INTERVARIETAL HYBRIDIZATION IN *Anthurium andreanum* Linden

By

RENU R. S.

THESIS

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DECLARATION

I hereby declare that this thesis entitled "Intervarietal hybridization 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 of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,

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RENU R. S.

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Certified that this thesis entitled "Intervarietal hybridization in *Anthurium andreanum* Linden" is a record of research work done independently by Ms. Renu, R. S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
30-9-1999

Dr. S. T. Mercy
(Chairman, Advisory Committee)
Professor
Department of Plant Breeding and Genetics
College of Agriculture, Vellayani
Thiruvananthapuram

APPROVED BY:

CHAIRMAN

Dr. S.T. MERCY

MEMBERS

1. Dr. R. GOPIMONY

2. Dr. P. SARASWATHI

3. Dr. V. L. SHEELA

EXTERNAL EXAMINER

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INTRODUCTION

1. INTRODUCTION

Interest in *Anthurium* as a potential cut flower crop is increasing in India. Anthuriums are relatively easy to grow and under proper conditions, produce long lasting flowers all the year round. Though numerous cultivars with different flower sizes, shapes and colours are available in the international market, cultivars suited for Indian conditions are very few. So at present improved varieties are imported from The Netherlands at very high price for use as planting material and this has reduced the profit margin in the commercial cultivation of this crop. Moreover, this practice will be constrained in the near future due to the forthcoming patent controls and trade restrictions. So evolving improved indigenous cultivars will help to increase the popularity and profitability of *Anthurium* cultivation.

The genus *Anthurium* belonging to the family *Araceae*, is the largest consisting of more than 700 species (Sheffer and Croat, 1983). This genus which comprises about one third of the total number of species in the family *Araceae*, is the most morphologically diverse and taxonomically complex one (Croat, 1980). The name *Anthurium* means tail flower in Greek ('Anthos' = flower and 'aura' = tail). The two species of the genus with commercial importance are *Anthurium andreanum* Linden ('oil cloth flower', 'tail flower' or 'palette flower') and *Anthurium scherzerianum* ('flamingo flower' or 'flame plant'); both of which have magnificent flowers and attractive foliage.

Most anthuriums are native to tropical rain forests of the mid Latin American belt and are primarily epiphytic in nature. The most popular species, *A. andreanum* is a native of South-West Columbia (Singh, 1987). In their

natural habitat, they are epiphytic climbers and receive ample water with good drainage. In cultivation too, anthuriums prefer an evenly moist growing moist medium. They have a long juvenile phase of vegetative growth followed by a generative phase in which flowers are produced (Christensen, 1971).

The present day cultivars of anthuriums are mostly hybrids of different species involving mainly *A. andreanum* and *A. scherzerianum*. There is an abundance of genetic variability in some species of *Anthurium* as revealed by the karyotype analysis and meiotic studies by Lalithambika (1978) and Satyadas (1985). These facts point out the possibility of achieving crop improvement in *Anthurium* through controlled hybridisation and selection.

Hybridisation followed by selection is the accepted method used for improving anthuriums (Kamemoto and Nakasone, 1955). Hybridisation between selected varieties with good combining ability can be used for creating valuable *Anthurium* hybrids with desirable floral characters (Mercy and Dale, 1994). Before undertaking any meaningful hybridisation programme, cross compatibility analysis between selected parents is a pre-requisite.

The present study is undertaken with the aim of analysing the variability and cross compatibility among ten selected commercially superior *A. andreanum* varieties. Intervarietal hybridisation to generate hybrid population with variability in qualities such as plant size, suckering ability, spadix frequency, spathe size, colour and texture was the ultimate objective of this study.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The importance of doing cross compatibility studies before undertaking any hybridisation programme is well known. So, the present study was initiated to analyse the cross compatibilities among ten commercially important varieties of *Anthurium andreanum* through intervarietal hybridization (For this, a total of seventeen morphological characters and six compatibility parameters were analysed). Reported studies in this direction, involving *Anthurium andreanum*, are very few. A review of the works relevant to the study is attempted here.

I. MORPHOLOGICAL STUDIES

Detailed 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.

1. Plant height

Plant height is used for distinguishing between different varieties of crop plants. Tisdale *et al.* (1985) reported that plant height can be used as an index of plant growth.

Heights of *Anthurium andreanum* plants grown on 14 different substrates was studied by Hetman *et al.* (1981), Higaki and Imamura (1988) found that the height of plants decreased with increasing pH up to eight.

In a study on the anthurium cv. 'Hawaiian Red' Salvi (1997) observed that the plant height was significantly superior under 70 per cent shade +

750ppm BA. In another study on the same variety Abdussammed (1999) concluded that nutrient significantly influenced the plant height, both in ground as well as pot planting.

According to Bindu and Mercy (1994) the five varieties studied by them showed significant variation in plant height, ranging from 45 cm in the var. Lady Jane to 85 cm in the var. Pink. Sindhu (1995) recorded the height of six other varieties which ranged from 43 cm to 70 cm.

2. Number of leaves / spadices per year

Higaki and Rasmussen (1979) observed that anthuriums are slow growing producing only six to eight new leaves and vegetative buds on a stem axis per year. They reported that the growth in preflowering stage and flower production can be enhanced by using growth regulators like BA (1000 ppm) and GA (500 ppm).

The monthly patterns of leaf formation in *Anthurium* cultivars was analysed for four years by Klapwijk and Spek (1984) and they found that the average leaf number/m^2 of glass house rose from 1.5 in March to 5 in June, thereafter declining until the following March. Ray (1990) reported that a switch over from monopodial to homeophyllus sympodial growth was common in the genus *Anthurium*. In homeophyllus sympodial growth each renewal shoot produced a fixed number of leaves.

Mercy and Dale (1994) observed that *Anthurium* produced only five to eight new leaves on a stem axis per year and that with each new leaf, a new root also emerged. Salvi (1997) found that 80 per cent shade + 750 ppm BA gave the highest number of leaves.

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

Morphological studies conducted by Chirstensen (1971) showed that *A. andreanum* had a long juvenile phase of vegetative growth followed by a generative phase in which flower buds were produced. A long juvenile phase of 2½ to 3 years upto first flowering has also been reported by Mercy and Dale (1994).

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

On the basis of a study conducted on *A. andreanum* Lind. cv. *ozaki*, Higaki and Poole (1978) concluded that flower production decreased with age of plant.

Voogt (1979) reported that the cut flower yields of *A. andreanum* declined progressively with increase in the salinity of water used for glass house irrigation. Comparison of several materials with peat moss for the production of *Anthurium* flowers, conducted by Rodriquez *et al.* (1979), showed that the plants on bagasse produced the highest number of flowers followed by those on spent ground coffee.

Mercy and Dale (1994) opined that on an average one plant produced

about five to eight spadicies per year, each from the axil of a leaf.

Sindhu (1995) has recorded that the number of spadicies produced annually by an *Anthurium* plant varied from four to eight.

Recent studies by Abdussamed (1999) revealed that the effects of nutrients and growth regulators on interval of flower production was not significant.

3. Spate size : Width + Length

The size of spathe is a commercially important trait of *Anthurium* flowers.

In a study conducted on the effect of different media and fertilizer levels on *A. andreanum* cv. ozaki red, Higaki and Poole (1978) noticed that the flower size increased with age of the plant.

Based on the United States Department of Agriculture Standards, Singh (1987) proposed that *Anthurium* flowers can be graded according to average length and width of spadix as miniature (under 8 cm), small (8-10 cm), medium (10-13 cm), large (13-15 cm) and extra large (15 cm).

Henny *et al.* (1988) recorded that the *Anthurium* cv. 'Southern Blush' had an average spathe length of seven cm. and width of five cm.

In a study of five varieties of *A. andreanum*, Bindu and Mercy (1994) observed the largest spathe size for pink (10.4 x 9.7 cm) and the smallest for Lady Jane (6.5 x 3.5 cm). In a similar study Sindhu (1995) found that the varieties Pink and Kalympong Red produced super large flowers and the smallest flowers were produced in the variety white.

The variety 'Ruth Morat' syn. Lady Ruth had spathes larger that those of Lady Jane, with a mean width and length of 5.01 and 7.68 cm. respectively (Oglesby Plant Laboratory Inc., 1996). Henny (1999) recorded that the new variety Red Hot had six to seven cm long and four to five cm wide spathes.

4. Spathe candle ratio

Bindy and Mercy (1994) recorded that the candle length of five varieties of *A. andreanum* ranged from 4 cm. to 9.5 cm. The candle was long and fleshy in ordinary varieties like Pink, Red and White, while it was shorter and more slender in highly bred hybrids and exotics (Mercy and Dale, 1994).

Among the six *A. andreanum* varieties studied by Sindhu (1995) Kalympong red had the highest spathe-candle ratio (2.86 : 1) and White had the lowest ratio (2 : 1). Henny (1999) recorded that the miniature hybrid 'Red Hot' had a spathe size range of 10 to 12 cm and a candle length of 3 to 4 cm. This means that the Red not hybrid had a spathe candle ratio of 3.3 : 1.

5. Spathe colour

The presence of 3 - cyanidin glycoside and 1-pelargonidin glycoside in the spathes of *A. andreanum* was reported by Forsyth and Simmonds (1954).

Birdsey (1956) recorded that the *A. andreanum* plants offered in the trade have a complete colour range from white to dark red. According to Lowry (1972), spathe of all the cultivars of *A. andreanum* had the presence of both pelargonidin and cyanidin 3-rutinoside.

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 .....".

The anthocyanins in the spathes of *A. andreanum* cvs. were studied by Iwata *et al.* (1979) and they were identified to be cyanidin 3 - rhamnosyl glucoside and pelargonidin 3 - rhamnosyl glucoside. They also analysed the genetics of spathe colour and found that both the pigments were present in the red cultivars Ozaki, Kaumana, Kozohara, Kansako No. 1 and Nakazawa and in the pink cultivar, Marian Seefurth. The orange and coral coloured contained only pelargonidin 3 - rhamnosyl glucoside. In white varieties either pelargonidin pigment or both cyanidin and pelrogonidin pigments are absent.

Maurer (1979) while describing the techniques of cross - pollinating in *A. scherzerianum*, discussed the presence of recessive characters i.e., A = with anthocyanin and a = without anthocyanin, B = whole spathe coloured and b = spotted spathe. When the parents were Aa/Bb, the descendents were 9 red (AB), 2 red spots on white (Abb-) and 4 white (aa B- and aabb).

Iwata *et al.* (1985) inferred 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 dark red colours, whereas a predominance of pelargonidin 3 - rhamnosyl glucoside resulted in coral to orange. Another pigment flavone present in large and variable amounts was characterized; but notdemonstrated to have a modifying effect on cyanic shades.

Henny *et al.* (1988) observed that the *Anthurium* hybrid 'Southern Blush' produced through interspecific hybridisation had a medium pink spathe

with a slight lavender tint.

Based on detailed analysis on the genetics of spahte colours in anthuriums, Kamemoto *et al.* (1988) came to the conclusion that two major genes, M and O were responsible for the five major colours *A. andreanum* : 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 - rutiuoside and gene O controlled that of pelargonidin 3 - rutinoside. Red and pink resulted when both M and O genes are present, and orange and coral resulted when only O gene was present. The double recessive mmoo produced white. The recessive oo was 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 appeared to be 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) classified the clours of the important cultivars and new introductions in Hawaii according to the Royal Horticultural Society colour chart.

Wannakrairoj and Kamemoto (1990) in their study on inheritance of purple spathe in *Anthurium*, proposed a scheme for the genetic control of purple spathe colour. A recessive allele 'p' modified the colour of anthocyanins controlled by M and O loci. They found 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 in dominant or recessive condition.

Mercy and Dale (1994) reported that the colour of spathe fades gradually as flowers get older. After fertilization of candle, the spathe becomes green and photosynthetic.

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

Abdussamed (1999) found that the anthocyanin content of *Anthurium* cv. 'Hawaiian Red' was significantly altered under different levels of growth regulator and nutrient treatments. The highest values for anthocyanin content in ground and pot for nutrient were 85.07 mg/g and 93.90 mg/g respectively, while for growth regulators, the corresponding values were 67.88 mg/g and 84.18 mg/g respectively.

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

6. Spathe texture

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

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

blistered.

Sindhu (1995) noticed 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. Kalympong Red, Kalympong Orange and Chilli Red showed intermediate spathe texture and deep to shallow blisters.

7. Candle colour

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

Arndt (1991) described the *A. scherzerianum* variety 'Arabella' as having red spathe and candle. Observations by Mercy and Dale (1994) revealed that the candle had a single colour red, pink or green in ordinary *Anthurium* varieties and hybrids had yellow, white, pink or red colours in two or more bands.

Studies by Sindhu (1995) on 6 varieties of *A. andreanum* showed that the candle had either a single colour or two or more bands of colours.

The new *Anthurium* hybrid 'Red Hot' is reported to have a candle which is orange - red apically, blending to red basally (Henny, 1999).

8. Position of candle

Arndt (1991) described the *A. scherzerianum* hybrid 'Arabella' as having red spathe with recurving spadix.

Mercy and Dale (1994) observed that in good commercial varieties of *A. andreanum*, the flower bearing candle was attached to the base of the spathe at an angle of 25^0 to 40^0. They also recommended that ideal *Anthurium* varieties should have a short candle, curving towards the tip of the spathe and held at an angle less than 45^0.

In an investigation by Sindhu (1995), the maximum angle of 75^0 between the base of candle to the plane of spathe was observed in the var. Honeymoon Red, which was not desirable. The ideal *Anthurium* spadix with an angle less than 45^0 were found in varieties Chilli Red, Kalympong Orange, Kalympong Red etc.

9. Number of flowers per candle

Watson and Shirakawa (1967) observed that the *Anthurium* 'flower' consisted of a modified leaf, the spathe and a flower spadix with over 300 spirally attached minute flowers. Croat and Bunting (1978) reported that the flowers of *Anthurium* were bisexual and was closely conjested on cylindrical spikes and arranged in a series of spirals on the spadix.

According to Bindu and Mercy (1994), *Anthurium* 'flower' had a candle bearing about 50-150 sessile flowers. Mercy and Dale (1994) reported that *Anthurium* 'flower' was actually an inflorescence termed 'spadix', which is a racemose inflorescence with a slender floral axis (candle) bearing 150 to 350 bisexual sessile flowers in acropetal succession.

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

10. Life of spadix

Paull (1982) recorded the visible changes accompanying the senescence of *Anthurium* flowers as spathe - gloss loss, necrosis of spadix and greening of spathe and spadix. These changes were nonreversible process leading to death of spadix.

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

The life of unfertilized spadix was observed by Sindhu (1995) and it ranged from 1½ months in Kalympong Orange to 3½ months in Honeymoon Red. For fertilized spadices, this period ranged from 4½ - 8 months.

11. Suckering ability

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.

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. *A. andreanum* variety Pink is a profusely suckering variety but the variety is not valuable commercially. Foliar spraying with Gibberellic acid (GA) or Benzyl adenine (BA) (500-1000 ppm) was found to increase sucker

production. Sindhu(1995) noticed the maximum sickening ability in the variety pink and the least for the Kalympong red variety.

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

12. Days to initiation of female phase

Croat (1980) reported that *Anthurium* species generally had maturation of flowers initiated from the basal portion and development proceeds regularly in the direction of the apex. However *A. andreanum* was not included among the protogynous species of Anthurium listed by him.

Studies on five *A. andreanum* varieties by Bindu and Mercy (1994) revealed that, the *Anthurium andreanum* flowers are bisexual and protogynous. Mercy and Dale (1994) observed that the flowers were protogynous and the female reproductive structures or gynoecium reached receptivity about 4-7 days after the opening of the spathe.

In the six varieties studied by Sindhu (1995) the days to initiation of female phase ranged within a period upto 10 days, after opening of spathe, with the variety Honeymoon Red showing the longest period for female phase initiation.

13. Number of days in female phase

Daumann (1921) recorded that the pistllate phase can be discerned by stigmatic droplets which were formed as the stigma becomes receptive.

Croat (1980) noticed that the duration of female phase in *Anthurium* species may range from as short as half a day in *A. ravenii* to 28 days in *A. caperatum* and *A. luteynii*. The female phase varied from three to twelve days in the five varieties studied by Bindu and Mercy (1994). Mercy and Dale (1994) reported that receptive female phase can be detected easily by an experienced eye, as a viscous and colourless exudate is secreted by receptive stigmas at this time which is sticky to touch. Some insect activity also be seen at this time. The receptive female phase lasted for three to seven days.

Sindhu (1995) observed that the duration of female phase ranged from 5-25 days with the variety Chilly Red showing the shortest period. The Kalympong varieties remained in the female phase for the longer periods.

14. Days of interphase

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

Bindu and Mercy (1994) noticed that stigmatic droplets dry up before any stamens emerged out. The interphase for the five varieties studied by them ranged from four to seven days. They found that during rainy season, the

interphase is prolonged or the male phase is completely suppressed. Mercy and Dale (1994) reported that the interphase lasted for about one week in general.

In a study by Sindhu (1995) the interphase in *A. andreanum* was found to range from 4 to 10 days. Prolonged interphase with the suppression of male phase was observed from March to August in several varieties.

15. Duration of male phase

Croat (1980) observed that the initiation of stamen emergence appeared to be equal from all parts of the sapdix or initial maturation and staminal exertion appeared for many flowers in the basal fourth, basal third or basal half of the candle and further development proceeded in a systematic manner. Bindu and Mercy (1994) recorded that the anther exertion started from the base and proceeded regularly towards the apex and the duration of male phase ranged from 3 to 7 days in the five *A. andreanum* varieties studied by them.

According to Mercy and Dale (1994), all the anthers on a candle emerged in about 4-8 days.

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

16. Pollen fertility

Appearance of the pollen alone, even at collection time is not always a good index of viability (Stanley and Linskens, 1974). So pollen fertility is

tested either by using specific stains or by *in vitro* growth studies.

Mitu and Acatrinei (1974) deduced that the germination of pollen grains was proportional to pollen grain stainability.

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

In a pollen fertility study of five varieties of *A. andreanum,* Bindu and Mercy (1994) noticed that pollen fertility ranged from 20.4 per cent in Honeymoon Red to 28.8 per cent in Pink, using the acetocarmine staining method. Pollen fertility assessed using *in vitro* pollen germination method varied from 9.7 per cent in Lady Jane (pink) to 17.9 per cent in Pink. She inferred that the high pollen sterility in *A. andreanum* may be due to its hybrid nature.

17. Pollen emergence pattern

In *Annona reticulata* (Farooqi *et al.*, 1970) and Bhindi (Mishra and Singh, 1988), the anthesis and anther dehiscence are favoured by low temperature of the day. In *A. andreanum,* Sindhu (1995) observed that the interphase was prolonged with the suppression of male phase from March to August. Anthesis occurs on sunny days between 8 to 10 a.m. and on cloudy and rainy days anther dehiscence is delayed (Mercy and Dale, 1994).

COMPATIBILITY STUDIES

Mercy and Dale (1994) suggested that hybridisation between selected varieties of *Anthurium andreanum* should produce valuable and novel hybrids. An evaluation of the compatibility between different varieties is a pre-requisite for undertaking such works.

According to Kamemoto and Nakasone (1955), hybridisation and selection was the most common method for improving anthuriums. They identified that characters to be selected were productivity, flower colour, shape and texture, short internodes and suckering ability. Controlled hybridisation indicated that neither white nor red flower colour exhibited dominance and pink was an intermediate hetrozygous condition.

A general mode of spathe colour inheritance in *A. andreanum* was suggested by several workers based on intraspecific and interspecific hybridisation (Kamemoto and Nakasone, 1955, '63; Kamemoto, Nakasone and Arajaki, 1969; Sheffer and Kamemoto, 1977).

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

Selection has been widely used as a method to develop suitable cultivars in the major Anthurium producing countries. Of 113 clones evaluated by Kamemoto and Nakasone (1963), 13 were recommended for commercial cutflower production. Two cultivars Uniwai (an exceptionally high yielding

white) and Marian Seefurth with a rose coloured spathe were evolved by clonal selection. They also postulated that the inheritance of spathe colour was under the control of multiple alleles and modifying genes. The presence of both the orange and magenta pigments in the pink cultivar, 'Marian seefurth', which arose from a cross between a white clone and a pink clone, substantiates the hypothesis that separate genes designated as M and O are responsible for the production of magenta and orange pigments respectively.

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

Sheffer and Kamemoto (1976) evaluated the interspecific cross compatibilities among 56 species of *Anthurium* and 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.

Good cross compatibility between *A. andreanum, A. concinnatum, A. hoffmani, A. lindenianum, A. micromysterium, A. nymphaefolium* and *A. pinchinchae* was recorded by Sheffer and Kamemoto (1977). Using this they developed some cultivars, all of which successfully flowered.

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

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

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

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

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

Henny *et al.* (1988) obtained 'Southern Blush', a hybrid for foliage producers through interspecific hybridization of a large pink-flowered *A. andreanum* cv. with *A. amnicola* (a dwarf species collected in Costa Rica, which is very

floriferous but bears small lavender spathes rarely more than 2 cm long). 'Southern Blush' was intermediate in size between its parents, spathes were about 7.0 cm long and 5.0 cm wide and are a medium pink with a slight lavender tint.

Kamemoto *et al.* (1988) explained that the five major spathe colours in *A. andreanum* : red, orange, pink, coral and white, are controlled by two major genes M and O. They found that crosses between two pink produced offspring in the ratio of 9 red to pink : 3 orange to coral; 4 white. They concluded that coral was hetrozygous for 0 and recessive for m. Crosses between two corals gave 3 orange to coral : 1 white. Pink crossed to a coral can be expected to give a ratio of 3 red to pink : 3 orange to coral : 2 white. Pink crossed to a double recessive white gave 1 red to pink : 1 orange to coral : 2 white. Based on these observations they gave the genotypes of major colours as MMOO, MMOo and MmOO for red, MmOo for pink, mmOO for orange, mmOo for coral and MMoo, Mmoo and mmoo for white. So, orange and white types breed true.

Henny (1989), while studying the development, testing and release of new ornamental aroid cultivars, opined that the studies of factors affecting the flowering, pollination, seed set and genetics of ornamental tropical aroids made possible the development of new *Anthurium* hybrids suitable for use as indoor foliage plants. Hybrids selected for greenhouse tests were asexually propagated from cuttings or by tissue culture. Hybrids selected for release were propagated by tissue culture and distributed.

According to Arndt (1991) 'Arabella', a German *A. scherzerianum*

variety was developed in a breeding programme between 1979 and 1985. It was a compact, early flowering, medium sized plant with dark green, short leaves and red spathe and spadix.

Marutani *et al.* (1993) did the detailed cytological analysis of *A. andreanum*, its related taxa and their hybrids. They concluded that regular bivalent formation at prometaphase 1 of meiosis in pollen mother cells of species hybrids suggested close genomic relationships among parental taxa. On the other hand, reduction in pollen fertility estimated by the pollen stainability in those hybrids suggested genetic divergence of spices.

Mercy and Dale (1994) suggested the use of hybridisation between selected varieties with good combining ability to produce novel and valuable *Anthurium* hybrids. They added that a commercial variety should have small to medium sized leaves, extensive root system, short internodes, strong and straight inflorescence axis, medium sized spathe with deep wrinkles and short, thin and downward curving candles.

Bindu and Mercy (1994) worked out the karyotype of five commercial *Anthurium* varieties and found that all of them had a somatic chromosome number of $2n = 30 + 2B$. They observed a wide range of meiotic abnormalities, morphological variations, karyotypic differences, high pollen sterility and stomatal characters and concluded that all these points to the hybrid nature of the species.

Kuehnle *et al.* (1995) made attempts to transfer systemic resistance to bacterial a pathogens from *A. antioquiense* to cultivated *A. andreanum* and got resistant F_1 hybrids. They concluded that production of hortiuclturally

desirable varieties take many years because it is a perrnial crop, with a long juvenile stage (two to three years) and slow seed germination (six months). As the genetics of the available resistance was not properly understood, resistant cultivars which were properly understood, resistant cultivars which were released soon became susceptible to blight.

Sindhu (1995) analysed the cross compatibility among six *A. andreanum* varieties viz. Honeymoon Red (HR), Chilli Red (CR), Kalympong Orange (KO), Kalympong Red (KR), Pink (P) and White (W). A large number of combinations were incompatible. Among the 24 surviving crosses which reached flowering stage, the highly compatible crosses were HR × P and P × HR. The cross combinations, HR × CR, HR × KR, CR × W, KR × P, P × P and W × KR exhibited medium fruit set and high germination. The cross combinations that showed incompatibility were KO × KR, CR × HR, CR × P, W × CR, KR × KR and W × KO.

Oglesby Plant Laboratory Inc. (1996) described a variety 'Ruth Morat' syn. Lady Ruth as a derivative from the cross *A. antioquiense* × Rotolante 1. This hybrid had spathes larger than those of Lady Jane, with a mean width and length of 50.1 and 76.8 mm, respectively. Anthura (1997), submitted for registration, a variety 'Champion', derived from *A. andreanum* hybrids. This variety had small leaves and flowers with cupped white spahte held above the canopy and red spadix.

Henny (1999) described the new interspecific *Anthurium* hybrid 'Red Hot' as highly suitable for pot planting because of its compact growth, freely branching growth habit and production of numerous showy red spathes. 'Red

Hot' originated from hybridisation of *A. amnicola* Dressler, a dwarf species with small lavender spathes and a naturally clumping growth habit, with an unnamed selection of *A. andreanum* (accession code G-79) that had pink spathes. One of the resulting F_1 hybrids was designated as the female parent and crossed with *Anthurium* x 'Lady Jane' to produce the progeny, from which 'Red Hot' was selected. 'Lady Jane', according to Kamemoto and Kuehnle (1996) was an interspecific hybrid with *A. antioquiense* Engler in its background; however, its exact origin was unknown.

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

1. Percentage of candles bearing fruits

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

Eighty one per cent fruiting spadices were obtained through self pollination, 65.4 per cent through intraspecific crosses and 28 per cent through interspecific crosses. Higher percentage of fruiting spadices were got from Group II, III and V than the groups I, IV and VI. The range of chromosome numbers found in the species included in group I may be the reason for the low percentage of hybrids in this group. The presence of B-chromosomes was found to affect the viability (Bhattaglia, 1964; Sheffer and Kamemoto, 1976).

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

All the six varieties evaluated by Sindhu (1995) viz. Honeymoon Red, Chilli Red, Kalympong Orange, Kalympong Red, Pink and White, showed good percentage of candles bearing fruits. This percentage was maximum for the variety white (93 per cent) and lowest for the variety Kalympong Red (50 per cent).

2. Number of fruits/candle

Zimmer (1986) studied the problems in the development of *Anthurium*

cultivars and identified the absence of full fruit set in spadix as a major one. He added that the period of 5 - 12 months taken for fruit ripening also was an impediment.

Based on their attempts to transfer resistance to bacterial pathogens from *A. antioquiense* to cultivated *A. andreanum*, Kuehnle *et al.* (1995) concluded that production of horticulturally desirable varieties took many years since it is a perennial crop, with a long juvenile phase (two to three years) and slow seed germination (six months).

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

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

3. Percentage of fruit set / candle

Based on cross compatibility studies using six varieties, Sindhu (1995), recorded that the maximum percentage fruit set was observed for the cross P x HR (52.3 per cent) followed by HR x P (44.3 per cent). The lowest percentage fruit set was observed in the cross KR x KR (0.4 per cent).

4. Number of seeds / berry

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

Pierik *et al.* (1974) opined that breeding of *A. andreanum* was handicapped by the long period from fertilization to ripening of seeds (6-7 months). Geir (1989) also recorded that the time required for seed maturity was about 6 - 7 months for *A. andreanum* and 10-12 months for *A. scherzerianum*.

According to Mercy and Dale (1994) in the commercial varieties of *A. andreanum*, each berry contained one or two seeds and the seeds matured in about 4 - 7½ months. Seeds remained enclosed within the thin fruit wall in a gelatinous pulp and if not harvested, remained attached to the candle for a few days more before they dried up and fell off the candle.

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

5. Seed size

In the six varieties studied by Sindhu (1995), the berries were usually single seeded and sometimes double seeded. When two seeds were seen in a

berry, usually one of them was smaller than the other. Pink and Honeymoon Red varieties produced larger sized seeds and the Kalympond varieties produced comparatively smaller sized seeds.

6. Percentage of germination of seed

Based on seed germination studies in *A. scherzerianum* hybrids, Bachthaler (1977) concluded that, the fresh seeds germinated in light or darkness at 10-35^0 C with an optimum at 20 - 25^0 C in light, when germination occurred after 5-7 days. After drying and stroing at 20^{0}C for 24 h, germination under favourable conditions was 70 - 75 percentage.

In another study by Bachthaler (1978), seeds extracted from (1) green (unripe), (2) reddish (half-ripe), (3) red (ripe) or (4) reddish brown (over ripe) berries were placed in petridishes on damp, sterile sand and kept at 25^0 C in 12 h light (about 1200 lux). The first three groups showed 100 per cent germination, but group four only 42 per cent. Group two and three were the first to germinate and were the most suitable for commercial seed production.

While studying the storage of seeds of *A. scherzerianum* hybrids, Bachthaerler (1979) observed that the best storage temperature was 10^{0}C and after about 6 weeks 60 per cent of the seeds germinated. Of seed from berries treated with thiram dust before storage, 95 per cent germinated after 12 weeks at 10^{0}C and 60 per cent after 16 weeks.

Szendel *et al.* (1982) germinated the seeds of *A. andreanum* harvested at three maturity stages and those of *A. scherzerianum* at one maturity stage (light orange) on three substrates, at pH ranging from 4 to 8 in light or

darkness at 18, 24 or 28^{0}C. In *A. andreanum*, the best germination was obtained on a high peat substrate, at pH 4-5 in light at 28^{0}C using seeds harvested at an early maturity stage (yellow green to light orange).

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

Giley (1989) observed that, in *Anthurium*, the pulp was removed from ripe berries in water, and the seed was sown immediately on the surface of a damp medium and placed under 80 per cent shade and high humidity. The germination was completed within 14 days.

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

Among the six varieties studied by Sindhu (1995), the maximum average germination was observed in combinations with the variety White as the female parent (63.4 per cent) and the lowest germination in the variety Kalympong Orange. Highest germination percentage among the crosses was recorded for the cross Honeymoon Red x Chilli Red (78 per cent).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 1997-'99 was aimed at hybridisation between ten selected varieties of *Anthurium andreanum* Linden to produce novel hybrids.

MATERIALS

The following ten commercially important *Anthurium* varieties, showing variations in spathe colour, shape and size and other commercially valuable morphological characters were selected for the study from the germplasm available in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani.

1. Liver Red (LR) (Plate 1)
2. Dragon's Tongue Red (DT) (Plate 2)
3. Pompon Red (PR) (Plate 3)
4. Lady Jane Red (LJ) (Plate 4)
5. Ceylon Red (CR) (Plate 5)
6. Tropical Red (TR) (Plate 6)
7. Mauritius Orange (MO) (Plate 7)
8. Nitta Orange (NO) (Plate 8)
9. Midori Green (MG) (Plate 9)
10. Merengue White (MW) (Plate10)

Plate 1. ***Anthurium andreanum*** **var. Liver Red**

Plate 2. ***Anthurium andreanum*** **var. Dragon's Tongue Red**

Plate 3. ***Anthurium andreanum*** **var. Pompon Red**

Plate 1

Plate 2

Plate 3

METHODS

The ten selected parent varieties were raised as pot culture experiment under completely randomised design. 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, coconut husk and charcoal mixed in 7 : 1 : 1 : 1 ratio respectively. Plants with well developed roots were placed over this and the plants anchored with more potting mixture. Coarse sand was used as a filler. The potting materials used and the method of planting ensured good drainage.

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

Regular applications of fertilizers were given at weekly intervals. NPK mixture 17 : 17 : 17 was applied at a strength of 5 gm/l as aqueous solution. Once in a month, additional nutrients like diluted cowdung water and fermented and diluted groundnut, neemcake mixture were also given. For this, 1 kg neem cake and 1 kg groundnut cake were fermented in 5 l water for two days. The mixture was then diluted by adding 45 l very dilute cowdung water. Half a litre of clear supernatant solution was then applied to each pot.

PLANT PROTECTION

1. For the control of blight/anthracnose caused by *Colletorichum gloeosporioides* regular applications of the following chemicals were undertaken :

a. Bavistin 50 % WP @ 2 g / litre or

b. Dithane M-45 @ 2 g / litre

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

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

4. Need based applications of metacid (2 g/l) or Nuvacron (2g/l) were given to control leaf feeding caterpillars and grass hoppers. Mites were controlled using Kelthane (3 ml/l).

5. Snales and slugs were controlled by picking by hand and also by the application of Furadan 3G @ 2-3 ga/pot.

MORPHOLOGICAL STUDIES

Observations on the following 17 morphological and floral characters were recorded and their mean values were taken.

1. Plant height

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

2. Number of leaves/spadices per year

The number of leaves/spadices produced during the one year period from June, 1998 to May 1999 was observed and recorded.

Plate 4. ***Anthurium andreanum*** **var. Lady Jane Red**

Plate 5. ***Anthurium andreanum*** **var. Ceylon Red**

Plate 6. ***Anthurium andreanum*** **var. Tropical Red**

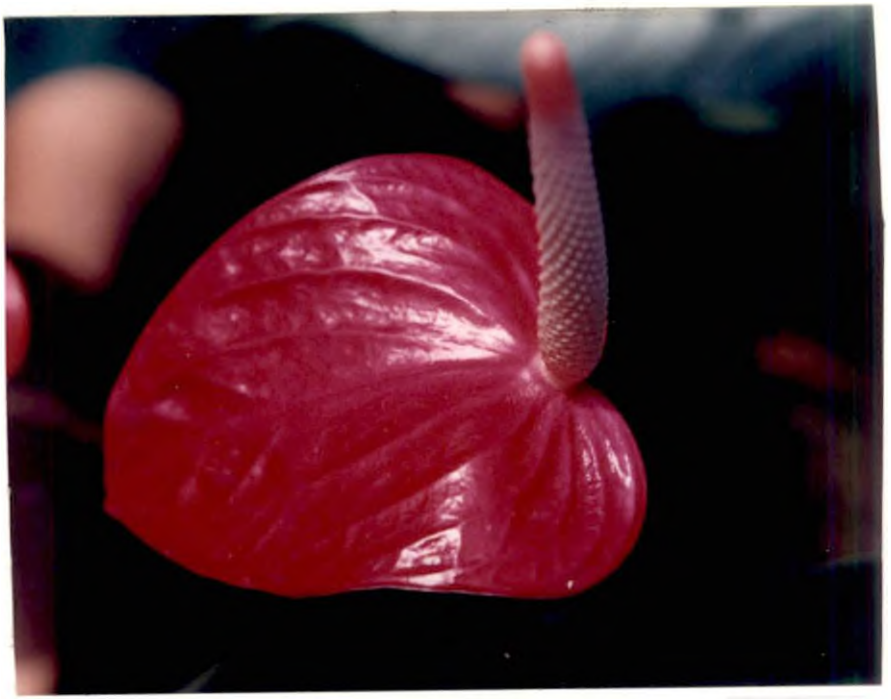


Plate 4

Plate 5

Plate 6

3. Type of inflorescence axis

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

4. Spathe size : Width + Length

The width and length of the spathe in centimeters, were added and recorded as the spathe size.

5. Spathe - candle ratio

This was calculated as the ratio of the mean value of spathe size to that of the length of the candle.

6. Spathe colour

The spathe colour of each variety was recorded after visual observation.

7. 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 variety.

8. Candle colour

Visual observation was used to record the candle colours.

9. Position of candle

The angle between the base of the candle and the plane of the subtending spathe was taken and recorded.

Plate 7. ***Anthurium andreanum*** **var. Mouritius Orange**

Plate 8. ***Anthurium andreanum*** **var. Nitta Orange**

Plate 9. ***Anthurium andreanum*** **var. Midori Green**

Plate 10. ***Anthurium andreanum*** **var. Merengue White**

Plate 7

Plate 8

Plate 9

Plate 10

10. Number of flowers per candle

The total number of flowers arranged spirally on the candle from the base to the tip were counted and recorded for each variety.

11. Life of spadix

The period between the first day of emergence of the spathe and the time of yellowing of inflorescence axis withering of spathe and shrivelling of candle was recorded as the life of spadix.

12. Suckering ability

The ability of the plant to produce new suckers from the base of the mother plant was observed and recorded as either low, medium or high.

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 honeydew or stigmatic droplets was recorded as the days to inhibition of female phase.

14. Number of days in female phase

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

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.

16. Duration of male phase

The period in days taken for the emergence of anthers from the basal flowers to the top most flowers in a candle was recorded as duration of male phase.

17. Pollen fertility

Pollen fertility was assessed using acetocarmine staining method. Pollen grains were collected during the male phase from all the 10 varieties and stained with 1 : 1 glycerine-acetocarmine stain (2 per cent). Five slides were made for each variety and from each slide, ten microscopic fields were scored and the data recorded. Unstained, undersized, partially stained and shrivelled pollen grains were scored as sterile and the uniformly stained, properly filled pollen as fertile. Fertility of each variety was estimated as percentage of the number of fertile pollen grains to the total number of pollen grains scored.

The pollen fertility was calculated as,

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

II Compatibility studies

The data from the intervarietal hybridisations using the ten selected varieties was used for compatibility analysis. Hybridisation in all the possible combinations using these varieties were carried out and the compatability was analysed using the percentages of fruit set, seed set and seed germination.

Table 1 Matrix showing the 100 possible cross combinations

♀ \ ♂	LR	DT	PR	LJ	CR	TR	MO	NO	MG	MW
LR	LR×LR	LR×DT	LR×PR	LR×LJ	LR×CR	LR×TR	LR×MO	LR×NO	LR×MG	LR×MW
DT	DT×LR	DT×DT	DT× PR	DT× LJ	DT× CR	DT× TR	DT×MO	DT×NO	DT×MG	DT×MW
PR	PR×LR	PR×DT	PR× PR	PR× LJ	PR× CR	PR× TR	PR×MO	PR×NO	PR×MG	PR×MW
LJ	LJ×LR	LF×DT	LJ× PR	LJ × LJ	LJ× CR	LJ × TR	LJ ×MO	LJ×NO	LJ×MG	LJ×MW
CR	CR×LR	CR×DT	CR× PR	CR× LJ	CR× CR	CR× TR	CR× MO	CR× NO	CR × MG	CR× MW
TR	TR×LR	TR×DT	TR× PR	TR× LJ	TR× CR	TR× TR	TR×MO	TR×NO	TR×MG	TR×MW
MO	MO×LR	MO×DT	MO× PR	MO× LJ	MO× CR	MO×TR	MO×MO	MO×NO	MO×MG	MO×MW
NO	NO×LR	NO×DT	NO× PR	NO× LJ	NO× CR	NO× TR	NO×MO	NO×NO	NO×MG	NO×MW
MG	MG×LR	MG×DT	MG× PR	MG× LJ	MG× CR	MG×TR	MG× MO	MG×NO	MG×MG	MG×MW
MW	NW×LR	MW×DT	MW×PR	MW× LJ	MW×CR	MW×TR	MW×MO	MW×NO	MW×MG	MW×MW

HYBRIDISATION TECHNIQUE IN ANTHURIUM

Individual flowers of *Anthurium andreanum* is bisexual, but they show a clear protogynous nature. 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 pollination. When the female phase started as indicated by the maturity of lower flowers, pollen was collected from the male parent and brushed on to the candle of female parent. This was done in the morning hours as the anthesis occurred between 8 and 9 a.m.

Repeated pollinations were done over a period of 5 to 7 days and the spadix was kept-bagged for one more month. Each pollinated spadix was clearly labelled showing the cross and the data of crossing.

1. Percentage of candles bearing fruits

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

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

2. Number of fruits/candle

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

3. Percentage of fruit set/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.

4. Number of seeds/berry

The number of seeds in each ripe berry was recorded.

5. Seed size

The length and breadth of seeds were measured in millimeters and recorded. In berries with two or more seeds separate measurements were taken for each seed.

6. Percentage 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 germination was done in full shade. The number of seeds that germinated was noted and percentage of germination calculated as,

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

STATISTICAL ANALYSIS

1. Analysis of variance and co-variance

Analysis of variance and co-variance were done to test the varieties with respect to various traits and to estimate the variance components and other genetic parameters like correlation coefficient, heritability, genetic advance etc. (Singh and Choudhary, 1979). Table 2 represents the analysis of variance and co-variance.

From this table other genetic parameters are estimated as follows :

	X	Y
Environmental variance	$(\sigma^2_e) = \sigma^2_{ex} = E_{xx}$	$\sigma^2_{ey} = E_{yy}$
Genotypic variance	$(\sigma^2_g) = \sigma^2_{gx} = \frac{G_{xx} - E_{xx}}{r}$	$\sigma^2_{gy} = \frac{G_{yy} - E_{yy}}{r}$
Phenotypic variance	$(\sigma^2_p) = \sigma^2_{px} = \sigma^2_{gx} + \sigma^2_{ex}$	$\sigma^2_{py} = \sigma^2_{gy} + \sigma^2_{ey}$

Table 2 Analysis of variance / covariance

Source	df	Observed mean square XX	Expected mean square XX	Observed mean sum of products XY	Expected mean sum of products	Observed mean square YY	Expected mean square YY
Block	(r-1)	B_{xx}		B_{xy}		B_{yy}	
Genotype	(v-1)	G_{xx}	$\sigma^2ex + \sigma^2gx$	G_{xy}	$\sigma exy + r\,\sigma gxy$	G_{yy}	$\sigma^2ex + ro^2gx$
Error	(v-1) (r-1)	E_{xx}	σ^2x	E_{xy}	σexy	E_{yy}	σ^2ey
Total	(rv-1)	T_{xx}		T_{xy}		T_{yy}	

Hence we have the following estimate

$\sigma^2g\,(x) = (G_{xx} - E_{xx}) / r$ $\qquad$ $\sigma^2ex = E_{xx}$

$\sigma^2g\,(y) = (G_{yy} - E_{yy}) / r$ $\qquad$ $\sigma^2ey = E_{yy}$

$\sigma g\,(xy) = (G_{xy} - E_{yy}) / r$ $\qquad$ $\sigma e\,(xy) = E_{xy}$

Heritability (broad sense) $H^2 = \frac{\sigma^2_{gx}}{\sigma^2_{px}}$ (Jain, 1982)

Genetic advance as percentage of mean = $\frac{k\, H^2\, \sigma^2_{px}}{\overline{x}} \times 100$

[Where k = selection differential = 2.06 at 5 per cent selection]

(Miller *et al.*, 1958)

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

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

Genotypic coefficient of variation (GCV) = $\frac{\sigma_{gx}}{\overline{x}} \times 100$

Phenotypic coefficient of variation (PCV) = $\frac{\sigma_{px}}{\overline{x}} \times 100$

7. Analysis of the pollen emergence pattern in the ten varieties

Pollen emergence of the ten varieties in each month, from August, 1998 to July, 1999, was recorded. The Cochran Q Test as given by Siegal and Castellan (1988) was applied to this data to find out the equality of proportions.

a) A score of '+' was assigned to each "success" of pollen emergence and a score of '–' was assigned to each "failure" of pollen emergence.

b) The scores were cast into a N x K table, where N is the number of months and k is the number of varieties.

c) The value of Q was determined using the equation

$$Q = \frac{p(p-1)\left[\Sigma C_j^2 - \frac{(\Sigma C_j)^2}{p}\right]}{p\,\Sigma R_j - \Sigma R_j^2}$$

Where Q is distributed approximatesly as λ^2 with $d_f = k - 1$.

C_j = total number of '+' in i^{th}column

R_j = total number of '+' in i^{th} column

The significance of computed Q value was tested with reference to the λ^2 table (Panse and Sukhatme, 1957).

RESULTS

4. RESULTS

The experimental data were collected on various morphological characters of the ten varieties selected for the present study. The data were statistically analysed and the results obtained are presented here.

A. MORPHOLOGICAL STUDIES

1. Mean performance of individual traits

The mean performance of each of the ten *Anthurium andreanum* varieties for the twelve characters under study are furnished in Table 3. The analysis of variance, revealed significant differences among the ten varieties for all the characters studied.

The highest mean plant height was recorded by the variety Pompon Red (70.9 cm) which was on par with Liver Red (65.34 cm) and Mauritius Orange (63.82) cm). Midori Green (29.7 cm) recorded the lowest mean value for height. The varieties Merengue white (34.94 cm) and Tropical Red (37.16 cm) were on par with Midori Green.

For the character number of leaves or spadices per year, the maximum value of 7.6 was exhibited by Lady Jane Red, which was on par with Liver Red and Pompon Red. Merengue white (4.8) recorded the lowest number of leaves or spadices per year. The varieties Tropical Red, Mauritius Orange and Nitta Orange were on par with Merengue white.

Spathe size was observed to be the highest in Dragon's Tongue Red (30.74 cm), which was on par with Midori Green (26.90 cm). The lowest

Table 3 Mean values of twelve quantitative characters in *A. andreanum* Linden

Sl. No.	Varieties	Plant height (cm)	No. of leaves or spadicies per year	Spathe size : width + length (cm)	Candle length (cm)	Spathe - candle ratio	Position of candle	No. of flowers per candle	Life of spadix (months)	Days to initiation of female phase	No. of days in female phase	Days of interphase	Duration of male phase
		1	2	3	4	5	6	7	8	9	10	11	12
1.	Liver Red	65.34	6.8	19.80	6.66	2.94	61^0	360	3.15	5.8	11.2	10.20	5.6
2.	Dragon's Tongue Red	58.12	6.2	30.74	8.02	3.58	66^0	366	2.90	4.4	12.8	8.39	7.4
3.	Pompn Red	70.90	6.6	17.12	6.80	2.54	35^0	444	2.65	6.6	10.8	-	-
4.	Lady Jane Red	46.20	7.6	18.20	6.50	2.64	71^0	450	2.65	3.6	6.4	6.80	6.6
5.	Ceylon Red	50.56	6.4	21.26	7.18	2.90	44^0	420	3.65	4.0	10.4	9.80	7.6
6.	Tropical Red	37.16	5.2	17.48	5.74	3.12	37^0	254	2.80	4.8	10.2	5.80	10.4
7.	Mauritius Orange	63.82	5.4	22.62	6.00	3.12	38^0	416	2.95	6.8	16.4	7.60	5.4
8.	Nitta Orange	41.86	5.8	23.54	5.86	3.96	43^0	324	2.50	6.6	10.6	-	-
9.	Midori Green	29.70	6.0	26.90	6.60	4.04	43^0	330	3.20	6.2	9.2	-	-
10.	Merengue White	34.94	4.8	21.30	7.26	2.90	45^0	440	2.70	4.8	12.2	4.80	7.4
	F n_1, n_2	13.30**	5.12**	9.01**	2.78*	10.84**	9.44**	11.60**	4.28**	8.49**	4.44**	13.84**	8.74**
	SE	3.89	0.37	1.44	0.42	0.16	4.18	18.97	0.17	0.40	1.22	0.54	0.56
	CD	11.12	1.05	4.11	1.21	0.45	11.96	54.23	0.47	1.16	3.49	1.56	1.63

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

value was recorded by Pompon Red (17.12), which was on par with those of Tropical Red, Lady Jane and Red and Liver Red.

The highest mean candle length was recorded for the variety Dragon's Tongue Red (8.02 cm) followed by Merengue White (7.26 cm) and Ceylon Red (7.18 cm), which were on par with Dragon's Tongue Red. The variety Tropical Red showed the lowest value of 5.74 cm, which was on par with Nitta Orange, Mauritius Orange, Lady Jane Red, Midori Green, Liver Red and Pompon Red.

Spathe candle ratio ranged from 4.04 in Midori Green to 2.54 in Pompon Red. Nitta Orange (3.96) was on par with Midori Green. Lady Jane Red, Ceylon Red, Merengue White and Liver Red were on par with Pompon Red.

The position of candle was highest (71^0) which was on par with Dragons Tongue Red (66^0) and Liver Red (61^0). The least angle was recorded by Pompon Red (35^0). The varieties Tropical Red (37^0), Mauritius Orange (38^0), Midori Green (43^0), Nitta Orange (43^0), Ceylon Red (44^0) and Merengue white (45^0) were on par with Pompon Red.

The mean number of flowers per candle ranged from 450 in Lady Jane Red to 254 in Tropical Red. Pompon Red, Merengue White, Ceylon Red and Mauritius Orange were on par with Lady Jane Red. None of these varieties were on par with Tropical Red.

The highest mean life of spadix was obtained for Ceylon Red (3.65 months) which was on par with Midori Green (3.2 months). The lowest mean was recorded by Nitta Orange (2.5 months).

Plate 11. ***A. andreanum*** **flower with candle in early female phase**

Plate 12. ***A. andreanum*** **flower with candle in late female phase**

Plate 13. ***A. andreanum*** **flower with candle showing initiation of male phase**

Plate 14. ***A. andreanum*** **flower with candle in late male phase**

Plate 11

Plate 12

Plate 13

Plate 14

The mean number of days to initiation of female phase ranged from 6.8 in Mauritius Orange to 3.6 in Lady Jane Red. The varieties Pompon Red, Nitta Orange, Midori Green and Liver Red are on par with Mauritius Orange, while the varieties Ceylon Red and Dragons Tongue Red are on par with Lady Jane Red.

For the character number of days in female phase, the mean number of days ranged from 16.4 in Mauritius Orange to 6.4 in Lady Jane Red. Mean number of days recorded by Mauritius Orange (9.2) was on par with that of Lady Jane. There was no significant difference in the number of days in female phase among the other varieties (Plates 11and 12).

No anther production was observed in the varieties Pompon Red, Nitta Orange and Midori Green during the period of this study. So observations on days on interphase and duration of male phase could not be recorded for these varieties.

Among the seven varieties on which the days of interphase were recorded, the highest mean number of days of interphase was shown by Liver Red (10.2) which was on par with Ceylon Red (9.8). The lowest number of days of interphase was shown by Merengue White (4.8) which was on par with that of Tropical Red (5.8).

The highest mean duration of male phase was obtained for Tropical Red (10.4). None of the varieties were on par with Tropical Red. The lowest mean was recorded by Mauritius Orange (5.4) which was on par with Liver Red (5.6) and Lady Jane Red (6.6) (Plates 13 and 14).

Table 4 Components of total variance for the ten traits in *A. andreanum*

Sl. No.	Characters	σ^2_g	σ^2_e	σ^2_p	GCV %	PCV %
1.	Plant height (cm)	186.37	75.73	262.10	27.38 (1)	32.47 (1)
2.	No. of leaves or spadices per year	0.55	0.67	1.22	12.22 (8)	18.18 (8)
3.	Spathe size (width + length) (cm)	16.56	10.34	26.10	18.58 (5)	23.68 (5)
4.	Candle length (cm)	0.32	0.89	1.21	8.44 (10)	16.49 (9)
5.	Spathe - cnadle ratio	0.25	0.13	0.37	15.60 (7)	19.16 (6)
6.	Position of candle (degrees)	147.62	87.50	235.12	25.16 (2)	31.75 (3)
7.	No. of flowers per candle	3817.61	1800	5617.61	16.24 (6)	19.70 (7)
8.	Life of spadix (months)	0.09	0.14	0.23	10.26 (9)	16.30 (10)
9.	Days to initiation of female pahse	1.23	0.82	2.05	20.69 (3)	26.71 (4)
10.	No. of days in female phase	5.12	7.44	12.56	20.53 (4)	32.16 (2)

σ^2_g - genotypic variance
σ^2_e - environmental variance
σ^2_p - phenotypic variance

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

Figures in brackets denote rank of the variety

Table 5 Heritability and genetic advance for the ten traits in *A. andreanum*

Sl. No.	Characters	Heritability (%)	Genetic advance (at 5 %)	Genetic advance as % of mean
1.	Plant height (cm)	71.11	23.71	47.55
2.	No. of leaves or spadices per year	45.18	1.03	16.94
3.	Spathe size (width and length) (cm)	61.56	6.58	30.05
4.	Candle length (cm)	26.23	0.59	8.86
5.	Spathe candle ratio	66.30	0.83	26.15
6.	Position of candle (degrees)	62.79	19.83	41.06
7.	No. of flowers per candle	67.96	104.93	27.58
8.	Life of spadix (months)	39.63	0.39	13.38
9.	Days to initiation of female phase	60.00	1.77	33.02
10.	No. of days in female phase	40.77	2.98	27.04

2. Variability studies

The genotypic and environmental components of phenotypic variance and coefficients of variation for the ten characters (the two characters days of interphase and duration of male phase were excluded from variability studies as no anther production was observed in the varieties Pompon Red, Nitta Orange and Midori Green) are presented in the Table 4 and the corresponding graphical representation in Fig. 1. The maximum value for GCV was observed for plant height (27.38 per cent) followed by position of candle (25.16 per cent), days to initiation of female phase (20.69 per cent) and number of days in female phase (20.53 per cent). The lowest GCV was observed for life of spadix (16.30 per cent). The highest PCV also was observed for plant height (32.47 per cent) followed by number of days in female phase (32.16 per cent), position of candle (31.75 per cent), days to initiation of female phase (26.71 per cent) and spathe size (23.68 per cent). PCV also was lowest for the character, life of spadix (16.30 per cent).

The difference between genotypic and phenotypic coefficient of variation was least number of flowers per candle (3.46 per cent) followed by spathe-candle ratio. It was maximum for the character number of days in female phase (11.63 per cent) followed by candle length, position of candle, life of spadix and days to initiation of female phase.

3. Heritability and genetic advance

Heritability and genetic advance values of the ten traits are given in Table 5. They are graphically represented in Fig. 2. The highest value for

heritability was recorded by the trait plant height (71.11 per cent) followed by number of flowers per candle (67.96 per cent), spathe-candle ratio (66.30 per cent), position of candle (62.79 per cent), spathe size (61.56 per cent) and days to initiation of female phase (59.99 per cent). Lowest heritability was for candle length (26.23 per cent).

Expected genetic advance was maximum for plant height (47.55 per cent) followed by position of candle (62.79 per cent). The lowest genetic advance was recorded for candle length (8.86 per cent). Both heritability and genetic advance were highest for the trait plant height.

4. Correlation studies

The genotypic, phenotypic and environmental correlation coefficients were estimated for all the possible 45 (10 C_2) pairs of characters. The results of correlation analysis are presented in Tables 6, 7 and 8.

a. Plant height : This trait exhibited high positive genotypic correlation with number of leaves/spadices per year (0.461), number of flowers per candle (0.458) and number of days in female phase (0.455). At phenotypic level also high positive, but nonsignificant correlations were exhibited with number of leaves/spadices per year and number of flowers per candle. Significant positive correlation at phenotypic level was exhibited with the trait number of days in female phase (0.351) and at environmental level with candle length (0.340). Significant negative correlation at genotypic, phenotypic and environmental level was exhibited with spathe candle ratio.

Table 6 The genotypic correlation coefficients among the ten traits in *Anthurium*

Characters	No. of leaves/spadices per year	Spathe size	Candle length	Spathe - candle ratio	Position of candle	No. of flowers/ candle	Life of spadix	Days to initiation of female phase	Number of days in female phase
Plant height	0.461	-0.183	0.163	-0.489	0.111	0.458	0.061	0.293	0.455
No. of leaves/spadices per year		-0.233	0.168	-0.342	0.668	0.363	0.069	-0.329	-0.693
Spathe size			0.489	0.820	0.248	-0.220	0.225	0.054	0.395
Candle length				-0.041	0.589	0.537	0.477	-0.606	0.207
Spathe - candle ratio					-0.085	-0.689	0.058	0.366	0.091
Position of candle						0.210	-0.093	-0.647	-0.418
No. of flowers/candle							-0.007	-0.149	0.105
Life of spadix								-0.273	0.059
Days to initiation of female phase									0.575

Table 7 The phenotypic correlation coefficients among the ten traits in *Anthurium*

Characters	No. of leaves/spadices per year	Spathe size	Candle length	Spathe - candle ratio	Position of candle	No. of flowers/ candle	Life of spadix	Days to initiation of female phase	Number of days in female phase
Plant height	0.270	-0.085	0.227	-0.440**	0.096	0.264	0.026	0.173	0.351*
No. of leaves/spadices per year		-0.037	0.170	-0.246	0.561**	0.307*	0.209	-0.174	-0.395**
Spathe size			0.505**	0.590**	0.233	-0.100	0.132	0.028	0.142
Candle length				-0.225	0.236	0.278*	0.062	-0.229	-0.104
Spathe - candle ratio					-0.077	-0.451**	-0.060	0.253	0.064
Position of candle						0.168	0.141	-0.427**	-0.214
No. of flowers/candle							0.034	-0.222	-0.029
Life of spadix								-0.108	0.079
Days to initiation of female phase									0.239

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

Table 8 The environmental correlation coefficients among the ten traits in *Anthurium*

Characters	No. of leaves/spadices per year	Spathe size	Candle length	Spathe - candle ratio	Position of candle	No. of flowers/ candle	Life of spadix	Days to initiation of female phase	Number of days in female phase
Plant height	0.022	0.109	0.340*	-0.336*	0.068	-0.178	-0.017	-0.054	0.256
No. of leaves/spadices per year		0.188	0.177	-0.137	0.454**	0.252	0.314*	-0.007	-0.170
Spathe size			0.580**	0.183	0.208	0.120	0.044	-0.013	-0.118
Candle length				-0.417**	-0.007	0.105	-0.138	0.022	-0.260
Spathe - candle ratio					-0.063	0.034	-0.199	0.059	0.037
Position of candle						0.090	0.395**	-0.077	-0.005
No. of flowers/candle							0.085	-0.355*	-0.192
Life of spadix								-0.052	0.092
Days to initiation of female phase									-0.093

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

b. Number of leaves/spadices per year : At genotypic level, this character exhibited positive correlation with position of candle (0.668), plant height (0.461), number of flowers per candle (0.363). Negative correlation at genotypic and phenotypic level was exhibited with number of days in female phase (-0.693 and -0.395 respectively). At phenotypic level also significant positive correlation was exhibited with position of candle and number of flowers per candle (0.307) and significant negative correlation with number of days in female phase (-0.395). Significant positive correlation at environmental level also was shown with position of candle (0.454). Significant correlation at environmental level was shown with life of spadix (0.314) alone.

c. Spathe size : This trait showed positive genotypic correlation with all the traits except number of flowers per candle (-0.220), plant height (-0.183) and number of leaves/spadices per year (-0.233). Significant positive correlation was observed with candle length, at genotypic, phenotypic and environmental levels. Positive genotypic and significant phenotypic correlation was shown with spathe candle ratio (0.820 and 0.590 respectively). Positive genotypic correlation (0.395) and negative environmental correlation (-0.118) was shown with number of days in female phase.

d. Candle length : Positive genotypic correlation was exhibited with all the traits except spathe candle ratio and days to initiation of female phase. Positive genotypic and phenotypic correlations were exhibited with position of candle,

number of flowers per candle and life of spadix. Candle length showed significant positive phenotypic correlations with spathe size (0.505) and number of flowers per candle (0.278). Significant positive environmental correlations were exhibited with spathe size (0.580) and plant height (0.340). Negative correlations were shown with spathe candle ratio at all the three levels. Negative genotypic (-0.606) and phenotypic (-0.229) correlations were exhibited with days to initiation of female phase.

e. Spathe - candle ratio : Positive genotypic correlation was highest with spathe size (0.820) followed by days to initiation of female phase (0.366), High negative correlation was shown with number of flowers per candle at genotypic and phenotypic levels. At phenotypic level this trait showed significant positive correlation with spathe size (0.590) and plant height (-0.440). Environmental correlation was significantly negative with candle length (-0.417) and plant height (-0.336).

f. Position of candle : Maximum positive and negative genotypic correlations were shown with number of leaves/spadices per year (0.668) followed by candle length (0.589) and days to initiation of female phase (-0.647) and number of days in female phase (-0.418) respectively. At phenotypic level, position of candle exhibited significant positive correlation with number of leaves/spadices per year (0.561). Significant negative phenotypic correlation also was shown with days to initiation of female phase (-0.427). Environmental correlation was significantly positive with number of leaves/spadices per year (0.454) and life of spadix (0.395).

g. Number of flowers per candle : Maximum positive genotypic correlation was shown with candle length (0.537) followed by plant height (0.458) and number of leaves/spadices per year (0.363). Phenotypic correlation was significantly positive with number of leaves/spadices per year (0.307) followed by candle length (0.278) whereas it was significantly negative with spathe candle ratio (-0.451). Significant negative environmental correlation was observed with days to initiation of female phase (-0.355).

h. Life of spadix : At the genotypic level, maximum positive correlation was shown with candle length (0.477) followed by spathe size (0.225), number of leaves/spadices per year (0.069) and plant height (0.061), number of days in female phase (0.059) and sapthe candle ratio (0.058). Highest and lowest phenotypic correlations were shown with number of leaves/spadices per year (0.209) and days to initiation of female phase (-0.108) respectively. Life of spadix showed significant positive environmental correlations with position of candle (0.395) and number of leaves/spadices per year (0.314).

i. Days to initiation of female phase : Maximum positive genotypic correlation was shown with number of days in female phase (0.575), spathe candle ratio (0.366) and plant height (0.293). Maximum negative correlation was with position of candle (-0.647) followed by candle length (-0.606). Positive phenotypic correlation was highest with spathe candle ratio (0.253) whereas it was significantly negative with position of candle (-0.427).

Table 9 Variation in six qualitative characters of *A. andreanum* Linden among the ten varieties

	Varieties	Spathe colour	Spathe texture	Candle colour
1.	Liver Red	Deep Maroon	Thick, smooth, glossy	Pink
2.	Dragon's Tongue Red	Bright Red	Thin, smooth, glossy	Light pink
3.	Pompon Red	Dark Red	Thin, shallowly blistered, glossy	Yellow
4.	Lady Jane	Dark Pink	Thin, smooth glossy	Light pink
5.	Ceylon Red	Red	Medium thick, Shallowly blistered, glossy	Green
6.	Tropical Red	Bright Red	Thick, medium blistered, glosy	Yellow
7.	Mauritius Orange	Dark Orange	Thick deeply blistered, glossy	Light yellow
8.	Nitta Orange	Light Orange	Thin, medium blistered, glossy	Yellow
9.	Midori Green	Light Green	Medium thick, deeply blistered, glossy	Light green
10.	Merengue White	White	Medium thick, shallowly blistered, glossy	Pink

Table 9 continued .....

	Varieties	Suckering ability	Pollen fertility (%)	Type of infloresence axis
1.	Liver Red	Very high	42.0	Long, straight and strong
2.	Dragon's Tongue Red	Low	28.0	Long, straight and very strong
3.	Pompon Red	Very low	-	Long, straight and strong
4.	Lady Jane	Very high	14.0	Long, straight and strong
5.	Ceylon Red	Very high	21.0	Medium long , straight and strong
6.	Tropical Red	Very low	29.0	Long, straight and strong
7.	Mauritius Orange	Medium	13.7	Long, straight and strong
8.	Nitta Orange	Medium	-	Short, straight and thin
9.	Midori Green	Medium	-	Short, straight and thin
10.	Merengue White	Low	18.0	Long, straight and strong

j. Number of days in female phase : Genotypic correlation was highest with days to initiation of female phase (0.575) followed by plant height and spathe size. Highest negative correlation was with number of leaves/spadices per year (-0.693), followed by position of candle (-0.418). At phenotypic level it exhibited significant positive correlation with plant height (0.351) and significant negative correlation with number of leaves or spadices per year (-0.395). Positive environmental correlations were exhibited with plant height (0.256), life of spadix (0.092) and spathe candle ratio (0.037).

5. Other important morphological traits

1. Spathe colour : Liver red had deep maroon coloured spathe. Red coloured varieties showed variation from dark red to bright red to red. Lady Jane had dark pink spathe. Mauritius Orange had dark orange spathe, while Nitta Orange had light orange spathe. Midori Green had light green and Merengue White had white spathe (Table 9).

2. Spathe texture : Thick, smooth and glossy spathes wer seen for Liver Red and Dragon's Tongue Red. Pompon Red had thin shallowly blistered spathes while Lady Jane had thin and smooth spathes. Spathes were medium thick and shallowly blistered for Ceylon Red while it was medium thick and deeply blistered in Midori Green. Tropical Red had thick, medium blistered, spathes while Mauritius Orange had thick and deeply blistered spathes. Spathes were thin and medium blistered in Nitta Orange and medium thick and shallowly blistered in Merengue White.

3. Candle colour : Candle colour varied from light pink in Dragon's Tongue Red and Lady Jane to pink in Liver Red and Merengue White. It ranged from cream in Ceylon Red to light yellow in Mauritius Orange to yellow in Pompon Red, Tropical Red and Nitta Orange. Midori Green had light green candles.

4. Suckering ability : Suckering producing ability is an important trait considered in selection of superior types. It was very high for 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.

5. Pollen fertility : Comparison of pollen fertility estimated using acetocarmine method reveals that, Liver Red had the highest pollen fertility of 42 per cent followed by Tropical Red (29 per cent), Dragon's Tongue Red (28 per cent) and Ceylon Red (21 per cent). The lowest values were recorded for Mauritius Orange (13.7 per cent), Lady Jane (14 per cent) and Merengue White (18 per cent).

6. Type of infloresence axis : The nature of infloresence axis which is an important commercial trait varied from long, straight and very strong in Dragon's Tongue Red to long, straight and strong in Liver Red, Pompon Red, Lady Jane, Tropical Red, Mauritius Orange and Merengue White. The varieties Nitta Orange and Midori Green had short, straight and thin axis while Ceylon Red had medium long, straight and strong infloresence axis.

Table 10 Pollen emergence pattern of the ten varieties of *A. andreanum* from August 1998 to July 1999

Varieties / Months	Liver red	Dragon's Tongue Red	Pompon Red	Lady Jane	Ceylon Red	Tropical Red	Mauritius Orange	Nitta Orange	Midori Green	Merengue White	Average temperature (Max.)	Average temperature (Min.)
Aug. 1998	+	+	-	+	+	+	-	-	-	+	29.9	24.3
Sep. 1998	+	+	-	+	+	+	-	-	-	+	29.5	24.2
Oct. 1998	+	+	-	+	+	+	-	-	-	-	29.7	23.6
Nov. 1998	+	+	-	+	+	+	+	-	-	+	30.1	23.2
Dec. 1998	+	+	-	+	+	+	-	-	-	+	30.6	22.8
Jan. 1999	+	+	-	+	+	+	-	-	-	-	31.2	21.9
Feb. 1999	+	+	-	+	+	+	-	-	-	+	31.4	22.8
Mar. 1999	+	+	-	-	+	-	-	-	-	-	32.5	24.4
Apr. 1999	-	+	-	-	-	-	-	-	-	-	31.4	24.9
May 1999	-	-	-	-	-	-	-	-	-	+	30.5	24.0
June 1999	+	+	-	-	-	-	-	-	-	+	29.9	23.9
Jul. 1999	+	+	-	+	+	-	-	-	-	+	29.0	23.5

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

B. Compatibility studies

Intervarietal crossing in all possible combinations involving the ten selected *Anthurium* varieties was done, depending on the availability of receptive spadices and fresh pollen (Plate15). This was done with the aim of finding the compatibility between the varieties on the basis of,

1. Percentage of candles bearing fruits
2. Percentage of fruit set/candle and
3. Percentage germination of seed

A total of 208 crossings were done which included 67 of the 100 possible combinations (including selfs). This 67 combinations covered 60

Plate 15. Pollinating Midori Green flowers in female phase

Plate 16. The cross combination PR x LR showing high fruit set

Plate 17. The cross combination DT x LJ showing low fruit set

Plate 15

Plate 16

Plate 17

cross combinations and 7 selfs. Crossings involving Pompon Red, Nilta Orange and Midori Green as pollen parents could not be done due to lack of pollen production in these varieties. Of the 67 crosses and selfs made, a total of 37 combinations were successful.

The results of compatibility analysis based on the eight parameters studied are presented below.

I. Compatibility based on performance of the varieties as female parents

1) Percentage of candles bearing fruits

a) Liver Red : Seven out of the ten possible combinations involving this variety could be attempted. Percentage of candles bearing fruits was highest for the cross LR x DT (60 per cent) and lowest for the cross LR x TR (20 per cent). The cross LR x LJ and LR x MO did not set any fruit. Selfing resulted in 25 per cent success (Table 11 and 12).

b. Dragon's Tongue Red : A total of seven crosses could be attempted of which five were successful. Highest percentage of candles bearing fruits was obtained for the cross DT x LJ (50 per cent) followed by DT x LR, DT x CR and DT x MW (33.3 per cent). The crosses DT x TR and DT x MO did not set any fruit. Selfing gave 20 per cent success.

c. Pompon Red : Out of the 10 possible combinations six crosses could be attempted and five were successful. Highest percentage of success was for the cross PR x LR (83.3 per cent) followed by PR x DT (60 per cent) and the lowest percentage was obtained for the cross PR x MW (33.3 per cent). PR x

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

♀ \ ♂	LR	DT	PR	LJ	CR	TR	MO	NO	MG	MW
LR	4	5	-	3	7	5	3	-	-	3
DT	3	5	-	2	3	5	3	-	-	3
PR	6	5	-	2	4	3	-	-	-	3
LJ	6	5	-	1	3	2	2	-	-	3
CR	4	5	-	5	2	5	4	-	-	4
TR	4	5	-	2	4	1	1	-	-	2
MO	4	6	-	2	3	3	1	-	-	5
NO	3	3	-	1	1	4	-	-	-	2
MG	2	2	-	1	2	1	2	-	-	3
MW	4	3	-	2	2	2	-	-	-	1

Table 12 Matrix showing percentage of candles bearing fruits in each combination among ten varieties of *A. andreanum*

♀ \ ♂	LR	DT	PR	LJ	CR	TR	MO	NO	MG	MW	Average
LR	25.0	60.0	-	0	42.9	20.0	0	-	-	33.3	25.89
DT	33.3	20.0	-	50.0	33.3	0	0	-	-	33.3	24.27
PR	83.3	60.0	-	0	50.0	0	-	-	-	33.3	37.77
LJ	33.3	0	-	0	100.0	0	0	-	-	100.0	33.33
CR	50.0	60.0	-	0	0	60.0	25.0	-	-	100.0	42.14
TR	0	0	-	0	25.0	0	0	-	-	50.0	10.71
MO	0	0	-	0	66.6	0	0	-	-	0	9.51
NO	33.3	33.3	-	100.0	100.0	25.0	-	-	-	50.0	51.93
MG	50.0	0	-	0	100.0	0	0	-	-	66.6	30.94
MW	50.0	66.6	-	0	100.0	0	-	-	-	0	43.32

LJ and PR x TR were unsuccessful. Self combinations could not be attempted due to absence of pollen emergence.

d. Lady Jane Red : Out of the seven combinations attempted, only three were successful, of which LJ x CR and LJ x MW gave 100 per cent candles bearing fruits while the cross LJ x LR gave 33.3 per cent success. LJ x DT, LJ x TR and LJ x MO and LJ x LJ failed to produce any candles bearing fruits.

e. Ceylon Red : Seven combinations could be attempted of which five were successful. The combination CR x MW gave the highest percentage of successful crosses (100 per cent) followed by CR x DT and CR x TR (60 per cent). The cross CR x MO had the lowest success (25 per cent). The cross CR x LJ and the self CR x CR were unsuccessful.

f. Tropical Red : Out of the seven combinations attempted only two were successful, of which TR x MW gave 50 per cent success followed by TR x CR (25 per cent). Selfing was not successful. The crosses TR x LR, TR x DT, TR x LJ and TR x MO were not successful.

g. Mauritius Orange : Seven of the ten possible combinations were attempted. Only MO x CR (66.6 per cent) was successful. Selfing gave no candle with fruit set. The crosses MO x DT, MO x LJ, MO x TR and MO x MW were all unsuccessful.

h. Nitta Orange : As the frequency of flower production was low, total of six out of the ten possible combinations only could be attempted, all of which gave candles with fruit set. The crosses NO x LJ and NO x CR gave 100 per

cent of candles bearing fruits followed by NO x MW (50 per cent). The cross NO x TR (25 per cent) gave the lowest per cent of success.

i. Midori Green : Out of the seven combinations attempted, three were successful. The cross MG x CR gave the highest percentage of candles bearing fruits (100 per cent) followed by MG x MW (66.6 per cent). The lowest success was obtained for MG x LR (50 per cent).

j. Merengue white : Out of the ten possible combinations, only five could be attempted in this variety. Of these three were successful and the cross MW x CR gave 100 per cent success followed by MW x DT (66.6 per cent). The cross MW x LR gave the lowest success (50 per cent). MW x LJ and MW x TR were unsuccessful.

Among the ten varieties, the maximum percentage of candles bearing fruits was obtained in the variety Nitta Orange (51.93 per cent) followed by Merengue White (43.32 per cent) and Ceylon Red (42.14 per cent). The lowest value was obtained for Mauritius Orange (9.51 per cent).

2. Number of fruits / candle

In *Anthurium*, the fruit is a berry which is pushed out of the candle when mature. The fruit colour varied from creamish yellow to dark red. The number of fruits per candle varied from five to as high as 183 (Table 13).

a) Liver Red : Among the five crosses which showed successful fruit set, the maximum average number of fruits / candle was observed for LR x DT (121) followed by LR x MW (91) and the lowest in LR x LR (11).

b) Dragon's Tongue Red : The number of fruits / candle in the crosses involving DT ranged from five in DT x LJ to 66 in DT x CR. The average number of berries / candle was 37.

c. Pompon Red : Out of the four successful crosses, the highest number of fruits / candle was seen in PR x LR (183) followed by PR x CR (162). The lowest number of berries / candle was seen for PR x DT (48).

d. Lady Jane Red : There crosses showed successful fruit set of which the highest average number of fruits per candle was seen for LJ x MW (29) followed by LJ x LR (14) and LJ x CR (13).

e. Ceylon Red : Among the five crosses which showed fruit set, the highest average number of berries per candle was seen for CR x MW (98) followed by CR x DT (69). The lowest was for CR x TR (17).

f. Tropical Red : Out of the two successful crosses, TR x CR had an average of 56 fruits / candle followed by TR x MW (43).

g. Mauritius Orange : In the crosses involving Mauritius Orange, only MO x CR was successful which had an average of 33 fruits per candle.

h. Nitta Orange : Six crosses involving Nitta Orange were successful, of which NO x TR (79) followed by NO x CR (73) showed the highest average number of fruits per candle. Fruit set was lowest for the cross NO x MW (33).

i. Midori Green : Among the three successful crosses, the highest average number of fruits / candle was seen for MG x LR (49) and the lowest for MG x MW (22).

j. Merengue white : Three crosses were successful, of which the highest average number of fruits per candle was observed for MW x LR (88) followed by MW x CR (85) and MW x DT (81).

Among the ten varieties, the highest average number of fruits per candle was observed for the variety Pompon Red (122) followed by Merengue white (85). This was lowest for Lady Jane Red (19). The number of berries harvested per candle was highest for the variety Pompon Red in the crosses PR x LR (183) and PR x CR (162). The lowest value was got for the cross DT x LJ (5). Among the two successful selfings, DT x DT had an average of 34 fruits, while LR x LR produced an average of 11 fruits per candle.

3. Percentage of fruit set / candle

Percentage of fruit set/candle for the 10 parental varieties is given below.

a. Liver Red : The highest percentage of fruit set among the crosses of Liver Red was obtained for LR x DT (37.4 per cent) followed by LR x MW (31.6 per cent). Selfing gave the lowest percentage of fruit set (3.8 per cent) (Table 14).

b. Dragon's Tongue Red : In Dragon's Tongue Red, the cross combination DT x CR had the maximum percentage fruit set (24.0 per cent) followed by DT x LR (15.8 per cent) and the lowest for the combination DT x LJ (2.3 per cent) (Plate 17). Selfing gave 11.6 per cent fruit set.

c. Pompon Red : Among the crosses of Pompon Red, PR x LR (57.6 per cent) (Plate 16) had the highest percentage fruit set followed by PR x CR (40.5

Table 13 Matrix showing average number of fruits per candle in each combination among ten varieties of *A. andreanum*

♀ \ ♂	LR	DT	PR	LJ	CR	TR	MO	NO	MG	MW	Average
LR	11	121	-	-	61	26	-	-	-	91	62
DT	52	34	-	5	66	-	-	-	-	28	37
PR	183	48	-	-	162	-	-	-	-	93	122
LJ	14	-	-	-	13	-	-	-	-	29	19
CR	51	69	-	-	-	17	29	-	-	98	53
TR	-	-	-	-	56	-	-	-	-	43	50
MO	-	-	-	-	33	-	-	-	-	-	33
NO	49	67	-	40	73	79	-	-	-	33	57
MG	49	-	-	-	39	-	-	-	-	22	37
MW	88	81	-	-	85	-	-	-	-	-	85

Table 14 Matrix showing average percentage of fruit set in each combination among ten varieties of *A. andreanum*

♀ \ ♂	LR	DT	PR	LJ	CR	TR	MO	NO	MG	MW	Average
LR	3.8	37.4	-	-	28.3	8.8	-	-	-	31.6	21.9
DT	15.8	11.6	-	2.3	24.0	-	-	-	-	8.5	12.4
PR	57.6	11.4	-	-	40.5	-	-	-	-	26.2	33.9
LJ	3.6	-	-	-	3.6	-	-	-	-	8.1	5.1
CR	15.2	17.7	-	-	-	5.8	7.7	-	-	43.8	18.0
TR	-	-	-	-	29.3	-	-	-	-	18.8	24.1
MO	-	-	-	-	11.4	-	-	-	-	-	11.4
NO	21.6	22.2	-	12.3	30.3	34.8	-	-	-	16.9	23.2
MG	16.5	-	-	-	14.8	-	-	-	-	8.3	13.2
MW	26.7	23.0	-	-	32.2	-	-	-	-	-	27.3

per cent) and PR x DT had the lowest percentage fruit set of 11.4 per cent. Selfing could not be attempted due to absence of pollen production.

d. Lady Jane Red : In Lady Jane Red, the percentage fruit set varied from 8.1 per cent in LJ x MW to 3.6 per cent in LJ x CR and LJ x LR. Selfing was unsuccessful.

e. Ceylon Red : The percentage fruit set in the crosses involving Ceylon Red was highest in the combination CR x MW (38.9 per cent) followed by CR x DT (17.7 per cent) and was the lowest in CR x TR (5.8 per cent). Selfing was unsuccessful.

f. Tropical Red : The highest percentage fruit set among the crosses of Tropical Red was for TR x CR (29.3 per cent) followed by TR x MW (18.8 per cent). Other combinations as well as selfing gave no successful fruit set.

g. Mauritius Orange : The only successful cross in Mauritius orange was MO x CR which had a percentage fruit set of 11.5 per cent.

h. Nitta Orange : In Nita Orange, the highest percentage fruit set was observed for NO x TR (34.8 per cent) followed by NO x CR (30.0 per cent) and the lowest value in the combination NO x LJ (13.7 per cent). Though six cross combinations were successful in this variety, selfing was not successful.

i. Modori Green : Among the crosses of Midori Green, the highest percentage fruit set was recorded for MG x LR (16.5 per cent) and the lowest in MG x MW (8.36 per cent). Selfing could not be attempted due to absence of pollen production.

j. Merengue White : The highest percentage fruit set among the crosses of Merengue White, the highest percentage fruit set was recorded for MW x CR (32.2 per cent) and the lowest in MW x DT (25.0 per cent). Selfing was unseccessful.

Among the successful crosses, the highest average percentage of fruit set was obtained for the cross PR x LR (57.6 per cent). Among the ten parent varieties, the highest average percentage fruit set was observed for Pompon Red (33.9 per cent) followed by Merengue White (27.3 per cent) and Tropical Red (24.1 per cent). It was lowest for the variety Lady Jane Red (5.1 per cent).

Only two selfings i.e., LR x LR or DT x DT produced successful fruit set.

4. Duration of Fruit Maturity

The data on the duration of fruit maturity in the ten Anthurium varieties is as follows (Table 15) (Plates 18, 19 and 20).

a. Liver Red : In Liver Red, the months taken for fruit maturity on an average ranged from 5.5 months in LR x MW and in the self combination of LR x LR, to 4.5 months in LR x TR. The fruits of LR x CR took 5.25 months while those of LR x DT took 4.7 months to reach maturity.

b. Dragon's Tongue Red : Among the crosses of Dragon's Tongue Red, the maximum duration for fruit maturity was seen in the cross DT x CR (7.5 months) followed by DT x MW (6 months). The lowest duration was recorded for T x LJ (4-5 months). The self combination of DT x DT showed fruit maturity time of 5.5 months.

Plate 18. The cross combination LR x CR showing ripe berries

Plate 19. The combination MG x LR showing ripe berries

Plate 20. Ripe berries

1. **CR x LR**
2. **MG x LR**
3. **LR x DT**
4. **PR x MW**

Plate 18

Plate 19

Plate 20

Table 15 Data from intervarietal hybridisation among ten varieties of *A. andreanum*

Combination	Duration of fruit maturity (Months)		Number of days for germination	Single seeds (%)	Two seeds (%)	Three seeds (%)	Berries with single seeds		Berries with two seeds		Berries with three seeds	
	Range	Average					Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)
LR × LR	5 - 6	5.5	5 - 7	90.9	9.1	-	3.2	2.5	3.0	2.25	-	-
LR × DT	4 - 5	4.7	9 - 10	81.1	18.9	-	4.6	2.7	4.2	2.4	-	-
LR × CR	5 - 5.5	5.25	4 - 9	82.1	17.5	-	3.7	3.3	3.0	2.5	-	-
LR × TR	4.5	4.5	5 - 8	92.3	7.7	-	3.5	3.25	3.0	2.5	-	-
LR × MW	5.5	5.5	3 - 7	78.4	21.6	-	3.75	3.5	3.5	3.25	-	-
DT × LR	5.0	5.0	-	78.6	21.4	-	3.0	2.5	2.75	2.5	-	-
DT × DT	5.5	5.5	5 - 6	100.0	0	-	3.5	2.8	-	-	-	-
DT × LJ	4 - 5	4.5	7 - 8	100.0	0	-	2.5	2.25	-	-	-	-
DT × CR	7.5	7.5	6 - 9	81.0	19.0	-	4.0	2.25	3.25	2.0	-	-
DT × MW	6.0	6.0	5 - 6	100.0	0	-	3.0	2.75	-	-	-	-

Table 15 Contd .....

Combination	Duration of fruit maturity (Months)		Number of days for germination	Single seeds (%)	Two seeds (%)	Three seeds (%)	Berries with single seeds		Berries with two seeds		Berries with three seeds	
	Range	Average					Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)
PR × LR	4.75 - 5	4.9	4 - 7	80.4	19.6	-	5.0	2.5	4.0	2.3	-	-
PR × DT	5 - 6	5.7	6 - 7	85.2	14.8	-	4.75	4.5	4.6	4.25	-	-
PR × CR	6 - 6.5	6.25	8 - 9	34.3	60.4	5.3	4.5	2.5	4.2	2.30	4.0	2.0
PR × MW	6.5	6.5	7 - 9	77.0	23.0	-	3.0	2.75	2.5	2.0	-	-
LJ × LR	3.5 - 4.5	3.8	4 - 12	100.0	0	-	3.2	2.5	-	-	-	-
LJ × CR	4.5 - 5	4.5	7 - 10	100.0	0	-	3.2	2.5	-	-	-	-
LJ × MW	4.5 - 5.5	4.8	5 - 9	100.0	0	-	3.6	2.5	-	-	-	-
CR × LR	6 - 7	6.3	4 - 6	37.5	62.5	-	4.75	3.0	4.25	2.5	-	-
CR × DT	4.5 - 6	5.2	4 - 5	91.3	8.7	-	4.1	2.3	3.75	2.25	-	-
CR × TR	6 - 6.5	6.4	6 - 8	100.0	0	-	3.7	2.5	-	-	-	-
CR × MO	6.5	6.5	5 - 7	77.8	22.2	-	3.5	3.25	3.0	2.25	-	-
CR × MW	5 - 7	6.0	5 - 9	96.3	3.7	-	4.6	2.4	3.6	2.1	-	-

Table 15 Contd .....

Combination	Duration of fruit maturity (Months)		Number of days for germination	Single seeds (%)	Two seeds (%)	Three seeds (%)	Berries with single seeds		Berries with two seeds		Berries with three seeds	
	Range	Average					Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)
TR × CR	6	6	6 - 7	88.9	11.1	-	3.5	2.0	3.25	1.75	-	-
TR × MW	5	5	5 - 8	100	0	-	3.75	2.5	-	-	-	-
MO × CR	5.5 - 6	5.75	6 - 8	100	0	-	3.5	2.25	-	-	-	-
NO × LR	5	5	5 - 9	93.2	6.8	-	4.25	3.6	3.75	3.5	-	-
NO × DT	5	5	6 - 9	100	0	-	3.25	2.25	-	-	-	-
NO × LJ	5.5	5.5	4 - 6	92.5	7.5	-	4.75	2.9	4.25	2.5	-	-
NO × CR	5.75	5.75	5 - 8	80.8	19.2	-	4.5	3.3	4.0	2.9	-	-
NO × TR	5.5	5.5	6 - 9	88.1	11.9	-	4.5	4.25	3.75	3.5	-	-
NO × MW	5	5	4 - 7	95.7	4.3	-	3.0	2.75	2.75	2.5	-	-
MG × LR	5	5	5 - 9	68.1	31.9	-	3.5	2.9	3.1	2.5	-	-
MG × CR	5 - 5.5	5.25	-	94.9	5.1	-	3.75	2.3	3.5	2.0	-	-
MG × MW	5 - 5.25	5.1	-	100	0	-	1.9	1.5	-	-	-	-
MW × LR	45 - 475	4.6	5 - 10	93.8	6.2	-	5.0	2.5	4.25	2.25	-	-
MW × DT	5 -6	5.5	9 - 12	88.4	11.6	-	4.2	2.25	3.7	2.0	-	-
MW × CR	5 - 5.5	5.25	4 - 8	91.7	8.3	-	3.5	2.25	3.0	2.1	-	-

c. Pompon Red : The highest duration for fruit maturity among the crosses of Pompon Red, was taken by PR x MW (6.5 months) followed by PR x CR (6.25 months). The lowest average duration was recorded for PR x LR (4.9 months).

d. Lady Jane Red : In the three successful crosses of Lady Jane Red, the duration for fruit maturity ranged from 4.8 months in LJ x MW to 3.8 months in LJ x LR. The other cross LJ x CR recorded a duration of 4.6 months.

e. Ceylon Red : In Ceylon Red, the average duration for fruit maturity was highest in the combination CR x MO (6.5 months) followed by CR x TR (6.4 months). It was lowest in the cross CR x DT (5.2 months).

f. Tropical Red : Among the only two successful cross combinations involving Tropical Red, the average duration for fruit maturity was 6 months in TR x CR and 5 months in TR x MW.

g. Mauritius Orange : The only successful cross in Mauritius Orange, MO x CR, took a duration of 5.75 months to reach fruit maturity.

h. Nitta Orange : In Nitta Orange, the average duration for fruit maturity ranged from 5.75 months in NO x CR to five months in NO x LR, NO x DT and NO x MW.

i. Midori Green : The average duration for fruit maturity in Midori Green, ranged from 5.25 in MG x CR to 5 months in MG x LR.

j. Merengue White : Among the combinations of Merengue White, the average duration for fruit maturity ranged from 5.5 months in MW x DT to 4.6 months in MW x LR.

The average time taken for fruit maturity among the ten varieties ranged from 4.4 months in Lady Jane Red to 5.8 months in Pompon Red and Mauritius Orange and 6.1 in Ceylon Red. All the varieties except Lady Jane Red took on an average more than five months to reach fruit maturity.

5. Number of seeds/berry

The data recorded on the number of fruits/berry for the 10 *Anthurium* varieties are given below. The fruit in *Anthurium* is a beryy which usually contains one or two seeds and rarely 3 seeds. The seeds are embedded in a sticky jelly-like pulp.

a. Liver Red : In Liver Red, the percentage of berries with single seeds was highest for the cross LR x TR (92.3 per cent) and the percentage of berries with two seeds was highest in the cross LR x DT (18.9 per cent).

b. Dragon's Tongue Red : Among the four successful combinations involving DT, only a single seed was seen in the berries from the crosses DT x DT, DT x LJ and DT x MW. Only in the cross DT x CR, two seeds per berry was seen i.e., in 19 per cent of the fruits.

c. Pompon Red : All the successful crosses involving Pompon Red produced berries with one as well as two seeds, of which the cross PR x DT produced the highest percentage of berries with single seeds (85.2 per cent). The cross

PR x CR had two seeds/berry in 60.4 per cent of the berries, while three seeds per berry was seen in 5.3 per cent of the berries of this cross. This was the only cross in which three seeded berries were obtained.

d. Lady Jane Red : The three cross involving Lady Jane Red, LJ x LR, LJ x CR and LJ x MW, all produced berries with single seeds only.

e. Ceylon Red : In Ceylon Red, the highest percentage of berries with single seeds was recorded for the cross CR x TR (100 per cent) followed by the cross CR x MW (96.3 per cent). Berries with two seeds were more than those with single seeds in the cross CR x LR (62.5 per cent).

f. Tropical Red : Among the two successful crosses in Tropical Red, the cross TR x MW has 100 per cent of the berries with single seeds while the other cross TR x CR had 88.9 per cent of berries with single seeds.

g. Mauritius Orange : In MO x CR, which was the only successful cross involving Mauritius Orange, all the berries had only one seed each.

h. Nitta Orange : In Nitta Orange the highest percentage of berries with single seeds was recorded by the cross NO x DT (100 per cent) followed by NO x MW (95.7 per cent). The highest per cent of double seeds was recorded for the cross NO x CR (19.2 per cent).

i. Midori Green : Among the three crosses involving Midori Green, MG x MW produced only berries with single seeds. The highest percentage of double seeds was seen in the berries from the cross MG x LR (31.9 per cent).

j. Merengue White : In Merengue White variety, the percentage of berries with single seeds ranged from 93.8 per cent in the cross MW x LR to 88.4 per cent in the cross MW x DT.

All the crosses showed high percentage of berries bearing single seeds except the two crosses CR x LR and PR x CR, which showed a higher percentage of berries with two seeds. The cross combination CR x LR had 62.5 percentage of berries with two seeds each while the cross PR x CR had 60.4 per cent double seeded berries. The combination PR x CR also had 5.3 per cent berries with three seeds each.

6. Seed size

Size of seeds from the berries of same cross combination showed variation depending on whether the berries contained one, two or three seeds. As the number of seeds in the berry increased the average size of seeds decreased. The data on seed size of the ten *Anthurium* varieties studied are recorded below.

a. Liver Red : In the variety Liver Red, the largest seeds in single seeded as well as two seeded berries were produced in the cross LR x DT (4.6 x 2.7 mm and 4.2 x 2.4 mm respectively). Smallest seeds in the single seeded berries was seen in LR x LR (3.2 x 2.5 mm) and in double seeded berries in the crosses LR x LR and LR x CR (3 x 2.5 mm) (Plate 21).

b. Dragon's Tongue Red : The cross DT x CR had single seeded berries with the largest seed size, among the crosses of Dragon's Tongue Red (4.0 x 2.25 mm). Largest seed size in double seeded berries also was observed in the same

Plate 21. Ripe berries and seeds of the cross combination LR x DT

Plate 22. Germinated seeds of the cross combination PR x LR

Plate 23. Germinated seeds of the cross combination PR x MW

Plate 21

Plate 22

Plate 23

cross (3.25 x 2.0 mm). The cross DT x LJ had exceptionally small seeds (2.5 x 2.25 mm).

c. Pompon Red : In Pompon Red, the largest seeds in single seeded berries, was seen in the cross PR x LR (5 x 2.5 mm) and the smallest in PR x MW (3 x 2.75 mm). The largest and the smallest seeds among double seeded berries was seen in PR x DT (4.6 x 4.25 mm) and PR x MW (2.5 x 2 mm) respectively. The three seeded berries in the cross PR x CR had an average size of 4 x 2.0 mm.

d. Lady Jane Red : All the three crosses of Lady Jane Red produced only single seeded berries whose size ranged from 3.6 x 2.5 mm in LJ x MW to 3.2 x 2.5 mm in LJ x LR and LJ x CR.

e. Ceylon Red : Among the five successful crosses of Ceylon Red, the cross CR x LR produced berries with the largest seed size (4.75 x 3 mm). Among the two seeded berries also this cross had the largest seed size (4.25 x 2.5 mm). The smallest seeds in single and double seeded berries was seen for the cross CR x MO (3.50 x 3.25 mm and 3.0 x 2.75 mm respectively).

f. Tropical Red : In Tropical Red, the cross TR x MW had the largest seeds among single seeded berries (3.75 x 2.5 mm). The double seeded berries of the cross TR x CR had an average size of 3.25 x 1.75 mm.

g. Mauritius Orange : The only successful cross in Mauritius Orange, MO x CR, had only berries with single seeds, which had an average seed size of 3.5 x 2.25 mm.

h. Nitta Orange : Among the six crosses of Nitta Orange, the largest seeds in single seeded berries was recorded for the crosses NO x LJ (4.75 x 2.9 mm) and NO x CR (4.5 x 3.3 mm). The cross NO x DT produced the smallest seeds (3.25 x 2.25 mm). The highest average size among double seeded berries also was seen for the cross NO x LJ (4.25 x 2.5 mm).

i. Midori Green : In Midori Green, the largest seeds in single as well as double seeded berries was recorded for the cross MG x CR (3.75 x 2.3 mm and 3.1 x 2.5 mm respectively). The cross MG x MW had very small seeds (1.9 x 1.5 mm). These seeds did not germinate.

j. Merengue White : In Merengue White, the cross MW x LR had the largest seeds in single seeded berries (5 x 2.5 mm). The smallest seeds in single as well as double seeded berries was seen for the cross MW x CR (3.5 x 2.25 mm and 3.0 x 2.1 mm respectively).

7. Number of days for germination

In some crosses, the seeds at the time of fruit maturity had tip of radicle emerging from the seed coat. Such seeds germinated immediately, while other seeds took some time for radicle emergence (Plates 22 and 23). The data on days for germination of the ten *Anthurium* varieties under study is given below.

In the variety Liver Red, the days taken for germination ranged from 3 - 7 days in LR x MW up to 9 - 10 days in LR x DT. In Dragon's Tongue Red, the cross DT x CR took 6 - 9 days for germination while DT x LJ took 7 - 8

days for germination. DT x DT and DT x MW took 5 - 6 days for germination. The highest number of days for germination, among the crosses of Pompon Red was taken by PR x CR (8 - 9 days) and the lowest by PR x LR (4 - 7 days). In Lady Jane Red, the days for germination ranged from 4 - 12 days in LJ x LR to 7 - 10 days in LJ x CR to 5 - 9 days in LJ x MW. In Ceylon Red the higher number of days for germination was recorded for the cross CR x TR (6-8 days) and CR x MW (5-9 days). The cross CR x DT recorded lowest number of days (4-5 days). The two successful crosses in Tropical Red took 6-7 days (TR x CR) and 5-8 days (TR x MW) for germination. The cross MO x CR, the only one which was successful in Mauritius Orange took 6-8 days for germination. In Nitta Orange, days for germination ranged from 6-9 days in NO x DT and NO x TR to 4-6 days in NO x LJ. In Midori Green, only the cross MG x LR germinated, which took 5-9 days for germination. The cross MW x DT, took the highest number of days (9-12 days) for germination, among the crosses of Merengue White. MW x CR took the lowest number of days for germination (4-8 days).

8. Percentage germination of seed

From a total of 37 combinations, seeds were harvested and kept for germination on moist cotton in petri plates. Among these only 34 showed germination and the three crosses, DT x LR, MG x CR and MG x MW did not germinate at all (Table 16).

a. Liver Red : In the variety Liver Red, LR x LJ had the highest percentage of seed germination (59.1 per cent). The lowest was for LR x TR and LR x

Table 16 Matrix showing average percentage of Seed germination in each combination among ten varieties of *A. andreanum*

♀ \ ♂	LR	DT	PR	LJ	CR	TR	MO	NO	MG	MW	Average
LR	33.3	34.3	-	-	59.1	25.0	-	-	-	25.0	35.34
DT	0.0	42.4	-	20.0	70.4	-	-	-	-	87.5	43.96
PR	54.4	23.9	-	-	25.5	-	-	-	-	41.4	36.30
LJ	62.9	-	-	-	30.8	-	-	-	-	60.0	51.23
CR	51.1	53.3	-	-	-	70.0	10.1	-	-	74.0	51.68
TR	-	-	-	-	51.1	-	-	-	-	86.9	69.00
MO	-	-	-	-	26.1	-	-	-	-	-	26.10
NO	61.4	55.3	-	48.8	44.8	62.1	-	-	-	75.0	57.90
MG	6.9	-	-	-	0.0	-	-	-	-	0.0	2.30
MW	62.5	74.4	-	-	57.7	-	-	-	-	-	64.87

MW (25 per cent). The selfing LR x LR gave 33.3 per cent germination.

b. Dragon's Tongue Red : Among the five crosses that showed fruit set in Dragon's Tongue Red, only four had successful seed germination. The highest germination was for the cross DT x MW (87.5 per cent) followed DT x CR (70.4 per cent). The seeds of DT x LR did not germinate while DT x LJ showed only 20 per cent germination (Plate 24). The selfing DT x DT gave 42.4 per cent germination.

c. Pompon Red : In Pompon Red, the cross PR x LR showed the highest percentage of seed germination (54.4 per cent) while PR x DT (23.9 per cent) had the lowest value (Plate 25).

d. Lady Jane Red : In Lady Jane Red, the highest seed germination was observed for LJ x LR (62.9 per cent) followed by LJ x MW (60.0 per cent). LJ x CR had the lowest i.e., 30.8 per cent, germination.

e. Ceylon Red : Among the crosses of Ceylon Red, the germination percentage ranged from 74 per cent in CR x MW to 10.1 per cent in CR x MO. CR x TR recorded 70 per cent seed germination.

f. Tropical Red : Only two crosses of Tropical Red were successful, of which TR x MW had 86.9 per cent germination while the other cross TR x CR had 51.1 per cent germination.

Plate 24. DT x LJ : Low seed germination

Plate 25. PR x MW : Medium seed germination

Plate 26. NO x TR : High seed germination

Plate 24

Plate 25

Plate 26

g. Mauritius Orange : The only successful cross of Mauritius Orange MO x CR had 26.1 per cent germination.

h. Nitta Orange : In Nitta Orange, the highest seed germination percentage was observed for the cross NO x MW (75.0 per cent) followed by NO x TR (62.1 per cent) (Plate 26). NO x CR had only 44.8 per cent seed germination.

i. Midori Green : Eventhough three crosses showed fruit set in Midori Green, only MG x LR showed seed germination (6.9 per cent). Seeds of MG x CR and MG x MW did not germinate.

j. Merengue White : Among the crosses of Merengue White, MW x DT recorded the highest percentage seed germination (74.4 per cent) followed by MW x LR (62.5 per cent). MW x CR recorded the lowest percentage of seed germination (57.7 per cent).

Among the ten varieties, Tropical Red showed the highest average percentage seed germination (69 per cent) followed by Merentage White (64.9 per cent). The lowest percentage was recorded for Midori Green (2.3 per cent), as the seeds from two of its crosses did not germinate at all.

9. Survival percentage of seedlings at four to six month stage

Out of the 34 combinations that germinated successfully, seedlings belonging to three crosses did not survive beyond four months. These crosses were DT x LJ, LJ x CR and MG x LR. The cross TR x MW showed 100 per

Table 17 Matrix showing survival percentage of seedlings at four to six months stage among ten varieties of *A. andreanum*

♀ \ ♂	LR	DT	PR	LJ	CR	TR	MO	NO	MG	MW	Average
LR	75.0	81.8	-	-	64.5	57.1	-	-	-	72.4	70.2
DT	-	30.6	-	0.0	60.6	-	-	-	-	81.0	43.1
PR	92.2	50.0	-	-	58.3	-	-	-	-	71.4	67.9
LJ	64.7	-	-	-	0.0	-	-	-	-	32.4	32.4
CR	62.7	57.3	-	-	-	33.3	25.0	-	-	89.0	53.5
TR	-	-	-	-	52.2	-	-	-	-	100.0	76.1
MO	-	-	-	-	82.6	-	-	-	-	-	82.6
NO	87.1	50.8	-	52.3	75.3	92.7	-	-	-	94.4	75.4
MG	0.0	-	-	-	-	-	-	-	-	-	0.0
MW	61.4	51.7	-	-	77.1	-	-	-	-	-	63.4

- No fruit set
0 No seed germination
0.0 No survival of germinated seedlings

Plate 27 MW x DT : one month old seedlings

Plate 28. NO x LR : Three month old seedlings

Plate 29. NO x LR : Six month old seedlings

Plate 27

Plate 28

Plate 29

cent seedling survival followed by NO x MW (94.4 per cent). Seedlings of the crosses NO x TR, PR x LR, CR x MW and NO x LR also showed good survival percentage (87.1 to 92.7 per cent) (Table 17).

Among the varieties, the highest average seedling survival was recorded for Mauritius Orange (82.6 per cent) followed by Tropical Red (76.1 per cent) and Nitta Orange (75.4 per cent) (Plates 27, 28 and 29). None of the seedlings involving Midori Green survived. Lady Jane also recorded a low seedling survival of 32.4 per cent.

10 Compatibility parameters based on the performance of the ten varieties as pollen parents

Highest percentage of candles bearing fruits was shown by Ceylon Red (58.8 per cent) followed by Merengue White (51.8 per cent), Liver Red (35.8 per cent) and Dragon's Tongue Red (29.9 per cent). Lowest percentages were recorded for Lady Jane Red (15.0 per cent), Tropical Red (10.5 per cent) and Mauritius Orange (3.6 per cent) (Table 18).

Number of fruits per candle was the highest for the variety Dragon's Tongue Red (70) followed by Ceylon Red (65) and Liver Red (62). In Mauritius Orange and Lady Jane Red the number of fruits were relatively lower (29 and 23 respectively).

Higher percentage fruit set was observed for the varieties Ceylon Red (23.8 per cent), Dragon's Tongue Red (20.6 per cent), Merengue White (20.3 per cent) and Liver Red (20.1 per cent). It was lowest in Mauritius Orange (7.7 per cent) and Lady Jane (7.3 per cent).

Table 18 Compatibility parameters based on the performance of the ten varieties of *A. andreanum* as pollen parents

Varieties	Percentage of candle bearing fruit	Number of fruits per candle	Percentage fruit set	Percentage seed germination	Pollen fertility (per cent)
Liver Red	35.8	62	20.1	41.6	42
Dragon's Tongue Red	29.9	70	20.6	47.3	28
Pompon Red*	-	-	-	-	-
Lady Jane Red	15.0	23	7.3	34.4	14
Ceylon Red	58.8	65	23.8	40.6	21
Tropical Red	10.5	41	16.5	52.4	29.1
Mauritius Orange	3.6	29	7.7	10.1	13.7
Nitta Orange*	-	-	-	-	-
Midori Green*	-	-	-	-	-
Merengue White	51.8	55	20.3	56.2	22

* No pollen emergence occured during the two year period of study

Percentage seed germination was the highest for Merengue White (56.2 per cent) followed by Tropical Red (52.4 per cent), Dragon's Tongue Red (47.3 per cent), Liver Red (41.6 per cent) and Ceylon Red (40.6 per cent). It was lowest for Mauritius Orange (10.1 per cent).

DISCUSSION

5. DISCUSSION

The present study was undertaken with the objective of producing novel hybrids of *Anthurium* with variations in commercial qualities. For the development of superior genotypes, information on different genetic parameters like variability, heritability genetic advance and correlation is a prerequisite. All the ten varieties under the present study showed wide variation for all the qualitative and quantitative characters studied. Cross compatibility analysis based on the response to intervarietal hybridisation was done to select superior parents for hybridisation programmes. Pollen emergence pattern, which is one of the factors that determine the suitability of a variety as pollen parent, was also analysed for the ten varieties studied.

The ten varities under the present study showed significant variation in height ranging from 29.7 cm in Midori Green to 70.9 cm in Pompon Red. The varieties Liver Red and Mauritius Orange also were tall, with heights on par with that of Pompon Red. The heights of varieties Merengue White and Tropical Red were less and on par with Midori Green. Abdussamed (1999) has reported that nutrients significantly influenced the plant height, both the ground as well as pot planting. But plant height can be considered a varietal character, as earlier studies by Bindu and Mercy (1994) showed that the five varieties studied by them significantly varied in their heights. The six varieties studied by Sindhu (1995) also recorded significant variation in height.

The present investigation revealed that one spadix each was found to be produced from the axil of each leaf so that the number of leaves and number of spadicies produced annually per plant was the same. The annual production of

leaves or spadicies was highest in Lady Jane Red (7.6) which was on par with those of Liver Red and Pompon Red. The lowest number of 4.8 was recorded in Merengue White which was on par with those of Tropical Red, Mauritius Orange and Nitta Orange. Similar close correlation between the number of leaves and the number of flowers was observed by Gajek and Schwarz (1980). Steen and Vijverberg (1973) compared the productivity of 120 individual *Anthurium* plants and found that it ranged between four to sixteen flowers over the two years. Mercy and Dale (1994) recorded the annual production of spadicies as five to eight while Sindhu (1995) recorded it as four to eight. The observations in the present study are in conformity with these reports.

In commercial *Anthurium* cultivation spathe size is an important character which determines the value of the cutflower. Spathe size is taken as the sum of the length and width of the spathe. The United States Department of Agriculture Standards were used by Singh (1987) to grade the *Anthurium* flowers as miniature (under 8 cm), small (8-10 cm), medium (10-13 cm), large (13-15 cm) and extra large (15 cm) based on width (in cm) of the spathes. A more acceptable classification proposed by Mercy and Dale (1994) graded the flowers, based on length + width measurements, as super large (30 cm and above), large (25-29 cm), medium (20-24 cm), small (15-20 cm) mini (12-14 cm) and micro (9-11 cm). Following this classification, the variety Dragon's Tongue Red with an average spathe size of 30.74 cm alone produced super large flowers, among the ten varieties studied. Midori Green had large spathes (26.9 cm) while Nitta Orange had medium sized (spathes (23.5 cm). But the spathe sizes of Midori Green and Nitta Orange were not significantly different

from each other. Similar sized spathes of 15-20 cm were seen in Liver Red, Pompon Red, Lady Jane Red and Tropical Red. None of the varieties produced mini and micro sized flowers. Pompon Red produced the smallest flowers with a spathe size of (17.12 cm). In an earlier study Sindhu (1995) found that the varieties Pink and Kalympong Red produced super large flowers while Kalympong Orange and Honeymoon Red varieties produced large flowers. These varieties recorded higher spathe size indices as they are not of commercial nature. Most of the varities in the present study showed small to medium sized flowers as they are of commercial nature.

Short and slender candle is a desirable feature for *Anthurium* flowers. In the present investigation, the longest candles were recorded for Dragon's Tongue Red (8.02 cm) which was on par with those of Merengue White and Ceylon Red. The varieties Tropical Red, Nitta Orange, Mauritius Orange, Lady Jane Red, Liver Red, Pompon Red and Midori Green produced smaller candles which were on par with each other. The candle length ranged from 5.74 cm to 8.02 cm. The five varities studied by Bindhu and Mercy (1994) showed a candle length range of 4 cm to 9.5 cm. The candle length of the six varities studies by Sindhu (1995) ranged from 6.6 cm to 12.1 cm. Seven out of the ten varieties studied in the present investigation have short candles which is a desirable feature. Studies by Mercy and Dale (1994) showed that the candle was long and fleshy in ordinary non-commercial varieties, while it was shorter and more slender in highly bred hybrids.

Among the ten varieties studied spathe - candle ratio, which depends on spathe size and candle length, was highest Midori Green (4.04) followed by

Nitta Orange (3.96) and were on par with each other. Dragon's Tongue Red had a spathe - candle ratio of 3.58 which was on par with that of Nitta Orange. Spathe - candle, ratios were lower in Liver Red, Pompon Red, Lady Jane Red, Ceylon Red and Merengue White. These varieties had smaller spathes with longer candles. The six varieties studied by Sindhu (1995) showed a range in spathe - candle ratio from 2 to 2.86, while the varieties in the present study showed a range from 2.54 in Pompon Red to 4.04 in Midori Green. According to Hennny (1999) the new miniature hybrid 'Red Hot' had a spathe size of 10 - 12 cm and a candle length of 3 to 4 cm, which implies that it has a spathe candle ratio of about 3.3.

Mercy and Dale (1994) recommended that ideal *Anthurium* varieties should have a short candle, curving towards the tip of the spathe and held at an angle less than 45^0. Such ideal position of candle was observed in Pompon Red, Ceylon Red, Tropical Red, Mauritius Orange, Nitta Orange, Midori Green and Merengue White. The average angle between spathe and candle in Liver Red, Dragon's Tongue Red and Lady Jane Red were above 45^0. In a similar study Sindhu (1995) found that the varieties with the ideal position of candles were Chilli Red, Kalympong Orange, Kalympong Red and White.

The commercial *Anthurium* flower consists of a modified bract, the spathe and hundreds of small flowers on the candle like inflorescence, which is botanically a spadix. The flowers are bisexual, regular protogynous, arranged in a series of spirals on the candle, in an acropetal succession (Mercy and Dale, 1994). The number of flowers per candle for different varieties was variously reported as 300 by Watson and Shirakawa (1967), 50-150 by Bindhu and

Mercy (1994), 150 - 350 by Mercy and Dale (1994) and as 175-375 by Sindhu (1995). The present study revealed that the number of flowers per candle varied from variety to variety. It ranged from 254 in Tropical Red to 450 in Lady Jane Red. The varieties Pompon Red, Ceylon Red, Mauritius Orange and Merengue White were on par with Lady Jane Red. None of the varieties were on par with Tropical Red.

According to Paul (1982), the non reversible visible changes accompanying the senescence of *Anthurium* flowers were, loss of spathe-gloss, necrosis of spadix and greening of spathe and spadix. Mercy and Dale (1994) also noted that snescence was marked by yellowing of peduncle and withering of spathe and candle, which took nearly 4 to 7 months from the emergence of young spadix. In the present study, the time span from emergence of a spadix 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 about 3.8 to 7.5 months. Similar results were obtained by Sindhu (1995) also, who observed 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.

Studies by Paul (1980) revealed that, in *Anthurium* species flower maturation started from the basal portion and proceeded regularly towards the apex. He listed many protogynous species of *Anthurium*, in which *A. andreanum* was not included. However, later studies by Bindu and Mercy (1994) and Mercy and Dale (1994) revealed the protogynous nature of *A. andreanum* varieties. Observations in the present study also highlighted the clear

protogynous nature of this species. The number of days, from the day the candle became visible to initiation of female phase was observed to vary from 3.6 to 6.8 days. Initiation of female phase was identified by the slight projection by stigmas and presence of a viscous exudate on the candle. The longest period for initiation of female phase was in Mauritius Orange and the shortest in Lady Jane Red. Sindhu (1995) also reported that the days to initiation of female phase ranged within a period up to ten days, with the variety Honeymoon Red showing the longest period among the six varieties studied by her.

The number of days in female phase was recorded based on the presence of exerted stigma, honey-dew like secretion and some amount of insect activity. Daumann (1921) and Mercy and Dale (1994) have recommended the used of above criteria to identify the female phase. The duration of female phase in the 10 varieties under the present study varied from 6.4 days in Lady Jane Red to 16.4 days in Mauritius Orange. But there were individual flowers in which the female phase lasted up to 21 days and this was observed in Mauritius Orange. Croat (1980) reported that, although in some species like *A. armeniense*, *A. caperatum*, *A. fatoense* etc., the stigmas did not form droplets they were glistening, often exerted and assumed to be receptive. He added that the duration of female phase many range from half a day to as long as 28 days. The duration was reported to be three to twelve days by Bindu and Mercy (1994) and as three to seven days by Mercy and Dale (1994). Among the six varieties studied by Sindhu (1995), this duration ranged from five to 25 days.

The interphase between the female and male phase was marked by the drying up of stigmatic droplets. Observations from the seven varieties under the present study showed that the interphase may range from 4.8 to 10.2 days on an average. The variety Liver Red had the longest interphase period and the shortest was in Merengue White (Days of interphase and male phase could not be recorded for the varieties Pompon Red, Nitta Orange and Midori Green in which no pollen production was observed during the period of this study). Croat (1980) observed that the duration of interphase was several days in most *Anthurium* species, whereas in a few of them the time lag was so short that it was not certain whether those species were homogamous or protogynous. Bindu and Mercy (1994) noticed that interphase lasted for about four to seven days, while Mercy and Dale (1994) opined that it may last for about a week in general. Studies on six varieties by Sindhu (1995) showed that interphase last for four to ten days. Suppression of male pahse in some varieties during March to August period was observed by her also.

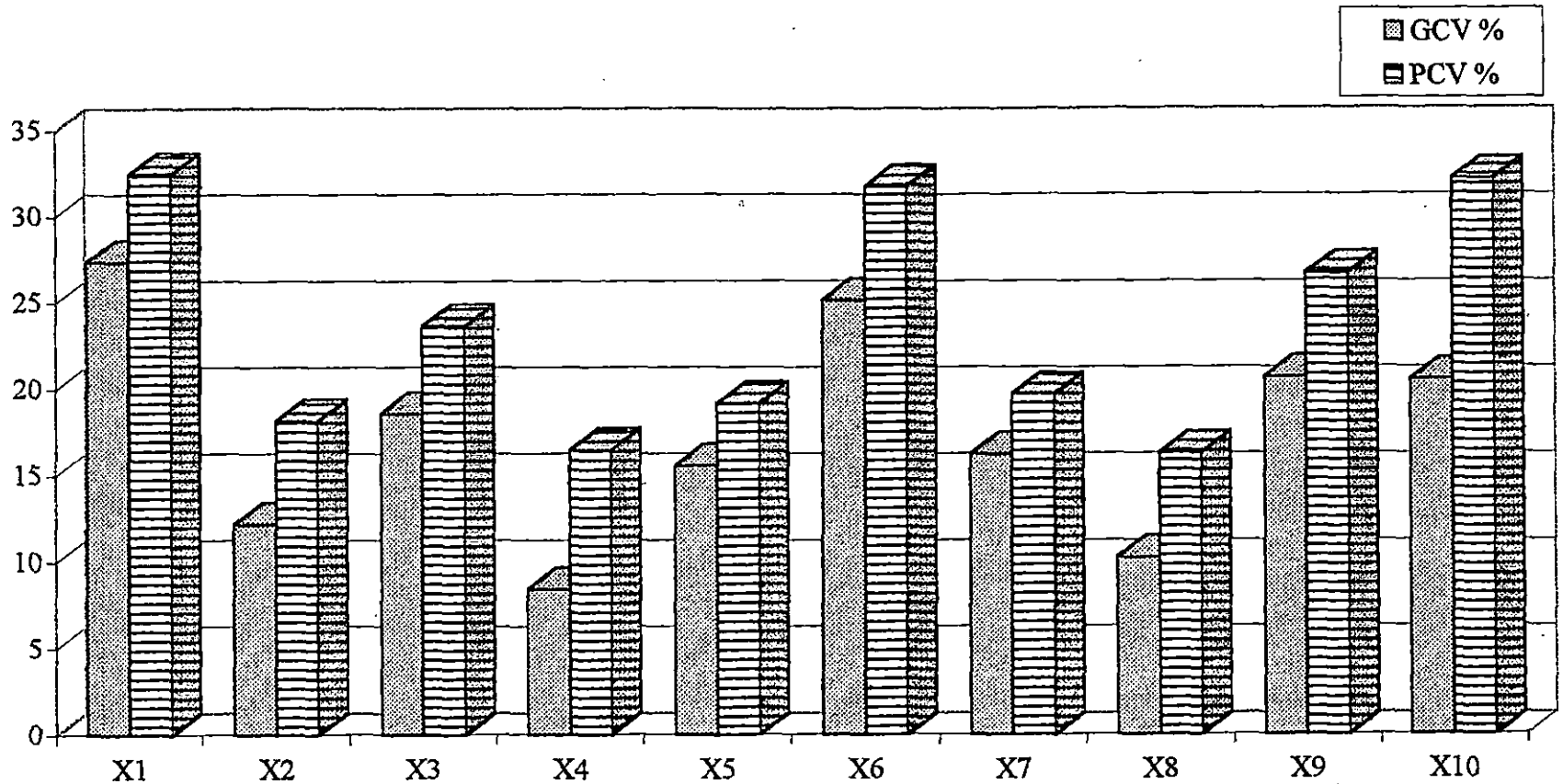
Following the interphase, a male phase was observed, marked by anther extrusion starting from the base of the candle and proceeding upwards. The average number of days for which the candles remained in male phase ranged from 5.4 days in Mauritius Orange to 10.4 days in Tropical Red. Croat (1980) reported that in some *Anthurium* species, the male phase lasted for several weeks and that anther emergence may be scattered as in *A. caperatum* or sporadic as in *A. luteynii*. Similar scattered anther emergence on the candle was observed in the variety Mauritius Orange under the present study. In the varieties Dragon's Tongue Red and Tropical Red, sometimes only a portion of

the candle showed anther emergence. Such observations were recorded by Sindhu (1995) also, in the variety Kalympond Red. Bindu and Mercy (1994) reported that male phase lasted for 3 to 7 days, whereas Mercy and Dale (1994) observed that it may last for 4 to 8 days. In the six varieties studied by Sindhu (1995), the duration of male phase ranged from 3 to 8 days.

Genetic variability in a population is the raw material for crop improvement. The total variability was partioned into heritable and non heritable components with the help of genetic parameters like genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2) and genetic advance (GA) which serve as full guidelines for selection (Genetic analysis of variability for the two characters, days of interphase and duration of male phase could not be done as no anther production was observed in the varieties Pompon Red, Nitta Orange and Midori Green during the period of the study).

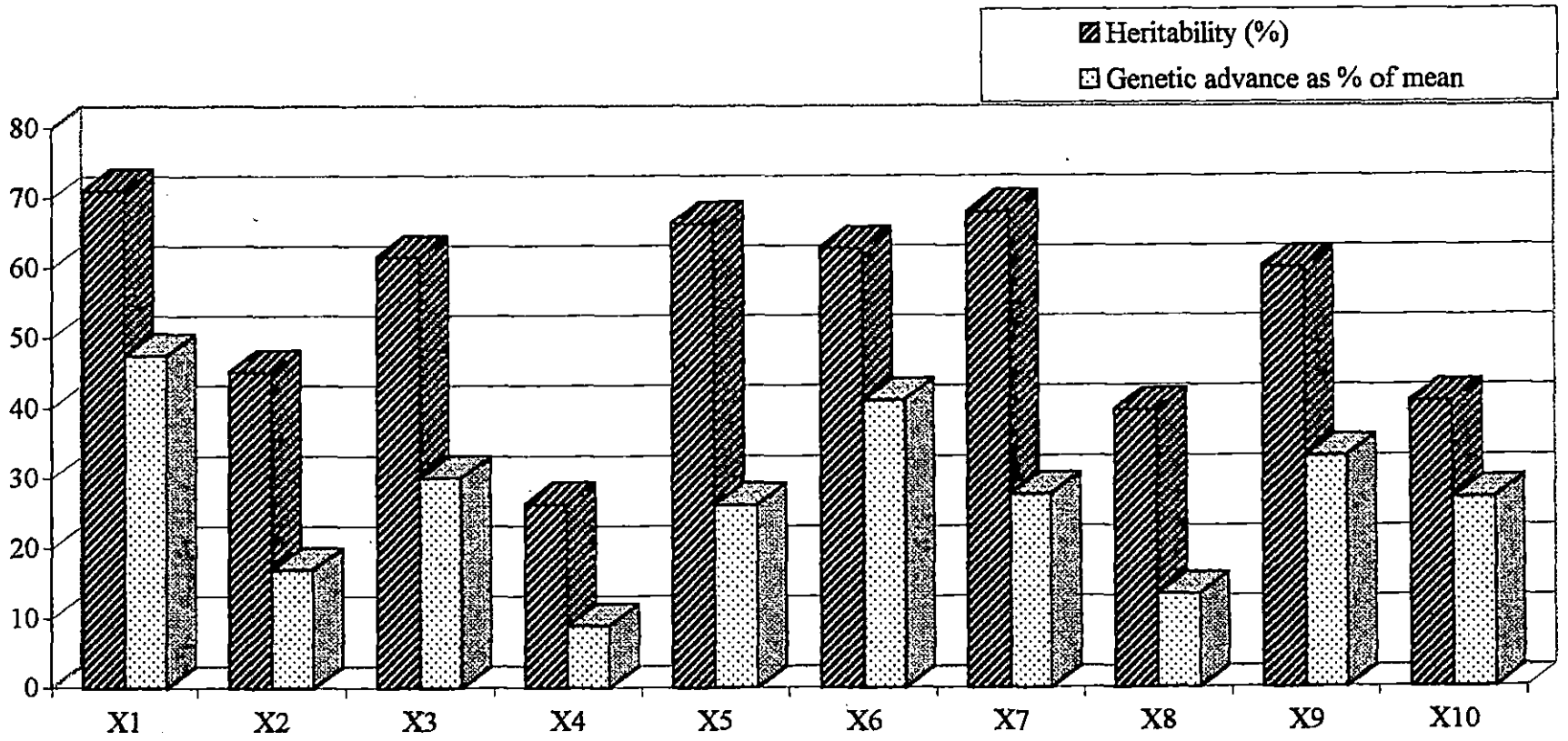
Phenotypic and genotypic coefficients of variation were estimated based on the coefficients of variation and these parameters were used to compare the variability among the ten varieties. The GCV provides a valid basis for comparing and assessing the range of genetic diversity for quantitative characters and PCV measures the extent of total variation. GCV and PCV are better indices for comparison of characters with different units of measurement, than estimates of quantitative varaition like range and variation around mean.

Fig. 1 Components of total variance for the ten traits in *A. andreanum*



X1 - Plant height (cm)
X2 - No. of leaves or spadices per year
X3 - Spathe size (width + length) (cm)
X4 - Candle length (cm)
X5 - Spathe candle ratio
X6 - Position of candle (degrees)
X7 - No. of flowers per candle
X8 - Life of spadix (months)
X9 - Days to initiation of female phase
X10 - No. of days in female phase

Fig. 2 Heritability and genetic advance for the ten traits in *A. andreanum*



X1 - Plant height (cm)
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X4 - Candle length (cm)
X5 - Spathe candle ratio
X6 - Position of candle (degrees)
X7 - No. of flowers per candle
X8 - Life of spadix (months)
X9 - Days to initiation of female phase
X10 - No. of days in female phase

A persual of Table --, shows that high PCV combined with high GCV were obtained for plant height, position of candle, days to initiation of female phase, number of days in female phase and spathe size. This revealed a greater extend of variability for these characters, thereby suggesting good scope for improvement of these important characters through selection. Plant height recorded the highest GCV and PCV.

Lower values of GCV and PCV were estimated for the characters candle length and life of spadix, indicating low magnitude of variability. So, improvement of these characters has only a limited scope.

The characters, number of days in female phase, candle length, position of candle, life of spadix and days to initiation of female phase showed maximum differences between GCV and PCV, which indicates that the influence of environment on these characters is considerable. But the lower differences between GCV and PCV of the characters flowers per candle and spathe - candle ratio point out that the variations observed in these characters are mainly due to genetic reasons and that the environmental influence on these characters is less.

Heritability estimates the transmissibility of characters from one generation to other and it provides a measure of the value of selection for different attributes. But high heritability does not necessarily mean a high genetic advance for a particular character (Allard, 1960). Heritability along with genetic advance is more useful than heritability alone in predicting the resultant effect of selecting the best individuals (Johnson *et al.*, 1955).

In the present study, the highest values for heritability and genetic advance were receorded for plant height. The characters spathe size, spathe - candle ratio, position of candle, number of flowers per candle and days to initiation of female phase also recorded a relatively high heritability of above 60 percentage. These characters also showed relatively higher genetic advance values. According to Panse (1957), the characters with high heritability and genetic advance were controlled by additive gene action and therefore amenable to genetic improvement through selection.

Candle length showed the lowest values for both heritability and genetic advance, which shows that this character is highly influenced by envirioment.

The commercially important characters plant height and position of candle showed relatively higher heritability and genetic advance values and so, they can be improved through selection.

Characters genetically related to each other tend to move in the same direction under selection favouring any one of such related traits. Such a correlated response to selection is the basic property of quantitative traits under the control of polygenic system. The qualitative traits governed by one or a few genes do not exhibit correlated changes on selection (Sharma, 1994). The genotypic correlation between characters provides a reliable measure of genetic association between the characters and helps to differentiate the vital association useful in breeding from the non-vital ones (Falconer, 1981).

The genotypic, phenotypic and environmental correlation between all the possible pairs of characters wre analysed. This revealed that plant height is positively correlated at genotypic level with number of leaves or spadices per

year, number of flowers per candle and number of days in female phase. So a selection for increased height will result in plants with more number of spacides per year. Plant height was negatively correlated with spathe - candle ratio at all the three levels.

The number of leaves or spadices per year was found to have high positive genotypic correlation with position of candle (i.e., the angle between spathe and candle) and number of flowers per candle. Since plants with lesser angle between spathe and candle and lower number of flowers per candle are desirable, their positive association with number of spadices produced per year is not a favourable one.

According to Mercy and Dale (1994), ideal *Anthurium* variety should have medium sized spathe. Correlation study revealed that spathe size was positively correlated with all the traits except number of flowers per candle, plant height and number of leaves or spadices per year. Significant positive correlation at all the three levels was shown with candle length. So a selection for smaller spathe size will result in shorter candles also.

Candle length exhibited positive correlation with all the traits except spathe - candle ratio and days to initiation of female phase. It had high positive genotypic correlation with position of candle (angle between spathe and candle) and number of flowers per candle. Since a decrease in candle length, angle between spathe and candle and number of flowers per candle is desired in commercial *Anthurium* varieties, this association is a useful one.

At genotypic level, spathe - candle ratio exhibited high positive correlation with spathe size and days to initiation of female phase. It was

highly negatively correlated with number of flowers per candle. Since selection in *Anthurium* is aimed at higher spathe - candle ratio and lower number of flower per candle, their negative correlation is useful to the breeder.

Mercy and Dale (1994) recommended that in a commercial *Anthurium* variety, angle between spathe and candle should be less. Position of candle (angle between spathe and candle) showed highest negative genotypic correlation with days to initiation of female phase followed by number of days in female phase. It had positive genotypic correlation with candle length and number of leaves or spadices per year.

Number of flowers per candle had high positve genotypic correlation with candle length, plant height and number of leaves or spadices per year. In *Anthurium* less number of flowers per candle is one of the desired features.

Life of spadix, which is an important commercial character, was found to be positvely correlated with candle length, spathe size, number of leves or spadices per year, plant height, number of days in female phase and spathe - candle ratio.

At genotypic level, days to initation of female phase had high positive correlation with number of days in female phase, spathe - candle ratio and plant height. Highest negative correlation was with position of candle followed by candle length.

Number of days in female phase had high positive genotypic correlation with days to initation of female phase, plant height and spathe size. Highest negative genotypic correlation was with number of leves or spadices per year followed by position of candle.

The ten varieties under the present study showed a complete range of spathe colour, from deep maroon to pink to orange, green and white. This wide variation can be explained on the basis of many studies conducted on the mechanism of spathe colour development in *Anthurium*. Iwata *et al.* (1970) identified the anthocyanins in the spathes of *A. andreanum* to be cyanidin 3-rhamnosyl glucoside and pelargonidin 3 - rhamnosyl glucoside. They concluded that both the pigments were present in the red cultivars while orange and coral contained only pelargonidin 3 - rhamnosyl glucoside. In white either or both these pigments are absent. Iwata *et al.* (1985) further explained that a predominance of cyanidin 3 - rhamonosyl glucoside resulted in coral to orange. They have added that flavone, which is another group of pigments, although present in variable amounts, had no effect cyanic shades. So the variety Lady Jane with dark pink spathes and the varieties Liver Red, Dragon's Tongue Red, Pompon Red, Ceylon Red and Tropical Red with red coloured spathes have the presence of both the above pigments while Mauritius Orange and Nitta Orange have only pelargonidin 3 - rhamnosyl glucoside. In Merengue White either cyanidin 3-rhamnosyl glucoside or both the pigments are absent.

The genetics of spathe colour inheritance was studied in detail by Kamemoto *et al.* (1988). They concluded that two major genes, Mand O were responsible for the five major colours : red, orange, pink, coral and white. The gene M was found to control the production of cyanidin 3-rutionoside while gene O controlled that of pelargonidin 3 - rutinoside. Red and pink resulted when both M and O genes are present. So the red and pink spathed varieties

under the present study have both M and O genes. But the variation in red spathe colour from maroon to dark red to bright red to red and pink is explained by their finding that, the incremental effects of M appeared to be greater than that of O and therefore the intensity of colours decreased from MMOO, MMOo, MmOO to MmOo. They have also concluded that orange had a genotype of mmOO and was true breeding. So, the varieties Mauritius Orange and Nitta Orange with orange spathe must be having the mmOO genotype and are true breeding. The recessive oo was epistatic to M, and therefore white resulted when both were recessive (mmoo) or M was in combination with recessive oo (Mmoo, Mmoo). So, the variety Merengue White's genotype has to be either mmoo ro MMoo or Mmoo. Wannakrairoj and Kamemoto (1990) studied the inheritnce of purple spathe in *Anthurium* and proposed a scheme to explain this. A recessive allele 'p' was found to modify the colour of anthocyanins controlled by M and O loci. A spathe was purple when the genotype was M -O-pp. The dominant P allele has no effect on red, orange or coral spathe colours. The p allele was found to have no effect on the white genotypes whether it is in dominant or recessive condition. Thus,

MMOO
MmOO = Red
MMOo

MmOo = Pink

mmOO = Orange

mmOo = Coral

MMoo
Mmoo = White
mmoo

M-O-pp = Purple

The dominant P allele has no effect on colour in any combination.

Spathe texture showed high variation among the ten varieties studied; from thick and deeply blistered spathe in Mauritius Orange to thin and smooth spathe in Lady Jane Red. According to Birdsey (1956), Linden described the spathe of *A. andreanum* based on varying degrees of smoothness and blistering. Mercy and Dale (1994) have opined that the spathe of floral anthuriums may be smooth, thick and glossy without prominent veins or it may be thinner, deeply veined and blistered. The six varieties studied by Sindhu (1995) also showed variation from thick to thin and deep to shallowly blistered spathes.

Candle colour was light pink in Dragon's Tongue Red and Lady Jane Red, pink in Liver Red and Merengue White, cream in Ceylon Red and light yellow in Mauritius Orange. The three varieties, Pompon Red, Tropical Red and Nitta Orange had yellow candles while Midori Green alone had light green candles. According to Mercy and Dale (1994), the candle had a single colour red, pink or green in ordinary *Anthurium* varieties and hybrids had yellow, white, pink or red colours in two or more bands. Sindhu (1995) reported that the six varieties studied by her had candles with either a single colour or two or more bands of colours. Henny (1999) observed that the *Anthurium* hybrid 'Red Hot' had a candle which was orange-red apically blending to red basally.

Though propagation of anthuriums using sucker is a slow process, it is an important trait considered in the selection of superior genotypes. The present investigation revealed that suckering ability was very high for Liver Red and Lady Jane, high for Midori Green, medium for Dragon's Tongue Red, Ceylon Red, Mauritius Orange and Nitta Orange, low for Merengue White and very low for Pompon Red and Tropical Red. Mercy and Dale (1994) opined that most of the good commercial *Anthurium* varieties were very shy suckering or did not sucker at all. They recommended the use of Gibberellic acid (GA) or Benzyl adenine (BA) (500-1000 ppm) to increase the rate of sucker production. Similar effect of growth regulators on sucker production had been reported by Higaki and Rasmussen (1979), Salvi (1997) and Abdussamed (1999).

The acetocarmine staining method was used to find the pollen fertility of the selected varieties (Pollen fertility of Pompon Red, Nitta Orange and Midori Green can not be found out as no pollen production occured in these during the period of study. The highest pollen fertility was observed for Liver Red (42 per cent) followed by Tropical Red and Dragon's Tongue Red. Mauritius Orange (13.7 per cent) and Lady Jane (14 per cent) recorded the lowest pollen fertility values. Mitu and Acatrinei (1974) reported that the germination of pollen grain was proportional to pollen grain stain ability as, acetocarmine preferentially stains the chromosome or nucleus. The observations by Lalithambika (1978) that the pollen sterility of *A. andreanum* vary from 70 - 75 per cent, is in conformity with the findings of the present study. Bindu and Mercy (1994) reported that the pollen fertility in

A. andreanum vary from 20.4 per cent to 28.8 per cent, which again substantiates the findings of this study. As sterility is a condition frequently associated with hybridity, we can take the low pollen fertility in *A. andreanum* as an indication of its hybrid nature. Based on the cytological studies of five varieties, Bindu and Mercy (1994) concluded that the low fertility can also be done to the high degree of meiotic abnormalities like clumping, lagging of chromosomes at anaphase, unequal segregation, preocious disjunction of chromosomes, chromosome eliminaiton through micronuclei etc. found in *A. andreanum*. However, whether the B chromosomes had any effect on pollen fertility determination was not clear.

The nature of inflorescence axis is one of the most important factors that determine the appearance and hence the value of *Anthurium* flowers, when marketed as cutflower. Among the ten varieties studied, the axis nature varied from long, straight and very strong in Dragon's Tongue Red to short, straight and thin in Nitta Orange and Midori Green. Liver Red, Pompon Red, Lady Jane Red, Tropical Red, Mauritius Orange and Merengue White had long, straight and strong inflorescence axis while Ceylon Red alone had medium long, straight and strong inflorescence axis. Mercy and Dale (1994) suggested that good *Anthurium* hybrids should have strong and straight inflorescence axis.

A study of the pollen emergence pattern of the ten varieties for the one year period of August 1998 to July 1999 revealed significant difference among the varieties with respect to pollen emergence pattern. No pollen emergence was observed for three varieties viz., Pompon Red, Nitta Orange and Midori

Green during the year under report. A pattern was observed for pollen emergence in all the other varieties except Merengue White; where it showed a scattered distribution. In the other varieties the pollen emergence was found to be low during the months from March to June. A suppression of male phase during March to August period in *A. andreanum* was observed by Sindhu (1995) also. Interestingly it may be mentioned that usually the temperature during summer months in the state goes up or may reach 36 to 37^{0}C during March. However in the year 1998-'99 (year of report) the temperature reached only a maximum of 32.5^{0}C due to intermittent rains through out the summer months. It may be due to this lower temperature that the suppression of male phase was restricted to the months of March to June 1999. Generally the temperature is higher and when the temperature is higher the anther emergence has been found to be suppressed for March to August or even up to September.

The optimum temperature for *A. andreanum* has been reported to be 22^{0}C to 25^{0}C (Mercy and Dale, 1994) i.e., 22^{0}C night temperature and 25^{0}C day temperature. In the pesent study, no pollen has been produced by the three varieties i.e., Pompon Red, Nitta Orange and Midori Green probably because these three values are extermly sensitive to the temperature regime. In the month of January the average night temperature was 21.9 but the average day temperature was 31.2^{0}C. Other seven varieties showed low pollen emergence during March to June during which period night temperature was on a range of 23.9 to 24.4^{0}C, which is considarably higher than the optimum tempearature of 22^{0}X. Day time temperature during this period was also high varying from 29.9 to 32.5^{0}C.

These varieties produce pollen only when the day time temperature was between 29.0 to 31.4^{0}C. Interestingly the variety Dragon's Tongue produced pollen throughout 11 months of the year with a slight suppression during the month of May, while the variety Liver Red produced pollen for 10 months of the year. Polen emergence was suppressed in this vareity only during April and May.

For analysing the cross compatibility among the ten *A. andreanum* varieties under study, intervarietal hybridisation was undertaken. A total of 208 crossings involving 67 combinaitons were done, which included 60 cross combinations and 7 self. Crossings involving three varieties Pompon Red, Nitta Orange and Midori Green as pollen parents could not be attempted, as no pollen emergence was observed in these varieties during the period of study. Hybridisation and selection was pointed out by Kamemoto and Nakasone (1955), as the acepted method for improving anthuriums.

Both intraspecific as well as interspecific hybiridisation was used by early *Anthurium* breeders. Birdsey (1956) attributed much of the variation in blistering patterns of spathes of *A. andreanum* to interspecific hybridisation. Interspecific cross compatibility evaluation among 56 species of *Anthurium* by Sheffer and Kamemoto (1976) revealed that, hybrids of *A. andreanum* and *A. scherzerianum* were not readily obtainable. But they got hybrids of *A. andreanum* with six other colosely related species. Kaneko and Kamemoto (1978) suggested that cultivated *Anthurium* forms were derived from interspecific hybrids which are supposed to have arisen spontaneously in early species collections. A new interspecific hybrid, 'Southern Blush' was produced by

Henny *et al.* (1988) by crossing a large pink - flowered *A. andreanum* cv. with *A. amnicola*. Kuehule *et al.* (1995) transferred systemic resistance to bacterial pathogens from *A. antioquiense* to cultivated *A. andreanum* and got resistant F_1 hybrids.

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

The three important parameters used for compatibility analysis in the present study were percentage of fruiting candles, percentage of fruit set per candle and percentage seed germination. Among the cross combinations attempted, the percentage of fruiting candles was 100 per cent for the cross LJ x CR, LJ x MW, CR x MW, NO x LJ, NO x CR, MG x CR and MW x CR. No fruit bearing candles were produced in 25 cross combinations attempted. The only two selfing that were successful were LR x LR and DT x DT. Among the ten parental varieties the percentage of fruiting candles was maximum for variety Nitta Orange (51.93 per cent). The varieties Merengue White, Ceylon Red and Pompon Red also showed good percentage of fruiting candles. It was lowest for Mauritius Orange (9.51 per cent). 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. Among the six varieties studied by Sindhu (1995), the variety white had maximum percentage of fruiting candles (93 per cent) and the lowest was for Kalympong Red (50 per cent). Selfings and crosses resulted in 66.2 per cent and 76.5 per cent fruiting spadices respectively. In the present study involving 10 *A. andreanum* varieties selfing and crossing gave 22.5 per cent and 31.06 per cent success respectively.

The fruit is a berry in *Anthurium*. Mercy and Dale (1994) observed that a candle with developing fruits could be visually identified from the second month of fertilization, as it became swollen and fleshy with developing fruits embedded in it. The colour of ripe berries varied from creamish yellow to dark red. Individual cross combinations that recorded highest number of fruits per candle were PR x LR (183) followed by PR x CR (162). The crosses LR x DT and CR x MW also recorded high number of fruits per candle. The lowest fruit count of five candle was obtained for the cross DT x LJ. The variety Pompon Red recorded the highest average number of fruits per candle while Lady Jane recorded the lowest number. Merengue White also had relatively higher number of fruits per candle. The two successful selfings LR x LR and DT x DT produced 11 and 34 fruits per candle respectively. Mercy and Dale (1995) observed that a well fertilized candle may have upto 100 to 200 fruits per candle. 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.

Absence of full fruit set in spadix was identified as a major problem in

the development of *Anthurium* cultivars by Zimmer (1986). In the present study also the percentage of fruit set was below 50 per cent for all the cross except PR x LR, which had 57.6 per cent fruit set. The cross DT x LJ had only 2.3 per cent fruit set while LJ x CR had 3.6 per cent fruit set. The variety with maximum percentage fruit set was Pompon Red followed by Merengue White. Lady Jane and Mauritius Orange had the lowest percentage of fruit set. In the study using six *Anthurium* varieties, conducted by Sindhu (1995), the cross P x HR recorded the highest (44.3 per cent) KR x KR recorded the lowest (0.4 per cent) fruit set per candle.

Among the ten varieties studied, the duration from the day of pollination to the day of berry ripening ranged from 4.4 months in Lady Jane Red to 6.1 months in Ceylon Red. The highest average fruit maturity period was observed for the cross DT x CR (7.5 months) and the lowest was for LJ x LR (3.8 months). All the varieties except Lady Jane took an average of more than five months to reach fruit maturity. Similar duration for fruit ripening was observed by Sindhu (1995). She has recorded that this duration ranged from 5 to 6.8 months. Duration for fruit maturity in *Anthurium* was recorded as 6-8 months by Singh (1987), as 6-7 months by Geir (1987), as 5-12 months by Zimmer (1986) and as 4-7½ months by Mercy and Dale (1994). All these reports together with the observations of the present study confirms that the long fruit ripening period in *A. andreanum* is one of the resons that contribute to the slow progress of *Anthurium* breeding programmes.

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

one or two seeds. In the present study, it was found that all the crosses showed high percentage of berries bearing single seeds except the two crosses CR x LR and PR x CR. Eleven out of the 37 successful crosses had only single seeded berries. All the successful crosses involving Lady Jane as female parent had only berries with single seeds. The only cross that had three seeds per berry was PR x CR (3 seeds in 5.3 per cent of the berries). In the compatibility study by Sindhu (1995) also, the percentage of single seeded berries was more than that of double seeded berries in all the crosses except one. The percentage of single seeded berries ranged from 37 per cent to 100 per cent.

The size of seeds from the berries of same cross showed variation depending on whether they contained one, two or three seeds. In a berry with two seeds, one of the seeds was usually smaller than the other. The largest seeds among two seeded berries were observed for the crosses PR x LR, PR x DT and MW x LR. Among single seeded crosses, the largest seeds were seen in TR x MW. The smallest seeds of size 1.9 x 1.5 mm found in MG x MW did not germinate. Sindhu (1995) also observed that when two seeds were seen in a berry, usually one was smaller. Pink and Honeymoon Red varieties produced larger sized seeds while the Kalympong varieties produced smaller seeds.

In some ripe berries, it was observed in the present study, that the seeds at the time of harvest had the tip of radicle emerging from the seed coat. Such seeds germinated immediately. In other crosses the days taken for germination ranged from three to twelve days. The maximum of 12 days was taken by the crosses LJ x LR and MW x DT. Anthurium seeds, according to Singh (1987)

took 6-8 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.

Seeds from 37 successful combinations were kept for germination in petri plates, of which only 34 combinations showed germination. The seeds crosses DT x LR, MG x CR and MG x MW did not germinate. The cross DT x MW recorded the highest value of 87.5 per cent germination. The crosses TR x MW, NO x MW, MW x DT and CR x MW also showed good germination. Since all these crosses involve Merengue White, this variety can be safely selected as a parent in breeding programmes. None of the seeds obtained from the crosses involving Midroi Green germinated except MG x LR. Even this cross had only 6.9 per cent germination. Among the ten parent varieties, Tropical Red showed the highest average percentage of seed germination (69 per cent) followed by Merengue White (64.9 per cent). The lowest percentage was recorded for Midori Green (2.3 per cent).

Bachthaler (1977) observed that 70-75 per cent of *A. scherzerianum* seeds germinated, after drying and storing at 20^0C for 24 h. In another study Bachthaler (1978) observed that 100 per cent of the seeds from unripe, half-ripe and ripe berries germinated, while only 42 per cent of the seeds from over-ripe berries germinated. Mercy and Dale (1994) opined that the seeds from crosses between ordinary hardy varieties showed above 90 per cent germination. However, seeds produced from exotic varieties were smaller in size and poor in germination. This observation explains the low percentage of germination found in the highly improved varieties, Midori Green and

Mauritius Orange, under the present study. Sindhu (1995) observed that the variety white had the highest average germination percentage (63.4 per cent) and Kalympong Orange had the lowest germination. Among the crosses, Honeymoon Red and Chilli Red recorded the highest germination of 78 per cent.

Data on the survival of seedlings at four to five months showed that the seedlings of only 31 combinations out of the 34 cross combinations that germinated survived for more than four months. Seedlings of the crosses DT x LJ, LJ x CR and MG x LR failed to survive. All the seedlings of the cross TR x MW survived, i.e., this cross showed 100 per cent seedling survival. Other crosses with good seedling survival were NO x MW, NO x TR, PR x LR, CR x MW and NO x LR. The highest average seedling survival was recorded for the crosses of Mauritius Orange and the lowest for Midori Green. So, in addition to the low levels of fruit set and seed germination, the high mortality of seedlings in the early stages also can be considered as a major constraint in the development of new *Anthurium* hybrids.

The compatibility among the varieties based on this performance as pollen parents also was analysed. Since no pollen emergence was recorded for Pompon Red, Nitta Orange and Midori Green, this analysis is based on the other seven varieties only. The percentage of candles bearing fruits was highest for Ceylon Red and lowest for Mauritius Orange. Highest number of fruits per candle was observed for Dragon's Tongue Red and Ceylon Red and it was lowest in Lady Jane. The highest percentage of fruit set (23.8 per cent) was recorded for Ceylon Red and the lowest (7.3 per cent) for Lady Jane. The percentage seed germination varied from 56.2 per cent in Merengue White to

10.1 per cent in Mauritius Orange. Based on overall performance as pollen parents, the most successful varieties were Liver Red, Dragon's Tongue Red, Ceylon Red and Merengue White which had relatively higher pollen fertility also. But the variety Tropical with good pollen fertility had relatively low percentages of candles bearing fruits and fruit set. The least successful varieties Lady Jane and Mauritius Orange, also had the lowest percentage of pollen fertility.

The compatibility reactions, among the 67 combinations attempted, based on fruiting candles, fruit set and seed germination were converted into a linear scale for easy computation of compatibility in a novel manner. The percentage of fruiting candles which ranged from 0 - 100 per cent, were divided into four compatibility classes as, high (100-76 per cent) - A, medium (75-26 per cent) - B, low (25-1 per cent) - C and nil (0 per cent) - D. The percentage of fruit set ranged from 2.3 to 57.6 per cent. These values were classified as high (above 40 per cent) - A, medium (39-20 per cent) - B, low (19-1 per cent) - C and nil (0 per cent) - D. The percentage of seed germination, which ranged from 0 to 87.5 per cent was classified as, high (above 50 per cent) - A, medium (49-20 per cent) - B, low (19-1 per cent) - C and nil (0 per cent) - D. A score of 3 points was assigned to the class A, 2 for class B, 1 for class C and 0 for class D. The total score of the 67 combinations that ranged from 0 to 9 was analysed to get an idea of the cross compatibility relations among the ten varieties under study.

Among the 67 combinations attempted, 30 crosses were found to be completely incompatible with a score of zero (Table 19 a). Out of the 37

Table 19a Compatibility score on the basis of the performance of ten varieties 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 = O point)

Sl. No.	Gross combinations	Fruiting candles (per cent)	Fruit set (per cent)	Seed germination	Total score	Varietal score
1.	LR × LR	C	C	B	4	
2.	LR × DJ	B	B	B	6	
3.	LR × LJ	D	-	-	0	
4.	LR × CR	B	B	A	7	
5.	LR × TR	C	C	B	4	
6.	LR × MO	D	-	-	0	
7.	LR × MW	B	B	B	6	27
8.	DT × LR	B	C	D	3	
9.	DT × DJ	C	C	B	4	
10.	DT × LJ	B	C	B	5	
11.	DT × CR	B	B	A	7	
12.	DT × TR	D	-	-	0	
13.	DT × MO	D	-	-	0	
14.	DT × MW	B	C	A	6	25
15.	PR × LR	A	A	A	9	
16.	PR × DJ	B	C	B	5	
17.	PR × LJ	D	-	-	0	
18.	PR × CR	B	A	B	7	
19.	PR × TR	D	-	-	0	
20.	PR × MW	B	B	B	6	27
21.	LJ × LR	B	C	A	6	
22.	LJ × DJ	D	-	-	0	
23.	LJ × LJ	D	-	-	0	
24.	LJ × CR	A	C	B	6	
25.	LJ × TR	D	-	-	0	
26.	LJ × MO	D	-	-	0	
27.	LJ × MW	A	C	A	7	19
28.	CR × LR	B	C	A	6	
29.	CR × DJ	B	C	A	6	
30.	CR × LJ	D	-	-	0	
31.	CR × CR	D	-	-	0	
32.	CR × TR	B	C	A	6	
33.	CR × MO	C	C	C	3	
34.	CR × MW	A	A	A	9	30

Table 19a contd .....

Sl. No.	Gross combinations	Fruiting candles (per cent)	Fruit set (per cent)	Seed germination	Total score	Varietal score
35.	TR × LR	D	-	-	0	
36.	TR × DJ	D	-	-	0	
37.	TR × LJ	D	-	-	0	
38.	TR × CR	C	B	A	6	
39.	TR × TR	D	-	-	0	
40.	TR × MO	D	-	-	0	
41.	TR × MW	B	C	A	6	12
42.	MO × LR	D	-	-	0	
43.	MO × DJ	D	-	-	0	
44.	MO × LJ	D	-	-	0	
45.	MO × CR	B	C	B	5	
46.	MO × TR	D	-	-	0	
47.	MO × MO	D	-	-	0	
48.	NO × MW	D	-	-	0	5
49.	NO × LR	B	B	A	7	
50.	NO × DJ	B	B	A	7	
51.	NO × LJ	A	C	B	6	
52.	NO × CR	A	B	B	7	
53.	NO × TR	C	B	A	6	
54.	NO × MW	B	C	A	6	39
55.	MG × LR	B	C	C	4	
56.	MG × DJ	D	-	-	0	
57.	MG × LJ	D	-	-	0	
58.	MG × CR	A	C	D	4	
59.	MG × TR	D	-	-	0	
60.	MG × MO	D	-	-	0	
61.	MW × MW	B	C	D	3	11
62.	MW × LR	B	B	A	7	
63.	MW × DJ	B	B	A	7	
64.	MW × LJ	D	-	-	0	
65.	MW × CR	A	B	A	8	
66.	MW × TR	D	-	-	0	
67.	MW × MW	D	-	-	0	22

successful combinations, the crosses with highest compatibility score of nine (AAA) were PR x LR and CR x MW. Both these combinations are expected to produce commercially valuable hybrids as all the four varieties involved have desirable commercial characters. The reciprocal cross MW x CR (of the cross CR x MW) had the next highest compatibility score of eight. The other reciprocal cross PR x LR could not be attempted due to lack of pollen emergence. Crosses involving Mauritius Orange and Midori Green showed relatively lower compatibility scores of five, four and three. Higher compatbility scores were obtained for most of the crosses of Liver Red, Pompon Red, Ceylon Red, Nitta Orange and Merengue White. The crosses DT x LR, MG x CR and MG x MW showed successful fruit set; but the seeds from these failed to germinate, resulting in very low compatibility score.

In general, considering all crosses involving the ten varieties as female parents, Nitta Orange appeared to be the most compatible, showing the best performance with a total compatibility score of 39 for 6 surviving crosses. This variety missed only one cross i.e., with the variety Mauritius Orange which did not produce any fruting candles. The variety Ceylon Red appear to be the next best female parent with a total score of 30 with five surviving crosses. Varieties Liver Red and Pompon Red had a total compatibility score of 27 each with 5 and 4 surviving crosses respectively. The variety Mauritius Orange showed lowest compatibility score of 5 from a single surviving cross with the variety Ceylon Red. Compatibility analysis based on the performance of seven varieties as male prents.

Compatibility score of the ten varieties under study, as male parents,

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

(A = 3 points, B = 2 points, C = 1 point and D = O point)

Sl. No.	Gross combinations	Fruiting candles (per cent)	Fruit set (per cent)	Seed germination	Total score	Varietal score
1.	LR × LR	C	C	B	4	
2.	DJ × LR	B	C	D	3	
3.	PR × LR	A	A	A	9	
4.	LJ × LR	B	C	A	6	
5.	CR × LR	B	C	A	6	
6.	TR × LR	D	-	-	0	
7.	MO × LR	D	-	-	0	
8.	NO × LR	B	B	A	7	
9.	MG × LR	B	C	C	4	
10.	MW × LR	B	B	A	7	46
11.	LR × DT	B	B	B	6	
12.	DJ × DT	C	C	B	4	
13.	PR × DT	B	C	B	5	
14.	LJ × DT	D	-	-	0	
15.	CR × DT	B	C	A	6	
16.	TR × DT	D	-	-	0	
17.	MO × DT	D	-	-	0	
18.	NO × DT	B	B	A	7	
19.	MG × DT	D	-	-	0	
20.	MW × DT	B	B	A	7	35
21.	LR × LJ	D	-	-	0	
22.	DJ × LJ	B	C	B	5	
23.	PR × LJ	D	-	-	0	
24.	LJ × LJ	D	-	-	0	
25.	CR × LJ	D	-	-	0	
26.	TR × LJ	D	-	-	0	
27.	MO × LJ	D	-	-	0	
28.	NO × LJ	A	C	B	6	
29.	MG × LJ	D	-	-	0	
30.	MW × LJ	D	-	-	0	11
31.	LR × CR	B	B	A	7	
32.	DJ × CR	B	B	A	7	
33.	PR × CR	B	A	B	7	
34.	LJ × CR	A	C	B	6	
35.	CR × CR	D	-	-	0	

Table 19 b Contd .....

Sl. No.	Gross combinations	Fruiting candles (per cent)	Fruit set (per cent)	Seed germination	Total score	Varietal score
36.	TR × CR	C	B	A	6	
37.	MO × CR	B	C	B	5	
38.	NO × CR	A	B	B	7	
39.	MG × CR	A	C	D	4	
40.	MW × CR	A	B	A	8	57
41.	LR × TR	C	C	B	4	
42.	DJ × TR	D	-	-	0	
43.	PR × TR	D	-	-	0	
44.	LJ × TR	D	-	-	0	
45.	CR × TR	B	C	A	6	
46.	TR × TR	D	-	-	0	
47.	MO × TR	D	-	-	0	
48.	NO × TR	C	B	A	6	
49.	MG × TR	D	-	-	0	
50.	MW × TR	D	-	-	0	16
51.	LR × MO	D	-	-	0	
52.	DJ × MO	D	-	-	0	
53.	LJ × MO	D	-	-	0	
54.	CR × MO	C	C	C	3	
55.	TR × MO	D	-	-	0	
56.	MO × MO	D	-	-	0	
57.	MG × MO	D	-	-	0	3
58.	LR × MW	B	B	B	6	
59.	DJ × MW	B	C	A	6	
60.	PR × MW	B	B	B	6	
61.	LJ × MW	A	C	A	7	
62.	CR × MW	A	A	A	9	
63.	TR × MW	B	C	A	6	
64.	MO × MW	D	-	-	0	
65.	NO × MW	B	C	A	6	
66.	MG × MW	B	C	D	3	
67.	MW × MW	D	-	-	0	49

best four out of the

Table 20 Comparison of compatibility performance of the ten varieties *A. andreanum* as female and male parents

Female parent			Male parent		
Ranking	Variety	Score	Ranking	Variety	Score
I	Nitta Orange	39	I	Ceylon Red	57
II	Ceylon Red	30	II	Merengue White	49
III	Liver Red	27	III	Liver Red	46
IV	Pompon Red	27	IV	Dragon's Tongue Red	35

revealed that compatibility reactions of the varieties as male parents were different from the compatibility reactions of these as female parents (Table 19 b). The best male parent was found to be Ceylon Red with a total compatibility score of 57 from nine successful combinations followed by Merengue White with a score of 49 from nine successful combinations. The variety Liver Red closely followed with a compatibility score of 46 from eight crosses. The lowest compatibility scores were obtained for Lady Jane (11) and Mauritius Orange (3).

The results indicated that compatibility performance of a variety as female parent was different from its performance as male parent (Table 20). The variety Nitta Orange was the best performer as female parent while as male parent Ceylon Red performed best. However some similarities of performance also could be observed. The variety Ceylon Red performed well both as female parent and male parent. This variety was the second best performer with a score of 30 as female parent and the best performer with a score of 57 as male parent. The variety Liver Red also performed well with a compatibility score of 27 as female parent and 46 as male parent.

The variety Merengue White which appeared to be an excellent performer with a score of 49 as male parent was an indifferent performer with a score of 22 as female parent. Unfortunately the variety Nitta Orange which was the best compatible female parent could not be assessed as to its ability to combine as male parent as the variety did not produce any pollen during the period of study.

SUMMARY

6. SUMMARY

The present study 'Intervarietal hybridisation in *Anthurium andreanum* Linden' was undertaken to evaluate the morphological /floral characters and to analyse compatibility relations among ten selected vareities of *A. andreanum*. The study revealed the tremendous scope for genetic improvement in this crop.

The analysis of variance revealed significant variation among the varieties for the twelve quantitative characters viz., plant height, number of leaves or spadicies per year, spathe size (width + length), candle length, spathe-candle ratio, position of candle, number of flowers per candle, life of spadix, days to initiation of female phase, number of days in female phase, days of interphase and duration of male phase.

Variability studies revealed that high phenotypic coefficient of variation (PCV) along with high genotypic coefficient of variation (GCV) are present for plant height, position of candle, days to initiation of female phase, number of days in female phase and spathe size. This suggests that there is an excellent scope to improvement of these characters through selection. The characters such as number of flowers per candle and spathe-candle ratio showed lower difference between GCV and PCV, revealing that the environmental influence on these characters is less.

The characters that showed high heritability coupled with high genetic advance values were plant height, spathe size, spathe-candle ratio, position of candle, number of flowers per candle and days to initiation of female phase. So, these characters are controlled by additive gene action and therefore, are amenable to genetic improvement through selection.

Correlation studies revealed that plant height is positively correlated at genotypic level with number of leaves or spadices per year. Spathe size and candle length were positively correlated at phenotypic, genotypic and environmental levels. Candle length showed high positive genotypic correlation with position of candle and number of flowers per candle. Life of spadix was found to have high positive genotypic correlation with candle length, spathe size, number of leaves of spadices per year, plant height, number of days in female phase and spathe-candle ratio. The genotypic correlation between characters helps to differentiate the vital associations useful in breeding from non-vital ones.

A study of five qualitative traits such as spathe colour, spathe texture, candle colour, suckering ability and type of inflorescence axis revealed high variation for these also.

The pollen fertility, estimated using acetocarmine staining method, was highest for Liver Red (42 per cent) and lowest for Mauritius Orange (13.7 per cent). Pollen fertility study shows that most of the varieties have low to very low pollen fertility values. Pollen emergence pattern showed significant difference among the ten varieties studied. In Pompon Red, Nitta Orange and Midori Green complete absence of pollen emergence was observed. In the other seven varieties, pollen emergence was low in the months from March to June, during which the average maximum and minimum temperatures were relatively high. Pollen emergence was highest during October to December months.

Intervarietal hybridisation was done to analyse the cross compatibility between the ten varieties based on percentage of candles bearing fruits, fruit set and seed germination. A total of 67 combinations were attempted consisting of 60 cross combination and seven selfs. Out of these no fruit bearing candles were obtained for 30 combinations (25 cross and 5 self combination). Hundred per cent fruit bearing candles were obtained for LJ x CR, LJ x MW, CR x MW, NO x LJ, NO x CR, MG x CR and MW x CR. The only two selfings that produced successful fruit set, seed set and seed germination were LR x LR and DT x DT.

The number of fruits per candle ranged from 183 in PR x LR to five in DT x LJ. Average number of fruits per candle was the highest for Pompon Red and the lowest for Lady Jane. Low percentage of fruit set was found to be a major problem in intervarietal crosses in anthuriums. The percentage of fruit set was below 50 per cent for all the crosses except PR x LR, which had 57.6 per cent fruit set. The highest and lowest percentages of fruit set were observed for Pompon Red and Lady Jane.

All the varieties except Lady Jane took more than five months to reach fruit maturity. The longest duration of 6.1 months was recorded for Ceylon Red. Long fruit ripening period was found to be one of the reasons that contribute to the slow progress of *Anthurium* breeding programmes. Out of the 37 successful crosses, 26 had two seeded berries and only one (PR x CR) had three seeded berries. The days taken for germination varied from three to 12 days. The maximum period of 12 days for seed germination was taken by the cross LJ x LR and MW x DT.

Out of the seeds from 37 combinations kept for germination, only 34 showed germination. The seeds of DT x LR, MG x CR and MG x MW failed to germinate. The seed germination was highest in DT x MW (87.5 per cent). Among the ten varieties seed germination varied from 69 per cent in Tropical Red to 2.3 per cent in Midori Green.

Seedlings from only 31 combinations, out of the 34 crosses that germinated, survived for more than four months. Seedling survival was 100 per cent in TR x MW. The highest average seedling survival was recorded for the crosses of Mauritius Orange and the lowest for Midori Green.

Scoring of the compatibility reactions, of the intervarietal crosses among the ten *Anthurium* varieties, on a scale from 0 - 9, showed that the crosses with the highest compatibility score of nine were PR x LR and CR x MW. As all the four parental varieties involved have desirable commercial characters these two combinations are excepted to produce valuable hybrids. In general the best female parents were found to be Nitta Orange, Liver Red and Pompon Red which had higher total compatibility scores.

A similar analysis of the performance of the ten varieties as male parents revealed that the best pollen parents are Ceylon Red, Merengue White and Liver Red. Mauritius Orange and Lady Jane did not perform well as pollen parents.

The performance of the variety as female parent was found to be different from its performance as male parent. Only the varieties Ceylon Red and Liver Red performed well both as female as well as male parent.

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INTERVARIETAL HYBRIDIZATION IN *Anthurium andreanum* Linden

By

RENU R. S.

ABSTRACT OF THE THESIS
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DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF AGRICULTURE
VELLAYANI
THIRUVANANTHAPURAM

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ABSTRACT

The present study on evaluation of morphological characters and compatibility reactions among ten selected *Anthurium andreanum* varieties, was undertaken to analyse the scope for genetic improvement in this crop.

The analysis of variance revealed significant variation among the ten varieties for the twelve quantitative characters studied. This reveals the high genetic potential for the improvement of this crop.

Variability studies indicated that high phenotypic and genotypic coefficients of variation for the characters plant height, position of candle, days to initiation of female phase, number of days in female phase and spathe size. The characters with heritability coupled with high genetic advance values were plant height, spathe size, spathe-candle ratio, position of candle, number of flowers per candle and days to initiation of female phase, indicating additive gene action.

Plant height was found to be positively correlated with number of leaves or spadices per year. Spathe size and candle length were positively correlated. Candle length had high positive genotypic correlation with position of candle and number of flowers per candle.

Pollen fertility ranged from 42 per cent in Liver Red to 13.7 per cent in Mauritius Orange. Study of pollen emergence pattern revealed significant differences among the varieties. Pollen emergence was completely absent in Pompon Red, Nitta Orange and Midori Green during the period of study. Pollen production was high in the cooler months of October to December and

was suppressed during the hot months of March to June.

Cross compatibility analysis based on the results of intervarietal hybridisation was done using the three parameters; i.e., percentage of candles bearing fruits, percentage fruit set and percentage seed germination.

The percentage of fruit bearing candles were highest for Nitta Orange (51.93 per cent) and lowest for Mauritius Orange (9.51 per cent). The only two selfings that produced fruiting candles were LR x LR and DT x DT.

The number of fruits per candle ranged from five to 183. The variety Pompon Red had the highest average number of fruits per candle and it was lowest for Lady Jane.

The percentage of fruit set was below 50 per cent for all the crosses except PR x LR. The crosses involving Pompon Red as female parent had the highest percentage of fruit set.

The number of days taken for seed germination varied from three to twelve days. The seed germination was highest (87.5 per cent) for the cross DT x MW. Among the varieties it ranged from 69 per cent in Tropical Red to 2.3 per cent in Midori Green.

Seedling survival at four to six month stage was highest for the crosses of Mauritius Orange and the lowest for those of Midori Green. The cross TR x MW showed 100 per cent seedling survival.

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 of nine for PR x LR and CR x MW crosses. The best female parents were identified as Nitta Orange, Liver Red and Pompon Red

based on the overall performance.

The analysis of the performance of varieties as pollen parents on the same basis showed that Ceylon Red, Merengue White and Liver Red are the best pollen parents. These observations showed that the performance of a variety as female parent was different from its performance as male parent. Only the variety Ceylon Red and Liver Red performed well both as female and male parent.