GENETIC VARIABILITY AND CHARACTER ASSOCIATIONS IN *Anthurium andreanum* Linden

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In Memory of
My
"Beloved Mother"

DECLARATION

I hereby declare that this thesis entitled **"Genetic variability and character associations in *Anthurium andreanum* Linden"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

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ASISH K. BINODH

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LIST OF ABBREVIATIONS

1.	ANOVA	-	Analysis of variance
2.	ANACOVA	-	Analysis of covariance
3.	BA	-	Benzyl adenine
4.	CD	-	Critical difference
5.	cv.	-	Cultivar
6.	df	-	degrees of freedom
7.	GA	-	Genetic Advance
8.	GA_3	-	Gibberellic acid
9.	GCV	-	Genetic coefficient of variation
10.	H^2	-	Heritability (Broad sense)
11.	OD	-	Optical density
12.	PCV	-	Phenotypic coefficient of variation
13.	pv.	-	Pathovar
14.	SE_m	-	Standard error of mean
15.	var.	-	Variety

INTRODUCTION

1. INTRODUCTION

Anthurium is currently being promoted as an export oriented cut flower crop suitable for commercial cultivation. It is a tropical plant of great beauty grown for its colourful long lasting flowers and handsome foliage. The warm humid tropical climate of Kerala in South India is congenial for its wide spread cultivation.

Anthuriums belong to the monocot family Araceae and are native of tropical zones of the Central and South America. This family is the most morphologically diverse and taxonomically complex one (Croat, 1980). The name *Anthurium* means tail flower in Greek ('Anthos' = flower and 'aura' = tail). Two species of the genus with commercial importance are *Anthurium andreanum* Linden ('oil cloth flower', 'tail flower', 'palette flower') and *A. scherzerianum* ('flamingo flower' or 'flame plant'), both of which have magnificent flowers and attractive foliage. The popular anthurium 'flower' is actually a compound inflorescence called spadix.

Anthuriums are semi-terrestrial and perennial epiphytic plants with creeping arborscent stem. The 'flower' consists of a colourful, shiny, heart shaped modified leaf (spathe) surrounding a straight or slightly curved inflorescence 'candle' (spadix). It produce flowers all round the year, one flower from each axil. This free flowering sequence of leaf, flower and new leaf is maintained throughout the life of the plant. The domesticated plant is erect with large to small sized ever green leaves.

The valuable part of the plant is its cordate blistered and glossy spathe which is a modified leaf subtending the fleshy inflorescence bearing small sessile flowers.

Anthurium andreanum is a native of South-West Columbia which was brought to Europe in 1876 (Singh, 1987). From Europe, the species spread to Brazil and Hawaii. Anthurium was introduced in India *via* England by coffee and tea planters who wanted showy exotic plants for their bungalows. Even now some of the old tea and coffee plantations in Assam, Darjeeling and Coorg have beautiful and exotic anthurium specimens. Towards the middle of the last century, some varieties from Hawaii reached Kalympong of West Bengal the derivatives of which are now known as Kalympong varieties.

Anthurium andreanum is grown mainly for cut flower production. Major production areas are Hawaii, Netherlands and Mauritius. Anthurium ranks eleventh among cutflowers. The export of Anthurium from Mauritius (where it is the national flower) has risen from thirty thousand rupees in 1968 to thirty million rupees in 1990 and the trade is catching up due to new market prospects and low cost of cultivation as compared to those in Holland and Hawaii.

Anthurium cut flower production in India is still in its infancy, due to lack of elite planting materials at reasonable price, standardised cultural practices and adequate infrastructure for marketing. It is only very recently that anthurium flowers have made their presence felt in Indian florists shops. Few growers in Salem, Yercaud, Thiruvananthapuram, Kochi, Mercara and Kalympong have started anthurium cultivation on a large scale for cut flower production (Singh, 1987, 1992).

Anthurium andreanum is an out breeding species with protogynous flowers. Protogyny is a mechanism to prevent self fertilisation, as the stigmatic surface becomes receptive about 7-10 days before pollen shed. Cross pollination among selected plants is preferred in commercial seed production. The time required from pollination to the maturity of the seed is about 4½ to 7½ months.

The karyotype analysis and meiotic studies by Lalithambika (1978) and Satyadas (1985) revealed that there is an abundance of genetic variability present

in some species of anthurium. The genetic variability present in *A. andreanum* provides great scope for crop improvement through controlled hybridisation and selection.

Hybridisation and selection is the most common and proven method of anthurium breeding (Sheffer and Kamemoto, 1976, 1977, Maurer, 1979 Henny *et al.*, 1988). This is being practiced in leading anthurium growing countries of the world such as Netherlands, Mauritius, Hawaii, Philippines, Srilanka etc. Hybridisation between selected varieties with good combining ability can be used for evolving valuable anthurium hybrids with desirable plant characters such as compact plant type, medium sized leaves, heart shaped spathe, wrinkled spathe texture, slender short downward curving candles and straight, long inflorescence axis (Mayadevi, 2001).

This study was undertaken to estimate the genetic variability of fifty genotypes of anthurium. It will help the breeder to select superior genotypes for the development of new commercial varieties.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Anthurium is a cut-flower crop that has recently come into economic prominence in Kerala. The only species of commercial value is *Anthurium andreanum* which is native of Columbia. The warm humid tropical climate of Kerala can be easily adapted for its wide spread cultivation.

Genetic variability forms the basis of plant breeding for crop improvement because plant breeding operates on variability. A fraction of the source of variability that goes into the development of a hybrid/variety determines the quality of hybrids with respect to their adaptability, agronomic performances, disease and insect resistance etc.

Hybridization followed by selection is the best method to achieve crop improvement in anthurium. The crop is highly heterozygous with great genetic potential which is yet to be exploited. So the present study was initiated to select superior genotypes for the development of new commercial varieties. Reported studies in this direction, involving *A. andreanum* are very few. A review of the works relevant to the study is attempted here.

2.1 CULTIVATION ASPECTS

Anthuriums require a warm green house with 75 per cent shading from direct sunlight and an atmospheric humidity 70-80 per cent humid condition. The temperature range is between 25 and 28°C during the day and 18 and 22°C during the night with optimum being 22 to 25°C. The relative humidity is also very important for growth and development of anthurium, the optimum being around 75 per cent. The morphological characters, flower production and quality of

flowers are affected by the intensity of light. The optimum shade requirement is 75 per cent (Mercy and Dale, 1994).

Anthurium needs a light, well drained medium rich in organic matter and with good aeration and water holding capacity. They are usually grown in a medium consisting of sand, cowdung, brick pieces, charcoal and coconut husk in Kerala which provide 100 per cent drainage (Mercy and Dale, 1994).

2.2 NUTRITION

According to Steen and Vijverberg (1973), neither nitrogen nor potash had any significant effect on flower yield in Netherlands. The plants were fertilized with nitrite of lime and or potassium sulphate immediately after planting and five months later, or else, where left unfertilized and all the plants grow equally well.

Colour break down of spathe tissue of anthurium is a typical symptom of calcium deficiency. Calcium application significantly reduced this disorder (Higaki *et al.*, 1980).

A. andreanum cv. 'Lady Jane' was grown with weekly application of 20:20:20 NPK fertilizer at 200, 400, 600 and 800 mg l^{-1}, and the study showed that, the plant growth was best at the lower two fertilizer levels. Higher levels were found to be detrimental (Henny and Fooshee, 1988).

Higaki *et al.* (1992) and Holley *et al.* (1994) reported that the maximum flower yield in anthurium was obtained when leaf tissue level was 1.87 per cent for N, 0.17 per cent for P and 2.07 per cent for K. However, no relationship was observed between the P content in leaves and flower size or stem length.

Studies in the Kerala Agricultural University (Salvi, 1997) revealed that application of NPK complex of 17:17:17 at the rate of 1 per cent at weekly intervals produced the maximum height and increased other biometrical characters in *A. andreanum* cv. 'Hawaiian Red'.

2.3 GROWTH REGULATORS

Nakasone and Kamemoto (1962) reported that light intensity and GA_3 concentration are important factors in regulating flower production in anthurium.

Application of GA_3,BA and Ethephon at 750 and 1500 ppm was tried in *A. andreaum* cv. 'Hawaiian Red' (Salvi, 1997). BA 750 ppm at monthly interval period produced more plant height, leaf length, breadth and petiole length. GA_3 performed better than BA and Ethephon.

2.4 PLANT HEIGHT

Tisdale *et al.* (1985) reported that plant height can be used as an index of plant growth. According to Higaki and Imamura (1988) the height of plants gradually decreased with increasing pH upto 8.0

Bindu and Mercy (1994) observed that the five varieties of the genus *Anthurium* studied by them showed significant variation in plant height ranging from 45 cm in the var. 'Lady Jane' to 85 cm in the var. 'Pink'.

Sindhu (1995) recorded the height of six varieties of *A. andreanum* which ranged from 43 to 70 cm. In a study on the anthurium cv. 'Hawaiian Red', Salvi (1997) observed that the plant height was superior under 70 per cent shade + 750 ppm BA. In another study on the same variety Abdussammed (1999) concluded that nutrients significantly influenced plant height both in ground as well as in pot planting.

Renu (2000) recorded significant variation in plant height ranging from 29.7 cm in var. 'Midori Green' to 70.9 cm in 'Pompon Red'. The varieties 'Liver Red' and 'Mauritius Orange' also were tall, with heights almost on par with that of the var. 'Pompon Red'.

Mayadevi (2001) recorded the height of twenty varieties of *A. andreanum* which ranged from 42.5 cm in var. 'Midori Green' to 96.67 cm in var. 'White'.

2.5 INTERNODE LENGTH

Singh (1987) reported that a desirable anthurium should produce short internodes inorder to limit the height of the plant.

Mercy and Dale (1994) were of the opinion that a commercial variety should have simple leaves borne singly on long stalks with sheathing bases in a spiral rosette with very short internodes so that the plant has a compact bushy appearance.

Mayadevi (2001) recorded the internode length of five parents and 10 F_1 hybrids. Mean internode length ranged from 1.00 cm ('Pink') to 1.52 cm ('Liver Red') among the parents and in the hybrids it ranged from 1.02 cm (P x CR) to 1.34 cm (HR x P).

2.6 SUCKERING ABILITY

Suckering is a natural method of vegetative propagation in anthurium and the ability to produce suckers is a very desirable attribute for commercial varieties.

Higaki and Rasmussen (1979) observed that some cultivars produced basal suckers readily while others had to be stimulated to produce suckers by foliar application of N-6 Benzyl adenine at 1000 mg l^{-1}.

Mercy and Dale (1994) reported that propagation of anthurium using suckers was a very slow and undependable process because most of the good commercial and hybrid varieties were very shy suckering or did not sucker at all. 'Pink' is a profusely suckering variety but is not commercially valuable. Foliar

spraying with Gibberellic acid (GA_3) or Benzyladenine (BA) (500-1000 ppm) was found to increase sucker production. Sindhu (1995) observed maximum number of suckers in the var. 'Pink' and the least in the var. 'Kalympong Red'.

Salvi (1997) inferred that a treatment combination of 80 per cent shade and 750 ppm BA was the best for maximising sucker production. Abdussammed (1999) reported that nutrients failed to make any significant influence on the number of suckers produced per plant, but application of growth regulators increased the sucker production in *A.andreanum* significantly. The highest values were recorded for $GA_3$1000 ppm which was on par with a combination of BA and GA_3 at 250 ppm each.

Among the ten varieties of anthurium studied by Renu (2000), it was seen that sucker producing ability is an important trait considered in the selection of superior types. It was very high for varieties 'Liver Red', 'Lady Jane' and 'Ceylon Red ("Fla Red"), medium for 'Midori Green', 'Mauritius Orange' and 'Nitta orange', low for 'Merengue White' and 'Dragon's Tongue Red' and very low for 'Pompon Red' and 'Tropical Red'.

Mayadevi (2001) while studying twenty varieties of anthurium observed maximum number of sucker production for varieties 'Pink' and 'Lady Jane' (4) followed by 'Liver Red', 'Honeymoon Red' and 'Kalympong Orange' (3.67, 3.67, 3.33). Very low suckers were produced by varieties 'Nitta Orange', 'Merengue White' and 'Tropical Red'.

2.7 LEAF SIZE / LEAF AREA

Medium sized leaf is considered best for an ideal commercial anthurium plant type as plants with medium leaves are more compact and occupy less green house space than those with large spready leaves.

Sheffer and Kamemoto (1978) made crosses between *A. scherzerianum* and *A. wendlingerii* and produced a hybrid and observed the leaf size of parents and hybrids for comparison and found that the length and position of the leaf blade were intermediate between the highly contrasting characters of the parental species.

Among the five varieties of *A. andreanum* studied by Bindu (1992) the length of leaves ranged from 13.5 to 26 cm and width ranged from 8.7 to 23 cm. Leaf size was maximum for 'Pink' and minimum for 'Lady Jane' and 'Chilli Red'.

Mercy and Dale (1994) were of the opinion that the leaves of commercially valuable floral anthuriums should be small to medium sized, narrow and elongated. Large and exuberantly growing leaves indicated primitiveness and were undesirable.

Sindhu (1995) reported that the variety 'Pink' produced bigger sized leaves whereas 'White' and 'Chilli Red' produced smaller sized leaves which are commercially more valuable than 'Pink'.

Salvi (1997) in *Anthurium andreanum* var. 'Hawaiian Red' reported that the leaf length and breadth were significantly influenced by shade and growth regulators. The treatment combination 60 per cent shade + Hoagland solution + 750 ppm BA produced the longest leaves (10.50 cm) while 60 per cent shade + fertilizer complex + 750 ppm BA produced the broadest leaves (8.00 cm).

Abdussammed (1999) reported that the leaf length, breadth and leaf area were not influenced significantly by the nutrients either in ground or in pot planting.

Mayadevi (2001) inferred that the var. 'Chilli Red' had the least leaf area (66.26 cm^2) followed by var. 'Kalympong Red' (66.92 cm^2). 'Honeymoon Red' had the largest leaf area of 88.89 cm^2 which is not ideal.

2.8 DAYS FROM EMERGENCE TO MATURITY OF LEAVES

Mayadevi (2001) reported that the number of days required for the leaves from emergence to maturity ranged from 41.40 days in the variety 'Honeymoon Red' to 44.40 days in the variety 'Pink'.

2.9 DAYS FROM EMERGENCE TO MATURITY OF INFLORESCENCE

Mayadevi (2001) observed that the days from emergence to maturity of inflorescence ranged from 44.60 days in 'Chilli Red' to 50.60 days in 'Honeymoon Red' in the parents while the range of this character in hybrids was from 41 days in HR x P to 54 days in HR x KR.

2.10 NUMBER OF LEAVES OR SPADICES / PLANT / YEAR

Morphological studies conducted by Christensen (1971) showed that *Anthurium andreanum* had a long juvenile phase of vegetative growth followed by a generative phase in which flower buds were produced.

Steen and Vigverberg (1973) on comparing the productivity and inflorescence quality of 120 individual anthurium plants found that their productivity was highly variable ranging from four to sixteen flowers over two years. Leffering (1975) observed that in plants that received 45 per cent of available light, productivity increased from 5 to 12 flowers per plant per year.

Higaki and Poole (1978) while studying on variety 'Ozaki' found that the flower production increased with age of the plant. Higaki and Rasmussen (1979) found that anthuriums are slow growing, producing only six to eight new leaves and vegetative buds on a stem axis per year.

Gajek and Schwarz (1980) are of opinion that there is a close correlation between the number of leaves and number of flowers.

Singh (1987) reported that the most commonly cultivated varieties produced flowers all round the year at the rate of one flower from each leaf axil. The sequence of leaf, flower and new leaf was maintained throughout the life of the plant.

Mercy and Dale (1994) observed that anthurium was slow growing and produced only five to eight new leaves on a stem axis per year and generally with each new leaf, a root also emerged.

Sindhu (1995) has recorded that the number of spadices produced annually by an anthurium plant varied from four to eight. Abdussammed (1999) revealed that the effects of nutrients and growth regulators on interval of flower production was not significant.

Renu (2000) showed that one spadix each was produced from the axil of each leaf so that the number of leaves and number of spadices produced annually per plant was the same. The annual production of leaves or spadices was the highest in 'Lady Jane Red' (7.6) followed by 'Liver Red' and 'Pompon Red'.

Mayadevi (2001) reported that among the varieties studied, 'Honeymoon Red' had the highest number of spadices (7.6). She also stated that the average production ranged from 4.67 to 8.00.

2.11 CANDLE LENGTH

The candle (spadix) is the inflorescence proper, bearning small bisexual flowers embedded in slanting rows in an acropetal succession. The larger the candle, the more the number of flowers. Commercially, slender and short candles are more preferred over long thick candles.

Bindu (1992) reported, the candle length of five varieties of *A. andreanum* which ranged from 4 to 9.5 cm. In ordinary varieties of 'Pink', 'Red' and

'White' the candle was long and fleshy, but in highly bred hybrids and exotics, the candle was shorter and more slender (Mercy and Dale, 1994). The candle length of 6 varieties studied by Sindhu (1995) ranged from 6.6 cm to 12.1 cm.

Renu (2000) reported that the commercial varieties like 'Tropical Red', 'Nitta Orange', 'Mauritius Orange', 'Lady Jane Red', 'Pompon Red' and 'Midori Green' produced smaller candles. Mayadevi (2001) studied the candle length of five parents and 10 F_1 hybrids. Longest candle was recorded for 'Pink' (12.72 cm) and shortest in 'Liver Red' (7.18 cm) among the parents. In the hybrids it ranged from 5.9 cm (P x LR) to 10.38 cm (HR x LR).

2.12 INCLINATION OF CANDLE

Inclination of candle is an important factor as cut flower anthurium is considered. A downward curving candle is an extremely desirable character for commercial anthurium varieties as this helps in packing a larger number of inflorescence in a box during transportation.

Arndt (1991) reported that *A. scherzerianum* hybrid 'Arabella' have red spathe with recurving spadix. Mercy and Dale (1994) observed that flower bearing candle in good commercial variety was attached to the base of spathe held at an angle slanting or curving at 25° to 40°. According to them ideal anthurium spadix with a high market value must have shorter candle curving towards the tip of the spathe at an angle less than 45°.

In an investigation by Sindhu (1995) the maximum angle of 75° between the base of the candle to the plane of the spathe was observed in the variety 'Honeymoon Red' which is not desirable. The ideal anthurium spadix with an angle less than 45° were found in varieties 'Chilli Red', 'Kalympong Orange' and 'Kalympong Red'.

Renu (2000) while studying anthurium varieties observed an ideal position of candles for 'Pompon Red', 'Chilli Red', 'Tropical Red', 'Mauritius Orange', 'Nitta Orange', 'Merengue White' and 'Midori Green'.

Mayadevi (2001) in her study with 5 parents and 10 F_1 hybrids observed that the inclination of candle ranged from 21° in 'Kalympong Red' to 78.2° in 'Honeymoon Red' among the parents. The hybrids also showed significant difference for this character ranging from 20.80° (HR x CR) to 89.60° (HR x P).

2.13 NUMBER OF FLOWERS / CANDLE

The larger the candle, the more the number of flowers per candle. Though varieties like 'Honeymoon Red' and 'Pink' have large candles with flowers up to 400 or more, they are not preferred and these varieties are non-commercial. Ideal commercial varieties have smaller candles with lesser number of flowers.

Watson and Shirakawa (1967) observed that the *Anthurium* 'flower' consisted of a modified leaf, the spathe and a flower, bear spadix with over 300 spirally attached minute flowers.

Croat and Bunting (1978) reported that the flower of anthurium were bisexual and was closely congested on cylinderical spike and arranged in a series of spirals on the spadix.

Singh (1987) noticed that the anthurium flower is a combination of colourful modified leaf (spathe) and hundreds of small flowers on the pencil - like protrusion (spadix), the flowers are arranged in a series of spirals, both spadix and spathe are borne on a leaf less stalk or peduncle.

Bindu and Mercy (1994) were of the opinion that anthurium 'flower' had a candle bearing about 50-150 sessile flowers. Mercy and Dale in the same year

reported that anthurium 'flower' was actually an inflorescence termed 'spadix' which is racemose with a slender floral axis (candle) bearing 150 to 350 bisexual sessile flowers in acropetal succession.

Sindhu (1995) observed that the average number of flowers produced were maximum in 'Pink' and 'Honeymoon Red' varieties (325 flowers) and the lowest in variety 'Chilli Red' (175 flowers).

Renu (2000) observed that the number of flowers per candle varied from variety to variety which ranged from 254 in 'Tropical Red' to 450 in 'Lady Jane Red'.

Mayadevi (2001) recorded that the number of flowers per candle ranged from 372 in 'Chilli Red' to 600 in 'Pink' among the parents. In the hybrids, P x LR had the minimum number of flowers per candle of about 400 while HR x P and P x KR had the maximum number of flowers per candle of about 600.

2.14 LIFE OF SPADIX

Paull (1982) observed the visible changes accompanying the senescence of anthurium flowers as spathe - gloss loss, necrosis of spadix and greening of spathe and spadix. These changes were non reversible processes leading to the death of spadix.

Mercy and Dale (1994) reported that the life of an unfertilized spadix was about two months while that of a fertilized inflorescence was about 4-7 months. Senescence was marked by yellowing of peduncle followed by withering of spathe and candle.

Sindhu (1995) observed the life of unfertilized spadix which ranged from one and a half months in 'Kalympong Orange' to three and a half months in

'Honeymoon Red'. For fertilized spadices, the period ranged from four and a half to eight months.

Salvi (1997) inferred that among the growth regulators, BA 1500 ppm gave maximum longevity to spadix in the variety 'Hawaiian Red' ie., 152.81 days.

Valsalakumari *et al.* (1998) reported that in *A. andreanum* cv. 'Agnihotri', the longevity of spadix was maximum with 1000 ppm GA_3which was on par with 1500 ppm GA_3. Abdussammed (1999) noticed that combined application of BA + GA_3- 250 ppm recorded the highest longevity of spadix.

Renu (2000) observed that among the ten varieties studied, variety ' Nitta Orange' had a time span from emergence of spathe to its senescence as 2.5 months while the variety 'Ceylon Red' had 3.7 months in case of unfertilized spadices. For fertilized spadices, the life span was found to be higher, ranging from about 3.8 to 7.5 months.

Mayadevi (2001) recorded that the time span from emergence of a spadix to its senescence varied from 98 days in variety 'Chilli Red' to 120.40 days in 'Honeymoon Red' in case of unfertilized spadices.

2.15 DAYS TO INITIATION OF FEMALE PHASE

Croat (1980) stated that in *Anthurium* species, maturation of flowers was initiated generally from the basal portion of the spadix (Candle) and the development proceeds acropetally towards the apex. However *A. andreanum* was not included among the protogynous species of anthurium listed by him.

Mercy and Dale (1994) observed that the flowers of *A. andreanum* are protogynous and the female reproductive structure or gynoecium reached receptivity about 4-7 days after the opening of the spathe.

In 1995, Sindhu studied that the days to initiation of female phase occurred within a period upto 10 days, after opening of spathe, with the variety 'Honeymoon Red' showing the longest period for female phase initiation.

In a study of ten varieties of *A. andreanum* Renu (2000) reported that the mean number of days to initiation of female phase ranged from 3.60 days in 'Lady Jane Red' to 6.80 days in 'Mauritius Orange'.

According to Mayadevi (2001), the number of days from the day the candle become visible to initiation of female phase was observed to vary from 4.40 days in 'Kalympong Red' to 6.80 days in 'Honeymoon Red' and 'Liver Red'. Among the hybrids studied it ranged from 3.60 to 6.20 days. She also reported the protogynous nature of the species.

2.16 NUMBER OF DAYS OF FEMALE PHASE

Daumann (1921) showed that pistillate phase can be discerned by stigmatic droplets which was formed as the stigma becomes receptive.

Croat (1980) observed that the duration of female phase in *Anthurium* species may range from as short as half a day in *A. ravenii* to 28 days in *A. caperatum* and *A. luteynii.*

Bindu and Mercy (1994) reported that the female phase varied from three to twelve days in the five varieties of *A. andreanum* studied.

Mercy and Dale (1994) observed the receptive female phase as a viscous colourless exudate secreted by receptive stigma which is sticky to touch. The receptive female phase lasted for three to seven days in different varieties.

Sindhu (1995) noticed that the duration of female phase ranged from 5 to 25 days in the variety 'Chilli Red' showing the shortest period while Kalympong varieties had longer duration.

Renu (2000) in her study with ten varieties reported that the duration of female phase varied from 6.40 days in variety 'Lady Jane Red' to 16.40 days in 'Mauritius Orange'. She also observed individual flower in which the duration lasted upto 21 days in 'Mauritius Orange'.

According to Mayadevi (2001) the duration of female phase ranged from 7.40 days in 'Pink' to 13.60 days in 'Kalympong Red'. For hybrids the period ranged from 9.60 to 12.80 days.

2.17 DAYS OF INTERPHASE

The interval period between female and male was several days in most *Anthurium* species, whereas in a few of them the time lag was so short that it was not certain whether the species involved were homogamous or protogynous (Croat, 1980).

Bindu and Mercy (1994) observed that the stigmatic droplets dry up before any stamens emerge out. The interphase of five varieties studied by them ranged from 4 to 7 days. During rainy seasons the interphase is prolonged.

Sindhu (1995) studied the interphase in *A. andreanum* which ranged from 4 to 10 days. Prolonged interphase with the suppression of male phase was observed from March to August in several varieties.

Renu (2000) reported that the interphase was marked by the drying up of stigmatic droplets. Observation from seven varieties showed that the interphase ranged from 4.80 to 10.20 days. Variety 'Liver Red' had the longest interphase period while the variety 'Merengue White' the shortest.

Mayadevi (2001) from her study concluded that the interphase ranged from 7.80 days in 'Chilli Red' to 11.20 days in 'Pink'. Among the hybrids studied, HR x CR and P x CR recorded an interphase period of 9.39 and 12.60 days respectively.

2.18 DURATION OF MALE PHASE

Croat (1980) reported that the initiation of stamen emergence appeared to be equal from all parts of the spadix or initial maturation and staminal exertion appeared for many flowers in the basal fourth, basal third or basal half of the candle and further development proceeded in a systematic manner from base to tip.

Bindu and Mercy (1994) opined that the duration of male phase ranged for a period of 3 to 7 days. They noticed the anther exertion started from the base and proceeded regularly towards the apex in all the varieties. During rainy season the male phase may sometimes be completely suppressed.

Mercy and Dale (1994) reported that all the anthers in a candle emerged in about 4 to 8 days. Male phase may be suppressed for long or short periods and the anther emergence is comparatively less during the month of March to July.

Sindhu (1995) in her study concluded that the male phase may range from 3 to 8 days depending on the variety. She also noticed the irregular appearance of stamens on the candle.

Renu (2000) among the varieties studied concluded that the average number of days for which the candles remained in male phase ranged from 5.4 days in 'Mauritius Orange' to 10.4 days in 'Tropical Red'. Scattered anther emergence on the candle was observed in the variety 'Mauritius Orange'.

Mayadevi (2001) reported that the average number of days the candle remained in the male phase ranged from 5 days in the variety 'Chilli Red' to 7.2 days in variety 'Honeymoon Red'. Crosses P x KR recorded a maximum of 9.6 days while HR x CR recorded a minimum of 5.6 days.

2.19 POLLEN FERTILITY

Mitu and Acatrinei (1974) reported that germination of pollen grain was proportional to pollen grain stainability. Stanley and Linskens (1974) observed that the appearance of the pollen alone, even at collection time is not always a good index of viability. So pollen fertility is tested either by using specific stains or by *in vitro* growth studies for correct assessment of pollen fertility and viability.

According to Lalithambika (1978) the pollen sterility of different species of *Anthurium* varied from 63.0 per cent (*A. cordatum*) to 96.5 per cent (*A. veitchii*). She noticed a pollen sterility of 70-75 per cent for *A. andreanum*. Satyadas (1985) reported that pollen sterility varied from 67 per cent (*A. warocqueanum*) to 80 per cent (*A. ornatum*).

Bindu and Mercy (1994) noticed that the pollen fertility ranged from 20.4 per cent in 'Honeymoon Red' to 28.8 per cent in 'Pink'. They inferred that high pollen sterility may be due to high degree of meiotic abnormalities like clumping, lagging of chromosomes at anaphase, unequal segregation, chromosome elimination through micronuclei etc. found in *A. andreanum*.

Renu (2000) estimated the pollen fertility of ten varieties of anthurium and revealed that the variety 'Liver Red' had the highest pollen fertility of 42 per cent followed by 'Tropical Red' (29 %). 'Mauritius Orange' and 'Lady Jane Red' recorded the lowest fertility value of 14 and 13.7 per cent.

Mayadevi (2001) from her study inferred that high pollen fertility was observed for the variety 'Liver Red' (45.90 %) followed by 'Pink' (28.40 %).

2.20 COLOUR OF YOUNG LEAF AND PETIOLE

The colour of young tender leaves of *Anthurium andreanum* varied from light green to deep reddish brown (Mercy and Dale, 1994).

Sindhu (1995) reported that the petioles are slender and long and there are variations in the colour of both petiole and young leaves in all the varieties studied by her. The petiole colour ranged from green, greenish purple and purple. The young tender leaves showed light green, green, greenish brown, light brown and brown colour.

2.21 PLANT TYPE

Mayadevi (2001) observed that the varieties 'Liver Red' and 'Chilli Red' had compact plant type, 'Honeymoon Red' and 'Pink' had spreading plant type while 'Kalympong Red' with semispreading plant type.

2.22 SPATHE COLOUR

Spathe colour is an important character which gives a sense of pleasure to human beings. Spathe colour varies from pure white to deep maroon among the popular commercial varieties of anthurium. Pastal shades such as white, light Pink, Coral, light orange etc. are preferred in countries like China, Japan and Korea, while darker shades are preferred in middle east, USA, Singapore and Malaysia. The presence of 3-cyanidin glycoside and 1-pelargonidin glycoside in the spathes of *A. andreanum* was identified by Forsyth and Simmonds (1954), while the major spathe colours reported by them were red, orange, pink, green and white.

Birdsey (1956) described the spathe of native *A. andreanum* from Columbia as orange scarlet or vermilon whereas the commercial varieties showed a complete colour range from white to dark red. According to Lowry (1972), spathes of all the cultivars of anthurium contained both pelargonidin and cyanidin 3-rutinoside pigments.

Bailey (1976) identified *A. andreanum* Lind. "as one of the parents of a group of hybrids with large showy puckered spathes from black red to red, salmon pink and white ....."

Iwata *et al.* (1979) identified the pigments to be cyanidin 3-rhamnosyl glucoside and pelargonidin 3-rhamnosyl glucoside. Genetics of spathe colour revealed the presence of both the pigments in the red cultivars 'Ozaki', 'Kaumana', 'Kozahara', 'Kansako No.1' and 'Nakazqwa' and in the pink cultivar 'Marian seefurth'. The orange and coral coloured spathes contained only pelargonidin 3-rhamnosyl glucoside. In white varieties both the pigments were absent.

Maurer (1979) while describing the techniques of cross pollination in *A. scherzerianum* discussed the presence of recessive characters ie., A = with anthocyanin and a = without anthocyanin B = whole spathe coloured and b = spotted spathe. When the parents were Aa/Bb, the descendants were 9 red (AB), 3 red spots in white (Abb-) and 4 white (aaB- and aabb).

Iwata *et al.* (1985) stated that the spathe colour in anthurium was determined by the relative concentrations of anthocyanins : a pre-dominance of cyanidin 3-rhamnosyl glucoside resulted in pink to red colours whereas a predominance of Pelargonidin 3-rhamnosyl glucoside resulted in coral to orange. Another pigment flavone which is present in large and variable amounts was characterised; but not demonstrated to have a modifying effect on cyanic shades.

Henny *et al.* (1988)inferred that the hybrid 'Southern Blush' produced through interspecific hybridization, had a medium pink spathe and with a slight lavender tint.

Kamemoto *et al.* (1988) after detailed analysis on the genetics of spathe colour in anthuriums concluded that two major genes, M and O were responsible for the five major colours : red, orange, pink, coral and white. The dosages of M and O genes affect colours. The gene M was found to control the production of cyanidin 3-rutinoside while the gene O controlled pelargonidin 3-rutinoside. Red and Pink resulted when both M and O genes are present with pink being the double

heterozygote and orange and coral resulted when only O gene was present. White colour was produced in double recessive condition (mmoo). The recessive oo is epistatic to M, and therefore white resulted when both were recessive (mmoo) or M was in combination with recessive oo (MMoo, Mmoo). Orange and white were found to be true breeding. The incremental effects of M was greater than that of 0, and therefore the intensity of colours decreased from MMOO, MMOo, MmOO to MmOo. Orange is mmOO and coral is mmOo.

Criley (1989) grouped the colours of the important cultivars and new introductions in Hawaii according to the Royal Horticultural Society colour chart.

Wannakrairoj and Kamemoto (1990) while studying the inheritance of purple spathe in anthurium, proposed a scheme for the genetic control of purple spathe colour. A recessive allele 'P' modified the colour of anthocyanins controlled by M and O loci ie., recessive epistasis. They observed that a spathe was purple when the genotype was M-O-pp. If the 'P' locus was dominant, M-O-PP was red, while mmOO-pp was orange and mmO-PP was coral. The 'P' allele has no effect on the white genotypes whether it is dominant or recessive.

Mercy and Dale (1994) were of the opinion that colour of spathe fades gradually as flower gets older. After fertilization of candle, the spathe becomes gradually green and photosynthetic. They also reported that spathe colours varied from white to pink to coral to orange to brown to red to crimson to deep maroon and some varieties had spathes of two or more colours.

Sindhu (1995) observed that the dark and brightly coloured flowers, which are commercially important were produced by the varieties 'Chilli Red' and 'Kalympong Red'.

Abdussammed (1999) observed that the anthocyanin content of *Anthurium* cv. 'Hawaiian Red' was significantly altered under different levels of growth

regulators and nutrient treatments. The highest value for anthocyanin content in ground and pot for nutrient were 85.07 mg/g and 93.9 mg/g respectively, while for growth regulators the values were 67.88 mg/g and 84.18 mg/g respectively.

Henny (1999) described that the new anthurium hybrid 'Red Hot' had spathes that were medium red at anthesis, which later changed to a lighter red prior to senescence.

Nirmala *et al.* (1999) reported that the relative concentrations of cyanidin and pelargonidin affects the spathe colour. They concluded that it is very difficult to relate the visible colour with anthocyanin in the spathe. Indian Institute of Horticulture Research grouped the genotypes into 4 groups (Red, orange, coral and white) based on the presence of cyanidin and pelargonidin along with an unknown pigment. Renu (2000) grouped the spathe colour of ten varieties into deep maroon to dark red, red, light orange to dark orange, light green and white.

Mayadevi (2001) inferred that anthocyanins contribute various colours to spathe from deep maroon to light pink. Red coloured varieties showed variation from dark red (CR) and (KR) to red (HR). The mean total anthocyanin content ranged from 121.38 mg/g in Pink to 386.56 mg/g in 'Liver Red' in the parents while the range of this character was from 146.03 mg/g (HR x LR) to 330.95 mg/g (KR x CR) in the hybrids. Based on the anthocyanin contents, the probable spathe colour genotypes of five parents and their F_1 hybrids have been worked out for the first time in anthurium by correlating the total average anthocyanin content of the spathe of each variety to the incremental effect of the two anthocyanin producing genes, M and O.

2.23 SPATHE TEXTURE

A blistered crickled spathe texture is commercially preferred over a smooth spathe as the former is much more visually attractive.

According to Birdsey (1956), Linden described the spathe of *Anthurium andreanum* and its varying degrees of smoothness and blistering.

Arndt (1991) reported that the spathe of *A. scherzerianum* variety 'Arabella' as, broad with free lobes and a shallow sinus. Mercy and Dale (1994) suggested that the spathe in floral anthuriums may be smooth, thick and glossy without prominent veins or it may be thinner, deeply veined and blistered.

Sindhu (1995) observed that the variety 'Honeymoon Red' had smooth, thick and glossy spathes without prominent veins while 'Pink' and 'White' had smooth, thin and lightly veined spathes. Intermediate spathe texture and deep to shallow blisters were observed in varieties 'Kalympong Red', 'Kalympong Orange' and 'Chilli Red'.

Renu (2000) described the spathe texture in ten varieties of anthurium as thick smooth glossy, thin smooth glossy, thin shallowly blistered glossy, medium thick shallow blistered glossy, thick medium blistered glossy and thick deeply blistered glossy.

Mayadevi (2001) while studying 5 parents and 10 F_1, hybrids in anthurium noticed thick smooth and glossy spathe texture for 'Liver Red' and 'Honeymoon Red', medium thick smooth spathes for 'Pink' and thick deeply blistered glossy spathes for 'Kalympong Red' and 'Chilli Red' among the parents. Thick smooth and glossy spathes were observed for HR x P, HR x LR, P x CR and KR x CR. Medium thick blistered and glossy spathes for HR x CR and P x LR. P x KR and LR x CR showed thick medium blistered glossy spathes.

2.24 CANDLE COLOUR

In non-commercial and semi-commercial varieties like 'Honeymoon Red', 'Pink', 'White' etc., candles of single solid colours are usually seen. However most of the new hybrid varieties have double coloured candles.

Gajek and Schwarz (1980) identified the anthurium variety 'Iga Gold' with shiny red spathe and a white candle with yellow tip and variety 'Ellrina' with light salmon spathe and sulphur yellow spadix to be the best suited for green house cultivation.

Arndt (1991) observed *A. scherzerianum* var. 'Arabella' had red spathe and candle. Mercy and Dale (1994) in their observations revealed that the candle had a single colour red, pink or green in ordinary anthurium varieties and hybrids had candles with yellow, white, pink or red colour in two or more bands.

Sindhu (1995) reported that the six varieties studied had candles with either a single colour or two bands of colours. Henny (1999) reported that the new anthurium hybrid 'Red Hot' had candle which is orange-red apically, blending to red basally.

Renu (2000) in her study on ten varieties of *A. andreanum* observed that the candle had a single colour of pink, light pink, yellow, light yellow, green and light green.

Mayadevi (2001) while studying the divergence of hundred genotypes observed candle colours of red, light red, pink, light pink, yellow, yellowish white, white and cream.

2.25 TYPE OF INFLORESCENCE AXIS

The nature of inflorescence axis is one of the most important factors that determines the appearance and hence the value of anthurium flowers, when marketed as cut flowers.

Mercy and Dale (1994) suggested that good anthurium hybrids should have short and straight inflorescence axis. Mayadevi (2001) reported that among the

five parents and 10 F_1 studied, the axis nature varied from long, straight and very strong in all the parents and hybrids except for the parent variety KR in which it is long, thin and slightly curving.

2.26 POLLEN EMERGENCE PATTERN

In *A. andreanum* anthesis occurs on sunny days between 8 to 10 a.m. and on cloudy and rainy days anther dehiscence is delayed (Mercy and Dale, 1994). Sindhu (1995) observed that the interphase was prolonged with the suppression of male phase from March to August.

Renu (2000) revealed that anther dehisence occurred in the early morning hours between 8 and 10 a.m. Pollen emergence pattern during the period of one year from August, 1998 to July, 1999 were analysed using Cochrans Q test for quality of proportion. The value of Q was found to be significant which showed that there was significant difference among the varieties with respect to pollen emergence pattern. No pollen emergence was recorded for the varieties 'Pompon Red', 'Nitta Orange' and 'Midori Green' during that year. Also the emergence of pollen was found to follow a regular pattern in all the varieties except 'Merengue White'. In all the varieties, the pollen emergence was low in the months from March to June, during which the average maximum and minimum temperature were higher than the rest of the months. Pollen emergence was highest during October - November - December months.

2.27 STAGE OF HARVEST

The 'flowers' are harvested after the unfolding of the spathe is complete. The appearance of female phase on the spadix is also used as a criterion for harvesting the inflorescence.

According to Kamemoto (1962) 'flowers' are cut at the leaf axil when one third to three quarters of the bisexual flowers embedded in the fleshy spadix are open.

Antoine (1994) opined that the 'flowers' are harvested in the morning with their long stalks and most blooms are harvested at about three quarters maturity because at this time it is believed that they have the longest shelf life as cut flower.

The spadix are cut for sale along with their long stalks when the spathes are fully opened and the candles show about one third to two third, female phase maturity, mostly around 7-10 days after spathe opening (Mercy and Dale, 1994).

Prasad *et al.* (1996) reported that anthurium 'flowers' are harvested when the spathe completely unfurls and the spadix is well developed. When one-third of the true flowers on the spadix mature, a change of colour can be observed that moves from base to tip of the spadix and at that stage, the flowers are harvested.

Salvi (1997) observed that in inflorescence having 1/3 rd flowers opened on spadix, the spathe blueing and gloss loss were late (20.0 and 22.3 days, respectively) and it also had the longest vase life (23.33 days).

Singh (1998) had specified that anthurium flowers are harvested when three quarters of the stigmas along the spadix have become receptive.

2.28 COMPATIBILITY STUDIES

Kamemoto and Nakasone (1955) suggested that hybridization and selection were the common methods for improving anthuriums. They identified that character to be selected were flower productivity, spathe colour, shape and texture, short internodes and suckering ability. Controlled hybridization indicated that neither white nor red flower colour exhibited dominance and pink was an intermediate heterozygous condition.

Several workers (Kamemoto and Nakasone, 1955, 1963; Kamemoto *et al.* 1969) studied spathe colour inheritance in *Anthurium andreanum* based on intraspecific and interspecific hybridization.

Birdsey (1956) attributed much of the variation in blistering pattern of spathes of *A. andreanum* to hybridization of this species with *A. lindenianum*, *A. ornatum* and *A. nymphaefolium* and suggested the name *A. cultorum* to highlight the hybrid character.

Selection has been widely used as a method to develop suitable cultivars in the major anthurium producing countries. Of 113 clones evaluated by Kamemoto and Nakasone (1963), 13 were recommended for commercial cut flower production. Two cultivars ie., 'Uniwai' (an exceptionally high yielding White) and 'Marian Seefurth' with a rose coloured spathe were evolved by clonal selection. They also postulated that the inheritance of spathe colour was under the control of multiple alleles and modifying genes. The presence of both the orange and magenta pigments in the pink cultivar, 'Marian Seefurth' which arose from nine crosses between a white clone and a pink clone, substantiates the hypothesis that separate genes designated as M and O are responsible for the production of magenta and orange pigments respectively.

Two seedlings selections, 'Anuenue' and 'Chameleon' for cut flower production and a compact clone 'Red Elf' suitable for pot growing were described by Kamemoto *et al.* (1969).

Sheffer and Kamemoto (1976) evaluated the interspecific cross compatibilities among 56 species of *Anthurium* and concluded that interspecific hybrids with *A. andreanum* and *A. scherzerianum* were not readily obtainable. But they got hybrids of *A. andreanum* with six other closely related species.

Sheffer and Kamemoto (1977) noticed good cross compatibility among *A. andreanum*, *A. nymphaefolium* and *A. pinchinchae*. Using this, they developed some cultivars, all of which successfully flowered.

Kamemoto and Sheffer (1978) developed a new species hybrid, with a greyish - orange spathe from the cross *A. scherzerianum* x *A. wendlingerii*, characteristics such as the length and coil of the spadix and the position of the leaf blade were intermediate between the highly contrasting characteristics of the two parental species. Fertility in the hybrid was good, indicating the relatively close taxonomic relationship of the two species.

Kaneko and Kamemoto (1978) revealed that the chromosome numbers 2n=30 for *A. andreanum* Linden 'Kaumana' and 2n=30+2B for *A. uniwai*. Meiotic configurations in pollen mother cells were similar for both, with exception of 2B chromosomes in the latter. They concluded that meiotic irregularities suggested a hybrid orgin for cultivated anthuriums.

Kaneko and Kamemoto (1979) found that chromosome of *Anthurium* species was 2n = 30 + 2B. They informed that the appearance of off-springs with 2,3 and 4B chromosomes, on self pollination, indicated the transmission of B chromosomes through both pollen and egg.

Based on the evaluation trial, Leeuwen (1984) identified the anthurium cultivars 'Avo-nette', 'Avo-tineko', 'Favoriet', 'Germa', 'Avo-claudia', 'Avo-Ingrid', 'Nova-Aurora', 'Avo-Jose', 'Jamaica', 'Hoenette', 'Sarina' and 'Avo-Anueke' to be the best.

Zimmer (1986) while reviewing the problems in the development of anthurium cultivars, noticed in *A. scherzerianum*, first inflorescence appreared 12-15 months after sowing, but began flowering regularly only after 18-24 months. The spadix seldom had full fruit set. Berries contained 2-3 seeds and ripening took 5-12 months. The species was highly variable and cultivar selection was made from F_1 plants. Tissue culture from selected genotypes took 4-5 months to form plantlets. He added that the selection of a promising genotype took 10-12 years.

Henny *et al.* (1988) obtained 'Southern Blush', a hybrid for foliage producers through interspecific hybridization of a large pink flowered *Anthurium andreanum* with *A. amnicola* [(a dwarf species collected from Costa Rica, which is very floriferous but bears small lavender spathe (nearly more than 2 cm long)]. 'Southern Blush' was intermediate in size between its parents, spathes were about 7.0 cm long and 5.0 cm wide and were medium pink with a slight lavender tint.

Kamemoto *et al.* (1988) described the major spathe colours in *Anthurium andreanum* as red, orange, pink, coral and white, were controlled by two major genes M and O. They found that crosses between two pink produced offsprings in the ratio of 9 red to Pink : 3 orange to Coral : 4 white. They concluded that coral was heterozygous for O and recessive for m. Crosses between two corals gave 3 orange to coral : 1 White. Pink crossed to a coral can be expected to give a ratio of 3 red to pink : 3 orange to coral : 2 white. Pink crossed to a double recessive white gave 1 pink : 1 coral : 2 white. Based on these observations they gave the genotypes of major colours as MMOO, MMOo and MmOO for red, MmOo for Pink, mmOO for orange, mmOo for coral and MMoo, Mmoo and mmoo for white. Orange and white types breed true.

Marutani *et al.* (1993) from their detailed cytological analysis of *Anthurium andreanum,* its related taxa and their hybrids concluded that regular bivalent formation at prometaphase I of meiosis in pollen mother cells of species hybrids suggested close genomic relationship among parental taxa. On the other hand, reduction in pollen fertility estimated by the pollen stainability in those hybrids suggested genetic divergence of the species.

All the five commercial varieties studied by Bindu and Mercy (1994) showed a somatic chromosome number of 30+2B. The B chromosomes are either acentric or telocentric.

Kuehnle *et al.* (1994) produced F_1 hybrids of *Anthurium andreanum* and *A. antioquiense* resistant to bacterial pathogens. They concluded that production of superior cultivars will take many year as it is a perennial crop.

Mercy and Dale (1994) opined that hybridization between selected varieties with good combing ability can produce novel and valuable anthurium hybrids. They also added, a commercial variety should have small to medium sized leaves, extensive root system, short internodes, strong and straight inflorescence and short, thin and downward curving candles.

Compatibility analysis by Sindhu (1995) revealed that a large number of combinations were incompatible. The maximum percentage of fruits (52.3) was harvested from the cross P x HR. Among the 24 combinations obtained, HR x P and P x HR were found to show the highest compatibility. The duration of fruit maturity ranged from 4.5 to 8.0 months.

Oglesby Plant Laboratory Inc. (1996) described an anthurium variety 'Ruth Morat' syn. 'Lady Ruth' as a derivative from the cross *A. antioquiense* x *A. rotolante* 1. This hybrid had spathes larger than those of variety 'Lady Jane' with a mean width and length of 50.1 and 76.8 mm respectively.

Anthura Company (1997) submitted for registration, an anthurium variety 'Champion', derived from *A. andreanum* hybrids. This variety had small leaves and flowers with cupped white spathe held above the canopy and red spadix.

Henny (1999) explained the new interspecific anthurium hybrid 'Red Hot' as highly suitable for pot planting because of its compact growth, freely branching growth habit and production of numerous showy red spathes. The variety 'Red Hot' originated from hybridisation of *A. amnicola*. Dressler, a dwarf species with small lavender spathes and a naturally clumping growth habit, with an unnamed selection of *A. andreaum* (accession code G-79) that

had pink spathes. One of the F_1 hybrids that resulted was designated as the female parent and crossed with anthurium variety 'Lady Jane' to produce the progeny, from which 'Red Hot' was selected.

Renu (2000) studied the cross compatibility between ten varieties based on the percentage of candles bearing fruits, fruit set and seed germination. The percentage of fruit bearing candles were highest for variety 'Nitta Orange' (51.93) and lowest for variety 'Mauritius Orange' (9.51). The percentage of fruit set was below 50 for all the crosses except for 'Pompon Red' and 'Liver Red'. The cross involving variety 'Pompon Red' as female had the highest percentage of fruit set. Seed germination was highest (87.5%) for the cross 'Dragons Tongue' x 'Merengue White'. Scoring of the compatibility reactions based on fruiting candles, fruit set and seed germination, on a scale ranging from 0 to 9, showed the highest compatibility score for Pompon Red x Liver Red (PR x LR) and 'Ceylon Red x 'Merengue White' (CR x MW) crosses. The best female parents were found to be varieties 'Nitta Orange', 'Liver Red' and 'Pompon Red'. Varieties 'Ceylon Red', 'Merengue White' and 'Liver Red' performed well as pollen parents. The varieties 'Ceylon Red' and 'Liver Red' performed well both as female and male parent.

Compatibility was estimated using the data on the percentage of candles bearing fruits, fruit set/candle and germination of seeds.

2.28.1 Percentage of Candles Bearing Fruits

The 1592 pollinations done by Sheffer and Kamemoto (1976) included 20 selfs, 19 intraspecific cross combination, 315 intra group interspecific cross combinations (including reciprocals) and 29 different intragroup cross combinations (including reciprocals). The species were divided into six distinct morphological groups on the basis of important Englerian characters of the number of ovule per locule, colour and shape of the berry, shape of inflorescence,

shape and texture of the leaf. Group I and II were separated on the basis of the number of ovules per locule. Group III and IV were Engler's section Pachynerium and Schizoplacium respectively. The remaining species were included under groups V and VI and were organised into two groups on the basis of leaf texture, berry shape and colour. Intra and intergroup pollinations were done, fruits harvested and germinating seeds obtained.

Self pollination resulted in 81 per cent fruiting spadices, intra-specific and interspecific cross combination resulted in 65.4 per cent and 28.1 per cent fruiting spadices respectively.

Group II, III and V gave higher percentage of fruiting spadices and flowering hybrids than group I, probably due to the range of chromosome numbers found in the species included in this group. The presence of B-chromosomes also affected the viability (Bhattaglia, 1964, Sheffer and Kamemoto, 1976a).

The high degree of cross compatibility in group V indicated their relatively close relationship. The lowest percentage of fruits harvested and hybrids flowered were obtained in group VI, the most morphological diverse of the groups. Only a single flowering hybrid progeny was obtained from the intergroup cross of VI x IV (*A. triangulum* x *A. digitatum*). This successful cross suggested the possible misplacement of *A. triangulum*, since flowering hybrids were not obtained between this species and others within group VI. This cross produced a vigorous sterile hybrid, but the reciprocal cross resulted in weak seedlings which died early.

All the six varieties of *A. andreanum* studied by Sindhu (1995) *viz.*, 'Honeymoon Red', 'Chilli Red', 'Kalympong Orange', 'Kalympong Red', 'Pink' and 'White', showed good percentage of candle bearing fruits. This percentage was maximum (93) for the variety 'White' and lowest (50) for the variety 'Kalympong Red'.

Based on the results of intervarietal hybridisation done using ten varieties of *A. andreanum*, Renu (2000) observed that the percentage of fruit bearing candles was highest (51.93) for 'Nitta Orange' and lowest (9.51) for 'Mauritius Orange'. The only two selfings that produced fruiting candles were for varieties 'Liver Red' and 'Dragon's Tongue'.

2.28.2 Number of Fruits / Candle

Zimmer (1986) studied the problem in the development of anthurium cultivars and identified the absence of full fruit set in spadix. He also inferred that the period of 5-12 months taken for fruit ripening also was an impediment.

Mercy and Dale (1994) observed that in a well fertilized candle, about 100-200 or more berries developed. A candle with developing fruits could be visually identified from the second month of fertilization, as it became swollen and fleshy with developing fruits embedded in it. In about eight weeks, tip of the berries started projecting out like small pin heads.

Among the varieties studied by Sindhu (1995), the maximum average number of fruits was produced in 'Pink' followed by 'Honeymoon Red'. The lowest number of fruits was obtained from 'Kalympong Red'. The maximum number of fruits (170) was harvested from the cross 'Pink' x 'Honeymoon Red' and the lowest number (2) from 'Kalympong Red' x 'Kalympong Red'.

Renu (2000) studied cross compatibility using ten varieties and observed that the number of fruits per candle ranged from 5 to 183. The variety 'Pompon Red' had the highest average number of fruits per candle and it was lowest for 'Lady Jane'.

2.28.3 Percentage of Fruit Set / Candle

Among the six varieties studied by Sindhu (1995), the maximum percentage fruit set (52.3) was observed for the cross 'Pink' x 'Honeymoon Red'

followed by its reciprocal (44.3). The lowest percentage of fruit set (0.4) was observed in selfing of 'Kalympong Red'.

Renu (2000) noticed that the percentage of fruit set was below 50 per cent for all the crosses involving ten varieties of *A. andreanum* except 'Pompon Red' x 'Liver Red'. The cross involving 'Pompon Red' as female parent had the highest percentage of fruit set.

2.29 NUMBER OF SEEDS / BERRY

In anthurium the spadix seldom had full fruit set. Berries contained usually one or two or nearly three seeds and for ripening it took 5-10 months (Zimmer, 1986).

Geier (1989) reported that time required from pollination to the maturity of seeds was about 6-7 months for *A. andreanum* and 10-12 months for *A. scherzerianum*

Mercy and Dale (1994) observed that in the commercial varieties of *Anthurium andreanum*, each berry contained one or two seeds and the seeds matured in about 4 to 7½ months. Seeds remain enclosed within the thin fruit wall in a gelatinous pulp and if not harvested will remain attached to the candle for a few days more before they dry up and fall off the candle.

Sindhu (1995) studied the six varieties of *A. andreanum* and observed that the percentage of single seeds produced was more than the double seeds except in the cross involving varieties 'Kalympong Red' x 'Honeymoon Red', where the percentage of double seed was 63. The percentage of single seeds ranged from 37 to 100.

2.30 PERCENTAGE GERMINATION OF SEEDS

Zimmer and Bahnemann (1982) reported that the *A. scherzerianum* seeds from different sources varied in their ability to germinate at low, sub-optimal

temperatures. Optimum germination temperature was found to be 20-25°C, but some seeds germinated well at 10 to 15°C.

Criley (1989) reported that, in anthurium, the pulp was removed from ripe berries in water and the seeds were sown immediately on the surface of a damp medium and placed under 80 per cent shade in conditions of high humidity. The germination proceeded within 14 days.

Szendel *et al.* (1992) found that the seeds of *A. andreanum* harvested at three maturity stages and those of *A. scherzerianum* at one maturity stage (light orange) were allowed to germinate on 3 substrates, at pH ranging from 4 to 8 in light or darkness and at temperatures of 18, 24 and 28°C. In *A. andreanum* the best germination was obtained on high peat substrate, at pH 4-5 in light at 28°C using seeds harvested at an early maturity stage (yellow-green to orange).

According to Mercy and Dale (1994) the hybrid seeds from crosses between ordinary hardy varieties of *A. andreanum* had above 90 per cent germination and their seedlings showed high survival fitness and vigour. Seeds produced in crosses between exotic varieties were smaller in size and poor in germination.

Sindhu (1995) with ten varieties of *A. andreanum* concluded that the maximum average seed germination was observed in combinations with the variety 'White' as the female parent (63.4 %) and the lowest germination in the variety 'Kalympong Orange'. Highest germination percentage among the crosses was recorded for the cross 'Honeymoon Red' x 'Chilli Red' (78 %).

In the compatibility study Renu (2000) recorded that the seed germination was highest (87.5 %) in 'Dragon's Tongue' x 'Merengue White'. Seed germination percentage varied from 69 per cent in 'Tropical Red' to 2.3 per cent in 'Midori Green' among the varieties.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was undertaken to estimate the genetic variability of fifty genotypes of anthurium based on multiple characters (morphological and floral) for the selection of superior genotypes. The investigation was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2000-2002.

3.1 MATERIALS

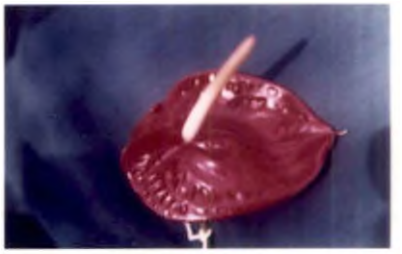
The following fifty genotypes of anthurium showing variations in spathe colour, shape, size and other commercially valuable morphological characters, generated through hybridization in NARP(SR) project available in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani were utilized for the study (Plate 1). Genotypes (Plates 2 to 6) selected were:

1. 'Mauritius Orange' x 'Liver Red' [MO x LR]
2. 'Mauritius Orange' x 'Kalympong Red (1)' [MO x KR(1)]
3. 'Mauritius Orange' x 'Kalympong Orange (2)' [MO x KR(2)]
4. 'Kalympong Orange' x 'Chilli Red' [KO x CR]
5. 'Kalympong Orange' x 'Liver Red' [KO x LR]
6. 'Kalympong Orange' x 'Dragon's Tongue Red' [KO x DT]
7. 'Kalympong Red' x 'Dragon's Tongue Red' [KR x DT]
8. 'Kalympong Red' x 'Liver Red' [KR x LR]
9. 'Kalympong Red' x 'Chilli Red' [KR x CR]
10. 'Liver Red' x 'Dragon's Tongue Red' [LR x DT]
11. 'Liver Red' x 'Pompon Red' [LR x PR]

Plate 1. General View of the Experimental field

12. 'Liver Red' x 'Fla Red' [LR x FR]
13. 'Nitta Orange' x 'Tropical Red' [NO x TR]
14. 'Nitta Orange' x 'Pompon Red' [NO x PR]
15. 'Nitta Orange' x 'Dragon's Tongue Red' [NO x DT]
16. 'Nitta Orange' x 'Chilli Red' [NO x CR]
17. 'Nitta Orange' x 'Liver Red (1)' [NO x LR(1)]
18. 'Nitta Orange' x 'Liver Red (2)' [NO x LR(2)]
19. 'Orange Glory' x 'Kalympong Red' [OG x KR]
20. 'Orange Glory' x 'Liver Red' [OG x LR]
21. 'Orange Glory' x 'Dragon's Tongue Red' [OG x DT]
22. 'Honeymoon Red' x 'Lima White' [HR x LW]
23. 'Fla Red' x 'Chilli Red (1)' [FR x CR(1)]
24. 'Fla Red' x 'Chilli Red (2)' [FR x CR(2)]
25. 'Fla Red' x 'Dragon's Tongue Red (1)' [FR x DT(1)]
26. 'Fla Red' x 'Dragon's Tongue Red (2)' [FR x DT(2)]
27. 'Fla Red' x 'Kalympong Red' [FR x KR]
28. 'Fla Red' x 'Liver Red' [FR x LR]
29. 'Fla Red' x 'Merengue White (1)' [FR x MW(1)]
30. 'Fla Red' x 'Merengue White (2)' [FR x MW(2)]
31. 'Merengue White' x 'Fla Red (1)' [MW x FR(1)]
32. 'Merengue White' x 'Fla Red (2)' [MW x FR(2)]
33. 'Merengue White' x 'Pompon Red' [MW x PR]
34. 'Merengue White' x 'Dragon's Tongue Red' [MW x DT]
35. 'Tropical Red' x 'Merengue White' [TR x MW]
36. 'Lady Jane' x 'Merengue White' [LJ x MW]
37. 'Pompon Red' x 'Kalympong Red' [PR x KR]
38. 'Pompon Red' x 'Mauritius Orange' [PR x MO]
39. 'Pompon Red' x 'Dragon's Tongue Red' [PR x DT]
40. 'Pompon Red' x 'Orange Glory' [PR x OG]
41. 'Pompon Red' x 'Merengue White' [PR x MW]

MO × LR



KR × DT

MO × KR(1)

KR × LR

MO × KR(2)

KR × CR

KO × CR

KR × CR

KO × LR

LR × DT

Plate 2. Different Genotypes of *Anthurium andreanum*

42. 'Pompon Red' x 'Liver Red (1)' [PR x LR(1)]
43. 'Pompon Red' x 'Liver Red (2)' [PR x LR(2)]
44. 'Pompon Red' x 'Liver Red (3)' [PR x LR(3)]
45. 'Pompon Red' x 'Fla Red (1)' [PR x FR(1)]
46. 'Pompon Red' x 'Fla Red (2)' [PR x FR(2)]
47. 'Pompon Red' x 'Fla Red (3)' [PR x FR(3)]
48. 'Pompon Red' x 'Fla Red (4)' [PR x FR(4)]
49. 'Dragon's Tongue Red' x 'Kalympong Red' [DT x KR]
50. 'Dragon's Tongue Red' x 'Fla Red' [DT x FR]

3.2 METHODS

The selected plants of the above fifty genotypes were raised in pot culture experiment in a completely randomised design with three replications.

The bottom one third of each pot was filled with broken bricks and the middle one third portion was filled with a mixture of coarse sand, broken bricks, dried coconut husk pieces and charcoal mixed in 7:1:1:1 ratio, respectively. The plants with well developed roots were placed over this and the plants anchored with more potting mixture. Coarse sand was used in the potting medium and the method of planting ensured 100 per cent drainage.

Artificial shade of 75 per cent was provided with black polypropylene agro-shade netting. Mist irrigation was provided two to three times each day depending on temperature conditions.

Regular application of fertilizers were given at weekly intervals. NPK mixture 17:17:17 was applied at a strength of 5g/l as aqueous solution once in a month. Additional nutrients like diluted cowdung water and fermented and diluted groundnut - neem cake mixture were given once in a month. For

LR × PR

NO × CR

LR × FR

NO × LR(1)

NO × TR

NO × LR(2)

NO × PR

OG × KR

NO × DT

OG × LR

Plate 3. Different Genotypes of *Anthurium andreanum*

preparing the latter 2 kg of groundnut cake and 4 kg of neem cake were fermented in 5 litres of water for two days. The mixture was then diluted by adding 245 litres by very dilute cowdung water. About 200 ml of the seived fertilizer solution was then applied to each pot.

Plant protection measures undertaken were as follows:

1. For the control of blight / anthracnose by *Colletotrichum gleosporioides* regular application of any of the following chemicals were used.

   a) Bavistin 50 per cent WP @ 2g/litre or

   b) Indofil M-45 @ 2g/litre

2. Need based application of Streptocycline @ 0.05 g/litre were given to control the bacterial blight caused by *Xanthomonas axonopodis* pv. *dieffenbachiae*.

3. Dusting of BHC 50 per cent WP was adopted against termites and ants.

4. Need based applications of Metacid (2g/l) or Nuvacron (2g/l) were used to control leaf feeding caterpillars and grass hoppers. Mites were controlled by using Kelthane (2ml/l).

5. Snails and slugs were collected by picking by hand and also by the application of Furadan 3 G @ 2-3 g/pot.

3.2.1 Morphological Studies

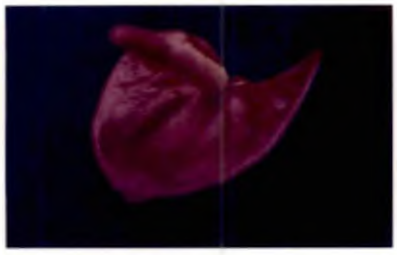
The plant materials with stabilised vegetative and floral characters were used for taking all observations. Observations on the following twenty three characters (Vegetative, floral and qualitative) were recorded and their mean values were taken.

OG × DT

FR × DT(2)

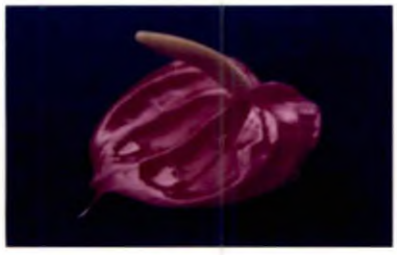
HR × LW

FR × KR



FR × CR(1)

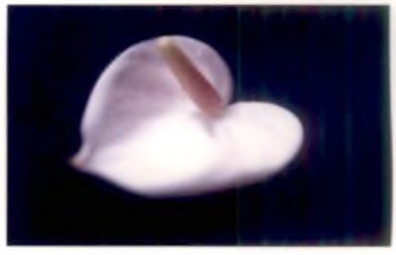
FR × LR



FR × CR(2)

FR × MW(1)

FR × DT(1)



FR × MW(2)

Plate 4. Different Genotypes of *Anthurium andreanum*

3.2.1.1 Vegetative Characters

3.2.1.1.1 Plant Height

Plant height in centimeters were recorded from the base of the plant to the top of the top most leaf.

3.2.1.1.2 Internode Length

The distance between two nodes was measured from the base of the plant and recorded in centimeters.

3.2.1.1.3 Suckering Ability

The ability of the plant to produce new suckers from the base of the mother plant was observed and the number of suckers was recorded.

3.2.1.1.4 Leaf Area

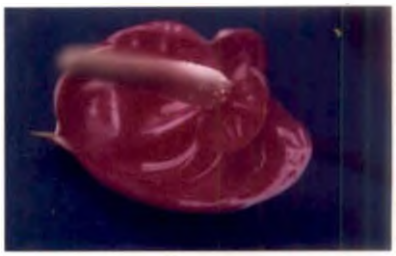
The maximum length and breadth of the third leaf were used for the estimation of leaf area. The third leaf was chosen as this would be the leaf which will be fully unfurled and has achieved its full growth and spread of the leaf blade.

The leaf area of fifty genotypes were measured by applying linear regression.

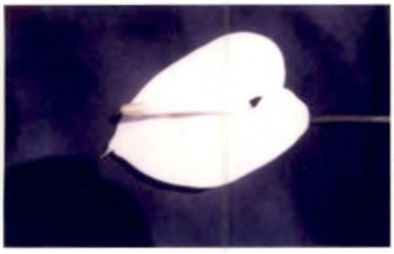
$Y = 9.53 + 0.64\ x$ (Mayadevi, 2001)

where, x = maximum leaf length x maximum leaf breadth

MW × FR(1)



LJ × MW



MW × FR(2)

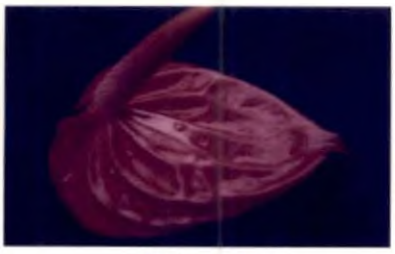
PR × KR

MW × PR

PR × MO

MW × DT

PR × DT

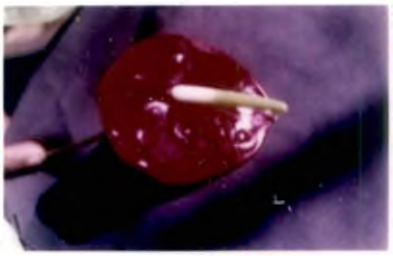


TR × MW

PR × OG

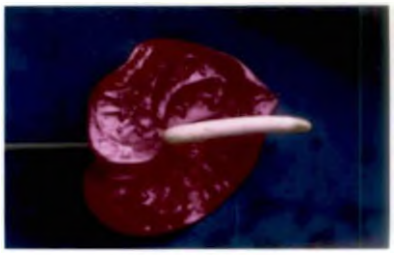
Plate 5. Different Genotypes of *Anthurium andreanum*

PR × MW



PR × FR(2)

PR × LR(1)



PR × FR(3)

PR × LR(2)

PR × FR(4)

PR × LR(3)

DT × KR

PR × FR(1)

DT × FR

Plate 6. Different Genotypes of *Anthurium andreanum*

3.2.1.2.1.6 Life of Spadix / Longevity of Spadix

The period between the first day of emergence of inflorescence upto the time of its yellowing, withering of spathe and shrivelling of candle was recorded as the life of spadix or the longevity of spadix.

3.2.1.2.1.7 Days to Initiation of Female Phase

The number of days from the emergence of the spathe to the first emergence of mature stigmas of the basal flowers, identified by the presence of honey dew or stigmatic droplets was recorded as the days to initiation of female phase.

3.2.1.2.1.8 Duration of Female Phase

The number of days of stigmatic receptivity of the spadix, which is the period between the emergence of stigmas in the basal flowers to the top most flowers, was recorded.

3.2.1.2.1.9 Days of Interphase

The duration between the end of female phase and the emergence of anthers from the basal flowers, indicating the start of male phase, was recorded as the days of interphase.

3.2.1.2.1.10 Duration of Male Phase

The period in days for the emergence of the first anthers in the spadix to the emergence of its last anthers was recorded.

3.2.1.2.1.11 Pollen Fertility

Pollen fertility was assessed using acetocarmine staining method. Pollen grains were collected during the male phase from all the genotypes and stained with 1:1 glycerine - acetocarmine stain (2 %). Five slides were made for each genotype and from each slide, ten microscopic fields were scored and the data recorded. Unstained, undersized, partially stained and shrivelled pollen grains were scored as sterile while the uniformly stained, properly filled pollen as fertile. Fertility of each genotype was estimated as percentage of the number of fertile pollen grains to the total number of pollen grains scored.

Pollen fertility was calculated as,

$$\text{Pollen fertility} = \frac{\text{No. of well filled and uniformly stained pollen grains}}{\text{Total number of pollen grains}} \times 100$$

3.2.1.2.1.12 Estimation of Total Anthocyanin

Estimation of anthocyanin was done as per the method described by Rangana (1977). The initial step was alcoholic extraction of the plant material (spathe). One gram of the spathe sample from each genotype was extracted with ethanolic hydrochloric acid, filtered through a Buchner funnel using Whatman No.1 filter paper and the filtrate was then diluted with ethanolic hydrochloric acid to 50 ml to yield optical density values within the optimum range of the spectrophotometer (535 nm). The anthocyanin content was then calculated using the following relationship and the quantity was expressed as mg/100 gm of the sample.

Total OD per 100g of sample (x) = [(Absorbance at 535nm) x (Volume made up of the extract used for colour development) x (Total volume) x 100] ÷ [Volume {ml of the extract) used x Weight of sample taken]

The absorbance of a solution containing 1 mg per ml is equal to 98.2 (constant).

Therefore,

$$\text{Total anthocyanin in mg per 100 g of the sample} = \frac{x}{98.2}$$

3.2.1.2.2 Qualitative Characters

3.2.1.2.2.1 Colour of Young Leaf and Petiole

The young leaf colour and petiole colour of each genotypes were recorded by visual observation when the leaves were not opened fully.

3.2.1.2.2.2 Plant Type

Plant type was recorded for each genotype by visual observation.

3.2.1.2.2.3 Spathe Colour

The spathe colour of each genotype was recorded by visual observation.

3.2.1.2.2.4 Spathe Texture

The degree of blistering, thickness of spathe, presence of veins and the glossiness of spathe were recorded to differentiate the spathe texture of each genotype.

3.2.1.2.2.5 Candle Colour

Visual observation was used to record the candle colours.

3.2.1.2.2.6 Type of Inflorescence Axis

Length, nature and strength of inflorescence axis in each genotype were observed and recorded.

3.2.2 Statistical Analysis

3.2.2.1 Biometrical Techniques Applied

Mean, variance, standard error and co-efficient of variation were the basic parameters estimated. The significance of the genotypic differences was tested through analysis of variance technique. The character associations were estimated through correlation coefficients using analysis of co-variance technique. Heritability co-efficient, genetic advance and selection index were estimated. The methodology in the estimation of the parameters are given below.

3.2.2.1.1 Analysis of Variance / Co-variance

With two characters X and Y measured on 'g' genotypes raised in completely randomised design with 'r' replications, the variance co-variance analysis (ANACOVA) is as follows :

Source	df	Mean square		
		X	Y	XY
Between genotypes	(g-1)	G_{xx}	G_{yy}	G_{xy}
Error	(r-1) (g-1)	E_{xx}	E_{yy}	E_{xy}

Estimates of components of variance and co-variance

Variance / co-varianace	Genotypic	Environmental	Phenotypic
X	$\sigma^2_{gx} = \frac{G_{xx} - E_{xx}}{r}$	$\sigma^2_{ex} = E_{xx}$	$\sigma^2_{px} = \sigma^2_{gx} + \sigma^2_{ex}$
Y	$\sigma^2_{gy} = \frac{G_{yy} - E_{yy}}{r}$	$\sigma^2_{ey} = E_{yy}$	$\sigma^2_{py} = \sigma^2_{gy} + \sigma^2_{ey}$
XY	$\sigma_{gxy} = \frac{G_{xy} - E_{xy}}{r}$	$\sigma_{exy} = E_{xy}$	$\sigma_{pxy} = \sigma_{gxy} + \sigma_{exy}$

3.2.2.1.2 Co-efficient of Variation

Phenotypic and genotypic coefficients of variation (PCV and GCV) for a trait X were estimated as:

$$GCV = \frac{\sigma_{gx}}{\bar{x}} \times 100$$

$$PCV = \frac{\sigma_{px}}{\bar{x}} \times 100$$

where,

σ_{gx} = Genotypic standard deviation

σ_{px} = Phenotypic standard deviation

$\bar{x}$ = Mean of the character under study

3.2.2.1.3 Heritability Coefficient and Genetic Advance

Heritability (H^2) in broad sense was estimated as the proportion of heritable component of variation.

$$\text{Heritability coefficient } H^2 = \frac{\sigma_{gx}^2}{\sigma_{px}^2} \times 100 \qquad \text{(Jain, 1982)}$$

$$\text{Genetic advance as percentage of mean (GA)} = \frac{kH^2\sigma_{px}}{\bar{x}} \times 100$$

where k is the selection differential whose value is 2.06 if five per cent selection is to be practised (Miller *et al.*, 1958).

3.2.2.1.4 Correlation Analysis

The correlation coefficients (phenotypic, genotypic and environmental) were worked out as

$$\text{Genotypic correlation } (r_{gxy}) = \frac{\sigma_{gxy}}{\sigma_{gx} \times \sigma_{gy}}$$

$$\text{Phenotypic correlation } (r_{pxy}) = \frac{\sigma_{pxy}}{\sigma_{px} \times \sigma_{py}}$$

$$\text{Environmental correlation } (r_{exy}) = \frac{\sigma_{exy}}{\sigma_{ex} \times \sigma_{ey}}$$

3.2.2.1.5 Path Coefficient Analysis

The direct and indirect effect of component characters on number of flowers per candle were estimated through path analysis technique (Wright, 1954 and Dewey and Lu, 1959).

Lenka and Mishra suggested the following scales for the categorization of direct and indirect effects.

Scale			Category
0.00	to	0.09	Negligible
0.10	to	0.19	Low
0.20	to	0.29	Medium
0.30	to	0.99	High
		≥ 1.00	Very High

(Lenka and Mishra, 1973)

3.2.2.1.6 Selection Index

The various genotypes were discriminated based on 17 characters using the selection index developed by Smith (1947) based on the discriminant function of Fisher (1936).

The selection index is described by the function

$$I = b_1x_1 + b_2x_2 + ... + b_kx_k.$$

The function

$$H = a_1G_1 + a_2G_2 + ... + a_kG_k$$

describes the merit of a plant where x_1, x_2, ... x_k are the phenotypic values and G_1,G_2.... G_k are the genotypic values of the plant with respect to the characters x_1, x_2.... x_k. H denotes the genetic worth of the plant. The regression coefficients, b_1, b_2.... b_k are estimated in such a way that the correlation between H and I is maximum. The maximisation of the correlation will result to an equation of the form $\underset{\sim}{P}\underline{b} = \underset{\sim}{G}\underline{a}$ and hence $\underline{b} = \underset{\sim}{P}^{-1}\underset{\sim}{G}\underline{a}$, where P is the phenotypic and G is the genotypic variance covariance matrix respectively. The elements of vector $\underline{a}$ is assigned unit values.

RESULTS

4. RESULTS

Fifty genotypes of *Anthurium andreanum* were evaluated in green house, each genotype being replicated thrice. The data were statistically analysed and the results are presented in the following sub heads.

4.1 Evaluation of genotypes for their performance

4.2 Estimation of variability components

4.3 Estimation of heritability and genetic advance

4.4 Correlation among different characters

4.5 Path coefficient analysis

4.6 Selection index

4.1 EVALUATION OF GENOTYPES FOR THEIR PERFORMANCE

The analysis of variance revealed significant genotypic differences for all the characters studied and the results are furnished in Table 1. The mean performance of each of the fifty genotypes for vegetative, floral and qualitative characters are presented in Table 2 (a, b and c).

We tried to classify the genotypes into low, medium and high based on the area property of normal distribution as

Category	Criterion
Low	$< \bar{x} - 1.96\ \sigma_{n-1}$
Medium	Between $\bar{x} \pm 1.96\ \sigma_{n-1}$
High	$> \bar{x} + 1.96\ \sigma_{n-1}$

where, $\bar{x}$ is the mean

σ_{n-1} is the standard error of the mean

Table 1. Analysis of variance of vegetative (1-5) and floral (6-17) characters in 50 *Anthurium andreanum* genotypes

Sl. No.	Characters	Mean square	
		Genotypes	Error
	Degrees of freedom	49	100
1.	Plant height (cm)	280.64**	21.79
2.	Internode length (cm)	0.38**	1.64
3.	Suckering ability	0.83**	0.23
4.	Leaf area (cm^2)	8944.57**	172.80
5.	Days from emegence to maturity of leaves	123.62**	0.47
6.	Days from emergence to maturity of inflorescence	.50.84**	0.31
7.	Number of spadices/plant/year	2.14**	0.73
8.	Candle length (cm)	3.39**	0.19
9.	Inclination of candle to spathe (degrees)	932.44**	1.70
10.	Number of flowers/candle	30537.33**	109.48
11.	Life of spadix (days)	1250.01**	2.37
12.	Days to initiatin of female phase	5.92**	0.13
13.	Duration of female phase	7.12**	8.67
14.	Days of interphase	19.77**	0.15
15.	Duration of male phase	10.61**	0.25
16.	Pollen fertility (%)	315.31**	1.00
17.	Anthocyanin content (mg/g)	55394.65**	48.18

** - Significant at 1 per cent level * - Significant at 5 per cent level

Table 2(a). Vegetative character differentiation in *Anthurium andreanum* genotypes

Sl. No.	Genotypes	Plant height (cm)	Internode length (cm)	Suckering ability	Leaf area (cm^2)	Days from emergence to maturity of leaves
1.	MO x LR	39.27	1.27	1.67	128.73	30.33
2.	MO x KR(1)	36.90	1.37	2.00	170.28	18.33
3.	MO x KR(2)	40.10	1.57	2.33	124.45	29.33
4.	KO x CR	55.67	1.47	2.33	136.52	21.33
5.	KO x LR	42.33	1.60	2.67	126.30	30.00
6.	KO x DT	36.67	1.07	2.33	58.03	29.67
7.	KR x DT	45.90	1.80	1.67	180.45	24.33
8.	KR x LR	47.43	1.87	2.67	117.69	23.33
9.	KR x CR	49.23	2.43	2.67	227.98	29.00
10.	LR x DT	49.00	1.60	2.33	166.44	23.00
11.	LR x PR	64.80	2.43	2.33	174.06	35.67
12.	LR x FR	49.03	1.83	3.00	182.38	26.67
13.	NO x TR	40.43	1.77	1.67	119.86	24.00
14.	NO x PR	34.93	1.77	2.00	109.45	20.00
15.	NO x DT	49.43	1.90	1.67	128.60	33.67
16.	NO x CR	28.67	1.33	2.33	90.28	30.33
17.	NO x LR(1)	27.70	1.67	2.33	98.26	16.33
18.	NO x LR(2)	33.13	1.10	2.00	103.75	36.00
19.	OG x KR	56.50	1.23	1.33	186.70	23.33
20.	OG x LR	39.37	1.00	1.67	115.61	15.33
21.	OG x DT	53.37	1.67	1.67	106.60	17.00
22.	HR x LW	58.87	2.23	3.00	258.12	21.67
23.	FR x CR(1)	34.60	1.47	1.67	99.12	28.33
24.	FR x CR(2)	42.27	1.60	2.00	119.61	21.67
25.	FR x DT(1)	23.47	1.20	1.67	116.09	28.33
26.	FR x DT(2)	44.43	1.60	2.00	101.37	30.67
27.	FR x KR	42.67	1.37	1.67	124.99	26.67

Table 2(a) Continued

Sl. No.	Genotypes	Plant height (cm)	Internode length (cm)	Suckering ability	Leaf area (cm^2)	Days from emergence to maturity of leaves
28.	FR x LR	43.53	1.87	2.00	150.20	23.00
29.	FR x MW(1)	53.70	1.73	1.33	219.64	29.33
30.	FR x MW(2)	27.40	1.23	1.33	148.62	36.33
31.	MW x FR(1)	50.20	2.57	1.67	323.77	18.67
32.	MW x FR(2)	39.83	1.40	1.00	120.36	21.33
33.	MW x PR	30.27	0.97	1.33	48.62	33.00
34.	MW x DT	32.83	1.60	1.00	122.06	38.33
35.	TR x MW	33.43	1.67	1.33	168.77	38.33
36.	LJ x MW	22.17	1.07	3.00	41.32	29.67
37.	PR x KR	48.00	1.60	1.67	162.22	37.33
38.	PR x MO	33.77	1.33	1.67	75.29	22.67
39.	PR x DT	46.50	1.47	1.33	173.48	19.33
40.	PR x OG	46.43	1.53	2.00	150.44	21.67
41.	PR x MW	43.13	1.60	1.67	152.09	23.33
42.	PR x LR(1)	57.83	1.80	1.67	193.64	33.67
43.	PR x LR(2)	44.43	1.77	2.00	170.54	33.00
44.	PR x LR(3)	41.33	1.43	2.00	194.69	35.33
45.	PR x FR(1)	40.43	1.27	2.00	106.23	29.67
46.	PR x FR(2)	28.17	1.67	2.33	82.49	32.33
47.	PR x FR(3)	27.60	1.53	2.67	120.84	31.00
48.	PR x FR(4)	35.70	1.37	2.67	134.38	30.33
49.	DT x KR	36.70	1.33	1.00	74.67	25.33
50.	DT x FR	34.67	1.73	1.33	153.96	41.00
F		12.876**	23.217**	3.661**	51.761**	261.160**
SEm		2.695	0.739	0.274	7.589	0.397
CD		7.585	0.208	0.773	21.359	1.117

* - Significant at 5 per cent level ** - Significant at 1 per cent level

Table 2(b). Floral character differentiation in *Anthurium andreanum* genotypes

Sl. No.	Genotypes	Days from emergence to maturity of inflorescence	Number of spadices/ plant/year	Candle length (cm)	Inclination of candle to spathe (degrees)	Number of flowers/candle	Life of spadix (days)
1.	MO x LR	31.00	3.33	6.30	61.00	434.33	76.33
2.	MO x KR(1)	37.67	4.33	6.23	89.33	413.67	124.67
3.	MO x KR(2)	29.00	3.67	4.77	66.33	375.00	95.33
4.	KO x CR	24.33	4.67	5.77	69.00	188.33	67.00
5.	KO x LR	24.67	5.00	3.37	26.00	193.33	63.66
6.	KO x DT	27.33	7.00	3.70	69.00	195.33	48.33
7.	KR x DT	34.67	4.00	4.30	68.00	221.67	61.00
8.	KR x LR	32.67	3.33	4.77	54.00	338.33	53.67
9.	KR x CR	31.00	4.00	4.83	73.00	291.67	48.33
10.	LR x DT	36.67	4.00	4.83	53.67	425.00	62.33
11.	LR x PR	31.00	4.67	3.87	28.67	235.67	82.67
12.	LR x FR	36.00	3.67	5.30	69.00	361.67	92.00
13.	NO x TR	25.33	5.00	4.27	35.67	316.67	71.00
14.	NO x PR	30.67	4.00	3.57	24.33	283.33	95.67
15.	NO x DT	32.00	4.33	4.60	30.00	336.33	70.00
16.	NO x CR	27.67	4.67	3.53	29.33	312.33	61.33
17.	NO x LR(1)	16.67	6.33	5.57	29.67	269.33	92.67
18.	NO x LR(2)	32.00	5.67	5.77	70.33	268.33	101.00
19.	OG x KR	31.67	5.33	4.33	20.33	219.33	55.67
20.	OG x LR	28.00	4.33	5.33	23.00	219.67	87.67
21.	OG x DT	31.33	6.67	3.80	20.00	328.33	120.00
22.	HR x LW	26.33	3.67	5.17	29.33	438.33	96.00
23.	FR x CR(1)	25.67	4.00	5.77	37.33	205.00	75.67
24.	FR x CR(2)	28.33	4.00	3.50	40.67	208.00	80.33
25.	FR x DT(1)	27.33	4.33	4.67	29.00	218.33	61.33
26.	FR x DT(2)	31.00	4.67	5.77	37.67	298.33	53.33
27.	FR x KR	30.00	4.33	3.40	24.67	207.33	74.33
28.	FR x LR	30.00	3.67	5.87	30.00	361.00	86.33

Table 2(b) Continued

Sl. No.	Genotypes	Days from emergence to maturity of inflorescence	Number of spadices/ plant/year	Candle length (cm)	Inclination of candle to spathe (degrees)	Number of flowers/candle	Life of spadix (days)
29.	FR x MW(1)	33.33	4.33	9.17	52.33	591.33	102.00
30.	FR x MW(2)	31.67	3.33	3.13	40.00	383.33	70.33
31.	MW x FR(1)	30.00	4.00	5.97	40.00	689.33	122.33
32.	MW x FR(2)	35.33	4.67	4.17	39.00	350.33	120.67
33.	MW x PR	32.00	4.33	4.03	73.33	304.33	70.67
34.	MW x DT	32.00	3.33	4.77	60.33	461.67	62.33
35.	TR x MW	28.00	3.00	4.83	47.00	416.67	71.33
36.	LJ x MW	31.33	4.33	3.17	40.00	149.67	56.33
37.	PR x KR	32.00	4.33	5.77	27.67	296.67	99.67
38.	PR x MO	32.00	5.33	4.63	10.67	295.00	60.67
39.	PR x DT	37.00	3.00	5.10	57.67	363.33	104.00
40.	PR x OG	33.67	3.67	5.30	48.33	372.67	62.00
41.	PR x MW	26.00	4.00	4.03	50.33	362.00	79.67
42.	PR x LR(1)	31.33	4.00	4.80	29.67	416.67	95.00
43.	PR x LR(2)	22.67	4.33	3.77	38.67	379.00	66.67
44.	PR x LR(3)	33.67	4.00	4.67	27.33	321.67	61.67
45.	PR x FR(1)	33.00	4.00	4.33	39.67	367.67	65.33
46.	PR x FR(2)	28.67	5.00	4.27	40.33	347.33	66.67
47.	PR x FR(3)	24.00	5.00	5.67	30.00	371.00	54.00
48.	PR x FR(4)	28.00	5.33	3.93	29.67	399.33	66.00
49.	DT x KR	25.33	4.33	3.53	40.33	312.33	53.00
50.	DT x FR	27.67	5.00	4.43	54.00	325.33	81.33
	F	165.749**	2.946**	17.951**	546.385**	278.930**	526.736**
	SEm	0.319	0.492	0.250	0.754	6.040	0.889
	CD	0.899	1.385	0.706	2.122	17.001	2.503

* - Significant at 5 per cent level ** - Significant at 1 per cent level

Table 2(b) Continued

Sl. No.	Genotypes	Days to initiation of female phase	Duration of female phase	Days of interphase	Duration of male phase	Pollen fertility (%)	Anthocyanin content (mg/g)
1.	MO x LR	7.00	8.00	8.00	9.33	28.19	221.21
2.	MO x KR(1)	6.67	6.33	10.33	8.33	23.78	162.25
3.	MO x KR(2)	7.00	7.00	11.67	5.00	22.99	167.58
4.	KO x CR	7.33	6.00	8.67	8.33	21.74	201.63
5.	KO x LR	5.00	4.00	7.33	7.67	32.90	192.46
6.	KO x DT	5.67	4.00	7.67	6.67	25.99	200.89
7.	KR x DT	7.33	5.00	7.00	7.33	10.59	153.08
8.	KR x LR	5.00	4.33	6.00	10.33	18.60	190.42
9.	KR x CR	8.00	7.00	5.67	8.67	11.61	276.17
10.	LR x DT	8.00	7.00	3.00	7.67	10.33	695.51
11.	LR x PR	4.67	6.00	6.67	7.33	33.50	171.09
12.	LR x FR	3.00	6.00	7.00	8.00	46.17	234.55
13.	NO x TR	7.33	5.00	8.67	7.67	29.45	214.87
14.	NO x PR	6.00	5.00	5.00	9.00	30.88	190.77
15.	NO x DT	7.33	7.00	9.67	8.00	29.92	240.73
16.	NO x CR	3.33	6.00	5.00	7.00	31.43	163.95
17.	NO x LR(1)	7.00	6.00	8.00	8.00	35.11	225.05
18.	NO x LR(2)	7.00	8.00	7.00	6.67	33.57	292.56
19.	OG x KR	6.67	3.67	4.00	10.33	27.32	139.17
20.	OG x LR	6.67	4.33	3.00	9.33	35.55	163.27
21.	OG x DT	6.00	4.00	3.00	8.67	44.05	120.84
22.	HR x LW	6.00	6.00	10.00	8.00	24.33	411.82
23.	FR x CR(1)	3.00	5.00	6.00	8.67	120.87	222.65
24.	FR x CR(2)	6.33	7.00	7.00	9.67	12.43	225.05
25.	FR x DT(1)	3.33	5.00	3.00	7.00	15.02	86.22
26.	FR x DT(2)	6.00	7.33	3.00	7.33	16.59	149.01
27.	FR x KR	7.00	4.00	7.00	11.33	22.91	26.81
28.	FR x LR	7.00	7.33	10.67	10.00	8.16	393.41

Table 2(b) Continued

Sl. No.	Genotypes	Days to initiation of female phase	Duration of female phase	Days of interphase	Duration of male phase	Pollen fertility (%)	Anthocyanin content (mg/g)
28.	FR x LR	7.00	7.33	10.67	10.00	8.16	393.41
29.	FR x MW(1)	5.33	6.00	9.00	9.00	14.29	311.95
30.	FR x MW(2)	5.00	6.00	6.00	11.33	12.24	70.27
31.	MW x FR(1)	5.33	11.33	7.33	10.00	15.28	160.56
32.	MW x FR(2)	6.00	5.00	4.00	6.33	19.48	33.94
33.	MW x PR	8.00	6.00	3.00	12.67	36.62	166.33
34.	MW x DT	4.00	6.00	3.00	4.00	28.94	228.44
35.	TR x MW	7.00	5.00	4.00	12.00	12.02	179.22
36.	LJ x MW	4.00	4.00	5.00	6.00	50.80	156.14
37.	PR x KR	6.67	6.00	2.00	7.00	31.70	142.90
38.	PR x MO	7.00	8.00	10.00	8.00	25.94	173.59
39.	PR x DT	5.67	7.00	7.00	11.67	21.66	451.12
40.	PR x OG	6.33	9.00	5.00	6.00	27.46	435.16
41.	PR x MW	4.00	6.33	8.67	10.67	19.49	149.44
42.	PR x LR(1)	7.00	7.33	3.67	6.00	18.07	376.10
43.	PR x LR(2)	5.00	8.00	4.00	5.33	11.66	245.42
44.	PR x LR(3)	8.00	4.67	10.33	8.00	33.39	710.79
45.	PR x FR(1)	7.00	9.00	10.33	8.00	12.13	267.82
46.	PR x FR(2)	7.00	6.00	7.33	7.33	7.03	448.74
47.	PR x FR(3)	8.00	5.00	9.00	6.67	34.06	232.85
48.	PR x FR(4)	8.00	7.00	6.00	7.00	28.09	268.50
49.	DT x KR	5.00	5.00	8.00	10.67	25.20	186.69
50.	DT x FR	5.00	6.00	3.00	9.67	30.49	214.53
	F	44.412**	82.144**	134.810**	41.871**	313.549**	1149.744**
	SEm	0.210	0.169	0.221	0.290	0.578	4.007
	CD	0.593	0.478	0.622	0.817	1.629	11.278

* - Significant at 5 per cent level ** - Significant at 1 per cent level

Table 2(c). Qualitative character differentiation in *Anthurium andreanum* genotypes

Sl. No.	Genotypes	Colour of of young leaf	Colour of petiole	Plant type	Spathe colour	Spathe texture	Candle colour	Type of inflorescence axis
1	MO x LR	Light brown	Brownish green	Compact	Red	Medium thick deeply *blisteredglossy*	Pinkish yellow	Short thick straight
2	MO x KR(1)	Brownish green	Brownish green	Semi spreading	Red	Thick blistered glossy	Light pink	Long thick slightly curved
3	MO x KR(2)	Brownish green	Brownish green	Semi spreading	Dark red	Thick blistered glossy	Light pink	Long thick slightly curved
4	KO x CR	Green	Green	Spreading	Red	Thick smooth	Yellowish white	Short straight thin
5	KO x LR	Brownish green	Brownish green	Compact	Red	Medium thick deeply blistered glossy	Light pink	Short straight thin
6	KO x DT	Green	Green	Compact	Bright red	Thick blistered glossy	Pinkish white	Short thick straight
7	KR x DT	Brownish green	Green	Compact	Dark red	Thick blistered glossy	Yellowish white	Short thick straight
8	KR x LR	Reddish brown	Reddish brown	Compact	Dark red	Thick blistered glossy	Pinkish white	Long thick slightly curved
9	KR x CR	Brownish green	Brownish green	Spreading	Deep maroon	Medium thick deeply blistered glossy	Pinkish white	Long thick slightly curved
10	LR x DT	Brownish green	Brownish green	Semi spreading	Deep maroon	Thick blistered glossy	Light pink	Long thick slightly curved

Table 2 (c) Continued

Sl. No.	Genotypes	Colour of of young leaf	Colour of petiole	Plant type	Spathe colour	Spathe texture	Candle colour	Type of inflorescence axis
11	LR x PR	Reddish brown	Reddish brown	Compact	Maroon	Medium thick deeply blistered glossy	Yellow	Long thick slightly cuvred
12	LR x FR	Reddish brown	Reddish brown	Semi spreading	Red	Medium thick smooth	Yellow	Long curving thin
13	NO x TR	Brownish green	Brownish green	Spreading	Bright red	Medium thick deeply blistered	Yellowish white	Long straight strong
14	NO x PR	Brownish green	Brownish green	Compact	Dark red	Thick blistered glossy	Cream	Long curving thin
15	NO x DT	Green	Green	Spreading	Red	Medium thick deeply blistered glossy	Yellowish white	Long thick slightly curved
16	NO x CR	Brownish green	Brownish green	Compact	Orange	Medium thick deeply blistered glossy	Yellowish white	Long thick slightly curved
17	NO x LR(1)	Brownish green	Green	Compact	Red	Medium thick smooth	Yellowish white	Long curving thin
18	NO x LR(2)	Light brown	Green	Compact	Maroon	Medium thick smooth	Yellowish white	Long curving thin
19	OG x KR	Green	Green	Semi spreading	Dark orange	Medium thick deeply blistered glossy	Yellow	Long curving thin
20	OG x LR	Brownish green	Green	Compact	Orange	Medium thick deeply blistered glossy	Yellow	Short straight thin

Table 2(c) Continued

Sl. No.	Genotypes	Colour of of young leaf	Colour of petiole	Plant type	Spathe colour	Spathe texture	Candle colour	Type of inflorescence axis
21	OG x DT	Brownish green	Green	Compact	Dark red	Medium thick deeply blistered glossy	Pink	Long curving thin
22	HR x LW	Light brown	Green	Spreading	Dark red	Medium thick deeply blistered glossy	Yellowish white	Long curving thin
23	FR x CR(1)	Reddish brown	Brownish green	Compact	Dark red	Medium thick smooth	Light red	Short straight thin
24	FR x CR(2)	Reddish brown	Reddish brown	Compact	Dark red	Medium thick smooth	Yellowish white	Long thick, slightly curve
25	FR x DT(1)	Reddish brown	Reddish brown	Compact	Dark red	Thick smooth glossy	Light pink	Short straight thin
26	FR x DT(2)	Light brown	Brownish green	Spreading	Dark red	Thick smooth glossy	White	Short straight thin
27	FR x KR	Green	Green	Compact	Pink	Thick blistered glossy	Cream	Short straight thin
28	FR x LR	Reddish brown	Reddish brown	Spreading	Dark red	Thick blistered glossy	Yellow	Short straight thin
29	FR x MW(1)	Reddish brown	Reddish brown	Semi spreading	Red	Thick blistered glossy	Yellow	Long strong slightly curved
30	FR x MW(2)	Reddish brown	Brownish green	Semi spreading	White	Medium thick smooth	Light red	Long strong slightly curved

Table 2(c) Continued

Sl. No.	Genotypes	Colour of of young leaf	Colour of petiole	Plant type	Spathe colour	Spathe texture	Candle colour	Type of inflorescence axis
31	MW x FR(1)	Brownish green	Brownish green	Spreading	White with pink veins	Medium thick deeply blistered glossy	Light pink	Long strong slightly curved
32	MW x FR(2)	Brownish green	Light brown	Semi spreading	White	Thick blistered glossy	Pink	Short thick straight
33	MW x PR	Brownish green	Light brown	Semi spreading	White	Medium thick deeply blistered glossy	Pinkish white	Long straight strong
34	MW x DT	Reddish brown	Green	Semi spreading	Maroon	Medium thick deeply blistered glossy	Light red	Long thick slightly curved
35	TR x MW	Reddish brown	Reddish brown	Spreading	Maroon	Medium thick deeply blistered glossy	Red	Long straight strong
36	LJ x MW	Green	Green	Compact	Dark red	Thick blistered glossy	Light pink	Short straight thin
37	PR x KR	Light brown	Light brown	Compact	Bright red	Medium thick deeply blistered glossy	Yellowish white	Long strong slightly curved
38	PR x MO	Brownish green	Green	Compact	Bright red	Medium thick deeply blistered glossy	Yellowish white	Long thick slightly curved
39	PR x DT	Reddish brown	Reddish brown	Semi spreading	Dark red	Thick blistered glossy	Light pink	Short straight thin

Table 2(c) Continued

Sl. No.	Genotypes	Colour of of young leaf	Colour of petiole	Plant type	Spathe colour	Spathe texture	Candle colour	Type of inflorescence axis
40	PR x OG	Brownish green	Brownish green	Semi spreading	Bright red	Thick blistered glossy	Yellowish white	Long thick slightly curved
41	PR x MW	Green	Green	Compact	Light orange	Medium thick deeply blistered glossy	Cream	Long straight strong
42	PR x LR(1)	Reddish brown	Reddish brown	Semi spreading	Dark red	Medium thick deeply blistered glossy	Yellowish white	Long thick slightly curved
43	PR x LR(2)	Reddish brown	Reddish brown	Semi spreading	Deep maroon	Thick blistered glossy	Reddish pink	Long curving thin
44	PR x LR(3)	Reddish brown	Reddish brown	Compact	Maroon	Medium thick deeply blistered glossy	Yellow	Long straight strong
45	PR x FR(1)	Green	Brownish green	Semi spreading	Maroon	Medium thick deeply blistered glossy	Yellowish white	Long thick slightly curved
46	PR x FR(2)	Reddish brown	Reddish brown	Compact	Bright red	Thick blistered glossy	Red	Long curving thin
47	PR x FR(3)	Brownish green	Light brown	Compact	Red	Thick blistered glossy	Light pink	Short thick straight
48	PR x FR(4)	Reddish brown	Reddish brown	Compact	Dark red	Medium thick deeply blistered glossy	Yellowish white	Short straight thin
49	DT x KR	Brownish green	Brownish green	Spreading	Red	Medium thick smooth	Reddish pink	Short thick straight
50	DT x FR	Brownish green	Brownish green	Spreading	Bright red	Thick blistered glossy	Yellowish white	Short straight thin

Of the seventeen characters studied, only six characters showed normal distribution pattern (Table 3) while other characters did not show much variation among the genotypes. The internode length of all the genotypes was classified in 'medium' category. The classification of genotypes which falls under the normal distribution pattern are shown in Table 4.

Table 3. Percentage distribution of fifty *Anthurium andreanum* genotypes into low, medium and high groups

Sl. No.	Characters	Low	Medium	High
1.	Plant height (cm)	32	40	28
2.	Suckering ability	20	64	16
3.	Leaf area (cm^2)	14	72	14
4.	Days from emergence to maturity of inflorescence	26	48	26
5.	No. of spadices/plant/year	12	80	8
6.	Candle length (cm)	30	40	30

4.1.1 Vegetative Characters

4.1.1.1 Plant Height

The average height of the plant was observed as 41.28 cm with a range of 22.17 to 64.80 cm. About 40 per cent of the genotypes had medium height in between 36.01 and 46.55 cm. Some genotypes (32 %) had low height ie., less than 36.01 cm and the remaining had height greater than 46.55 cm.

Table 4. Classification of fifty *Anthurium andreanum* genotypes

Sl. No.	Character	Mean	Limits $x \pm 1.96\ \sigma_{n-1}$	Sl.No. of genotypes in different classes		
				Low $< x - 1.96\ \sigma_{n-1}$	Medium Between $x \pm 1.96\ \sigma_{n-1}$	High $> x + 1.96\ \sigma_{n-1}$
1.	Plant height (cm)	41.28	36.01 to 46.55	14,16,17,18,23,25, 30,33,34,35,36,38, 46,47,48,50 (32 %)	1,2,3,5,6,7,13,20,24, 26,27,28,32,39,40,41, 43,44,45,49 (40 %)	4,8,9,10,11,12,15,19, 21,22,29,31,37,42 (28 %)
2.	Suckering ability	1.88	1.37 to 2.46	19,29,30,32,33, 34,35,39,49,50 (20 %)	1,2,3,4,6,7,10,11,13,14, 15,16,17,18,20,21,23,24 25,26,27,28,31,37,38, 40,41,42,43,44,45,46 (64 %)	5,8,9,12,22,36, 47, 48 (16 %)
3.	Leaf area (cm^2)	138.70	92.20 to 183.40	6,16,33,36,38,46,49 (14 %)	1,2,3,4,5,7,8,10,11,12,13 14,15,17,18,20,21,23,24, 25,26,27,28,30,32,34,35, 37,39,40,41,43,45,47,48,50 (72 %)	9,19,22,29,31,42,44 (14 %)

Table 4 (Continued)

Sl. No.	Character	Mean	Limits $x \pm 1.96 \sigma_{n-1}$	Sl.No. of genotypes in different classes		
				Low $< x - 1.96 \sigma_{n-1}$	Medium Between $x \pm 1.96 \sigma_{n-1}$	High $> x + 1.96 \sigma_{n-1}$
4.	Days from emergence to maturity of inflorescence	30	27.8 to 32.2	4,5,6,13,16,17,23,25 23,25,41,43,47,49,50 (26 %)	1,3,9,11,14,15,18,19,20, 21,24,26,27,28,30,31,33, 34,35,37,38,42,46,48 (48 %)	2,7,8,10,12,22,29,32, 36,39,40,44,45 (26 %)
5.	No. of spadices/ plant/year	4.38	3.42 to 5.34	1,8,30,34,35,39 (12 %)	2,3,4,5,7,9,10,11,12,13, 14,15,16,19,20,22,23,24, 25,26,27,28,29,31,32,33, 36,37,38,40,41,42,43,44, 45,46,47,48,49,50 (80 %)	6,17,18,21 (8 %)
6.	Candle length (cm)	4.71	4.22 to 5.20	5,6,11,14,16,21,24, 27,30,32,33,36, 43,48,49 (30 %)	3,7,8,9,10,13,15,19, 22,25,34,35,38,39,41, 42,44,45,46,50 (40 %)	1,2,4,12,17,18,20,23, 26,28,29,31,37,40,47 (30 %)

4.1.1.2 Internode Length

The average internode length was found to be 1.56 cm. The internode length ranged from 0.97 cm in MW x PR to 2.57 cm in MW x FR(1). All the genotypes (100 %) with internode length in between 0.11 to 3.01 cm were grouped under the medium category.

4.1.1.3 Suckering Ability

Suckering ability was found to be more variable among the genotypes. The average number of suckers produced was 1.88 with a range of 1.00 in MW x DT, MW x FR(2) and DT x KR to 3.00 in LR x FR, HR x LW and LJ x MW. Most of the genotypes (64 %) had suckers with a range of 1.37 to 2.46 which comes under medium category. 20 per cent of the genotypes had suckers less than 1.37 were categorized under low and those with suckers greater than 2.46 were under high category.

4.1.1.4 Leaf Area

The average leaf area was 138.70 cm^2. The genotypes differed in their leaf area by 41.32 to 323.77 cm^2. Most of the genotypes (72 %) had a medium leaf area in between 92.20 to 183.40 cm^2. An equal distribution of genotypes were observed in low and high categories.

4.1.1.5 Days from Emergence to Maturity of Leaves

The average days for the emergence of leaves to its maturity was observed as 27.56 with a range of 15.33 days in OG x LR to 41 days in DT x FR.

4.1.2 Floral Characters

4.1.2.1 Quantitative Characters

4.1.2.1.1 Days from Emergence to Maturity of Inflorescence

The average days from emergence to maturity of inflorescence was 30. Between the genotypes this character ranged from 16.67 days in NO x LR(1) to 37.67 days in MO x KR(1). When this character was grouped as low, medium and high, 48 per cent of genotypes falls under medium category. An equal distribution of genotypes (26 %) was observed in low (<27.8 days) and high (>32.2 days).

4.1.2.1.2 Number of Spadices / Plant / Year

The average number of spadices per plant per year was 4.38. The maximum number of spadices per plant per year was observed in KO x DT (7) while the minimum in PR x DT and TR x MW(3). Most of the genotypes (80 %) had medium number of spadices / plant / year (3.42 - 5.34). 12 per cent of genotypes had less than 3.42 spadices and a few genotypes (8 %) had a higher number of spadices / plant / year ie., more than 5.34.

4.1.2.1.3 Candle Length

The average candle length was 4.71 cm. Genotype FR x MW(2) had the minimum candle length of 3.13 cm while FR x MW(1) had maximum candle length of 9.17 cm. An equal distribution of genotypes (30 %) with length less than 4.22 cm and greater than 5.20 cm were under low and high category. Remaining 40 per cent of genotypes were under medium category (4.22 – 5.20).

4.1.2.1.4 Inclination of Candle

The inclination of the candle observed on an average as 43.10° with a range of 10.67 degree in PR x MO to 89.33 degree in MO x KR(1).

4.1.2.1.5 Number of Flowers / Candle

The average number of flowers per candle was observed to be 328.81. This character ranged from 149.67 in LJ x MW to 689.33 in MW x FR(1).

4.1.2.1.6 Life of Spadix

The average days for the opening of inflorescence (spadix) to its death was observed as 77.08 with a range of 48.33 days in KO x DT and KR x CR to 124.67 days in MO x KR(1).

4.1.2.1.7 Days to Initiation of Female Phase

The average number of days required for the initiation of female phase was 6.1. This character ranged from 3 days [FR x CR(1), LR x FR] to 8 days [KR x CR, LR x DT, MW x PR, PR x LR(3), PR x FR(3), PR x FR(4)].

4.1.2.1.8 Duration of Female Phase

Duration of female phase on an average lasted for about 6.1 days with a range of 3.67 days in OG x KR to 11.33 days in MW x FR(1).

4.1.2.1.9 Days of Interphase

The average number of days of interphase was found to be 6.49. The genotype PR x KR had minimum days of interphase as 2 while the MO x KR(2) had maximum of 11.67 days.

4.1.2.1.10 Duration of Male Phase

The duration of male phase on an average was found to be 8.29 days. The maximum duration was observed in the genotype MW x PR as 12.67 days, while the genotype MW x DT had the minimum of 4 days.

4.1.2.1.11 Pollen Fertility

Pollen fertility was minimum for the genotype PR x FR(2) (7.03 %) and was maximum for the genotype LJ x MW (50.80 %). Pollen fertility on an average was found to be 24.24 per cent.

4.1.2.1.12 Total Anthocyanin Content

The mean total anthocyanin content ranged from 26.81 mg/g in the genotype FR x KR to 710.79 mg/g in the genotype PR x LR(3). Total anthocyanin content on an average was 234.86 mg/g.

4.1.2.2 Qualitative character

4.1.2.2.1 Colour of Young Leaf and Petiole

The colour of young leaf showed range from Light brown to Reddish brown to Brownish green to Green. Colour of petiole also varied from Light brown to Reddish brown to Brownish green to Green.

4.1.2.2.2 Plant Type

Most of the genotypes had compact nature of the plants followed by semi spreading and spreading types.

4.1.2.2.3 Spathe Colour

The colour range was deep maroon, maroon, dark red, red, light red, dark orange, orange, pink and white. Genotype OG x DT had double colour spathe, obaki (Dark red with green margin) (Plate 4).

4.1.2.2.4 Spathe Texture

Spathe texture showed variation from thick blistered glossy to medium thick deeply blistered glossy, thick smooth glossy and medium thick smooth. Majority of the genotypes showed medium thick deeply blistered glossy spathe texture.

4.1.2.2.5 Candle Colour

Candle colour varied from Red [TR x MW and PR x FR(2)] to light red, reddish pink, pink, light pink, pinkish yellow, pinkish white, yellow, yellowish white and cream (PR x MW, FR x KR, NO x PR).

4.1.2.2.6 Type of Inflorescence Axis

Nature of inflorescence axis is an important commercial trait. Long straight and strong inflorescence axis which is most desirable was exhibited by the genotypes NO x TR, MW x PR, TR x MW, PR x MW and PR x LR(3). Other genotypes showed inflorescence axis as long curving thin, short straight thin, long thick slightly curved, short thick straight and long strong slightly curved.

4.2 ESTIMATION OF VARIABILITY COMPONENTS

The genotypic and environmental components of phenotypic variance are presented in Table 5 along with the coefficient of variation (CV) which being a relative measure of variation is used for comparison among characters measured in different units.

Table 5. Components of the total variance for different characters in *Anthurium andreanum*

Sl. No.	Characters	σ^2p	σ^2g	σ^2e	GCV (%)	PCV (%)
1.	Plant height (cm)	108.08	86.28	21.79	22.50	25.18
2.	Internode length (cm)	0.14	0.12	0.02	22.33	23.79
3.	Suckering ability	0.43	0.20	0.23	23.19	33.83
4.	Leaf area (cm^2)	3096.73	2923.92	172.80	38.50	39.62
5.	Days from emergence to maturity of leaves	41.52	41.05	0.47	23.74	23.37
6.	Days from emergence to maturity of inflorescence	17.15	16.84	0.31	13.58	13.70
7.	No. of spadices/plant/year	1.20	0.47	0.73	15.65	24.95
8.	Candle length (cm)	1.26	1.07	0.19	21.92	23.78
9.	Inclination of candle to spathe (degrees)	311.95	310.75	1.71	40.86	40.97
10.	No. of flowers/candle	10252.09	10142.61	109.48	30.63	30.79
11.	Life of spadix (days)	418.25	415.88	2.37	26.45	26.53
12.	Days to initiation of female phase	2.06	1.98	0.13	22.77	23.54
13.	Duration of female phase	2.43	2.34	0.09	25.10	25.56
14.	Days of interphase	6.69	6.54	0.15	39.39	39.83
15.	Duration of male phase	3.70	3.45	0.25	22.40	23.21
16.	Pollen fertility (%)	105.77	104.77	1.01	42.22	42.42
17.	Anthocyanin content (mg/g)	18497.00	18448.82	48.18	57.83	57.91

PCV - Phenotypic coefficient of variance

GCV - Genotypic coefficient of variance

σ^2p - Phenotypic variance

σ^2g - Genotypic variance

σ^2e - Environmental variance

Maximum variability both at phenotypic (57.91 %) and genotypic (57.83 %) levels were observed for total anthocyanin content followed by pollen fertility (PCV 42.42 per cent and GCV 42.22 %) and inclination of candle to spathe (PCV 40.97 per cent and GCV 40.86 %). Duration of interphase and leaf area also registered a high value of 39.83 per cent, 39.62 per cent and 38.39 per cent, 38.50 per cent at both phenotypic and genotypic levels respectively. The minimum variability was recorded by the character days from emergence to maturity of inflorescence as 13.70 per cent for PCV and 13.58 per cent for GCV.

Plant height, internode length, suckering ability, days from emergence to maturity of leaves, candle length, number of flowers per candle, number of spadices per plant per year, days to initiation of female phase, duration of female phase and duration of male phase differed in their ranks at phenotypic and genotypic levels while all other seven characters were in the same order of variation both at phenotypic and genotypic levels.

The environmental influence was maximum for the character leaf area followed by number of flowers per candle, anthocyanin content and plant height while for all other characters under study it was minimum.

4.3 HERITABILITY AND GENETIC ADVANCE

The estimates of heritability and genetic advance are presented in the Table 6.

Robinson (1965) classified the heritability estimates in cultivated plants as low with 5-10 per cent heritability, medium with 10-30 per cent heritability and greater than 30 per cent as high. In the present study, all the characters showed high heritability as per Robinsons classification.

Table 6. Heritability and genetic advance for seventeen characters in *Anthurium andreanum*

Sl. No.	Character	Heritability (%)	Genetic advance (at 5 %)	Genetic advance (as % of mean)
1.	Plant height (cm)	79.83	17.10	41.42
2.	Internode length (cm)	88.10	0.67	42.95
3.	Suckering ability	47.01	0.63	32.64
4.	Leaf area (cm^2)	94.41	108.24	77.06
5.	Days from emergence to maturity of leaves	98.86	13.12	47.60
6.	Days from emergence to maturity of inflorescence	98.21	8.38	27.73
7.	No. of spadices/plant/year	39.34	0.88	20.09
8.	Candle length (cm)	84.96	1.96	41.58
9.	Inclination of candle to spathe (degrees)	99.45	36.18	83.94
10.	No. of flowers/candle	98.93	206.35	62.76
11.	Life of spadix (days)	99.43	41.89	54.35
12.	Days to initiation of female phase	95.53	2.77	45.41
13.	Duration of female phase	96.43	3.10	50.82
14.	Days of interphase	97.80	5.21	80.28
15.	Duration of male phase	93.16	3.69	44.51
16.	Pollen fertility (%)	99.05	20.98	86.55
17.	Anthocyanin content (mg/g)	99.73	279.44	118.98

Allard (1960) classified heritability as low (less than 30 %), medium (30-60 %) and high (above 60 %). According to this classification all the characters showed high heritability except for the characters suckering ability (47.01 %) and number of spadices per plant per year (39.34 %) which showed medium heritability.

From the table it was found that highest heritability was recorded for the character anthocyanin content (99.73 %) followed by inclination of candle to spathe (99.45 %), life of spadix (99.43 %) and pollen fertility (99.05 %). Number of spadices per plant per year showed least value for heritability (39.34 %).

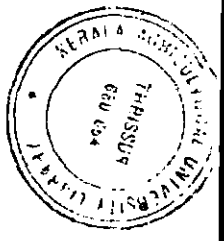
Genetic advance as percentage of mean is independent of the unit of measurement and hence is used for comparison among characters. Maximum genetic advance was obtained for anthocyanin content (118.98 %) followed by pollen fertility (86.55 %). Least genetic advance was obtained for the character number of spadices per plant per year (20.09 %) if five per cent selection to be practiced.

4.4 CORRELATION AMONG DIFFERENT CHARACTERS

The results of phenotypic, genotypic and environmental correlations among the various characters are presented in Table 7 (a, b & c) and Figure V, VI & VII respectively. The significance for both phenotypic and environmental correlations were tested. However, no test is available to detect the significance of genotypic correlation coefficients.

4.4.1 Phenotypic Correlation

Plant height was found to have significant positive correlation with internode length, leaf area and days from emergence to maturity of inflorescence.



However, no significant correlation was observed for plant height with other characters.

Internode length showed significant positive correlation with plant height, leaf area, number of flowers per candle and duration of female phase. For all other character internode length was not significantly correlated.

Leaf area showed significant positive correlation with plant height, internode length, days from emergence to maturity of inflorescence, candle length, number of flowers per candle, life of spadix and duration of female phase, while it showed significant negative correlation with pollen fertility.

Days from emergence to maturity of leaves observed negative significant correlation only with life of spadix. All other characters had no significant correlation.

Days from emergence to maturity of inflorescence showed significant negative correlation with number of spadices per plant per year and positive significant correlation with plant height and leaf area.

Candle length was found to have significant positive correlation with leaf area, number of flowers per candle, life of spadix and duration of female phase.

Number of flowers per candle showed significant positive correlation with internode length, leaf area, candle length, life of spadix and duration of female phase while significant negative correlation was observed for number of spadices per plant per year and pollen fertility.

Number of spadices per plant per year showed significant negative correlation with days from emergence to maturity of inflorescence, number of flowers per candle and significant positive correlation with pollen fertility.

Table 7(a). Phenotypic correlation coefficients among seventeen characters in *Anthurium andreanum*

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X2	0.5734**															
X3	0.0394	0.1763														
X4	0.5904**	0.6571**	0.0255													
X5	-0.1886	-0.0587	-0.0637	-0.0677												
X6	0.2955*	0.0464	-0.0421	0.2856*	-0.0353											
X7	0.2166	0.1746	-0.0717	0.4515**	-0.0887	0.1603										
X8	-0.0211	-0.0192	0.0383	0.0759	0.0838	0.2614	0.2406									
X9	0.1785	0.3683**	-0.1479	0.6078**	0.0273	0.2633	0.4726**	0.1440								
X10	-0.1076	-0.2040	0.0656	-0.2553	-0.0818	-0.3043*	-0.1207	-0.1630	-0.2718*							
X11	0.2242	0.2253	-0.1543	0.3602**	-0.3382*	0.2344	0.3402*	0.0498	0.3941**	-0.0041						
X12	0.1308	-0.0460	0.0288	0.0475	-0.0680	0.0671	0.1151	0.0345	0.0536	0.0877	-0.0306					
X13	0.1431	0.2691*	-0.0068	0.3354*	0.0091	0.1261	0.3017*	0.1676	0.5667**	-0.1828	0.2099	0.1504				
X14	0.0647	0.1062	0.2168	0.1265	-0.1845	-0.0243	0.1869	0.1063	0.1396	-0.0326	0.0646	0.2117	0.1883			
X15	0.0575	-0.0141	-0.2598	0.1048	-0.1892	0.0259	-0.0112	0.0170	0.0300	-0.1808	0.0776	0.0752	-0.1119	0.0251		
X16	-0.1004	-0.1802	0.1816	-0.3031*	0.0018	-0.0025	-0.1517	-0.1186	-0.2684*	0.2787*	0.1060	-0.1145	-0.3264*	-0.0980	-0.1507	
X17	0.1840	0.1090	0.1916	0.2609	0.0398	0.2580	0.2270	0.0554	0.2637	-0.1470	-0.0949	0.3173*	0.2448	0.1915	-0.1235	-0.1572

X1 - Plant height (cm)
X2 - Internode length (cm)
X3 - Suckering ability
X4 - Leaf area (cm2)
X5 - Days from emergence to maturity of leaves
X6 - Days from emergence to maturity of inflorescence
X7 - Candle length (cm)
X8 - Inclination of candle to spathe (degrees)
X9 - No. of flowers/candle
X10 - No. of spadices/plant/year
X11 - Life of spadix
X12 - Days to initiation of female phase
X13 - Duration of female phase
X14 - Days of interphase
X15 - Duration of male phase
X16 - Pollen fertility (%)
X17 - Anthocyanin content (mg/g)

* - Significant at 5 per cent level

** - Significant at 1 per cent level

Table 7(b). Genotypic correlation coefficients among seventeen characters in *Anthurium andreanum*

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X2	0.6377															
X3	0.0755	0.2356														
X4	0.6447	0.7172	-0.0060													
X5	-0.2053	-0.0601	-0.1131	-0.0696												
X6	0.3236	0.0466	-0.0529	0.2982	-0.0349											
X7	0.2314	0.1868	-0.0847	0.4892	-0.0943	0.1713										
X8	-0.0240	-0.0266	0.0513	0.0762	0.0847	0.2641	0.2544									
X9	0.2021	0.3999	-0.2203	0.6292	0.0278	0.2670	0.5168	0.1453								
X10	-0.1157	-0.2824	0.2066	-0.4559	-0.1305	-0.4931	-0.1844	-0.2667	-0.4358							
X11	0.2488	0.2417	-0.2406	0.3725	-0.3418	0.2382	0.3712	0.0503	0.3980	0.0072						
X12	0.1204	-0.0500	0.0220	0.0487	-0.0680	0.0647	0.1133	0.0374	0.0531	0.1760	-0.0319					
X13	0.1628	0.2975	-0.0247	0.3500	0.0059	0.1317	0.3419	0.1723	0.5804	-0.3253	0.2154	0.1583				
X14	0.0654	0.1043	0.3111	0.1232	-0.1897	-0.0274	0.2079	0.1074	0.1408	-0.0393	0.0645	0.2232	0.1947			
X15	0.0362	-0.0259	-0.3966	0.1093	-0.1957	0.0324	-0.0206	0.0159	0.0369	-0.2881	0.0767	0.0741	-0.1122	0.0347		
X16	-0.1148	-0.1922	0.2577	-0.3120	0.0025	-0.0042	-0.1583	-0.1192	-0.2721	0.4419	0.1072	-0.1197	-0.3314	-0.1005	-0.1558	
X17	0.2086	0.1168	0.2766	0.2699	0.0391	0.2607	0.2441	0.0556	0.2661	-0.2328	-0.0955	0.3284	0.2510	0.1951	-0.1292	-0.1580

X1 - Plant height (cm)
X2 - Internode length (cm)
X3 - Suckering ability
X4 - Leaf area (cm2)
X5 - Days from emergence to maturity of leaves
X6 - Days from emergence to maturity of inflorescence
X7 - Candle length (cm)
X8 - Inclination of candle to spathe (degrees)
X9 - No. of flowers/candle
X10 - No. of spadices/plant/year
X11 - Life of spadix
X12 - Days to initiation of female phase
X13 - Duration of female phase
X14 - Days of interphase
X15 - Duration of male phase
X16 - Pollen fertility (%)
X17 - Anthocyanin content (mg/g)

Table 7(c). Environmental correlation coefficients among seventeen characters in *Anthurium andreanum*

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X2	0.2493															
X3	-0.0211	0.0984														
X4	0.2893*	0.0360	-0.1252													
X5	-0.1279	-0.0719	0.1730	-0.0179												
X6	0.1491	0.0658	-0.0632	-0.0480	-0.0699											
X7	0.1496	0.0970	-0.0644	0.1457	-0.0535	0.0733										
X8	0.0079	0.0777	0.0590	0.1178	-0.0186	0.0369	0.2354									
X9	-0.0223	-0.1425	0.0301	-0.0122	-0.0227	0.0075	-0.0300	-0.0146								
X10	-0.1222	-0.1404	-0.0411	0.1226	-0.0057	0.0212	-0.0468	0.0659	0.0011							
X11	0.0750	-0.0340	0.1863	-0.0412	0.0755	-0.0978	-0.0339	-0.0430	-0.0758	-0.1472						
X12	0.2345	-0.0071	0.0767	0.0302	-0.0929	0.1483	0.1428	-0.0839	0.0959	-0.0964	0.0060					
X13	0.0029	-0.0796	0.0713	0.0316	0.1646	-0.0818	-0.1068	-0.0780	-0.0097	0.1195	-0.0736	0.0000				
X14	0.1043	0.1836	0.0548	0.2308	0.1265	0.1257	-0.0441	0.0400	0.0715	-0.0715	0.0904	-0.0477	-0.0296			
X15	0.2236	0.1034	0.0139	0.0376	-0.0482	-0.1435	0.0701	0.0913	-0.2006	-0.0311	0.1891	0.0907	-0.1125	-0.2075		
X16	0.0379	-0.0192	0.0805	-0.0598	-0.0611	0.1215	-0.1709	-0.0438	0.0920	0.0372	-0.0583	0.0267	-0.1390	0.0639	-0.0389	
X17	-0.0934	-0.0297	0.0570	-0.0853	0.1772	0.0068	0.1151	0.0048	-0.1053	-0.0284	0.0503	0.0092	-0.1454	-0.1596	0.0769	-0.0320

X1 - Plant height (cm)
X2 - Internode length (cm)
X3 - Suckering ability
X4 - Leaf area (cm2)
X5 - Days from emergence to maturity of leaves
X6 - Days from emergence to maturity of inflorescence
X7 - Candle length (cm)
X8 - Inclination of candle to spathe (degrees)
X9 - No. of flowers/candle
X10 - No. of spadices/plant/year
X11 - Life of spadix
X12 - Days to initiation of female phase
X13 - Duration of female phase
X14 - Days of interphase
X15 - Duration of male phase
X16 - Pollen fertility (%)
X17 - Anthocyanin content (mg/g)

* - Significant at 5 per cent level
** - Significant at 1 per cent level

Life of spadix showed significant positive correlation with leaf area, candle length and number of flowers per candle while significant negative correlation with days from emergence to maturity of leaves.

Days to initiation of female phase showed significant positive correlation with anthocyanin content only.

Duration of female phase showed significant positive correlation with internode length, leaf area, candle length and number of flowers per candle, while significant negative correlation was observed for pollen fertility.

Suckering ability, inclination of candle to spathe, duration of interphase and duration of male phase were not significantly correlated with any of the characters studied.

Pollen fertility showed significant positive correlation with number of spadices per plant per year. But it was significant and negatively correlated with leaf area, number of flowers per candle and duration of female phase.

Anthocyanin content was significant and positively correlated only with days to initiation of female phase.

4.4.2 Genotypic Correlation

Genotypic correlation values are higher than the phenotypic values. Most of the characters had positive correlation with each other.

4.4.3 Environmental Correlation

Most of the estimates of the environmental correlation coefficients for the characters are low and insignificant indicating the least effect of environment in the expression of the characters studied. However, plant height showed a

significant positive correlation with leaf area and vice versa under controlled environmental conditions.

4.5 PATH COEFFICIENT ANALYSIS

Number of flowers per candle (Y) was taken as the dependent variable for path analysis. The component characters selected for analysis were internode length (X_2), leaf area (X_4), days from emergence to maturity of inflorescence (X_6), candle length (X_7), number of spadices per plant per year (X_{10}), life of spadix (X_{11}), duration of female phase (X_{13}) and pollen fertility (X_{16}). The direct and indirect effects of these characters on number of flowers per candle were presented in Table 8.

The correlation between X_2 and Y was found to be 0.3999 is positive but its direct effect was negative and negligible. The medium indirect effect via. X_4 (0.2645) and low indirect effect via. X_{13} (0.1024) were the major contributors of this correlation. The correlation between X_4 and Y was 0.6292 and its direct effect was also high (0.3688). Most of the indirect effects were negligible while via. X_{13} was low. The correlation between X_6 and Y was positive while its direct effect was negative and negligible. A low indirect effect was observed via. X_4 while all other indirect effects were negligible. The direct effect of X_7 on Y was low (0.1531) while its correlation with Y was 0.5168. Low indirect effects were recorded via. X_4 and X_{13}. The correlation between X_{10} and Y was negative while its direct effect was also negative and low. Indirect effect via. X_4 and X_{13} were also low and negative. Direct effect of X_{11} (0.1554) and indirect effect via. X_4 were mainly responsible for this correlation. The correlation between X_{13} and Y was 0.5804, its direct effect was also high (0.3441) and indirect effect via. X_4 was observed to be low 0.1291 while the remaining indirect effects were negligible.

Table 8. Direct and indirect effect of component characters on number of flowers/candle

Characters		X_2	X_4	X_6	X_7	X_{10}	X_{11}	X_{13}	X_{16}	Genotypic Correlation
Internode length	X_2	-0.0771	0.2645	-0.0018	0.0286	0.0515	0.0375	0.1024	-0.0058	0.3999
Leaf area	X_4	-0.0553	0.3688	-0.0112	0.0749	0.0831	0.0579	0.1204	-0.0094	0.6292
Days from emergence to maturity of inflorescence	X_6	-0.0036	0.1100	-0.0377	0.0262	0.0899	0.037	0.0453	-0.0001	0.2670
Candle length	X_7	-0.0144	0.1804	-0.0065	0.1531	0.0336	0.0577	0.1176	-0.0048	0.5168
No. of spadices/plant/year	X_{10}	0.0218	-0.1682	0.0186	-0.0282	-0.1823	0.0011	-0.1119	0.0133	-0.4358
Life of spadix	X_{11}	-0.0186	0.1374	-0.0090	0.0568	-0.0013	0.1554	0.0741	0.0032	0.3980
Duration of female phase	X_{13}	-0.0229	0.1291	-0.0050	0.0523	0.0593	0.0335	0.3441	-0.0100	0.5804
Pollen fertility	X_{16}	0.0148	-0.1151	0.0002	-0.0242	-0.0806	0.0167	-0.1140	0.0320	-0.2721

Residue = 0.40

Direct effect - diagonal values

Indirect effect - off diagonal values

Correlation between X_{16} and Y was negative while its direct effect was positive and negligible. Low negative indirect effect was observed via. X_4 and X_{13} are the characters which are more associated with Y. 60 per cent of the variation in flower production was attributed to the eight characters under study as evident from the residue of 40 per cent.

4.6 SELECTION INDEX

Selection index for the genotypes was computed based on the seventeen characters and the genetic gain was also worked out. The selection index was worked out as follows:

$$I = 0.5281\ X_1 + 17.6211\ X_2 - 0.0298\ X_3 + 0.8876\ X_4 + 0.9084\ X_5 + 1.4939\ X_6 + 1.4287\ X_7 + 0.9638\ X_8 + 0.98991\ X_9 - 0.0487\ X_{10} + 1.0749\ X_{11} + 0.9760\ X_{12} + 1.3488\ X_{13} + 0.8150\ X_{14} + 1.1636\ X_{15} + 0.9024\ X_{16} + 1.0095\ X_{17}.$$

Accordingly selection index values were worked out and presented in descending order in Table 9. High index values were recorded by the genotype *LR x DT* followed by *FR x MW(1), PR x LR(3), MW x FR(1), HR x LW* and so on. Least index value was recorded by the genotype FR x KR, indicating that the improvement of the character for this genotype is comparatively less than that of the genotypes with high indices.

If we select parents based on selection index for crop improvement, we can expect 45 per cent genetic gain in the next generation.

Table 9. Selection index arranged in descending order

Sl. No.	Genotypes	Selection index
1.	LR x DT	4690
2.	FR x MW(1)	4501
3.	PR x LR(3)	4497
4.	MW x FR(1)	4485
5.	HR x LW	4244
6.	PR x DT	3961
7.	PR x LR(1)	3851
8.	PR x OG	3713
9.	FR x LR	3550
10.	LR x FR	3399
11.	PR x FR(2)	3389
12.	MO x KR(1)	3372
13.	MW x DT	3302
14.	MO x LR	3283
15.	KR x CR	3248
16.	PR x FR(4)	3174
17.	PR x LR(2)	3127
18.	TR x MW	3111
19.	NO x LR(2)	3048
20.	PR x FR(1)	3031
21.	DT x FR	3007
22.	NO x DT	2997
23.	MO x KR(2)	2992
24.	PR x FR(3)	2910
25.	PR x MW	2832

Table 9 (Continued)

Sl. No.	Genotypes	Selection index
26.	NO x TR	2765
27.	KR x LR	2760
28.	PR x KR	2735
29.	LR x PR	2684
30.	OG x DT	2634
31.	NO x PR	2609
32.	NO x LR(1)	2604
33.	FR x MW(2)	2577
34.	MW x PR	2524
35.	KR x DT	2516
36.	FR x CR(2)	2477
37.	DT x KR	2464
38.	MW x FR(2)	2458
39.	KO x CR	2458
40.	NO x CR	2439
41.	FR x DT(2)	2414
42.	FR x CR(1)	2356
43.	PR x MO	2341
44.	OG x KR	2340
45.	KO x LR	2296
46.	OG x LR	2283
47.	KO x DT	2176
48.	FR x DT(1)	1922
49.	LJ x MW	1859
50.	FR x KR	1857

DISCUSSION

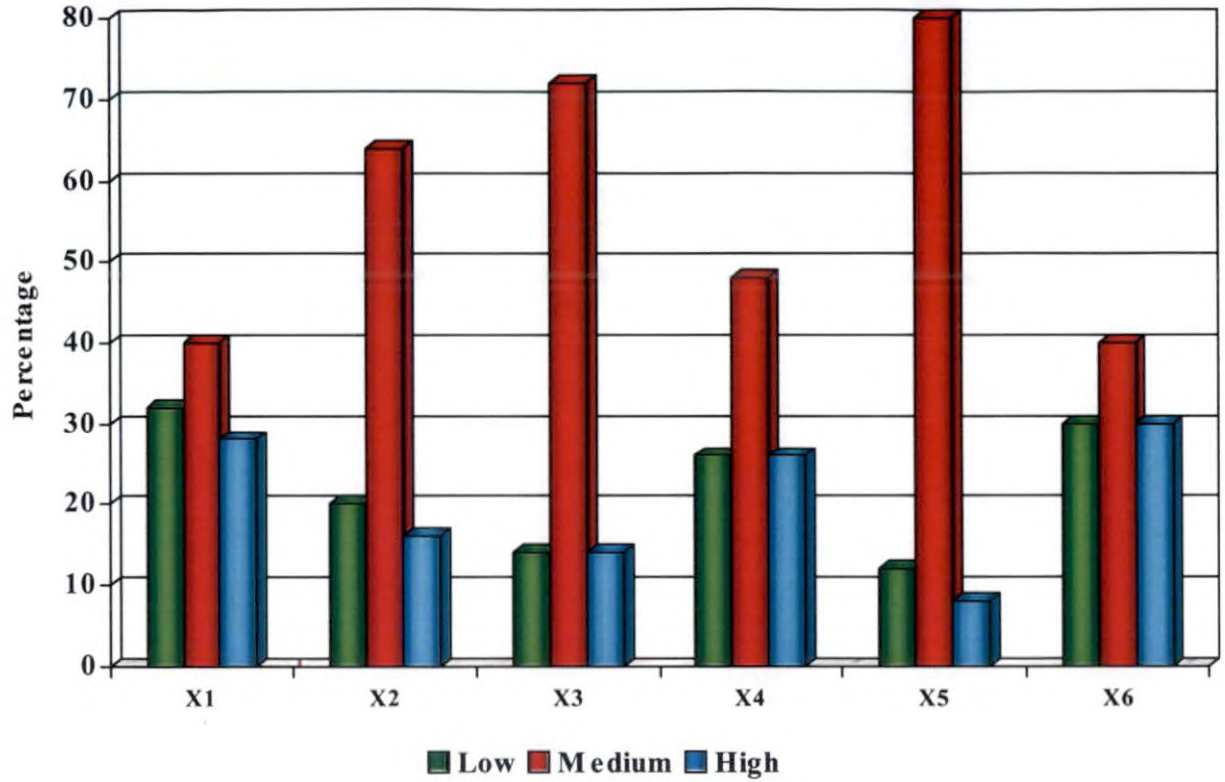
5. DISCUSSION

The cultivation of anthurium especially *Anthurium andreanum* Linden for cut flower has gained greater importance in recent times. Anthuriums being tropical plants are grown for their brightly coloured showy flowers which are of grand beauty. Due to differences in the genetic makeup of the individuals of a population or the environment in which they are grown, variations are observed. Exploitation of variations (genetic) are useful for the improvement of any crop. In the present study the variability among different morphological and floral characters were studied and their results are discussed below.

5.1 MEAN PERFORMANCE

All the fifty genotypes under the present study showed wide variations for all the quantitative and qualitative characters studied. Fig. 1 shows the percentage distribution of fifty genotypes for seven characters.

The average plant height observed was 41.28 cm with a range of 22.17 cm (LJ x MW) to 64.80 cm (LR x PR). Of the fifty genotypes studied 40 per cent had medium height in between 36.01 cm and 46.55 cm, 32 per cent had height less than 36.01 cm and 28 per cent had height greater than 46.55 cm. Plant height can be considered as varietal character, as earlier studies by Bindu and Mercy (1994) showed that the five varieties studied by them, varied significantly in their heights. The six varieties studied by Sindhu (1995) also recorded significant variation in height. Renu (2000) recorded significant variation in plant height from 29.70 to 70.90 cm. According to Mayadevi (2001) the plant height ranged from 42.5 cm in 'Midori Green' to 96.67 cm in the variety 'White'. The mean



X1 - Plant height
X2 - Suckering ability
X3 - Leaf area
X4 - Days from emergence to maturity of inflorescence
X5 - No. of spadices / plant / year
X6 - Candle length

Fig. 1. Percentage distribution of fifty genotypes with low, medium and high groups

mean internode length ranged from 0.97 cm in MW x PR to 2.57 cm in MW x FR(1). Plants with short leaf internodes which give the plant a compact appearance are preferred (Mercy and Dale, 1994). According to Singh (1987) a desirable anthurium should produce short internodes to limit the height of the plant. Mayadevi (2001) observed that the mean internode length among hybrids ranged from 1.02 to 1.34 cm and in the five parents it ranged from 1.00 to 1.52 cm. The present study is in confirmation with the above reports with all the genotypes having medium internode length.

Mature plants three or more years old produce plantlets called suckers from the base of the stem, one or two at a time. This is however, a very slow and independable process because most of the good commercial and hybrid varieties are very shy suckering or do not sucker at all. In the present study, it was observed that the average number of suckers ranged from 1.00 in MW x DT, MW x FR(2) and DT x KR to 3.00 in LR x FR, HR x LW and LJ x MW with a mean of 1.88 suckers. This character is found to be variable among genotypes. Twenty per cent of the genotypes belong to low category, 64 per cent in medium category and 16 per cent in high category. Propagation of anthurium using suckers is very slow because most of the good commercial and hybrid varieties are shy in suckering (Mercy and Dale, 1994). Suckering is a very desirable character as it increases plant number and thereby the overall productivity. Mayadevi (2001) observed maximum number of sucker production (4) for varieties 'Pink' and 'Lady Jane' and the least number of suckers for varieties 'Nitta Orange', 'Merengue White' and 'Tropical Red'.

The genotypes differed in their leaf area by 41.32 cm^2 in LJ x MW to 323.77 cm^2 in MW x FR(1) with an average of 138.70 cm^2. Most of the genotypes (72 %) had medium leaf area in between 92.20 cm^2 to 183.40 cm^2. Mercy and Dale (1994) opined that the leaves of commercially valuable floral anthuriums should be small to medium sized, narrow and elongated. Large and exuberantly growing leaves were undesirable. Salvi (1997) reported that the

different levels of shade and growth regulators have significant influence on the index and total leaf area of the plants. With decline in shade intensity leaf area also decreased significantly. Mayadevi (2001) reported that variety 'Chilli Red' had the least leaf area of 66.26 cm^2 followed by variety 'Kalympong Red' (66.92 cm^2). The average number of days taken from emergence to the maturity of leaves ranged from 15.33 days in OG x LR to 41 days in DT x FR. The sequence of leaf, flower and new leaf is maintained throughout the entire life of the plant and the intervals between leaf emergence are shortened or lengthened with changes in the environmental conditions (Singh, 1995). Mayadevi (2001) observed that this character ranged from 41.40 days (HR) to 44.40 days in (Pink). The average days from emergence to maturity of inflorescence in the present study was 16.67 days in NO x LR(1) to 37.67 days in MO x KR(1). According to Mayadevi (2001) this character ranged from 44.60 to 50.60 days in the parents and 41 to 54 days among the hybrids.

Morphological studies conducted by Christensen (1971) observed that *Anthurium andreanum* had a long juvenile phase for vegetative growth followed by a generative phase in which flower buds were produced. In the present study, the average number of spadices produced ranged from three in PR x DT and TR x MW to seven in KO x DT. Eighty per cent of the genotypes had medium number of spadices ranging from 3.42 to 5.34. Steen and Vigverberg (1973) compared the productivity of 120 individual anthurium plants and found that it ranged between 4-16 flowers over two years. Similar close correlation between the number of leaves and number of flowers was observed by Gajek and Schwarz (1980). Mercy and Dale (1994) recorded the annual production as five to eight. Sindhu (1995) had observed it ranging from four to eight. According to Mayadevi (2001) generally a single spadix was found to be produced from the axil of each leaf so that number of leaves and number of spadices produced annually in a plant were equal. The present study was in confirmation with the above reports.

Short and slender candles are more commercially preferred over long and thick candles. In the present investigation, the average candle length ranged from 3.13 cm in FR x MW (2) to 9.17 cm in FR x MW (1). Forty per cent of the genotypes had candle length in between 4.22 to 5.20 cm. The five varieties studied by Bindu and Mercy (1994) showed a range of 4.00 to 9.50 cm. Mercy and Dale (1994) reported that the candle was long and fleshy in ordinary non-commercial varieties, while it was shorter and more slender in highly bred hybrids. The candle length of six varieties studied by Sindhu (1995) ranged from 6.60 to 12.10 cm. According to Mayadevi (2001) the variety 'Pink' had longest candle (12.72 cm) and shortest in the variety 'Liver Red' (7.18 cm). Among the hybrids it ranged from 5.90 to 10.38 cm. A downward curving candle is an extremely desirable character for commercial anthurium varieties and this helps in packing a larger number of inflorescence in a box during transportation. In the present study the inclination ranged from 10.67° in PR x MO to 89.33° in MO x KR(1). Mercy and Dale (1994) recommended that ideal anthurium flower should have short candle, curving towards the tip of the spathe and held at an angle less than 45°. Such inclination of candle were exhibited by 28 genotypes out of the 50 studied. Sindhu (1995) observed the maximum angle of 75°. Mayadevi (2001) noticed that the inclination of candle ranging from 21° to 78.20° among parents. The hybrids too showed significant difference ranging from 20.80° to 89.60°.

The commercial anthurium flower consists of a modified bract, the spathe and hundreds of small flowers on the candle like inflorescence, which is botanically a spadix. The flowers are bisexual regular, protogynous, arranged in a series of spirals on the candle in an acropetal succession (Mercy and Dale, 1994). The number of flowers per candle for different varieties were variously reported as 300 by Watson and Shirakawa (1967), 50-150 by Bindu and Mercy (1994), 150-350 by Mercy and Dale (1994), 175-375 by Sindhu (1995) and 254-450 by Renu (2000). Mayadevi (2001) observed that the number of flowers ranged from

372 to 600 in the parents and 400 to 600 in the hybrids. The present study revealed that the number of flowers per candle varied from genotype to genotype. It ranged from 149 in LJ x MW to 689 in MW x FR(1).

According to Paull (1982), the non-reversible visible changes accompanying the senescence of anthurium flower were, loss of spathe-gloss, necrosis of spadix and greening of spathe and spadix. Mercy and Dale (1994) observed that the senescence was marked by yellowing of the peduncle and withering of spathe and candle, which took nearly 4 to 7 months from the emergence of young spadix. In the present study, the life span from emergence of a spadix to its senescence varied from 48.33 days in KO x DT to 124.67 days in MO x KR(1). Sindhu (1995) reported that the life of unfertilized spadix was about 1.5 to 3.5 months while, in fertilized spadices it increased to 4.5 to 8 months. Mayadevi (2001) also reported the emergence of a spadix to its senescence varied from 98 days in 'Chilli Red' to 120.40 days in 'Honeymoon Red' among the parents. A wide variability of this character was seen among the hybrids with a range of 110.80 days in LR x KR to 126 days in HR x KR.

In *Anthurium* species maturation of flower was initiated generally from the basal portion of the spadix (candle) and proceeded acropetally towards the apex, where *A. andreanum* was not included among the protogynous species (Croat, 1980). However, later studies by Bindu and Mercy (1994) and Mercy and Dale (1994) revealed the protogynous nature of *A. andreanum* varieties. Observation in the present study clearly highlighted the protogynous nature of this species. The number of days from the day the candle become visible to initiation of female phase was observed to vary from 3 days [FR x CR(1), LR x FR] to 8 days [KR x CR, MW x PR, PR x LR(3), PR x FR(3), PR x FR(4)]. Initiation of female phase was identified by the slight projection of stigmas and presence of a viscous exudate on the candle. Sindhu (1995) also reported that the days to initiation of female phase ranged with in a period upto 10 days, with the varieties 'Honeymoon Red' showing the highest period among the six varieties studied by her. Renu

(2000) observed longest period for initiation of female phase in 'Mauritius Orange' and the shortest in 'Lady Jane Red'. Mayadevi (2001) also reported that the initiation of female phase ranged from 4.40 days in 'Kalympong Red' to 6.80 days in 'Honeymoon Red' and 'Liver Red' among the parents, but among the hybrids this character ranged from 3.60 days (HR x KR, P x CR) to 6.20 days (HR x CR).

The number of days in female phase was recorded based on the exerted stigma, honeydew like secretion and some amount of insect activity on the candle. Daumann (1921) and Mercy and Dale (1994) have recommended the above criteria to identify the female phase. Duration of female phase ranged from 3.67 days in OG x KR to 11.33 days in MW x FR(1). Croat (1980) reported that, although in some species like *A. armeniense*, *A. caperatum*, *A. fatoense* etc., the stigmas did not form droplets they were glistening, often exerted and assumed to be receptive. He added that the duration of female phase may range from half a day to as long as 28 days. The duration was reported to be three to twelve days by Bindu and Mercy (1994) and as three to seven days by Mercy and Dale (1994). Among the six varieties studied by Sindhu (1995) the duration ranged from 5-25 days. The duration of female phase in the ten varieties studied by Renu (2000) varied from 6.40 days in 'Lady Jane Red' to 16.40 days in 'Mauritius Orange', but there were individual flowers in which the female phase lasted upto 21 days and this was observed in 'Mauritius Orange'. Mayadevi (2001) observed that the duration of female phase ranged from 7.40 days in 'Pink' to 13.60 days in 'Kalympong Red' among the parents. The hybrids also showed a wide range of variability from 9.60 days (HR x KR, LR x CR and KR x CR) to 12.80 days (HR x LR).

The interphase between female and male phase was marked by drying up of stigmatic droplets. Observation in the present study showed that the interphase ranged from two days in PR x KR to 11.67 days in MO x KR(2). Croat (1980) observed that the duration of interphase was several days in most *Anthurium*

species, whereas in a few of them the time lag was so short that it was not certain whether those species were homogamous and protogynous. Bindu and Mercy (1994) noticed that the interphase lasted for about 4-7 days, while Mercy and Dale (1994) opined that it may last for about a week in general. Studies on six varieties by Sindhu (1995) showed that interphase lasted for 4-10 days. Observation by Renu (2000) from the seven varieties showed that the interphase may range from 4.8 to 10.2 days on an average. 'Liver Red' had the longest interphase period and shortest was recorded in 'Merengue White'. Mayadevi (2001) observed an interphase of 7.80 days in 'Chilli Red' and 11.20 days in 'Pink' among the parents. In the hybrids it ranged from 9.39 days (HR x CR) to 12.60 days (P x CR).

Following the interphase, male phase starts, which was marked by the extrusion of anthers starting from the base of the candle, proceeding towards tip of the candle. In the present study, observation for this character on an average ranged from four days in MW x DT to 12.67 days in MW x PR with a mean of 8.29 days. Bindu and Mercy (1994) reported that the male phase lasted for 3 to 7 days whereas, Mercy and Dale (1994) observed that it may last for about 4 to 8 days. Sindhu (1995) in the six varieties studied, observed that this character lasted for about 3 to 8 days. Mayadevi (2001) reported that the average number of days for which the candles remained in male phase ranged from 5 days in 'Chilli Red' to 7.20 days in 'Honeymoon Red' in the parents. Among the hybrids the duration was maximum in P x KR (9.60 days) and minimum in HR x CR (5.60 days). The present study also reveals that during the month from March to July the male phase is suppressed in all the genotypes under observation, which is in confirmation with the studies by Mercy and Dale (1994), Sindhu (1995), Renu (2000) and Mayadevi (2001). In very cold or hot seasons, the male phase may be suppressed for shorter or longer periods. Anther emergence is comparatively less during March to July.

Observations in the present study revealed high pollen fertility for the genotype LJ x MW (50.80 %) followed by LR x FR (46.17 %). Lalithambika (1978) noticed pollen fertility of 25-30 per cent for *A. andreanum*. Satyadas (1985) reported the pollen fertility range of 20 per cent (*A. warocqueanum*). Bindu and Mercy (1994) reported that the pollen fertility ranged from 20.40 to 28.80 per cent. They concluded that the low fertility can also be due to high degree of meiotic abnormalities like clumping, lagging of chromosomes at anaphase, unequal segregation, precocious disjunction of chromosome, chromosome elimination through micronuclei etc. found in *A. andreanum*. Mayadevi (2001) in her study with five parents and 10 F_1s observed high pollen fertility for the parent 'Liver Red' (45.90 %) followed by 'Pink' (28.40 %) whereas in hybrids it was highest in HR x LR (34.70 %) followed by LR x KR (32.32 %). Sterility is a condition frequently associated with hybridity. We can take low pollen fertility in *A. andreanum* as an indication of its hybrid nature.

Spathe colour is the important character which gives a sense of pleasure to human beings. Anthocyanin contribute various colours to the spathe. This correlation was supported by many workers. Iwata *et al.* (1979) identified the anthocyanins in the spathe of *A. andreanum* to be cyanidin 3-rhamnosyl glucoside and pelargonidin 3-rhamnosyl glucoside. They concluded that both the pigments were present in the red cultivars while orange and coral varieties contained only pelargonidin 3-rhamnosylglucoside. In white cultivars either both these pigments or pelargonidin only are absent. In the present study, anthocyanin content ranged from 26.81 mg/g in FR x KR with pink spathe to 710.79 mg/g in PR x LR(3) with maroon spathe. Genotypes HR x LW, PR x OG, PR x FR(2), PR x DT having varying red coloured spathe have the presence of both the pigments in high concentration (411.82 to 451.12 mg/g). In the genotype LR x DT the anthocyanin content was observed as 695.51 mg/g whose spathe colour was deep maroon. The genotype OG x DT had double coloured spathe to red spathe with green margins (Obaki type) with an anthocyanin content of 120.84 mg/g

(Plate 3). The white genotypes MW x FR(2), FR x MW(2), MW x FR(1) (White spathe with pink veins) and MW x PR have anthocyanin content ranging from 33.94 to 166.33 mg/g.

The genetics of spathe colour inheritance was studied in detail by Kamemoto *et al.* (1988). They concluded that two major genes, M and O were responsible for the five major colours - red, orange, pink, coral and white. The gene M was found to control the production of cyanidin 3-rutinoside while gene O controlled that of pelargonidin 3-rutinoside. Red and pink resulted when both M and O genes are present. In the present study, the genotypes having red and pink coloured spathes have both M and O genes. The incremental effects of M appeared to be greater than that of O and therefore, the intensity of colour decreased from MMOO, MMOo, MmOO to MmOo. From this it was revealed that the variation in red spathe colour from maroon to dark red to red to pink was observed. They also concluded that orange had a genotype of mmOO and was true breeding while mmOo expressed coral. The recessive oo was epistatic to M and therefore, white colour resulted when both were recessive (mmoo) or M was in combination with recessive oo (MMoo, Mmoo). From Kamemoto and co workers study the summary of spathe colour and their phenotypes are as follows.

MMOO, MmOO, MMOo → Reds

MmOo → Pink

mmOO → Orange

mmOo → Coral

MMoo, Mmoo, mmoo → White

According to Wannakrairoj and Kamemoto (1990) a recessive allele P, was found to modify the colour of anthocyanins controlled by M and O loci. A spathe was purple when the genotype was M-O-pp. The dominant P allele has no effect on colour development in any combinations.

Mercy and Dale (1994) reported that the spathe colours varied from white to pink to coral to orange to brown to red to crimson to deep maroon and some varieties had spathes of two or more bands. Sindhu (1995) observed dark and brightly coloured flowers, which are commercially important and were produced by the varieties 'Chilli Red' and 'Kalympong Red'. Renu (2000) grouped the spathe colour of ten varieties into deep maroon to white. Mayadevi (2001) inferred that anthocyanins contribute various colours to spathe from deep maroon to light pink. Based on the anthocyanin content, the spathe colour of the parents ranged from deep maroon, dark red, red and pink and in the ten F_1 hybrids, it ranged from deep maroon to dark red to red to dark pink. All the above reports are in agreement with the present study.

The colour of young leaf and petiole showed variation from reddish brown to green. Mercy and Dale (1994) observed that the colour of young tender leaves varied from deep reddish brown to light green which was in conformity with the findings of the present study. According to Sindhu (1995) the colour of petiole ranged from purple to green and that of young leaf from light green to brown. According to Mayadevi (2001) compact plant types were exhibited by the varieties 'Liver Red' and 'Chilli Red'. 'Kalympong Red' had semi spreading plant type. Observation in the present study revealed the compact nature of plants for most of the genotypes. Compact nature of plants are ideal for commercial varieties as they occupy less space so that more number of plants can be accommodated in a limited space.

Blistered crickled spathe texture is commercially preferred over smooth spathe. Spathe texture showed variation from thick blistered glossy to medium

thick deeply blistered glossy to thick smooth glossy to medium thick smooth. But majority of the spathe showed medium thick deeply blistered glossy texture which are commercially preferred. According to Birdsey (1956) Linden described the spathe of *A. andreanum* based on varying degrees of smoothness and blistering. Mercy and Dale (1994) suggested that the spathe of floral anthuriums may be smooth, thick and glossy with out prominent veins or it may be thinner, deeply veined and blistered. Six varieties studied by Sindhu (1995) also showed variation from thick to thin and deep to shallowly blistered spathe. Spathe texture showed high variation among the ten varieties studied by Renu (2000) from thick and deeply blistered spathe in 'Mauritius Orange' to thin and smooth spathe in 'Lady Jane Red'. Mayadevi (2001) observed high variation for the spathe texture among the parents and the hybrids studied from thick smooth glossy in 'Honeymoon Red' and 'Liver Red' to medium thick and smooth in 'Pink' to deeply blistered glossy spathes in 'Kalympong Red' and 'Chilli Red'. In the hybrids the spathe texture ranged from thick, smooth and glossy to medium thick blistered and glossy.

In non-commercial and semi-commercial varieties candles of single colour are usually seen. But the new hybrids produced double coloured candles. In the present study, candle colour ranged from red to light red to reddish pink to pink to light pink to pinkish yellow to pinkish white to yellow to yellowish white to cream. Gajek and Schwarz (1980) observed white candles with yellow tip for varieties 'Iga Gold'. According to Mercy and Dale (1994), candle had a single colour namely red, pink or green in ordinary anthurium varieties and hybrids had yellow, white, pink or red colour in two or more bands. Sindhu (1995) reported that the six varieties studied had candles with either a single colour or two or more bands of colours. Henny (1999) observed in anthurium hybrid 'Red Hot' had a candle which was orange-red apically blending to red basally. Renu (2000) also reported various colours for the candle ranging from pink ('Dragons Tongue Red', 'Lady Jane Red', 'Liver Red' and 'Merengue White') cream ('Fla Red'), light yellow ('Mauritius Orange') yellow ('Pompon Red', 'Tropical Red', 'Nitta

Orange') and light green ('Midori Green'). Mayadevi (2001) observed the candle colour from pink to light pink, yellow to yellowish white to red and cream for the parents and hybrids studied.

Nature of inflorescence axis is one of the most important factors that determines the appearance and hence the value of anthurium flowers when marketed as cut flower. Mercy and Dale (1994) suggested that good anthurium hybrids should have strong and straight inflorescence axis. In the present study, long straight and strong inflorescence axis which is most desirable was exhibited by the genotypes NO x TR, NO x CR, MW x PR, TR x MW, PR x MW and PR x LR(3). Among the ten varieties studied by Renu (2000), the axis nature varied from long, straight and very strong in 'Dragons Tongue Red' to short, straight and thin in 'Nitta Orange' and 'Midori Green'. 'Liver Red', 'Pompon Red', 'Lady Jane Red','Tropical Red','Mauritius Orange" and 'Merengue White' had long straight and strong inflorescence axis while 'Fla Red' alone had medium long straight and strong inflorescence axis. According to Mayadevi (2001) inflorescence axis varied from long straight and very strong in all the parents and hybrids except for the parent variety 'kalympong Red' on which it is long thin and slightly curved which is not desirable.

5.2 VARIABILITY COMPONENTS

The magnitude of variability present in a crop species is of almost important as it provides the basis for effective selection. Since, the observed variability in a population is the sum of variation arising due to genotypes and environmental effects, knowledge of genetic variation contributing to gain under selection is essential (Allard, 1960).

Phenotypic co-efficient of variation (PCV) and genotypic co-efficient of variation (GCV) were estimated based on the co-efficients of variation and these parameters were used to compare the variability among the 50 genotypes. The

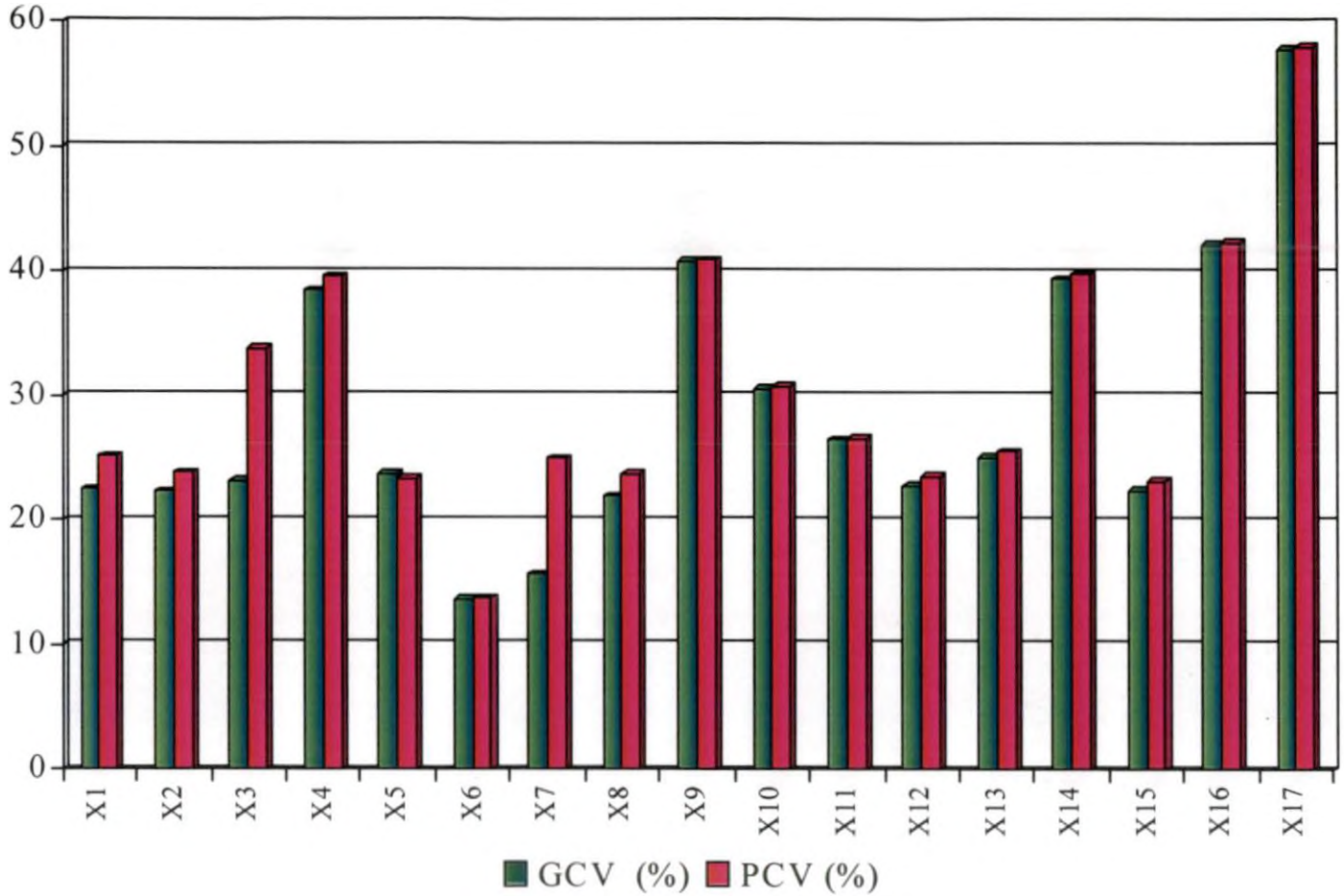


Fig. 2. GCV and PCV for the seventeen characters of *Anthurium andreanum*

GCV provides a valid base for comparing and assessing the range of genetic diversity for quantitative character and PCV measures the extent of total variation. GCV and PCV are better indices for comparison of characters with different units of measurement, than estimates of quantitative variation like range and variation around mean.

Perusal of Table 5, shows that high PCV combined with high GCV were obtained for total anthocyanin content, pollen fertility, inclination of candle, days of interphase and leaf area. This revealed a greater extent of variability for these characters, thereby suggesting good scope for improvement of these important characters through selection. Total anthocyanin content recorded highest GCV and PCV. Lower value of GCV and PCV were estimated for the character, days from emergence to maturity of inflorescence, number of spadices per plant per year and internode length, indicating low magnitude of variability. So, improvement of these characters has only a limited scope (Fig. 2).

The characters suckering ability, number of spadices per plant per year, plant height and candle length showed maximum differences between GCV and PCV, which indicates that the influence of environment on these characters is considerable. But the low differences between GCV and PCV for the characters total anthocyanin content, life of spadix, inclination of candle, days from emergence to maturity of inflorescence pointed out that the variations observed in these characters are mainly due to genetic reasons and that the environmental influence on these characters are lesser.

5.3 HERITABILITY AND GENETIC ADVANCE

Heritability estimates the transmissibility of character from one generation to other and it provides a measure of the value of selection for different attributes. But heritability does not necessarily mean a high genetic advance for a particular character (Allard, 1960). Heritability along with genetic advance is more useful than heritability alone in predicting the resultant effect of selecting the best

X1 - Plant height

X2 - Internode length

X3 - Suckering ability

X4 - Leaf area

X5 - Days from emergence to maturity of leaves

X6 - Days from emergence to maturity of inflorescence

X7 - No. of spadices / plant / year

X8 - Candle length

X9 - Inclination of candle to spathe

X10 - No. of flowers / candle

X11 - Life of sapdix

X12 - Days to initiation of female phase

X13 - Duration of female phase

X14 - Days of interphase

X15 - Duration of male phase

X16 - Pollen fertility

X17 - Anthocyanin content

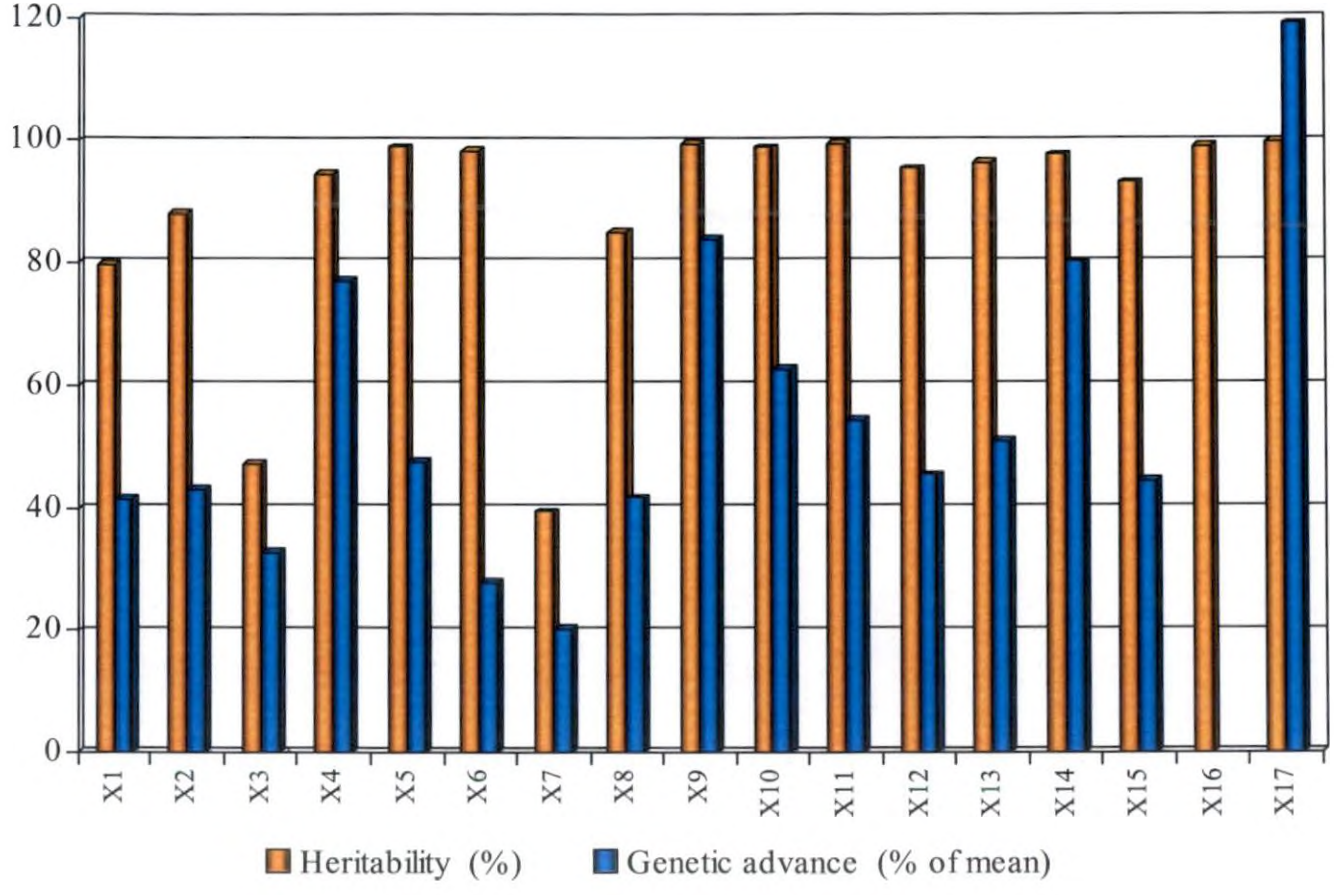


Fig. 3. Heritability and Genetic advance for the seventeen characters of *Anthurium andreanum*

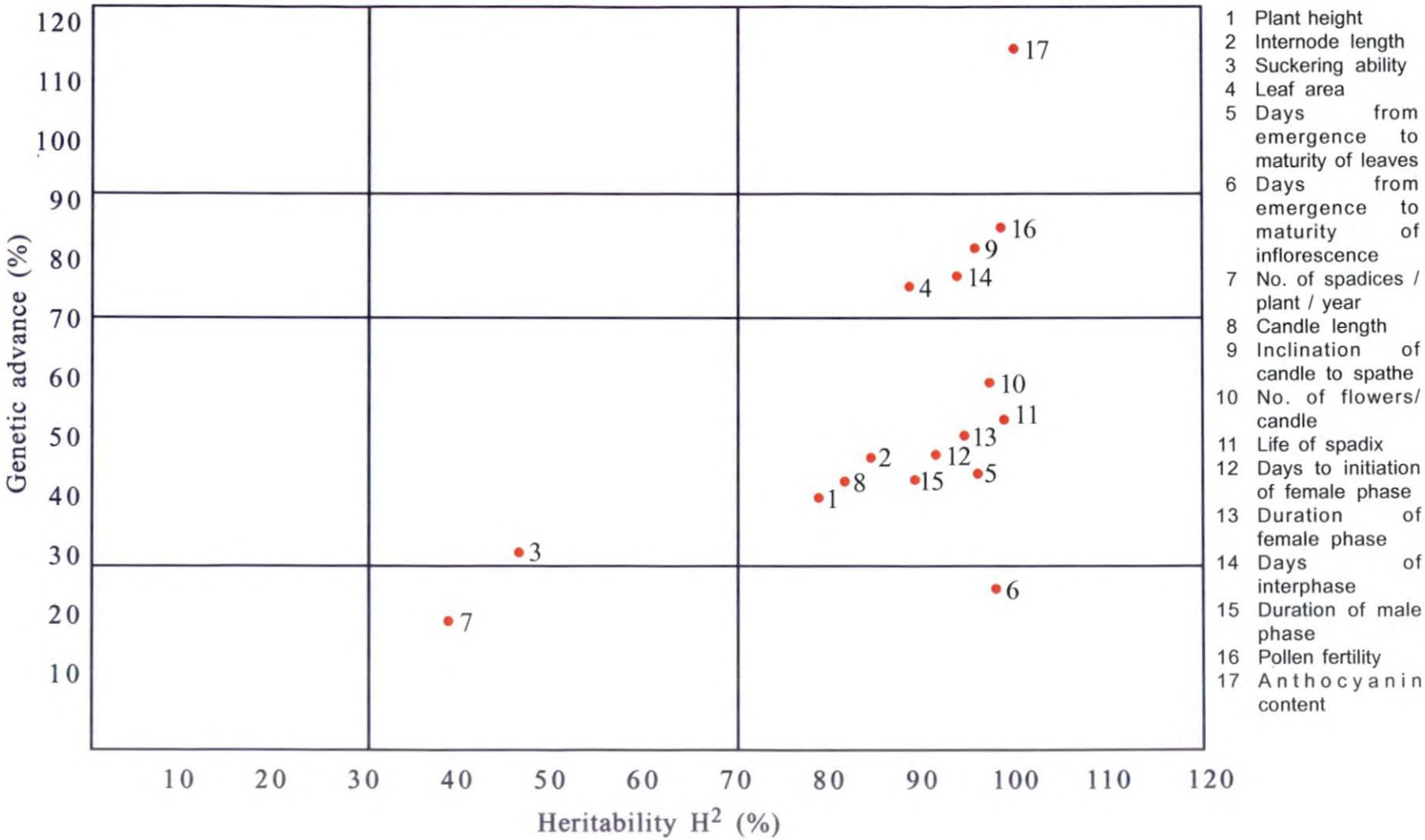


Fig. 4. Character distribution in terms of Heritability and Genetic Advance

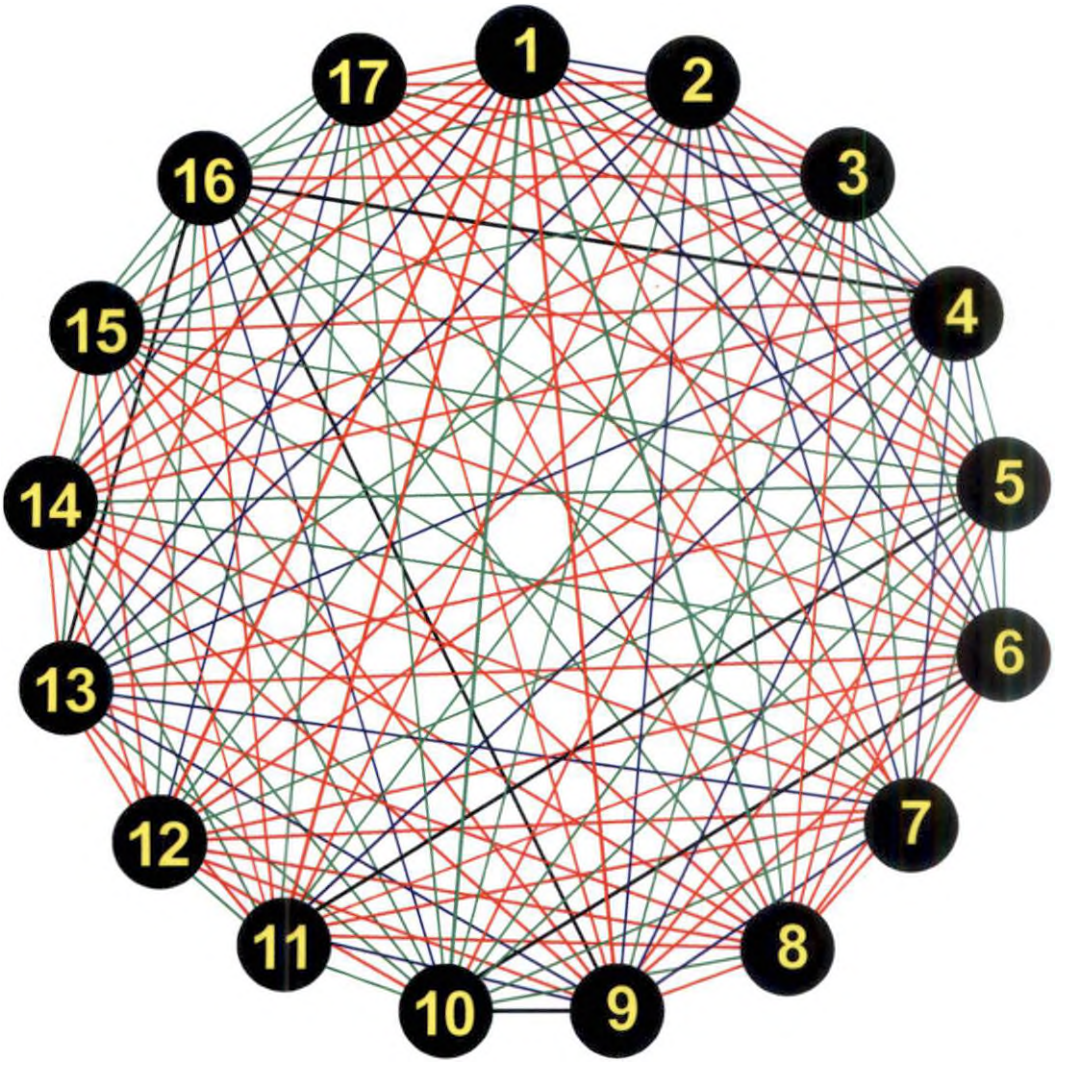
individuals (Johnson *et al.*, 1955). Fig. 3 shows the distribution of characters in terms of heritability (H^2) and genetic advance (GA). The characters total anthocyanin content, pollen fertility, inclination of candle and days of interphase recorded high heritability and genetic advance.

According to Robinson (1965) all the characters under the present study showed high heritability. So selection of phenotypically superior plants with respect to these characters will result in significant improvement in the next generation. But according to Allard (1960) all the characters except suckering ability and number of spadices per plant per year showed high heritability. If five per cent selection is to be practiced maximum genetic advance is expected for total anthocyanin content and the minimum for number of suckers per plant. Robinson *et al.* (1949) classified genetic advance as percentage of mean into low (< 20 %) and high (> 20 %). According to this classification all the characters under present study showed high genetic advance. Mayadevi (2001) inferred that all the characters except number of spadices per plant per year studied show high heritability and genetic advance. Comparison of the improvement expected from these characters are seen from Fig. 4.

High heritability and high genetic advance indicates that the character is controlled by additive gene action suggesting the possibility of genetic improvement of those characters through selection (Panse and Sukhatme, 1967). In the present study all the characters other than suckering ability and number of spadices per plant per year had high heritability coupled with high genetic advance which shows that genetic improvement of all those characters are possible through selection.

5.4 CORRELATION STUDIES

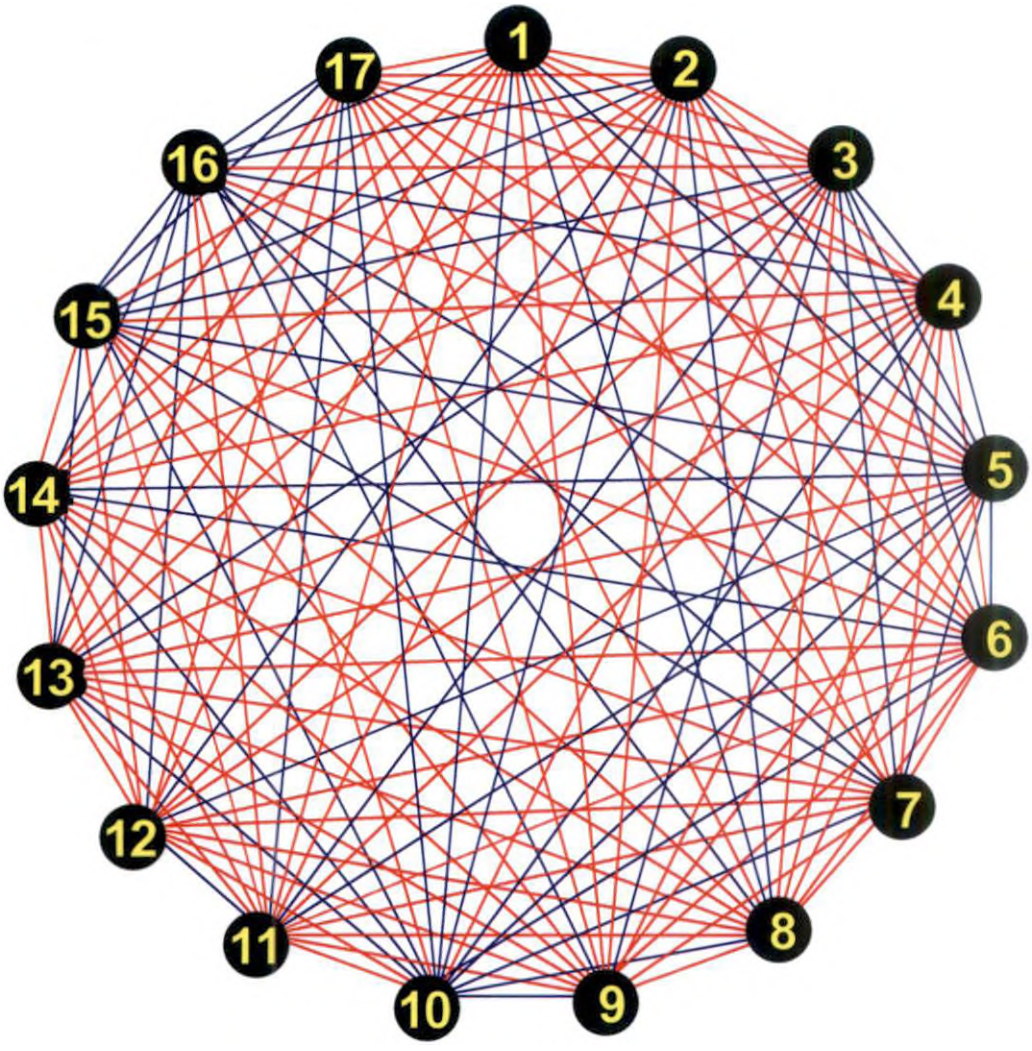
Characters genetically related to each other tend to move in the same direction under selection favouring any one of such related traits. Such a



1	Plant height
2	Internode length
3	Suckering ability
4	Leaf area
5	Days from emergence to maturity of leaves
6	Days from emergence to maturity of inflorescence
7	No. of spadices / plant / year
8	Candle length
9	Inclination of candle to spathe
10	No. of flowers/candle
11	Life of spadix
12	Days to initiation of female phase
13	Duration of female phase
14	Days of interphase
15	Duration of male phase
16	Pollen fertility
17	Anthocyanin content

Positive significant
Negative
Positive
Negative significant

Fig. 5. Phenotypic correlation coefficients among the characters



1	Plant height
2	Internode length
3	Suckering ability
4	Leaf area
5	Days from emergence to maturity of leaves
6	Days from emergence to maturity of inflorescence
7	No. of spadices / plant / year
8	Candle length
9	Inclination of candle to spathe
10	No. of flowers/candle
11	Life of spadix
12	Days to initiation of female phase
13	Duration of female phase
14	Days of interphase
15	Duration of male phase
16	Pollen fertility
17	Anthocyanin content

Positive

Negative

Fig. 6. Genotypic correlation coefficients among the characters

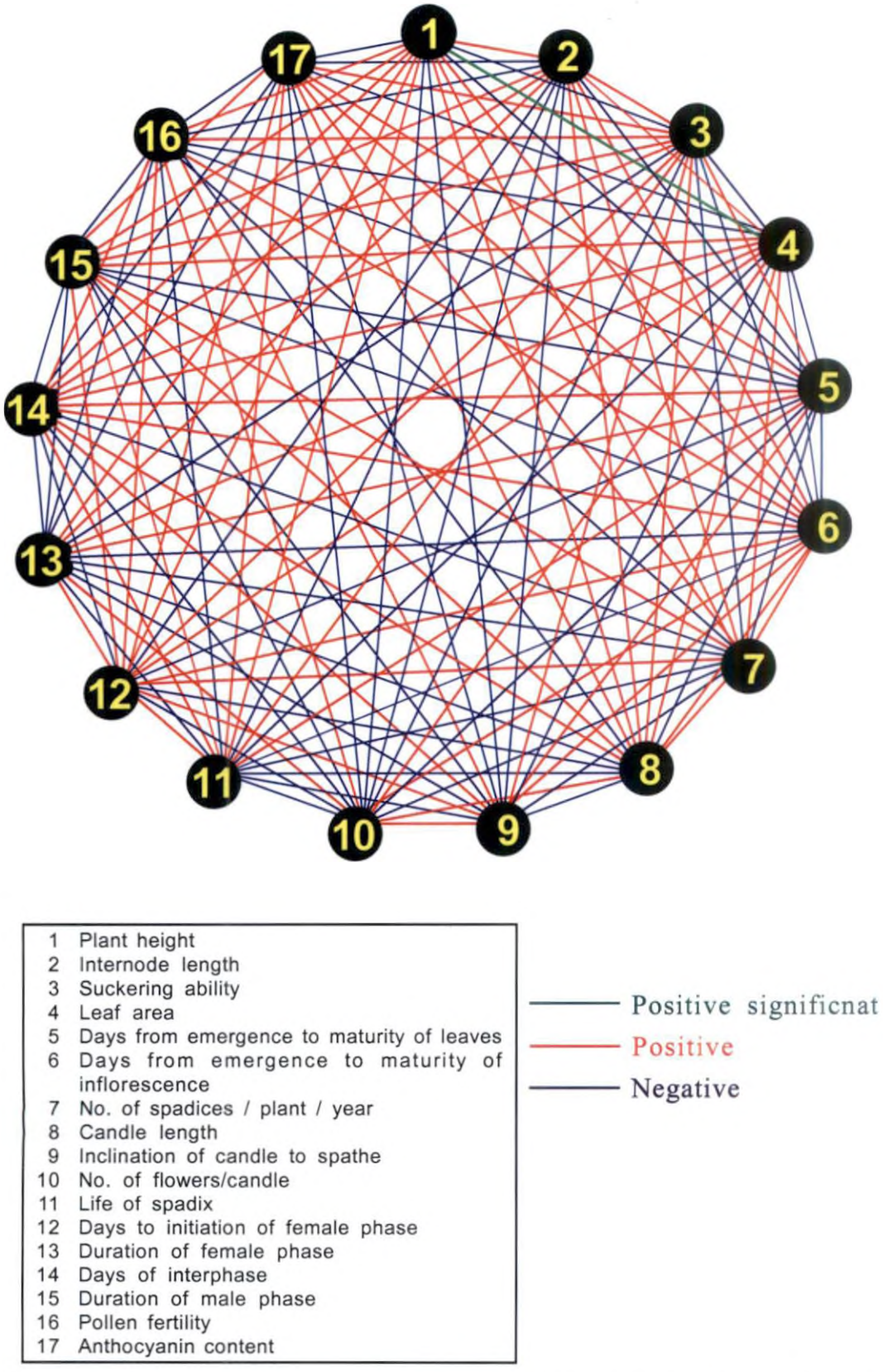


Fig. 7. Environmental correlation coefficients among the characters

correlated response to selection is the basic property of quantitative traits under the control of polygenic system. The quantitative traits governed by one or a few genes do not exhibit correlated changes on selection (Sharma, 1994). The genotypic correlation (inherant) between the characters helps to differentiate the vital association useful in breeding from non vital ones (Falconer, 1989).

The significance of pair-wise correlation are presented in Fig. 5, 6 and 7. The genotypic phenotypic and environmental correlations between all the possible pairs of characters are discussed. In the present study, number of flowers per candle showed positive genotypic correlation with plant height, internode length, leaf area, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, candle length, inclination of candle, life of spadix, days to initiation of female phase, duration of female phase, days of interphase, duration of male phase and anthocyanin content. This indicates that improvement of the character, number of flowers will result in overall increase of all the above characters. Candle length had high positive genotypic correlation with inclination of candle to spathe and number of flowers per candle. Since a decrease in candle length, angle between spathe and candle and number of flowers per candle is desired in commercial *Anthurium* varieties, their association is useful. This is in agreement with the observations of Renu (2000). Life of spadix, which is an important commercial character, was found to be positively correlated with candle length, number of spadices per plant per year, plant height and duration of female phase. The number of spadices per plant per year was found to have negative genotypic correlation with the inclination of the candle. Plants with less inclination of the candle and its negative association with number of spadices produced per plant per year is a favourable attribute. This is in conformity with the reports of Mayadevi (2001).

Phenotypic correlation was observed for all the 17 characters and most of them showed significant correlation among themselves. Environmental

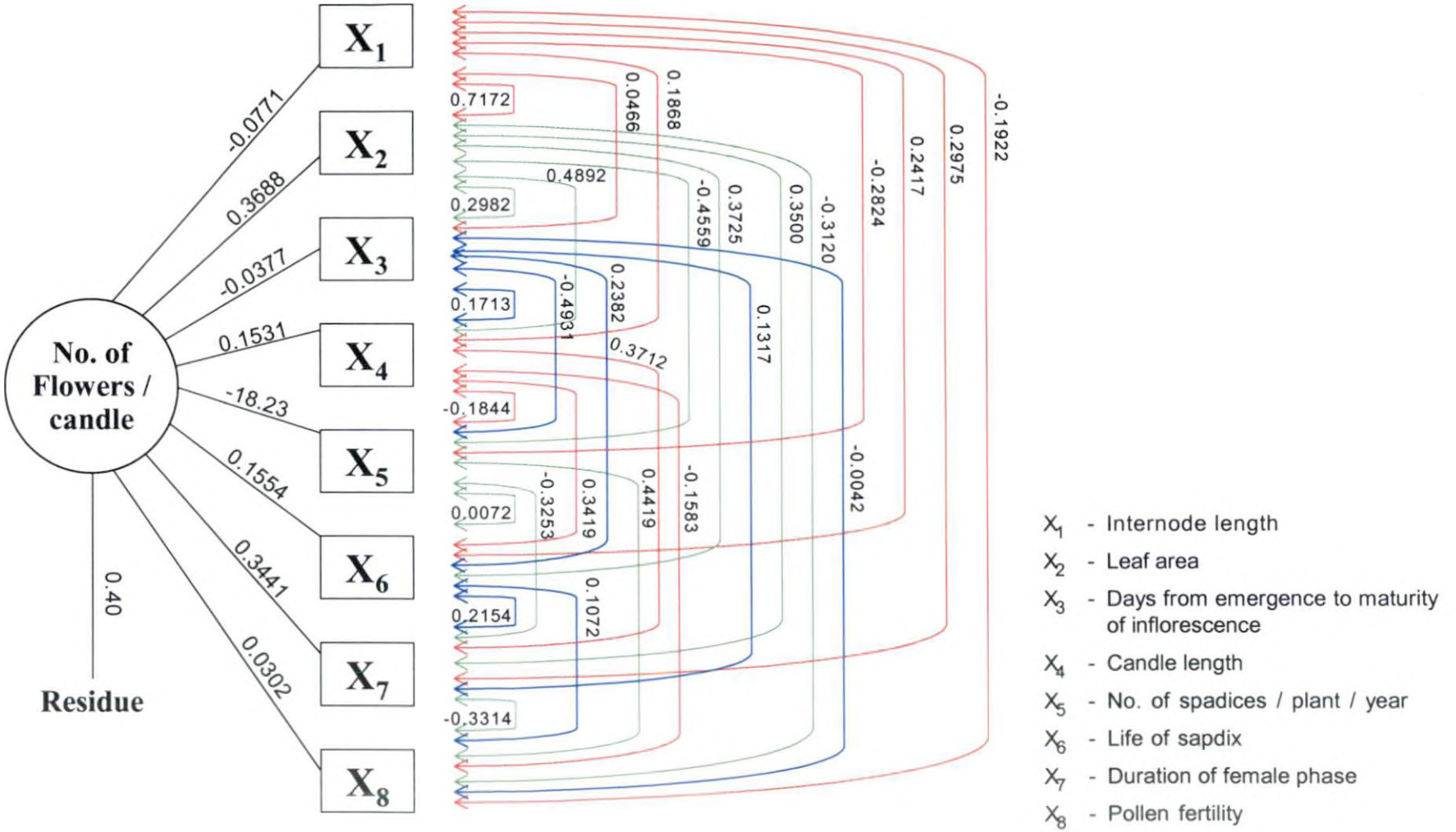


Fig. 8. Path diagram

correlations are absent for almost all pairs of characters except for plant height with leaf area and vice versa which has significant positive correlation.

5.5 PATH COEFFICIENT ANALYSIS

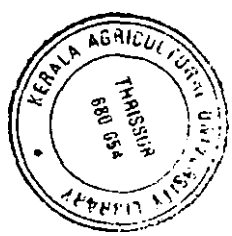
Plant breeders have to deal mostly with correlated characters during crop improvement programmes. Although correlation studies between yield and its components are useful, it does not give an exact picture of the relative importance of the various yield attributes. Rate of improvement is expected to be rapid if differential emphasis is laid on the component character during selection. Path coefficient analysis helps in partitioning the genotypic correlation coefficients into direct and indirect effect of the component characters and yield on the basis of which improvement programme can be derived effectively.

In the present study, high positive direct effects were recorded for leaf area (0.3688) and duration of female phase (0.3441), while candle length (0.1631), life of spadix (0.1554) and pollen fertility (0.0302) had low and negligible direct effects (Fig. 8). The other characters internode length (-0.0771), days from emergence to maturity of inflorescence (-0.0377) and number of spadices per plant per year (-0.1823) had negative direct effects. The characters leaf area and duration of female phase too had high genetic correlation. For selection of genotypes those characters having high direct positive effects are useful. Here, leaf area and duration of female phase are more associated with the dependent variable ie., number of flowers per candle. About 40 per cent of the variation in flower production was attributed by the environment (ie., Residue $03969 \approx 0.40$).

5.6 SELECTION INDEX

Selection of genotypes based on suitable index is highly efficient in any breeding programme. Selection index aids the breeder in indirect selection for genetic improvement in yield.

In the present investigation, the selection index for fifty genotypes was computed on the seventeen characters namely plant height, internode length, suckering ability, leaf area, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, number of spadices per plant per year, candle length, inclination of candle to spathe, number of flowers per candle, life of spadix, days to initiation of female phase, duration of female phase, days of interphase, duration of male phase, pollen fertility and anthocyanin content. The maximum values of selection index were recorded for the genotypes LR x DT, followed by FR x MW(1), PR x LR(3), MW x FR(1), HR x LW and so on. Least selection index value was observed for the genotypes FR x KR and LJ x MW, indicating that improvement of the character for these is comparatively less than that of the genotypes with high indices. Genetic gain was worked out and it revealed that if parents are selected based on selection index values for crop improvement 45 per cent genetic gain can be expected in the next generation.



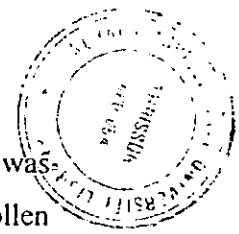
SUMMARY

6. SUMMARY

Genetic variability studies were conducted on fifty different genotypes of *Anthurium andreanum* Linden, generated from a previous hybridization programme in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani. The results of the analysis are summarised below.

- Significant genotypic differences were observed among the 50 genotypes for all the seventeen characters namely plant height, internode length, suckering ability, leaf area, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, number of spadices per plant per year, candle length, inclination of candle to spathe, number of flowers per candle, life of spadix, days to initiation of female phase, duration of female phase, days of interphase, duration of male phase, pollen fertility and total anthocyanin content.

- Medium plant height which is a desirable attribute was exhibited by 40 per cent of genotypes studied. All the genotypes in the present study showed medium internode length which is ideal. 72 per cent of the genotypes had medium sized leaf which is considered best for an ideal, commercial anthurium plant type as plants with medium sized leaves are more compact and occupy less green house space than those with large spready leaves. Commercially, slender and short candles are more preferred over long and thick candles and such type of candles were observed in 40 per cent of the genotypes studied. A down-ward curving candle is an extremely desirable character for commercial anthurium varieties and in the present study 62 per cent of the genotypes showed an inclination for the candle less than 45°.



- The pollen fertility, estimated using acetocarmine staining method was highest for LJ x MW (50.80 %) and low for PR x FR(2) (7.03 %). Pollen fertility study shows that most of the genotypes have low to very low pollen fertility. Pollen emergence pattern was observed among the fifty genotypes and found that it was low in the months from March to July, during which the average maximum and minimum temperature were relatively high.

- The total anthocyanin content were estimated and it was high for the genotypes PR x LR(3) with maroon coloured spathe (710.79 mg/g) and lowest in the genotype FR x KR with pink coloured spathe (26.81 mg/g). Genotype OG x DT showed double coloured spathe (obaki) with an anthocyanin content of 120.84 mg/g.

- A study of six qualitative trait such as colour of young leaf and petiole, plant type, spathe colour, spathe texture, candle colour and type of inflorescence axis revealed high variation.

- All the characters, except leaf area and number of flowers per candle were highly influenced by genotypic variation.

- Variability studies revealed that high phenotypic co-efficient of variation (PCV) along with high genotypic coefficient of variation (GCV) are present for total anthocyanin content, pollen fertility inclination of candle to spathe and duration of interphase. This suggests that there is an excellent scope for improvement of these characters through selection. The characters such as total anthocyanin content, life of spadix and days from emergence to maturity of inflorescence showed lower difference between GCV and PCV, revealing that the environmental influence on these character is less.

- Based on Allards classification of heritability all the characters except suckering ability and number of spadices per plant per year showed high heritability. High heritability was observed for the characters anthocyanin content followed by pollen fertility.

- According to Robinson *et al.*, classification all the seventeen characters studied showed high genetic advance with anthocyanin content at the top followed by pollen fertility.

- High heritability coupled with high genetic advance which was exhibited by almost all the characters except suckering ability and number of spadices per plant per year indicates that the characters are controlled by additive gene action suggesting the possibility of genetic improvement through selection.

- Almost all the characters except suckering ability, inclination of candle to spathe, days of interphase and duration of male phase are significantly correlated with each other both at phenotypic and genotypic levels.

- Number of flowers per candle had positive significant correlation with many characters namely internode length, leaf area, days from emergence to maturity of inflorescence, candle length, number of spadices per plant per year, life of spadix, duration of female phase and pollen fertility. This indicates that the improvement of the character number of flowers per candle will result in overall increase of all the positively correlated characters. Candle length had high positive genotypic correlation with inclination of candle to spathe and number of flowers per candle. Decrease in candle length results in decreased inclination of candle to spathe and number of flowers per candle which is a desirable attribute. The genotypic correlation between characters helps to differentiate the vital association useful in breeding from non vital ones.

- Environmental correlation was absent for all the characters except plant height with leaf area indicating the influence of environment on this character.

- The character leaf area and duration of female phase which had high positive direct effect are more associated with the dependent variable. ie., number of flowers per candle and 40 per cent of variation in flower production was attributed by the environment.

- The maximum selection index values were possessed by the genotypes LR x DT followed by FR x MW(1), PR x LR(3), MW x FR(1), HR x LW and so on indicating the improvement of the characters for these genotypes. Least selection index values were observed by the genotypes FR x KR and LJ x MW. The improvement of the character with less selection index value was comparatively lesser than those with higher indices. If parents are selected based on selection index value, 45 per cent genetic gain can be expected in the next generation.

- To conclude, reductions in plant height, leaf area, internode length, days to maturity of leaves, days to maturity of inflorescence, inclination of candle, candle length and increase in number of spadices and suckers per plant and high pollen fertility are highly desirable attributes for a good commercial anthurium plant. The protogynous nature of flower and low pollen fertility implies the hybrid nature of the plant. Hence selection of superior plants having the above mentioned desirable attributes will result in significant improvement of anthurium in the next generation through hybridization followed by selection which is the easiest and sure method for achieving genetic improvement.

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GENETIC VARIABILITY AND CHARACTER ASSOCIATIONS IN *Anthurium andreanum* Linden

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8. ABSTRACT

Genetic variability studies was conducted on fifty different genotypes of *Anthurium andreanum* Linden, generated from a previous hybridisation programme in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani.

The analysis of variance revealed significant variation among the fifty genotypes for all the seventeen quantitative characters studied. This reveals the high genetic potential for the improvement of this crop.

Variability studies indicated that high phenotypic and genotypic coefficients of variation for the characters of total anthocyanin content, pollen fertility, inclination of candle to spathe and duration of interphase. Except for leaf area and number of flowers per candle, all the other characters were highly influenced by genotypic variation. High heritability with a good genetic advance was found for all characters except for suckering ability and number of spadices/plant/year which exhibited medium heritability and high genetic advance. These results indicated that selection of plants which were phenotypically superior with respect to fifteen of the characters studied will certainly result in a significant improvement in the next generations.

Plant height was found to have significant positive phenotypic correlation with internode length, leaf area and days from emergence to maturity of inflorescence. Candle length showed significant positive correlation with leaf area, number of flowers per candle, life of spadix and duration of female phase.

Genotypic correlations were higher and for most of the characters it showed high positive correlations. Most of the estimates of the environmental correlation

coefficients for the characters are low and insignificant indicating the least effect of environment in the expression of the characters studied.

Pollen fertility ranged from 7.03 per cent in PR x FR(2) to 50.80 per cent in LJ x MW. The protogynous nature of the flower and low pollen fertility suggests the hybrid nature of the crop. During the months from March to July, the pollen emergence pattern was less where the maximum and minimum temperatures were relatively high.

Path coefficient analysis revealed that the characters leaf area and duration of female phase are more associated with number of flowers per candle and 40 per cent variation in flower production was attributed by the environment. High selection index values were recorded by the genotype LR x DT followed by FR x MW(1), PR x LR (3), MW x FR(1). If parents are selected based on selection index values, 45 per cent genetic gain can be expected in the next generation.