COMPATIBILITY STUDIES OF THREE WAY CROSSES IN *Anthurium andreanum* Linden

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DECLARATION

I hereby declare that this thesis entitled **"Compatibility Studies of Three way Crosses 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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LIST OF ABBREVIATIONS

%	per cent
^{0} C	Degree Celcius
ANACOVA	Analysis of covariance
ANOVA	Analysis of variance
CD	Critical difference
cm	Centimeters (s)
CR	Ceylon Red
cv.	cultivar
df	degrees of freedom
ECV	Environmental coefficient of variation
et al.	and others
Fig.	Figure
FK	Fla King
g	Gram(s)
GCV	Genotypic coefficient of variation
HR	Honeymoon Red
i.e.	That is
KO	Kalympong Orange
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
viz.	Namely

INTRODUCTION

1. INTRODUCTION

Flowers are considered to be the most beautiful, magnificent and delicate creation of God. Flower arrangements in the drawing rooms, offices, hotels and hospitals have become the style of the day.

Anthurium is a tropical plant grown for its colourful long lasting flowers and handsome foliage. Anthuriums belong to the monocot family Araceae and are native of tropical zones of the Central and South America. This family is the most morphologically diverse and taxonomically complex one (Croat, 1980)

Anthurium, the national flower of Mauritius, owes its name to the Greek word *Anthos* meaning flower and *Aura* meaning tail referring to its spadix or candle. Out of over 500 species reported so far, only 10 or 15 are in trade. The most important commercial species for flower production are *Anthurium andreanum* Linden ('oilcloth flower', 'tail flower', 'palette flower') and *A. scherzerianum* ('flamingo flower'), both of which have magnificent flowers and attractive foliage.

The popular anthurium 'flower' is a compound inflorescence called spadix. The 'flower' consists of a colourful, shiny, heart shaped modified leaf (spathe) surrounding a straight or slightly curved inflorescence 'candle' (spadix). The spadix and spathe are borne on a leafless stem or peduncle. The inflorescence is produced all round the year from the axil of a leaf.

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

Anthurium andreanum is a native of South West Columbia, which was brought to Europe in 1876 (Singh, 1987). It was a flourishing business in the developed countries. But because of the rapid industrialization they found no time to think of flowers. Thus slowly the cultivation spread to developing countries. Anthurium ranks 11 among the

cut flowers. Now the total area of anthurium cultivation in the world is estimated to be just over 500 hectares. Hawaii, Holland, Mauritius, Taiwan and Philippines are the major production areas. In India, cultivation is restricted to southern parts especially Kerala, Karnataka and Tamil Nadu.

A. andreanum, the mainly cultivated anthurium, is an outbreeding species with protogynous nature. Protogyny is a mechanism to prevent self pollination, as the stigmatic surface becomes receptive seven to ten days prior to pollen shed (Singh, 1992). Cross pollination among selected plants is preferred in commercial seed production. The time required from pollination to the maturity of the fruit is about 4 to 7.5 months.

The karyotype analysis and meiotic studies by Lalithambika (1978) and Satyadas (1985) revealed that there is an abundance of genetic variability present in some species of *Anthurium*. The genetic variability present in *A. andreanum* provides great scope for crop improvement through controlled hybridization and selection.

Hybridisation and selection is the most common and proven method of anthurium breeding (Sheffer and Kamemoto, 1976,1977 and Henny *et al.*, 1988). Hybridisation between selected varieties with good combining ability can be used for evolving valuable anthurium hybrids with desirable plant characters such as compact plant type, medium sized leaves, heart shaped spathe with symmetrical lobes, wrinkled spathe texture, straight long inflorescence axis and a reclining spadix to facilitate packing (Mayadevi, 2001).

Though the world trade of anthurium is increasing, its cultivation in India is still in infancy. Some serious constraints confronting the enthusiastic prospective growers are the lack of suitably adapted good quality planting materials in sufficiently large numbers at reasonable rates for commercial cultivation and the absence of a stable and steady market.

The present study is undertaken with the aim of assessing the genetic variability and compatibility of 14 genotypes of *Anthurium andreanum*.

The female parents selected for compatibility studies were those having less desirable characters like thin flower stalk, long upright candle etc. while the selected male parents were having desirable characters. 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 andreanum is one of the most important cut flower crops of the world. The cultivation of this crop has recently been identified as a thrust area of Indian agriculture. The warm humid tropical climate of Kerala is very well suited for the cultivation of anthurium.

Anthurium is a highly cross pollinated crop and displays high amount of variability. Hybridisation followed by selection is the best and proven method to achieve crop improvement in anthurium. The crop is highly heterozygous with great potential which is yet to be exploited.

In the present study, an attempt is made to assess the compatibility between some selected hybrids with four commercially accepted Holland varieties through a hybridization programme. A review of the works relevant to the study is presented here.

2.1 MORPHOLOGICAL STUDIES

A study of the morphological characteristics of parent varieties helps in understanding the variability that exist among them. It also helps in the identification and classification of varieties.

2.1.1 Plant Height

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

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

Renu (2000) recorded plant height ranging from 29.7 cm in var. Midori Green to 70.9 cm in var. Pompon Red. The varieties Liver Red and Mauritius Orange also had heights on par with var. Pompon Red.

Mayadevi (2001) recorded the height of twenty varieties of *A. andreanum* which ranged from 42.5 cm in var. Midori green to 96.67 cm in var. White. The height of the genotypes varied from 22.17 cm to 64.80 cm in the study conducted by Asish (2002).

2.1.2 Internode Length

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

According to Mercy and Dale (1994) 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.

In the work done by Mayadevi (2001) 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 (HR x P).

Asish (2002) recorded that internode length ranged from 0.97 cm in MW x PR to 2.57 in MW x FR (1).

2.1.3 Suckering Ability

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

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

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

valuable type. Foliar spraying with gibberellic acid (GA_3) (500 ppm) or Benzyl adenine (BA) (500-1000 ppm) was found to increase sucker production. Sindhu (1995) observed maximum number of suckers in the var..Pink and the least in the var. Kalympong Red.

Salvi (1997) inferred that a treatment combination of 80 per cent shade and 750 ppm BA was the best for maximising sucker production. Abdussammed (1999) reported that nutrients failed to make any significant influence on the number of suckers produced per plant but application of growth regulators had remarkable effect. GA_3 1000 ppm or a combination of BA and GA_3 at 250 ppm each was the best.

Among the ten varieties of anthurium studied by Renu (2000) sucker production was high for varieties Liver Red, Lady Jane and Ceylon 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) 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 while studying twenty varieties of anthurium.

Among the fifty genotypes studied by Asish (2002) the number of suckers ranged from 1.00 in MW x DT, MW x FR (2) and DT x KR to 3.00 in LR x FR, HR x LW and LJ x MW.

2.1.4 Leaf Size or Leaf Area

For an ideal commercial anthurium plant. medium sized leaf is considered best since such plants are more compact and occupy less green house space than those with large spread leaves.

Kamemoto and Sheffer (1978) made crosses between *A. scherzerianum* and *A. wendlingerii* and produced a hybrid and observed the leaf size of parents and hybrids for comparison and found that the length and

position of the leaf blade were intermediate between the highly contrasting characters of the parental species.

Bindu (1992) observed that the length of leaves ranged from 13.5 to 26.0 cm and width ranged from 8.7 to 23 cm. Leaf size was maximum for Pink and minimum for Lady Jane and Chilli Red.

Leaves of commercially valuable floral anthuriums should be small to medium sized, narrow and elongated according to Mercy and Dale (1994).

Sindhu (1995) observed that the variety Pink produced bigger leaves whereas White and Chilli Red produced small sized leaves which were commercially more valuable than Pink.

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

Mayadevi (2001) inferred that the var. Chilli Red had the least leaf area (66.26 cm^2) followed by var. Kalympong Red (66.92 cm^2). Honeymoon Red had the longest leaf area of 88.89 cm2 which is not ideal.

Leaf area ranging from 41.32 to 323.77 cm^2 was reported by Asish (2002) in his study of fifty genotypes.

2.1.5 Number of Leaves or Spadices per Plant

A. andreanum had a long juvenile phase of vegetative growth followed by a generative phase in which flower buds were produced as observed by Christensen (1971) while conducting morphological studies.

The productivity and inflorescence quality of 120 individual anthurium plants were compared by Steen and Vigverberg (1973) and found that their productivity was highly variable ranging from four to

sixteen flowers over two years. Leffering (1975) observed that in plants that received 45 per cent of available light, productivity increased from five to twelve flowers per plant per year.

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

There is a close correlation between number of leaves and number of flowers according to Gajek and Schwarz (1980). Singh (1987) reported that the most commonly cultivated varieties produced flowers all round the year at the rate of one flower from each leaf axil. The sequence of leaf, flower and new leaf was maintained throughout the life of the plant.

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

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

In the study done by Renu (2000), it was observed that one spadix was produced from the axil of each leaf so that the number of leaves and number of spadices produced annually per plant was the same. The annual production of leaves or spadices was the highest in Lady Jane Red (7.60) followed by Liver Red and Pompon Red.

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

2.1.6 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.

Among the 50 genotypes studied by Asish (2002), the average days for the emergence of leaves to its maturity was observed as 27.56 with a range of 15.33 days in OG x LR to 41.00 days in DT x FR.

2.1.7 Days from Emergence to Maturity of Inflorescence

The days from emergence to maturity of inflorescence ranged from 44.6 days in Chilli Red to 50.6 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 as observed by Mayadevi (2001). In his study, Asish (2002) observed that this character ranged from 16.67 days in NO x LR (1) to 37.67 days in MO x KR (1).

2.1.8 Candle Length

The spadix of the inflorescence is called as candle and it bears the true flowers. The flowers are very small, embedded in the candle in slanting rows in an acropetal succession. The larger the candle, the more the number of flowers. Commercially, slender and short candles are preferred to long thick candles.

The candle length of five varieties of *A. andreanum* ranged from 4 to 9.5 cm according to Bindu (1992). In ordinary varieties of 'Pink' 'Red' and 'White' the candle was long and fleshy, but in highly bred hybrids and exotics, the candle was shorter and more slender (Mercy and Dale, 1994). The candle length of six varieties studied by Sindhu (1995) ranged from 6.6 cm to 12.1 cm.

The commercial varieties like Tropical Red, Nitta Orange, Mauritius Orange, Lady Jane Red, Pompon Red, Midori Green produced smaller candles as observed by Renu (2000). In the study by Mayadevi (2001), longest candle was recorded for Pink (12.72 cm) and shortest in

Liver Red (7.18 cm) among the parents. In the hybrids it ranged from 5.0 cm (P x LR) to 10.38 (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 maximum candle length of 9.17 cm.

2.1.9 Inclination of Candle

Anthuriums with downward curving candles are more preferred commercially as this helps in packing a large number of inflorescence in a box during transportation.

Mercy and Dale (1994) observed that flower bearing candle in a good commercial variety was attached to the base of spathe held at an angle slanting or curving at 25° to 40°. According to them, ideal anthurium spadix with a high market value must have shorter slender candle curving towards the tip of the spathe at an angle less than 45°.

Sindhu (1995) observed ideal anthurium spadix with an angle less than 45° in varieties Chilli Red, Kalympong Orange and Kalympong Red. In Honeymoon Red, the angle was 75°, which is not desirable. Renu (2000) reported 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 five parents and 10 F_1 hybrids observed that the inclination of candle ranged from 21.0° in Kalympong Red to 78.2° in Honeymoon Red among the parents. The hybrids also showed a range from 20.8° (HR x CR) to 89.6° (HR x P). Asish (2002) observed that inclination of candle ranged from 10.67° in PR x MO to 89.33° in MO x KR (1).

2.1.10 Life of Spadix

The visible changes accompanying the senescence of anthurium flowers as reported by Paull (1982) are spathe-gloss loss, necrosis of

spadix and greening of spathe and spadix. These changes were non-reversible processes leading to the death of spadix.

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

Sindhu (1995) reported that the life of unfertilized spadix ranged from 1.5 months in Kalympong Orange to 3.5 months in Honeymoon Red. For fertilized spadices, the period ranged from 4.5 to 8 months.

According to Salvi (1997) among different growth regulators, BA 1500 ppm gave maximum longevity to spadix i.e., 152.81 days in the variety Hawaiian Red. Abdussammed (1999) noticed that combined application of BA + GA_3, 250 ppm recorded the highest longevity of spadix.

Among the 10 varieties studied by Renu (2000) the time span from emergence of a spathe to its senescence varied from 2.5 months in Nitta Orange to 3.7 months in Ceylon Red, in the case of unfertilized spadices. For fertilized spadices, the life span was found to be higher, ranging from about 3.8 to 7.5 months.

Mayadevi (2001) recorded that the longevity of spadix ranged from 98.00 days in Chilli Red to 12.40 days in Honeymoon Red in case of unfertilized spadices. Asish (2002) recorded that the average days taken for opening of inflorescence to its death was 77.08.

2.1.11 Days to Initiation of Female Phase

According to Croat (1980) maturation of flowers in *Anthurium* species was initiated generally from the basal portion of the spadix (candle) and the development proceeds acropetally. However *A. andreanum* was not included among the protogynous species of anthurium listed by him.

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.

2.1.13 Duration of Interphase

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

Sindhu (1995) reported that the interphase in *A. andreanum* ranged from four to 10 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.

According to Mayadevi (2001) the duration of interphase ranged from 7.80 days in Chilli Red to 11.20 days in Pink. The interphase period of 9.39 (HR x CR) to 12.60 (P x CR) was recorded by hybrids. In the study by Asish (2002) interphase ranged from two (PR x KR) to 11.67 days [MO x KR (2)].

2.1.14 Duration of Male Phase

Mercy and Dale (1994) observed that all the anthers in a candle emerged in about four to eight days. Male phase may be suppressed for long or short periods and the anther emergence is comparatively less during the months from March to July.

Sindhu (1995) reported that the male phase may range from three to eight days depending on the variety.

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 five in Chilli Red to 7.20 days in 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 four days MW x DT.

2.1.15 Pollen Fertility

Stanley and Linsken (1974) from their study inferred that appearance of the pollen alone, even at collection time is not always a good index of viability. So pollen fertility is tested either by using specific stains or by in vitro growth studies for correct assessment of pollen fertility and viability.

Lalithambika (1978) reported 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.*

Renu (2000) in her study found that pollen fertility ranged from 42 per cent (Liver Red) to 13.7 per cent (Lady Jane Red).

Mayadevi (2001) noticed high pollen fertility for Liver Red (45.90 %) followed by Pink (28.40 %). Among the 50 genotypes studied by Asish (2002), pollen fertility was found to be 24.24 per cent on an average.

2.1.16 Pollen Size

While studying the pollen grains of five varieties Bindu (1992) 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 germpore.

2.1.17 Colour of Petiole and Young Leaf

The colour of young tender leaves of anthurium 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. The petiole colour ranged from green, greenish purple and purple. The young 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).

2.1.18 Spathe Colour

The value of the flower depends to a large extent on the spathe colour. It varies from pure white to deep maroon among the popular commercial varieties of anthurium. Pastel shades such as white, light pink, coral, light orange etc. are preferred in countries like China, Japan and Korea, while darker shades are preferred in Middle East, USA, Singapore and Malaysia.

The presence of 3-cyanidin glycoside and 1-pelargonidin glycoside in the spathes of *A. andreanum* was identified by Forsyth and Simmonds (1954), while the major spathe colours reported by them were red, orange, pink, green and white. Birdsey (1956) described the spathe of native *A. andreanum* from Columbia as orange, scarlet or vermilion whereas the commercial varieties showed a complete colour range from white to dark red. According to Lowry (1972) spathes of all 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 cultivars 'Marian Seefurth'. The orange and coral coloured

spathes contained only pelargonidin 3-rhamnosyl glucoside. In white varieties both the pigments were absent.

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 colours whereas a predominance of pelargonidin 3-rhamnosyl glucoside resulted in coral to orange.

After detailed analysis on the genetics of spathe colour in Anthuriums, Kamemoto *et al.* (1988) concluded that two major genes, M and O were responsible for the five major colours: red, orange, pink, coral and white. The dosages of M and O genes affect colours. The gene M was found to control the production of cyanidin 3–rutinoside while the gene O controlled pelargonidin 3-rutinoside. Red and pink resulted when both M and O genes 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 were 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 introductions in Hawaii according to the Royal Horticultural Society colour chart.

While studying inheritance of purple spathe in anthurium, Wannakrairoj and Kamemoto (1990) proposed that 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 the colour of spathe fades gradually as flower gets older. Sindhu (1995) observed that the dark and brightly coloured flowers, which are commercially important, were produced by the varieties Chilli Red and Kalympong Red.

As per the studies conducted by Abdussammed (1999), the anthocyanin contents 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 nutrients were 85.07 mg g^{-1} and 93.9 mg g^{-1} respectively, while for growth regulators the values were 67.88 mg g^{-1} and 84.18 mg g^{-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.

According to Nirmala *et al.* (1999), 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 four groups (red, orange, coral and white) based on the presence of cyanidin and pelargonidin along with an unknown pigment. Renu (2000) grouped the spathe colour of ten varieties into deep maroon to dark red, red, light orange to dark orange, light green and white.

Anthocyanins contribute various colours to spathe from deep maroon to light pink as reported by Mayadevi (2001). Red coloured varieties showed variation from dark red (CR and KR) to red (HR). The mean total anthocyanin content ranged from 121.38 mg g^{-1} in 'Pink' to 386.56 mg g^{-1} in Liver Red in the parents while the range of this character was from 146.03 mg g^{-1} (HR x LR) to 330.95 mg g^{-1} (KR x CR) in the hybrids. Based on the anthocyanin contents, the probable

spathe colour genotypes of five parents and their hybrids have been worked out for the first time in anthurium by correlating the total average anthocyanin content of the spathe of each variety to the incremental effect of the two anthocyanin producing genes, M and O.

2.1.19 Spathe Texture

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

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

Arndt (1991) reported that the spathe of *A. scherzerianum* variety 'Arabella' as broad with free lobes and a shallow sinus.

Mercy and Dale (1994) suggested that the spathe in floral anthurium may be smooth, thick and glossy without prominent veins or it may be thinner deeply veined and blistered.

In the study conducted by Sindhu (1995) she observed that the variety Honeymoon Red had smooth, thick and glossy spathes without prominent veins while Pink and White had smooth, thin and lightly veined spathes. Intermediate spathe texture and deep to shallow blisters were observed in varieties like 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 five 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 obtained for

HR x P, HR x LR, P x CR and KR x CR. Medium thick blistered and glossy spathes for HR x CR and P X LR. P x KR and LR x CR showed thick medium blistered glossy spathes.

2.1.20 Candle Colour

In the different varieties of anthurium, candle takes varied colours and shades enhancing the beauty of the flower. Some anthuriums have single coloured candles while others have double coloured ones.

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

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

The six varieties studied by Sindhu (1995) 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.

The candle had a single colour of pink, light pink, yellow, light yellow, green and light green as observed by Renu (2000) in her study with ten varieties. Mayadevi (2001) while studying the divergence of hundred genotypes of anthurium observed candle colours of red, light red, pink, light pink, yellow, yellowish white, white and cream.

In the study done by Asish (2002) the candle colour varied from red to light red, reddish pink, pink, light pink, pinkish yellow, pinkish white, yellow, yellowish white and cream.

2.1.21 Type of Inflorescence Axis

The value of anthurium flowers depend on their inflorescence axis as its nature affects the appearance of the cut flower.

Mercy and Dale (1994) opined that good anthurium hybrids should have short and straight inflorescence axis. Among the five parents and 10 F_1s studied by Mayadevi (2001) the nature of the inflorescence axis varied from long, straight and very strong in all the parents and hybrids except for the parent variety KR in which it is long, thin and slightly curving.

In the study by Asish (2002), he observed long, straight and strong inflorescence axis in the genotypes Nitta Orange x Tropical Red, Merengue White x Pompon Red, Tropical Red x Merengue White, Pompon Red x Merengue White and Pompon Red x Liver Red (3).

2.2 COMPATIBILITY STUDIES

Hybridization and selection were the most common methods for improving anthuriums as suggested by Kamemoto and Nakasone (1955). They identified that character to be selected were flower productivity, spathe colour, shape and texture, short internodes and suckering ability.

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

Kamemoto and Nakasone (1963) evaluated 113 clones and selected 13 for commercial cut flower production. Two cultivars, Uniwai and Marian Seefurth were evolved by clonal selection. They also postulated that inheritance of spathe colour was under the control of multiple alleles and modifying genes.

Among the 56 species of Anthurium evaluated by Sheffer and Kamemoto (1976), 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.

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

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

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

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

Henny *et al* (1988) obtained Southern Blush, a hybrid for foliage produced through interspecific hybridization of a large pink flowered *A. andreanum* with *A. amnicola* (a dwarf species collected from Costa Rica which is very floriferous but bears small lavender spathe, more than 2 cm long). Southern Blush was intermediate in size between it parents,

spathes were about 7.0 cm long and 5.0 cm wide and were medium pink with a slight lavender tint.

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, short and straight inflorescence axis and short, thin and downward curving candles.

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

Henny (1999) reported 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. Red Hot originated from hybridization of *A. amnicola*, a dwarf species with small lavender spathes and naturally clumping growth habit, with an unnamed selection of A. *andreanum* (accession code G-79) that had pink spathes. One of the F_1 hybrids that resulted was designated as the female parent and crossed with anthurium variety, Lady Jane to produce the progeny from which 'Red Hot' was selected.

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 (51.93) 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 crosses involving Pompon Red as female parent had the highest percentage of fruit set. Seed germination

was highest (87.5%) for the cross Dragon's Tongue Red x Merengue White. Scoring of the compatibility reactions based on fruiting candles, fruit set and seed germination, on a scale ranging from 0 to 9 showed the highest compatibility score for Pompon Red x Liver Red and Ceylon Red x Merengue White crosses. The best female parents were found to be Nitta Orange, Liver Red and Pompon Red. 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.

2.2.1 Percentage of Candles Bearing Fruits

Sheffer and Kamemoto (1976) did 1592 pollinations which included 20 selfs, 19 intraspecifc 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 like the number of ovules per locule, colour and shape of the berry, shape of inflorescence, shape and texture of the leaf. Group I and II were separated on the basis of the number of ovules per locule. Group III and IV were Engler's section Pachynerium and Schizoplacium respectively. The remaining species were included under groups V and VI and were organized into two groups on the basis of leaf texture, berry shape and colour. Intra and intergroup pollinations were done, fruits harvested and germinating seeds obtained.

Self pollination resulted in 81 per cent fruiting spadices, intraspecific and interspeifc crosses combination resulted in 65.4 per cent and 28.1 per cent fruiting spadices respectively.

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

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

Good percentage of candles bearing fruits was observed by Sindhu (1995) in the six varieties (Honeymoon Red, Chilli Red, Kalympong Orange, Kalympong Red, Pink and White). It was maximum (93 %) for White and lowest (50 %) for Kalympong Red.

In the intervarietal hybridization done by Renu (2000) she 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 selfing that produced fruiting candles were for varieties. Liver Red and Dragon's Tongue Red.

2.2.2 Number of Fruits per Candle

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 became swollen and fleshy with developing fruits embedded in it. In about eight weeks, tip of the berries started projecting out like small pinheads.

Sindhu (1995) studied six varieties of *A. andreanum* and observed that maximum average number of fruits was produced in 'Pink' followed by Honeymoon Red. The maximum number of fruits (170) was

harvested from the cross Pink x Honeymoon Red and the lowest number (2) from Kalympong Red x Kalympong Red.

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.

2.2.3 Percentage of Fruit Set per Candle

The maximum percentage of fruit set (52.3 %) was observed for the cross Pink x Honeymoon Red and lowest (0.4 %) in the selfing of Kalympong Red among the varieties studied by Sindhu (1995).

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.

2.2.4 Seed Size

Sindhu (1995) observed that when two seeds were seen in a berry usually one was smaller. 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.

2.2.5 Number of Seeds per Berry

Berries contained usually on or two or nearly three seeds and for ripening it took 5 to 10 months (Zimmer, 1986).

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

According to Mercy and Dale (1994) in the commercial varieties of *Anthurium andreanum* each berry contained one or two seeds and the seeds matured in about 4 to 7 ½ months. Seeds remain enclosed within the thin fruit wall in a gelatinous pulp and if not harvested will remain attached to the candle for a few days more before they dry up and fall off the candle.

Among the six varieties studied by Sindhu (1995) she noticed that percentage of single seeds produced were more than the double seeds except in the cross involving varieties Kalympong Red x Honeymoon Red, where the percentage of double seeds were 63. The percentage of single seeds ranged from 37 to 100.

2.2.6 Percentage Germination of Seeds

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

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 started within 14 days.

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

Sindhu (1995) observed that the maximum average seed germination was observed in combinations with the variety White as the female parent (96.4 %) and the lowest germination in the variety Kalympong Orange. Highest germination percentage among the crosses was recorded for the cross Honeymoon Red x Chilli Red (78.0 %).

In the intervarietal hybridization programme Renu (2000) recorded that the seed germination was highest (87.5%) 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.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 2001-2003 to assess the compatibility and commercial qualities of three way crosses in *Anthurium andreanum* Linden by crossing 10 hybrids with four commercially accepted varieties.

3.1 MATERIALS

The following ten hybrids of anthurium showing variations for spathe colour, shape and size 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. Ordinary Orange x Kalympong Red (OO x KR)
2. Ordinary Orange x Pompon Red (OO x PR)
3. Pompon Red x Fla Red (PR x FR)
4. Pompon Red x Merengue White (PR x MW)
5. Pompon Red x Liver Red (PR x LR)
6. Pompon Red x Dragon's Tongue Red (PR x DT)
7. White x Lady Jane (W x LJ)
8. Kalympong Red x Liver Red (KR x LR)
9. Liver Red x Fla Red (LR x FR)
10. Fla Red x Kalympong Red (FR x KR)

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

1. Carre(C)
2. Acropolis White (A)
3. Tropical Red (T)
4. Honduras (H)

3.2 METHODS

The selected plants were raised in pots in a completely randomized design with four 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 5 g l^{-1} as aqueous solution once in a month. Additional nutrients like diluted cow dung water and fermented and diluted groundnut-neem cake mixture was given once in a month. The latter is prepared by fermenting 2 kg of groundnut cake and 4 kg of neem cake in 5 l of water for two days. The mixture was then diluted by adding 245 l of very dilute cowdung water. About 200 ml of sieved fertilizer solution was then applied to each pot.

Plant protection measures undertaken were as follows

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

a. Bavistin 50 per cent WP @ 2 g l^{-1} or
b. Indofil M-45 @ 2 g l^{-1}

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

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

Snails and slugs were hand picked and killed. The application of Furadan 3G @ 2 – 3 g per pot also gave a good control.

3.2.1 Morphological Studies

The plant materials with stabilized vegetative and floral characters were used for taking all the observations. Observations on the following 18 characters (vegetative and floral characters) of male (four genotypes) and female parents (ten hybrids) were recorded and their mean values were taken.

3.2.1.1 Quantitative Characters

3.2.1.1.1 Plant Height

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

3.2.1.1.2 Internode Length

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

3.2.1.1.3 Suckering Ability

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

3.2.1.1.7 Days from Emergence to Maturity of Inflorescence

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

3.2.1.1.8 Number of Spadices per Plant per Year

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

3.2.1.1.9 Total Anthocyanin Content

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

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

[Volume (ml of the extract) used x weight of sample taken].

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

Therefore, total anthocyanin in mg per 100 g of the sample = $\frac{X}{98.2}$

3.2.1.1.10 Candle Length

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

3.2.1.1.11 Inclination of Candle with the Spathe

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

3.2.1.1.12 Life of Spadix or Longevity of Spadix

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

3.2.1.1.13 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.

3.2.1.1.14 Duration of Female Phase

The period between the emergence of stigmas in the basal flowers to the top most flowers was recorded as the duration of female phase in days.

3.2.1.1.15 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.

3.2.1.1.16 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.

3.2.1.1.17 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 %). Two slides were made for each genotype and from each slide, ten microscopic fields were scored and the data were recorded. Unstained, partially stained and shriveled pollen grains were scored as sterile while the uniformly stained, properly filled pollen as fertile. Fertility of each genotype was estimated as percentage of the number of fertile pollen grains to the total number of pollen grains scored.

Pollen fertility in percentage was calculated as,

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

3.2.1.1.18 Pollen Size

Pollen grains were measured using ocular micrometer after calibration. Calibration 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 and standard error were calculated to find out the average diameter of the pollen grain.

$$\text{Standard error} = \frac{\sigma}{\sqrt{N}}$$

where, σ is the standard deviation and N is the total number of pollen grains measured.

Average diameter = Mean ± Standard error

3.2.1.2 Qualitative Characters

3.2.1.2.1 Colour of Petiole and Young Leaf

The colour of petiole and young leaf of each genotype was recorded.

3.2.1.3.2 Spathe Colour

The spathe colour of each genotype was recorded by visual observation

3.2.1.2.3 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.

3.2.1.2.4 Candle Colour

Visual observation was used to record the candle colours.

3.2.1.2.5 Types 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 Techniques Applied

The data collected were subjected to statistical analysis using analysis of variance and analysis of covariance techniques. Heritability coefficient, genetic advance and 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	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

$$GCV = \frac{\sigma_{gx}}{\bar{x}} \times 100 \quad ; \quad PCV = \frac{\sigma_{px}}{\bar{x}} \times 100$$

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

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

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

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

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

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

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

3.2.2 Compatibility Studies

Crossing was carried out between the ten selected genotypes, which were used as the female parents, and the four commercially important Holland 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 Holland varieties

♀ \ ♂	C	A	T	H
OO x KR	(OO x KR)x C	(OO x KR) x A	(OO x KR) x T	(OO x KR) x H
OO x PR	(OO x PR) x C	(OO x PR) x A	(OO x PR) x T	(OO x PR) x H
PR x FR	(PR x FR) x C	(PR x FR) x A	(PR x FR) x T	(PR x FR) x H
PR x MW	(PR x MW) x C	(PR x MW)x A	(PR x MW)x T	(PR x MW) x H
PR x LR	(PR x LR) x C	(PR x LR) x A	(PR x LR) x T	(PR x LR) x H
PR x DT	(PR x DT) x C	(PR x DT) x A	(PR x DT) x T	(PR x DT) x H
W x LJ	(W x LJ)x C	(W x LJ) x A	(W x LJ) x T	(W x LJ) x H
KR x LR	(KR x LR) x C	(KR x LR) x A	(KR x LR) x T	(KR x LR) x H
LR x FR	(LR x FR) x C	(LR x FR) x A	(LR x FR) x T	(LR x FR) x H
FR x KR	(FR x KR) x C	(FR x KR) x A	(FR x KR) x T	(FR x KR) x H

Depending upon the availability of receptive spadices and fresh pollen only 28 crosses could be attempted.

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. About 150 to 350 of them are present in a single candle. The flowers show a clear protogynous condition and so no emasculation was needed. The spadix of the selected female parent plant 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

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

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 times 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 petri dishes to induce germination. The number of seeds that germinated within four to nine days was noted and percentage of germination calculated as

$$\frac{\text{Number of seeds germinated}}{\text{Number of seeds kept for germination}} \times 100$$

RESULTS

4. RESULTS

The experimental data were collected on various morphological characters of 14 genotypes of *Anthurium andreanum*. The data were statistically analysed and the results obtained are presented here.

4.1 EVALUATION OF GENOTYPES FOR THEIR PERFORMANCE

The mean performance of each of the 14 varieties for the 18 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 (Table 2 and Plates 1,2).

4.1.1 Quantitative Characters

4.1.1.1 Vegetative Characters

4.1.1.1.1 Plant Height

The variety Carre recorded the lowest mean plant height (21.25 cm) which was on par with the genotype W x LJ (22.50 cm). The highest mean plant height was recorded by the genotype PR x DT (44.00 cm) followed by Acropolis White (41.00 cm).

4.1.1.1.2 Internode Length

The minimum value of 1.20 cm was exhibited by Carre. No genotype was on par with it. The maximum value was exhibited by PR x DT and Acropolis White (1.48 cm).

4.1.1.1.3 Number of Suckers per Plant

Lowest number of suckers was produced for the variety Acropolis White (0.25). Sucker production was highest for the genotype OO x KR (2.25). In genotypes W x LJ, Carre, Tropical Red and Honduras no suckers were produced during the course of study.

Table 2. Analysis of variance of vegetative (1-6) and floral (7-18) characters in 14 *Anthurium andreanum* genotypes

Characters		Mean square	
		Genotype	Error
	Degrees of freedom	13	42
1.Plant height, cm		209.34**	1.99
2.Internode length, cm		0.03	3.77
3.Number of suckers per plant		2.03*	0.107
4. Leaf area, cm^2		16855.39**	1.01
5. Number of leaves per plant		1.18*	0.24
6. Days from emergence to maturity of leaves		69.57**	0.98
7. Days from emergence to maturity of inflorescence		32.48**	0.39
8. Number of spadices per plant per year		1.22*	0.26
9. Anthocyanin content, mg g^{-1}		31606.88**	4.12
10. Candle length, cm		3.86**	8.09
11. Inclination of candle, degrees		2404.99**	4.97
12. Life of spadix, days		700.96**	4.40
13.Days to initiation of female phase		9.83**	0.20
14. Duration of female phase, days		4.05**	0.21
15. Duration of interphase, days		20.66**	0.27
16. Duration of male phase, days		31.14**	0.35
17. Pollen fertility, %		492.39**	2.40
18. Pollen size, μ		202.43**	2.78

**-Significant at 1 % level

*Significant at 5 % 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 area, cm^2	Number of leaves per plant	Days from emergence to maturity of leaves
1	OO x KR	37.00	1.33	2.25	250.00	5.75	38.50
2	OO x PR	39.25	1.38	1.25	251.94	5.75	38.25
3	PR x FR	34.50	1.33	1.25	201.60	5.50	35.00
4	PR x MW	28.50	1.25	1.00	171.08	5.25	32.75
5	PR x LR	39.50	1.38	1.25	251.55	5.75	38.25
6	PR x DT	44.00	1.48	1.75	300.95	6.00	40.25
7	W x LJ	22.50	1.23	0.00	115.38	4.75	27.50
8	KR x LR	33.75	1.30	1.00	201.02	5.50	35.25
9	LR x FR	25.25	1.25	1.00	131.48	4.50	32.00
10	FR x KR	29.25	1.33	1.00	198.74	5.50	34.50
11	Carre	21.25	1.20	0.00	113.62	4.25	26.25
12	Acropolis White	41.00	1.48	0.25	301.10	6.00	38.25
12	Tropical Red	38.00	1.38	0.00	250.04	5.75	35.75
14	Honduras	27.75	1.25	0.00	134.93	5.25	32.00
$F_{13,42}$		105.297**	7.842**	18.923**	16657.090**	4.962**	71.263**
SE		0.705	0.031	0.164	0.503	0.244	0.494
CD		2.015	0.088	0.468	1.438	0.697	1.412

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

Sl. No.	Genotypes	1	2	3	4	5	6	7	8	9	10	11	12
1	OO x KR	35.00	5.75	192.26	7.05	30.00	78.00	2.75	8.00	5.50	8.75	20.70	27.61
2	OO x PR	35.25	5.75	112.89	5.75	46.75	85.50	7.75	8.25	8.00	9.00	15.68	27.13
3	PR x FR	31.75	5.50	226.97	5.30	22.50	73.25	6.50	7.75	7.00	8.00	24.45	22.64
4	PR x MW	30.50	5.25	213.45	5.88	32.25	69.50	5.75	7.00	5.75	7.50	33.08	24.51
5	PR x LR	35.75	5.75	221.37	5.30	46.75	89.75	8.00	8.00	8.25	9.75	12.56	26.54
6	PR x DT	35.50	5.75	194.57	6.18	120.75	101.50	8.00	8.25	9.25	10.25	9.26	23.54
7	W x LJ	29.50	4.50	17.40	5.93	29.00	62.00	5.25	6.00	0.00	0.00	0.00	0.00
8	KR x LR	30.50	5.50	234.26	7.00	21.00	72.00	6.25	7.50	6.75	8.00	28.45	26.34
9	LR x FR	29.25	4.50	255.16	4.75	37.50	63.00	5.50	6.50	5.50	7.25	34.65	28.48
10	FR x KR	30.25	5.50	20.57	4.63	41.50	65.75	6.00	7.00	6.25	7.50	32.14	25.36
11	C	29.00	4.25	157.96	4.88	31.00	59.50	4.50	5.50	4.50	6.50	35.70	22.94
12	A	35.75	6.00	10.09	7.95	52.50	97.00	7.75	9.00	8.25	10.75	16.23	26.75
13	T	35.25	5.75	188.19	6.70	52.25	82.00	8.00	8.50	7.75	9.00	20.04	27.48
14	H	29.50	5.25	259.18	5.30	40.50	68.25	5.25	6.75	5.50	12.00	35.13	25.51
$F_{13,42}$		83.961**	4.657**	7667.806**	47.749**	483.877**	159.136**	50.021**	18.923**	77.133**	88.666**	205.121**	72.831**
SE		0311	0256	1.015	0.142	1.115	1.049	0222	0231	0259	0296	0.775	0.834
CD		0.889	0.731	2.901	0.406	3.186	2.999	0.633	0.662	0.740	0.847	2.214	2.382

1. Days from emergence to maturity of inflorescence
2. Number of spadices per plant per year
3. Anthocyanin content, mg g^{-1}
4. Candle length, cm
5. Inclination of candle, degrees
6. Life of spadix, days
7. Days to initiation of female phase
8. Duration of female phase, days
9. Duration of interphase, days
10. Duration of male phase, days
11. Pollen fertility, %
12. Pollen size, μ

*Significant at 5 % level
** Significant at 1 % level

Table 5. Qualitative character differentiation in 14 genotypes of *A. andreanum*

Sl. No.	Genotypes	Colour of young leaf	Colour of petiole	Spathe colour	Spathe texture	Candle colour	Type of inflorescence axis
1.	OO x KR	Green	Green	Dark orange	Medium thick blistered	Yellowish white	Long thin curving
2.	OO x PR	Brown	Brown	Light orange	Medium thick lightly blistered	Yellowish white	Long thick straight
3.	PR x FR	Reddish brown	Reddish brown	Maroon	Medium thick blistered glossy	Yellowish white	Long thin curving
4.	PR x MW	Brown	Brown	Light orange	Medium thick deeply blistered glossy	Yellow	Long thin curving
5.	PR x LR	Reddish brown	Reddish brown	Deep maroon	Medium thick deeply blistered glossy	Pink	Long thick straight
6.	PR x DT	Reddish brown	Reddish brown	Dark Red	Thick, blistered glossy	Light pink	Short thin straight
7.	W x LJ	Greenish brown	Green	Pinkish white	Thin, smooth glossy	Cream	Short thick straight
8.	KR x LR	Reddish brown	Reddish brown	Dark Red	Medium thick blistered glossy	Cream	Short thin straight
9.	LR x FR	Reddish brown	Reddish brown	Light red	Medium thick deeply blistered glossy	Yellow	Short thick straight
10.	FR x KR	Green	Green	Light pink	Thick blistered glossy	Cream	Short thin straight
11.	C	Greenish brown	Greenish brown	Pink	Medium thick blistered	Cream	Short thin straight
12.	A	Green	Green	White	Thick deeply blistered	Yellowish white	Long thick straight
13.	T	Brown	Brown	Dark red	Medium thick blistered	Light yellow	Long thick straight
14.	H	Green	Green	Deep maroon	Medium thick deeply blistered	Creamish yellow	Short thick straight

OO x KR

PR x DT

OO x PR

W x LJ

PR x FR

KR x LR

PR x MW

LR x FR

PR x LR

FR x KR

Plate 1. Female parents

Carre

Acropolis White

Tropical Red

Honduras

Plate 2. Male parents

4.1.1.1.4 Leaf Area

Leaf area was minimum for the genotype Carre (113.62 cm^2) and maximum for the genotype Acropolis White (301.10 cm^2) which was on par with PR x DT (300.95 cm^2).

4.1.1.1.5 Number of Leaves per Plant

The lowest number of leaves per plant was shown by the genotype Carre (4.25) and the maximum value by the genotypes PR x DT and Acropolis White (6.00).

The genotypes OO x KR, OO x PR, PR x LR, Tropical Red (5.75), PR x FR, KR x LR and FR x KR (5.50) were on par with PR x DT and Acropolis White (6.00).

4.1.1.1.6 Days from Emergence to Maturity of Leaves

The least number of days for maturity was taken by Carre (26.25) which was on par with W x LJ (27.50). The maximum number of days was taken by the genotype PR x DT (40.25).

4.1.1.2 Floral Characters

4.1.1.2.1 Days from Emergence to Maturity of Inflorescence

The genotype Carre recorded the lowest mean value (29.00) for this character which was on par with LR x FR (29.25), Honduras and W x LJ (29.50). The highest mean value was recorded in the genotypes PR x LR and Acropolis White (35.75).

4.1.1.2.2 Number of Spadices per Plant per Year

The minimum number of spadices per plant per year was observed for the genotype Carre (4.25). The maximum number of spadices was exhibited in the genotypes Acropolis White (6) followed by OO x PR, PR x LR, PR x DT, OO x KR, Tropical Red (5.75), KR x LR, FR x KR and PR x FR (5.50) which were on par with Acropolis White.

4.1.1.2.3 Anthocyanin Content

The mean anthocyanin content ranged from 10.09 mg g^{-1} in Acropolis White to 259.18 mg g^{-1} in Honduras.

4.1.1.2.4 Candle Length

The variety FR x KR showed the lowest value of 4.63 cm which was on par with Carre (4.88 cm) and LR x FR (4.75 cm). The highest mean candle length was recorded for the variety Acropolis White (7.95 cm).

4.1.1.2.5 Inclination of Candle with the Spathe

The angle between the candle and the spathe was lowest for the genotype KR x LR (21.00°) which was on par with PR x FR (22.50°). The maximum angle was observed for the genotype PR x DT (120.75°)

4.1.1.2.6 Life of Spadix

The lowest mean life of the spadix was recorded by Carre (59.50 days). The highest mean was recorded for PR x DT (101.50).

4.1.1.2.7 Days to Initiation of Female Phase

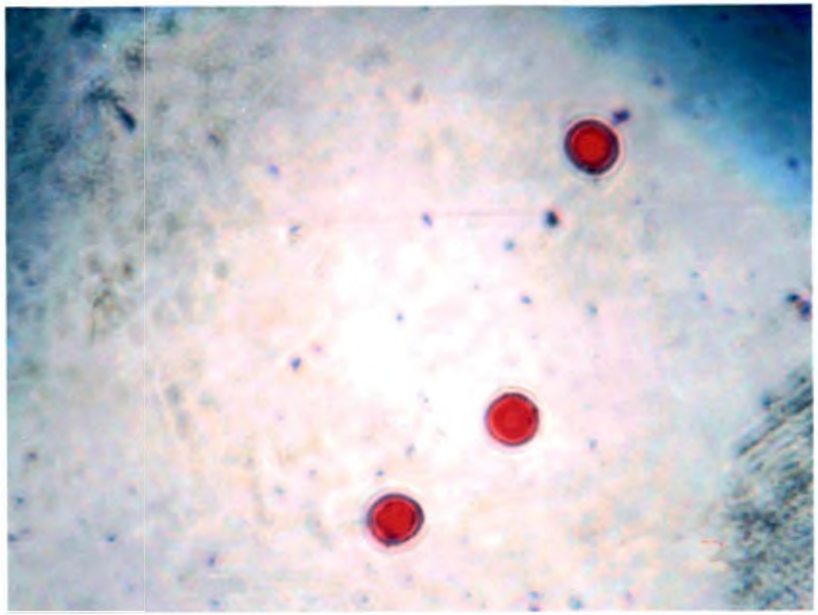
The mean number of days to initiation of female phase ranged from 2.75 in OO x KR to eight in PR x LR, PR x DT and Tropical Red.

4.1.1.2.8 Duration of Female Phase

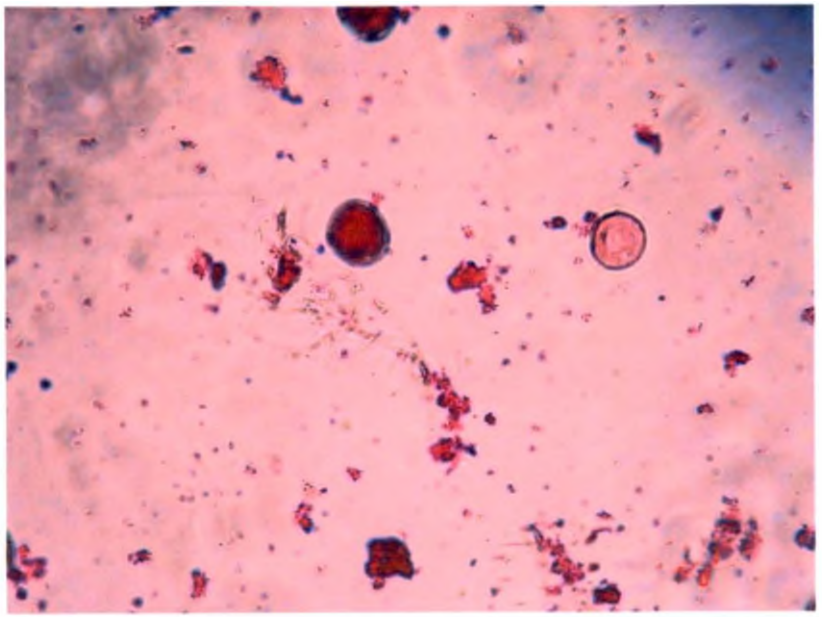
The lowest duration of female phase was observed for Carre (5.50 days) which was on par with W x LJ (6.00 days). The highest mean duration was obtained for the variety Acropolis White (9.00 days) that was on par with the variety Tropical Red (8.50 days) (Plate 3).

4.1.1.2.9 Days of Interphase

The days of interphase were minimum for the variety Carre (4.50 days) and maximum for the genotype PR x DT (9.25 days).



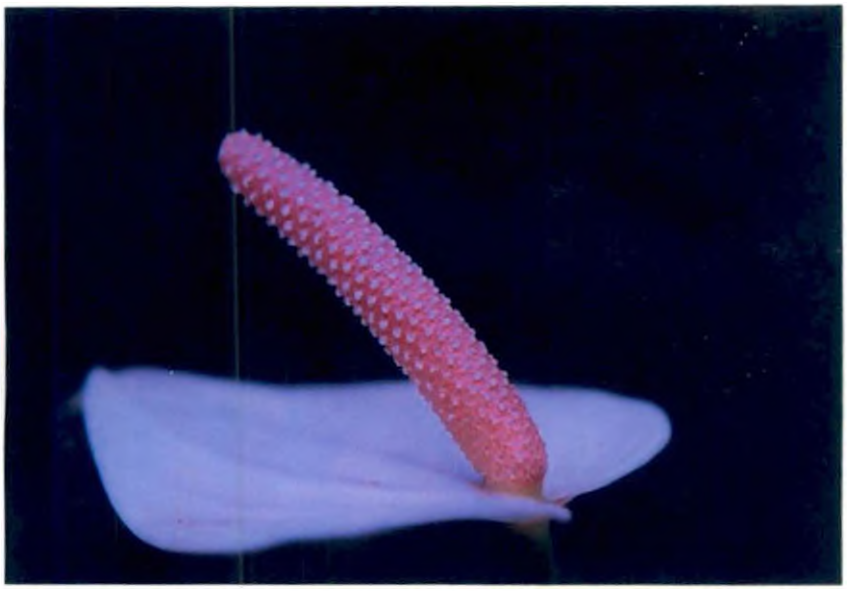
Fertile pollen grains



Fertile and sterile (lightly coloured) pollen grains

Plate 4. Pollen grains (45 x) of *Anthurium andreanum*

A. Female phase



B. Male phase

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

No anther production was observed in the genotype W x LJ during the period of this study. So observations on days of interphase, duration of male phase, pollen sterility and pollen morphology could not be recorded for this genotype.

4.1.1.2.10 Duration of Male Phase

The lowest mean duration of male phase was recorded by Carre (6.50 days) which was on par with LR x FR (7.25 days). The highest mean was obtained for the variety Honduras (12.00 days). None of the varieties were on par with Honduras (Plate 3).

4.1.1.2.11 Pollen Fertility

The pollen fertility was lowest for PR x DT (9.26 %) and PR x LR (12.56 %). It was highest for the variety Carre (35.70) (Plate 4).

4.1.1.2.12 Pollen Size

The mean size of the pollen ranged from to 22.64 μ in PR x FR to 28.48 μ in LR x FR. The genotypes PR x MW (24.51 μ), PR x DT (23.54 μ) and Carre (22.94 μ) were on par with PR x FR. The genotypes OO x KR (27.61 μ), Tropical Red (27.48 μ), and OO x PR (27.13 μ) were on par with LR x FR.

4.1.2 Qualitative Characters

4.1.2.1. Colour of Young Leaf and Petiole

The colour of young leaf showed a range 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.

4.1.2.2 Spathe Colour

The colour of the spathe showed variation like deep maroon, maroon, dark red, light red, dark orange, light orange, light pink and white.

4.1.2.3 Spathe Texture

Spathe texture showed variation from thick blistered glossy to medium thick deeply blistered glossy and thin smooth glossy.

4.1.2.4 Candle Colour

Candle colour varied from pink to cream, creamish yellow and yellowish white.

4.1.2.5 Type of Inflorescence Axis

Long, straight and strong inflorescence axis is commercially preferred which was seen in Acropolis White and Tropical Red. Among the female parents inflorescence axis was long thin and curving for OO x KR, PR x FR and PR x MW.

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.

The maximum value for genotypic and phenotypic coefficients of variation (Fig. 1) was observed for number of suckers per plant (GCV 80.84 and PCV 89.40 %) followed by inclination of candle to spathe (GCV 56.75 and PCV 56.99 %) and anthocyanin content (GCV 54.00 and PCV 54.02 %). Pollen fertility (GCV 48.72 and PCV 49.19 %), duration of interphase (GCV 35.82 and PCV 36.75 %) and duration of male phase (GCV 34.00 and PCV 34.76 %) also registered high values both at phenotypic and genotypic levels. The minimum variability was recorded by the character internode length (GCV 6.05 and PCV 7.62 %) followed by days from emergence to maturity of inflorescence (GCV 8.76 and PCV 8.97 %).

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, %	PCV, %
1	Plant height, cm	53.83	51.34	1.99	21.84	22.26
2	Internode length, cm	0.01	0.01	0.00	6.05	7.62
3	Number of suckers per plant	0.59	0.48	0.11	80.84	89.40
4	Leaf area, cm^2	4214.61	4213.59	1.01	31.63	31.63
5	Number of leaves per plant	0.47	0.24	0.24	9.00	12.77
6	Days from emergence to maturity of leaves	18.12	17.15	0.98	11.97	12.30
7	Days from emergence to maturity of inflorescence	8.41	8.03	0.39	8.76	8.97
8	Number of spadices per plant per year	0.50	0.24	0.26	9.14	13.22
9	Anthocyanin content, mg g^{-1}	7904.81	7900.69	4.12	54.00	54.02
10	Candle length, cm	1.03	0.95	0.08	16.49	17.18
11	Inclination of candle, degrees	604.97	600.00	4.97	56.75	56.99
12	Life of spadix, days	178.54	174.14	4.41	17.32	17.53
13	Days to initiation of female phase	2.60	2.41	0.20	24.90	25.89
14	Duration of female phase, days	1.17	0.96	0.21	13.19	14.59
15	Duration of interphase, days	5.37	5.10	0.27	35.82	36.75
16	Duration of male phase, days	8.05	7.70	0.35	34.00	34.76
17	Pollen fertility, %	124.90	122.50	2.40	48.72	49.19
18	Pollen size, μ	52.69	49.91	2.78	29.54	30.35

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.

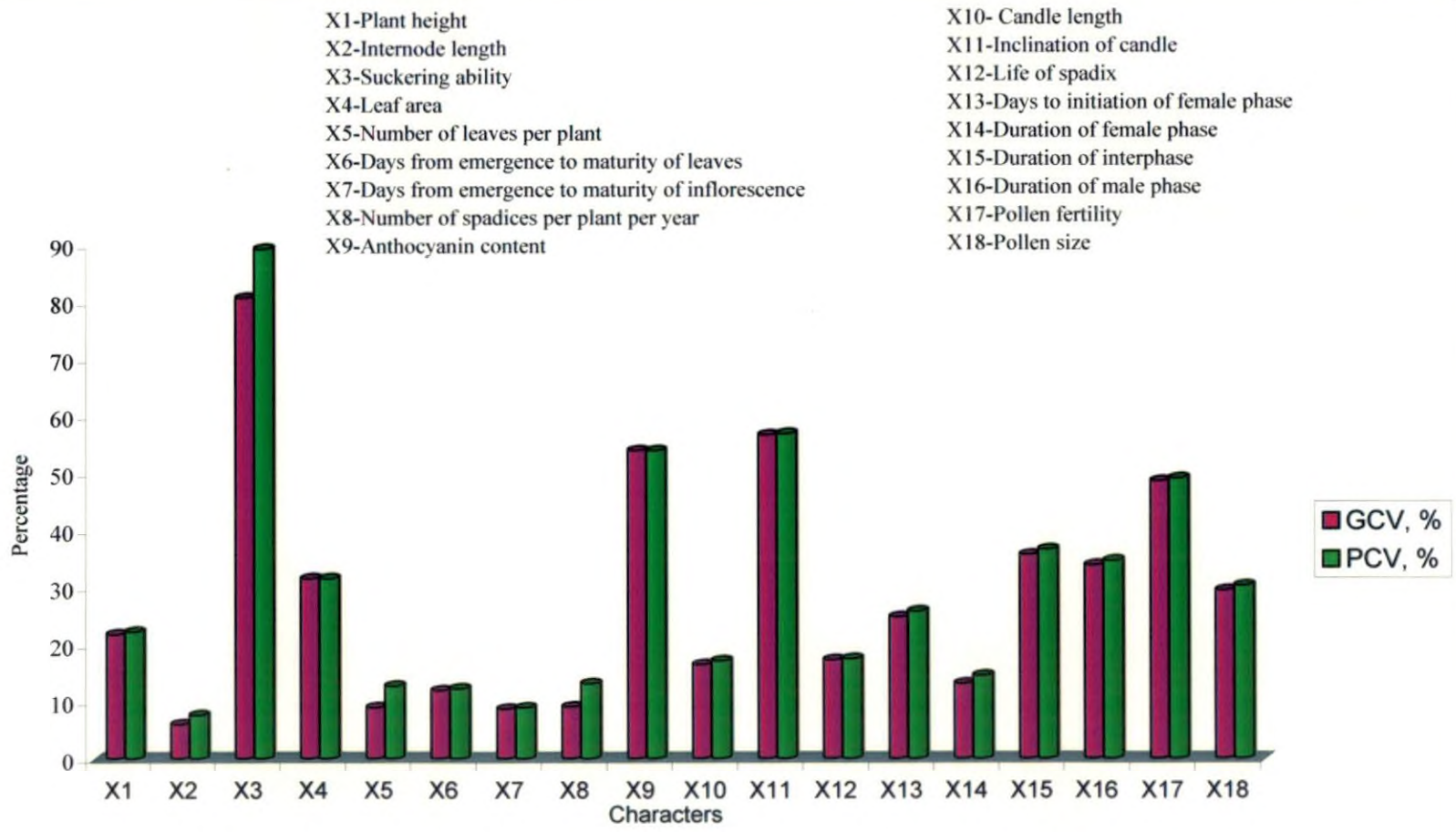


Fig. 1. GCV and PCV for the eighteen characters of *Anthurium andreanum* genotypes

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

Sl. No.	Characters	Heritability, %	Genetic advance, 5 %	Genetic advance, as % of mean
1	Plant height, cm	96.3	14.6	44.2
2	Internode length, cm	63.1	0.1	9.9
3	Number of suckers per plant	81.8	1.2	150.6
4	Leaf area, cm^2	99.9	133.7	65.1
5	Number of leaves per plant	49.8	0.7	13.1
6	Days from emergence to maturity of leaves	94.6	8.3	24.0
7	Days from emergence to maturity of inflorescence	95.4	5.7	17.6
8	Number of spadices per plant per year	47.8	0.7	13.0
9	Anthocyanin content, mg g^{-1}	99.9	183.1	112.2
10	Candle length, cm	92.1	1.9	32.6
11	Inclination of candle, degrees	99.2	50.3	116.4
12	Life of spadix, days	97.5	26.8	35.2
13	Days to initiation of female phase	92.5	3.1	49.3
14	Duration of female phase, days	81.8	1.8	24.6
15	Duration of interphase, days	95.0	4.5	71.9
16	Duration of male phase, days	95.6	5.6	68.4
17	Pollen fertility, %	98.1	22.6	99.4
18	Pollen size, μ	94.7	14.2	59.2

4.3 HERITABILITY AND GENETIC ADVANCE

Estimates of heritability and genetic advance values of 18 traits are presented in Table 7.

Allard (1960) classified heritability as low (less than 30 %) medium (30-60 %) and high (above 60 %). According to this classification the characters number of leaves per plant (49.8 %) and number of spadices per plant per year (47.8 %) showed medium heritability while all other characters recorded high heritability.

Maximum heritability was recorded for the characters leaf area and anthocyanin content (99.9 %). The characters inclination of candle (99.2 %), pollen fertility (98.1 %) and life of spadix (97.5 %) also recorded high heritability values. Number of spadices per plant per year (47.8 %) showed least value for heritability.

Genetic advance as percentage of mean is independent of the unit of measurement and hence is used for comparison among characters. Maximum genetic advance was obtained for the character number of suckers per plant (150.6 %) followed by inclination of candle (116.4 %) and anthocyanin content (112.2 %). The least genetic advance was obtained for the character internode length (9.9 %), at five per cent selection.

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 all the characters except number of suckers per plant, anthocyanin content, pollen fertility and pollen size. Internode length showed significant

positive correlation with plant height, leaf area, number of leaves per plant, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, number of spadices per plant per year, inclination of candle, life of spadix, days to initiation of female phase, duration of female phase and interphase.

Number of suckers per plant showed significant positive correlation with days from emergence to maturity of leaves only. All other characters had no significant correlation.

Leaf area was found to have significant positive correlation with plant height, internode length, number of leaves per plant, days from emergence to maturity of leaves and inflorescence, number of spadices per plant per year, candle length, inclination of candle, life of spadix, days to initiation of female phase, duration of female phase, duration of interphase, and duration of male phase.

Number of leaves per plant showed significant positive correlation with plant height, internode length, leaf area, days from emergence to maturity of leaves and inflorescence, number of spadices per plant per year, life of spadix, duration of female phase and interphase.

Days from emergence to maturity of leaves showed significant positive correlation with plant height, internode length, number of suckers per plant, leaf area, number of leaves per plant, days from emergence to maturity of inflorescence, number of spadices per plant per year, life of spadix, duration of female phase, interphase and male phase.

Days from emergence to maturity of inflorescence showed significant positive correlation with plant height, internode length, leaf area, number of leaves per plant, days from emergence to maturity of leaves, number of spadices per plant per year, life of spadix, duration of female phase and interphase. It also registered a significant negative correlation with pollen fertility.

Number of spadices per plant per year showed significant positive correlation with plant height, internode length, leaf area, number of leaves

per plant, days from emergence to maturity of leaves and inflorescence, life of spadix, duration of female phase and interphase.

The character anthocyanin content showed no significant correlation with any other character under observation.

Candle length was found to have significant positive correlation with plant height, leaf area, life of spadix and duration of female phase.

Inclination of candle to the spathe showed significant positive correlation with plant height, internode length, leaf area and life of spadix.

Life of spadix had significant positive correlation with all characters except number of suckers per plant, anthocyanin content and pollen size.

Days to initiation of female phase showed significant positive correlation with plant height, internode length, leaf area, life of spadix, duration of female phase.

Except the characters, number of suckers per plant, anthocyanin content, inclination of candle, pollen fertility and pollen size, duration of female phase registered significant positive correlation with all other characters studied.

Duration of interphase showed significant positive correlation with all the characters except number of suckers per plant per year, anthocyanin content, candle length, inclination of candle and pollen fertility.

Duration of male phase showed significant positive correlation with plant height, leaf area, days from emergence to maturity of leaves, life of spadix, duration of female phase and interphase and size of pollen.

Pollen fertility showed significant negative correlation with days from emergence to maturity of inflorescence and life of spadix. No significant positive correlation was observed for this character with any other character studied.

Pollen size was found to have significant positive correlation with duration of interphase and male phase.

Table 8. Phenotypic correlation coefficients among eighteen characters in *Anthurium andreanum* genotypes

	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_{17}
X_2	0.7899**																
X_3	0.4461	0.3396															
X_4	0.9611**	0.8172**	0.4413														
X_5	0.7034**	0.6308*	0.3665	0.7297**													
X_6	0.9324**	0.7350**	0.5945*	0.9161**	0.6947**												
X_7	0.9080**	0.7459**	0.3696	0.9187**	0.6414*	0.8378**											
X_8	0.7161**	0.5488*	0.3139	0.7056**	0.6348*	0.6951**	0.6206*										
X_9	0.0302	-0.1791	0.2550	-0.1357	-0.0682	0.0761	-0.0926	-0.0346									
X_{10}	0.5364*	0.4409	0.0543	0.5859*	0.4450	0.4548	0.5270	0.4444	-0.1892								
X_{11}	0.5658*	0.5780*	0.2123	0.5790*	0.3573	0.4972	0.5123	0.2894	-0.0350	0.1229							
X_{12}	0.9217**	0.8039**	0.3386	0.9296**	0.6593*	0.8337**	0.8898**	0.6364*	-0.0668	0.5369*	0.7062**						
X_{13}	0.6047*	0.5571*	-0.1091	0.5719*	0.3818	0.4791	0.5281	0.4088	-0.1018	0.1569	0.5160	0.6524*					
X_{14}	0.8809**	0.7282**	0.3122	0.8814**	0.6849**	0.8319**	0.8249**	0.7335**	-0.0401	0.5907*	0.3927	0.8173**	0.5542*				
X_{15}	0.8018**	0.6743**	0.3821	0.7820**	0.5476*	0.8000**	0.6648**	0.6072*	0.2497	0.2286	0.5163	0.7506**	0.6282*	0.7249**			
X_{16}	0.5963*	0.4508	0.2230	0.5577*	0.4484	0.6223*	0.4810	0.4785	0.3908	0.1903	0.3745	0.5682*	0.3116	0.5343*	0.8028**		
X_{17}	-0.4488	-0.4174	-0.1025	-0.4523	-0.3090	-0.3276	-0.5557*	-0.2138	0.4206	-0.3887	-0.3872	-0.5408*	-0.3755	-0.3511	0.0319	0.2810	
X_{18}	0.4231	0.2888	0.3113	0.4214	0.3160	0.5282	0.3245	0.3477	0.4441	0.0769	0.1191	0.3118	0.1618	0.4105	0.7550**	0.8076**	0.5238

X1 – Plant height, cm
X2 – Internode length, cm
X3 – Number of suckers per plant
X4 – Leaf area, cm^2
X5 – Number of leaves per plant
X6 – Days from emergence to maturity of leaves
X7 – Days from emergence to maturity of inflorescence
X8 – Number of spadices per plant per year
X9 – Anthocyanin content, mg g^{-1}
X10- Candle length, cm
X11- Inclination of candle, degrees
X12 – Life of spadix, days
X13 – Days to initiation of female phase
X14 – Duration of female phase, days
X15 – Duration of interphase, days
X16 – Duration of male phase, days
X17 – Pollen fertility, %
X18 – Pollen size, μ
*Significant at 5 % level
** Significant at 1 % level

Table 9. Genotypic correlation coefficient among eighteen characters in *Anthurium andreanum* genotypes

	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_{17}
X_2	1.0050																
X_3	0.5158	0.3441															
X_4	0.9784	1.0289	0.4876														
X_5	1.0587	1.0186	0.4862	1.0323													
X_6	0.9661	0.9459	0.6760	0.9427	1.0510												
X_7	0.9382	0.9350	0.4185	0.9402	0.9439	0.8667											
X_8	1.0305	1.0149	0.5024	1.0215	1.2269	1.0517	0.9322										
X_9	0.0313	-0.2272	0.2814	-0.1357	-0.1006	0.0777	-0.0942	-0.0461									
X_{10}	0.5698	0.5744	0.0652	0.6102	0.6560	0.4817	0.5728	0.6287	-0.1957								
X_{11}	0.5770	0.7385	0.2312	0.5813	0.5136	0.5157	0.5244	0.4011	-0.0342	0.1318							
X_{12}	0.9549	1.0218	0.3636	0.9412	0.9501	0.8758	0.9242	0.9011	-0.0671	0.5637	0.7166						
X_{13}	0.6350	0.7676	-0.0868	0.5938	0.6340	0.5141	0.5569	0.5838	-0.1057	0.1519	0.5395	0.6902					
X_{14}	0.9860	0.9911	0.4082	0.9729	1.0739	0.9576	0.9298	1.0621	-0.400	0.6725	0.4252	0.9033	0.6296				
X_{15}	0.8382	0.8412	0.3993	0.8026	0.8236	0.8285	0.7002	0.858	0.2562	0.2392	0.5336	0.7765	0.9756	0.8090			
X_{16}	0.6299	0.6018	0.2399	0.5707	0.6677	0.6630	0.4969	0.7562	0.3991	0.2051	0.3861	0.5871	0.3307	0.6370	0.8450		
X_{17}	-0.4614	-0.5170	-0.1174	-0.4568	-0.4681	-0.3332	-0.5747	-0.3354	0.4251	-0.4009	-0.3961	-0.5496	-0.3923	-0.4032	0.0362	0.2906	
X_{18}	0.4550	0.3802	0.3658	0.4012	0.4012	0.5495	0.3561	0.5582	0.4555	0.0700	0.1286	0.3315	0.1848	0.4938	0.7932	0.8465	0.5492

X1 – Plant height, cm
X2 – Internode length, cm
X3 – Number of suckers per plant
X4 – Leaf area, cm^2
X5 – Number of leaves per plant
X6 – Days from emergence to maturity of leaves
X7 – Days from emergence to maturity of inflorescence
X8 – Number of spadices per plant per year
X9 – Anthocyanin content, mg g^{-1}
X10- Candle length, cm
X11- Inclination of candle, degrees
X12 – Life of spadix, days
X13 – Days to initiation of female phase
X14 – Duration of female phase, days
X15 – Duration of interphase, days
X16 – Duration of male phase, days
X17 – Pollen fertility, %
X18 – Pollen size, μ
*Significant at 5 % level
** Significant at 1 % level

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

	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_{17}
X_2	0.0552																
X_3	-0.1419	0.3563															
X_4	0.3520	-0.0072	0.0647														
X_5	-0.2163	0.1394	0.1863	0.1503													
X_6	0.2265	0.0295	0.0000	-0.2014	-0.1605												
X_7	0.2104	0.1564	0.0000	0.1665	-0.0588	0.2906											
X_8	0.1237	-0.0190	0.0000	-0.0278	0.0715	-0.0706	-0.0561										
X_9	-0.1248	0.1010	0.0592	-0.0656	0.1704	0.1039	-0.1202	-0.1638									
X_{10}	-0.0059	0.0172	-0.0192	0.0670	0.0043	0.0784	0.1649	0.1350	-0.2303								
X_{11}	0.1079	-0.1134	0.1060	0.0876	-0.0438	-0.1108	0.1159	0.2035	-0.4670	-0.1201							
X_{12}	-0.1247	0.0232	0.2080	0.0453	0.0232	-0.2095	-0.0502	0.1884	-0.1289	-0.0589	0.0954						
X_{13}	0.1048	-0.1754	-0.2872	0.2491	-0.2477	-0.0272	0.0864	0.1050	-0.0299	0.2172	-0.0241	-0.0704					
X_{14}	0.0730	0.0630	-0.1179	0.2864	0.0000	-0.1041	0.0413	0.2261	-0.4109	0.0588	0.2538	0.1593	-0.0580				
X_{15}	0.0000	0.1690	0.3162	-0.0397	-0.1179	0.2794	-0.0370	0.1798	0.0144	0.0768	-0.0825	0.0877	-0.0778	0.1442			
X_{16}	-0.2066	-0.1313	0.1227	0.1008	-0.0823	-0.1728	0.1453	-0.2159	0.1271	-0.0388	-0.0811	0.0335	-0.3173	0.3255	0.0582		
X_{17}	-0.0126	-0.0331	0.0427	-0.0017	0.1837	-0.2076	0.0074	0.1573	-0.1108	-0.1959	0.2757	-0.1502	-0.0525	0.1689	0.0997	-0.0162	
X_{18}	-0.2598	-0.0371	-0.1080	-0.2946	0.2491	0.1492	-0.2828	-0.1675	0.1817	0.1782	-0.2675	-0.1894	-01773	0.2457	0.0652	0.0413	-0.1764

X1 – Plant height, cm
X2 – Internode length, cm
X3 – Number of suckers per plant
X4 – Leaf area, cm^2
X5 – Number of leaves per plant
X6 – Days from emergence to maturity of leaves
X7 – Days from emergence to maturity of inflorescence
X8 – Number of spadices per plant per year
X9 – Anthocyanin content, mg g^{-1}
X10- Candle length, cm
X11- Inclination of candle, degrees
X12 – Life of spadix, days
X13 – Days to initiation of female phase
X14 – Duration of female phase, days
X15 – Duration of interphase, days
X16 – Duration of male phase, days
X17 – Pollen fertility, %
X18 – Pollen size, μ
*Significant at 5 % level
** Significant at 1 % level

4.4.2 Genotypic Correlation

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

Plant height showed positive correlation with all characters studied except for pollen fertility.

Internode length, leaf area, number of leaves per plant, days from emergence to maturity of inflorescence, number of spadices per plant per year, candle length, inclination of candle, life of spadix and duration of female phase showed positive correlation with all other characters studied except anthocyanin content and pollen fertility.

Number of suckers per plant showed negative correlation with days to initiation of female phase and pollen fertility and a positive correlation for all other characters studied.

Days from emergence to maturity of leaves showed positive correlation for all the characters except pollen fertility.

Anthocyanin content showed positive correlation with plant height, number of suckers per plant, days from emergence to maturity of leaves, duration of interphase, duration of male phase, pollen fertility and pollen size.

Days to initiation of female phase showed positive correlation for all characters except number of suckers per plant, anthocyanin content and pollen fertility.

Duration of interphase and male phase showed positive correlation for all the characters studied. Pollen fertility showed positive correlation for anthocyanin content, duration of interphase, duration of male phase and pollen size. Pollen size showed positive correlation with all the characters studied.

4.4.3 Environmental Correlation

All the estimates of the environmental correlation coefficients for the characters under the present study were low and insignificant.

4.5 COMPATIBILITY STUDIES

Crossings involving the ten selected female parents and four male parents were done, 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 and

Percentage germination of seed

A total of twenty eight 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

OO x KR-Out of the four possible crosses attempted, only three were successful. The percentage of candles bearing fruits was highest for the crosses (OO x KR) x C and (OO x KR) x A (100 %). In the cross (OO x KR) x H, the percentage was lowest (50 %). The cross (OO x KR) x T was unsuccessful (Table 12).

OO x PR – Two crosses could be attempted and only one was successful. Only the cross (OO x PR) x A set fruit (100 %). The cross (OO x PR) x C was unsuccessful.

PR x FR – Two crosses could be attempted and neither of them were successful.

PR x MW – Three crosses were done and all of them were unsuccessful.

PR x LR - All the possible four crosses could be attempted and all were successful. The highest percentage of success was for this parent with Tropical Red and Honduras (100 %). The lowest percentage was obtained for the cross (PR x LR) x A (50 %).

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

♀ \ ♂	Carre	Acropolis White	Tropical Red	Honduras
OO x KR	5	7	6	6
OO x PR	5	4	-	-
PR x FR	-	4	-	5
PR x MW	4	4	4	-
PR x LR	4	5	7	5
PR x DT	5	4	-	4
W x LJ	-	3	-	4
KR x LR	-	4	6	-
LR x FR	5	4	-	5
FR x KR	5	7	-	5

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

♀ \ ♂	Carre	Acropolis White	Tropical Red	Honduras	Average
OO x KR	100.00	100.00	0.00	50.00	62.50
OO x PR	0.00	100.00	-	-	50.00
PR x FR	-	0.00	-	0.00	0.00
PR x MW	0.00	0.00	0.00	-	-
PR x LR	66.60	50.00	100.00	100.00	79.15
PR x DT	0.00	0.00	-	0.00	-
W x LJ	-	100.00	-	100.00	100.00
KR x LR	-	50.00	100.00	-	75.00
LR x FR	0.00	0.00	-	0.00	-
FR x KR	0.00	100.00	-	0.00	33.33

PR x DT – Three crosses were attempted and none of them were successful.

W x LJ - Two crosses could be attempted and both were successful. Both of them (W x LJ) x A and (W x LJ) x H showed 100 per cent success.

KR x LR – Two of the four possible crosses could be attempted. The cross (KR x LR) x T had higher success percentage (100 %) while the cross (KR x LR) x A recorded only 50 per cent success.

LR x FR – Three crosses could be attempted but none of them were found to be successful.

FR x KR - Out of the four possible combinations only three could be attempted. Only the cross (FR x KR) x A was successful.

Among the 10 female parents, the maximum percentage of candles having fruits was obtained for W x LJ (100.00 %) with two crosses, PR x LR (79.15 %) with all the crosses followed by KR x LR (75.00 %) with two crosses and OO x KR (62.50 %) with three crosses.

4.5.2 Number of Fruits per Candle

The fruit of anthurium is a berry (Plate 6). 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 of fruits per candle obtained in the various crosses are shown in Table 13. The fruit colour varied from yellow to dark red.

OO x KR – Among the three crosses which showed successful fruit set, the maximum number of fruits per candle was obtained for (OO x KR) x C (120) followed by (OO x KR) x H (103) and lowest in (OO x KR) x A (82).

OO x PR – Only the cross (OO x PR) x A was successful and 12 berries were obtained.

No berries were obtained for the crosses PR x FR, PR x MW, PR x DT and LR x FR because the crosses were not successful.

Table 13. Matrix showing average number of fruits per candle

♀ \ ♂	Carre	Acropolis White	Tropical Red	Honduras	Average
OO x KR	120	82	-	103	95
OO x PR	-	12	-	-	12
PR x FR	-	-	-	-	-
PR x MW	-	-	-	-	-
PR x LR	43	51	48	37	45
PR x DT	-	-	-	-	-
W x LJ	-	32	-	21	27
KR x LR	-	62	44	-	53
LR x FR	-	-	-	-	-
FR x KR	-	93	-	-	93

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

♀ \ ♂	Carre	Acropolis White	Tropical Red	Honduras	Average
OO x KR	34.29	23.40	-	29.40	29.03
OO x PR	-	3.20	-	-	3.20
PR x FR	-	-	-	-	-
PR x MW	-	-	-	-	-
PR x LR	10.75	12.75	12.00	9.25	11.19
PR x DT	-	-	-	-	-
W x LJ	-	9.30	-	5.50	7.40
KR x LR	-	17.20	12.20	-	14.70
LR x FR	-	-	-	-	-
FR x KR	-	22.68	-	-	22.68

PR x LR – All the crosses showed successful fruit set of which the cross (PR x LR) x A (51) showed highest number of fruits per candle followed by (PR x LR) x T (48). The lowest was for (PR x LR) x H (37).

W x LJ – Out of the two crosses attempted, (W x LJ) x A (32) had more fruits per candle than (W x LJ) x H (21).

KR x LR – Two crosses were attempted of which (KR x LR) x A had 62 fruits per candle and (KR x LR) x T had 44 fruits per candle.

FR x KR – Only the cross (FR x KR) x A was successful which had an average of 93 fruits per candle.

4.5.3 Percentage of Fruit Set per Candle

The percentage of fruit set per candle for the ten female parents is given below (Table 14 and Plate 5).

OO x KR – The highest percentage of fruit set among the crosses of OO x KR was obtained for (OO x KR) x C (34.29 %) and lowest for the cross (OO x KR) x A (23.40 %).

OO x PR – The one successful cross (OO x PR) x A had 3.2 per cent of fruit set per candle.

PR x LR - Among the crosses of PR x LR, (PR x LR) x A had the maximum percentage of fruit set (12.75 %) followed by (PR x LR) x T (12 %). The lowest was obtained for (PR x LR) x H (9.25 %).

W x LJ – Of the two crosses obtained for W x LJ, higher percentage of fruit set was obtained for the cross (W x LJ) x A (9.30 %) and lower for the cross (W x LJ) x H (5.50 %).

KR x LR – Comparing, the two successful crosses of KR x LR, the cross (KR x LR) x A got more percentage of fruit set (17.20 %) than the cross (KR x LR) x T (12.20 %).

FR x KR - The only successful cross in FR x KR was (FR x KR) x A which had a percentage fruit set of 22.68 per cent.

Among the successful crosses, the highest fruit set was obtained for the cross (OO x KR) x C (34.29 %), Among the ten female parents, the

highest average percentage fruit set was observed for OO x KR (29.03 %) with three crosses, followed by FR x KR (22.68 %) with only one cross. It was lowest for the variety OO x PR (3.20 %).

4.5.4 Duration of Fruit Maturity

The data on the duration of fruit maturity in the 10 female parents is as follows (Table 15).

OO x KR – In OO x KR, all the successful crosses took an average of 3.5 months for the fruits to mature.

OO x PR – The cross (OO x PR) x A took four months to mature.

PR x LR – Among the crosses of (PR x LR), the maximum duration of fruit maturity was seen in the cross (PR x LR) x H (5.5 months). The lowest duration was recorded for the cross (PR x LR) x T (4.5 months).

W x LJ - In the two crosses obtained for W x LJ, (W x LJ) x A took 5.5 months and (W x LJ) x H took five months to mature.

KR x LR – The cross (KR x LR) x A took more time to mature (5 months) when compared to the other crops (KR x LR) x T (4.5 months).

FR x KR – The only one successful cross (FR x KR) x A took 5.5 months to mature.

The time taken for fruit maturity among the ten female parents ranged from 3.5 months in OO x KR to 5.5 months in PR x LR, W x LJ and FR x KR.

4.5.5 Number of Seeds 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).

OO x KR – In OO x KR, the percentage of berries with single seeds was highest for the cross (OO x KR) x H (87.38 %) and the percentage of berries with two seeds was highest in the cross (OO x KR) x C (25.00 %).

OO x PR – All the berries were single seeded in the cross (OO x PR) x A.

PR x LR – Only single seeded berries were produced in the cross (PR x LR) x T. All other successful crosses of PR x LR produced berries with one as well as two seeds, of which the cross (PR x LR) x C produced the highest percentage of single seeded berries (74.42 %). The crosses (PR x LR) x A and (PR x LR) x H had almost equal percentage of single seeded berries (64.71 % and 64.86 % respectively) and two seeded berries (35.29 and 35.14 respectively).

W x LJ – In the two successful crosses obtained for W x LJ, the percentage of two seeded berries was more than the percentage of single seeded berries. The maximum percentage of two seeded berries was obtained for the cross (W x LJ) x A (81.25 %).

KR x LR – Between the two successful crosses of KR x LR, the cross (KR x LR) x T had maximum percentage of single seeded berries (72.73 per cent).

FR x KR – (FR x KR) x A was the only successful cross which had 84.95 per cent of single seeded berries.

4.5.6 Seed Size

The size of 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 and Plate 6).

OO x KR – In OO x KR, the largest seeds in single seeded berries was for the cross (OO x KR) x C (3.75 x 2.90 mm) and in double seeded berries, it was for (OO x KR) x H (3.5 x 2.00 mm). The smallest seeds in single seeded berries was for the cross (OO x KR) x A (3.5 x 2.00 mm) and in double seeded berries in the cross (OO x KR) x C (3.10 x 2.50 mm).

OO x PR – The only one successful cross (OO x PR) x A produced only single seeded berries with a size of 3.75 x 2.50 mm.

PR x LR – Among the four crosses of PR x LR, the largest seeds in single seeded berries was recorded for the cross (PR x LR) x H (4.75 x

Table 15. Data from the hybridisation programme among *A. andreanum* genotypes

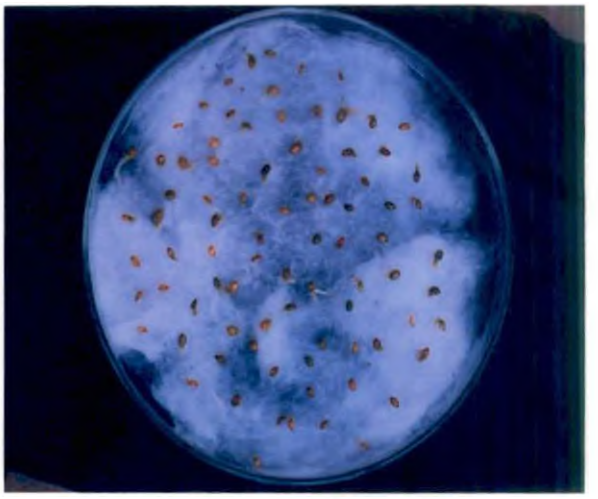
Combination	Duration of fruit maturity, months	Berries with		Berries with single seeds		Berries with two seeds		Number of days for germination
		Single seeds, %	Two seeds, %	Average length, mm	Average width, mm	Average length, mm	Average width, mm	
(OO x KR) x C	3.5	75.00	25.00	3.75	2.90	3.10	2.50	5-7
(OO x KR) x A	3.5	85.37	14.63	3.50	2.00	3.25	1.75	5-7
(OO x KR) x H	3.5	87.38	12.62	3.75	2.30	3.50	2.00	5-6
(OO x PR) x A	4.0	100.00	0.00	3.75	2.50	0.00	0.00	4-9
(PR x LR) x C	5.0	74.42	25.58	4.50	3.00	4.00	2.50	5-8
(PR x LR) x A	5.0	64.71	35.29	4.75	2.50	4.00	2.30	5-7
(PR x LR) x T	4.5	100.00	-	5.00	4.00	0.00	0.00	5-6
(PR x LR) x H	5.5	64.86	35.14	4.75	3.00	4.25	2.50	5-6
(W x LJ) x A	5.5	18.75	81.25	4.75	3.00	4.25	2.50	4-9
(W x LJ) x H	5.0	47.62	52.38	4.50	3.75	4.00	2.50	4-8
(KR x LR) x A	5.0	70.97	29.03	4.50	4.25	3.75	3.50	6-8
(KR x LR) x T	4.5	72.73	27.27	5.00	2.50	4.25	2.25	6-7
(FR x KR) x A	5.5	84.95	15.05	4.50	3.30	4.00	2.90	4-5

(PR x LR) x A

(W x LJ) x H

Plate 5. Fertilized candles of *Anthurium andreanum*

A. Berries and seeds



B. Germinating seeds

Plate 6. Berries, seeds and germinating seeds (9 days after harvest) of the cross (OO x KR) x A

3.00 mm). The cross (PR x LR) x T had only single seeds with the maximum size of 5.00x 4:00 mm. The average size of double seeded berries was 4.08 x 2.43 mm.

W x LJ – The seed size of single seeded berries and double seeded berries for the cross (W x LJ) x A was 4.75 x 3.00 mm and 4.25 x 2.50 mm respectively and that for the cross (W x LJ) x H was 4.50 x 3.75 mm and 4.00 x 2.50 mm respectively.

KR x LR – The seed size of the cross (KR x LR) x A was 4.50 x 4.25 mm for single seeded berries and 3.75 x 3.50 mm for double seeded berries. For the cross (KR x LR) x T, the seed size was 5.00 x 2.50 mm for single seeded berries and 4.25 x 2.25 mm for double seeded berries.

FR x KR - (FR x KR) x A was the only one successful cross obtained which had the seed size of 4.50 x 3.30 mm for single seeded berries and 4.00 x2.90 mm for double seeded berries.

4.5.7 Number of Days for Germination

The data on days for germination of the seeds obtained in various crosses are given below (Table 15).

In OO x KR, the days taken for germination ranged from 5 to 7 days in the various crosses. In OO x PR, the cross (OO x PR) x A took 4 to 9 days for germination. In PR x LR, the number of days taken for germination ranged from 5 to 8 in the different crosses. The crosses of W x LJ took 4 to 9 days for germination. In KR x LR, 6 to 8 days was taken by the seeds to germinate in the two successful crosses obtained. (FR x KR) x A, the only one successful cross obtained for FR x KR took only 4 – 5 days to germinate.

4.5.8 Percentage Germination of Seed

From the harvested berries, seeds were squeezed out and kept on moist cotton in petridishes after removing the sticky pulp around it. Seeds were obtained from 13 crosses (Table 16).

OO x KR – In OO x KR, (OO x KR) x H showed the highest percentage of seed germination (87.30 %). The lowest was for the cross (OO x KR) x A (60.90 %).

OO x PR - The only one successful cross (OO x PR) x A showed a germination percentage of 66.60 per cent.

PR x LR – Among the crosses of PR x LR the germination percentage ranged from 49.00 per cent in (PR x LR) x A to 81.10 per cent in (PR x LR) x H.

W x LJ – In the two crosses of W x LJ, (W x LJ) x H showed 88.9 per cent germination, while the cross (W x LJ) x A showed 78.10 per cent germination.

KR x LR – In KR x LR, the cross (KR x LR) x A showed 88.70 per cent germination while the cross (KR x LR) x T showed 81.80 per cent germination.

FR x KR – The only successful cross of FR x KR, (FR x KR) x A had 77.40 per cent germination.

Among the parents in which successful crosses were obtained, KR x LR showed the highest average percentage seed germination (85.25 %) followed by W x LJ (83.50 %) with two crosses. OO x KR showed an average per centage of seed germination of 77.17 per cent with three crosses and PR x LR with an average of 66.23 per cent with four crosses.

4.5.9 Survival Percentage of Seedlings at Four to Six Months Stage

Out of thirteen combinations that germinated successfully, the seedlings belonging to the cross (KR x LR) x T did not survive beyond four months. Seedlings of the cross (FR x KR) x A showed highest survival percentage (75.26 %) followed by (OO x KR) x C (75.00 %) (Table 17 and Plate 7).

Among the parents, the highest average seedling survival was recorded for FR x KR (75.26 %) in one cross followed by OO x KR (67.20 %) in three crosses and W x LJ (63.83 %) in two crosses. KR x LR showed a low seedling survival of 16.13 per cent.

(PR x LR) x A

(OO x KR) x H

Plate 7. Seedlings of the crosses at four months stage

Table 16. Matrix showing average percentage of seed germination

♀ \ ♂	Carre	Acropolis White	Tropical Red	Honduras	Average
OO x KR	83.30	60.90	-	87.30	77.17
OO x PR	-	66.60	-	-	66.60
PR x FR	-	-	-	-	-
PR x MW	-	-	-	-	-
PR x LR	74.40	49.00	60.40	81.10	66.23
PR x DT	-	-	-	-	-
W x LJ	-	78.10	-	88.90	83.50
KR x LR	-	88.70	81.80	-	85.25
LR x FR	-	-	-	-	-
FR x KR	-	77.40	-	-	77.40

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

♀ \ ♂	Carre	Acropolis White	Tropical Red	Honduras	Average
OO x KR	75.00	60.00	-	66.60	67.20
OO x PR	-	62.50	-	-	62.50
PR x FR	-	-	-	-	-
PR x MW	-	-	-	-	-
PR x LR	46.50	58.80	62.50	59.40	56.80
PR x DT	-	-	-	-	-
W x LJ	-	56.25	-	71.40	63.83
KR x LR	-	32.25	0.00	-	16.13
LR x FR	-	-	-	-	-
FR x KR	-	75.26	-	-	75.26

DISCUSSION

5. DISCUSSION

Anthurium is an ornamental crop of high demand among the cut flower growers. The long lasting nature of the flower is the main attraction despite the gorgeous colours and shades they display. In this part of thesis, first of all an attempt is made to discuss the results obtained after the statistical analysis of 18 characters in 14 genotypes of *A. andreanum*. Then, the results obtained on the cross compatibility studies, the main objective of this work is commented upon.

The 14 varieties under the present study showed significant variation in height ranging from 21.25 cm (Carre) to 44 cm (PR x DT). The six varieties studied by Sindhu (1995) 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 the variety White. The plant height ranged from 22.17 to 64.80 cm among the fifty genotypes studied by Asish (2002).

The present study showed an internode length ranging from 1.20 to 1.48 cm. Plants with short leaf internodes, which give the plant a compact appearance, are preferred (Mercy and Dale, 1994). According to Singh (1987), a desirable anthurium should produce short internodes to limit the height of the plant. Mayadevi (2001) observed that the mean internode length among hybrids ranged from 1.02 to 1.34 cm and in five parents it ranged from 1.00 to 1.52 cm. Asish (2002) observed an average internode length of 1.56 cm. The present studies are in conformation with the above reports.

The ability to produce suckers varied from genotype to genotype. The plant with more number of suckers per plant is an ideal and a very desirable character as it increases plant number and thereby the overall productivity.

In this study, maximum sucker production was seen in the genotype OO x KR (2.25) and lowest in Acropolis White (0.25). The varieties like Carre, Tropical Red, Honduras and W x LJ did not produce suckers at all during the course of study. Propagation of anthurium using suckers is very low because most of the good commercial and hybrid varieties are shy in suckering (Mercy and Dale, 1994). Mayadevi (2001) observed maximum number of sucker production (4) for the varieties Pink and Lady Jane and the least number of suckers for varieties Nitta Orange, Merengue White and Tropical Red. In the study by Asish (2002) most of the genotypes (64 %) had suckers with a range of 1.37 to 2.46 which comes under medium suckering types.

Leaf area showed variation according to the size of the leaf. The leaf area ranged from 113.62 cm^2 in Carre to 301.10 cm^2 in Acropolis White. The genotypes PR x MW, W x LJ, LR x FR, FR x KR, Carre and Honduras has small to medium leaves within a range of 100 to 200 cm^2. Mercy and Dale (1994) opined that the leaves of commercially valuable floral anthuriums should be small to medium sized, narrow and elongated. Large and exuberantly growing leaves are undesirable. Salvi (1997) reported that with decline in shade intensity, leaf area also decreased significantly. Mayadevi (2001) reported that variety Chilli Red had the least leaf area of 66.26 cm^2 followed by variety Kalympong Red (66.92 cm^2). Asish (2002) observed that most of the genotypes had a medium leaf area in between 92.20 to 183.40 cm^2.

The days from emergence to maturity of leaves ranged from 26.25 days in Carre to 40.25 days in PR x DT and the days from emergence to maturity of inflorescence ranged from 29.00 days in Carre to 35.75 days in PR x LR and Acropolis White.

A close correlation between the number of leaves and number of flowers was observed by Gajek and Schwarz (1980). 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 in a plant 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, only 5 to 6 leaves and 5 to 6 flowers can be produced by a plant in a year. Steen and Vigverberg (1973) compared the productivity of 120 individual anthurium plants and found that it ranged between four to sixteen flowers over two years. Mercy and Dale (1994) recorded the annual production as five to eight. The present study was in conformation with the above reports.

Short and slender candles are commercially preferred over long and thick candles. In the present study the genotypes FR x KR (4.63 cm) LR x FR (4.75 cm) and Carre (4.88 cm) had short candles. Mercy and Dale (1994) reported that the candle was long and fleshy in ordinary noncommercial varieties, while it was shorter and more slender in hybrids. The candle length of six varieties studied by Sindhu (1995) ranged from 6.60 to 12.10 cm. According to Mayadevi (2001) the variety Pink had longest candle (12.72 cm) and shortest in the variety Liver Red (7.18 cm). Among the hybrids it ranged from 5.90 to 10.38 cm. 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.

A downward curving candle is an extremely desirable character for commercial anthurium varieties and this helps in packing a larger number of inflorescence in a box during transportation. In this study the genotypes KR x LR (21^0), PR x FR (22.3^0), W x LJ (29^0), OO x KR (30^0), Carre (31^0), PR x MW (32.25^0) showed downward curving candles. The genotype PR x DT showed an angle of 120.75^0 which was not desirable. Mercy and Dale (1994) recommended that ideal anthurium flower should have short candle, curving towards the tip of the spathe and held at an angle less than 45^0. A maximum angle of 75^0 was observed by Sindhu (1995). Mayadevi (2001) noticed that the inclination of candle ranged from 21^0 to 78.2^0 among parents and from 20.80^0 to 89.60^0 among the

hybrids. In the study by Asish (2002) more than 50 per cent of the genotypes had an angle less than 45^0.

In this study, life of spadix varied from 59.5 days in Carre to 101.5 days in PR x DT. Mercy and Dale (1994) observed that it took nearly four to seven months for senescence marked by yellowing of the peduncle and withering of spathe and candle. Sindhu (1995) reported that the life of unfertilized spadix was about 1.5 to 3.5 months while, in fertilized spadices it increased to 4.5 to 8 months. In her study Mayadevi (2001), reported that it varied from 98 days in Chilli Red to 120.4 days in Honeymoon Red among parents, while in hybrids, a wide range from 110.80 days in LR x KR to 126.00 days in HR x KR could be observed. Asish (2002) observed that the life span of spadix varied from 48.33 days in KO x DT to 124.67 days in MO x KR (1).

Initiation of female phase was identified by honeydew secretion on the projected stigmas. It took 2.75 days in OO x KR to 8 days in PR x LR, PR x DT and T for the commencement of female phase. The days to initiation of female phase ranged within a period up to 10 days as reported by Sindhu (1995) with the varieties Honeymoon Red showing the highest period among the six varieties studied by her. The longest period for initiation of female phase was observed in Mauritius Orange and the shortest in Lady Jane Red as observed by Renu (2000). Mayadevi (2001) reported that the initiation of female phase ranged from 4.40 days in Kalympong Red to 6.80 days in Honeymoon Red and Liver Red among the parents, but among the hybrids this character ranged from 3.60 days (HR x KR, P x CR) to 6.20 days (HR x CR). Asish (2002) observed it to range from three to eight days.

Duration of female phase ranged from 5.5 days in Carre to 9 days in Acropolis White. Mercy and Dale (1994) have reported that the number of days of female phase can be recorded based on the exerted stigma, honeydew like secretion or sliminess of the candle when touched and some amount of insect activity on the candle. The duration was reported to

be three to seven days by Mercy and Dale (1994). Mayadevi (2001) observed that the duration of female phase ranged from 7.40 days in Pink to 13.60 days in Kalympong Red among the parents. The hybrids also showed a wide range of variability from 9.60 days (HR x KR, LR x CR and KR x CR) to 12.80 days (HR x LR). It ranged from 3.67 days in OG x KR to 11.30 days in MW x FR (1) as reported by Asish (2002).

The days starting from the drying up of stigmatic droplets to the day before the emergence of pollen is considered as the interphase. It ranged from 4.50 days in Carre to 9.25 days in PR x DT. The genotype W x LJ showed no pollen emergence during the period of this study. So the characters duration of interphase, duration of male phase, pollen fertility and pollen size couldn't be recorded for this genotype. Mercy and Dale (1994) opined that interphase may last for about a week in general. The interphase lasted for 4-10 days as reported by Sindhu (1995). As in the present study, among the 10 varieties studied by Renu (2000), three varieties Pompon Red, Nitta Orange and Midori Green showed no pollen emergence. The rest of the seven varieties showed a range from 4.8 to 10.2 on an average. Mayadevi (2001) observed an interphase of 7.80 days in Chilli Red and 11.20 days in Pink among the parents. In the hybrids it ranged from 9.39 days (HR x CR) to 12.60 days (P x CR). As per the study by Asish (2002), interphase ranged from two days in PR x KR to 11.67 days in MO x KR (2).

The male phase commences after the period of interphase marked by the extrusion of anthers starting from the base of the candle proceeding towards tip of the candle. In the present study it ranged from 6.5 days in Carre to 12.0 days in Honduras. Mercy and Dale (1994) observed that it may last for about four to eight days. Mayadevi (2001) reported that the average number of days for which the candles remained in male phase ranged from five days in Chilli Red to 7.20 days in Honeymoon Red in the parents. Among the hybrids the duration was maximum in P x KR (9.60 days) and minimum in HR x CR (5.60 days). Asish (2002) observed that

it ranged from four days in MW x DT to 12.67 days in MW x PR with a mean of 8.29 days. In the present study it was also revealed that from April to July, the male phase was suppressed in all the genotypes under observation, which is in conformation with the studies by Mercy and Dale (1994), Sindhu (1995), Renu (2000) and Mayadevi (2001).

In the present study, pollen fertility was maximum for Carre (35.70%) and was minimum for PR x DT (9.26%).The low pollen fertility reveals the hybrid nature of the crop. Pollen fertility of 25-30 per cent was noticed in *A. andreanum* by Lalithambika (1978). Satyadas (1985) reported pollen fertility of 20 per cent in *A. warocqueanum*. It ranged from 20.40 to 28.80 per cent as reported by Bindu (1992). They attributed low pollen fertility to high degree of meiotic abnormalities like clumping, lagging of chromosome at anaphase, unequal segregation, precocious disjunction of chromosome, chromosome elimination through micronuclei etc. found in the chromosomes of *A. andreanum*. Mayadevi (2001) in her study with five parents and 10 F_1s observed high pollen fertility for the parent Liver Red (45.90%) followed by Pink (28.40%) where as in hybrids it was highest in HR x LR (34.70%) followed by LR x KR (32.32%). Asish (2002) observed that pollen fertility was high for the genotype LJ x MW (50.80 %) followed by LR x FR (46.17 %).

The size of the pollen grains did not show much variation. It ranged from 22.64 μ (PR x FR) to 28.48 μ (LR x FR). Bindu (1992) also observed that pollen size among the varieties did not vary significantly.

Among the qualitative characters studied, colour of young leaf and petiole varied from brown to reddish brown to green. Mercy and Dale (1994) also observed that 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 leaf from light green to brown.

Spathe colour is one of the most important commercial attributes of anthurium. It is the anthocyanin pigments, that give colour to the spathe. In the present study anthocyanin content varied from 259.18 mg g^{-1} in

Honduras having maroon spathe to 10.09 mg g^{-1} in Acropolis White with white spathe. It was seen that the spathes, which had maroon and red shades, had high content of anthocyanin compared to spathes with paler colours like orange, pink and white. Mercy and Dale (1994) reported that the spathe colours varied from white to pink to coral to orange to brown to red to crimson to deep maroon and some varieties had spathes of two or more bands. Mayadevi (2001) reported that anthocyanins contribute various colours to spathe from deep maroon to light pink. Based on the anthocyanin content, the spathe colour of the parents ranged from deep maroon, dark red, red and pink and in the ten F_1 hybrids, it ranged from deep maroon to dark red to red to dark pink. In the study by Asish (2002), anthocyanin content ranged from 26.81 mg g^{-1} in FR x KR to 710.79 mg g^{-1} in PR x LR (3). The present study is in conformation with the above reports.

The texture of spathe is yet another important character and blistered spathe texture is commercially preferred to smooth spathe. Spathe texture showed variation from thick blistered glossy to medium thick deeply blistered to medium thick blistered to thin smooth glossy in the present study. According to Birdsey (1956) Linden described the spathe of *A. andreanum* based on varying degrees of smoothness and blistering. The spathe of floral anthuriums may be smooth, thick and glossy without prominent veins or it may be thinner, deeply veined and blistered as observed by Mercy and Dale (1994). The spathes showed variation from thick to thin and deep to shallowly blistered in the study in six varieties by Sindhu (1995). Renu (2000) observed 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) and Asish (2002) also spathe texture varied from thick blistered glossy to medium thick deeply blistered glossy to thick smooth glossy to medium thick smooth.

Candles with single as well as double colours were observed in the present study. Different colours like cream (W x LJ, KR x LR, FR x KR, Carre) shades of yellow (PR x MW, LR x FR, Honduras, Tropical Red) and Pink (PR x LR, PR x DT) were seen. In genotypes like OO x KR, OO x PR, PR x FR, Acropolis White, the candle had yellow tip and rest of the portion white. White candles with yellow tip were observed by Gajek and Schwarz (1980). According to Mercy and Dale (1994), candle had a single colour namely red, pink or green in ordinary anthurium varieties and hybrids had yellow, white, pink or red colour in two or more bands. Henny (1999) observed that in anthurium hybrid Red Hot it had a candle, which was orange-red apically blending to red basally. Renu (2000) reported various colours ranging from pink, cream, light yellow, yellow and light green. The candle colour of pink to light pink, yellow to yellowish white to red and cream was observed by Mayadevi (2001). Among the 50 genotypes studied by Asish (2002) colour ranged from red to light red to reddish pink to pink to light pink to pinkish yellow to yellowish white to cream.

Anthurium, being a cut flower crop, the straight nature of inflorescence axis is a character of utmost importance since it affects the overall appearance of the inflorescence. Good anthurium hybrids should have strong and straight inflorescence axis as reported by Mercy and Dale (1994). Desirable inflorescence axis was observed for OO x PR, PR x LR, Acropolis White and Tropical Red. Renu (2000) reported long straight and strong, inflorescence in varieties like Liver Red, Pompon Red, Lady Jane Red, Tropical Red, Mauritius Orange and Merengue White. 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. In the study by Asish (2002), desirable inflorescence axis was exhibited by the genotypes NO x TR, NO x CR, MW x PR, TR x MW, PR x MW and PR x LR (3).

5.2 VARIABILITY COMPONENTS

Variability forms the basis of all plant breeding programmes. From the variable genotypes available, we select the ones, which suit our requirement. The observed variability in a population is the sum of variation arising due to genotypic and environmental effects. The knowledge of genetic variation contributing to gain under selection is essential (Allard, 1960).

The coefficient of variation gives the extent of variation among different quantitative characters. It is a unit free measurement and is used to compare different observations taken in different scales. PCV gives the total variation that can be observed while GCV shows the range of genetic diversity.

In the present study, PCV and GCV values were more for number of suckers per plant, inclination of candle and anthocyanin content. High GCV values indicate high amount of genetic variability and has the possibility of selection. Low GCV values were recorded for internode length, days from emergence to maturity of inflorescence, number of leaves and spadices per plant per year. So selection will not be an effective method to improve these characters.

The difference between PCV and GCV was more for the characters number of suckers per plant, number of leaves and spadices per plant per year. So the influence of environment on these characters is high. The characters leaf area, days from emergence to maturity of inflorescence, anthocyanin content, inclination of candle and life of spadix recorded low difference between GCV and PCV indicating lesser influence of environment.

5.3 HERITABILITY AND GENETIC ADVANCE

For an effective selection it is necessary that members of population on which selection is practiced must vary in their genetic make up with respect to the character under question. It is only the genetically

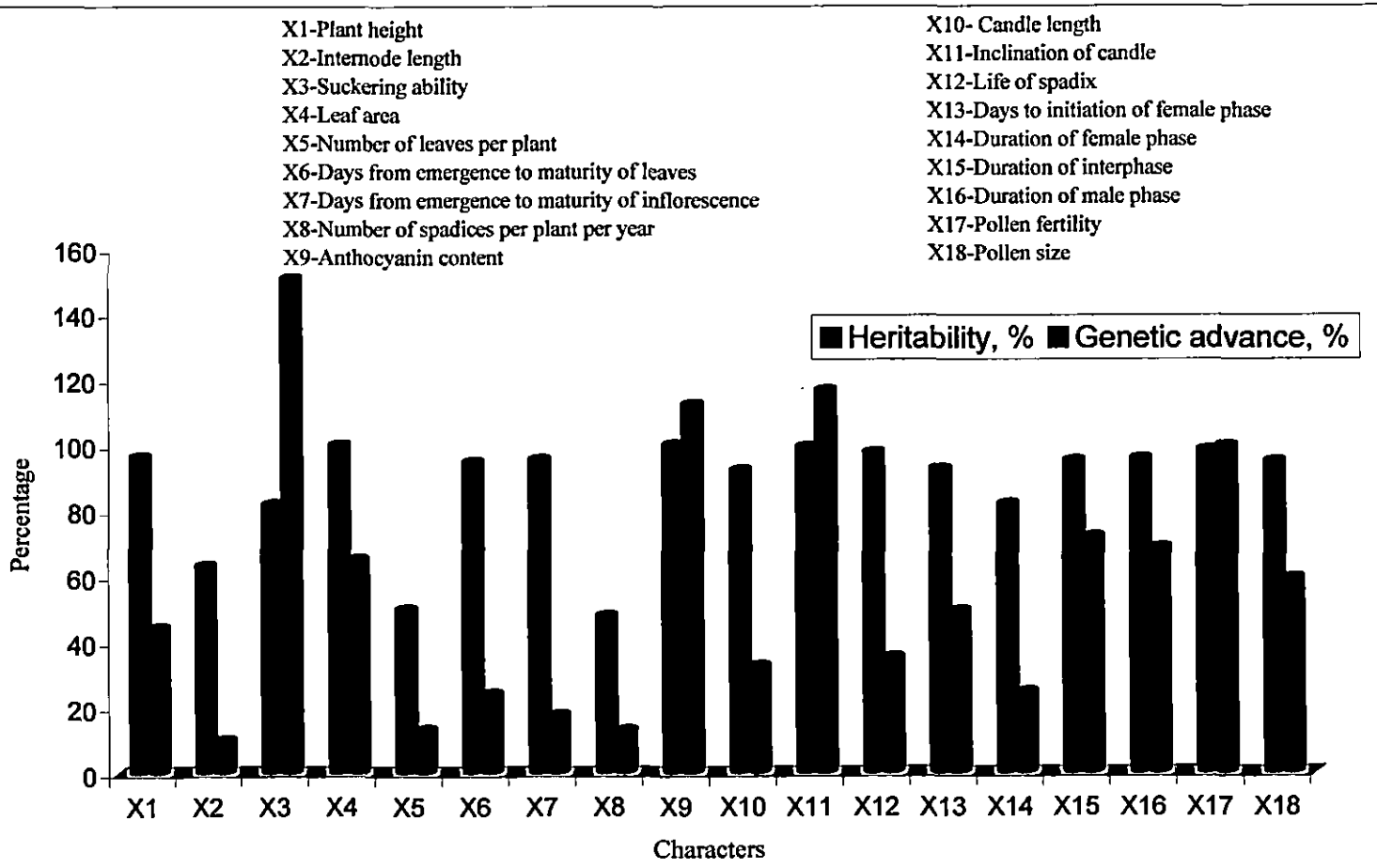


Fig. 2. Heritability and genetic advance for the eighteen characters of *Anthurium andreanum* genotypes

determined variation, which can be utilized for a permanent improvement of the production characteristics in a population. A quantitative measure which measures how much of the total variability existing in a population is caused by differences in the genetic make up of the individuals is the heritability coefficient.

Genetic advance gives information about possibility of improvement in subsequent generations. For successful crop improvement, GA is considered along with heritability. If a character is having high heritability and a high GA, selection will be effective and if GA is low simple selection will not give desired results. Heritability along with GA is more useful than heritability alone in predicting the resultant effect of selecting the best individuals (Johnson *et al.*, 1955).

High heritability and high GA 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). The characters suckering ability, inclination of candle, anthocyanin content and pollen fertility showed high heritability combined with high genetic advance in the present study. So selection will be an effective method in improving these characters (Fig. 2).

Robinson *et al.* (1949) classified GA as percentage of mean into low (< 20 %) and high (> 20 %). According to this classification the characters internode length, number of leaves per plant, days from emergence to maturity of inflorescence and number of spadices per plant per year showed low GA, while it was high for all other characters.

5.4 CORRELATION STUDIES

Correlation coefficient is the statistical measure used to find out the degree and direction of association between two or more variables. Phenotypic correlation is the association between two variables which is directly observed and genotypic correlation shows the heritable association between two variables and it is important to the plant breeder.

The environmental correlation due to environmental effects or error variance is not heritable. The genotypic correlation (inherent) between the characters helps to differentiate the vital association useful in breeding from non-vital ones (Falconer, 1989).

If a positive correlation was 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.

In the present study, the environmental correlation coefficients were not at all significant for the characters studied. This indicates that the effect of the environment is negligible and so whatever variation available is due to the effect of the genes.

Height of the plant showed positive genotypic correlation with all the characters except pollen fertility. The positive correlation of plant height with candle may be attributed to the indirect effect of height resulting through an increase in the number of leaves.

The character, number of spadices per plant per year, showed positive correlation with almost all the characters except anthocyanin content and pollen fertility. So the improvement of this character results in over all improvement of all the characters studied. Candle length showed positive genotypic correlation with position of candle. This is in agreement with observations of Renu (2000). Life of spadix is an important commercial character. It is found to be positively correlated with all characters except anthocyanin content and pollen fertility at genotypic levels. Asish (2002) also observed positive correlation of life of spadix with candle length, number of spadices per plant per year, plant height and duration of female phase. Environmental correlation coefficients were not significant for any of the characters studied.

5.5 COMPATIBILITY STUDIES

Anthurium is a highly cross-pollinated crop. Hybridisation followed by selection is the most common method for improving anthuriums. An interesting fact is that though 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.

Compatibility studies were done by noting down the observations like percentage of candles bearing fruits, number of fruits per candle, 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 (OO x KR) x C, (OO x KR) x A, (OO x PR) x A, (PR x LR) x T, (PR x LR) x H, (W x LJ) x A, (W x LJ) x H, (KR x LR) x T and (FR x KR) x A. Fruit bearing candles were not produced in 15 cross combinations attempted. Among the 10 female parents percentage of fruiting candles was maximum for W x LJ (100.00 %). PR x LR, KR x LR and OO x KR also showed good percentage of fruiting candles. Hybridisation work by Sheffer and Kamemoto (1976) revealed that 81 per cent fruiting spadices was obtained through self pollination, 65.4 per cent through intraspecific crosses and 28 per cent through interspecific crosses .In the study conducted by Sindhu (1995) in six anthurium varieties, White had maximum percentage of fruiting candles (93 %) and the lowest was for Kalympong Red. Renu (2000) observed that selfing and crossing gave 22.50 per cent and 31.06 per cent success respectively in the ten selected *Anthurium andreanum* varieties studied by her.

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 in it. The highest number of fruits per candle

was obtained for the cross (OO x KR) x C (120) followed by (OO x KR) x H (103). The cross (FR x KR) x A also gave good number of fruits. It was lowest for the cross (OO x PR) x A with only 12 fruits. The highest average number of fruits was obtained for OO x KR while OO x PR recorded the lowest number. 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 respectively).

In this study, the percentage of fruit set was below 50 per cent for all the successful crosses. The highest fruit set was recorded by the cross (OO x KR) x C (34.29 %) followed by (OO x KR) x H (29.40). The lowest was for the cross (OO x PR) x A (3.20 %). The average percentage of fruit set was highest for the genotype OO x KR (29.03 %) and lowest for OO x PR (3.20 %). Zimmer (1986) reported that absence of full fruit set is a major problem in the development of *Anthurium* cultivars. While studying six *Anthurium* varieties, Sindhu (1995) recorded highest fruit set per candle for the cross Pink x Honeymoon Red (44.3 %) and lowest for the cross KR x KR (0.4 %). Renu (2000) recorded highest value for fruit set for the cross PR x LR (57.6 %) and lowest for DT x LJ (2.3 %).

In the present study the time taken for the maturation of berries ranged from 3.5 months [(OO x KR) x C, (OO x KR) x A, (OO x KR) x H] to 5.5 months [(PR x LR) x H, (W x LJ) x A, (FR x KR) x A]. In the work done by Sindhu (1995) the duration ranged from 5 to 6.8 months. It ranged from 4 to 7.5 months as reported by Mercy and Dale (1994). Among the ten varieties studied by Renu (2000), the duration ranged from 4.4 months in Lady Jane Red to 6.1 months in Ceylon Red.

The number of seeds per berry was observed as one or two. All the crosses in the present study showed high percentage of berries bearing

single seeds except the two crosses (W x LJ) x A and (W x LJ) x H. Zimmer (1986) reported that the berries contained two or three seeds. Mercy and Dale (1994) had reported that *Anthurium* berries have one or two seeds. In the compatibility studies by Sindhu (1995) and Renu (2000) also, the percentage of single seeded berries reported was more than that of double seeded berries in most of the crosses.

In a berry with two seeds, one of the seeds was usually smaller than the other. In the cross (PR x LR x T), only single seeded berries were present and it had a maximum value. Among the berries with two seeds, the largest seeds were observed for the crosses (PR x LR) x H and (W x LJ) x A. 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.

High percentage of germination (above 80 %) was obtained for the cross (OO x KR) x C, (OO x KR) x H, (PR x LR) x H, (W x LJ) x H, (KR x LR) x A and (KR x LR) x T. For all other crosses it was above 50 per cent except (PR x LR) x A (49 %). In the study by Renu (2000), highest germination percentage was for the cross DT x MW and lowest for MG x LR (6.9 %). In her study, the crosses, DT x LR, MG x CR and MG x MW did not germinate.

In the present study, the number of days taken for germination ranged from four to nine. The maximum number of days was taken by the crosses (OO x PR) x A and (W x LJ) x A. According to Singh (1987) anthurium seeds took six to eight days for germination. Criley (1989) reported that the 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 and it ranged from 3 to 12 days in the study by Renu (2000).

Data on the survival of seedlings at four to six months showed that 12 out of 13 crosses were carried beyond four months. The seedlings of

the cross (KR x LR) x T failed to survive. No cross showed 100 per cent survival. The highest rate was shown by the cross (FR x KR) x A (75.26 %) and lowest by (KR x LR) x A (32.25 %). The same female parents showed highest and lowest average survival percentage respectively. 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 too. Accordingly, the percentage of fruiting candles which ranged from 0 to 100 per cent were divided into four compatibility classes as

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

The percentage of fruit set in the present study ranged from 3.20 to 34.29 per cent. These values were classified as

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

The percentage of seed germination, which ranged from 49.0 to 88.9 per cent, was classified as

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

Thus the crosses of the10 female parents were linearly scored on the basis of percentage of fruiting candles, fruit set and seed germination as shown in the Table 18. It could be gathered from the table that the parents OO x KR and PR x LR got the highest varietal scores. So OO x

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

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

Sl. No.	Crosses	Fruit candles, %	Fruit set, %	Seed germination, %	Total score	Varietal score
1.	(OO x KR) x C	A	A	A	9	
2.	(OO x KR) x A	A	B	B	7	
3.	(OO x KR) x T	D	D	D	0	
4.	(OO x KR) x H	B	B	A	7	23
5.	(OO x PR) x C	D	D	D	0	
6.	(OO x PR) x A	A	C	B	6	
7.	(OO x PR) x T	D	D	D	0	
8.	(OO x PR) x H	D	D	D	0	6
9.	(PR x FR) x C	D	D	D	0	
10.	(PR x FR) x A	D	D	D	0	
11.	(PR x FR) x T	D	D	D	0	
12.	(PR x FR) x H	D	D	D	0	0
13.	(PR x MW) x C	D	D	D	0	
14.	(PR x MW) x A	D	D	D	0	
15.	(PR x MW) x T	D	D	D	0	
16.	(PR x MW) x H	D	D	D	0	0
17.	(PR x LR) x C	B	C	B	5	
18.	(PR x LR) x A	B	C	C	4	
19.	(PR x LR) x T	A	C	B	6	
20.	(PR x LR) x H	A	C	A	7	22
21.	(PR x DT) x C	D	D	D	0	
22.	(PR x DT) x A	D	D	D	0	
23.	(PR x DT) x T	D	D	D	0	
24.	(PR x DT) x H	D	D	D	0	0
25.	(W x LJ) x C	D	D	D	0	
26.	(W x LJ) x A	A	C	B	6	
27.	(W x LJ) x T	D	D	D	0	
28.	(W x LJ) x H	A	C	A	7	13
29.	(KR x LR) x C	D	D	D	0	
30.	(KR x LR) x A	B	C	A	6	
31.	(KR x LR) x T	A	C	A	7	
32.	(KR x LR) x H	D	D	D	0	13
33.	(LR x FR) x C	D	D	D	0	
34.	(LR x FR) x A	D	D	D	0	
35.	(LR x FR) x T	D	D	D	0	
36.	(LR x FR) x H	D	D	D	0	0
37.	(FR x KR) x C	D	D	D	0	
38.	(FR x KR) x A	A	B	B	7	
39.	(FR x KR) x T	D	D	D	0	
40.	(FR x KR) x H	D	D	D	0	7

KR and PR x LR could be judged as the best female parents. The highest score for an individual cross was obtained for (OO x KR) x C. So this cross was the most compatible cross. All those crosses which were carried beyond four months stage showed a linear score of five or more than five except (PR x LR) x A.

SUMMARY

6. SUMMARY

The present study, 'Compatibility studies of three way crosses in *Anthurium andreanum* Linden' was undertaken to evaluate the morphological characters of the 14 selected genotypes of *A. andreanum* and to analyse the compatibility reactions among them. The study revealed tremendous scope for genetic improvement in this crop.

The analysis of variance revealed significant variation among the 18 characters *viz.*, plant height, internode length, suckering ability, leaf area, number of leaves per plant, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, number of spadices per plant per year, anthocyanin content, candle length, inclination of candle, 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.

A study of pollen fertility, estimated using acetocarmine method indicated that most of the genotypes had low fertility values. It ranged from 9.26 per cent in PR x DT to 35.70 per cent in Carre. 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. It was completely absent in the genotype W x LJ during the period under study.

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, inclination of candle and anthocyanin content. This suggests that there is an excellent scope for the improvement of these characters through selection. The characters, leaf area, days from emergence to maturity of inflorescence, anthocyanin content, inclination of candle and life of spadix recorded low difference between GCV and PCV indicating lesser influence of environment.

The characters, leaf area, anthocyanin content and inclination of candle showed high heritability along with high genetic advance. So these characters are controlled by additive gene action and therefore are amenable to genetic improvement through selection.

Correlation studies revealed that plant height was positively correlated with all the characters except number of suckers per plant, anthocyanin content, pollen fertility and pollen size both at phenotypic and genotypic levels. Candle length showed positive correlation with position of candle at both levels. Life of spadix was found to have positive phenotypic and genotypic correlation for all the characters except number of suckers per plant, anthocyanin content and pollen size.

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

Intervarietal hybridisation was done to analyse the cross compatibility between 14 varieties (10 female parents and four commercially important Holland varieties as male parents) based on the percentage of candles bearing fruits, fruit set and seed germination.

A total of 28 crossings were attempted based on the availability of receptive spadices and fresh pollen, out of which 12 were successful.

In almost all the cross combinations the percentage of candles bearing fruits ranged from 50 to 100 per cent. The number of fruits per candle ranged from 12 to 120. The average number of fruits per candle was highest for OO x KR and the lowest for OO x PR. Low percentage of fruit set was found to be a major problem in intervarietal crosses in anthurium. 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 OO x PR and OO x KR respectively.

The berries obtained from different cross combinations took 3.5 to 5.5 months to mature. The shortest period for fruit maturation was for the

genotype OO x KR. The number of days for germination varied from four to nine days in various crosses. The range of four to nine was observed in two crosses (OO x PR) x A and (W x LJ) x A. Most of the crosses had a high percentage of single seeded berries compared to double seeded berries. The seeds obtained from most of the crosses showed a germination percentage of more than 60 per cent. It was lowest in (PR x LR) x A (49.00 %) and highest in (OO x KR) x H (87.30 %).

The seedlings from 12 combinations out of the 13 crosses that germinated, survived for more than four months. The lowest average survival was recorded by KR x LR and highest was recorded for the crosses, FR x LR (with only one cross) followed by OO x KR. The cross (KR x LR) x T did not survive beyond four to six months.

After scoring the different genotypes and crosses obtained on a scale from zero to nine, the cross with the highest compatibility score of nine was (OO x KR) x C and the best genotypes as female parents were OO x PR and PR x LR.

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COMPATIBILITY STUDIES OF THREE WAY CROSSES IN *Anthurium andreanum* Linden

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ABSTRACT

The evaluation of morphological characters and compatibility analysis of 14 selected genotypes was undertaken in the present study titled "Compatibility studies of three way crosses in *Anthurium andreanum* Linden.

The analysis of variance revealed significant variation among the 14 genotypes for the 18 characters studied. This reveals genetic potential for crop improvement.

Variability studies indicated high phenotypic, and genotypic coefficients of variation for the characters internode length, number of leaves and spadices per plant per year and days from emergence to maturity of leaves. The characters with high heritability coupled with high genetic advance values were leaf area, anthocyanin content and inclination of candle indicating additive gene action.

Plant height was found to be positively correlated with number of leaves or spadices per plant per year. Candle length had positive genotypic correlation with position of candle.

Pollen fertility ranged from 9.26 per cent in PR x DT to 35.70 per cent in Carre. Pollen emergence was completely absent in the genotype W x LJ during the course of the study. Pollen production was high in the cooler months of October to December and was suppressed in the months from March to June.

From the cross compatibility analysis, it was seen that the percentage of fruit bearing candles was highest for W x LJ (100.00 %) with two crosses. The cross PR x LR with all the possible four crosses gave a value of 79.15 per cent.

The number of fruits per candle ranged from 12 to 120. OO x KR had the highest average number of fruits per candle and it was lowest for OO x PR.

The percentage of fruit set was below 50 per cent for all the crosses. The crosses involving OO x KR 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 (87.30 %) for the cross (OO x KR) x H.

No cross showed 100 per cent survival beyond four to six months. For PR x LR with all the possible four crosses, the survival percentage was 56.80 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 nine for (OO x KR) x C. The best female parents identified were OO x KR and PR x LR based on the overall performance.