_4 L_0$	23.3 gh	12.4 i	12.3 j	13.0 h	11.8 h
$V_4 L_1$	27.6 e	15.5 e	14.9 gh	14.3 g	14.5 f
$V_4 L_2$	29.3 cde	17.8 c	15.9 f	16.5 e	15.0 e
$V_5 L_0$	17.8 j	12.1 i	11.9 k	12.0 i	8.8 k
$V_5 L_1$	21.6 hi	14.0 g	14.0 i	14.1 g	10.7 j
$V_5 L_2$	23.4 gh	14.7 f	15.1 g	15.2 f	11.5 i
CV (%)	**5.0**	**2.3**	**1.4**	**1.4**	**1.8**
LSD (0.05)	**1.9**	**0.5**	**0.3**	**0.3**	**0.4**

[x]Variety- V_1, Pink anthurium; V_2,White pink anthurium; V_3, White pink; V_4, Light pink anthurium and V_5, Green red anthurium and Light- L_0, Control; L_1, 40% reduce and L_2, 60% reduce light.

[y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) are vary significantly as per 0.05 level of probability.

4.6 Suckers plant^{-1}

Sucker number was showed significant variation among the anthurium varieties (V_1, Pink anthurium; V_2, White pink anthuruim; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium) (Appendix VI). Maximum number of sucker (3.0) was obtained from V_3 (Pink anthurium) and minimum (1.0) was from V_5 (Table 2). These results are in line with that of Smitha (1999) in anthurium who stated the numbers of sucker are dependant on cultivar.

Number of sucker was significantly influenced by light intensities like L_0, Control; L_1, 40% reduced light and L_2, 60% reduced light (Appendices VI). Maximum number of sucker (3.1) was obtained from L_2 (60% reduced light) and minimum (1.0) was counted from L_0 (Table 3). Similar opinion was provided by Shiba and Niar (2007) on anthurium who stated that sucker number was increased with increasing performance in some anthurium varieties under green house. In terms of asexual propagation organ like as sucker, arise from root to soil in 25% to 100% light intensity and develop their individual root (Sandberg, 1951; Sandberg and Schneider, 1953).

Phytochrome B signaling is very important for development of sucker or axillary shoot from axillary bud meristem and it's controlled by internal and environmental response of plants (Kebrom *et al.*, 2006). But in previous, it was assumed that growth regulator e.g. cytokinin is responsible for stimulating rooting sucker (Schier, 1981). Recently it has been revealed that not only plant hormone but also light signaling are associated with development of adventitious root (Halliday and Fankhauser, 2003 and Sorin *et al.*, 2005). In low light, sucker rises from the root meristem and depends on quality light (far red:red). Moreover, far red:red light is very significant for shade avoidance plants which recognized with environmental signaling and development (Casal *et al.*, 1986; Wan and Sosebee, 1998), nevertheless phytochrome B mutant act as major role for sucker shoot development (Kebrom *et al.,* 2006). Interestingly, number of sucker increased with developing more anthurium foliage canopy. Apart, suckers reserves parental root carbohydrate into soil and produces photosynthates (Schier and Johnston, 1971). Both root carbohydrate and photosynthates are used for shoot elongation and new leaf flushes.

Combination effects of varieties and light intensities were demonstrated significant difference by both interactions (Appendices VI). Greater number of sucker (4.5) found from V_3L_2 and lower (0.6) was from V_2L_0 combinations (Table 4). Lower number of sucker was also observed among V_4L_0 and V_5L_0 combinations, which was not identical variation.

4.7 Leaf area

Leaf area was statistically significant on leaf area among the Anthurium germplasms viz. V_1, V_2, V_3, V_4 and V_5 at different stages after transplanting (Appendix VI). Highest leaf area (186.5 cm^2) was found from V_1 (Pink anthurium) and lowest (131.3 cm^2) from V_5 at harvest stage respectively (Figure 12). These results are in agreement with the reports of Femina *et al.* (2006) in anthurium. Nirmala (1996), Palai *et al.* (1999) and Srinivasa and Reddy (2005) showed similar results in case of leaf area. Herein, the environmental factors i.e. temperature, relative humidity and light intensity also determines the leaf area.

Light intensities in leaf area were showed significant variation with different treatments viz. L_0, L_1, and L_2 at different stage (Appendix VI). Maximum leaf area (172.6 cm^2) was found from L_2 (60% reduced light) and minimum (147.0 cm^2) from L_0 at harvesting stage respectively (Figure 13). Stanton *et al.* (2010) revealed the partial shade with increased individual leaf area and higher specific leaf area. Uddin *et al.* (2012) also documented that 40% reduced light intensity increased leaf area in gerbera. Accordance this result was also supported by on Long-stemmed basket plant, dracaena, carnation, sweet pepper, weeping fig and croton

(Li *et al.,* 2014; Srikrishnah *et al.,* 2012; Hlatshwayo and Wahome, 2010; Medany *et al.,* 2009; Scuderi *et al.,* 2008). Contrasting results of very low irradiance also shows that leaf area decreases due to the reduction of photosynthesis (Srikrishnah *et al.*, 2012).

Interestingly, plants receive solar radiation during the growth period and shade adapting plants get low light but it captures more light energy for photosynthesis (Cockshull *et al.,* 1992; Challa and Bakker, 1998), which increases leaf area (Reich *et al.,* 1998). In low light condition, plant cell expansion and division stimulate to increase individual leaf area in shade plants (Schoch, 1982) and shade induces leaf plasticity in leaves cell for expansion leaf area (Cookson and Granier, 2006). As leaf area produce more in shade condition, photosynthetic activity also increases in shade. As way the of phenotypical character changes with plant height, stem length and even yield in low light. Carbon partition shows source and sink relationship in yield attributes, that's more photosynthesis occur in shade due to leaf area. Finally, yield of flower and color variation increased in shade condition (Scuderi *et al.*, 2008). In contrast the flower stage of anthurium has the strongest sink in the plant which can accelerate the emergence of the next flower, but it reduces the leaf area (Dufour and Guerin, 2003). This result also suggested that indoor pot plants can be grown in order to enhance their vegetative adaptability to the interiors decoration.

Combination effect of anthurium varieties and different light intensities in leaf area showed significant variation Interactions in between of Anthurium varieties like as V_1, V_2, V_3, V_4, and V_5, and light intensities as for example, L_0, L_1, and L_2, were remarked statistical significance (Appendix VI). Variation of this significance was observed among highest leaf area (211.7 cm^2) in V_1L_2 and lowest (135.1 cm^2) in V_5L_0 (Table 4).

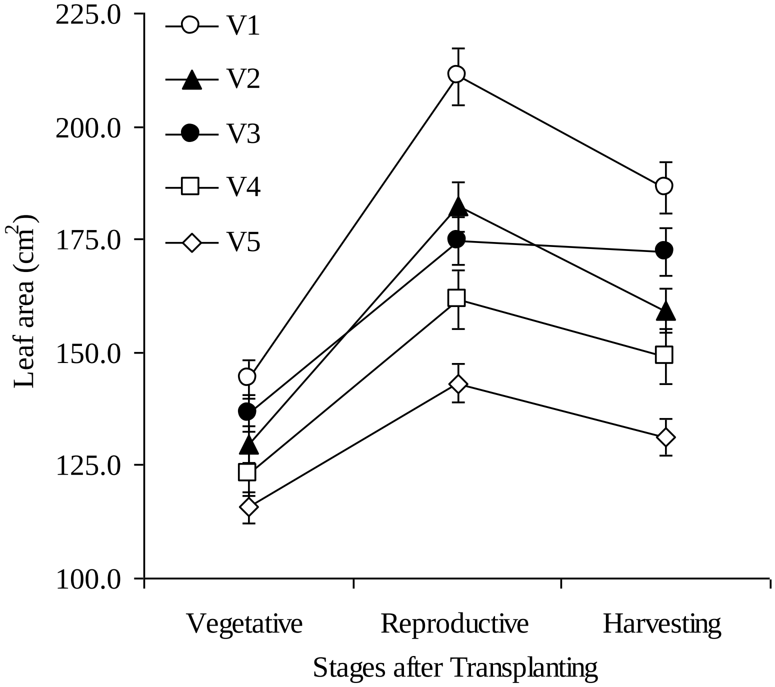


Figure 12. Leaf area of anthurium varieties at different stages after transplanting (V1, Pink anthurium; V2, White pink anthurium; V3, White anthurium; V4, Light pink anthurium and V5, Green red anthurium)

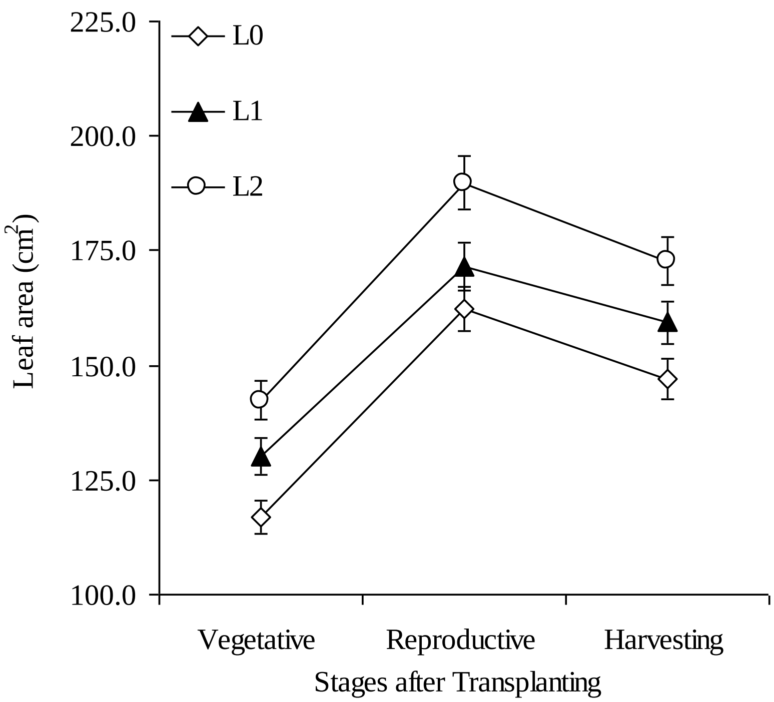


Figure 13. Leaf area of anthurium under different light intensities at different stages after transplanting of anthurium (L_0, Control; L_1, 40% reduced light and L_2, 60% reduced light)

4.8 SPAD value

Significant variation was founded on SPAD value with different varieties of anthurium viz. V_1 (Pink anthurium), V_2 (White pink anthurium), V_3 (White anthurium), V_4 (Light pink anthurium) and V_5 (Green red anthurium) at different stages after transplanting (Appendix VII). Maximum SPAD value (83.7%) was obtained from V_1 (Pink anthurium), where as minimum (26.0%) was reported from V_5 at harvest stage respectively (Figure 14).

SPAD value was showed the significant variation by different reduced light intensities viz. L_0, Control; L_1, 40% reduced light and L_2, 60% reduced light at different stages after transplanting (Appendix VII). Highest SPAD value (65.4) was obtained from L_2 and lowest (36.9) was reported form L_0 at harvest stage (Figure 15). Study submitted that 60% reduced light provided maximum SPAD value. Li *et al.* (2014) illustrated chlorophyll concentration increased at low irradiance of *Aeschynanthus longicaulis*. During the reducing light regimes under the shade, chlorophyll content increased with increase inverse ratio of chlorophyll a/b in seagrass (Wiginton and McMillan, 1979; Dennison and Alberte, 1982). As low light reduce photosynthetic activity (Taiz and Zeiger, 2006), but it does not change unit character of photosynthesis in low light. Even mesophyl cell of chloroplast is higher in low light and increases the ratio of chlorophyll per chloroplast in reduce light, which responses absorbance of ratio of UV light to chlorophyll in 50% reduced light (Abal *et al.,* 1994). This chloroplast is not only characterized higher number of thaylakoids per granum and higher stacking degree of thylakoids, but also broader granum in low light which promotes to increase chlorophyll flouroscence (Lichtenthaler *et al.,* 1981). Finally, low light efficiently captures more chlorophyll concentration through using light energy and decrease chlorophyll a/b ratio (Taiz and Zeiger, 2006). Ultimately, chlorophyll content does partitioning more carbon and induce flowering in low light or shade condition.

SPAD value was statistically significance combination with anthurium varieties along with the interaction of different light intensities (Appendix IX). Difference of this significance was observed among highest SPAD value (113.8) in V_1L_2 and lowest (24.1) in V_5L_0 (Table 4).

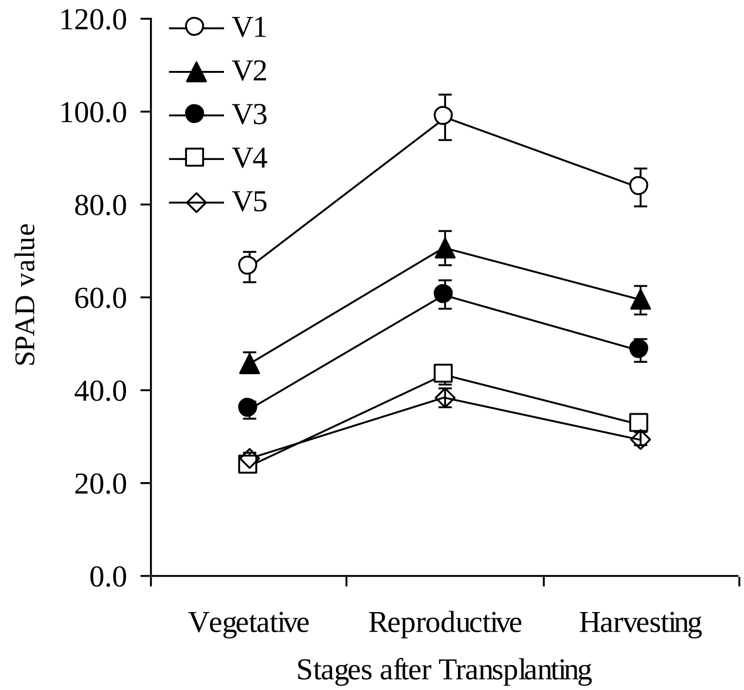


Figure 14. SPAD value of anthurium varieties at different stage after transplanting (V_1,Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium)

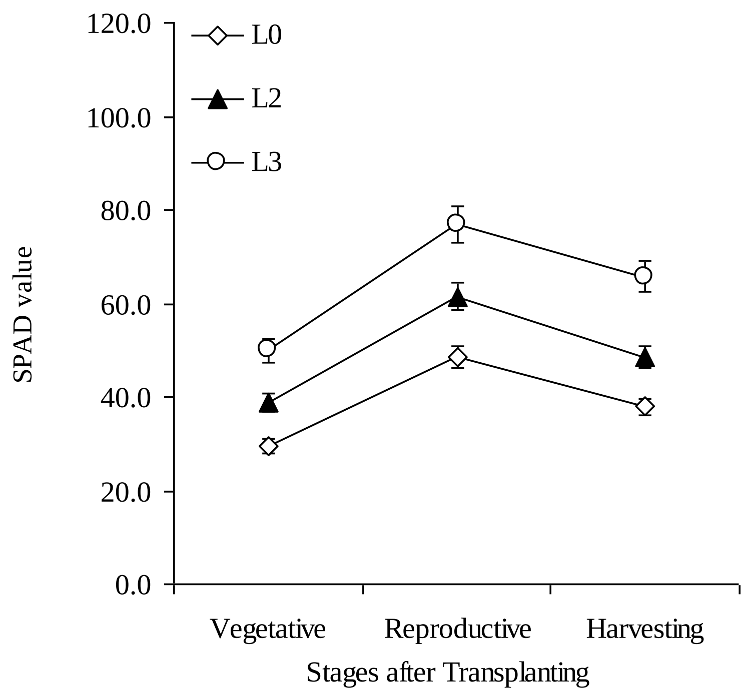


Figure 15. SPAD value of anthurium under different intensities at different stage after transplanting (L_0, Control; L_1, 40% reduced light and L_2, 60% reduced light)

4.9 Flower Stalk length

Anthurium Stalk length was documented statistical significance among anthurium different varieties like as V_1 (Pink anthurium), V_2 (White pink anthurium), V_3 (White anthurium), V_4 (Light pink anthurium) and V_5 (Green red anthurium) (Appendix VIII). Highest stalk length (29.1 cm) was obtained from V_1 (Pink anthurium); where as lowest (13.8 cm) from V_5 (Table 2). Accordance to range of Anthurium flower variation, it clarified the variation of stalk length (Agasimani *et al.* 2011).

Variability of stalk length was significantly varied with different light intensities viz. L_0 (Control), L_1 (40% reduced light) and L_2 (60% reduced light) (Appendix VIII and Figure 24). Longest stalk length (8.4 cm) was found from L_2 (60% reduced light); on the other hand minimum (3.7 cm) was in L_0 (Table 3). According to Mayoli *et al.* (2009), Ranunculus stalk length increased in shade condition. Least amount of light also increased flower stalk length in Anemone, Centaurea and Easter lily than full sunlight (Armitage, 1991 and Heins *et al.*, 1982).

Despite of low light condition, plant inter nodal length increases due to higher far red:red ratio (Downs *et al.,* 1957). That means photosynthetic assimilation rate (PAR) accumulates high percentage of photosynthesis in low irradiance compared to the high irradiance because light intensity influences the photosynthetic rate (Salisbury and Ross, 1991; Pasian and Lieth, 1989). Insufficient light also provide phytochrome for growth of stem length in wheat at low light environment (Perez-Casal, 1993). For adaptation of low light (60% reduced light) influences to promote stalk length relative to full sunlight. Length of flower stalk can promote the cut flower stalk which is related to flower post harvest life. Consequently, long stalk length retain high percentage of sucrose and it release slowly due to the long stalk, ultimately post harvest life enhancing.

Stalk length was differed significantly in Anthurium varieties viz. V_1 (Pink anthurium), V_2 (White pink anthurium), V_3 (White anthurium), V_4 (Light pink anthurium) and V_5 (Green red anthurium), where light intensities like as L_0 (Control), L_1 (40% reduced light) and L_2 (60% reduced light) were also showed the significant variation on stalk length (Appendix VIII). Highest result (32.1 cm) reported in V_1L_2 and lowest stalk length (10.4 cm) was recorded from V_5L_0 (Table 4). V_0L_0, V_3L_2 and V_4L_1 were found as non significant variation in combination and same result also showed in V_1L_1 and V_4L_2.

4.10 Flower stalk diameter

Stalk diameter was showed the significant variation in respect Anthurium varieties (Appendix VIII). Variation of stalk diameter was observed along with V_1, V_2, V_3, V_4 and V_5 varieties. Maximum stalk diameter (7.8 mm) was in V_1 (Germplasm-01) and minimum (4.0 mm) was in V_5 variety (Table 2).

Significant variation was found on flower stalk diameter with different light intensities viz. L_0 (Control), L_1 (40% reduced light) and L_2 (60% reduced light) (Appendix VIII). Maximum thickness of stalk (9.7 mm) was obtained from L_2 (60% reduced light), and minimum (5.3 mm) was counted from L_0 (Table 3). Dolatkhahi *et al.* (2013) illustrated similar results on gladiolus flower, who stated that flower stem diameter significantly increased in 65% shade condition. Similar agreement was also founded with Gerbera flower stalk diameter under shade condition by Singh and Srivastava (2008), Mantur and Patil (2012) and Mayoli *et al.* (2009).

Precisely, anthurium grows well in low light environment. This low light responses to far red:red ratio which expose to adapt shade avoidance environment. This environment helps to increased thickness of flower stalk through direct extension of flower development (Runkle and Heins, 2006 and Smith, 1994).

Nevertheless, low R/FR has no effect on low light environments, for this case it promotes the growth extension in shade tolerant plants (Runkle and Heins, 2006). Even, low light plants capture more lights due to use of plastic filter in leaves, and helps to increase the growth thickness of floriculture plants (Murakami *et al.*, 1996; Rajapakse *et al.*, 1999 and Kubota *et al.*, 2000).

Combined effect of stalk diameter was showed on the flower stalk diameter among different Anthurium varieties viz. V_1 (Pink anthurium), V_2 (White pink anthurium), V_3 (White anthurium), V_4 (Light pink anthurium) and V_5 (Green red anthurium) and light intensities like as L_0 (control), L_1 (40% reduced light) and L_2 (60% reduced light) (Appendices VIII). Utmost interaction of stalk diameter (11.3 mm) obtained from V_1L_2 treatments where as least interaction (2.8 mm) found in V_5L_0 treatments (Table 4).

Table 2. Variation of different anthurium varieties on growth and yield related traits of anthurium[y]

Variety[x]	No. of Sucker/plant	Flower stalk length (cm)	Flower stalk diameter (mm)
V_1	2.5 b	29.1 a	7.8 a
V_2	1.9 c	14.6 d	6.3 c
V_3	3.0 a	21.9 c	6.6 b
V_4	1.9 c	25.8 b	5.6 d
V_5	1.0 d	13.8 e	4.0 e
CV (%)	**13.9**	**4.2**	**5.9**
LSD (0.05)	**0.2**	**0.7**	**0.3**

[x]V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium

[y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) are vary significantly as 0.05 level of probability

Table 3. Variation of different light intensities on growth and yield related characteristics of anthurium[y]

Light	Sucker plant^{-1}	Flower stalk length (cm)	Flower stalk diameter (mm)
L_0	1.0 c	18.1 c	3.7 c
L_1	2.0 b	20.9 b	6.0 b
L_2	3.1 a	24.1 a	8.4 a
CV (%)	**13.9**	**4.2**	**5.9**
LSD (0.05)	**0.2**	**0.6**	**0.2**

[x] L_0, Control; L_1, 40% reduce light and L_2, 60% reduced light

[y] In a oclum means having similar letter (s) are statistically identical and those having dissimilar letter (s) are vary significantly as 0.05 level of probability

Table 4. Combined effects of different light intensities of different germplasms on growth and yield related traits of anthurium[y]

Treatments[x]	Sucker plant^{-1}		Leaf Area (cm^2) at harvesting stage		SPAD value		Flower stalk length (cm)		Flower stalk diameter (mm)	
$V_1 L_0$	1.3	g	169.1	cde	58.97	E	25.6	c	4.4	i
$V_1 L_1$	2.2	d	178.9	bc	78.28	b	29.6	b	7.8	d
$V_1 L_2$	4.0	b	211.7	a	113.8	a	32.1	a	11.3	a
$V_2 L_0$	0.6	h	146.9	gh	48.33	f	12.6	i	4.1	ij
$V_2 L_1$	2	de	163.4	de	57.9	e	14.5	h	6.0	g
$V_2 L_2$	3.1	c	167.4	cde	72.1	c	16.7	g	8.6	c
$V_3 L_0$	1.7	ef	159.8	def	36.25	h	18.6	f	3.7	j
$V_3 L_1$	2.8	c	171.6	cd	45.65	fg	21.4	e	6.6	f
$V_3 L_2$	4.5	a	185.3	b	63.33	d	25.8	c	9.5	b
$V_4 L_0$	0.8	h	139.4	hi	21.77	j	23.4	d	3.6	j
$V_4 L_1$	2.0	de	149.8	fgh	30.95	i	25.6	c	5.8	gh
$V_4 L_2$	2.8	c	158	efg	44.72	g	28.4	b	7.2	e
$V_5 L_0$	0.7	h	119.9	j	24.18	j	10.5	j	2.8	k
$V_5 L_1$	1.0	gh	133.1	i	29.75	i	13.6	hi	3.9	ij
$V_5 L_2$	1.3	fg	140.8	hi	34.63	h	17.3	fg	5.4	h
CV (%)	**13.9**		**5.5**		**4.3**		**4.2**		**5.9**	
LSD (0.05)	**0.4**		**12.53**		**3.0**		**1.3**		**0.5**	

[x]V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium and L_0, Control; L_1, 40% reduce light and L_2, 60% reduce light

[y] In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) are vary significantly as per 0.05 level of probability

4.11 Spathe length

It was influenced significantly on spathe length with different anthurium varieties (Appendix VIII). Higher spathe length (9.6 cm) was showed from V_3 (White anthurium) variety, on the other hand lower (6.9 cm) found in V_4 and V_5 (Table 5). There was no significance difference among V_1, V_4 and V_5 germplasms. V_3 variety exhibited the higher spathe length than other germplasms. Talia *et al.* (2003) found that 'Queen' had a bigger spathe.

Different light intensity was influenced the statistical significant difference on spath length (Appendix VIII). L_2 treatment carried out maximum (7.7 cm) spathe length and minimum (4.6 cm) was from L_0 (Table 6). Assis *et al.* (2011) observed spathe length increase significantly under the 80% shade condition of anthurium cultivars. Agreement of these results also evolved that 60% shade to 80% shade condition increased the size of strawberry flower and it was significance (Svenson, 1993).

As anthurium is epiphytes, lower light intensity can easily susceptible for their growth and flower development. Even shade tolerant plants can conserve light energy through their epidermal layer to messophyl cell and red abaxial layer (Middleton, 2001). Nevertheless, anthurium allocates more energy for defensive mechanism in low light to produce inconspicuous flower size and color in shade (Middleton, 2001). In low light condition, anthurium flower color becomes excellent and long lasting (Chen *et al.*, 1999). Interestingly, anthurium produces enlarge spathe due to obligate epiphytes behavior in low light intensity contrasting full sunlight (Middleton, 2001).

Observation of spathe length was examined statistically in respective anthurium varieties like as viz. V_1, V_2, V_3, V_4 and V_5 and light intensity as for example L_0, L_1 and L_2 (Appendix VIII). Find out this interaction also found higher spathe length

(12.2 cm) was obtained from V_3L_2 combination. On the other hand V_1L_0 and V_4L_0 combination were lower (5.1 cm) spathe length and it was non significance. Same results found among V_1L_0, V_4L_0 and V_5L_0 combination, and V_1L_2, V_4L_2, V_2L_2 and V_3L_1 also represented non significance variation (Table 7).

4.12 Spath breadth

Determination of spathe breadth was statistically influenced among different anthurium varieties (Appendix VIII). V_3 (White anthurium) was exhibited highest spathe breadth (8.3 cm) and lowest (5.1 cm) was obtained from V_1. There was no statistical significance difference between V_1 and V_4 germplasms (Table 5).

Light intensity was influenced on spathe breadth in respect of statistical variation (Appendix VIII). Maximum spath breath (7.7 cm) was revealed in L_2 (60% reduced light) and minimum (4.6 cm) was from L_0 (Table 6). Armitage (1991) showed that 55% shade increases the spathe width in contrast of annual and perennial cut flowers like as anthurium. Uddin *et al.* (2012) also showed gerbera flower diameter increased with 40% reduced light. Similar agreement was founded by Wang *et al.* (2007), Pathiratna and Perera (2005) and Zhao *et al.* (2012) in cucumber, cinnamon and peony of flower respectively. In contrast of sun and shade flowering plants, it is found that low rate of stomatal conduction lead to decrease the soluble sugar and soluble protein. Besides, these reduce components increase the flower diameter in reduced light condition (Zhao *et al.*, 2012). Interestingly, anthurium spathe size also increases the respiration rate of flower, and in particularly enhance the post harvest life of anthurium (Hew *et al.*, 1994).

Anthurium varieties and light intensities were statistically influenced with combination effect of spathe breadth (Appendix VIII). Higher Spathe breath (10.5 cm) was obtained from V_3L_2 combination, where as lower (3.8 cm) reported in

V_0L_0. Range of combination data was also showed non significance variation among V_1L_2, V_2L_2, V_3L_1 and V_4L_2 (Table 7).

4.13 Spadix length

Development of Anthurium was provoked statistical variation on spadix length in terms of different anthurium varieties (Appendix IX). Longest spadix length (5.4 cm) was obtained from V_1 (Pink anthurium) and smallest (2.0 cm) from V_5 (Table 5). Trend line of respective varieties showed up and down result of significant variation. Elibox and Umaharan (2008) documented that spadix length was higher in 26 anthurium varieties.

Length of spadix was significantly influenced with the different light intensities (Appendix IX). Highest spadix length (4.9 cm) obtained from 60% reduced light (L_2). On the other hand, lowest (2.6 cm) found in L_0 (Table 6). Takeshi *et al.* (2009) mentioned on anthurium that 80% shading enhanced the spadix length under greenhouse condition. Larger spadix was observed in 60% reduced light compare to 40% reduced light and this condition was suitable for growing and development of spathe and spadix of anthurium. According to Bushe *et al.* (2004) observed the shade clothe is favorable for anthurium flower quality, where as it decreases the quality of spathe and spadix quality through sun heat.

In terms of combination, spadix length exposed significant variation with anthurium varieties viz. V_1 (Pink anthurium), V_2 (White pink anthurium), V_3 (White anthurium), V_4 (Light pink anthurium) and V_5 (Green red anthuium) and light intensities viz. L_0 (Control), L_1 (40% reduced light), and L_2 (60% reduced light) (Appendix IX). Maximum spadix length (7.3 cm) was obtained from V_1L_2 combination, where as minimum (1.0 cm) was in V_5L_0. V_2L_0, V_3L_1, V_4L_0 and V_5L_2 observed the similar statistical difference, and accordance to statistical significance V_3L_0 and V_5L_1 was also parallel (Table 7).

4.14 Spadix breadth

Significant variation was statistically showed on spadix length among different anthurium varieties (Appendix IX). Regarding of variation spadix breadth was showed highest result (6.4 mm) in V_1 (Pink anthurium), considerably lowest spadix breadth (3.3 mm) obtained from V_5 (Table 5). This result also supported by Takahashi *et al.* (2009) on spadix breadth in anthurium flower.

Distinguished light intensity was statistically provoked on spadix breadth with respect of different light intensities (Appendix IX). For this variation, higher breadth of spadix (6.5 mm) was obtained from L_2 (60% reduced light), where as lower (2.9 mm) was reported from L_0 (Table 6). Similar agreement was reported by Assis *et al.* (2011) who mentioned that spadix breadth was increased by using 80% shade.

Combination effects of Anthurium varieties and light intensities were statistically observed significant on spadix breadth (Appendix IX). Higher combination of spadix breath (9.2 mm) was founded from V1L2 and lower (1.8 mm) was obtained from V5L0 combination (Table 7).

Table 5. Variation of different varieties on yield related traits of Anthurium[y]

Variety[x]	Spath Length (cm)	Spath breadth (cm)	Spadix length (cm)	Spadix breadth (mm)
V_1	7.0 c	5.1 d	5.4 a	6.4 a
V_2	7.2 b	6.5 b	3.8 c	4.7 c
V_3	9.5 a	8.3 a	3.0 d	3.7 d
V_4	6.9 c	5.2 d	4.3 b	5.1 b
V_5	6.9 c	5.7 c	2.0 e	3.3 e
CV (%)	**2.9**	**4.2**	**4.1**	**5.2**
LSD (0.05)	**0.2**	**0.2**	**0.1**	**0.2**

[x] V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium
[y] In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) are vary significantly as 0.05 level of probability

Table 6. Variation of different light intensities on yield related traits of Anthurium[y]

Light[x]	Spath Length (cm)	Spath breath (cm)	Spadix length (cm)	Spadix diameter (mm)
L_0	5.3 c	4.6 c	2.6 c	2.9 c
L_1	7.7 b	6.2 b	3.6 b	4.6 b
L_2	9.7 a	7.7 a	4.9 a	6.5 a
CV (%)	**2.9**	**4.2**	**4.1**	**5.2**
LSD (0.05)	**0.1**	**0.2**	**0.1**	**0.2**

[x]L_0, Control; L_1, 40% reduce light and L_2, 60% reduced light
[y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) are vary significantly as 0.05 level of probability

Table 7. Combined effects of varieties and light intensities on yield related traits of Anthurium[y]

Treatments[x]	Spath Length (cm)	Spath breath (cm)	Spadix length (cm)	Spadix diameter (mm)
$V_1 L_0$	5.1 i	3.8 j	3.9 f	4.0 fg
$V_1 L_1$	7.1 fg	5.1 gh	5.1 c	6.0 c
$V_1 L_2$	8.9 c	6.4 de	7.3 a	9.2 a
$V_2 L_0$	4.4 j	4.9 h	2.9 h	3.3 h
$V_2 L_1$	7.4 e	6.7 d	3.6 g	4.3 f
$V_2 L_2$	10.0 b	8 b	4.8 d	6.5 b
$V_3 L_0$	6.6 h	6.2 e	2.1 i	2.2 i
$V_3 L_1$	9.9 b	8.3 b	2.9 h	3.9 g
$V_3 L_2$	12.2 a	10.5 a	3.8 f	5.2 d
$V_4 L_0$	5.1 i	4.0 ij	3 h	3.4 h
$V_4 L_1$	6.8 gh	5.2 fg	4.4 e	5.2 d
$V_4 L_2$	8.9 c	6.5 de	5.4 b	6.7 b
$V_5 L_0$	5.3 i	4.3 i	1.0 j	1.8 j
$V_5 L_1$	7.2 ef	5.5 f	2.0 i	3.5 h
$V_5 L_2$	8.2 d	7.3 c	3.1 h	4.7 e
CV (%)	**2.9**	**4.2**	**4.1**	**5.2**
LSD (0.05)	**0.3**	**0.4**	**0.2**	**0.3**

[x]Variety viz. V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthuriuand Light intensity viz. L_0, Control; L_1, 40% reduce light and L_2, 60% reduce light

[y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) are vary significantly as per 0.05 level of probability

4.15 Candle position (Spathe)

Anthurium varieties were showed statistical variation on the candle position of anthurium (Appendix IX). Due to variation, highest candle position of spathe (148^0) was obtained from V_3 (White anthurium) and lowest (116.3^0) from V_5. There was no statistical difference among V_2 and V_4 varieties (Table 8).

Light intensities were also statistically demonstrated in candle position of spathe (Appendix IX). Utmost spathe candle position (142.1^0) was obtained from L_2 (60% reduced light) and least (130.2^0) was observed from L_0 (Table 9). Femina *et al.* (2006) found the similar results on the candle position of spathe of anthurium variety. Agreement of this result was also supported by Agasimani *et al.* (2011). In terms of anthurium flower candle is aesthetically important for color spathe. Spath candle also play significance role for consumer. As anthurium grow up well in shade condition. So, proper environment and good nursing is prerequisite for the quality of flower like as candle position. Interestingly, optimum shade of flower plant increases the shape and elongates their other character (Armitage, 1991). In anthurium, candle position of spathe focuses the quality of flower. Though it varies in variety to variety, however vertical candle position retains the flower quality. Whatever, direct sunlight suppress the flowering (Goodwin *et al.*, 1995).

Combined effect of anthurium varieties and light intensities were statistically significant on spathe candle position (Appendix IX). Highest spathe candle position (153.1^0) recorded in V_3L_2 combination and lowest (109.9^0) from V_4L_0 (Table 10). In case of combination was found similar significant among V_1L_1 and V_3L_0, though interaction was statistical difference.

4.16 Candle position (Spadix)

Candle position of spadix was significantly varied among different anthurium varieties like V_1 (Pink anthurium), V_2 (White pink anthurium), V_3 (White anthurium), V_4 (Light pink anthurium) and V_5 (Green red anthurium) (Appendix IX). Candle position of spadix was examined the highest (76.3^0) in V_3, while the lowest (38.1^0) was founded in V_5 (Table 8). Eliboxand Umaharan (2012) showed the variation of spadix angle in different anthurium varieties.

Significant variation was exhibited on candle position of spadix correspondingly along with different light intensities viz. L_0, L_1 and L_2 (Appendices IX). Maximum candle position of spadix (63.5^0) was observed from 60% reduced light (L_2), while minimum (49.6^0) found in control (L_0) (Table 9). In graph, trend line showed light range and variation on candle position (Spadix).

Anthurium varieties and light intensities were statistically provoked on consequence of candle position of spadix (Appendix IX). Due to the interaction of both factor showed difference findings which maximum candle position (85.6^0) was observed from V_3L_2 combination and minimum (34.8^0) from V_5L_0 combination (Table 10). Parallel significance was showed on candle position (Spadix) among V_2L_0 and V_5L_0 as well as V_2L_1 and V_4L_0.

4.17 Vase life

Vase life was significantly influenced in respect of different varieties of anthurium viz. V_1, Pink anthurium; V_2, White anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium (Appendix X). Maximum vase life (26.7 days) was found from V_3 (White anthurium) and minimum (15 days) obtained from V_5 (Table 9). Accordance the results with also was found by Elibox and Umaharan (2012), who evaluated the vase life of 26 anthurium varieties. Islam *et al.* (2013) also supported results who mentioned that anthurium vase life vary into variety to variety.

However, vase life varies due to the genetical factor in different anthurium. The cultivars shows a variety of symptoms, that is, peduncle base browning, loss of glossiness, spathe wilting (floppiness), spadix and spathe necrosis, and spathe discoloration (Paull *et al.,* 1985). Nevertheless, total length of vase life depends on the point that is considered as initiation of the vase life and it is also determined by maturity level on the spathe and spadix of anthurium flower (Agampodi and Jayawardena, 2007). Furthermore, mature cut flower has low abaxial stomata which increase vase life (Dufour and Guerin, 2003). Interestingly, anthurium spathe size increases the respiration rate of flower, and in particularly enhance the post harvest life of anthurium (Hew *et al.,* 1994). Herein, spathe color is also important for vase life. In terms of dominant pigment of anthurium flower correlates to the vase life, like as white spathe flower has flavones (Iwata *et al.,* 1985 and Avila-Rostant, 2010), which have a strong and proven antioxidant capacity (Rice-Evans *et al.,* 1997) and are excellent free radical scavengers. Furthermore, flavones are lipophilic and it maintains membrane integrity or roles in protection from photoinhibition (Dodd *et al.,* 1998; Gould *et al.,* 2000). In vase life study, V_3 variety found the longest vase life than other variety. So, it can be used as a better cut flower. On the other hand, anthocyanin concentration increases on senescence, which also corresponds to an increase in total phenols and phenol stimulates to change the brown color of spathe (Paull *et al.,* 1985).

4.18 Flowers plant^{-1}

Determination of flower per plant was statistically observed among different anthurium varieties (Appendix XI). Maximum flowers per plant (6.4) obtained from V_3 (White anthurium) and on the other hand lowest (2.4) showed from V_5 (Table 8). Yields of anthurium flowers vary in variety to variety (Shiva and Nair, 2008). Variation in flower yield is significantly influenced by variety, temperature and solar radiation (Leffring, 1975; Croat and Chavez, 2008).

Statistical variation was founded among different light intensities viz. L_0, L_1 and L_2 (Appendix XI). Higher number of flower (5.7) was in L_2 (60% reduced light) and lower (2.8) in control (L_0) (Table 9). Chen *et al.* (1999) documented average flower number increase in interior condition under low light. Singh *et al.* (2005) also reported that flower number of Chrysanthemum increased in 50% shade. However, different light shades induced flowers and flower buds (Munir *et al.*, 2004), because full sunlight do not support the vegetative growth and flowering in anthurium (Goodwin *et al.*, 1995). Due to the shade avoidance syndrome plants get ambient light in response of far red:red (Thomas, 2006). As high far red:red ratio is contain in low light, floral initiation induces to the promotion of far red (730 mμ) energy (Friend *et al.*, 1963). Response of this low r:fr is occupied by the acceleration of flowering in deficient response of phytochrome B mutant in *Arabidopsis thaliana* (Halliday *et al.*, 1994). Nevertheless, 60% reduced light enhanced anthurium flowering in low light. Further more, full sunlight has adverse affects on flowering of anthurium, as way to slow rate of flowering has observed in full sunlight among *Blandfordia grandiflora* (Goodwin *et al.*, 1995). If reduce light induce in anthurium, it can promote the flowering and increase desire size and shape.

In respective anthurium varieties and light intensities were statistically influenced in between combined interaction with V_1, V_2, V_3, V_4 and V_5 as well as L_0, L_1 and L_2 (Appendix XI). Flower per plant was exhibited significance difference among their corresponding variation, as far result of utmost flower (8.3) obtained from V_3L_2 combination and least (1.9) was showed from V_2L_0 combination (Table10).

Table 8. Variation of different anthurium varieties on yield related traits of anthurium[y]

Variety[x]	Spathe candle position (^{0})	Spadix candle position (^{0})	Vase Life	Flowers plant^{-1}
V_1	143 b	71.9 b	23 b	4.8 b
V_2	136.1 c	47.2 d	18.5 c	3.1 d
V_3	148 a	76.3 a	26.75 a	6.4 a
V_4	137.8 c	51.1 c	17.25 d	4.5 c
V_5	116.3 d	38.1 e	15 e	2.4 e
CV (%)	**2.0**	**2.7**	**4.0**	**6.6**
LSD (0.05)	**2.2**	**1.2**	**1.3**	**0.2**

[x]V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium

[y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) are vary significantly as 0.05 level of probability

Table 9. Variation of different light intensities on yield related traits of anthurium[y]

Light[x]	Spath candle position (^{0})	Spadix candle position (^{0})	Flowers plant^{-1}
L_0	130.2 c	49.6 c	2.8 c
L_1	136.4 b	57.7 b	4.2 b
L_2	142.1 a	63.5 a	5.7 a
CV (%)	**2.0**	**2.7**	**6.6**
LSD (0.05)	**1.7**	**1.0**	**0.2**

[x] L_0, Control; L_1, 40% reduce light and L_2, 60% reduced light
[y] In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) are vary significantly as 0.05 level of probability

Table 10. Combined effects of varieties and light intensities on yield related traits of anthurium[y]

Treatments	Candle position (spath)	Candle position (Spadix)	Flowers $plant^{-1}$
$V_1 L_0$	136 g	59.2 f	3.3 e
$V_1 L_1$	143.2 de	75.4 d	4.3 d
$V_1 L_2$	149.8 ab	81.2 b	6.7 b
$V_2 L_0$	131.6 h	41.9 k	1.9 g
$V_2 L_1$	136.6 fg	47.0 j	3.1 fg
$V_2 L_2$	140.1 ef	52.6 h	4.4 d
$V_3 L_0$	142.3 de	65.2 e	4.4 d
$V_3 L_1$	148.8 bc	78.2 c	6.5 b
$V_3 L_2$	153.1 a	85.6 a	8.3 a
$V_4 L_0$	131.1 h	46.7 j	3.2 e
$V_4 L_1$	137.1 fg	49.9 i	4.4 d
$V_4 L_2$	145.4 cd	56.7 g	5.9 c
$V_5 L_0$	109.9 k	34.8 m	1.1 h
$V_5 L_1$	116.6 j	37.8 l	2.8 f
$V_5 L_2$	122.4 i	41.6 k	3.4 e
CV (%)	**2.0**	**2.7**	**6.6**
LSD (0.05)	**3.9**	**2.2**	**0.4**

[x]Variety viz. V_1, Pink anthurium; V_2, White pink anthurium; V_3, White anthurium; V_4, Light pink anthurium and V_5, Green red anthurium and Light viz. L_0, Control; L_1, 40% reduce light and L_2, 60% reduce light

[y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) are vary significantly as 0.05 level of probability

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

Anthurium (*Anthurium andraeanum* Linden.) is one of the most beautiful ornamental cut flowers, which belongs to the family Araceae. It can be grown in low light or shade conditions as it is a tropical shade loving plant. Therefore, it is considered to maintain an appropriate shade level in gardens, apartments and other households where anthurium is being grown. Many anthurium varieties are grown in Bangladesh at home and nursery, but anthurium is still in its infancy and unavailable in flower market. So, screening of anthurium varieties should be done to investigate its development of interior foliage and cut flower under different light intensities in house condition as well as in commercial level.

In order to make popularity of anthurium under different shade conditions, a research was conducted at the Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka during the period from April 2013 to February 2014. this two factors experiment included five anthurium varieties viz. V_1 (Pink anthurium), V_2 (White pink anthurium), V_3 (White anthurium), V_4 (Light pink anthurium), V_5 (Green red anthurium) and three light intensities viz. L_0 (control), L_1 (40% reduced light), L_2 (60% reduced light) were carried out which was arranged in split-plot design with four replications.

Collected data were statistically analyzed for evaluation of the treatments for screening of best anthurium variety, the most suitable light intensity and the best combination of these two factors.

In terms of variety, maximum number of sucker (3.0) was found from V_3 (White anthurium) and lowest (1.0) was obtained from V_5 (Green red anthurium) respectively. Considering the variety, utmost leaf area (186.5 cm^2) was found from

V_1 (pink anthurium) and least (131.3 cm^2) obtained from V_5 (Green red anthurium) at harvest stage respectively. However, maximum chlorophyll percentage (83.6%) was obtained from V_1 (Pink anthurium), where as minimum (29.5%) was from V_5 (Green red anthurium) at harvest stage respectively. Among the anthurium variety, highest flower stalk length (29.1 cm) and diameter (7.8 mm) were achieved from V_1 (Pink anthurium), where as lowest stalk length (13.8 cm) and stalk diameter (4.0 mm) were provided from V_5 (Green red anthuruim). In terms of anthurium varieties, maximum spathe length (9.6 cm) and breath (8.3 cm) were showed from V_3 (White anthurium) respectively. On the other hand, minimum spathe length (6.9 cm) and breath (5.1 cm) accounted in V_4 (Light pink anthurium) and V_5 (Green red anthurium) respectively. Regarding the anthurium varieties, highest candle position of spathe (148^0) and spadix (76.3^0) observed from V_3 (White anthurium) and V_5 (Green red anthurium) provided the lowest candle position of spathe (116.3^0) and spadix (38.1^0). Interestingly, Maximum vase life (26.7) recorded from V_3 (White anthurium) and minimum (15) calculated in V_5 (Green red anthurium). Among the anthurium varieties, maximum flowers per plant (6.4) recorded from V_3 (White anthurium), on the other hand minimum (2.4) showed in V_5 (Green red anthurium).

Considering the light intensity, maximum number of sucker (3.1), leaf area (172.6 cm^2) and SPAD value (65.7%) were obtained from L_2 (60% reduced light) and minimum number of sucker (1.0), leaf area (147 .0 cm^2) and SPAD value (37.9%) were reported form L_0 (Control) at harvest stage respectively. Conversely, maximum stalk length (8.4 cm) and diameter (9.7 mm), spathe length (7.7 cm) and spathe breath (7.7 mm) were recorded from L_2 (60% reduced light), where as minimum stalk length (3.7 cm) and diameter (5.3 mm), spathe length (4.6 cm) and spathe breath (4.6 cm) were traced out from L_0 (Control). As far resume of range in light intensities, utmost candle position spathe (142.1^0) and spadix (63.5^0) resulted from L_2 (60% reduced light). On the other hand, least range of spathe

(130.2^0) and spadix (49.6^0) calculated from L_0 (control). In light intensity, higher number of flowers per plant (5.7) in L_2 (60% reduced light), where as lower (2.8) in L_0 (Control).

Inter-relationship variation between variety and light intensity, higher number of sucker (4.5) found from V_3L_2 and lower (0.6) was obtained from V_2L_0 combinations. In grouping of verities and light intensities, highest leaf area (211.7 cm^2) was documented from V_1L_2 and lowest (119.9 cm^2) was in V_5L_0. Interaction of varieties and light intensities, highest SPAD value (113.8) was recorded in V_1L_2 and lowest (24.1) was in V_5L_0. In relations of the anthurium varieties and light intensities, V_1L_2 corresponded to topmost results in terms of stalk length (32.1 cm) and diameter (11.3 mm) where as lowest results were attained from V5L0 (10.4 cm of stalk length and 2.8 mm of stalk diameter). In arrangement of anthurium varieties with light intensity, V_3L_2 produced longest spathe (12.2 cm) and (10.5 cm) breadth of anthurium. V_1L_0 and V_4L_0 reported shortest spathe (5.1 cm) as well as V_1L_0 showed smallest spathe breath (3.8 cm). In amalgamation, maximum candle position of spathe (153.1^0) and spadix (85.6^0) recorded in V_3L_2 combination, where as lowest spathe (109.9^0) and spadix (34.8^0) obtained from V_4L_0 and V_5L_0 respectively. In interaction of anthurium varieties with light intensities, utmost flowers per plant (8.3) obtained from V_3L_2 combination and least (1.9) was showed from V_2L_0.

5.2 Conclusion

From the above results it can be concluded that White anthurium (V_3) conceived the utmost number of suckers, spathe length and breadth, candle position of spathe and spadix, vase life and number of flowers. On the other hand, different light intensities also performed as excellent among all parameters. L_2 (60% reduce light) was found the best in growth and yield attributes with anthurium. Besides the interaction effect of anthurium varieties, V_1 (Pink anthurium) with 60% reduced light (L_2) showed the best in growth traits as well as V_3 (White anthurium) with 60% reduced light (L_2) was best combination with yield characters. In a nutshell, it can be concluded that White anthurium (V_3) is the best variety for flowering as well as 60% reduced light (L_2) is the best shade condition for anthurium.

5.3 Recommendations

Based on the findings of the research, the following recommendations are suggested:

- ® A cut flower, white anthurium is recommended to be grown in the farmers field
- ® 60% reduced light (L_2) can be used with V_1 (Pink anthurium) in interior foliage garden

5.4 Suggestions

Further research in the following areas may be carried out:

- ® Performance of all available anthurium varieties to grow under diffused light and shade conditions
- ® Development of colorful varieties under shade conditions as the market value of these varieties are superior to others

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APPENDICES

Appendix I. Analysis of variance of the data on plant height at different DAT of Anthurium

Source	Degrees of Freedom (df)	Mean Square for Plant height (cm) at				
		20 DAT	40 DAT	60 DAT	80 DAT	100 DAT
Factor A (Germplasm)	4	48.8*	137. 1*	234.8*	328.0*	358.9*
Factor B (Light)	2	33.8*	75.6*	98.2*	172.7*	191.9*
AB	8	4.1*	2.6*	1.1*	2.9*	3.6*
Error	45	0.4	1.0	1.9	1.5	1.7

*: Significant at 0.05 level of significance

Appendix II. Analysis of variance of the data on petiole length at different DAT of Anthurium

Source	Degrees of Freedom (df)	Mean square of petiole length (cm) at				
		20 DAT	40 DAT	60 DAT	80 DAT	100 DAT
Factor A (Germplasm)	4	6.4*	22.9*	60.9*	69.8*	64.5*
Factor B (Light)	2	35.8*	42.1*	72.2*	134.9*	185.3*
AB	8	0.9*	1.8*	3.0*	10.8*	11.6*
Error	45	0.1	0.1	0.0	0.0	0.1

*: Significant at 0.05 level of significance

Appendix III. Analysis of variance of the data on number of leaves at different DAT of Anthuirum

Source	Degrees of Freedom (df)	Mean square of Number of leaves at				
		20 DAT	40 DAT	60 DAT	80 DAT	100 DAT
Factor A (Germplasm)	4	12.7*	15.1*	22.6*	44.4*	35.6*
Factor B (Light)	2	28.9*	54.7*	50.1*	82.9*	86.7*
AB	8	0.2*	0.9*	0.7*	1.6*	2.0*
Error	45	0.1	0.1	0.1	0.1	0.0

*: Significant at 0.05 level of significance

Appendix IV. Analysis of variance of the data on leaf length at different DAT of Anthurium

Source	Degrees of Freedom (df)	Mean square of Leaves length (cm) at				
		20 DAT	40 DAT	60 DAT	80 DAT	100 DAT
Factor A (Germplasm)	4	32.8*	50.4*	51.9*	87.9*	102.9*
Factor B (Light)	2	37.5*	50.7*	72.6*	105.3*	121.8*
AB	8	1.6*	0.5*	0.3*	3.8*	3.3*
Error	45	0.0	0.1	0.0	0.1	0.1

*: Significant at 0.05 level of significance

Appendix V. Analysis of variance of the data on leaf breadth at different DAT of Anthurium

Source	Degrees of Freedom (df)	Mean square of Leaf breadth (cm) at				
		20 DAT	40 DAT	60 DAT	80 DAT	100 DAT
Factor A (Germplasm)	4	22.3*	44.0*	68.2*	91.9*	113.0*
Factor B (Light)	2	35.8*	35.5*	45.8*	61.2*	73.0*
AB	8	0.9*	1.0*	1.9*	1.0*	2.1*
Error	45	0.1	0.1	0.1	0.1	0.1

*: Significant at 0.05 level of significance

Appendix VI. Analysis of variance of the data on leaf area at different stages of Anthurium

Source	Degrees of Freedom (df)	Number of sucker	Mean Square of Leaf area (cm^2) at		
			Vegetative stages	Reproductive stages	Harvesting stages
Factor A (Germplasm)	4	6.789*	1456.102*	7638.375*	5394.635*
Factor B (Light)	2	22.195*	3238.957*	3918.783*	3283.49*
Interaction (A×B)	8	0.875*	67.322*	497.623*	156.996*
Error	45	0.08	29.17	140.374	77.462

*Significant at 0.05 level of significance

Appendix VII. Analysis of variance of the data on chlorophyll percentage at different stages of Anthurium

Source	Degrees of Freedom (df)	Mean Square of SPAD value at		
		Vegetative stages	Reproductive stages	Harvesting stages
Factor A (Germplasm)	4	3683.04*	7049.656*	5850.629*
Factor B (Light)	2	2106.324*	4080.799*	3940.953*
Interaction (A×B)	8	135.009*	343.753*	280.963*
Error	45	10.131	5.966	4.771

*Significant at 0.05 level of significance

Appendix VIII. Analysis of variance of the data on stalk length, stalk diameter, Spath length and breath of Anthurium

Source	Degrees of freedom (df)	Mean square of			
		Stalk length (cm)	Stalk diameter (cm)	Spath length (cm)	Spath breath (cm)
Factor A (Germplasm)	4	547.653*	23.132*	15.718*	21.12*
Factor B (Light)	2	176.902*	109.285*	95.077*	48.365*
Interaction (A×B)	8	2.273*	2.963*	1.582*	0.641*
Error	45	0.79	0.128	0.046	0.066

*Significant at 0.05 level of significance

Appendix IX. Analysis of variance of the data on spadix length, spadix diameter, candle position (Spath) and candle position (spadix) and number of sucker of Anthurium

Source	Degrees of Freedom (df)	Mean Square of			
		Spadix length (cm)	Spadix diameter (mm)	Candle position (spath)	Candle position (spadix)
Factor A (Germplasm)	4	19.973*	17.709*	1757.303*	3260.794*
Factor B (Light)	2	25.986*	62.234*	715.146*	983.475*
Interaction (A×B)	8	0.489*	1.143*	6.501*	57.002*
Error	45	0.023	0.059	7.385	2.302

*Significant at 0.05 level of significance

Appendix X. Analysis of variance of the data on vase life of Anthurium

Source	Degrees of Freedom (df)	Mean Square of
		Vase life
Factor A (Germplasm)	4	89.325*
Error	12	0.658

*Significant at 0.05 level of significance

Appendix XI. Analysis of variance of the data on number of flowers per plant of Anthurium

Source	Degrees of Freedom (df)	Mean Square of
		Flowers per plant
Factor A (Germplasm)	4	28.706*
Factor B (Light)	2	44.125*
Interaction (A×B)	8	0.686*
Error	45	0.077

*Significant at 0.05 level of significance