GENETIC IMPROVEMENT OF F_1 HYBRIDS IN *Anthurium andreanum* Linden

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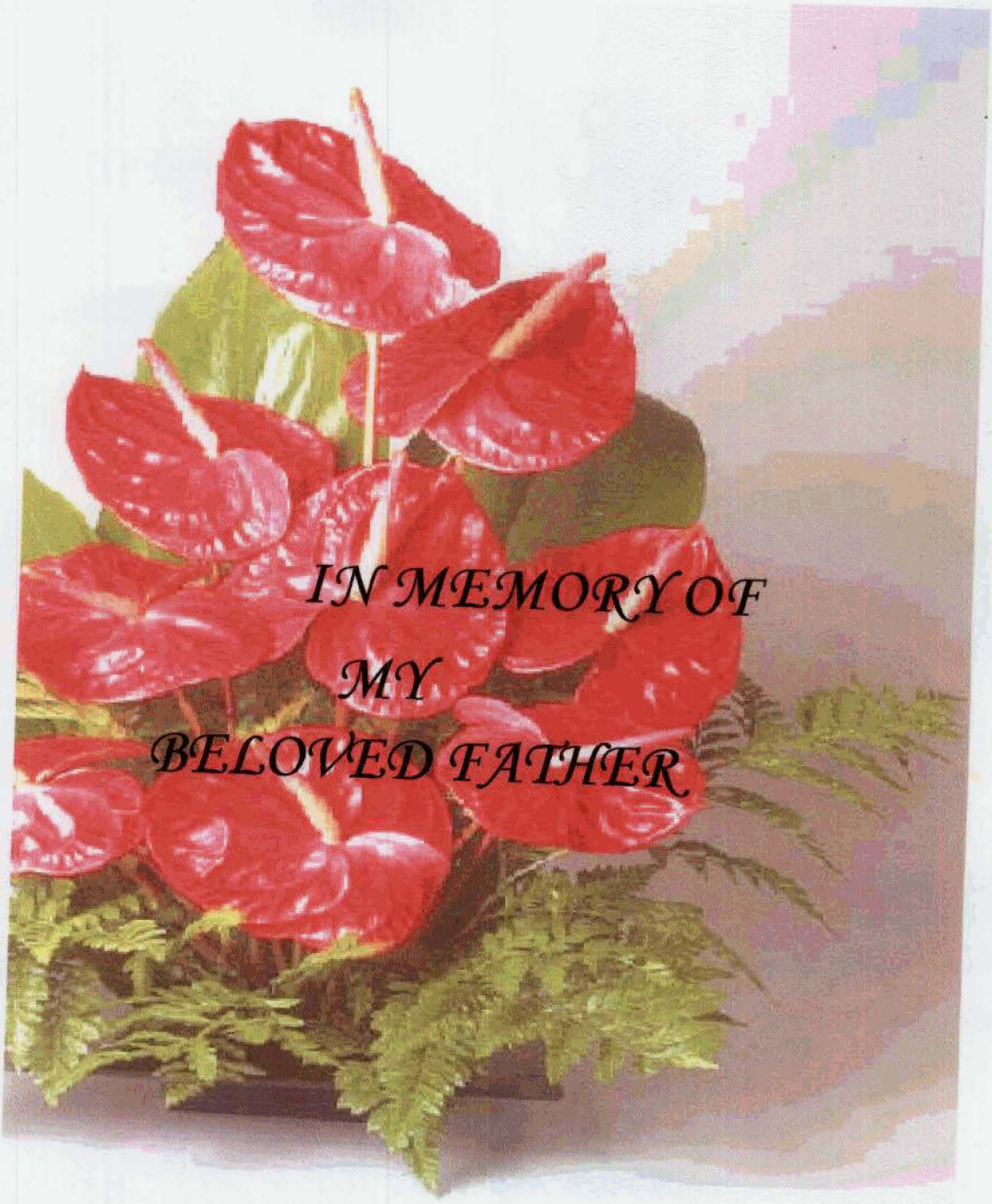
IN MEMORY OF
MY
BELOVED FATHER

DECLARATION

I hereby declare that this thesis entitled **"Genetic improvement of F_1 hybrids 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

Certified that this thesis entitled **"Genetic improvement of F_1 hybrids in *Anthurium andreanum* Linden"** is a record of research work done independently by **Mr. Pravin.R.S. (2002-11-13)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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LIST OF ABBREVIATIONS

^{0} C	Degree Celcius
ANACOVA	Analysis of covariance
ANOVA	Analysis of variance
AW	Acropolis White
CD	Critical difference
cm	Centimeters (s)
cv.	cultivar
df	degrees of freedom
et al.	and others
Fig.	Figure
g	Gram(s)
GCV	Genotypic coefficient of variation
HR	Honeymoon Red
i.e.	That is
KO	Kalympong Orange
LR	Liver Red
LW	Lima White
MG	Midori Green
ml	Millilitre
MO	Mauritius Orange
MSE	Error mean square
MW	Merengue White
NO	Nitta Orange
OG	Orange Glory
P	Pink
PCV	Phenotypic coefficient of variation
SS	Sum of squares
TR	Tropical Red
viz.	Namely

Introduction

1. INTRODUCTION

Among the various leading cut-flower crops of the world, anthuriums rank eleventh and its popularity is gaining importance rapidly. Anthuriums are tropical plants of grand beauty and are grown for their brilliantly coloured showy flowers and their unusually striking handsome foliage. The flowers of anthuriums are popular with the flower arrangers, because of their bold effect and lasting qualities (Bhatt and Desai, 1989 and Singh, 1995).

Anthuriums belong to the monocot family Araceae (Bailey, 1942). The neotropical genus *Anthurium* is the largest and most complex genus of Aroid group. The origin and relationships of wild species of the cultivated forms of anthuriums are some what obscure. The cultivated forms are probably derived from the inter specific hybrids which are supposed to have arisen spontaneously in the early anthurium collections (Birdsey, 1951).

The genus is abundant in many wet and cloudy forests of central and South America. There are about 600-800 species belonging to this genus exhibiting considerable morphological plasticity. Among the different species, three have gained commercial status viz., *A. andreanum* Linden grown chiefly for its cut-flowers, *A. Scherzerianum* Schott, grown as a flowering potted plant and *A. crystallinum Linden* grown as a foliage plant.

A. andreanum was introduced into cultivation and inevitably it spread rapidly with off-sets traded or sold at high prices, until it became a fairly common green house subject throughout the world. Together with some of its many hybrids, *A. andreanum* today forms the basis of a substantial cut-flower industry chiefly in Hawaii where much research has been done in its hybridization and culture (Kamemoto, 1981). The major international production centres of *A. andreanum* are Hawaii, Netherlands and Mauritius.

Anthuriums were introduced in India via England by coffee and tea planters who wanted showy exotic plants for their bunglows. The anthurium cut-

flower production in India is still in its infancy due to lack of elite planting materials and standard cultural practices. It is only very recently that anthurium flowers are seen in the Indian florists shops. A few growers in Yercaud, Salem district of Tamil Nadu, Cochin and Thiruvananthapuram of Kerala, Bangalore and Coorg region of Karnataka and in Kalympang of West Bengal have started growing anthuriums on a large scale for cut-flower production (Singh, 1995).

In anthuriums, the long peduncle along with the brightly coloured spathe upon which the spadix is borne, is regarded as the cut-flower of commercial trade. The spadix is a compact cylindrical spike bearing numerous flowers and the spathe is actually a modified bract (Geier, 1990).

Conventionally anthuriums are propagated by seeds which loose their viability quickly and hence should be sown immediately. It takes nearly 30-36 months for the seeding to flower and hence the crop improvement can progress at a slower pace.

Anthurium improvement by interspecific and intraspecific hybridization has led to the development of valued colour forms of spathe. There is an abundance of genetic variability in some species of *Anthurium* as revealed by the Karyotype analysis and meiotic studies by Lalithambika (1978) and Satyadas (1985). These facts point out the possibility of achieving crop improvement in *Anthurium* through hybridization and selection.

Hybridization followed by selection is the accepted method used for improving anthuriums (Kamemoto and Nakasone, 1955). Hybridization between selected varieties with good combining ability can be used for creating valuable *Anthurium* hybrids with desirable plant characters such as compact plant type, medium sized leaves, heart shaped spathe with symmetrical lobes, wrinkled spathe texture, straight long inflorescence axis and a reclining spadix to facilitate packing (Mayadevi, 2001).

With the above background taken with due consideration the present study is undertaken with the aim of assessing the genetic variability and compatibility of 14 genotypes of *Anthurium* and to improve specific commercial characters such as erect, long inflorescence axis, deep blisters of spathe and short downward curving candles of some promising F_1 hybrids. The hybrids obtained from the compatible crosses will come to bloom within a time span of three to four years and the desirable types can be selected from the lot.

Review of Literature

2. REVIEW OF LITERATURE

Anthurium is currently being promoted as an export oriented cut flower suitable for commercial cultivation in Kerala. The only species of commercial value in tropics is *A. andreanum* which is a native of Columbia. The warm humid tropical climate of Kerala can be easily adapted for its widespread cultivation.

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 improve some specific commercial characters of some promising F_1 hybrids in anthurium. 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 MORPHOLOGICAL AND FLORAL CHARACTERS

2.1.1 Cultivation Aspects

Anthuriums require a warm green house with 75 per cent shading from direct sunlight and atmospheric humidity 70-80 per cent. 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).

2.1.2 Nutrition

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

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

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

2.1.3 Plant Height

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

Bindu and Mercy (1994), observed that the five varieties of the genus of *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 cm. to 70 cm. In another study with 'Hawaiian Red' 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 var.

'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 20 varieties of *A. andreanum* which ranged from 45.5 cm in var. 'Midori Green' to 96.67 cm in var. 'White'. The height of the genotypes varied from 22.17 cm to 64.80 cm in the study conducted by Asish (2002). Premna (2003) observed a plant height of 21.25 cm ('Carre') to 44.00 cm ('PR x DT').

2.1.4 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 ten 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').

Asish (2002) recorded that internode length ranged from 0.97 cm in 'MW x PR' to 2.57 cm in 'MW x FR (1)'. Premna (2003) observed a maximum value of 1.48 cm ('PR x DT' and 'Acropolis White') and a minimum of 1.20 cm ('Carre').

2.1.5 Number of Suckers per Plant

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 Benzyl adenine (BA) (500-1000 ppm) was found to increase sucker production. Sindhu (1995) observed maximum number of suckers in the variety 'Pink' and the least in the variety '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 fail 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.

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 20 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'.

Asish (2002) with 50 genotypes observed 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'. Among 14 genotypes studied by Premna (2003) the sucker production was highest for the genotype '00 x KR' (2.25) and lowest for 'Acropolis White' (0.25).

2.1.6 Leaf Size/Leaf area

Medium sized leaves 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 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. 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 anthurium should be small to medium sized, narrow and elongated. Large and exuberantly growing leaves indicated premitiveness and were undesirable. Sindhu (1995) observed that the var. 'Pink' produced bigger sized leaves whereas 'White' and 'Chilli Red' produced smaller sized leaves which are commercially more valuable than 'Pink'.

Salvi (1997) with the variety 'Hawaiian Red' reported that 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). 'Honey moon Red' had the largest leaf area of 88.89 cm^2 which is not ideal.

Leaf area ranging from 41.32 to 323.77 cm^2 was reported by Asish (2002) in his study with 50 genotypes. Premna (2003) recorded a minimum leaf area for the genotype 'Carre' (113.62cm^2) and a maximum for 'Acropolis White' (301.10 cm^2).

2.1.7 Number of Leaves or Spadices/plant/year

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

Higaki and Poole (1978) while studying on var. 'Ozaki' found that the flower production increases with age of the plant. Higaki and Rasmussen (1979) found that anthuriums are slow growing, producing only 6-8 new leaves and vegetative buds on a stem axis per year.

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 through out the life of the plant.

Mercy and Dale (1994) observed that anthuriums are 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 4 to 8. Renu (2000) showed that one spadix each was produced from the axil of each leaves 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' (7.6) followed by 'Liver Red' and 'Pompon Red'.

Mayadevi (2001) reported that among the varieties studied 'Honeymoon Red' has the highest number of spadices (7.6). She also stated that the average production ranged from 4.67 to 8.00. Asish (2002) observed that, among 50 genotypes the maximum number was observed in KO x DT (7) while the minimum in 'PR x DT' and 'TR x MW(3)'.

Premna (2003) observed the maximum number of spadices in the genotypes 'Acropolis White', 'OO x PR', 'PR x DT' and 'Tropical Red' (6) and minimum number in the variety 'Carre' (4.25).

2.1.8 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'.

Asish (2002) with 50 genotypes observed the average days for the emergence of leaves to its maturity as 27.56 with the range 15.33 days in 'OG x LR' to 41.00 days in 'DT x FR'. Premna (2003) noticed the least number of days for maturity by 'Carre' (26.25) and a maximum number of days for the genotype 'PR x DT' (40.25).

2.1.9 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'. Asish (2002) in his study observed that this character ranged from 16.67 days in 'NO x LR (1)' to 37.67 days in 'MO x KR (1)'. Premna (2003) recorded the lowest mean value for the variety 'Carre' (29.00 days).

2.1.10 Candle Length

The candle (spadix) is the inflorescence proper, bearing 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 preferred over thick candles.

Bindu (1992) reported, the candle length of five varieties of *A. andreanum* which ranged from 4 cm to 9.5 cm. In ordinary varieties of 'Red', Pink' and 'White' the candle was long and fleshy but in highly bred hybrids and exotics, the candle was shorter and more slender according to Mercy and Dale (1994). The candle length of six 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 5 parents and 10 F_1 hybrids. Longest candle was recorded by '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').

Asish (2002) reported that among the 50 genotypes studied by him 'FR x MW (2)' had the minimum candle length of 3.13 cm while 'FR x MW (1)' had the maximum candle length of 9.19 cm. Premna (2003) in her study with 14 genotypes observed the lowest value for candle length for the genotype 'FR x KR' (4.63 cm) which was on par with 'Carre' (4.88 cm) and 'LR x FR' (4.75 cm).

2.1.11 Inclination of Candle with the Spathe

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 variety as this helps in packing a large number of inflorescence in a box during transportation.

Mercy and Dale (1994) reported that flower bearing candle in a good commercial variety was attached to the base of the spathe held at an angle slanting or curving at 25 to 40 ^{0}. 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 ^{0} between the base of the candle to the plane of the spathe was observed in the var. 'Honeymoon Red', which is not desirable. The ideal Anthurium spadix with an angle less than 45^0 were found in varieties 'Chilli Red', 'Kalympong Orange', '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 the candle ranged from 21 ^{0} in 'Kalympong Red' to 78.2 ^{0} in 'Honeymoon Red' among the parents. The hybrids also showed significant difference for the character ranging from 20.8 ^{0} ('HR x CR') to 89.6 ^{0} ('HR x P'). Asish (2002) observed that inclination of the candle ranged from 10.67 ^{0} in 'PR x MO' to 89.33 ^{0} in 'MO x KR (1)'. Premna (2003) reported the lowest angle for the genotype 'KR x LR' (21^0) which was on par with 'PR x FR' (22.5 ^{0}).

2.1.12 Number of Flowers/candle

The larger the candle the more number of flowers per candle. Though varieties like 'Honeymoon Red' and 'Pink' have large candles with flowers upto 400 or more. They are not preferred as these varieties are non-commercial. Ideal commercial varieties have smaller candles with less number of flowers.

Watson and Shirakawa (1967) observed that *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 flowers of anthurium were bisexual and was closely congested on a cylindrical 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 spathes are borne on a leafless 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 a racemose with a slender floral axis (candle) bearing 150-350 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 lowest in the variety 'Chilli Red' (175 flowers). Renu (2000) in her study found that 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 DT' and 'P x KR' had the maximum number of flowers per candle of 600.

2.1.13 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 unfertilized spadix was about 2 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.

Valsalakumari *et al.* (1998) reported that *A. andreanum* cv. 'Agnihotri' the longivity of spadix was maximum with 1000 ppm GA_3 which 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 10 varieties studied, var. 'Nitta Orange' had a life span from the emergence of spathe to its senescence was 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 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.

Asish (2002) observed that the average days taken for opening of inflorescence to its death was 77.08. Premna (2003) noted the lowest mean for the life of the spadix in the variety 'Carre' (59.50 days) and the highest for PR x DT (101.50 days).

2.1.14 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 development proceeds acropetally towards the apex.

Mercy and Dale (1994) reported that the flower 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 up to 10 days, after opening of spathe, with the variety 'Honeymoon Red' showing the longest period for female phase initiation.

Renu (2000) in her study with 10 varieties 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 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 species. Asish (2002) inferred that the average number of days required for the initiation of female phase was 6.1. Premna (2003) observed the mean number of days to initiation of female phase ranging from 2.75 in 'OO x KR' to 8.00 in 'PR x LR', 'PR x DT' and 'Tropical Red'.

2.1.15 Duration of Female Phase

Croat (1980) reported that the duration of pistillate phase was quite variable which ranged from only a few hours in *Anthurium ravenii* to 21-28 days in *A. luterynii* and *A. caperatum*. The female phase for the species *A. andreanum* varied from 3-12 days (Bindu, 1992).

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) reported that female phase ranged from 5 to 25 days. According to Renu (2000) the duration of female phase varied from 6.4 days in 'Lady Jane Red' to 16.4 days in 'Mauritius Orange'. She also observed individual flower in which the duration lasted upto 21 days in 'Mauritius Orange'.

Mayadevi (2001) from her study observed that the duration of female phase ranged from 7.4 days in 'Pink' to 13.6 days in 'Kalympong Red' and in hybrids it ranged from 9.6 to 12.8 days.

Duration of female phase on an average lasted for about 6.1 days with a range 3.67 days in 'OG x KR' to 11.33 days in 'MW x FR (1)' in a study by Asish (2002). Premna (2003) reported that duration of female phase ranged from 5.50 to 9 days in 14 genotypes studied.

2.1.16 Days of Interphase

The period between female and male phase was several days in most *Anthurium* species, where as 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 four to seven days. They also found that during rainy seasons, the interphase is prolonged.

Mercy and Dale (1994) reported that the interphase was about one week. In a study by Sindhu (1995) the interphase in *A. andreanum* ranged from four to ten days. Prolonged interphase with the suppression of male phase was observed from March to August in several varieties.

Renu (2000) observed that the interphase was marked by the drying up of stigmatic droplets . Observation from seven varieties showed that the interphase ranged from 4.8 to 10.2 days. The longest interphase was shown by 'Liver Red' and the shortest by 'Merengue White'.

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. Asish (2002) observed that interphase ranged from 2.00 ('PR x KR') to 11.67 days ('MO x KR (2)'). According

to Premna (2003) in a study with fourteen genotypes, the interphase ranged from 4.50 days ('Carre') to 9.25 days ('PR x DT').

2.1.17 Duration of Male Phase

Croat (1980) observed 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. Bindhu and Mercy (1994) recorded that the anther exertion started from the base and proceeded regularly towards the apex and the duration of male phase ranged from 3 to 7 days in the five *A. andreanum* varieties studied by them.

Mercy and Dale (1994) reported that all the anthers on a candle emerged in about 4-8 days. According to Sindhu (1995) the male phase may range from 3-8 days depending on the variety. She also noticed irregular appearance of stamens on the candle.

Among the ten varieties studied by Renu (2000) she noticed that the average number of days of male phase ranged from 5.4 days in 'Mauritius Orange' to 10.4 days in 'Tropical Red'.

According to Mayadevi (2001) the days of anther emergence ranged from 5 days in the variety 'Chilli Red' to 7.20 days in variety 'Honeymoon Red'. Among crosses, a maximum of 9.60 days ('P x KR') to a minimum of 5.60 days ('HR x CR') was recorded. Asish (2002) observed a maximum duration of 12.67 days ('MW x PR') to a minimum of 4 days ('MW x DT'). Premna (2003) recorded maximum duration of 12 days for the variety 'Honduras' and lowest for 'Carre' (6.50 days).

2.1.18 Pollen Fertility

Appearance of the pollen alone at collection time is not always a good index of viability (Stanley and Linsken, 1974). So pollen fertility is tested either by using specific stains or by *in vitro* growth studies.

Lalithambika (1978) noticed in a study that 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) also reported that the 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 per cent). 'Mauritius Orange' and 'Lady Jane Red' recorded the lowest fertility value of 14.0 and 13.7 per cent.

Mayadevi (2001) from her study inferred that high pollen fertility was observed for the variety 'Liver Red' (45.90 per cent) followed by 'Pink' (28.40 per cent). Among the 50 genotypes studied by Asish (2002), pollen fertility was found to be 24.24 per cent on an average.

Premna (2003) observed highest pollen fertility of 35.70 per cent for the variety 'Carre' followed by 'Honduras' 35.13 per cent.

2.1.19 Pollen Morphology – Size and Shape

Bindu (1992) while studying pollen grains of five varieties observed that the size of pollen grains varied from 87.2 x 86.4 μ (Lady Jane) to 81.8 x 68.0 μ (Pink). All the varieties had more or less round pollen with a germ pore.

2.1.20 Colour of Young Leaf and Petiole

The colour of young tender leaves of *A. andreanum* varied from light green to deep reddish brown (Mercy and Dale, 1994). Sindhu (1995) observed 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 young tender leaves showed light green, green, greenish brown, light brown and brown colour. Colour of petiole and young leaf ranged from green to brownish green and brown as observed by Asish (2002). Premna (2003) noticed a range from brown to reddish brown to greenish brown to green. The colour of the petiole also varied from brown to reddish brown to greenish brown to green.

2.1.21 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-pelergonidin 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 where as 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-rhamnosylglucoside. 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 *i.e.*, 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), 2 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 predominance of cyanidin-3-rhamnosyl glucoside resulted in pink to red colour where as 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 the 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 were 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 found to be true breeding. The incremental effects of M was greater than that of O 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 introduction in Hawaii according to the Royal Horticultural Society Colour Chart.

Wannakrairoj and Kamemoto (1990) while studying 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 *i.e.*, 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 flowers 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 (Liver Red) and some varieties had spathes of two or three colours (obaki).

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) found 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 mgg^{-1} and 93.9 mgg^{-1} respectively. While for growth regulators, the corresponding values were 67.88 mgg^{-1} and 84.18 mgg^{-1} 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 Horticultural 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 10 varieties into deep maroon to dark red, red, light orange, 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 ('Chilli Red') to red ('Honeymoon Red'). The mean total anthocyanin content ranged from 121.38 mgg^{-1} in Pink to 386.56 mgg^{-1} in 'Liver Red' in the parents while the range of this character was from 146.03 mgg^{-1} ('HR x LR') to 330.95 mgg^{-1} ('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.

Asish (2002) in his study on 50 genotypes found that the spathe colour range was deep maroon, maroon, dark red, red, light red, dark orange, pink and white. The genotype 'OG x DT' had double colour spathe of red and green. The spathe colour ranged from deep maroon to white in the 14 genotypes observed by Premna (2003).

2.1.22 Spathe Texture

Blistered 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 *A. andreanum* and its varying degrees of smoothness to blistering. Arndt (1991) reported that the spathe of *A. scherzerianum* variety 'Arabella' was 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 spathe 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 shallowly 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', 'HR x KR', '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.

Asish (2002) noticed that spathe texture varied from thick blistered glossy, medium thick deeply blistered glossy, thick smooth glossy and medium thick smooth. Premna (2003) observed that spathe texture varied

from thick blistered glossy to medium thick deeply blistered glossy and thin smooth glossy.

2.1.23 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 'Ellarina' with light salmon spathe and sulphur yellow spadix to be the best suited for green house cultivation.

Arndt (1991) *A. scherzerianum* var. 'Arabella' had red spathe and candle. Mercy and Dale (1994) in their observations revealed that the candle had a single colour of 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.

The candle colour varied from red to light red, reddish pink, pink, light pink, pinkish yellow, pinkish white, yellow, yellowish white and cream in fifty genotypes studied by Asish (2002). Premna (2003) in her study observed that candle colour varied from pink to cream, creamish yellow and yellowish white.

2.1.24 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's studied, the axis nature varied from long, straight and very strong in all the parents and hybrids except for the parent variety 'Kalympong Red' in which it is long, thin and slightly curving.

Asish (2002) reported that 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)'. Premna (2003) observed long, straight and strong inflorescence axis in 'Acropolis White' and 'Tropical Red'. Among female parents inflorescence axis was long thin and curving for 'OO x KR' and 'PR x MW'.

2.1.25 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 dehiscence 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 equality of proportions. The value of Q was found to be significant which showed that there was significant difference among the varieties with respect to pollen emergence. 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.

2.1.26 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 develped. 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 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.

2.2 COMPATIBILITY STUDIES

According to Kamemoto and Nakasone (1955), hybridization and selection were the most common methods for improving anthuriums. Productivity, flower colour, shape and texture, short internodes and suckering ability are different characters to be considered in selection. Controlled hybridisation indicated that neither white nor red flower colour was dominant and pink was an intermediate heterozygous condition.

A general mode of spathe colour inheritance in *Anthurium andreanum* was suggested by several investigators (Kamemoto and Nakasone, 1955, 1963, Kamemoto *et al.*, 1969; Sheffer and Kamemoto, 1977) based on intraspecific and interspecific hybridization.

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 *i.e.*, '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.

Kamemoto *et al.* (1969) described two seedling selections 'Anuenue' and 'Chameleon' for cut flower production and a compact clone 'Red Elf' suitable for growing as a pot plant. 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 followed.

Sheffer and Kamemoto (1978) evaluated the interspecific cross compatibilities among 56 species of *Anthurium* and they 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.

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

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

Kaneko and Kamemoto (1979) analysed the chromosome number of Anthurium sp. as 2n=30+3B. They informed that the appearance of offspring with 2,3 and 4B chromosome, on self pollination indicated the transmission of B chromosomes through both pollen and egg. Maurer (1979) described the techniques of cross pollinating *A. scherzerianum* and discussed the presence of recessive characters like lack of anthocyanin, spotted spathe etc.

Leeuwen (1984) in an evaluation trial 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 observed that in *A. scherzerianum* first inflorescence appeared 12-15 months after sowing but began flowering regularly only after 18-24 months. The spadix seldom had full fruit set. Tissue culture from selected genotypes took, 4-5 months to become 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 *A. andreanum* and *A. amnicola* (a dwarf species collected from Costa Rica, which is very floriferous but bears small lavender spathes, 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.

Marutani *et al.* (1993) conducted detailed cytological analysis of *A. andreanum*, its related taxa and their hybrids. They concluded that regular bivalent formation at prometaphase I of meiosis in pollen mother cells of species hybrids suggested close genomic relationships 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.

Mercy and Dale (1994) opined that hybridization between selected varieties with good combining ability could produce novel and valuable anthurium hybrids. They also added that 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.

Sindhu (1995) recorded that a large number of combinations were incompatible. The maximum percentage of fruits (52.3 per cent) 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.

Anthura (1997) submitted for registration, anthurium variety 'Champion', derived from *A. andreanum* hybrids. This variety had small leaves and flowers cupped white spathe held above the canopy and red spadix. Henny (1999) found that the new interspecific anthurium hybrid Red Hot is highly suitable for pot planting because of its compact growth, freely branching growth habit and production of numerous showy red spathes.

Cross compatibility studies were done by Renu (2000) in 10 varieties based on the percentage of candles bearing fruits, fruit set and seed germination. The percentages of fruit bearing candles were highest for 'Nitta Orange' (51.43) and lowest for '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 per cent) 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 PR x LR and 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 parents.

Premna (2003) after scoring the different genotypes and crosses obtained scale from zero to nine. The cross with the highest compatibility score of nine was '(OO x KR)' x C and the best female parents observed were 'OO x PR' and 'PR x LR'.

2.2.1 Percentage of Candles Bearing Fruits

Sheffer and Kamemoto in 1976a did 1592 pollinations which include 20 selfs, 19 intraspecific cross combinations, 315 intra group interspecific cross combinations (including reciprocals) and 29 different intra group cross combinations (including reciprocals). The species were divided into six distinct morphological groups on the basis of important Englerian characters of the number of ovules per locule, colour and shape of the berry, shape of inflorescence, shape and texture of the leaf. The species were group divided into six distinct morphological groups. Group I and II were separated on the basis of the number of ovules per locule. Group III and IV were Engler's sections Pachynerium and Schizoplacium respectively. The remaining species were included under groups V and VI and were organized into two groups on the basis of leaf texture, berry shape and colour. Intra and inter group pollinations were done, fruits harvested and germinating seeds obtained.

Self-pollination resulted in 81 per cent fruiting spadices. Intraspecific and interspecific cross combination resulted in 65.4 per cent and 28.1 per cent fruiting spadices respectively. Group I, III and V gave higher percentage of fruiting spadices and flowering hybrids than group I, IV and VI. The presence of B-chromosomes also effected the viability (Bhattaglia, 1964; Sheffer and Kamemoto, 1976a).

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. It was maximum (93 per cent) for the variety 'White' and lowest (50 per cent) for the variety 'Kalympong Red'. On the results of intervarietal hybridization 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'. Among the cross combinations attempted the percentage of fruiting candles was 100 per cent for nine crosses in a study on 14 genotypes by Premna (2003).

2.2.2 Number of Fruits/candle

Zimmer (1986) identified the absence of full fruit set in a spadix as a major problem in the development of anthurium cultivars. He added 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 to 200 or more berries had developed. A candle with developing fruits should be visually identified from the second month of fertilization as it become 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 six varieties studied by Sindhu (1995) the maximum average number of fruits was produced in the 'Pink' variety followed by 'Honeymoon Red'. The maximum number of fruits were harvested from the cross 'Pink' x 'Honeymoon Red' (170) and the lowest number from 'Kalympong Red' x 'Kalympong Red (2)'.

Among the ten varieties studied by Renu (2000) 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'.

Premna (2003) observed highest fruit set in the cross ('OO x KR') x C (120) and no berries were obtained for 'PR x FR', 'DR x MW', 'PR x DT' and 'LR x FR'.

2.2.3 Percentage of Fruitset/candle

Based on cross compatibility studies using six varieties, Sindhu (1995) recorded that the maximum percentage fruit set for the cross 'P x

HR' (52.3 per cent) followed by 'HR x P' (44.3 per cent). The lowest percentage fruit set was observed in the cross 'KR x KR' (0.4 per cent).

Renu (2000) reported that the percentage of fruit set was below 50 per cent for all the crosses involving two 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.

Premna (2003) observed highest fruit set for the cross ('OO x KR') x C (34.29 per cent). Among the ten female parents, the highest average percentage fruit set was observed for 'OO x KR' (29.03 per cent).

2.2.4 Number of Seeds/berry

Zimmer (1986) while evaluating the development of anthurium cultivars observed that the berries contained two to three seeds and for ripening it took 5-12 months.

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

According to Mercy and Dale (1994) in the commercial varieties of *A. andreanum*, each berry contained one or two seeds and the seeds matured in about 4-7.5 months. Seeds remain enclosed within the thin fruit wall in a gelatinous pulp and if not harvested, remain attached to the candle for a few days more before they dried up and fell off the candle.

In the compatibility study using six varieties by Sindhu (1995), the percentage of single seeds produced were more than the double seeds except in the cross 'Kalympong Red' x 'Honeymoon Red', where the percentage of double seeds was 63 per cent. The percentage of single seeds ranged from 37 per cent to 100 per cent.

Renu (2000) in study on ten varieties observed that the percentage of single seeded berries ranged from 34.30 to 100 percent and that of double seeded from 0 to 62.50.

Premna (2003) observed that the percentage of single seeds were more than the double seeds in most of the crosses.

2.2.5 Seed Size

Sindhu (1995) recorded that the berries were usually single seeded and sometimes double seeded. When two seeds were seen in a berry usually one of them was smaller. 'Pink' and 'Honeymoon Red' varieties produced larger sized seeds and the Kalympong varieties produced comparatively smaller sized seeds.

Renu (2000) reported that largest seeds in double seeded berries was for the crosses 'PR x LR', 'PR x DT' and 'MW x LR' and among the single seeded crosses, 'TR x MW' had the largest size.

Premna (2003) observed the maximum average length and width in single seeded berries for the cross 'PR x LR' x Tropical (5mm x 4mm) and for double seeded it was (4.25mm x2.50mm) for the crosses 'CR x LR' x 'Honduras' and 'W x LJ x 'Acropolis White'.

2.2.6 Percentage of Germination of Seeds

Zimmer and Bahnemann (1982) found that seeds of *A. scherzerianum* from different sources varied in their ability to germinate at low, suboptimal temperatures. Optimum germination temperature was recorded to be 20 – 25^{0}C, but some seeds germinated well at 10 or 15 ^{0}C .

Szendel *et al.* (1992) germinated the seeds of *A. andreanum* harvested at three maturity stages and those of *A. scherzecianum* at one maturity stage (light orange) on three substrates, at pH ranging from 4 to 8 in light or darkness at 18, 24 or 28°C. In *A. andreanum* the best

germination was obtained on a high peat substrate, at pH 4-5 in light at 28° C using seeds harvested at an early maturity stage.

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.

Mercy and Dale (1994) reported that, 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.

Sindhu (1995) observed that the maximum average seed germination was observed in combinations with the variety 'White' as the female parent (63.4 per cent) 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' (78.0 per cent).

Renu (2000) recorded that the seed germination was highest (87.5 per cent) in 'Dragon's Tongue Red' 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.

Premna (2003) recorded highest average germination percentage for the cross 'W x LJ' x 'Honduras' (88.90 per cent) and lowest for PR x LR x 'Acropolis White' (49 per cent).

Materials and Methods

3. MATERIALS AND METHODS

The present study was undertaken to improve specific commercial characters such as erect, long inflorescence axis, deep blisters of spathe and short downward curving candles of F_1 hybrids in *Anthurium andreanum* Linden by crossing 10 F_1 hybrids with four commercially accepted varieties. The investigation was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 2003-2004.

3.1 MATERIALS

The following ten F_1 hybrids of anthurium showing variations in spathe colour, shape, size and other commercially valuable morphological characters generated through hybridization in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani under NARP (SR) project were used as female parents.

1. 'Liver Red' x 'Dragon's Tongue Red' [LR x DT]
2. 'Fla Red' x 'Merengue White' (2) [FR x MW (2)]
3. 'Mauritius Orange' x 'Kalympong Red' (1) [MO x KR (1)]
4. 'Kalympong Orange' x 'Chilli Red' [KO x CR]
5. 'Pompon Red' x 'Fla Red' (1) [PR x FR (1)]
6. 'Nitta Orange' x 'Dragon's Tongue Red' [NO x DT]
7. 'Pompon Red' x 'Kalympong Red' [PR x KR]
8. 'Liver Red' x 'Pompon Red' [LR x PR]
9. 'Pompon Red' x 'Mauritius Orange' [PR x MO]
10. 'Orange Glory' x 'Dragon's Tongue Red' (2) [OG x DT (2)]

Four varieties with commercially acceptable qualities were used as male parents.

1. Acropolis White (AW)
2. Tropical Red (TR)
3. Orange Glory (OG)
4. Liver Red (LR)

3.2 METHODS

The selected parents and hybrids were raised in pot culture experiment under completely randomized design with three replications and observations were recorded from single plants (single plant per replication). 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 were 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^{-1} 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 preparing the latter 2 kg of neem cake were fermented in 5 l of water for two days. The mixture was then diluted by adding 245 l by very dilute cowdung water. About 200 ml of the sieved fertilizer solution was then applied to each pot.

Plant Protection

1. For the control of blight or anthracnose by *Colletotrichum gloeosporioides* regular application of following chemicals were used.

a. Bavistin 50 per cent WP @ 2g l^{-1} or

b. Indofil M-45 2 g l^{-1}

2. Dipping the roots of plants in Indofil M-45 at the time of planting helped to avoid soil borne diseases.

3. *Pseudomonas fluorescens* @ 2 per cent was applied as prophylactic measure against bacterial blight caused by *Xanthomonas axonopodis* pv. *dieffenbachiae* at weekly intervals.

4. Need based application of metacid (2g l^{-1}) or Nuvacron (2g l^{-1}) were used to control leaf feeding caterpillars and grass hoppers. Mites were controlled using Kelthane (2ml l^{-1}).

5. Snails and slugs were controlled by picking by hand and also by the application of furadan 3 g @ 2-3 g per pot.

Morphological Studies

The plant materials with stabilized vegetative and floral characters were used for taking all the observations. Observations on the following 22 characters (vegetative, floral and qualitative characters) of male (four genotypes) and female parents (Ten hybrids) were recorded and their mean values were taken.

3.2.1 Quantitative Characters

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 Sukering Ability

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

3.2.1.1.4 Leaf size or 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 the 14 parents were measured by applying linear regression.

$$y = 9.53 + 0.64\ x$$

Where y is the leaf area and x = maximum leaf length x maximum leaf breadth (Mayadevi, 2001).

3.2.1.1.5 Number of Leaves per Plant

The number of leaves per plant was noted and recorded.

3.2.1.1.6 Days from Emergence to Maturity of Leaves

Days from the emergence of the leaf to the maturity of leaves were recorded.

3.2.1.2 Floral Characters

3.2.1.2.1 Days from Emergence to Maturity of Inflorescence

The time taken from the emergence of inflorescence to its full maturity were recorded.

3.2.1.2.2 Number of Spadices per Plant per Year

The number of spadices produced during the one year period was noted and recorded.

3. 2.1.2.3 Candle Length

Candle length was measured in centimeters from the base of the candle to its tip.

3.2.1.2.4 Inclination of Candle

The angle between the base of the candle to the plane of the subtending spathe was taken with the help of a protractor.

3.2.1.2.5 Life of Spadix or 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.

3.2.1.2.6 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.

3.2.1.2.7 Duration of Female Phase

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

3.2.1.2.8 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.

3.2.1.2.9 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 were recorded.

3.2.1.2.10 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 per cent). Five slides were made for each genotype and from each slide, ten microscopic fields were scored and the data recorded. Unstained, 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.

3.2.1.2.11 Pollen Morphology (size and shape)

Pollen grains were measured using ocular micrometer after caliberation. Caliberation was done with the help of stage micrometer to obtain the measurement of ocular micrometer division and converted it to μ. The diameter of the pollen grains (100 pollen grains) were then measured. Based on this mean, standard deviation (σ) and standard error $\left[\frac{\sigma}{\sqrt{n}}\right]$ were calculated to find out the average diameter of the pollen grain.

Average diameter = Mean ± Standard error

3.2.1.2.2 Qualitative Characters

3.2.1.2.2.1 Colour of Petiole and Young Leaf

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

3.2.1.2.2.2 Spathe Colour

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

3.2.1.2.2.3 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.

3.2.1.2.2.4 Candle Colour

Visual observation was used to record the candle colour.

3.2.1.2.2.5 Type of Inflorescence Axis

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

3.2.1.3 Statistical Analysis

3.2.1.3.1 Biometrical Technique Applied

The data collected were subjected to statistical analysis using variance – covariance analysis. Heritability coefficient, genetic advance and phenotypic, genotypic and environmental correlation coefficients were estimated.

3.2.1.3.1.1 Analysis of Variance/Covariance

With two characters X and Y measured in g genotypes raised in completely randomized design with r replications, the variance, covariance 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}

The estimates of components of variance and covariance are given below:

Variance/ Covariance of	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	$\sigma_{gxy} = \frac{G_{xy} - E_{xy}}{r}$	$\sigma_{exy} = E_{xy}$	$\sigma_{pxy} = \sigma_{gxy} + \sigma_{exy}$

3.2.1.3.1.2 Coefficient 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

3.2.1.3.1.3 Heritability

$$\text{Heritability coefficient, } H^2 = \frac{\sigma_{gx}^2}{\sigma_{px}^2} \times 100$$

(in broad sense)

Allard (1960) classification

< 30 percent	- Low
30-60 percent	- Medium
>60 percent	- High

Robinson (1965) classification

5-10 percent	- Low
10-30 percent	- Medium
>30 percent	- High

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

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

3.2.1.3.1.4 Correlation Analysis

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

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

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

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

3.2.2 Compatibility Studies

Crossing was proposed between the ten selected genotypes, which were used as the female parents and the four commercially important varieties as male parents. Compatibility was studied using the percentages of fruit set, seed set and seed germination. The forty possible cross combinations are shown in Table 1.

Table 1 Forty possible cross combinations between ten selected female parents and four commercially accepted varieties.

♀ × ♂	Commercial varieties			
	AW	TR	OG	LR
LR x DT	[LR x DT] x AW	[LR x DT] x TR	[LR x DT] x OG	[LR x DT] x LR
FR x MW(1)	[FR x MW(1)] xAW	[FR x MW(1)] x TR	[FR x MW(1)] x OG	[FR x MW(1)] x LR
MO x KR(1)	[MO x KR(1)] x AW	[MO x KR (1)] x TR	[MO x KR(1)] x OG	[MO x KR (1)] x LR
KO x CR	[KO x CR] x AW	[KO x CR] x TR	[KO x CR] x OG	[KO x CR] x LR
PR x FR(1)	[PR x FR (1)] x AW	[PR x FR (1)] x TR	[PR x FR (1)] x OG	[PR x FR (1)] x LR
NO x DT	[NO x DT] x AW	[NO x DT] x TR	[NO x DT] x OG	[NO x DT] x LR
PR x KR	[PR x KR] x AW	[PR x KR] x TR	[PR x KR] x OG	[PR x KR] x LR
LR x PR	[LR x PR] x AW	[LR x PR] x TR	[LR x PR] x OG	[LR x PR] x LR
PR x MO	[PR x MO] x AW	[PR x MO] x TR	[PR x MO] x OG	[PR x MO] x LR
OG x DT	[OG x DT] x AW	[OG x DT] x TR	[OG x DT] x OG	[OG x DT] x LR

3.2.2.1 Hybridization Technique in Anthurium

The inflorescence in anthurium is called spadix, with an inflorescence axis (candle) and an enveloping modified bract called spathe, which is brightly coloured and highly ornamental. The true flowers of anthurium are bisexual and are embedded in the candle. The flowers show a clear protogynous condition and so no emasculation was needed. The spadix of the selected female parent was protected using a butter paper cover before the starting of the female phase to prevent unwanted pollen. When the female phase started as indicated by the viscous exudates from the lower flowers, pollen was collected from the male parent and brushed on to the candle of the female parent with wet hand.

The pollination was done between 8 and 9 am as the anthesis occurred during this time. Repeated pollinations were done over a period of five to seven days and the spadix was kept bagged with butter paper cover for one more month. Each pollinated spadix was clearly labelled showing the cross and date of crossing.

3.2.2.1.1 Percentage of Candles Bearing Fruits

Successfully fertilized inflorescence that remained healthy with strong and green peduncles were noted and their percentage was calculated as

$$\frac{\text{The number of candles bearing fruits}}{\text{Number of candles pollinated}} \times 100$$

3.2.2.1.2 Number of Fruits per Candle

The number of fruits in each successfully fertilized candle was counted and recorded.

3.2.2.1.3 Percentage of Fruit set per Candle

The percentage of flowers showing fruit set to the total number of flowers pollinated in a candle was calculated and recorded as the percentage of fruit set. Hundred per cent of the flowers were assumed to be pollinated in a candle pollinated four times, 90 per cent in candles pollinated three times, 60 per cent for two and 30 per cent for one pollination. The number of pollinations done varied depending upon the availability of receptive stigma and fresh pollen.

3.2.2.1.4 Number of Seeds per Berry

The number of seeds in each ripe berry was recorded.

3.2.2.1.5 Seed Size

The length and breadth of seeds were measured in millimeters and recorded. Separate measurements were taken for the seeds of single seeded and double seeded berries.

3.2.2.1.6 Percentage of Germination of Seed

The mucilage around the seeds was removed before sowing and the seeds were kept in moist cotton in petridishes to induce germination. The number of seeds that germinated within four to nine days was noted and percentage of germination calculated as percentage of number of seeds germinated to number of seeds kept for germination.

Results

4. RESULTS

The experimental data were collected on various morphological characters of 14 selected parents (10 females, 4 males) of *Anthurium andreanum* for the present study. The data were statistically analysed and the results obtained are presented here.

4.1 EVALUATION OF GENOTYPES FOR THEIR PERFOMANCE

The mean performance of each of the 14 varieties for the 17 characters (vegetative and floral characters under the study is furnished in Table 3,4 and 5). Analysis of variance revealed significant differences among the varieties for all the characters studied except internode length,number of leaves per plant and number of spadices per plant. (Table 2 and plates 1 & 2)

4.1.1 Morphological Characters

4.1.1.1 Vegetative Characters

4.1.1.1.1 Plant Height

The genotype NO x DT recorded the lowest mean plant height (30.80 cm) which was on par with the genotype KO x CR (34.7 cm) and LR x DT (32.17 cm). The highest mean plant height was recorded by the variety Liver Red (76.17 cm) followed by the genotype LR x PR (74.80 cm).

4.1.1.1.2 Internode Length

The minimum value of 0.93 cm was exhibited by the genotype MO x KR. The maximum value was exhibited by LR x PR 1.63 cm which was on par with FR x MW (1) (1.47 cm) and Liver Red (1.43 cm).

4.1.1.1.3 Number of Suckers per plant

Sucker production was highest for the variety Liver Red (4.00). Lowest number of suckers was produced for the genotypes KO x CR and PR x KR (0.33)

Table 2. Analysis of variance of vegetative (1-6) and floral (7-18) characters in *Anthurium andreanum* genotypes

Sl. No.	Characters	Degrees of freedom	Mean square	
			Genotype 13	Error 28
1	Plant height, cm		624.02**	10.26**
2	Internode length, cm		0.12	0.02
3	Number of suckers per plant		4.03**	0.29
4	Leaf size/leaf area,cm^2		7256.12**	183.41**
5	Number of leaves per plant		1.71	0.48
6	Days from emergence to maturity of leaves, days		17.61**	3.05*
7	Days from emergence to maturity of inflorescence, days		10.73**	2.17*
8	Number of spadices per plant per year		1.31	0.36
9	Candle length, cm		4.23**	0.35
10	Inclination of candle with the spathe, degrees		482.53**	27.06**
11	Life of spadix, days		368.64**	10.93**
12	Days to initiation of female phase, days		6.90**	1.19
13	Duration of female phase, days		8.09**	2.67*
14	Duration of interphase, days		5.51**	1.19
15	Duration of male phase, days		49.98**	1.45
16	Pollen fertility, per cent		711.77**	8.19**
17	Pollen size,μ		329.34**	2.01

*Significant at five per cent level ** Significant at one per cent level

Table 3. Vegetative character differentiation in *Anthurium andreanum* genotypes

Sl. No.	Genotypes	Plant height (cm)	Internode length (cm)	Number of suckers per plant	Leaf size / Leaf area (cm^2)	Number of leaves $plant^{-1}$	Days from emergence to maturity of leaves
1	LR x DT	32.17	1.03	0.67	98.27	7.00	34.33
2	FR x MW(1)	40.67	1.47	0.00	164.43	5.33	33.03
3	MO x KR(1)	45.37	0.93	1.00	117.10	5.67	31.97
4	KO x CR	34.70	1.30	0.33	112.43	6.00	31.67
5	PR x FR(1)	41.13	1.03	1.00	91.97	6.33	29.50
6	NO x DT	30.80	1.13	1.00	116.49	4.67	26.57
7	PR x KR	40.13	1.23	0.33	122.31	6.67	32.17
8	LR x PR	74.80	1.63	1.33	287.76	6.33	32.50
9	PR x MO	46.97	1.20	1.33	98.98	5.33	30.33
10	OG x DT	52.43	0.97	1.67	161.81	7.33	34.20
11	Orange Glory	63.67	1.33	3.00	184.71	6.67	34.17
12	Liver Red	76.17	1.43	4.00	138.58	7.03	29.33
13	Acropolis White	48.17	1.27	0.00	183.87	6.67	31.03
14	Tropical Red	42.20	1.20	0.00	150.18	6.33	35.67
Mean		47.81	1.23	1.12	144.92	6.24	31.89
$F_{13, 28}$		60.809**	6.845**	14.109**	43.379**	3.600**	5.778**
SE		1.850	7.663	0.309	7.819	0.398	1.008
CD		5.357	0.222	0.894	22.646	1.154	2.919

** Significant at one per cent level

Table 4. Floral character differentiation in *Anthurium andreanum* genotypes

Sl. No.	Genotypes	1	2	3	4	5	6	7	8	9	10	11
1	LR x DT	36.70	6.00	6.60	42.67	68.00	6.33	6.00	0.00	0.00	0.00	0.00
2	FR x MW(1)	37.20	4.67	7.17	62.43	72.00	6.30	7.07	0.00	0.00	0.00	0.00
3	MO x KR(1)	36.57	5.67	3.83	70.07	93.67	8.13	9.27	3.17	7.17	31.33	16.87
4	KO x CR	31.00	5.67	6.30	67.10	79.67	6.33	7.67	0.00	0.00	0.00	0.00
5	PR x FR(1)	31.70	6.00	4.97	43.13	62.33	9.27	7.27	4.17	5.33	41.67	22.23
6	NO x DT	33.57	4.67	5.17	45.90	83.00	9.00	6.33	2.33	8.10	24.33	24.47
7	PR x KR	34.50	6.00	6.93	48.80	84.00	7.20	10.33	4.67	9.60	20.33	23.97
8	LR x PR	34.37	5.67	7.83	61.43	82.33	4.50	9.50	3.33	5.67	34.67	19.33
9	PR x MO	35.03	5.00	8.00	26.10	93.00	4.33	7.50	0.00	0.00	0.00	0.00
10	OG x DT	32.17	6.33	6.70	62.63	87.67	6.00	5.50	5.10	10.00	14.67	16.80
11	OG	33.53	6.33	5.23	34.77	96.00	7.90	8.57	4.00	6.83	30.00	20.40
12	LR	33.57	7.00	6.13	58.67	76.00	5.70	9.10	5.10	6.10	40.67	24.97
13	AW	32.40	6.33	7.47	51.67	99.00	5.73	11.00	6.83	10.83	27.00	22.93
14	TR	34.37	5.67	6.53	52.33	93.33	7.70	8.83	6.27	9.83	27.67	24.53
Mean		31.85	5.53	6.12	48.78	78.33	6.69	8.06	3.53	5.90	20.16	15.17
$F_{13, 28}$		4.941**	3.677**	11.986**	17.832**	33.731**	5.823**	3.031**	2.767*	34.401**	86.902**	163.643**
SE		0.851	0.345	0.343	3.003	1.909	0.629	0.943	0.815	0.696	1.652	0.819
CD		2.464	0.999	0.994	8.699	5.528	1.821	2.732	2.359	2.016	4.786	2.372

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

1. Days from emergence to maturity of inflorescence, days
2. Number of spadices per plant per year
3. Candle length, cm
4. Inclination of candle with the spathe, degrees
5. Life of spadix, days
6. Days to initiation of female phase, days
7. Duration of female phase, days
8. Duration of interphase, days
9. Duration of male phase, days
10. Pollen fertility, per cent
11. Pollen size, μ

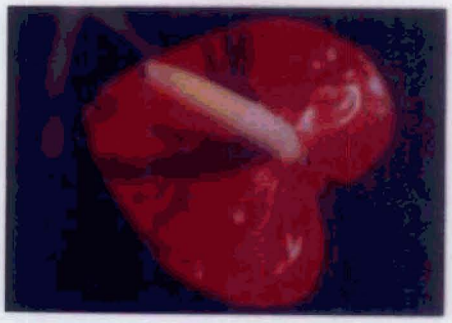
Table 5. Qualitative character differentiation in of *Anthurium andreanum* genotypes

Genotype	Colour of Young Leaf	Colour of Petiole	Spathe Colour	Spathe Texture	Candle Colour	Type of Inflorescence Axis
LR x DT	Greenish brown	Green	Deep maroon	Thick smooth glossy	Yellow	Long thick slightly curved
FR x MW(1)	Brown	Greenish brown	Light pink	Medium thick shallowly blistered glossy	Light yellow	Long thick curving
MO x KR(1)	Brown	Brown	Red	Thin slightly blistered glossy	Maroon	Medium long straight thin
KO x CR	Brown	Brown	Red	Thick smooth glossy	Light yellow	Medium long straight thin
PR x FR(1)	Green	Brown	Red	Thin blistered glossy	Light yellow	Medium long thin curving
NO x DT	Greenish brown	Green	Dark orange	Medium thick deeply blistered glossy	Yellow	Long thin curving
PR x KR	Reddish brown	Reddish brown	Red	Medium thick blistered glossy	Pink	Long thin curving
LR x PR	Greenish brown	Brown	Dark red	Medium thick blistered glossy	Light yellow	Long thick curving
PR x MO	Brown	Brown	Pink	Medium thick blistered glossy	Yellow	Long thin curving
OG x DT	Reddish brown	Reddish brown	Dark red	Medium thick deeply blistered glossy	Pink	Short medium thick curving
OG	Greenish brown	Greenish brown	Orange	Medium thick shallowly blistered glossy	Yellow	Long straight strong
LR	Brown	Brown	Deep maroon	Thick smooth glossy	Maroon	Long straight strong
AW	Greenish brown	Greenish brown	White	Thick smooth shallowly blistered glossy	Yellow	Long straight strong
TR	Reddish brown	Reddish brown	Dark red	Thick medium blistered glossy	Yellow	Long straight strong

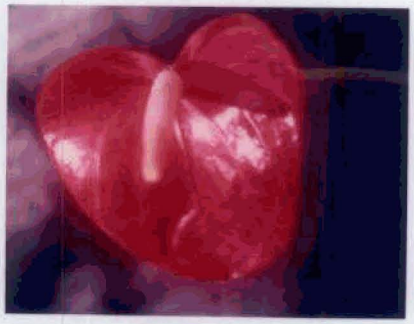
LR x PR

LR x DT

NO x DT

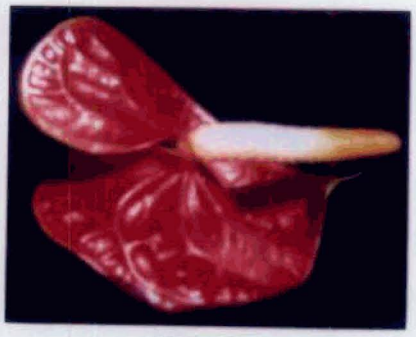


PR x FR (1)

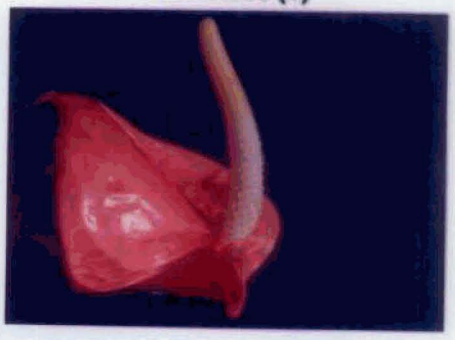


KO x CR

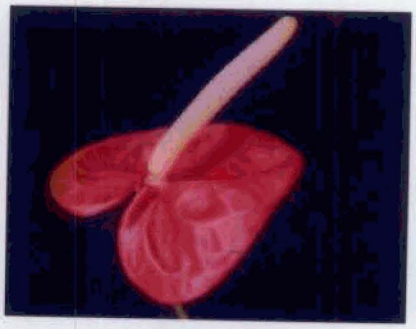
FR x MW (1)



OG x DT



PR x MO



PR x KR

MO x KR (1)

Plate 1. Female parents

Liver Red

Orange Glory

Acropolis White

Tropical Red

Plate 2. Male Parents

whereas Acropolis White, Tropical Red and FR x MW (1) did not produce any sucker at all during the period of study.

4.1.1.1.4 Leaf Area/Leaf Size

The leaf area was minimum for the genotype PR x FR (1) (91.97 cm^2) and maximum for the genotype LR x PR (287.76 cm^2) which was significantly different.

4.1.1.1.5 Number of Leaves per Plant

The lowest number of leaves per plant was shown by the genotype NO x DT (4.67) and the maximum value by the genotype OG x DT (7.33).

The genotypes FR x MW (1) (5.33), MO x KR (1) (5.67) and PR x MO (5.33) were on par with NO x DT (4.67). All other genotypes except KO x CR was on par with OG x DT (7.33).

4.1.1.1.6 Days from Emergence to Maturity of leaves

The least number of days for maturity was taken by NO x DT (26.57) which was on par with the variety Liver Red (29.33) and PR x FR (1) (29.53). The maximum number of days was taken by the genotype Tropical Red (35.67).

4.1.1.2 Floral Characters

4.1.1.2.1 Days from Emergence to Maturity of Inflorescence

The genotype KO x CR recorded the lowest mean value (31.00) for this character which was on par with PR x FR (1) (31.70), OG x DT (32.17) and Acropolis White (32.40). The highest mean value was recorded in the genotype FR x MW (1) (37.20).

4.1.1.2.2 Number of Spadices/Plant/Year

The minimum number of spadices per plant per year was observed for the genotypes FR x MW (1) and NO x DT (4.67) which were on par with genotype PR x MO (5.00). The maximum number of spadices was exhibited in the

genotype Liver Red (7.00) followed by OG x DT, Orange Glory and Acropolis White having mean value of 6.33.

4.1.1.2.3 Candle Length

The genotype MO x KR (1) recorded the lowest value of 3.83 cm which was significantly lower from others. The highest mean candle length was recorded for the genotype PR x MO (8.00 cm) followed by LR x PR (7.83 cm), Acropolis White (7.47 cm) and FR x MW (1) (7.17 cm).

4.1.1.2.4 Inclination of Candle with the Spathe

The angle between the candle and the spathe was lowest for the genotype PR x MO (26.10^0). The maximum angle was observed for the genotype MO x KR (1) (70.07^0).

4.1.1.2.5 Life of Spadix

The lowest mean life of the spadix was recorded by PR x FR (1) (62.33 days). The highest mean was recorded for the variety Acropolis White (99.00 days) followed by MO x KR (1) (93.67 days) and Tropical Red (93.33 days).

4.1.1.2.6 Days to Initiation of Female Phase

The mean number of days to initiation of female phase ranged from 4.33 in PR x MO to 9.27 in PR x FR (1).

4.1.1.2.7 Duration of Female Phase

The lowest duration of female phase was observed for the genotype OG x DT (5.50 days) which was on par with LR x DT (6.00 days), NO x DT (6.33 days), FR x MW (1) (7.07 days), PR x FR (1) (7.27 days) and PR x MO (7.50 days. The highest mean duration was obtained for the variety Acropolis White (11.00 days) (Plate 3).

4.1.1.2.8 Duration of Interphase

The days of interphase were minimum for the genotype NO x DT (2.33 days) and maximum for the variety Acropolis White (6.83 days).

No anther production was observed in the genotypes LR x DT, FR x MW (1), KO x CR and PR x MO during the period of the study. So observations on days on interphase, duration of male phase, pollen fertility and pollen morphology could not be recorded for these genotypes. Among the 10 genotypes on which the days of interphase were recorded the highest mean number of days of interphase was shown by Acropolis White (6.83) which was on par with Tropical Red (6.27). The lowest number of days of interphase was shown by NO x DT (2.33) which was on par with MO x KR (1) (3.17) and LR x PR (3.33).

4.1.1.2.9 Duration of Male Phase

The lowest mean duration of male phase was recorded by PR x FR (1) (5.33 days) which was on par with LR x PR (5.67 days). The highest mean duration of male phase was obtained for the variety Acropolis White (10.83 days) which was on par with OG x DT (10.00 days) and Tropical Red (9.83 days)(Plate 3)

4.1.1.2.10 Pollen Fertility

Comparison of pollen fertility estimated using acetocarmine method reveals that, PR x FR (1) had the highest pollen fertility of (41.67 per cent) followed by Liver Red (40.67 per cent), LR x PR (34.67 per cent) and MO x KR (1) (31.33 per cent). The lowest values were recorded for OG x DT (14.67 per cent), PR x KR (20.33 per cent) and Acropolis White (27.00 per cent).

4.1.1.2.11 Pollen Size

The mean size of the pollen ranged from 16.80 μ in OG x DT to 24.97 μ in Liver Red. The genotype MO x KR (1) (16.87 μ) was in par with OG x DT. The varieties Acropolis White (22.93 μ), Tropical Red (24.53 μ) and the genotypes NO x DT (24.47 μ) and PR x KR (23.97 μ) were on par with Liver Red.

A. Female phase

B. Male phase

Plate 3. *Anthurium andreanum* flower in female and male phase

4.1.1.3 Qualitative Characters

4.1.1.3.1 Colour of Young Leaf and Petiole

The colour of young leaf showed a range from brown to reddish brown to greenish brown to brownish green to green. The colour of petiole also varied from brown to light brown to reddish brown to greenish brown to green.

4.1.1.3.2 Spathe Colour

Liver Red and LR x DT had deep maroon coloured spathe. Red coloured varieties showed variation from dark red (LR x PR, OG x DT, Tropical Red) to red (KO x CR, PR x FR (1), PR x KR). PR x MO and FR x MW (1) showed pink and light pink coloured spathe. OG and NO x DT had orange and dark orange coloured spathe. (Table 5)

4.1.1.3.3 Spathe Texture

Thick smooth and glossy spathes were seen for KO x CR, Liver Red and LR x DT. Orange Glory and FR x MW (1) had medium thick shallowly blistered glossy spathes while MO x KR (1) had thin slightly blistered glossy spathes. Spathes were thin and blistered for PR x FR (1) while it was thick and medium blistered in Tropical Red, NO x DT and OG x DT had medium thick, deeply blistered glossy spathes. PR x KR, LR x PR and PR x MO had medium thick blistered glossy spathes. (Table 5)

4.1.1.3.4 Candle Colour

Candle colour varied from light yellow in LR x PR, FR x MW(1), KO x CR and PR x FR(1).It ranged from yellow in Tropical Red, Acropolis White, Orange Glory, PR x MO, NO x DT and LR x DT. Liver Red and FR x MW(1) showed maroon coloured candle. Candle colour was pink in the genotype PR x KR and OG x DT (Table 5).

4.1.1.3.5 Type of Inflorescence Axis

The nature of inflorescence axis which is an important commercial trait varied from long, straight and strong in Liver Red, Orange Glory, Acropolis

White and Tropical Red to medium long straight and thin in MO x KR (1) and KO x CR. Long thin and curving type of inflorescence axis were noticed in genotypes NO x DT, PR x KR and PR x MO. LR x PR and FR x MW (1) showed long thick and curving inflorescence axis while it was medium long thin and curving in 'PR x FR (1) and short, medium thick and curving in OG x DT.(Table 5)

4.2 ESTIMATION OF VARIABILITY COMPONENTS

The genotypic and environmental components of phenotypic variance are presented in Table 6, along with the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV), which is the relative measure of variation used for comparison among characters measured in different units.

Maximum variability both at phenotypic (110.80 per cent) and genotypic 99.82 per cent) were observed for number of suckers per plant followed by pollen fertility (GCV 52.39 per cent and PCV 53.30 per cent) and duration of male phase (GCV 50.60 per cent and PCV 52.82 per cent).

Pollen morphology (size) and leaf area also registered a high value of 48.25 per cent, 48.69 per cent and 33.50 per cent, 34.78 per cent at both genotypic and phenotypic levels respectively. The minimum variability was recorded by the character days from emergence to maturity of inflorescence as 4.96 per cent for GCV and 6.58 per cent for PCV.

Plant height, internode length, number of leaves per plant, number of spadices per plant per year, candle length, inclination of the candle with the spathe and duration of interphase also differed in their ranks at phenotypic and genotypic levels.

The environmental influence was maximum for the character leaf area followed by inclination of candle with the spathe, life of spadix, plant height and pollen fertility. While for all other characters under study it was minimum.

4.3 HERITABILITY AND GENETIC ADVANCE

Robinson (1965) classified the heritability estimates in cultivated plants as low with 5 – 10 per cent heritability, medium 10 – 30 per cent heritability and

Table 6. Components of the total variance for different characters in *Anthurium andreanum*

Sl. No.	Characters	σ^2_p	σ^2_g	σ^2_e	GCV (per cent)	PCV (per cent)
1	Plant height (cm)	214.85	204.59	10.26	**29.92**	30.66
2	Internode length (cm)	0.05	0.03	0.02	**14.08**	18.18
3	Number of suckers per plant	1.54	1.25	0.29	**99.82**	110.80
4	Leaf size/leaf area (cm^2)	2540.98	2357.57	183.41	**33.50**	34.78
5	Number of leaves per plant	0.89	0.41	0.48	**10.26**	15.12
6	Days from emergence to maturity of leaves	7.90	4.85	3.05	**6.91**	**8.81**
7	Days from emergence to maturity of inflorescence	5.02	2.85	2.17	**4.96**	**6.58**
8	Number of spadices per plant per year	0.68	0.32	0.36	**9.77**	14.24
9	Candle length (cm)	1.64	1.29	0.35	**18.09**	20.39
10	Inclination of candle with the spathe (degrees)	178.88	151.82	27.06	**23.70**	25.73
11	Life of spadix (days)	130.17	119.24	10.93	**13.07**	13.65
12	Days to initiation of female phase	3.09	1.90	1.19	**20.45**	26.08
13	Duration of female phase (days)	4.48	1.81	2.67	**16.53**	26.00
14	Duration of interphase (days)	3.16	1.17	1.99	**24.36**	40.00
15	Duration of male phase (days)	17.63	16.18	1.45	**50.60**	52.82
16	Pollen fertility (per cent)	242.72	234.53	8.19	**52.39**	53.30
17	Pollen size (μ)	111.12	109.11	2.01	**48.25**	48.69

σ^2_p -Phenotypic variance σ^2_g -Genotypic variance σ^2_e -Environmental variance

PCV -Phenotypic coefficient of variation GCV -Genotypic coefficient of variation

Table 7. Heritability and genetic advance of seventeen characters in *Anthurium andreanum*

Sl. No.	Characters	Heritability (per cent)	Genetic advance (5 per cent)	Genetic advance as percentage of mean
1	Plant height (cm)	95.22	28.75	60.13
2	Internode length (cm)	66.08	0.31	25.20
3	Number of suckers per plant	81.17	2.08	185.71
4	Leaf size/leaf area (cm^2)	92.78	96.34	66.48
5	Number of leaves per plant	46.07	0.90	14.42
6	Days from emergence to maturity of leaves	61.39	3.55	11.13
7	Days from emergence to maturity of inflorescence	56.77	2.62	7.69
8	Number of spadices per plant per year	47.06	0.80	13.82
9	Candle length (cm)	78.66	2.08	33.12
10	Inclination of candle with the spathe (degrees)	84.87	23.38	44.98
11	Life of spadix (days)	91.60	21.53	25.76
12	Days to initiation of female phase	61.49	2.23	33.09
13	Duration of female phase (days)	40.40	1.76	21.62
14	Duration of interphase (days)	37.03	1.35	30.41
15	Duration of male phase (days)	91.78	7.94	99.87
16	Pollen fertility (per cent)	96.63	31.01	106.09
17	Pollen size (μ)	98.19	21.32	98.48

greater than 30 per cent as high. In the present study, all the characters showed high heritability as per Robinson's classification. Allard (1960) classified heritability as low (less than 30 per cent), medium (30 – 60 per cent) and high (above 60 per cent). According to this classification all the characters showed high heritability except for the characters days from emergence to maturity of inflorescence (56.77 per cent), number of spadices per plant per year (47.06 per cent), number of leaves per plant (46.07 per cent), duration of female phase (40.40 per cent) and duration of interphase (37.03 per cent).

From the Table 7 it was found that high heritability was recorded for the character pollen size (98.19 per cent) followed by pollen fertility (96.63 per cent), plant height (95.22 per cent) and leaf area (92.78 per cent). Duration of interphase showed the least value of 37.03 per cent for heritability.

Genetic advance as percentage of mean is independent of the unit of measurement and hence is used for comparison of characters. Maximum genetic advance was obtained for number of suckers per plant (185.71 per cent) followed by pollen fertility (106.09 per cent) and duration of male phase (99.87 per cent). Least genetic advance was obtained for the character days from emergence to maturity of inflorescence (7.69 per cent).

4.4 CORRELATION AMONG DIFFERENT CHARACTERS

The phenotypic, genotypic and environmental correlation among the various characters are presented in Table 8, 9 and 10 respectively.

The significance for both phenotypic and environmental correlation was tested. However no test is available to detect the significance of genotypic correlation coefficient.

4.4.1 Phenotypic Correlation

Plant height was found to have significant positive correlation with number of suckers per plant (+0.6542), leaf size (+0.6426), number of spadices per plant per year (+0.4425), internode length (+0.4973) and pollen fertility (+0.5272). It showed significant negative correlation with days to initiation of

female phase (-0.3952). Internode length showed highly significant positive correlation with leaf area (+0.5871), while it showed negative correlation with days from emergence to maturity of leaves, life of spadix, days to initiation of female phase, duration of interphase, duration of male phase and pollen size.

Number of suckers per plant is not significantly correlated with any of the characters other than plant height where it is positively correlated (+0.6542), number of spadices per plant per year (+0.4515) and pollen fertility (+0.3896). This character is positively correlated with number of spadices per plant (+0.4515), pollen fertility (+0.3896), number of leaves per plant (+0.2781) and pollen size (+0.2496).

All characters are positively correlated with leaf area. It showed high significant positive correlation with plant height (+0.6426) and internode length (+0.5871)

Number of leaves per plant showed significant positive correlation with number of spadices per plant (+0.7829) at 1 per cent level of significance and duration of interphase (+0.499). It also registered negative correlation with days to initiation of female phase (-0.2542), days from emergence to maturity of inflorescence (-0.1637) and life of spadix (-0.0488).

Days from emergence to maturity of leaves showed negative correlation with internode length, number of suckers per plants, days to initiation of female phase, duration of female phase, pollen fertility and pollen size.

Days from emergence to maturity of inflorescence exhibited positive correlation with leaf size, inclination of candle with the spathe, life of spadix and duration of interphase while all other characters showed negative correlations.

Number of spadices per plant was found to have significant positive correlation with number of leaves per plant (+0.7829), plant height (+0.4425), number of suckers per plant (+0.4515) and pollen fertility (+0.3859) and showed

negative correlation with days from emergence to maturity of inflorescence, candle length and days to initiation of female phase.

Candle length showed high positive correlation with internode length (+0.4282), leaf size (+0.3475) and duration of interphase (+0.3199). Negative correlation was exhibited with the characters number of suckers per plant, days from emergence to maturity of inflorescence, number of spadices per plant, inclination of candle with the spathe, days to initiation of female phase, duration of male phase, pollen fertility and pollen size.

Inclination of candle with the spathe was found to have negative correlation with days to initiation of female phase (-0.0500), number of suckers per plant (-0.1316), candle length (-0.1284), life of spadix (-0.0920) and duration of interphase (-0.2066). None of the characters exhibited significant positive correlation with inclination of candle with the spathe. None characters showed significant positive correlation with life of spadix. It was negatively correlated with internode length, number of leaves per plant, inclination of candle with the spathe and days to initiation of female phase.

Days to initiation of female phase showed positive correlation only with duration of male phase (+0.2686), pollen fertility (+0.3102) and pollen size (+0.3614) which was significant from others. Duration of female phase showed positive correlation with all characters except for number of suckers per plant, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence and days to initiation of female phase.

Duration of interphase showed positive correlation with all characters except for internode length, number of suckers per plant, inclination of candle with the spathe, days to initiation of female phase and pollen fertility.

Duration of male phase showed positive significant correlation with pollen fertility (+0.6255), pollen size (+0.8656) and life of spadix (+0.4724). High

Table 8 Phenotypic correlation coefficients among seventeen characters in *Anthurium andreanum*

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}
X_2	0.4973**															
X_3	0.6542**	0.1851														
X_4	0.6426**	0.5871**	0.0916													
X_5	0.3155	0.0463	0.2781	0.1760												
X_6	0.0356	-0.0643	-0.1862	0.2419	0.3548											
X_7	-0.0584	-0.0117	-0.1786	0.0039	-0.1637	0.1514										
X_8	0.4425*	0.0665	0.4515*	0.0987	0.7829**	0.1446	-0.2823									
X_9	0.1493	0.4282*	-0.2067	0.3475	0.1600	0.2081	-0.0170	-0.0749								
X_{10}	0.1206	0.0793	-0.1316	0.2500	0.1162	0.1194	0.0395	0.0709	-0.1284							
X_{11}	0.1882	-0.0115	0.0160	0.2683	0.0488	0.1916	0.0592	0.0413	0.0747	-0.0920						
X_{12}	-0.3952*	-0.4294*	-0.0716	0.3437	-0.2542	-0.1059	-0.1163	-0.1772	-0.7194	-0.0500	-0.1090					
X_{13}	0.3279	0.3614*	-0.0459	0.2707	0.0346	-0.0453	-0.0354	0.2415	0.1473	0.0308	0.3723*	-0.1723				
X_{14}	0.0412	-0.0520	-0.1045	0.0273	0.4999**	0.3154	0.0200	0.3545	0.3199	-0.2066	0.1210	-0.1612	0.0497			
X_{15}	0.2079	-0.1773	-0.0492	0.2708	0.2370	0.0237	-0.2741	0.3057	-0.1810	0.1126	0.4724**	0.2686	0.2763	0.2540		
X_{16}	0.5272**	0.0752	0.3896*	0.2941	0.1735	-0.2248	-0.2453	0.3859*	-0.3927*	0.0614	0.0929	0.3102	0.4202*	-0.0235	0.6255**	
X_{17}	0.3564	-0.0195	0.2496	0.2572	0.1754	-0.1606	-0.2851	0.3508	-0.2972	0.0302	0.2565	0.3748*	0.3614*	0.0951	0.8656**	0.8687**

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

X_1 Plant height, cm
X_2 Internode length, cm
X_3 Number of suckers per plant
X_4 Leaf size/leaf area,cm^2
X_5 Number of leaves per plant
X_6 Days from emergence to maturity of leaves, days
X_7 Days from emergence to maturity of inflorescence, days
X_8 Number of spadices per plant per year
X_9 Candle length, cm
X_{10} Inclination of candle with the spathe, degrees
X_{11} Life of spadix, days
X_{12} Days to initiation of female phase, days
X_{13} Duration of female phase, days
X_{14} Duration of interphase, days
X_{15} Duration of male phase, days
X_{16} Pollen fertility, per cent
X_{17} Pollen size,μ

Table 9. Genotypic correlation coefficients among seventeen characters in *Anthurium andreanum*

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}
X_2	**0.6185**															
X_3	**0.7839**	0.1777														
X_4	**0.6898**	0.7457	0.1355													
X_5	**0.4946**	-0.1264	0.3530	0.2314												
X_6	**0.0914**	0.0484	-0.1874	0.3301	0.6551											
X_7	**-0.1271**	0.0447	-0.1296	-0.0201	-0.3727	0.3756										
X_8	**0.6189**	-0.1199	0.6156	0.1429	1.0168	0.2744	-0.5033									
X_9	**0.1813**	0.5836	-0.2483	0.4211	0.1460	0.2197	0.1010	-0.1129								
X_{10}	**0.1007**	0.1320	-0.1562	0.2899	0.0593	0.1546	-0.0633	0.1115	-0.1680							
X_{11}	**0.2034**	-0.0242	0.0049	0.2975	-0.0346	0.2062	-0.0464	0.0610	0.0832	-0.0679						
X_{12}	**-0.4793**	-0.5542	-0.1189	-0.4748	-0.1798	-0.2471	-0.1172	0.0048	-0.9111	-0.0493	-0.1916					
X_{13}	**0.4586**	0.4560	0.0135	0.4810	0.2978	0.0634	0.0276	0.4452	0.1014	0.2062	0.5577	-0.1038				
X_{14}	**0.1039**	-0.2284	-0.0603	-0.0431	0.7568	0.5184	0.0847	0.6610	0.5141	-0.3319	0.2661	-0.4108	0.4508			
X_{15}	**0.2186**	-0.1838	0.0741	0.2799	0.3742	0.0061	-0.3568	0.4789	-0.2052	0.1367	0.5158	0.3576	0.5813	0.3100		
X_{16}	**0.5477**	0.0744	0.4567	0.3045	0.2687	-0.2663	-0.3188	0.5621	-0.4588	0.1047	0.0851	0.4277	0.5424	0.0387	0.6804	
X_{17}	**0.3650**	0.0018	0.2966	0.2643	0.2910	-0.2443	-0.3881	0.4963	-0.3280	0.0397	0.2664	0.4579	0.5806	0.1623	0.9112	0.8948

X_1 **Plant height, cm**
X_2 **Internode length, cm**
X_3 **Number of suckers per plant**
X_4 **Leaf size/leaf area,cm^2**
X_5 **Number of leaves per plant**
X_6 **Days from emergence to maturity of leaves, days**
X_7 Days from emergence to maturity of inflorescence, days
X_8 Number of spadices per plant per year
X_9 Candle length, cm
X_{10} Inclination of candle with the spathe,degrees
X_{11} Life of spadix, days
X_{12} Days to initiation of female phase, days
X_{13} Duration of female phase, days
X_{14} Duration of interphase, days
X_{15} Duration of male phase, days
X_{16} Pollen fertility, per cent
X_{17} Pollen size,μ

Table 10. Environmental correlation coefficients among seventeen characters in *Anthurium andreanum*

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}
X_2	0.0524															
X_3	-0.3796*	0.2181														
X_4	-0.1414	0.0087	-0.2390													
X_5	-0.0834	0.2729	0.1936	0.1256												
X_6	-0.2527	-0.2631	-0.2003	-0.0510	0.0109											
X_7	0.2441	-0.0408	-0.3189	0.0636	0.0574	-0.1724										
X_8	0.1740	0.3152	0.2236	0.0207	0.5773**	0.0069	-0.0459									
X_9	-0.0740	0.0287	0.0412	-0.1106	0.2119	0.1930	-0.2775	0.0168								
X_{10}	0.3540	-0.0864	-0.0107	-0.0813	0.2759	0.0320	0.3263	-0.0012	0.0488							
X_{11}	-0.0285	0.0434	0.0943	-0.0919	-0.1096	0.2052	-0.1350	-0.0060	0.0308	-0.2899						
X_{12}	-0.2070	-0.2100	0.0470	0.1032	-0.3484	0.1202	-0.1153	-0.3877*	-0.2982	-0.0597	0.1944					
X_{13}	0.2582	0.2800	-0.1145	0.1242	-0.1668	-0.1604	-0.1438	0.0841	0.2523	-0.2992	0.1483	-0.2520				
X_{14}	-0.1184	0.1322	-0.2084	0.2582	0.3203	0.1381	-0.1129	0.1355	0.1157	-0.0663	-0.1480	0.0715	-0.2036			
X_{15}	0.0567	-0.2046	-0.1201	-0.1581	-0.0344	0.1074	0.0880	-0.0406	-0.0510	-0.0724	0.0060	-0.0015	-0.3497	0.3214		
X_{16}	0.0472	0.1473	-0.1946	0.1022	0.0482	-0.1723	-0.0759	0.0487	0.0826	-0.4680**	0.2416	-0.1738	0.5742**	-0.3202	-0.2871	
X_{17}	0.1156	-0.2674	-0.2685	-0.1172	-0.2140	0.3483	0.0533	0.1334	-0.1455	-0.1163	0.0980	0.2233	0.0392	-0.0263	-0.0173	0.1138

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

X_1 Plant height, cm
X_2 Internode length, cm
X_3 Number of suckers per plant
X_4 Leaf size/leaf area,cm^2
X_5 Number of leaves per plant
X_6 Days from emergence to maturity of leaves, days
X_7 Days from emergence to maturity of inflorescence, days
X_8 Number of spadices per plant per year
X_9 Candle length, cm
X_{10} Inclination of candle with the spathe,degrees
X_{11} Life of spadix, days
X_{12} Days to initiation of female phase, days
X_{13} Duration of female phase, days
X_{14} Duration of interphase, days
X_{15} Duration of male phase, days
X_{16} Pollen fertility, per cent
X_{17} Pollen size,μ

negative correlation was shown with days from emergence to maturity of inflorescence (-0.2741), candle length (-0.1810) and internode length (-0.1773).

Pollen fertility showed high positive correlation with pollen size (+0.8687) and duration of male phase (+0.6255). This character showed negative correlation with days from emergence to maturity of leaves, days from emergence to maturity of inflorescence candle length and duration of interphase.

Pollen size was found to have significant positive correlation with pollen fertility (+0.8687), duration of male phase (+0.8656), days to initiation of female phase (+0.3748) and duration of female phase (+0.3614). It also showed negative correlation with internode length (-0.0195), days from emergence to maturity of leaves (-0.1606), days from emergence to maturity of inflorescence (-0.2851) and candle length (-0.2972).

4.4.2 Genotypic Correlation

The magnitude of genotypic correlation coefficients were higher than that of phenotypic correlation coefficient. Since the environmental correlations were negligible between most of the characters, and also experiment being under strict environment control, the correlation may be attributed to genotypic effect.

Plant height showed positive correlation with all characters studied except for days from emergence to maturity of inflorescence (-0.1271) and days to initiation of female phase (-0.4793).

Internode length was positively correlated with plant height (+0.6185), number of suckers per plant (+0.1777), leaf area (+0.7457), days from emergence to maturity of inflorescence (+0.0447), days from emergence to maturity of leaves (+0.0484), candle length (+0.5836) inclination of candle (+0.1320), duration of female phase (+0.4560), pollen fertility (+0.0744) and pollen size (+0.0018). For all the other characters it was negatively correlated.

Number of suckers per plant was found to have negative correlation with days from emergence to maturity of leaves (-0.1874), days from emergence to maturity of inflorescence (-0.1296), candle length (-0.2483), inclination of candle (-0.1562), days to initiation of female phase (-0.1189) and duration of interphase (-0.0603). Leaf area showed positive correlation with all the characters except for days from emergence to maturity of inflorescence (-0.0201), days to initiation of female phase (-0.4748) and duration of interphase (-0.0431).

Number of leaves per plant was negatively correlated with internode length (-0.1264), days from emergence to maturity of inflorescence (-0.3727), life of spadix (-0.0346) and days to initiation of female phase (-0.1798).

Days from emergence to maturity of leaves exhibited negative correlation with number of suckers per plant (-0.1874), days to initiation of female phase (-0.2473), pollen fertility (-0.2663) and pollen size (-0.2443).

Days from emergence to maturity of inflorescence was positively correlated with internode length (+0.0447) days from emergence to maturity of leaves (+0.3756), candle length (+0.1010), duration of female phase (+0.0276) and duration of interphase (+0.0847).

Number of spadices per plant recorded negative correlation with internode length (-0.1199) followed by days from emergence to maturity of inflorescence (-0.5033) and candle length (-0.1129).

Candle length reported negative correlation with number of suckers per plant (-0.2483), number of spadices per plant (0.1129), inclination of candle (-0.1680), days to initiation of female phase (0.2052), pollen fertility (-0.4588) and pollen size (-0.3280).

Inclination of candle with the spathe was found to be negatively correlated with number of suckers per plant (-0.1562), days from emergence to maturity of inflorescence (-0.0633), candle length (0.1680), life of spadix (-0.0679), days to

initiation of female phase (-0.0493) and duration of interphase (-0.3319). Life of spadix observed a negative correlation with internode length (-0.0346), days from emergence to maturity of inflorescence (-0.0464), inclination of candle (-0.0679) and days to initiation of female phase (-0.1916).

Days to initiation of female phase exhibited negative correlation with all the characters except for number of spadices per plant (+0.0048), duration of male phase (+0.3576), pollen fertility (+0.4277) and pollen size (+0.4579).

Duration of female phase was positively correlated all the characters except for the character days to initiation female phase (-0.1038).

Duration of interphase showed negative correlation with internode length (-0.2284), number of suckers per plant (-0.0603), leaf area (-0.0431), inclination of candle (-0.3319) and days to initiation of female phase (-0.4108).

Duration of male phase was positively correlated with all the characters except for the characters internode length (-0.1838), days from emergence to maturity of inflorescence (-0.3568) and candle length (-0.2052).

Pollen fertility showed negative correlation with days from emergence to maturity of leaves (-0.2663), days from emergence to maturity of inflorescence (-0.3188) and candle length (-0.4588). Pollen size was found to be negatively correlated with days from emergence to maturity of leaves (-0.2443), days from emergence to maturity of inflorescence (-0.3881) and candle length (-0.3280).

4.4.3 Environmental Correlation

Duration of female phase is the only character which showed positive significant correlation with pollen fertility (0.5742) while inclination of candle with the spathe (-0.4680) showed negative significant correlation with pollen fertility. Number of spadices per plant showed negative significant correlation with days to initiation of female phase (-0.3877) and it showed significant positive correlation with number of leaves per plant (+0.5773). Plant height and number

of suckers per plant are negatively correlated with each other (-0.3796) and it was significant. For all the other characters it was low and insignificant.

4.5 COMPATIBILITY STUDIES

Crossings involving the ten selected female parents and four male parents were planned, depending on the availability of receptive spadices and fresh pollen (Table 11). This was done with the aim of finding the compatibility between the varieties on the basis of

Percentage of candles bearing fruits
Percentage of fruit set per candle
Percentage of germination of seed.

A total of twenty three crossings were attempted of which twelve were successful. The results of compatibility analysis carried out are presented below.

4.5.1 Percentage of Candles Bearing Fruits

LR x DT- Out of the two possible crosses attempted none were successful.

FR x MW (1)- Only two crosses could be attempted and both were found to be successful. The percentage of candles bearing fruits was highest for the cross [FR x MW (1)] x LR (100 per cent) followed by [FR x MW (1)] x OG (83.33 per cent).

MO x KR (1)- Three crosses were done and all of them were found to be unsuccessful.

KO x CR- No possible crosses could be attempted using KO x CR as female parent during course of study.

PR x FR (1) - Three crosses could be attempted out of which two of them were successful. The cross [PR x FR (1)] x OG showed higher percentage of candles bearing fruits (89 per cent) followed by [PR x FR (1)] x LR (66.67 per cent).

Table 11. Matrix showing the number of pollinations done in each combination among the genotypes of *A. andreanum*

♀ \ ♂	Orange Glory	Liver Red	Acropolis White	Tropical Red
LR x DT	7	0	5	0
FR x MW(1)	5	6	0	0
MO x KR(1)	6	4	5	0
KO x CR	0	0	0	0
PR x FR(1)	8	10	0	3
NO x Dt	7	8	0	0
PR x KR	0	9	9	5
LR x PR	7	4	6	9
PR x MO	5	6	4	0
OG x DT	0	4	0	0

Table 12. Matrix showing percentage of candles bearing fruits in each combination

♀ \ ♂	Orange Glory	Liver Red	Acropolis White	Tropical Red	Average
LR x DT	0	0	0	0	0
FR x MW(1)	83.33	100.00	0	0	91.67
MO x KR(1)	0	0	0	0	0
KO x CR	0	0	0	0	0
PR x FR(1)	89.00	66.67	0	0	77.84
NO x DT	0	0	0	0	0
PR x KR	0	100.00	100.00	0	100.00
LR x PR	83.33	0	89.00	0	86.17
PR x MO	58.33	100.00	100.00	0	86.11
OG x DT	0	100.00	0	0	100.00

Table 13 Matrix showing average number of fruits per candle

NO x DT - Two crosses were attempted and none of them were found to be successful.

PR x KR - Three crosses were done and two of them were successful. Both the crosses (PR x KR) x LR and (PR x KR) x AW showed 100 percentage of candles bearing fruits.

LR x PR - All the possible four crosses could be attempted and two of them were successful namely (LR x PR) x AW (89.00 per cent) and (LR x PR) x OG (83.33 per cent).

PR x MO - Three crosses could be attempted and all of them were successful the crosses (PR x MO) x LR and (PR x MO) x AW showed 100 per cent success followed by (PR x MO) x OG (58.33 per cent).

OG x DT - In OG x DT, only one cross could be attempted and it was found to be successful *i.e.* (OG x DT) x LR (100 per cent).

Among the 10 female parents, the maximum percentage of candles bearing fruits was obtained for PR x KR (100 per cent) with two crosses and OG x DT (100 per cent) with one cross followed by FR x MW (1) (91.67 per cent) with two crosses and LR x PR (86.17 per cent) with two crosses and PR x MO (86.11 per cent) with two crosses (Table 12).

4.5.2 Number of Fruits per Candle

The fruit of anthurium is a berry. The berries when ripe will be pushed out of the candle and they can be collected. The extrusion of berries takes place between 9 am and 10 am. The number fruits per candle obtained in various crosses are shown in Table 13. The fruit colour varies from yellow to dark red.

FR x MW (1)- Among the two successful crosses the maximum number of berries was obtained for the cross [FR x MW (1)] x LR (88) followed by [FR x MW (1)] x OG (30).

Table 13 Matrix showing average number of fruits per candle

♀ \ ♂	Orange Glory	Liver Red	Acropolis White	Tropical Red	Average
LR x DT	0	0	0	0	0
FR x MW(1)	30	88	0	0	59
MO x KR(1)	0	0	0	0	0
KO x CR	0	0	0	0	0
PR x FR(1)	28	25	0	0	27
NO x DT	0	0	0	0	0
PR x KR	0	64	56	0	60
LR x PR	113	0	23	0	68
PR x MO	47	51	29	0	42
OG x DT	0	37	0	0	37

Table 14. Matrix showing average percentage of fruit set in each combination

♀ \ ♂	Orange Glory	Liver Red	Acropolis White	Tropical Red	Average
LR x DT	0	0	0	0	0
FR x MW(1)	12.54	17.14	0	0	14.84
MO x KR(1)	0	0	0	0	0
KO x CR	0	0	0	0	0
PR x FR(1)	14.85	9.76	0	0	12.31
NO x DT	0	0	0	0	0
PR x KR	0	12.27	27.76	0	20.02
LR x PR	37.91	0	19.39	0	28.65
PR x MO	28.52	23.36	29.29	0	27.06
OG x DT	0	12.65	0	0	12.65

PR x FR (1)- Out of the two crosses attempted the cross [PR x FR (1)] x OG had higher number of fruits (28) compared to [PR x FR (1)] x LR (25).

PR x KR- Two crosses of which (PR x KR) x LR (64) had higher number of fruits per candle than (PR x KR) x AW (56).

LR x PR - Out of two successful crosses the cross (LR x PR) x OG showed the highest number of fruits per candle (113) followed by (LR x PR) x AW (23).

PR x MO- Of the attempted successful crosses (PR x MO) x LR recorded the highest number fruits per candle of 51 followed by (PR x MO) x OG with 47 berries and (PR x MO) x AW with 29 berries.

OG x DT- Only the cross (OG x DT) x LR was successful which had an average of 37 fruits per candle.

4.5.3 Percentage of Fruit Set Per Candle

The percentage of fruit set per candle for the successful crosses in female parent is given below (Table 14 and Plate 4)

FR x MW (1)- Among the two successful crosses the cross [FR x MW (1)] x LR obtained 17.14 per cent fruit set compared to [FR x MW (1)] x OG (12.54 per cent).

PR x FR (1) - Comparing the two successful crosses of PR x FR (1), the cross [PR x FR (1)] x OG got more percentage of fruit set (14.85 per cent) than the cross [PR x FR (1)] x LR (9.76 per cent).

PR x KR - Among the two successful crosses the cross (PR x KR) x AW had higher fruit set (27.76 per cent) followed by (PR x KR) x LR (12.27 per cent).

LR x PR - Of the two successful crosses obtained for LR x PR, higher percentage of fruit set was obtained for the cross (LR x PR) x OG (37.91 per cent) and (LR x PR) x AW (19.39 per cent).

PR x MO - Of the three successful crosses the highest fruit set was obtained for (PR x MO) x AW (29.29 per cent) followed (PR x MO) x OG (28.52 per cent) and (PR x MO) x LR (23.36 per cent).

OG x DT- The one successful cross (OG x DT) x LR showed 12.65 per cent fruit set per candle.

Among the 10 female parents the highest average percentage fruit set was observed for LR x PR (28.65 per cent) with two crosses followed by PR x MO (27.06 per cent) with three crosses.

4.5.4 Duration of Fruit Maturity

The duration of fruit maturity in the 10 female parent is as follows (Table 15)

FR x MW (1)- In FR x MW (1), the successful cross [FR x MW (1)] x OG took an average of 7 months for the fruits to mature while [FR x MW (1)] x LR took 6 months to mature.

PR x FR (1) - In different crosses with PR x FR (1) as female parent, with Orange Glory as male parent it took 7 months for the fruit to mature where as with Liver Red it took 5 months for fruits to mature.

PR x KR- Among the crosses of PR x KR, the maximum duration of fruit maturity was recorded in the cross (PR x KR) x LR (7 months) followed by (PR x KR) x AW (5 months).

LR x PR- In the two crosses obtained for LR x PR, (LR x PR) x OG and (LR x PR) x AW took 5 and 6 months for the fruits to mature.

PR x MO- Among the three successful crosses with PR x MO, (PR x MO) x OG recorded the maximum duration for fruit maturity of 8 months followed by (PR x MO) x LR 6.5 months and (PR x MO) x AW 4 months.

OG x DT- The only one successful cross (OG x DT) x LR took 5.5 months for the fruit to mature.

The time taken for fruit maturity among the 10 female parents ranged from 4 months in (PR x MO) x AW to 8 months in (PR x MO) x OG.

4.5.5 Number of Seed Per Berry

The fruit of anthurium *i.e.*, the berry contains one, two or rarely three seeds which is covered with a transparent sticky pulp (Table 15).

FR x MW (1)- In FR x MW (1), the percentage of barriers with single seeds was highest for the cross [FR x MW (1)] x OG (97.03 per cent) while it was low for [FR x MW (1)] x LR (71.22 per cent) and percentage of double seeded berries was highest in the cross [FR x MW (1)] x LR (28.78 per cent).

PR x FR (1) - Out of the two successful crosses the percentage of single seeded berries was 97.40 per cent in [PR x FR (1)] x OG followed by [PR x FR (1) x LR (96.97 per cent) in the case of double seeded berries it was 3.03 percentage in [PR x FR (1)] x LR followed by [PR x FR (1)] x OG having 2.60 percentage.

PR x KR- In both the successful crosses percentage of single seeded berries are more and is highest for (PR x KR) x LR (97.80 per cent) followed by (PR x KR) x AW (74.30 per cent). The percentage of double seeded berries comparatively more in the case of (PR x KR) x AW (25.70 per cent) while it was very low for (PR x KR) x LR (2.20 per cent).

LR x PR- The percentage of berries with single seeds was highest for the cross (LR x PR) x AW (70.10 per cent) followed by (LR x PR) x OG (47.28 per

cent), in the same cross with double seeds it was maximum (52.72 per cent) followed by (LR x PR) x AW (29.90 per cent).

PR x MO- Among the three successful crosses the highest percentage of single seeded berries was for the cross (PR x MO) x AW (94.69 per cent) followed by (PR x MO) x OG (85.43 per cent) and (PR x MO) x LR (66.35 per cent). The maximum double seeded berries obtained for (PR x MO) x LR (33.65 per cent) followed by (PR x MO) x OG (14.57 per cent).

OG x DT- The only successful cross (OG x DT) x LR had 83.00 per cent single seeded berries and remaining double seeded berries.

4.5.6 Seed Size

The size of the seeds of even the same cross combination varies depending upon whether they are obtained from single seeded berries or two seeded. The data recorded on the seed size are as follows. (Table 15).

FR x MW (1)- In FR x MW (1), the largest seeds in single and double seeded berries was for the cross [FR x MW (1)] x LR (3.70 x 3.07 mm) and (2.07 x 1.33 mm) respectively. Smaller seeds were obtained from the cross [FR x MW (1)] x OG (3.17 x 2.33 mm) and (2.00 x 1.50 mm) for single and double seeded berries respectively.

PR x FR (1) - Among the two successful crosses size of single seeded berries is larger for [PR x FR (1)] x LR (3.70 x 2.57 mm) and for double seeded berries larger seeds obtained from [PR x FR (1)] x OG (1.93 x 1.33 mm).

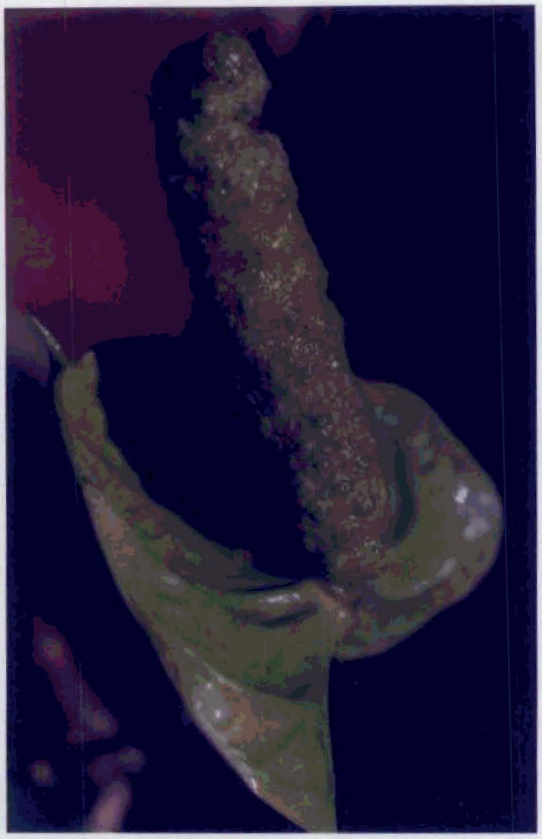
PR x KR- The seed size of single seeded and double seeded berries for the cross (PR x KR) x LR was 3.83 x 2.00 mm and 2.00 x 1.17 mm respectively and for the cross (PR x KR) x AW it was 3.33 x 2.27 mm and 2.67 x 2.03 mm respectively.

Table 15. Results from the hybridization programme among *A. Andreanum* genotypes

Combination	Duration of fruit maturity (months)	Berries		Berries with single seed		Berries with two seeds		Number of days for germination
		Single seed (per cent)	Two seeds (per cent)	Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)	
[FR x MW(1)] x OG	7	97.03	2.97	3.17	2.33	2.00	1.50	5-7
[FR x MW(1)] x LR	6	71.22	28.78	3.70	3.07	2.07	1.33	4-8
[PR FR(1)] x OG	7	97.40	2.60	3.00	2.33	1.93	1.33	5-9
[PR x FR(1)] x LR	5	96.97	3.03	3.70	2.57	0.93	0.67	4-8
[PR x KR] x LR	7	97.80	2.20	3.83	2.00	2.00	1.17	6-8
[PR x KR] x AW	5	74.30	25.70	3.33	2.27	2.67	2.03	6-7
[LR x PR] x OG	5	47.28	52.72	4.17	3.63	3.50	2.83	5-8
[LR x PR] x AW	6	70.10	29.90	4.17	3.90	3.50	2.50	5-8
[PR x MO] x OG	8	85.43	14.57	2.83	2.07	2.17	1.47	5-9
[PR x MO] x LR	6.5	66.35	33.65	4.07	3.07	3.27	2.50	5-8
[PR x MO] x AW	4	94.69	5.31	3.17	2.17	1.83	1.27	5-7
[OG x DT] x LR	5.5	83.00	17.00	3.43	2.60	1.50	1.07	6-9

First month

Second month



Fourth month

Sixth month

Plate 4. *Anthurium andreanum* at different stages of fruit maturity

LR x PR- Larger seed size was obtained for single single seeded berries in (LR x PR) x AW (4.17 x 3.90 mm) among two successful crosses. Larger double seeded berries was also for the same cross *i.e.* 3.50 x 2.83 mm.

PR x MO - The average size of single seeded and double seeded berries was maximum for (PR x MO) x LR (4.07 x 3.07 mm) and (3.27 x 2.50 mm) respectively.

OG x DT- Seed size of the only cross (OG x DT) x LR was 3.43 x 2.60 mm for single seeded berries and 1.50 x 1.07 mm for double seeded berries.

4.5.7 Number of Days for Germination

The data on days for germination of seeds obtained in various crosses are given below (Table 15). In FR x MW (1), the days taken for germination ranged from 5 to 7 days for the cross [FR x MW (1)] x OG and 4 to 8 days for the cross [FR x MW (1)] x LR. In PR x FR (1), the days taken for germination ranged from 5-9 days when male parent is OG and 4-8 days when male parent is LR. For the two crosses of PR x KR *viz.*, (PR x KR) x LR and (PR x KR) x AW it took 6-8 days and 6-7 days for germination. In LR x PR, the days taken for germination ranged from 5-8 days in the various crosses. PR x MO had three successful crosses, (PR x MO) x OG, (PR x MO) x LR and (PR x MO) x AW and for germination each took 5-9 days, 5-8 days and 5-7 days respectively. (OG x DT) x LR, the only one successful cross for OG x DT took 6-9 days for germination.

4.5.8 Percentage Germination of Seed

Seeds were squeezed out from the harvested berries and kept on moist cotton in petridishes after removing the sticky mucilagenous pulp around it. Seeds were obtained from 12 crosses (Table 16).

FR x MW (1) - In this parent the highest seed germination was for the cross [FR x MW (1)] x LR (74.93 per cent) followed by the cross [FR x MW (1)] x OG (72.30 per cent).

PR x FR (1) – Among the two successful crosses, the cross [PR x FR (1)] x LR showed higher seed germination percentage (85.13 per cent) compared to [PR x FR (1)] x OG (76.58 per cent).

PR x KR – In the two successful crosses with PR x KR, (PR x KR) x AW showed 80.85 per cent germination, while the cross (PR x KR) x LR showed 56.67 per cent germination.

LR x PR – In LR x PR, the cross (LR x PR) x OG showed 73.01 per cent germination while the cross (LR x PR) x AW shown 70.17 per cent germination.

PR x MO – Among the crosses of PR x MO, the germination percentage ranged from 57.55 per cent in (PR x MO) x OG to 79.64 per cent in (PR x MO) x LR.

OG x DT – The only successful cross of OG x DT, (OG x DT) x LR had 63.86 per cent germination.

Among the parents in which successful crosses were obtained PR x FR (1) reported the highest average percentage seed germination (80.86 per cent) followed by FR x MW (1) (73.62 per cent) with two crosses. LR x PR and PR x KR showed an average percentage of seed germination of 71.59 percentage and 68.76 percentage with two crosses each. PR x MO with three crosses showed an average percentage of seed germination of 65.24 per cent.

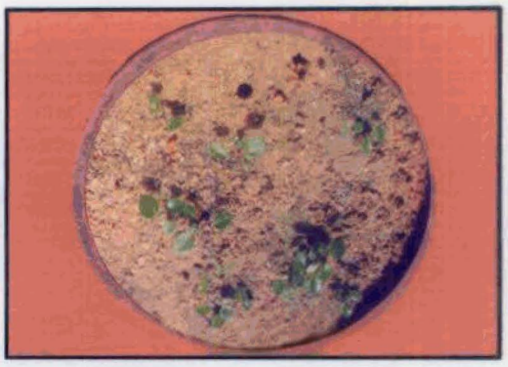
4.5.9 Survival Percentage of Seedlings at Four to Six Months Stage

The data on survival percentage of seedlings are given below (Table 17).

Out of 12 combinations that germinated successfully in the seedlings belonging to the cross [PR x FR (1)] x OG, (PR x MO) x OG and [PR x FR (1)] x LR did not survive beyond four months. Seedlings of the crosses (PR x KR) x AW showed the highest survival percentage 94.60 per cent followed by [FR x MW (1)] x LR (93.80 per cent).

Seedlings at five month stage

(PR x LR) x TR



(PR x MO) x LR

(LR x PR) x AW

[(FR x MW (1)] x LR

Seedlings at ten month stage

(LR x PR) x AW

Plate 5. Seedlings of the crosses at different maturity stages

Plate 6. General view of experimental plot

The highest average seedling survival was recorded for OG x DT (90.00 per cent) among parents with only a single cross followed by PR x KR (87.39 per cent) with two crosses. The cross PR x MO showed a seedling survival of 57.03 per cent.

Table 16. Matrix showing average percentage of seed germination

♀ \ ♂	Orange Glory	Liver Red	Acropolis White	Tropical Red	Average
LR x DT	0	0	0	0	0
FR x MW(1)	72.30	74.93	0	0	73.62
MO x KR(1)	0	0	0	0	0
KO x CR	0	0	0	0	0
PR x FR(1)	76.58	85.13	0	0	80.86
NO x DT	0	0	0	0	0
PR x KR	0	56.67	80.85	0	68.76
LR x PR	73.01	0	70.17	0	71.59
PR x MO	57.55	79.64	58.52	0	65.24
OG x DT	0	63.86	0	0	63.86

Table 17. Matrix showing survival percentage of seedlings at four to six months stage

♀ \ ♂	Orange Glory	Liver Red	Acropolis White	Tropical Red	Average
LR x DT	0	0	0	0	0
FR x MW(1)	76.40	93.80	0	0	85.10
MO x KR(1)	0	0	0	0	0
KO x CR	0	0	0	0	0
PR x FR(1)	0	0	0	0	0
NO x DT	0	0	0	0	0
PR x KR	0	80.17	94.60	0	87.39
LR x PR	48.4	0	75.0	0	61.70
PR x MO	0	86.50	84.60	0	57.03
OG x DT	0	90.00	0	0	90.00

Discussion

5. DISCUSSION

The cultivation of anthurium especially *Anthurium andreanum* Linden for cut flowers has assumed greater importance in recent times, owing to the premium prices it fetches both in domestic and international markets. Mostly unnamed types of Anthurium based on spathe colour are cultivated in India.

Basic information on the breeding behaviour of this crop to improve the existing types and varieties are lacking. Anthuriums are commercially propagated now by tissue culture. But in hybridization programme the seed progenies are raised. In the present study an attempt is made to improve the commercial characters through hybridization. Variability is statistically analysed along with cross compatibility studies and the results are discussed below.

5.1 MEAN PERFOMANCE

All the 14 genotypes studied showed wide variations for all the qualitative and quantitative characters. They showed significant variation in plant height ranging from 30.80 cm in NO x DT to 76.17 cm in Liver Red. The mean plant height observed was 47.81 cm. The heights of varieties LR x DT and KO x CR were less and on par with PR x KR.

Abdussammed (1999) has reported that nutrients significantly influenced the plant height, both in ground as well as pot planting. But plant height can be considered as a varietal character, as reported by Bindu and Mercy (1994). They reported significant variation for plant height in the five varieties studied. The six varieties studied by Sindhu (1995) also recorded significant variation in height.

Renu (2000) recorded significant variation in plant height ranging from 29.70 cm to 70.90 cm. According to Mayadevi (2001) the plant height ranged from 42.50 cm in Midori Green to 96.67 cm in ordinary White. Asish (2002) recorded the plant height of fifty genotypes ranged from 22.17 cm to 64.80 cm.

The mean internode length in the present study was 1.20 cm with a range of 0.93 cm in MO x KR (1) to 1.63 in LR x PR. Plants with short 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 which limit the height of the plant. Mayadevi (2001) reported that the mean internode length among the hybrids range from 1.02 to 1.34 cm and in five parents it ranged from 1.00 to 1.52 cm. Asish (2002) observed an average internode length of 1.56 cm and Premna (2003) recorded an internode length of 1.20 to 1.48 cm.

Though propagation of anthuriums using suckers is a very slow but good process, so suckering is an important trait considered in the selection of superior genotypes. The present investigation revealed that suckering was very high for Liver Red (4); low for KO x CR and PR x KR and nil for FR x MW (1), Acropolis White and Tropical Red. Mercy and Dale (1994) opined that most of the good commercial *Anthurium* varieties were very shy suckering or did not sucker at all. They recommended the use of Gibberellic acid (GA) or Benzyl adenine (BA) (500 – 1000 ppm) to increase the rate of sucker production. This indicates influence of hormones on suckering. Similar effect of growth regulators on sucker production had been reported by Higaki and Rasmussen (1979), Salvi (1997) and Abdussammed (1999). Mayadevi (2001) observed maximum number of sucker production (4) for the varieties Pink, Lady Jane and the least number of sucker for the varieties Nitta Orange, Merengue White and Tropical Red. In the study by Asish (2002) most of the genotypes (64 per cent) had suckers with a range of 1.37 to 2.46 which comes under medium suckering types. Premna (2003) noticed maximum sucker production in OO x KR (2.25) and lowest in Acropolis White (0.25).

Leaf area varied according to the size of the leaf. In the present study leaf area ranged from 91.97 cm^2 in PR x FR (1) to 287.76 cm^2 in LR x PR. Mercy and Dale (1994) reported that leaves of commercially valuable floral anthuriums should be small to medium sized, narrow and elongated. Large and exuberantly

growing leaves are undesirable. Salvi (1997) observed that with decline in shade intensity, leaf area also decreased significantly. Mayadevi (2001) reported that variety Chilli Red had the leaf area of 66.26 cm^2 followed by variety Kalympong Red 66.92 cm^2. Asish (2002) in his study with fifty genotypes observed that most of the genotypes had a medium leaf area in between 92.20 to 183.40 cm^2. Premna (2003) in her study with fourteen genotypes noticed that the leaf area ranged from 113.62 to 301.10 cm^2.

In the present study the days from emergence to maturity of leaves ranged from 26.57 days in NO x DT to 35.67 days in Tropical Red. Mayadevi (2001) recorded that the variety Honeymoon Red took 41.40 days and for variety Pink it was 44.40 days for maturity of leaves. Asish (2002) with 50 genotypes observed the average days for the emergence of leaves to its maturity as 27.56 with a range 15.33 days in OG x LR to 41.00 days in DT x FR. Premna (2003) noticed the least number of days for maturity of leaves for Carre (26.25) and a maximum number for PR x DT (40.25). The observations in the present study are in confirmation with these reports.

The present investigation revealed 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 highest in Liver Red (7.00) which was on par with Orange Glory, Acropolis White and OG x DT (6.33). The lowest number of 4.67 was recorded by FR x MW (1) and NO x DT . Similar close correlation between the number of leaves and the number of spadices was observed by Gajek and Schwarz (1980). Steen and Vijverberg (1973) compared the productivity of 120 individual anthurium plants and found that it ranged between four to sixteen spadices over the two years. According to Mayadevi (2001) generally a single spadix was found to be produced from the axil of each leaf so that the number of leaves and number of spadices produced annually were equal. As it takes more than a month to produce a new leaf or a new flower and with a leaf flower leaf pattern. Mercy and Dale (1994) recorded the annual production of spadices as five to eight while

Sindhu (1995) recorded it as four to eight. The present study was in confirmation with the above reports.

Short and slender candle is a desirable feature for *Anthurium* flowers. In the present investigation the genotypes MO x KR (1) (3.83 cm) and PR x FR (1) (4.97 cm) had short candles and PR x MO and LR x PR had longer candles (8.00 cm and 7.83 cm) which is not ideal. Mercy and Dale (1994) reported that the candle was long and fleshy in ordinary non commercial varieties, and it was shorter and more slender in hybrids. The five varieties studied by Bindu and Mercy (1994) showed a candle length range of 4.0 cm to 9.5 cm. The candle length of six varieties studied by Sindhu (1995) ranged from 6.6 cm to 12.1 cm. According to Mayadevi (2001) the variety Pink had longest candle (12.72 cm) and the variety Liver Red (7.18 cm) had shortest candle. Asish (2002) observed that the 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. Premna (2003) observed shorter candle in the genotypes FR x KR (4.63 m), LR x FR (4.75 cm) and Carre (4.88 cm).

Mercy and Dale (1994) recommended that ideal *Anthurium* varieties should have a short candle, curving towards the tip of the spathe and held at an angle less than 45^0. Such ideal position of candle was observed in PR x MO (26.10^0) and Orange Glory (34.77^0). In a similar study Sindhu (1995) found that the varieties with ideal position of candles were Chilli Red Kalympong Orange, Kalympong Red and White. Mayadevi (2001) noticed that the inclination of candle ranged from 21^0 to 78.20^0 among the parents and from 20.80^0 to 89.60^0 among the hybrids. Asish (2002) in his study of 50 genotypes reported that more than 50 per cent of the genotypes had an angle less than 45^0.

According to Paull (1982), the non reversible visible changes accompanying the senescence of *Anthurium* spadices were, loss of spathe-gloss, necrosis of spadix and greening of spathe and spadix. Mercy and Dale (1994) also noticed that senescence was marked by yellowing of 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 time span from the emergence of a spadix to its senescence varied from 62.33 days in PR x FR (1) to 99 days in Acropolis White in the case of unfertilized spadices. For fertilized spadices the life span was found to be higher, ranging from 178 to 254 days. Sindhu (1995) reported that the life of unfertilized spadix was about 1.5 to 3.5 months, while in fertilized spadices it varied from 4.5 to 8.0 months. Mayadevi (2001) in her study reported that it varied from 98 days in Chilli Red to 120.40 days in Honeymoon Red among parents, and in hybrids, it ranged widely from 110.80 days in LR x KR to 126.00 days in HR x KR. Similar results were obtained by Premna (2003) also, who reported that the life of the unfertilized spadix was about 59.5 to 101.5 days.

Initiation of female phase was identified by honeydew secretion on the projected stigmas. Studies by Mercy and Dale (1994) revealed that, in *Anthurium* species flower maturation started from the basal portion and proceeded regularly towards the apex. He listed many protogynous species of *Anthurium*, in which *A. andreanum* was included. However, later studies by Bindu and Mercy (1994), Sindhu (1995) and Renu (2000) revealed the protogynous nature of *A. andreanum* varieties. Observations in the present study also highlighted the clear protogynous nature of this species. The number of days required for visible initiation of female phase was observed to vary from 4.33 days in PR x MO to 9.27 days in PR x FR (1). Initiation of female phase was identified by the slight projection by stigmas and presence of viscous exudate on the candle. Sindhu (1995) also reported that the days to initiation of female phase ranged within a period upto ten days, with the variety Honeymoon Red showing the longest period among the six varieties studied by her. Renu (2000) observed longest period in Mauritius Orange and shortest in Lady Jane Red. Mayadevi (2001) noticed that the initiation of female phase ranged from 4.40 days among the parents to 6.80 days among the hybrids. Observation by Asish (2002) and Premna (2003) revealed the same results.

The period in female phase was recorded based on the presence of exerted stigma, honeydew like secretion and some amount of insect activity. Daumann (1921) and Mercy and Dale (1994) have recommended the above criteria to identify the female phase. The duration of female phase in the 14 varieties of the present study varied from 5.50 days in OG x DT to 11 days in Acropolis White. Similar observations were recorded by Asish (2002) and Premna (2003) also noticed that the female phase ranged from 5.50 to 9.00 days. In the present study there were individual flowers in which the female phase lasted upto 18 days and this was observed in Liver Red. Croat (1980) reported that, although in some species like *A. armeniense*, *A. carperatum*, *A. fatoense* etc., the stigmas did not form droplets but 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 25 days. Duration was reported as 3 to 12 days by Bindu and Mercy (1994), and as 5 to 25 days by Sindhu (1995).

The interphase between the female and male phase was marked by the drying up of stigmatic droplets. Observation from the fourteen varieties in the present study showed that the interphase may range from 2.33 to 6.83 days on an average. Almost similar observations was recorded by Bindu and Mercy (1994) who reported that the interphase lasted for about four to seven days. The variety Acropolis White had the longest interphase period and the shortest was in NO x DT. (Days of interphase and male phase could not be recorded for the varieties LR x DT, FR x MW (1), KO x CR and PR x MO in which no pollen production was observed during the period of this study). 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 or protogynous. Sindhu (1995) with six varieties noticed that interphase lasted for four to ten days. Asish (2002), Premna (2003) recorded that interphase ranged from 2.00 days to 9.20 days.

Following the interphase, a male phase was observed, marked by anther extrusion from the base of the candle and proceeding upwards. In the present

study the average number of days for which the candles remained in male phase ranged from 5.33 days [PR x FR (1)] to 10.83 days (Acropolis White). A very similar report was that of Bindu and Mercy (1994) who reported that the male phase lasted for 3 to 7 days. Croat (1980) reported that in some *Anthurium* species the male phase lasted for several weeks and that anther emergence may be scattered as in *A. caperatum* or sporadic as in *A. luteynii*. Similar scattered anther emergence on the candle was observed in the varieties Liver Red and Orange Glory under the present study. In the variety Acropolis White sometimes only a portion of the candle showed anther emergence such observations were recorded by Sindhu (1995) also in the variety Kalympong Red. Asish (2002) and Premna (2003) recorded that the male phase may last for 4 to 12 days.

The acetocarmine staining method was used to find the pollen fertility of the selected varieties. (The pollen fertility of LR x DT, FR x MW (1), KO x CR and PR x MO cannot be found out as no pollen production occurred in these during the period of study). The highest pollen fertility was observed for PR x FR (1) (41.67 per cent) followed by Liver Red (40.67 per cent). OG x DT (14.67 per cent) and PR x KR (20.33 per cent) recorded the lowest pollen fertility values. Mitu and Acatrinei (1974) reported that the germination of pollen grain was proportional to pollen grain stainability as acetocarmine preferentially stains the chromosome or nucleus. The observation by Lalithambika (1978) that the pollen fertility of *A. andreanum* vary from 25 to 30 per cent, is in confirmity with the results of present study. Mercy and Dale (1994) reported that the pollen fertility in *A. andreanum* vary from 20.40 per cent to 28.80 per cent, which again substantiates the present finding. As sterility is a condition frequently associated with hybridity, we can take the low pollen fertility in this crop as an indication of its hybrid nature. Based on the cytological studies of five varieties Bindu and Mercy (1994) concluded that low fertility can also be due to high degree of meiotic abnormalities like clumping, lagging of chromosomes at anaphase, unequal segregation, precocious disjunction of chromosomes, chromosome elimination through micronuclei etc., found in *A. andreanum*. Asish (2002) and

Premna (2003) recorded a pollen fertility range of 9.26 to 50.80 percentage. Pollen size was found to vary from 16.80 μ in OG x DT to 24.97μ. Premna (2003) also noticed that the size of pollen grain among the varieties did not vary significantly.

A study of five qualitative traits such as colour of young leaf and petiole, spathe colour, spathe texture, candle colour and type of inflorescence axis revealed slight variations. The colour of young leaf showed a range from brown to reddish brown to greenish brown to brownish green to green. The colour of petiole also varied from brown to light brown to reddish brown to greenish brown to green. Mercy and Dale (1994) also observed that the colour of young leaves varied from deep reddish brown to light green. According to Sindhu (1995) it ranged from purple to green and that of young leaves from light green to brown. Premna (2003) in her study with 14 genotypes observed a colour range for the young leaves from brown to reddish brown to greenish brown to green. The colour of petiole also varied from brown to reddish brown to greenish brown to green.

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 O controlled that of pelargonidin-3-rutinoside. Red and pink resulted when both M and O are present. So the red and pink spathed varieties under the present study have both M and O genes. But the variation in red spathe colour from maroon to dark red to bright red to red and pink was explained by their findings that, 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. They have also concluded that orange have a genotype of mmOO and was true breeding while mmOo expressed a light orange shade called coral. The recessive oo is epistatic to M and white colour resulted when both are recessive (mmoo) or M was in combination with oo (MMoo, Mmoo). Wannakrairoj and Kamemoto (1990) studied the

inheritance of purple spathe in anthurium and proposed a scheme to explain this. A recessive allele p, was found to modify the colour of anthocyanins controlled by M and O loci. The spathe was purple when the genotype was M_O_pp. The dominant P allele had no effect on colour in any combinations. The colour genotypes and their phenotypes are as follows.

MMOO
MmOO = Reds
MMOo

MmOo = Pink
mmOO = Orange
mmOo = Coral

MMoo
Mmoo = White
mmoo

M-O-pp = Purple

The 14 genotypes in the present study varied from deep maroon to dark red to red to pink to light pink to orange to dark orange is in confirmation with above reports.

Spathe texture showed wide variation among the 14 genotypes studied, from thick smooth and glossy to medium thick shallowly blistered glossy to thin slightly blistered glossy to thin blistered to thick medium blistered to medium thick deeply blistered glossy to medium thick blistered glossy spathes. According Birdsey (1956) Linden described the spathe *A. andreanum* based on varying degrees of smoothness and blistering. Mercy and Dale (1994) opined that the spathe of floral anthuriums may be smooth, thick and glossy without prominent veins or it may be thinner deeply veined and blistered. The six varieties studied

by Sindhu (1995) also showed variation from thick to thin and deep to shallowly blistered spathe. Renu (2000) noticed that the spathe texture showed high variation among the 10 varieties from thick and deeply blistered in Mauritius Orange to thin and smooth in Lady Jane Red. In the studies by Mayadevi (2001), Asish (2002) and Premna (2003) also spathe texture varied from blistered glossy to medium thick deeply blistered glossy to thick smooth glossy to medium thick smooth.

The candle colour was light yellow [LR x PR, FR x MW (1), KO x CR and PR x FR (1)], yellow (Tropical Red, Acropolis White, Orange Glory, PR x MO, NO x DT and LR x DT), maroon [Liver Red and FR x MW (1)] and pink in PR x KR and OG x DT. According to Mercy and Dale (1994), the candle had a single colour red, pink or green in ordinary anthurium varieties and hybrids had yellow, white, pink or red colours 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 that the anthurium hybrid Red Hot had a candle which was orange red apically blending to red basally. The candle colour of pink to light pink, yellow to yellowish white to red and green was observed by Mayadevi (2001). Asish (2002) and Premna (2003) also observed a colour range from red to light red to reddish pink to pink to light pink to pinkish yellow to yellowish white to cream.

The nature of inflorescence axis is one of the 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. Among the 14 genotypes studied straight and strong inflorescence axis which is more desirable was seen for Liver Red, Orange Glory, Acropolis White and Tropical Red. 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 great importance 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 and genotypic coefficients of variation were estimated based on the coefficients of variation and these parameters were used to compare the variability among the 14 genotypes. The GCV provides a valid basis for comparing and assessing the range of genetic diversity for quantitative characters 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.

A perusal of Table 6, shows that high PCV combined with high GCV were obtained for number of suckers per plant, duration of male phase, pollen fertility and pollen size. This revealed a great extent of variability for these characters, thereby suggesting good scope for improvement of these important characters through selection. Number of suckers per plant recorded highest GCV and PCV. Lower values of GCV and PCV were estimated for the characters days from emergence to maturity of inflorescence, days from emergence to maturity of leaves and number of spadices per plant indicating low magnitude of variability. So, improvement of these characters has only a limited scope (Fig.1). The characters duration of interphase, duration of female phase, number suckers per plant and number of leaves per plant 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 pollen size, pollen fertility, life of spadix and leaf size pointed out that the variation observed in these characters are mainly due to genetic reasons and environmental influence on these characters was less.

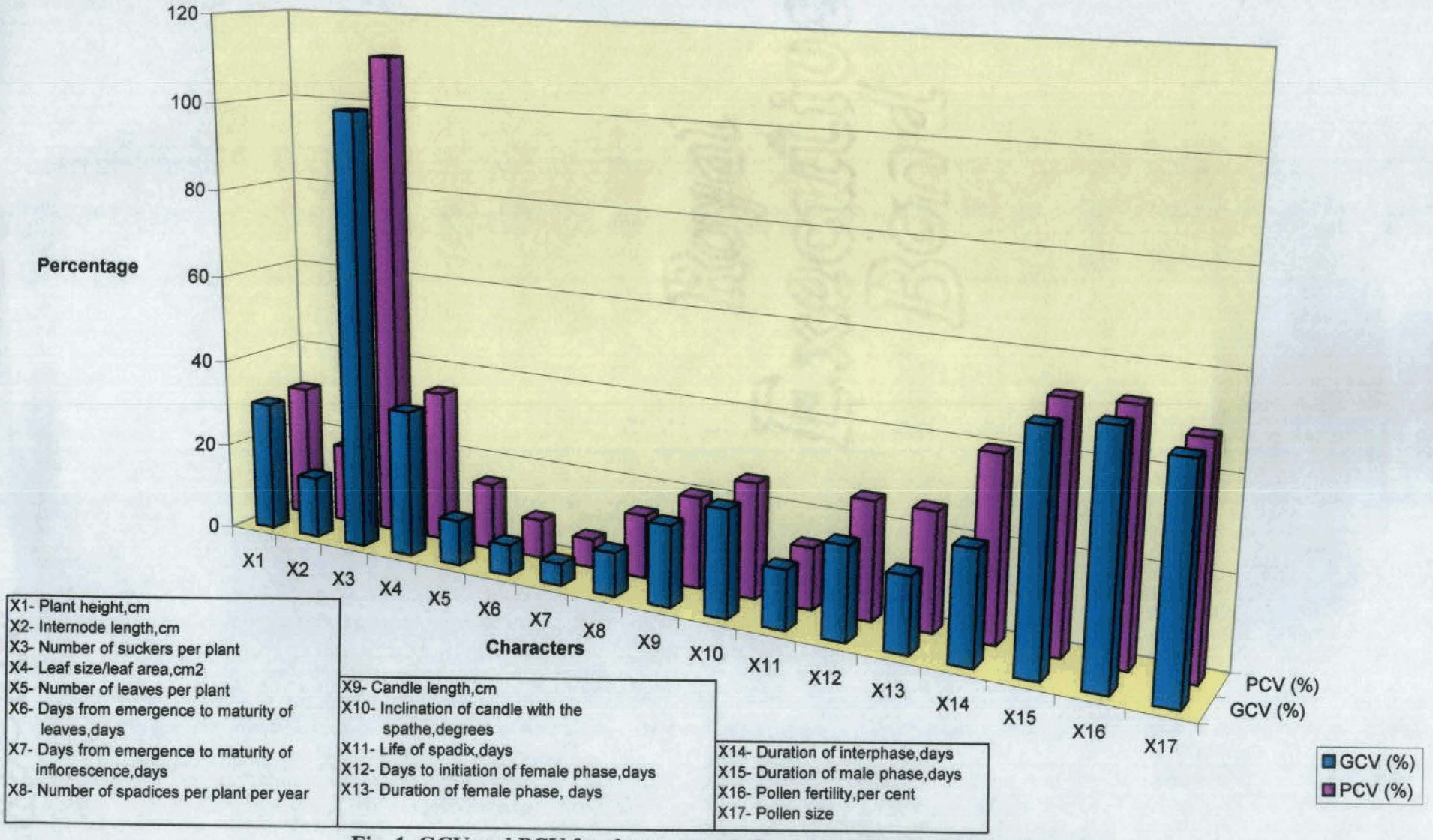


Fig. 1. GCV and PCV for the seventeen characters of *Anthurium andreanum*

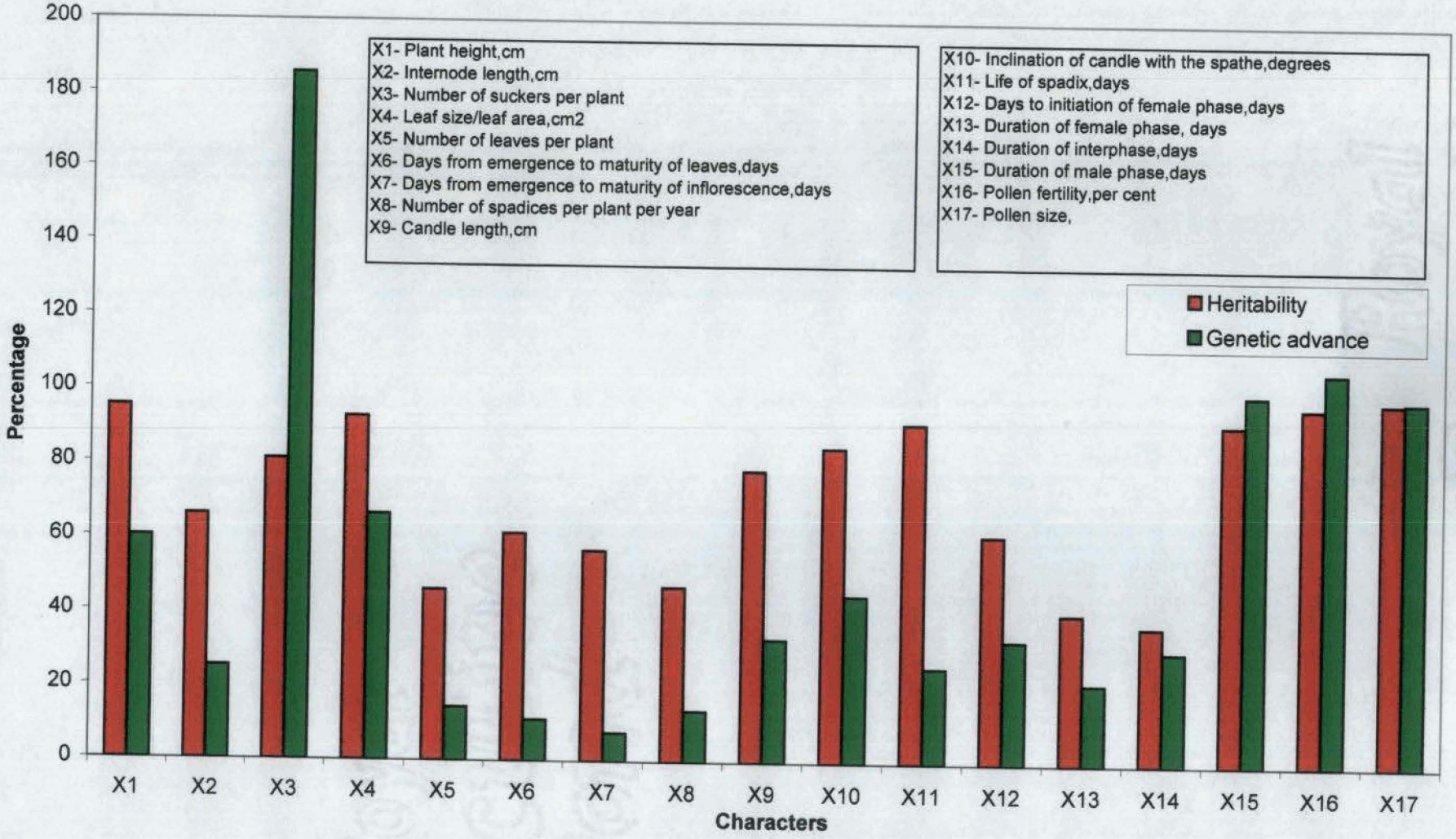
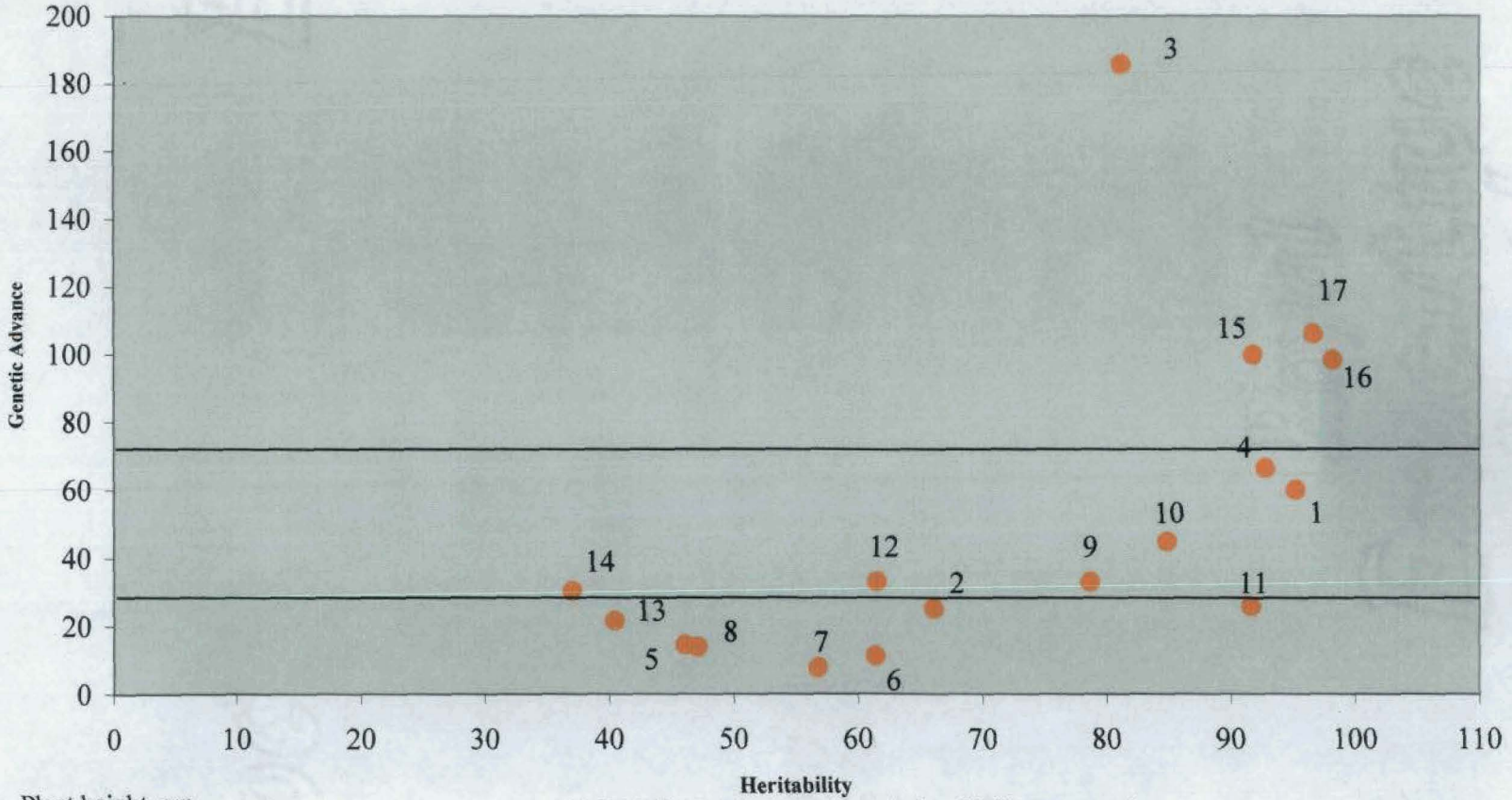


Fig. 2. Heritability and genetic advance for the seventeen characters of *Anthurium andreanum* genotypes



1 Plant height, cm
2 Internode length, cm
3 Number of suckers per plant
4 Leaf size/leaf area, cm^2
5 Number of leaves per plant
6 Days from emergence to maturity of leaves, days
7 Days from emergence to maturity of inflorescence, days
8 Number of spadices per plant per year
9 Candle length, cm
10 Inclination of candle with the spathe, degrees
11 Life of spadix, days
12 Days to initiation of female phase, days
13 Duration of female phase, days
14 Duration of interphase, days
15 Duration of male phase, days
16 Pollen fertility, per cent
17 Pollen size, μ

Fig. 3. Heritability and genetic advance as percentage of mean for different characters

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 individuals (Johnson *et al.*, 1955). Fig. 2 shows the distribution of characters in terms of heritability (H^2) and genetic advance (GA). The characters pollen fertility, pollen size and number of suckers per plant 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 for the characters duration of interphase, duration of female phase, number of leaves per plant and number of spadices per plant showed high heritability.

If 5 percentage selection is to be practiced maximum genetic advance is expected for leaf size and minimum for internode length. Robinson *et al.* (1949) classified genetic advance as percentage of mean into low (<20 per cent) and high (>20 per cent) and according this classification the characters plant height, leaf size, inclination of candle, life of spadix, pollen fertility and pollen size showed high genetic advance while it is low for all other characters. Mayadevi (2001) inferred that all the characters except number of spadices per plant per year showed high heritability and genetic advance. According to Asish (2002) anthocyanin content, pollen fertility, inclination of candle and days of interphase recorded high heritability and genetic advance. Premna (2003) recorded high heritability and genetic advance for the characters suckering ability, inclination of

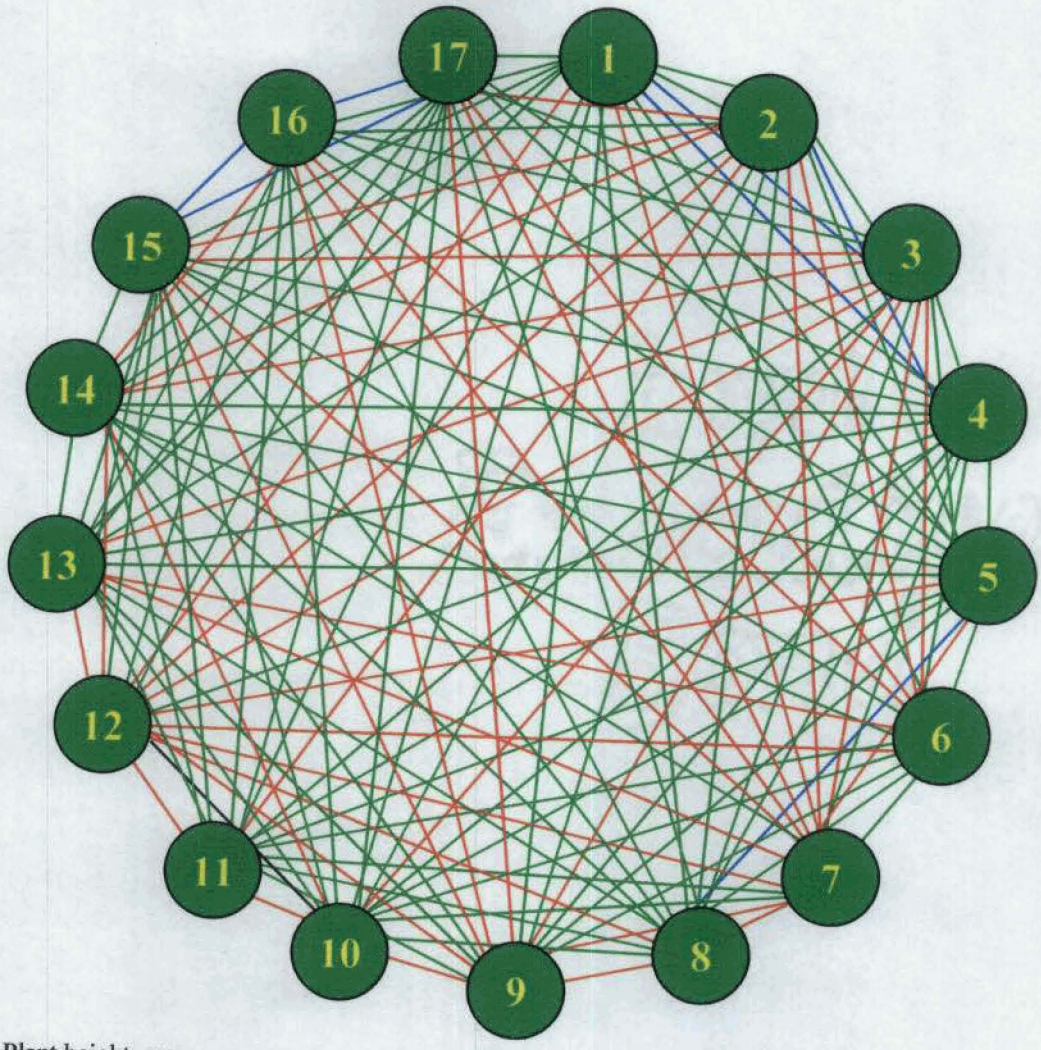
candle, anthocyanin content and pollen fertility. Comparison between heritability and genetic advance was shown in Fig. 3.

High heritability and 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 the characters pollen fertility, pollen size, number of suckers per plant and duration of male phase recorded high heritability coupled with high genetic advance which shows that genetic improvement of these characters are possible through selection.

5.4 CORRELATION STUDIES

Genetically related characters tend to move in the same direction under selection favouring any one of such related traits. Such 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 (inherent) between the characters helps to differentiate the vital association useful in breeding from non-vital ones, Falconer (1989).

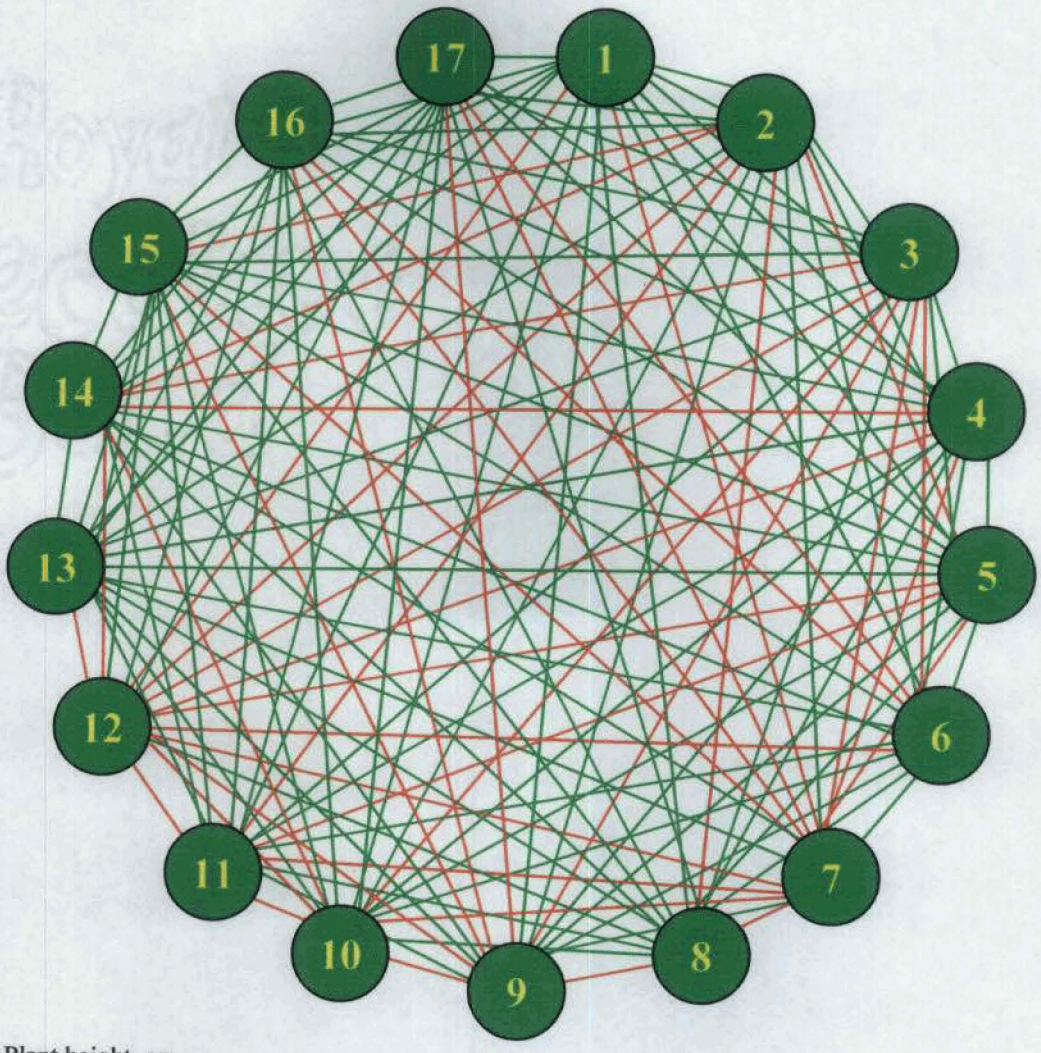
The significance of pair-wise correlation are presented in Fig. 4,5 and 6. The genotypic, phenotypic and environmental correlations between all the possible pairs of characters are discussed. In the present study plant height showed highly significant positive phenotypic correlation with number suckers per plant and leaf size. It showed positive correlation with all the characters except for days from emergence to maturity of inflorescence and days to initiation of females. If a positive correlation is observed for a pair of characters, certainly improvement in one character will improve the other character also, thus helping a breeder to select characters on the correlated response to selection. If the improvement in one character results in a decrease in other character, this will also help the breeder in the selection of character if necessary. Similar results have been reported by Asish (2002) and Premna (2003).



1 Plant height, cm
2 Internode length, cm
3 Number of suckers per plant
4 Leaf size/leaf area,cm^2
5 Number of leaves per plant
6 Days from emergence to maturity of leaves, days
7 Days from emergence to maturity of inflorescence, days
8 Number of spadices per plant per year
9 Candle length, cm
10 Inclination of candle with the spathe,degrees
11 Life of spadix, days
12 Days to initiation of female phase, days
13 Duration of female phase, days
14 Duration of interphase, days
15 Duration of male phase, days
16 Pollen fertility, per cent
17 Pollen size,μ

Positive significant
Positive
Negative
Negative significant

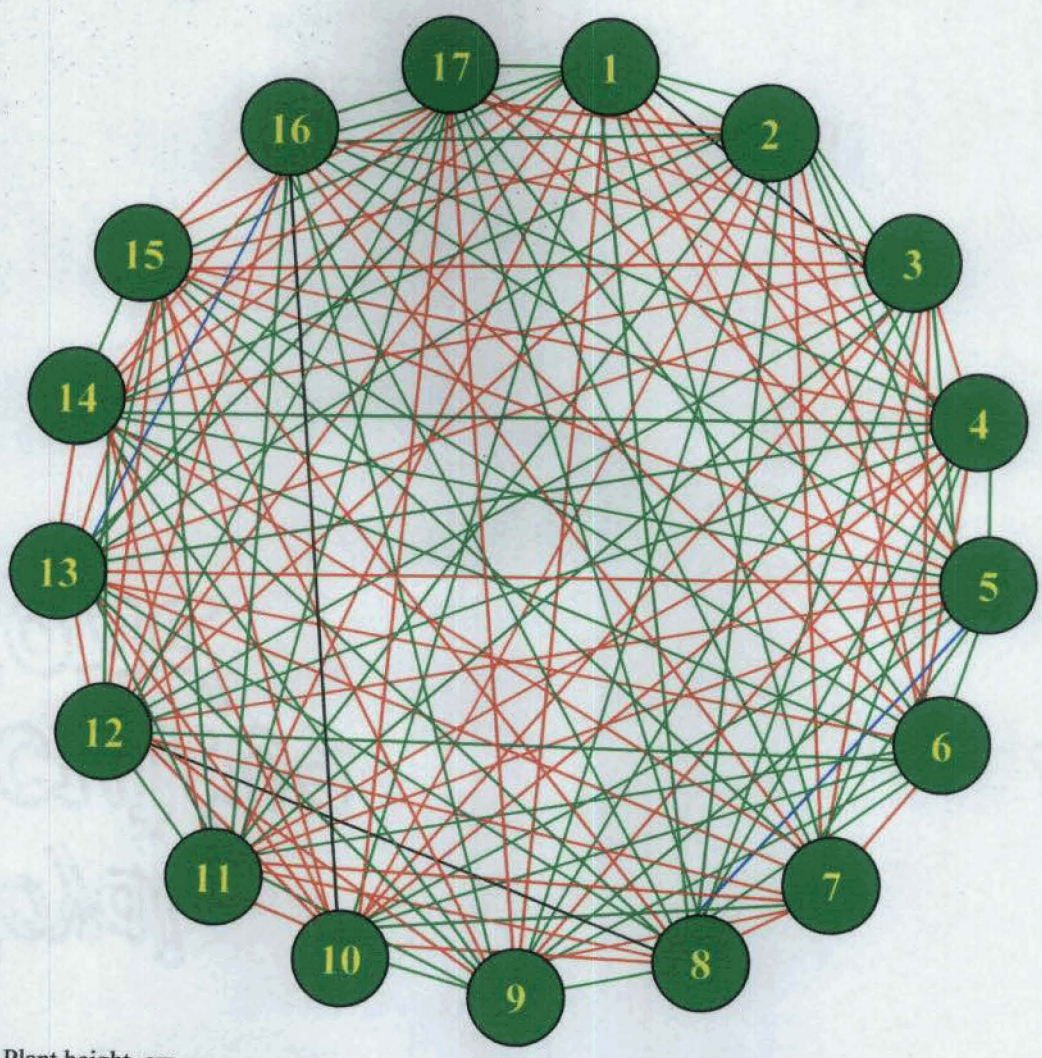
Fig. 4 Phenotypic correlation coefficient among the characters



1 Plant height, cm
2 Internode length, cm
3 Number of suckers per plant
4 Leaf size/leaf area,cm^2
5 Number of leaves per plant
6 Days from emergence to maturity of leaves, days
7 Days from emergence to maturity of inflorescence, days
8 Number of spadices per plant per year
9 Candle length, cm
10 Inclination of candle with the spathe,degrees
11 Life of spadix, days
12 Days to initiation of female phase, days
13 Duration of female phase, days
14 Duration of interphase, days
15 Duration of male phase, days
16 Pollen fertility, per cent
17 Pollen size,μ

Positive
Negative

Fig. 5 Genotypic correlation coefficient among the characters



1 Plant height, cm
2 Internode length, cm
3 Number of suckers per plant
4 Leaf size/leaf area,cm^2
5 Number of leaves per plant
6 Days from emergence to maturity of leaves, days
7 Days from emergence to maturity of inflorescence, days
8 Number of spadices per plant per year
9 Candle length, cm
10 Inclination of candle with the spathe,degrees
11 Life of spadix, days
12 Days to initiation of female phase, days
13 Duration of female phase, days
14 Duration of interphase, days
15 Duration of male phase, days
16 Pollen fertility, per cent
17 Pollen size,μ

Positive significant
Positive
Negative
Negative significant

Fig. 6 Environmental correlation coefficient among the characters

Environmental correlations are absent for almost all pairs of characters except for the duration of female phase with pollen fertility and vice-versa which has significant positive correlation, the number of spadices per plant which showed significant negative correlation with days to initiation of female phase and significant positive correlation with number of leaves per plant. Negative significant correlation coefficient was found between plant height and number of suckers per plant. Pollen fertility showed significant negative correlation with inclination of candle with the spathe.

Plant height showed positive genotypic correlation with all the characters except days from emergence to maturity of inflorescence and days to initiation of female phase. So a selection for increased height will result in plants with more number of spadices per year. Duration of female phase showed positive genotypic correlation with all characters except days to initiation of female phase. Plant height and internode length showed positive genotypic correlation with leaf area. This is in agreement with observation of Asish (2002). Life of spadix which is an important commercial character was found to be positively correlated with candle length, leaf area, number of leaves per plant, plant height and duration of female phase. Life of spadix showed positive correlation with duration of female phase. Asish (2002) and Premna (2003) also observed positive correlation of life of spadix with duration of female phase. As in the present study Premna (2003) also found that days to initiation of female phase is positively correlated with most of the characters. Candle length showed very high negative genotypic correlation with days to initiation of female phase. Duration of male phase, pollen fertility and pollen size are highly positively correlated with each other at genotypic level.

5.5 COMPATIBILITY STUDIES

Anthurium is a highly cross-pollinated crop. Hybridization followed by selection is the most common method for improving anthurium. Although hybridization appears to be successful at the beginning in many crosses,

combination may still be incompatible. This is evidenced by yellowing of the candle two to three months after fertilization. So cross-compatibility analysis is done before undertaking genetic improvement programmes.

A total of forty crossings involving ten female parents and four male parents were done. Hybridization and selection was pointed out by Kamemoto and Nakasone (1955), as the accepted method for improving anthuriums.

Both intraspecific as well as interspecific hybridization was used by early anthurium breeders. Birdsey (1956) attributed much of the variation in blistering patterns of spathes of *A. andreanum* to interspecific hybridization. Interspecific cross compatibility, evaluation among 56 species of *Anthurium* by Sheffer and Kamemoto (1976) revealed that hybrids of *A. andreanum* and *A. scherzerianum* were not readily obtainable. But they got hybrids of *A. andreanum* with six other closely related species. Kaneko and Kamemoto (1978) suggested that cultivated anthurium forms were derived from interspecific hybrids which are supposed to have arisen spontaneously in early species collections. A new interspecific hybrid, Southern Blush, was produced by Henny *et al.*(1988) by crossing a large pink-flowered *A. andreanum* cv. with *A. amnicola.* Kuehnle *et al.* (1994) transferred systemic resistance to bacterial pathogens from *A. antioquiense* to cultivated *A. andreanum* and got resistant hybrids.

Hybridization between selected varieties with good cross compatibility was recommended by Mercy and Dale (1994). In 1997 Anthura submitted for registration a variety Champion, derived from *A. andreanum* hybrids. Henny (1999) described a new *Anthurium* hybrid Red Hot which originated from hybridization of *A. amnicola.* Dressler with an unnamed selection of *A. andreanum* (accession code G-79) one of the resulting F_1 hybrids was designated as the female parent and crossed with *Anthurium* into Lady Jane to produce the progeny, from which Red Hot a miniature type was selected.

The three important parameters used for compatibility analysis in the present study were percentage of fruiting candles, percentage of fruit set per

candle and percentage of seed germination. Among the cross combinations attempted the percentage of fruiting candles was 100 per cent for the crosses [FR x MW (1)] x LR, (PR x KR) x LR, (PR x KR) x AW, (PR x MO) x LR, (PR x MO) x AW and (OG x DT) x LR. No fruit bearing candles were produced in 11 cross combination attempted. Among the 10 female parent, percentage of fruiting candles was maximum for PR x KR and OG x DT (100 per cent). [FR x MW (1)] x OG, [PR x FR (1)] x OG, [PR x FR (1)] x LR, (LR x PR) x OG and (LR x PR) x AW also showed good percentage of fruiting candles (above 80 per cent). Hybridization work by Sheffer and Kamemoto (1976) revealed that 81 per cent fruiting spadices was obtained through self polinations, 65.4 per cent intraspecific crosses and 28 per cent through interspecific crosses. Sindhu (1995) observed that in the six anthurium varieties White had the maximum percentage of fruiting candles (93 per cent) and the lowest for Kalympong Red. Renu (2000) reported that selfing and crossing gave 22.50 pr cent and 31.06 per cent success respectively in the ten selected *A. andreanum* varieties studied by her. Among the 10 female parents Premna (2003) observed a 100 percentage of fruiting candle for W x LJ.

In anthurium the fruit is a berry Mercy and Dale (1994) observed that a candle with developing fruits could be visually identified from the second month of fertilization, as it becomes swollen and fleshy with developing fruits embedded on it. The colour of ripe berries varied from creamish yellow to dark red. Individual cross combinations that recorded highest number of fruits per candle were (LR x PR) x OG (113) followed by [FR x MW (1)] x LR (88). The crosses (PR x KR) x AW and (PR x KR) x LR also recorded higher number of fruits per candle. (LR x PR) x AW and (PR x MO) x AW recorded lowest number of fruits per candle. A well-fertilized candle may have up to 100 to 200 fruits per candle according to Mercy and Dale (1994). In the cross compatibility study conducted by Sindhu (1995), the cross Pink x Honeymoon Red had 170 fruits per candle while the self Kalympong Red x Kalympong Red had only two fruits per candle. Renu (2000) obtained PR x LR and PR x CR as the crosses with highest number

of seeds (183 and 162). Premna (2003) obtained the highest number of fruits for the cross (OO x KR) x C (120) followed by (OO x KR) x H (103).

Absence of full fruit set in spadix was identified as a major problem in the development of *Anthurium* cultivars by Zimmer (1986). In the present study also the percentage of fruit set was below 50 per cent for all the successful crosses. The highest fruit set was recorded by the cross (LR x PR) x OG (37.91 per cent) followed by (PR x MO) x AW (29.29 per cent). The lowest was for the cross [PR x FR (1)] x LR (9.76 per cent). The average percentage of fruit set was highest for the genotype LR x PR (28.65 per cent) and lowest for PR x FR (1) (12.31 per cent). In the study using six anthurium varieties, conducted by Sindhu (1995) the cross P x HR (44.30 per cent) and lowest for the cross KR x KR (0.40 per cent). Renu (2000) observed the highest value for fruit set for the cross PR x LR (57.60 per cent). Premna (2003) observed highest fruit set for the cross (OO x KR) x C (34.29 per cent).

In the present study the duration from the day of pollination to the day of berry ripening ranged from 4 months [(PR x MO) x AW] to 8 months [(PR x MO) x OG]. All the other varieties took more than five months to reach fruit maturity. Similar duration of fruit maturity was observed by Sindhu (1995). She has recorded that this duration ranged from 5 to 6.8 months. Duration of fruit maturity in *Anthurium* was recorded as 6 –8 months by Singh (1987), as 5-12 months by Zimmer (1986) and as 4 –7.5 months by Mercy and Dale (1994). Among the 10 varieties studied by Renu (2000) the duration ranged from 4.4 months in Lady Jane Red to 6.1 months in Ceylon Red. Premna (2003) observed highest fruit set for the cross (OO x KR) x C (34.29 per cent). All the reports together with the observations of the present study confirms that the long fruit ripening period in *A. andreanum* is one of the reasons that contribute the slow progress of *Anthurium* breading programmes.

According to Zimmer *et al.* (1986) the berries contained two to three seeds. Mercy and Dale (1994) had reported that *Anthurium* berries contained one

or two seeds. In the present study it was found that all the crosses showed higher percentage of berries bearing single seeds except the cross (LR x PR) xOG. In the compatibility study by Sindhu (1995) also the percentage of single seeded berries were more than double seeded berries. Percentage of single seeded berries ranged from 37 to 100 per cent. In a berry with two seeds one of the seeds was usually smaller than another. In a berry largest seed among the two seeded berries were observed for the crosses (LR x PR) x OG (3.50 x 2.83 mm) followed by (LR x PR) x AW (3.50 x 2.50 mm). Sindhu (1995) also observed that when two seeds were seen in a berry usually one was smaller. Renu (2000) obtained largest seeds in double seeded berries for the crosses PR x LR, PR x DT and MW x LR and among the single seeded crosses, Tropical Red x Merengue White had the largest size. Among single seeded berries maximum seed size was for (LR x PR) x AW (4.17 x 3.90 mm). Premna (2003) reported that in the cross (PR x LR) x T only single seeded berries were present and it had maximum value.

In some ripe berries it was observed in the present study, that the seeds at the time of harvest had the tip of radicle emerging from the seed coat, such seeds germinated immediately. The number of days taken for germination ranged 4 to 9 days. The maximum number of 9 days by the crosses (OG x DT) x LR (6 to 9 days). [PR x FR (1)] x OG and (PR x MO) x OG had taken 5 – 9 days for germination.

Anthurium seeds, according to Singh (1987) took six to eight days for germination. Criley (1989) reported that seeds germinated within 14 days. In the six varieties studied by Sindhu (1995) the number of days for germination ranged from 6 to 14 days while it was 3 to 12 days in a study by Renu (2000). Premna (2003) observed a maximum number of days for germination from four to nine days.

Survival of seedlings at four to six months in the present study showed that 9 out of 12 crosses were carried beyond four months. The seedlings of the cross [PR x FR (1)] x OG, [PR x FR (1)] x LR and (PR x MO) x OG failed to survive. No cross showed 100 per cent survival. The highest rate was shown by

the cross (PR x KR) x AW (94.60 per cent) and lowest by (LR x PR) x OG (48.40 per cent). The highest survival percentage was showed by the female parents OG x DT (90.00 per cent) with only a single cross. So in addition to low levels of fruit set and seed germination the high mortality of seeds in the early stages can be considered as a major constraint in the development of anthurium hybrids. Premna (2003) found that highest survival percentage was for the cross (FR x KR) x A (75.26 per cent) and lowest by (KR x LR) x A (32.25 per cent). In the study by Renu (2000), out of 34 cross combinations that germinated only 31 cross combinations survived for more than four months.

A novel method for easy computation and understanding of compatibility reactions was devised by Renu (2000). A similar type of classification is done in the present study also. Accordingly, the percentage of fruiting candles which ranged from 0 to 100 per cent were divided into four compatibility classes as

High	(100-76 per cent)	- A
Medium	(75-26 per cent)	- B
Low	(25-1 per cent)	- C
Nil	(0 per cent)	- D

The percentage of fruit set in the present study ranged from 9.76 per cent to 29.29 per cent and these values were classified into four classes as

High	(above 30 per cent)	- A
Medium	(20-29 per cent)	- B
Low	(1-19 per cent)	- C
Nil	(0 per cent)	- D

The percentage of seed germination, which ranged from 56.67 to 85.13 per cent, was classified as

High	(above 80 per cent)	- A
Medium	(50-79 per cent)	- B
Low	(1-49 per cent)	- C
Nil	(0 per cent)	- D

Table 18. Compatibility score on the basis of performance of 10 genotypes of *A. andreanum* as female parents based on fruiting candles, fruit set and seed germination.

Sl. No.	Crosses	Fruiting candles (per cent)	Fruit set (per cent)	Seed germination (per cent)	Total score	Varietal score
1	[LR x DT] x OG	D	D	D	0	
2	[LR x DT] x LR	D	D	D	0	
3	[LR x DT] x AW	D	D	D	0	
4	[LR x DT] x TR	D	D	D	0	0
5	[FR x MW(1)] x OG	A	C	B	6	
6	[FR x MW(1)] x LR	A	C	A	7	
7	[FR x MW(1)] x AW	D	D	D	0	
8	[FR x MW(1)] x TR	D	D	D	0	13
9	[MO x KR(1)] x OG	D	D	D	0	
10	[MO x KR(1)] x LR	D	D	D	0	
11	[MO x KR(1)] x AW	D	D	D	0	
12	[MO x KR(1)] x TR	D	D	D	0	0
13	[KO x CR] x OG	D	D	D	0	
14	[KO x CR] x LR	D	D	D	0	
15	[KO x CR] x AW	D	D	D	0	
16	[KO x CR] x TR	D	D	D	0	0
17	[PR x FR(1)] x OG	A	C	A	7	
18	[PR x FR(1)] x LR	B	C	A	6	
19	[PR x FR(1)]x AW	D	D	D	0	
20	[PR x FR(1)]x TR	D	D	D	0	13
21	[NO x DT] x OG	D	D	D	0	
22	[NO x DT] x LR	D	D	D	0	
23	[NO x DT] x AW	D	D	D	0	
24	[NO x DT] x TR	D	D	D	0	0
25	[PR x KR] x OG	D	D	D	0	
26	[PR x KR] x LR	A	C	B	6	
27	[PR x KR] x AW	A	B	A	8	
28	[PR x KR] x TR	D	D	D	0	14
29	[LR x PR] x OG	A	B	A	8	
30	[LR x PR] x LR	D	D	D	0	
31	[LR x PR] x AW	A	C	B	6	
32	[LR x PR] x TR	D	D	D	0	14
33	[PR x MO] x OG	B	B	A	7	
34	[PR x MO] x LR	A	B	A	8	
35	[PR x MO] x AW	A	B	A	8	
36	[PR x MO] x TR	D	D	D	0	23
37	[OG x DT] x OG	D	D	D	0	
38	[OG x DT] x LR	A	C	A	7	
39	[OG x DT] x AW	D	D	D	0	
40	[OG x DT] x TR	D	D	D	0	7

A = 3 points B = 2 points C = 1 point and D = 0 point

Table 19. Compatibility score on the basis of the performance of 4 varieties of *A. andreanum* as male parents based on fruiting candles, fruit set and seed germination.

Sl No.	Fruiting candles(per cent)	Fruit set (per cent)	Seed germination (per cent)	Seed germination (per cent)	Total score	Varietal score
1	[LR x DT] x OG	D	D	D	0	
2	[FR x MW(1)] x OG	A	C	B	6	
3	[MO x KR(1)] x OG	D	D	D	0	
4	[KO x CR] x OG	D	D	D	0	
5	[PR x FR(1)] x OG	A	C	A	7	
6	[NO x DT] x OG	D	D	D	0	
7	[PR x KR] x OG	D	D	D	0	
8	[LR x PR] x OG	A	B	A	8	
9	[PR x MO] x OG	B	B	A	7	
10	[OG x DT] x OG	D	D	A	0	28
11	[LR x DT] x LR	D	D	D	0	
12	[FR x MW(1)] x LR	A	C	A	7	
13	[MO x KR(1)] x LR	D	D	D	0	
14	[KO x CR] x LR	D	D	D	0	
15	[PR x FR(1)] x LR	B	C	A	6	
16	[NO x DT] x LR	D	D	D	0	
17	[PR x KR] x LR	A	C	B	6	
18	[LR x PR] x LR	D	D	D	0	
19	[PR x MO] x LR	A	B	A	8	
20	[OG x DT] x LR	A	C	A	7	34
21	[LR x DT] x AW	D	D	D	0	
22	[FR x MW(1)] x AW	D	D	D	0	
23	[MO x KR(1)] x AW	D	D	D	0	
24	[KO x CR] x AW	D	D	D	0	
25	[PR x FR(1)] x AW	D	D	D	0	
26	[NO x DT] x AW	D	D	D	0	
27	[PR x KR] x AW	A	B	A	8	
28	[LR x PR] x AW	A	C	B	6	
29	[PR x MO] x AW	A	B	A	8	
30	[OG x DT] x AW	D	D	D	0	22
31	[LR x DT] x TR	D	D	D	0	
32	[FR x MW(1)] x TR	D	D	D	0	
33	[MO x KR(1)] x TR	D	D	D	0	
34	[KO x CR] x TR	D	D	D	0	
35	[PR x FR(1)] x TR	D	D	D	0	
36	[NO x DT] x TR	D	D	D	0	
37	[PR x KR] x TR	D	D	D	0	
38	[LR x PR] x TR	D	D	D	0	
39	[PR x MO] x TR	D	D	D	0	
40	[OG x DT] x TR	D	D	D	0	0

A=3 points B= 2 points C= 1 points and D= 0 points

The crosses of the ten female parents were linearly scored on the basis of percentage of fruiting candles, fruit set and seed germination as shown in the Table 18 and 19. From the Table it was found that the female parent PR x MO got the highest varietal score. So PR x MO could be judged as the best female parent. Among male parent the variety Liver Red got the highest varietal score and hence can be selected as the best male parent. The highest score for an individual cross was obtained for the crosses (PR x KR) x AW, (LR x PR) x OG, (PR x MO) x LR and (PR x MO) x AW. So these were the most compatible crosses. The female parents LR x DT, MO x KR (1), KO x CR, NO x DT and male parent Tropical Red showed poor performance during the course of study. All those crosses which were carried beyond four months stage showed a linear score of five or more than five.

Summary

6. SUMMARY

The present study, 'Genetic improvement of F_1 hybrids in *Anthurium andreanum* Linden' was undertaken to improve specific commercial characters such as erect, long inflorescence axis, deep blisters of spathe and short downward candles of ten selected F_1 hybrids in anthurium. The study revealed tremendous scope for genetic improvement in this crop. The results of the analysis were summarised below.

- Analysis of variance revealed significant variation among the seventeen quantitative characters studied viz., plant height, suckering ability, leaf area, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, candle length, inclination of candle with the spathe, life of spadix, days to initiation of female phase, duration of female phase, duration of interphase, duration of male phase, pollen fertility and pollen size.

- Pollen fertility estimated using acetocarmine method indicated that most of the genotypes had low fertility values. 'PR x FR (1)' had the highest pollen fertility of 41.67 per cent followed by 'Liver Red' (40.67 per cent). Pollen emergence was low in the months from March to June, during which the average maximum and minimum temperatures were relatively high. Pollen emergence was highest during October to December months.

- Variability studies revealed that high PCV (Phenotypic coefficient of variation) along with high GCV (Genotypic coefficient of variation) were present for number of suckers per plant, pollen fertility and duration of male phase. This suggests that there is an excellent scope for improvement of these characters through selection. The characters, pollen size, life of spadix, plant height and pollen fertility showed low difference between PCV and GCV revealing that the environmental influence on these characters is less. The character number of suckers per plant pollen

of fruit set was below 50 per cent for all the crosses. The lowest and highest percentage of fruit set was observed for 'PR x FR (1)' and 'LR x PR' respectively.

- The berries obtained from different cross combinations took 4 to 8 months to mature. The shortest period for fruit maturation was observed for the cross ('PR x MO') x AW. The number of days for germination varied from 4 to 9 days in various crosses. The range of 4 to 8 was observed in two crosses ['FR x MW (1)'] x LR and ['PR x FR (1)'] x LR.

- Most of the crosses had a high percentage of single seeded berries compared to double seeded berries except for the cross between 'LR x PR' and 'Orange Glory'. The seeds obtained from most of the crosses showed a germination percentage of more than 50 per cent. It was lowest in 'OG x DT' (63.86 per cent) and highest in 'PR x FR (1)' (80.86 per cent).

- Seedlings of 9 out of 12 crosses that germinated survived for more than four months. The highest average survival was recorded by 'OG x DT' (with only one cross) and lowest was recorded for the genotype 'PR x MO'.

- After scoring the different genotypes and crosses obtained on a scale from zero to nine, the crosses with highest compatibility score of eight were for the crosses ('PR x KR') x AW, ('LR x PR') x OG, ('PR x MO') x LR and ('PR x MO') x AW. The performance of the variety as female parent was found to be different from its performance as male parent. Among the ten female parents 'PR x MO', 'LR x PR' and 'PR x KR' performed as the best female parents and among the four male parents 'Liver Red' performed as the best pollen parent.

fertility and pollen size showed high heritability coupled with high genetic advance. So these characters are controlled by additive gene action and therefore amenable to genetic improvement through selection.

- Correlation studies revealed that plant height showed significant positive phenotypic correlation with number of suckers per plant, leaf size, internode length, number of spadices per plant and pollen fertility and showed negative significant correlation with days to initiation of female phsae. Plant height also showed positive genotypic correlation with most of the characters. Duration of female phase showed positive genotypic correlation with all characters except for days to initiation of female phase. The environmental correlations were absent for almost all pairs of characters except between a few characters. The genotypic correlation between characters helps to differentiate the vital association useful in breeding from non-vital ones.

- A study of five qualitative characters such as colour of young leaf and petiole spathe colour, spathe texture, candle colour and type of inflorescence axis also showed considerable variation among the genotypes studied.

- Intervarietal hybridization was done to analyse the cross compatibility between 14 varieties (Ten female parents and four commercially important varieties as male parents) based on the percentage of candles bearing fruits, fruit set and seed germination.

- A total of 23 crossings were attempted based on the availability of receptive spadices and fresh pollen, out of which 12 were found to be successful. Among the 12 successful crosses percentage of candles bearing fruits was 100 per cent for six crosses. Maximum number of 113 fruits was obtained for the cross ('LR x PR') x OG followed by ['FR x MW (1)'] x LR with 88 fruits. The average number of fruits per candles was highest for 'LR x PR' and lowest for 'PR x FR (1)'. The percentage

of fruit set was below 50 per cent for all the crosses. The lowest and highest percentage of fruit set was observed for 'PR x FR (1)' and 'LR x PR' respectively.

- The berries obtained from different cross combinations took 4 to 8 months to mature. The shortest period for fruit maturation was observed for the cross ('PR x MO') x AW. The number of days for germination varied from 4 to 9 days in various crosses. The range of 4 to 8 was observed in two crosses ['FR x MW (1)'] x LR and ['PR x FR (1)'] x LR.

- Most of the crosses had a high percentage of single seeded berries compared to double seeded berries except for the cross between 'LR x PR' and 'Orange Glory'. The seeds obtained from most of the crosses showed a germination percentage of more than 50 per cent. It was lowest in 'OG x DT' (63.86 per cent) and highest in 'PR x FR (1)' (80.86 per cent).

- Seedlings of 9 out of 12 crosses that germinated survived for more than four months. The highest average survival was recorded by 'OG x DT' (with only one cross) and lowest was recorded for the genotype 'PR x MO'.

- After scoring the different genotypes and crosses obtained on a scale from zero to nine, the crosses with highest compatibility score of eight were for the crosses ('PR x KR') x AW, ('LR x PR') x OG, ('PR x MO') x LR and ('PR x MO') x AW. The performance of the variety as female parent was found to be different from its performance as male parent. Among the ten female parents 'PR x MO', 'LR x PR' and 'PR x KR' performed as the best female parents and among the four male parents 'Liver Red' performed as the best pollen parent.

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GENETIC IMPROVEMENT OF F_1 HYBRIDS IN *Anthurium andreanum* Linden

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ABSTRACT

The present study, 'Genetic improvement of F_1 hybrids in *Anthurium andreanum* Linden' was undertaken to improve specific commercial characters such as erect, long inflorescence axis, deep blisters of spathe and short downward candles of ten selected F_1 hybrids in anthurium.

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

Variability studies indicated high phenotypic and genotypic coefficients of variation for the characters number of suckers per plant, pollen fertility and duration of male phase. The characters with high heritability coupled with high genetic advance values were found for characters number of suckers per plant, pollen fertility and pollen size. These characters are therefore controlled by additive gene action and amenable to genetic improvement through selection.

Plant height was found to have highly significant positive phenotypic correlation with number of suckers per plant, leaf size, internode length, number of spadices per plant and pollen fertility. Duration of female phase showed positive genotypic correlation with all characters except days to initiation of female phase. The environmental correlations were absent for almost all pairs of characters except for a few characters .

Pollen fertility estimated using acetocarmine method indicated that most of the genotypes had low fertility values. 'PR x FR (1)' had the highest pollen fertility of 41.67 per cent followed by 'Liver Red' (40.67 per cent). Pollen emergence was low in the months from March to June, during which the average

maximum and minimum temperatures were relatively high. Pollen emergence was highest during October to December months.

A study of five qualitative characters such as colour of young leaf and petiole spathe colour, spathe texture, candle colour and type of inflorescence axis also showed considerable variation among the genotypes studied. Intervarietal hybridization was done to analyse the cross compatibility between 14 varieties (Ten female parents and four commercially important varieties as male parents) based on the percentage of candles bearing fruits, fruit set and seed germination.

A total of 23 crosses were attempted based on the availability of receptive spadices and fresh pollen, out of which 12 were found to be successful. Among the 12 successful crosses percentage of candles bearing fruits was 100 per cent for six crosses. Maximum number of 113 fruits was obtained for the cross ('LR x PR') x OG followed by ['FR x MW (1)'] x LR with 88 fruits. The average number of fruits per candles was highest for 'LR x PR' and lowest for 'PR x FR (1)'. The percentage of fruit set was below 50 per cent for all the crosses. The lowest and highest percentage of fruit set was observed for 'PR x FR (1)' and 'LR x PR' respectively.

From the cross compatibility analysis, it was seen that the percentage of fruit bearing candles was highest for the female parents 'PR x KR' and 'PR x MO' with two crosses each and 'OG x DT' with a single cross (100 per cent). The number of fruit per candle ranged from 23 to 113. 'LR x PR' had the highest average number of fruits per candle and it was lowest for 'PR x FR (1)'. The percentage of fruit set was below 50 per cent for all the crosses. The crosses involving 'LR x PR' had the highest average percentage of fruit set.

The number of days taken for germination varied from four to nine days. The seed germination was highest for the cross ('PR x FR(1)') x LR (85.13 per cent). No cross showed 100 per cent survival beyond four to six months. For 'OG x DT' with only a single cross the survival percentage was maximum of 90 per cent. Scoring of the compatibility reactions based on the percentage of

fruiting candles, fruit set and seed germination on a scale ranging from zero to nine showed the highest compatibility score of eight for the crosses ('PR x KR') x AW, ('LR x PR') x OG, ('PR x MO') x LR and ('PR x MO') x AW. Among the ten female parents 'PR x MO', 'LR x PR' and 'PR x KR' performed as the best female parents and among the four male parents 'Liver Red' performed as the best pollen parent.