PERFORMANCE ANALYSIS AND COMBINING ABILITY STUDIES IN ANTHURIUM CULTIVARS

by
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(2010-22-101)

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2015

DECLARATION

I, hereby declare that this thesis entitled **"PERFORMANCE ANALYSIS AND COMBINING ABILITY STUDIES IN ANTHURIUM CULTIVARS"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for award of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **"PERFORMANCE ANALYSIS AND COMBINING ABILITY STUDIES IN ANTHURIUM CULTIVARS"** is a record of research work done independently by Mrs. Sheena, A (2010-22-101) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

a.i.	Active Ingredient
et al.	And others
@	At the rate of
ANOVA	Analysis of variance
BA	Benzyl adenine
cm	Centimetre(s)
CD	Critical difference
cv.	Cultivar
^{0}C	Degrees Celsius
EC	Emulsifiable Concentrate
FYM	Farm Yard Manure
Fig.	Figure
GCV	Genotypic coefficient of variation
GCA	General combining ability
g	Gram
μ	micron
mg	milligram
ml	Millilitre
mm	Millimetre
MAP	Months after planting
MS	Murashige and Skoog's (1962)
viz.	Namely
NAA	Naphthalene acetic acid
%	Per cent
PCV	Phenotypic coefficient of variation
cm^2	Square centimeter
SCA	Specific combining ability
var.	Variety
WP	Wettable powder

Introduction

1. INTRODUCTION

Anthurium is the most popular and economically important genus in the family Araceae. It is well known for its attractive and long-lasting spathes of various colours, shapes, textures and sizes, which have contributed to its emergence as an important tropical ornamental crop. In the genus *Anthurium*, approximately 20 species are used as ornamental plants, with *Anthurium andreanum* being the most popular for potted plant and cut flower (Wang and Chuang, 2013). In addition, anthurium is valued as an indoor plant and was reported as a viable phytoremediation plant for interior environments where volatile formaldehyde is the main air pollutant (Kim *et al.*, 2010). Around 81.4 million stems of anthuriums were sold as cut flower in the Dutch auctions of 2012 (Matsumoto *et al.*, 2013).

In the genus *Anthurium*, more than 600 species originated in Tropical America (Boyce and Croat, 2012). *Anthurium andraeanum* Linden ex Andre′ was discovered by Eduard Andre in 1870 as a tropical ornamental species with a limited range of spathe colours. The colour range has been augmented through interspecific hybridization with other anthurium species belonging to the sections Calomystrium and Porphyrochitonium. The present day commercially cultivated anthuriums are complex interspecific hybrids, between *A. andraeanum* Linden ex Andre′ and other species, collectively referred to as *Anthurium andreanum* (Hort.) (Kamemoto and Kuehnle, 1996).

The international market demands different colours throughout the year and it thrives on novelties. Novel colours fetch premium prices than conventional colours. Due to the increasing demand for cut flowers in the world market, large numbers of novel anthurium cultivars produced in Netherlands and Hawaii are being imported for commercial cultivation into the growing countries (Nowbuth *et al.*, 2005).

In India, Anthurium cultivars introduced from major growing centres such as Hawaii, Holland, Mauritius and Sri Lanka have well adapted to various agro climatic situations and are being grown over the past 30 years. The production of anthurium flowers has been one of the most reliable sources of agricultural outputs in the state of Mizoram and it is extending to the states of Meghalaya, Nagaland and Manipur with success (Lalrinfeli, 2013). Anthuriums are one of the floricultural resources in the forefront of cut flower production in India, especially in Kerala. As a high value crop with high productivity per unit area and amenable to cultivation both in metros and rural areas, anthuriums are first among the priority floricultural crops for Kerala. Because of the suitability of this crop for low cost plantation and production in the prevailing agro climatic conditions of Kerala, many small and medium scale entrepreneurs are engaged in anthurium cultivation (Bejoy *et al.*, 2008).

Acquisition of new germplasm and their evaluation is essential in breeding programmes. Plant characteristics that continue to be important in evaluating accessions for breeding cut-flower and potted anthuriums are colour, spathe shape, spathe size, yield, foliage shape and fragrance (Halloran and Kuehnle 1998). Since novelty is an important prerequisite of ornamental cut flower industry, varieties suited to changing consumer demand are necessary.

Newer varieties with good floricultural attributes are required to meet the requirements of export oriented production. So hybridization programmes with expanded selection is necessary for furthering crop improvement. As a supportive requisite for the anthurium production sector in Kerala, the present research programme is undertaken with the aim of evaluation of introduced cultivars of anthurium for growth, flowering and floral attributes, assessment of their compatibility with cultivars having breeding potential and production of novel anthurium cultivars through inter-varietal hybridization.

Review of Literature

2. REVIEW OF LITERATURE

Anthurium is one of the most popular tropical cut flowers belonging to the family Araceae. They are produced and traded internationally as cut flowers, flowering potted plants, foliage plants and landscape plants. Anthurium cultivars introduced from various parts of the world are well adapted to different agro climatic situations in India. Hybridization followed by selection is the best method to achieve crop improvement in anthurium. The crop is highly heterozygous with great genetic potential which is yet to be exploited. So the present study was conducted to produce new varieties of anthurium through intervarietal and interspecific hybridization and to evaluate the performance of introduced anthurium varieties. A brief review of the works relevant to the study is presented in this chapter.

2.1 CULTURAL REQUIREMENTS

Higaki and Poole (1978) reported that anthuriums grow best in a well aerated medium with good water retention capacity and good drainage. A good medium should provide anchor to the roots and stem so that the plant will not topple over as it grows larger, but provide sufficient moisture, nutrients, and aeration to the plant.

According to Mercy and Dale (1994), anthuriums require a warm green house with 75 per cent shading from direct sunlight and atmospheric humidity of 70-80 per cent. The temperature range is between 25 to 28°C during the day and 18 to 22°C during the night with optimum being 22 to 25°C. They are usually grown in a medium consisting of sand, cow dung, brick pieces, charcoal and coconut husk which provide 100 per cent drainage.

Salvi (1997) reported that weekly application of 1.0 per cent NPK fertilizer complex of 17:17:17 produced the maximum height and increase in other biometrical characters in *Anthurium andreanum* cv. Hawaiian Red.

According to Dufour and Guerin (2005), anthurium plantlet growth begins with a monopodial vegetative period and the duration of this juvenile period was strongly influenced by fertilization. Nitrogen deficiency in anthurium resulted in diminished yield and flower quality, besides the increased juvenile period.

Maximum leaf length (17.63 cm), leaf width (8.52 cm), number of suckers (1.88), stalk length (37.31 cm), spadix length (5.00 cm), spadix girth (6.04 mm) and number of spadices (2.25) were recorded in split application of 30:20:40 g NPK in cv. Choco by Srinivasa (2006a).

Srinivasa (2006b) reported that all the vegetative and reproductive characters recorded maximum values at 80 per cent shade level in anthurium cv. Honduras.

A relative humidity of not less than 60 per cent and a temperature of not more than 18-28°C are preferred by cultivars grown in Kerala. The tolerable level of light in the tropical region during summer is 20-30 per cent. Excess light causes yellowing and scorching of leaves. Very low light intensity causes excessive vegetative growth and low flowering. It is preferable to grow anthurium in the open, under artificial shade structures for better growth and yield (KAU, 2007).

Rajeevan *et al.* (2007) reported that a temperature of 15- 30°C and relative humidity of 60-70 per cent is ideal for the growth of anthurium in Kerala.

Significant difference was observed with respect to 10 varieties and two seasons compared by Agasimani *et al.* (2011b). All the varieties performed well in winter (September to December) compared to rainy (May to August) with respect to foliage and floral characters. Variety Esmeralda performed well in both rainy and winter season. Mean number of flowers (2.9) was highest in winter compared to rainy (2.5).

Singh *et al.* (2011) reported that the medium comprised of saw dust + brick pieces + wooden charcoal + soil + sand + FYM (2:1:1:1:1:1) recorded high leaf area (229.11 cm^2), petiole length (21.31 cm), minimum days to flowering (260.47 days), stalk length (36.16 cm), spathe length and width (8.5 and 8.08 cm respectively) and number of flowers per plant (6.07). The maximum number of leaves per plant (7.40), highest number of suckers per plant (5.00) and longest inflorescence longevity (63.53 days) were recorded in treatment combination involving saw dust + wooden charcoal + soil + sand + FYM (2:1:1:1:1).

Cuquel *et al.* (2012) concluded that the growing media utilized enhanced the commercial quality of the flowers. Best flowers were produced in anthurium plants grown in the growing media with wood shavings + organic compost (1:1).

According to Khawlhring *et al.* (2012), anthuriums grown under 75 per cent shade house resulted in better consistent growth as compared to those grown under natural tree shade.

Gurjar *et al.* (2012) reported that foliar spray of NPK nutrients with a ratio of 30:20:40 applied weekly once significantly improved spathe length (4.99 cm), spathe width (3.99 cm), flower stalk length (21.98 cm) and suckers per plant (2.93). While, weekly once spray of NPK with 20:20:40 ratio resulted in maximum flower longevity (46.83 days) and vase life (19.67 days).

2.2 MORPHOLOGICAL CHARACTERS

2.2.1 Plant Height

On a mature anthurium plant, stem growth was reported to be about 5cm per year (Higaki *et al.*, 1984). Intermediate height between parents, *A. andreanum* and *A. amnicola* was obtained in an interspecific hybrid Southern Blush (Henny *et al.*, 1988).

Bindu and Mercy (1994) studied five varieties of anthurium and reported significant variation in plant height, ranging from 45 cm in the variety Lady Jane to 85 cm in the variety Pink. Sindhu (1995) reported that height of six varieties of anthurium ranged from 43 to 70 cm.

Renu (1999) compared ten anthurium varieties which showed significant variation in plant height ranging from 29.7 cm in Midori Green to 70.9 cm in Pompon Red. Mayadevi (2001) recorded the height of 20 anthurium varieties which ranged from 45.5 cm in Midori Green to 96.67 cm in cultivar White. The height of the genotypes varied from 22.17 cm to 64.80 cm in the study conducted by Asish (2002). Premna (2003) observed a plant height of 21.25 cm to 44.00 cm.

Pravin (2004) in the study with 14 genotypes of anthurium found significant variation in plant height, which ranged from 30.80 cm to 76.17 cm with a mean height of 47.81 cm.

Srinivasa and Reddy (2005) evaluated the performance of anthurium cultivars Honduras, Tinora, Senator, Tropical and Pasricha for cut flower production and reported that Honduras recorded the maximum plant height (40.94 cm).

Shiva and Nair (2008b) reported significant variations in plant height among 14 anthurium cultivars, ranging from 4.27 cm in cultivar Taurus to 9.22 cm in Mirage.

Madhukumar (2010) evaluated the performance of 40 genotypes and all the genotypes showed significant variation in plant height ranging from 17.33 cm in Nitta Orange to 43.25 cm in Liver Red. The mean plant height observed was 28.51 cm.

Jadhav *et al.* (2012) reported a maximum plant height of 57.58 cm in variety Esmeralda under fertigation.

2.2.2 Number of Leaves

The sequence of leaf, flower and new leaf was reported to be maintained throughout the life of the plant (Singh, 1987). Anthuriums were reported slow growing, producing only 6-8 new leaves and vegetative buds on a stem axis per year by Criley (1989).

Mercy and Dale (1994) observed that anthuriums were slow growing and produced only five to eight new leaves on a stem axis per year and generally with each new leaf, a root also emerged. Renu (1999) reported that annual production of leaves or spadices was the highest in Lady Jane (7.6) followed by Liver Red and Pompon Red.

Shiva and Nair (2008 b) reported that the cultivar Mirage produced maximum number of leaves (5.88) while the cultivars Agnihotri, Mauritius and Wrinkled Orange produced higher number of leaves per month.

Madhukumar (2010) reported that lowest number of leaves or spadices per plant was produced by the genotype Chocos (4.55) followed by Arun Gold and 'White x Lady Jane' (4.83) while the maximum number in the genotype Rembolina (7.42) followed by Grace (7.37).

Agasimani *et al.* (2011a) reported that var. Esmeralda produced maximum number of leaves per plant (5.20) which was significantly superior to other varieties and the minimum value of 3.05 leaves were recorded in var. Grace.

Jacob (2011) reported an annual leaf production of 7.54 numbers in var. Acropolis and 7.02 in var. Tropical.

2.2.3 Leaf Area

Sheffer and Kamemoto (1978) crossed *A. scherzerianum* and *A. wendlingerii* and observed that the length and position of leaf blade in the hybrid was intermediate between the parental species.

Bindu (1992) reported that the length of leaves ranged from 13.5 to 26 cm among the five varieties studied. Leaf size was maximum for var. Pink and minimum for Lady Jane and Chilli Red. According to Mercy and Dale (1994), the leaves of commercially valuable floral anthuriums should be small to medium sized, narrow and elongated. Large and exuberantly growing leaves were found undesirable.

Sindhu (1995) observed that the var. Pink produced bigger sized leaves whereas White and Chilli Red produced smaller sized leaves which were commercially more valuable than Pink. Abdussammed (1999) reported that the leaf length, breadth and leaf area were not influenced significantly by the nutrients either in ground or in pot planting.

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

Leaf area ranging from 41.32 to 323.77 cm^2 was reported by Asish (2002) in the study with 50 genotypes. Premna (2003) recorded a minimum leaf area for the genotype Carre (113.62 cm^2) and a maximum for Acropolis White (301.10 cm^2). Ravidas (2003) reported maximum leaf area (681.3 cm^2) in the variety Candy Queen which was on par with Agnihothri (579.4 cm^2) and Lima (556.8 cm^2). Leaf area was lesser in the varieties Eureka Red (377.7 cm^2) and Red Dragon (306.3 cm^2).

Among 14 anthurium varieties studied by Pravin (2004), the leaf area varied according to the size of the leaf and it ranged from 91.97 cm^2 to 287.76 cm^2.

According to Agasimani *et al.* (2011a), var. Esmeralda produced maximum leaf length (18.49 cm), leaf breadth (14.84 cm) and leaf area (237.24 cm^2). Variety Chias had the lowest leaf length (13.32 cm), leaf breadth (8.84 cm) and leaf area (100.10 cm^2).

Jacob (2011) in a nutrient trial reported that total leaf area in cultivar Acropolis was higher (2939.35 cm^2) than Tropical (2155.52 cm^2).

2.2.4 Number of Suckers per Plant

Kamemoto and Nakasone (1963) reported that differences in productivity of suckers were clearly evident among anthurium clones. The cultivars Kaumana and Nitta were prolific producers of suckers. Suckering was reported to be good for quick propagation but an extreme proliferation of suckers adversely affected flower production and undesirable. It was observed that suckering ability is generally transmitted to the offsprings.

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 @ 1000 mg l^{-1}.

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

Sindhu (1995) observed maximum number of suckers in the variety Pink and the least in the variety Kalimpong Red. Salvi (1997) inferred that a treatment combination of 80 per cent shade and BA @ 750 mg l^{-1} was the best for maximising sucker production.

Sucker production was reported to be high in the varieties Liver Red, Lady Jane and Ceylon Red and low in Merengue White, Dragon's Tongue and Tropical Red (Renu, 1999).

Mayadevi (2001) observed maximum number of sucker production for varieties Pink and Lady Jane (4 no.) followed by Liver Red, Honeymoon Red and Kalimpong Orange (3.67, 3.67and 3.33 numbers respectively). Very few suckers were produced by varieties Nitta Orange, Merengue White and Tropical Red.

Asish (2002) observed a range of one to three suckers in 50 genotypes of anthurium. Ravidas (2003) reported highest number of suckers for Red Dragon (3.22) and least number for the cultivar Agnihothri (2.33). Pravin (2004) reported that suckering was very high in the cultivar Liver Red (4) and low in Acropolis White and Tropical Red.

Shiva and Nair (2008a) observed maximum number of suckers in the cultivar Mirage (2.0) and the cultivars Mirage, Agnihothri and Deep Pink were found suitable for sucker production.

Madhukumar (2010) found maximum sucker production in the genotype Liver Red (3). Lowest number of suckers was found in the genotypes Lady Jane and Esmeralda (0.67). Fifty per cent of genotypes did not produce suckers.

According to Agasimani *et al.* (2011a), var. Ivory (4.14) recorded highest number of suckers while var. Jewel recorded minimum number of suckers per plant (0.49).

Jacob (2011) reported that in cultivar Tropical the total number of suckers produced up to 18 MAP was influenced by the manurial treatments. The number of suckers produced varied from 1.5 to 2.08 in different nutrient trials. The cultivar Acropolis did not produce suckers during the period of study.

2.2.5 Days from Emergence to Maturity of Leaves

Dai and Paull (1990) reported that seven days after flower emergence, a new leaf emerged from the old leaf sheath axil and the new leaf sheath elongated very slowly and reached its maximum length of 15 cm at 21 days from previous flower emergence. Seven days after new leaf emergence, the petiole reached its highest elongation rate of 1.9 cm per day, which then declined slightly for the next seven days. When the petiole reached its full length (21 days after leaf emergence and 42 days after flower emergence), the growth rate declined to 1.0 cm per day. The leaf petiole continued to elongate very slowly for another 14 to 21 days and stopped 42 days after subtending leaf emergence and 56 days after flower emergence.

Mayadevi (2001) reported that the number of days required for the leaves from emergence to maturity ranged from 41.40 days in the variety Honeymoon Red to 44.40 days in the variety Pink. Premna (2003) noticed the least number of days for leaf maturity by Carre (26.25 days) and a maximum number of days for the genotype 'Pompon Red x Dragon's Tongue' (40.25 days).

According to Madhukumar (2010), the least number of days for maturity of leaves was taken by the genotype 'Pompon Red x Orange Glory' (25.89 days) which was on par with the variety Carrie (26.78 days), Rembolina (26.89 days), Geisha white (28.15 days) and Ceasor violet (28.39 days). The maximum number of days was taken by the genotype Agnihotri (36.6 days) followed Vezuvious Red (35.55 days), Flirt (35.31 days) and Lady Jane (35.17 days).

2.2.6 Colour of Young Leaf and Petiole

Dai and Paull (1990) reported that in cultivar Kaumana, the colour of young leaf was olive-brown. According to Mercy and Dale (1994), the colour of young tender leaves of *A. andreanum* varied from light green to deep reddish brown. Sindhu (1995) observed that the petioles were slender and long and there were variations in the colour of both petiole and young leaves in all the varieties studied. The young tender leaves showed light green, green, greenish brown, light brown and brown colour.

Colour of petiole and young leaf ranged from green to brownish green and brown as observed by Asish (2002). Premna (2003) noticed a range from brown to reddish brown to greenish brown to green in colour of young leaf and petiole.

Pravin (2004) reported that the colour of young leaf showed a range from brown to reddish brown to greenish brown to brownish green to green. The colour of petiole varied from brown to light brown to reddish brown to greenish brown to green.

Madhukumar (2010) observed that the colour of young leaf showed a range from brown to reddish brown to greenish brown to green to light green. The colour of petiole varied from brown to reddish brown to greenish brown to green.

2.2.7 Internodal Length

According to Higaki *et al.* (1984), the short and thick stems of anthuriums had nodes approximately 1 cm apart depending on the cultivar and the environment. Increased shade promoted longer internodes, while high light produced shorter internodes regardless of cultivar and opined that long and thin stems may have internodes as long as 15 cm.

Singh (1987) opined that a desirable anthurium should produce short internodes in order to limit the height of the plant. Mercy and Dale (1994) reported that a good commercial variety should have a compact bushy appearance with very short internodes.

Mayadevi (2001) reported that mean internode length ranged from 1.00 cm in cultivar Pink to 1.52 cm in Liver Red among the parents and in the hybrids it ranged from 1.02 to 1.34 cm.

Premna (2003) observed a maximum value of 1.48 cm (Pompon Red x Dragon's Tongue) and Acropolis White and a minimum of 1.20 cm (Carre). Internodal length was found to be maximum in the varieties Lima (3.67 cm) and Nitta (3.11 cm). Shortest internodes were recorded in the varieties Red Dragon (1.72 cm) and Candy Queen (1.78 cm) by Ravidas (2003).

Madhukumar (2010) reported that among 40 genotypes, Agnihotri recorded the minimum internodal length of 0.97 cm, which was on par with 'White x Lady Jane' (0.98 cm) and maximum by Esmeralda (2.02 cm).

2.3 FLORAL CHARACTERS

2.3.1 Number of Spadices per Plant per Year

Anthurium produces flowers all round the year, one flower from each leaf axil. Kamemoto and Nakasone (1963) discussed the sequence of leaf and inflorescence production in anthurium. The inflorescence emerged about a month after leaves appear and preceded the next new leaf by a few weeks. This sequence of emergence was maintained throughout growth, although the intervals between leaf emergences varied depending upon environmental conditions.

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

Higaki and Poole (1978) while studying the var. Ozaki found that the flower production increased with age of the plant. Singh (1987) reported that the most commonly cultivated varieties produced flowers all round the year at the rate of one flower from each leaf axil and the sequence of leaf, flower and new leaf was maintained throughout the life of the plant.

Kamemoto *et al.* (1986) reported that yields of anthuriums vary from 3.4 to 7.6 flowers per plant per year and a new flower appeared every 48 to 107 days. Variation in flower yield was found to be significantly influenced by temperature and solar radiation.

Sindhu (1995) recorded that the number of spadices produced annually by an anthurium plant varied from 4 to 8. Renu (1999) reported that one spadix each was produced from the axil of each leaf. The annual production of spadices was highest in Lady Jane (7.6) followed by Liver Red and Pompon Red. Cultivars were found to vary in flower production.

Praneetha *et al.* (2002) reported that the accession 'AA-43' and Lady Jane recorded the highest number of flowers per plant per year (18.2).

Premna (2003) observed the maximum number of spadices in the genotypes Acropolis White and Tropical Red (6) and minimum number in the variety Carre (4.25). According to Ehrenberger *et al.* (2003), flower yield of anthurium varied depending on the genotypes.

Pravin (2004) revealed that the number of leaves and number of spadices produced annually per plant were the same and the annual production of leaves or spadices was highest in Liver Red (7.00) which was on par with Orange Glory and Acropolis White (6.33).

Srinivasa and Reddy (2005) reported that the cultivar Honduras recorded the maximum number of spadices per plant (8.13). Shiva and Nair (2008b) reported that maximum number of flowers were obtained with var. Honey followed by Mauritius and Wrinkled Orange.

Madhukumar (2010) reported that lowest number of spadices per plant was produced by the genotype Chocos (4.55) followed by Arun Gold (4.83) while the maximum for Rembolina (7.42) followed by Grace (7.37). According to Agasimani *et al.* (2011a), the maximum number of flowers produced per plant per year was in variety Esmeralda (9.33) and minimum in variety Ivory (3.33).

Maximum number of flowers per plant was recorded in variety Titicaca (7.2) while minimum (4.1) was recorded in Ivory by Islam *et al.* (2013).

2.3.2 Days from Emergence to Unfurling of Spathe

Higaki *et al.* (1984) described the spathe of anthurium as a modified leaf. Klapwijk and van der Spek (1988) recorded the patterns of inflorescence formation in six anthurium cultivars and observed that the time required for buds to develop into blooms ready for harvest ranged from about 65 to 75 days.

Dai and Paull (1990) reported that development of the spathes of anthuriums start before the emergence of flowers from the leaf sheaths and was characterised by a double sigmoidal growth curve. The growth rate was initially rapid which declined 14 days after flower emergence. By 21st day, the spathe had almost stopped growing and the slow growth rate lasted for 7 days and was followed by a second peak of growth 35 to 42 days after flower emergence. This was followed by a second decline in growth rate which continued to day 63, when the spathe reached its full length. According to them flower initiation started approximately 90 days before its emergence.

Mayadevi (2001) observed that the days from emergence to maturity of inflorescence ranged from 44.60 days in Chilli Red to 50.60 days in Honeymoon Red. Asish (2002) observed a range from 16.67 to 37.67 days and Premna (2003) recorded the lowest number of days for this character in variety Carre (29.00 days).

Ravidas (2003) reported that the duration from spike emergence to unfurling of spathe was maximum in the variety Agnihothri (25.33 days) whereas the varieties Lima and Candy Queen took only 19.00 days. Pravin (2004) reported that the days from emergence to maturity of inflorescence ranged from 31.00 days to 37.20 days.

Madhukumar (2010) reported that the genotype Grace recorded the lowest mean value (23.83) for days from emergence to maturity of inflorescence and highest for the genotype Liver Red (33.39 days).

2.3.3 Spathe Colour

2.3.3.1 Spathe Colour Pigment

Birdsey (1951) described the spathe of native *A. andreanum* from Columbia as orange scarlet or vermilon where as the commercial varieties showed a complete colour range from white to dark red.

The five major spathe colors reported in anthurium were red, pink, orange, coral, and white (Kamemoto *et al.*, 1988). However, other colors such as green, brown and spatial bicolors involving green lobes with any of the five major spathe colors in the center were also reported. In anthurium, the major colour pigments in the spathe were reported to be anthocyanin derivatives. Kamemoto and Kuehnle (1996) reported that chlorophyll also contributed to spathe colour, either alone gave a completely green spathe, or in combination with other anthocyanin pigments gave a brown spathe.

The five major spathe colors were determined by two anthocyanins, pelargonidin 3-rutinoside (pelargonidin 3-rhamonsylglucoside) and cyanidin 3-rutinoside (cyanidin 3-rhamonsylglucoside), found exclusively in the hypodermal layers of abaxial and adaxial surfaces of the spathe (Iwata *et al.*, 1979; Higaki *et al.*, 1984; Ehrenberger and Kuehnle, 2003). Pelargonidin 3- rutinoside was responsible for orange and coral spathes, whereas both pelargonidin 3- rutinoside and cyanidin 3-rutinoside were found in red and pink spathes (Iwata *et al.*, 1979). Coral and pink spathes had anthocyanins in lower concentrations compared with their orange and red counterparts (Iwata *et al.*, 1985). The whites lacked both anthocyanins but contained colorless flavone glycosides. In a leaf survey of 142 species from 58 genera of the family Araceae, Williams *et al.* (1981) found that flavone C-glycosides comprised 82 per cent of the major flavonoids.

Wannakrairoj and Kamemoto (1990a) found that in the anthurium spathe, the location of anthocyanin differed from species to species and could be located in the epidermis, hypodermis and/or mesophyll. In *A. amnicola* Dressler, peonidin 3- rutinoside was reported in addition to pelargonidin and cyanidin glucosides. In combination with cyanidin 3-rutinoside, this compound accounts for the lavender spathe and purple spadix of the species (Marutani *et al.*, 1987).

Dai and Paull (1990) reported that in cultivar Kaumana, spathe color development started 28 days before emergence when the flower was 50 per cent of full development with flower length (4.5 cm). Red colour appeared in the middle and spread upwards and downwards. At flower emergence, the spathe, excluding the lobes, was 75 per cent red. The lobes did not develop full redness until 7 to 10 days after emergence.

Mercy and Dale (1994) reported that colour of spathe faded gradually as flowers became older. After fertilization of spadix, the spathe gradually became green and photosynthetic.

Nirmala *et al.* (1999) reported that the relative concentrations of cyanidin and pelargonidin affect the spathe colour and they grouped anthurium genotypes into four groups (red, orange, coral and white) based on the presence of cyanidin and pelargonidin along with an unknown pigment.

Renu (1999) grouped the spathe colour of 10 varieties into deep maroon to dark red, red, light orange, light orange to dark orange, light green and white.

Mayadevi (2001) inferred that anthocyanins contribute various colours to spathe from deep maroon to light pink. Red coloured varieties showed variation from dark red (Chilli Red) to red (Honeymoon Red). The mean total anthocyanin content ranged from 121.38 mg g^{-1} in Pink to 386.56 mg g^{-1} in Liver Red.

The spathe colour ranged from deep maroon to white in the 14 genotypes observed by Premna (2003). Asish and Mayadevi (2006) studied relative concentrations of anthocyanin and its influence on spathe colour in 50 morphologically diverse and taxonomically complex genotypes of anthurium with a spathe colour range of deep maroon, maroon, dark red, red, light red, dark orange, pink and white. Genotypes with high anthocyanin content had maroon spathes, while those with low anthocyanin content had pink spathes.

Shiva and Nair (2008b) while studying 14 genotypes found that the spathe colour range was deep red, red and orange.

Madhukumar (2010) repoted that the colour of the spathe showed variation like deep maroon, maroon, dark red, medium red, red, dark orange, orange, light orange, pink, white, green, violet, brown and some spathe with double colours.

Lanlan *et al.* (2012) compared the seasonal changes and the related physiological factors of the spathes when they were normal and green. They found that when the spathe was green, the contents of total anthocyanins, total flavonoids, soluble protein, soluble sugar, and mineral element potassium were generally lower than normal where as the chlorophyll content and enzyme activity were higher than normal. They speculated that the changes of the anthocyanin/chlorophyll content ratio directly caused the spathe greening.

According to Li *et al.* (2013), the content of the anthocyanin cyanidin 3-rutinoside, and the ratio of cyanidin 3-rutinoside content to pelargonidin 3-rutinoside content were negatively correlated with spathe lightness and cyanidin 3-rutinoside and pelargonidin 3-rutinoside were the key factors responsible for the red, pink, and purple spathe colours. They also reported that flavonols and flavones accounted for the yellow hue of the spathe.

2.3.3.2 Genetics of Spathe Colour

The genetic basis of the major spathe colors in anthurium was investigated by Kamemoto and Nakasone (1955, 1963). Kamemoto *et al.* (1988) produced evidence for two genes, M and O, controlling the major spathe colors in *A. andreanum*. Recessive epistasis of the O locus over the M reflected the biochemical pathway for anthocyanin biosynthesis. Based on the genetic model of Kamemoto *et al.* (1988), MmOo, MmOO, MMOo, and MMOO produced red-spathed (red and pink) phenotypes; mmOo and mmOO produced orange-spathed (orange and coral) phenotypes; and mmoo, Mmoo, and MMoo produced white-spathed phenotypes. Furthermore, the dosages of M and O genes reflected the range of colors obtained; pink cultivars were postulated to be heterozygous for M and O loci, and coral cultivars were heterozygous for the O locus. It was further postulated that the incremental effect of M was greater than O and mmoo = Mmoo = MMoo < mmOo < mmOO < MmOo < MmOO < MMOo < MMOO.

Wannakrairoj and Kamemoto (1990b) proposed a scheme for the genetic control of purple spathes in *Anthurium*. According to them the recessive allele *p* modifies the color of anthocyanins controlled by the *M* and *O* loci. A spathe is purple when the genotype is *M-O-pp*. If the *P* locus is dominant, *M–O– is* red, while *mmO – is* orange. The *p* allele has no effect on the –oo (white) genotype. The genetic model developed by Kamemoto *et al.* (1988) has not been validated in interspecific hybrids belonging to *A. andreanum*. Furthermore, there was evidence that white spathed cultivars may be regulatory mutants (Collette, 2002).

Elibox and Umaharan (2008a) proposed a duplicate recessive epistasis model for spathe colour inheritance involving genes O and R, in which either O or

R or both in the recessive form would result in white-spathed progeny. The dosage effect of particularly the R gene accounted for the differentiation of reds from pinks and oranges from corals.

Avila-Rostant *et al.* (2011) investigated flavonoid and anthocyanin levels, and the expression profiles of four flavonoid biosynthetic genes in 16 anthurium cultivars with varying spathe colours. The differences between red and pink cultivars and orange and red cultivars were evident in both the anthocyanin and flavonoid levels as well as in the levels of expression of the genes F3H and ANS controlled by the regulatory element 'R'. They assumed that the higher level of expression of F3H gene in the red cultivars than in the pink cultivars as the reason for the different anthocyanins detected in the reds compared to the pinks.

Gopaulchan *et al.* (2014) reported that white cultivars, which were homozygous recessive either for O or R genes or both, exhibited reduced expression of the anthocyanin biosynthetic genes and hence had negligible levels of anthocyanin.

2.3.3.3 Anthocyanin Content

Abdussammed (1999) found that the anthocyanin content of cv. Hawaiian Red altered significantly under different treatments. The highest value for anthocyanin content in ground and pot for nutrient treatment were 85.07 mg g^{-1} and 93.9 mg g^{-1} respectively, while for growth regulator treatment, the values were 67.88 mg g^{-1} and 84.18 mg g^{-1} respectively.

Mayadevi (2001) reported that total anthocyanin content ranged from 121.38 mg g^{-1} in cv. Pink to 386.56 mg g^{-1} in Liver Red in the parents while the range of this character was from 146.03 mg g^{-1} (Honeymoon Red x Liver Red) to 330.95 mg g^{-1}(Kalimpong Red x Chilly Red) in the hybrids.

Premna.(2003) reported that the mean anthocyanin content ranged from 10.09 mg g^{-1} in Acropolis White to 259.18 mg g^{-1} in Honduras.

Asish and Mayadevi (2006) revealed that the mean total anthocyanin content ranged from 26.81 mg g^{-1} (pink spathe) to 710.79 mg g^{-1} (maroon spathe).

According to Madhukumar (2010), the total anthocyanin content showed wide variation among the genotypes and it ranged from 9.73 to 482.05 mg g^{-1}.

Hui *et al.* (2013) reported that the anthocyanin content of the anthurium plants cultivated in open air in Hainan Island of China began to decrease from July, and then increased after October under the effect of lower average temperature. While the chlorophyll accumulation increased after August, and decreased from November. After August, more nitrogen in the spathe was benefited for the accumulation of chlorophyll and the content of potassium increased from October, which was in favour of the anthocyanin accumulation.

2.3.4 Spathe Length and Breadth

Higaki and Poole (1978) noticed that spathe size of cultivar Ozaki Red 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 plus 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).

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

Henny (1999) recorded that the variety Red Hot had a spathe size of 10 to 12 cm. Renu (1999) studied spathe size of 10 varieties and revealed that variation in the spathe size ranging from 17.12 cm in Pompon Red to 30.74 cm in Dragon's Tongue.

Mayadevi (2001) observed average spathe length of 10.80 cm with a range of 6.33 cm to 21.33 cm and width of spathe with an average of 7.76 cm. The width ranged from 4.27 cm to 13 cm.

Shiva and Nair (2008b) observed that the spathe size ranged from 5.80 to

8.52 cm. The maximum spathe size was recorded in Mauritius followed by Honey.

Madhukumar (2010) reported the maximum spathe size for Acropolis White (123.43 cm^2) which was on par with Geisha white (118.18 cm^2), Carrie (115.44 cm^2) and Boroque (107.00 cm^2). Agasimani *et al.* (2011a) reported that the variety Esmeralda had the maximum spathe length (15.71cm) and variety Ivory had the minimum (7.54 cm). Titicaca had the maximum spathe breadth (16.18cm) and minimum spathe breadth was recorded in Aymara (7.04 cm).

Jacob (2011) reported that the cultivar Tropical produced longer spathes (16.81 cm) than Acropolis (15.31 cm). However, Acropolis recorded wider spathe (12.97 cm) than Tropical (12 cm).

Islam *et al.* (2013) reported that spathe length and breadth were significantly influenced by varieties and maximum spathe length was recorded by Triticaca (15.3 cm) whereas minimum (6.3 cm) was recorded by Ivory. Maximum spathe breadth (13.5 cm) was recorded by variety Titicaca while minimum spathe breadth (6.2 cm) was recorded by Jewel.

2.3.5 Spathe Texture

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

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

Mayadevi (2001) reported thick, smooth and glossy spathe texture for Liver Red and Honeymoon Red, medium thick smooth spathes for var. Pink and thick deeply blistered glossy spathes for Kalimpong Red and Chilli Red. Asish (2002) noticed that spathe texture varied from thick blistered glossy, medium thick deeply blistered glossy, thick smooth glossy and medium thick smooth in various cultivars.

According to Madhukumar (2010), spathe texture showed wide variation among the 40 genotypes studied like thick smooth glossy to thick medium blistered glossy, medium thick medium blistered glossy to medium thick slightly blistered glossy, thick slightly blistered glossy to medium thick slightly blistered nonglossy, thin slightly blistered glossy to medium thick slightly blistered nonglossy spathes.

2.3.6 Spadix Colour

Kamemoto and Nakasone (1963) reported that the most common spadix color was yellow when the spadix was immature, changing to white with the maturity of botanical flowers as indicated by the protuberances on the spadix. Other colors of immature spadices were red, purple, brown, gold, cream, and green, along with intergrading shades. Reddish spadices retained their colour, or changed to purple or white.

Mercy and Dale (1994) revealed that the spadix had a single colour of red, pink or green in ordinary anthurium varieties, whereas hybrids had spadices with yellow, white, pink or red colour in two or more bands.

Kamemoto and Kuehnle (1996) reported that cultivars with a red spathe usually had a bright yellow spadix, while the colour of the spadix varied from orange to red in cultivars with a pink spathe. In the orange spathe group, spadices were either orange or yellow, whereas in cultivars with a white spathe, spadices were pink to bright red. Other colours such as purple, bronze and green were also found in the spadix. Carotenoid pigments were reported to be present in spadix tissue where they were responsible for the bright yellow colour. All other spadix colours are flavonoid-based.

Renu (1999) in the study on ten varieties of *A. andreanum* observed that the spadix had a single colour of pink, light pink, yellow, light yellow, green and light green. Mayadevi (2001) observed spadix colours of red, light red, pink, light pink, yellow, yellowish white, white and cream among the 100 genotypes studied.

The spadix colour varied from red to light red, reddish pink, pink, light pink, pinkish yellow, pinkish white, yellow, yellowish white and cream in 50 genotypes studied by Asish (2002). Premna (2003) observed that spadix colour varied from pink to cream, creamish yellow and yellowish white.

Madhukumar (2010) reported that the spadix colour showed variations like pink, light yellow, yellow, maroon, yellowish white, creamish white and greenish yellow.

2.3.7 Spadix Length

Dai and Paull (1990) reported that in cultivar 'Kaumana', the spadix growth in the flower was slow and continuous inside the tightly furled spathe. The spadix grew from 0.15 cm to 0.42 cm within 35days, with a constant growth rate of 0.01 cm per day. Then the growth rate doubled, and the spadix length increased to 0.6 cm, 28 days before flower emergence.

Bindu (1992) reported the spadix length ranged from 4.0 to 9.5 cm. In ordinary varieties of 'Red', Pink' and 'White' the spadix was long and fleshy but in hybrids and exotics, the spadix was shorter and more slender according to Mercy and Dale (1994). Renu (1999) reported that the commercial varieties *viz*., Tropical Red, Nitta Orange, Mauritius Orange, Lady Jane Red, Pompon Red and Midori Green produced smaller spadices.

Ravidas (2003) reported that the varieties Lima (9.11 cm), Candy Queen (8.56 cm) and Agnihothri (8.11 cm) had the longest spadices. Short spadices were exhibited by the varieties Red Dragon, Eureka Red and Nitta (6.22, 6.78 and 6.89 cm respectively).

Srinivasa and Reddy (2005) reported maximum spadix length and girth in the cultivar Honduras with values 6.57 cm and 7.93 mm respectively. Agasimani *et al.* (2011a) in an evaluation trial reported that variety Esmeralda had the maximum spadix length (8.24 cm) and minimum spadix length was recorded in var. Grace (3.35 cm).

2.3.8 Spathe/Spadix ratio

Sindhu (1995) studied six varieties which had a spathe/ spadix ratio ranged from 2.0 in cv. White to 2.86 in Kalympong Red. Renu (1999) reported that the ratio ranged from 2.54 in Pompon Red to 4.04 in Midori Green. The variety Dragon's Tongue had a spathe/ spadix ratio of 3.58 which was on par with that of Nitta Orange. Spathe/spadix ratios were lower in Liver Red, Lady Jane Red, Ceylon Red and Merengue White. These varieties had smaller spathes with longer candles.

2.3.9 Type of Spadix

Mercy and Dale (1994) suggested that good anthurium hybrids should have short and straight inflorescence axis. Mayadevi (2001) reported that the nature of spadix varied from long, straight and very strong in all the parents and hybrids except for the parent variety Kalimpong Red in which it is long, thin and slightly curving.

Premna (2003) observed long, straight and strong inflorescence axis in Acropolis White and Tropical Red.

Among the 14 genotypes studied, straight and strong inflorescence axis which is more desirable was seen for Liver Red, Orange Glory, Acropolis White and Tropical Red (Pravin, 2004).

Madhukumar (2010) reported that among the 40 genotypes studied, type of spadix showed variations like long thick straight, long thin straight, long thick curved, long thin curved, medium thick straight, medium thick curved, medium thin curved, short thick straight, short thin straight, short thick curved and short thin curved.

2.3.10 Inclination of Spadix with the Spathe

According to Mercy and Dale (1994), ideal anthurium spadix with a high market value must have shorter spadix curving towards the tip of the spathe at an angle less than 45°.

In an investigation by Sindhu (1995) the maximum angle of 75° between the bases of the spadix to the plane of the spathe was observed in the var. Honeymoon Red, which was not desirable. The ideal spadices with angle less than 45° were found in varieties Chilli Red, Kalimpong Orange, Kalimpong Red. Renu (1999) while studying anthurium varieties observed an ideal position of spadices for Pompon Red, Chilli Red, Tropical Red, Mauritius Orange, Nitta Orange, Merengue White and Midori Green.

Mayadevi (2001) observed that the inclination of the spadix ranged from 21° in Kalimpong Red to 78.20° in Honeymoon Red. Ravidas (2003) reported that the least angle of orientation of spadix to spathe was noticed in Candy Queen (40°) and it was highest in the variety Nitta (65°).

Madhukumar (2010) observed that the angle between the spadix and the spathe was lowest for the genotype Orange Glory (35.33°) followed by 'Tropical Red x Merengue White' (35.83°) and Pompon Red (37.5°). The maximum angle was observed for the genotype Vezuvious Red (75.67°) which was on par with 'White x Lady Jane' (75°) and Gold Spark (71.67°).

Jacob (2011) reported that inclination of the spadix with spathe was significantly less in cv. Tropical (40.71°) than in Acropolis (60.9°). Islam *et al.* (2013) reported that var. Aymara showed minimum angle (30°) which was considered to be superior and variety Jewel exhibited maximum angle (60°).

2.3.11 Vase Life

According to Kamemoto (1962), the keeping quality of anthurium flowers was maximum when 3/4th of the length of spadix had changed colour. Large and medium sized flowers kept better than small and miniature ones.

Watson and Shirakawa (1967) reported that the relatively few stomatal openings on the colourful spathe, and abundant layers of waxy cuticle on both the spathe and peduncle prevented significant water loss and the numerous tiny flowers on the spadix was attributed for water loss in anthurium cut flowers.

Senescence of flowers was reported to be associated with the plugging of stem vascular tissues accompanied by the loss in weight, visible changes including loss of spathe glossiness, necrosis of spadix, blueing of spathe, stem collapse and abscission of the spathe and spadix from the stem (Akamine, 1976).

Paull and Goo (1985) described the symptoms of cut flower senescence in anthurium as loss of spathe glossiness, spathe and spadix browning, and spathe wilting due to water stress. Another symptom, spathe blueing, is attributed to an increase in pH from 5.2 to 5.6 caused by an increase in ammonium ions resulting from the breakdown of proteins. Vase life was reported to be determined by a complex criterion based on whichever of these symptoms appears first.

Salvi (1997) reported that harvesting at $1/3^{rd}$ of true flowers opened on the spadix resulted in maximum vase life.

Varieties differ in vase life as well as the longevity in packing. Several pre harvest and post harvest factors also influence the longevity of cut flowers (Abdussamed, 1999). van Doorn (1999) observed that vascular occlusion that results in reduced hydraulic conductivity at the peduncle base contributed to the water stress induced senescence symptoms in anthurium.

Pawar *et al.* (2002) reported that the vase life of Tropical Red was found maximum in plants grown in the coconut coir pieces substrate (14.40 days), while it was minimum in plants grown in brick pieces (10.60 days).

Mujaffar and Sankat (2003) reported that anthurium cut flowers were able to maintain a positive water balance for an extended period compared with other flowers. Waxing of the spadix tissue was found to significantly extend the shelf life of anthuriums as the water loss occurs primarily through the numerous tiny flowers on the pencil like spadix.

Elibox and Umaharan (2008b) reported that vase life varied from 14 to 49 days with the cultivars Evergreen, Spirit, and Venus had short vase life (14 to 15 days) whereas Cuba and Honduras had extremely long vase life (greater than 45 days). Some signs of deterioration such as peduncle base browning and spadix necrosis were common to all cultivars, whereas other symptoms (spathe floppiness, loss of lustre, and discoloration) were specific to only certain cultivars. Spathe necrosis was evident in all cultivars except Cuba. Photo bleaching or lightening and blueing were the most common forms of spathe discoloration and blueing was evident in all red-spathed cultivars.

Agasimani *et al.* (2011a) observed maximum vase life in var. Esmeralda (21days) where as minimum in Ivory (10 days). Jacob (2011) reported that flowers of Tropical (10.13 days) had significantly greater vase life than Acropolis (9.36 days).

Farrell *et al.* (2012) investigated the role of water status in determining vase life in three anthurium cultivars *viz.*, Spirit, Success and Honduras. Spadix necrosis (bloom degradation) under controlled conditions determined end of vase life as 15, 18, and 36 days respectively. Spathe relative water content was closely associated with bloom degradation with all three cultivars reaching end of vase life at about 75 per cent spathe relative water content.

Islam *et al.* (2013) reported that maximum vase life was observed in var. Titicaca (16 days) while minimum was recorded in Caesar (10 days) among the five varieties used in the study. They concluded that vase life of flower is seemed to be an inherent capacity of the cultivar.

2.3.12 Number of True Flowers per Spadix

Kamemoto and Nakasone (1963) described the flower of *A. andreanum* as hermaphroditic with a two-carpelled ovary and four anthers.

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

Bindu and Mercy (1994) were of the opinion that anthurium flower had a spadix bearing about 50 -150 sessile flowers. Mercy and Dale (1994) reported that anthurium spadix was racemose with a slender floral axis bearing 150-350 bisexual sessile flowers in an acropetal succession.

Sindhu (1995) observed that the average number of flowers produced were maximum in cv. Pink and Honeymoon Red (325 flowers) and lowest in the variety Chilli Red (175 flowers). Renu (1999) found that number of flowers per spadix varied from 254 in Tropical Red to 450 in Lady Jane Red.

Mayadevi (2001) recorded that the number of flowers per spadix ranged from 372 in Chilli Red to 600 in Pink among the parents. In the hybrids, 'Pink x Liver Red' had the minimum number of flowers per spadix of about 400 while 'Honeymoon Red x Dragon's Tongue' and 'Pink x Kalimpong Red' had the maximum number of flowers per spadix of 600.

Madhukumar (2010) observed the maximum number of flowers per spadix for the genotype 'Kalimpong Red x Liver Red' (518.67) and minimum number for the genotypes 'Liver Red x Pompon Red' and Corolix (196) which was followed by Vezuvious Red and Diva Pink (221.33).

2.3.13 Days to Initiation of Female Phase

Croat (1980) described the flowering behavior of the inflorescence of anthurium which started with a brief female phase, where the small flowers were receptive with presence of a minute droplet of stigmatic fluid. The maturation of flowers initiated generally from the basal portion of the spadix and development proceeded towards the apex.

Dai and Paull (1990) reported that in cultivar Kaumana, during spadix elongation true flower maturation progressed from the base to the apex. At day 35, zero to 20 per cent of the true flowers were matured, while 14 days later, 50 per cent of the flowers were matured. The spadix matured an additional 20 per cent of the flowers in the following 14 days and reached full maturity 77 days after flower emergence.

Mercy and Dale (1994) reported that the gynoecium reached receptivity about 4-7 days after the opening of the spathe. Sindhu (1995) reported that initiation of female phase occurred within a period up to 10 days after opening of spathe. The variety Honeymoon Red took the longest period for female phase initiation.

Renu (1999) reported that the mean number of days to initiation of female phase ranged from 3.60 days in Lady Jane Red to 6.80 days in Mauritius Orange.

According to Mayadevi (2001), the number of days from the day the spadix become visible to initiation of female phase varies from 4.40 days in Kalimpong Red to 6.80 days in Honeymoon Red and Liver Red. Among the hybrids studied it ranged from 3.60 to 6.20 days. Ravidas (2003) reported that in variety Nitta, the female phase started on the same or within one or two days of the unfurling of the spathe. The variety Red Dragon took more time to start female phase (6.00 days).

Pravin (2004) reported that the number of days required for visible initiation of female phase varied from 4.33 to 9.27 days. Madhukumar (2010) observed that the mean number of days to initiation of female phase ranged from 3.55 to 10.55 days. The genotype Lady Jane recorded the lowest mean value (3.55 days) for this character followed by Vezuvious Red (3.78 days) and Ceasor Violet (4.00 days). The highest mean value was recorded for the genotype Boroque (10.55 days) which was on par with the variety Rembolina (10.44 days) and Diva Pink (9.72 days).

2.3.14 Duration of Female Phase

Bush (1979) reported that the flowers near the base of the spadix matured first and the entire spadix completed stigmatic receptivity stage before any flower started to shed pollen thus prevented self fertilization within a single spadix.

Croat (1980) reported that the duration of pistillate phase was quite variable which ranged from only a few hours in *A. ravenii* to 21-28 days in *A.luterynii.*

Bindu (1992) reported that the female phase in anthurium varied from 3-12 days. Mercy and Dale (1994) observed that during the receptive female phase a viscous colourless exudate was secreted by receptive stigma, which was sticky to touch. This phase lasted for three to seven days in different varieties.

Sindhu (1995) reported that female phase ranged from 5 to 25 days. According to Renu (1999), the duration of female phase varied from 6.4 days in Lady Jane Red to 16.4 days in Mauritius Orange. It was also observed that the individual flower in which the duration lasted upto 21 days in Mauritius Orange.

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

Asish (2002) reported that duration of female phase on an average lasted for about 6.1 days with a range 3.67 days to 11.33 days. Premna (2003) reported that duration of female phase ranged from 5.50 to 9 days in 14 genotypes studied.

Ravidas (2003) observed the longest female phase in the variety Eureka Red (20.33 days) which was significantly superior to all other varieties. The duration was shortest in the variety Red Dragon (12.00 days).

2.3.15 Days of Interphase

Croat (1980) reported that the period between female and male phase was several days in most anthurium species, where as in a few of them the time lag was so short that it was not certain whether the species involved were homogamous or protogynous. The period between female and male phase in *A. pittieri* was reported to be 10 to 20 days.

The interphase of five varieties studied by Bindu and Mercy (1994) ranged from four to seven days. They also reported prolonged duration of interphase during rainy seasons. In a study by Sindhu (1995) the interphase ranged from four to ten days. Prolonged interphase with the suppression of male phase was observed from March to August in several varieties.

Renu (1999) observed that the interphase was marked by the drying up of stigmatic droplets. Observation from seven varieties showed that the interphase ranged from 4.8 to 10.2 days. The longest interphase was shown by Liver Red and the shortest by Merengue White.

Mayadevi (2001) concluded that the interphase ranged from 7.80 days in

Chilli Red to 11.20 days in Pink. Among the hybrids studied, interphase period ranged from 9.39 to12.60 days. Asish (2002) observed that interphase ranged from 2.00 to 11.67 days. According to Premna (2003), the interphase ranged from 4.50 days (Carre) to 9.25 days (Pompon Red x Dragon's Tongue).

Ravidas (2003) observed the longest interphase in Lima (20.00 days) followed by Nitta (16.00 days). Shortest interphase was observed in Red Dragon (3.67 days). Pravin (2004) reported that the interphase ranged from 2.33 to 6.83 days on an average among the 14 varieties studied.

Madhukumar (2010) reported that the highest mean number of days to interphase was shown by Nitta Orange (9.22 days) which was on par with Liver Red (9.18 days), Diva Pink (8.00 days), Arun Gold (8.00 days) and Dragon's Tongue (7.96 days). The lowest mean number of days to interphase was shown by Vezuvious Red (3.55 days) which was on par with Geisha white (3.67 days), Gold Spark (3.89 days), Chocos and Orange Glory (4.33 days), Ceasor violet (4.5 days) and Chekas (4.67 days).

2.3.16 Duration of Male Phase

Bush (1979) reported that elongation of the filaments push the anthers out from under the tepals and caused pollen shedding in anthurium.

Croat (1980) observed that the initiation of stamen emergence appeared to be equal from all parts of the spadix or initial maturation and staminal exertion appeared for many flowers in the basal fourth, basal third or basal half of the spadix and further development proceeded in a systematic manner. The lateral pair of stamens emerged first, usually one at a time followed by the anterior and then the posterior stamens of the alternate pair. Differences were exhibited in the degree of exertion, the disposition with respect to the stigma, and the degree of retraction and changes in pollen color. In some species the stamens were retracted completely after opening while in some others the stamens emerged scarcely but forced the pollen out in long ribbons.

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 anthurium varieties studied by them.

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

According to Jung-Bin *et al.* (1999), the pollen shedding habits varied greatly dependant on the variety. Most varieties shed pollen after their stigmas were no longer receptive. However, some varieties occasionally shed pollen soon after the spathe unfurled.

Among the ten varieties studied by Renu (1999), it was noticed that the average number of days of male phase ranged from 5.4 days in Mauritius Orange to 10.4 days in Tropical Red.

According to Mayadevi (2001), the days of anther emergence ranged from 5 days in the variety Chilli Red to 7.20 days in variety Honeymoon Red. Ravidas (2003) observed the longest duration for male phase in the variety Red Dragon (20.67 days) and shortest in the variety Lima (9.33 days). No pollen emergence was observed in the variety Candy Queen during the period of observation.

Pravin (2004) reported that the average number of days for which the spadices remained in male phase ranged from 5.33 days to 10.83 days. Madhukumar (2010) recorded the lowest mean duration of male phase in Corolix (3.37 days) which was on par with Rembolina (3.67 days), Grace (3.87 days), Esmeralda (4.33 days), Hawaian orange (4.77 days) and Kalimpong Orange (4.99 days). The highest mean duration of male phase was obtained for the genotype 'Tropical Red x Merengue White' (10.89 days) followed by Acropolis white (10.36 days), Jewel and Arun Gold (10.33 days).

2.3.17 Pollen Fertility

According to Stanley and Linskens (1974), mere appearance of the pollen was not always a good index of viability. The capacity of the pollen to germinate and grow is also to be assessed.

Lalithambika (1978) noticed that the pollen sterility of different species of anthurium varied from 63.0 per cent (*A. cordatum*) to 96.5 per cent (*A. veitchii*) and a pollen sterility of 70-75 per cent for *A. andreanum*.

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

Renu (1999) estimated the pollen fertility of ten varieties of anthurium and revealed that the variety 'Liver Red' had the highest pollen fertility of 42 per cent followed by Tropical Red (29 %). Mauritius Orange and Lady Jane Red recorded the lowest fertility value of 14.0 and 13.7 per cent respectively.

Mayadevi (2001) observed high pollen fertility for the variety Liver Red (45.90 %) followed by cv. Pink (28.40 %). Among the 50 genotypes studied by Asish (2002), pollen fertility was found to be 24.24 per cent on an average. Premna (2003) observed highest pollen fertility of 35.70 per cent for the variety Carre followed by Honduras 35.13 per cent.

Ravidas (2003) found that the highest pollen fertility of 69.8 per cent in *A. crystallinum* followed by Agnihothri (64.6%). Lowest pollen fertility was observed in Lima (16.6 %).

According to Pravin (2004), most of the genotypes had low pollen fertility values. Bai *et al.* (2005) studied eight developmental stages in the pollen grains of anthurium cultivar Arizona and reported that the pollens in seventh developmental stage had 50 per cent viability while it declined to 30 per cent at the eighth developmental stage.

Madhukumar (2010) revealed that Liver Red had the highest pollen fertility of 43.01 per cent followed by Lady Jane (36.14 %). The lowest value was recorded for Diva Pink (2.59 %) which was on par with Corolix (2.95 %), Grace (3.41 %), Elan red (4.49 %), Rembolina (4.58 %) and Jewel (5.89 %).

Patil and Aswath (2011) studied pollen characters of *A. andreanum* and observed that the plant produced a large number of pollen grains per anther which were more or less uniform in size, round in shape with a single germ pore. Only a small percentage of pollen grains were fertile which reflects the hybrid nature of the species. Determination of pollen fertility by *in vitro* pollen germination method was found to be more accurate than by acetocarmine staining.

2.3.18 Pollen Morphology

Croat (1980) reported that pollen colour and texture were variable in *A. andreanum.* Pollen colour was generally orange, yellow, purplish or white. The colour faded within a day and generally turns white with age.

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

Premna (2003) noticed that the pollen size ranged from 22.6 μ to 28.4μ. Among the fourteen genotypes studied by Pravin (2004), the average pollen size ranged from 16.80 μ to 24.97μ.

Ravidas (2003) reported that the average size of pollen grains of the different parents showed significant variation. Pollen grains were largest (25μ) in the variety Agnihothri followed by *A. crystallinum,* Lima and Eureka Red. Smallest pollen grains were produced by Red Dragon and *A. amnicola* (16.6μ). All the parents under the investigation had more or less round pollen.

Madhukumar (2010) reported that the mean size of the pollen ranged from 14.67μ in Arun Gold to 25.18 μ in Lady Jane. Pollen shape ranged from round to oval and majority of the genotypes had round pollen.

2.3.19 Pollen Emergence Pattern

In *A. andreanum* anther dehiscence was observed during 8 to 10 a.m. on sunny days and delayed in cloudy and rainy days (Mercy and Dale, 1994). Renu (1999) reported that no pollen emergence was recorded for the varieties Pompon Red, Nitta Orange and Midori Green during the observation period.

According to Madhukumar (2010), the pollen emergence was low in the months from March to June, during which the average maximum and minimum temperature were higher than the rest of the months. Pollen emergence was highest during October to December.

2.4 FRUIT SET AND SEED DEVELOPMENT

Pierik *et al.* (1974) opined that breeding of *A. andreanum* was affected by the long period from fertilization to ripening of seeds (6-7 months).

Zimmer (1986) observed that anthurium berries contained two to three seeds and for ripening, it took 5-12 months. He identified the absence of full fruit set in spadix and long ripening period as the problems in the development of anthurium cultivars.

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

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

Ravidas (2003) reported that the varieties differed significantly regarding the duration to attain seed maturity. The shortest period to attain full maturity of seed was observed in the variety Red Dragon (145.00 days). The longest period was taken by the variety Agnihothri that took 208.3 days to attain seed maturity.

2.4.1 Percentage of Spadices Bearing Fruits

Sheffer and Kamemoto (1976) reported that self-pollination resulted in 81 per cent fruiting spadices. Intraspecific and interspecific cross combination resulted in 65.4 per cent and 28.1 per cent fruiting spadices respectively.

Sindhu (1995) studied six varieties *viz*., Honeymoon Red, Chilli Red, Kalympong Orange, Kalympong Red, Pink, and White and all varieties showed good percentage of spadix bearing fruits. It was maximum (93 %) for the variety White and lowest (50 %) for the variety Kalimpong Red.

Renu (1999) observed that the percentage of fruit bearing spadices was highest (51.93) for Nitta Orange and lowest (9.51) for Mauritius Orange. The only two selfings that produced fruiting spadices were for varieties Liver Red and Dragon's Tongue.

Among the cross combinations attempted, the percentage of fruiting spadices was 100 per cent for nine crosses in a study on 14 genotypes studied by Premna (2003). Among the 12 successful crosses, six crosses had 100 per cent spadices with fruits (Pravin, 2004).

Madhukumar (2010) attempted a total of 127 crosses based on the availability of receptive spadices and fresh pollen, of which 80 were found to be successful. The percentage of spadices bearing fruits ranged from 50 to 100 per cent. Among the selected 15 genotypes, the maximum percentage of spadices bearing berries was obtained for 'Pompon Red x Orange Glory' (90.00 %) followed by Acropolis White (66.67 %). The lowest value (5 %) was obtained for Esmeralda. Among the cross combinations attempted the percentage of fruiting spadices were 100 per cent for 41 crosses and 50 per cent for 39 crosses. No fruit bearing spadices were produced in 47 cross combinations attempted.

2.4.2 Number of Fruits per Spadix

Mercy and Dale (1994) observed that in a well-fertilized spadix about 100 to 200 or more berries developed.

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

Among the ten varieties studied by Renu (1999) the number of fruits per spadix ranged from 5 to 183. The var. Pompon Red had the highest average number of fruits per spadix and it was lowest in Lady Jane.

Among the 12 successful crosses studied by Pravin (2004), percentage of spadices bearing fruits was 100 per cent for six crosses. Fruit number ranged from 88 to 113.

Madhukumar (2010) reported that the number of fruits per spadix ranged from five in 'Esmeralda x (Pompon Red x Orange Glory)' to 85 in '(Pompon Red x Orange Glory) x (Orange Glory x Dragon's Tongue)'. The average number of fruits per spadices was highest for Liver Red and lowest in Esmeralda. The percentage of fruit set was below 50 per cent for all the crosses. The lowest and highest percentage of fruit set was observed in Ceasor Violet and Liver Red respectively.

2.4.3 Percentage of Fruit Set

Based on cross compatibility studies using six varieties, Sindhu (1995) recorded the maximum percentage of fruit set for the cross 'Pink x Honeymoon Red' (52.3 %) followed by 'Honeymoon Red x Pink' (44.3 %).

Renu (1999) reported that the percentage of fruit set was below 50 per cent for all the crosses involving two varieties of *A. andreanum* except 'Pompon Red x Liver Red'. The cross involving Pompon Red as female parent had the highest percentage of fruit set.

Premna (2003) observed highest fruit set for the cross '(Ordinary Orange x Kalimpong Red) x Carre' (34.29 %). Among the ten female parents, the highest average percentage fruit set was observed in 'Ordinary Orange x Kalimpong Red' (29.03 %).

Pravin (2004) reported that the percentage of fruit set was below 50 per cent for all the crosses. The lowest and highest percentage of fruit set was observed in 'Pompon Red x Fla Red (1)' and 'Liver Red x Pompon Red' respectively.

Madhukumar (2010) observed that the percentage of fruit set was below 50 per cent for all the successful crosses. The cross '(Pompon Red x Orange Glory) x (Orange Glory x Dragon's Tongue)' recorded the highest fruit set (21.14 %) followed by 'Liver Red x Dragon's Tongue' (16.76 %). The lowest was in the cross 'Esmeralda x (Pompon Red x Orange Glory)' which had 1.75 per cent fruit set. The average percentage of fruit set was highest for the genotype Liver Red (14.47 %) with three crosses and lowest for Ceasor Violet (1.34 %) with five crosses.

2.4.4 Number of Seeds per Fruit

Mercy and Dale (1994) reported that in commercial varieties of anthurium, each berry contained one or two seeds.

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

Renu (1999) in study on ten varieties observed that the percentage of single seeded berries ranged from 34.30 to 100 per cent and that of double seeded from 0 to 62.50 per cent. Pravin (2004) reported that most of the crosses had a high percentage of single seeded berries compared to double seeded berries except for the cross between 'Liver Red x Pompon Red' and Orange Glory.

According to Madhukumar (2010), most of the crosses had a high percentage of single seeded berries compared to double seeded berries except for the cross 'Fla Red x Liver Red'. Percentage of single seeded berries ranged from 37.21 to 100 per cent.

2.4.5 Seed Size

Sindhu (1995) reported that when two seeds were seen in a berry usually one of them was smaller. The cv. Pink and Honeymoon Red varieties produced larger sized seeds and the Kalimpong varieties produced comparatively smaller sized seeds.

Renu (1999) reported that largest seeds in double seeded berries were obtained in the crosses 'Pompon Red x Liver Red', 'Pompon Red x Dragon's Tongue' and 'Merengue White x Liver Red' and among the single seeded crosses, 'Tropical Red x Merengue White' had the largest size.

Premna (2003) observed the maximum average length and width in single seeded berries for the cross '(Pompon Red x Liver Red) x Tropical' (5mm x 4mm) and for double seeded it was (4.25mm x 2.50mm) for the crosses '(Ceylon Red x Liver Red) x Honduras' and '(White x Lady Jane) x Acropolis White'.

Madhukumar (2010) reported that in a berry with two seeds, one of the seeds was usually smaller than another. In a berry, largest seed among the two seeded berries were observed for the crosses 'Acropolis White x (Pompon Red x Orange Glory)' with a seed size of 3.53 x 2.27 mm.

2.4.6 Seed Germination

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

Mercy and Dale (1994) reported that, the hybrid seeds from crosses between ordinary hardy varieties of *A. andreanum* had above 90 per cent germination and their seedlings showed high survival and vigour.

Sindhu (1995) observed the maximum average seed germination in combinations with the variety White as the female parent (63.4 %) and the lowest in the variety Kalimpong Orange. Highest germination percentage among the crosses was recorded for the cross 'Honeymoon Red x Chilli Red' (78.0 %).

Renu (1999) recorded that the seed germination was highest (87.5 %) in 'Dragon's Tongue Red x Merengue White'. Seed germination percentage varied from 69 per cent in Tropical Red to 2.3 per cent in Midori Green among the varieties.

Pravin (2004) recorded a range of 4 to 9 days in various crosses for seed germination. The seeds obtained from most of the crosses showed a germination percentage of more than 50 per cent. It was lowest in 'Orange Glory x Dragon's Tongue' (63.86 %) and highest in 'Pompon Red x Fla Red (1)' (80.86 %).

Madhukumar (2010) observed that some seeds at the time of harvest had the tip of radicle emerging from the seed coat and such seeds germinated immediately. The number of days taken for germination ranged from 4 to 9 days.

2.4.7 Seedling Survival up to Flowering

Renu (1999) observed that the highest average seedling survival was recorded for Mauritius Orange. None of the seedlings involving Midori Green survived. Lady Jane also recorded a low seedling survival of 32.4 per cent. Out of the 34 combinations that germinated successfully, seedlings belonging to three crosses did not survive beyond four months.

Premna (2003) recorded that seedlings of 12 out of 13 crosses that germinated survived for more than four months. The highest average survival was recorded by 'Fla Red x Kalimpong Red' and lowest was in the genotype 'Kalimpong Red x Liver Red'.

Pravin (2004) observed seedlings of 9 out of 12 crosses that germinated survived for more than four months. The highest average survival was recorded by 'Orange Glory x Dragon's Tongue' and lowest was recorded for the genotype 'Pompon Red x Mauritius Orange'.

According to Madhukumar (2010), seedlings of 57 out of 73 crosses that germinated survived for more than four months. The seedling survival percentage ranged from 38.46 per cent in 'Lady Jane x (Pompon Red x Orange Glory)' to 81.25 per cent in '(Kalimpong Red x Liver Red) x Dragon's Tongue'. The highest average survival was recorded by Liver Red and lowest was recorded for the genotype Lady Jane.

2.4.8 Seedling Characters

Christensen (1971) noted that *A. scherzerianum* Schott and *A. andreanum* Linden have juvenile phases followed by generative phases. In the juvenile stage, leaves have short sheaths with a vegetative bud in the axil, while in the generative stage an inflorescence bud is situated in the axil of the leaves. Instead of a leaf sheath, the sheath covering the axil and upper part of the petiole base protecting the inflorescence bud is composed of stipules. As the plant matures a flower bud forms at the axil of the leaf with no petiole sheath. Instead the stipules from the sheath cover the axil and upper part of the petiole base, thus protecting the flower bud.

Dufour and Guerin (2003) reported that the duration of the monopodial juvenile phase was a varietal character. In the first stages development, the plant produced a leaf and an axillary bud at each node. As the leaf size increased, the apparent phyllochron decreased. The leaves had short sheaths surrounding the stem, at the petiole base and leaf size increased up to leaf number 16 and flower size increased up to flower number 7, which corresponded to leaf number 14 in anthurium cultivar Kaumana.

2.5 *IN VITRO* GERMINATION OF SEEDS

Traditionally seeds or offshoots and nodal cuttings are used to propagate anthurium. In Araceae, propagation through seeds was reported to be difficult in certain taxa that fail to develop viable seeds due to incompatibility (Sheffer and Kamemoto, 1976). Anthurium fruits contain only 1 to 2 seeds, which were reported to be viable only for 2–3 days after harvest with very low germination of 20–30 per cent (Jahan *et al.*, 2009). Hence, studies on techniques that promote *in vitro* germination of seeds are important to maximize the rate of germination and further growth of seedlings for uniform genetic quality and health.

Vegetative propagation is desirable in anthurium. However, the conventional vegetative propagation of anthuriums by separating young plants from parents was reported to be time consuming and took years to develop commercial qualtities of the elite clones (Kamemoto and Kuehnle, 1996). Micropropagation is an attractive alternative to propagate anthuriums in large quantity at a faster rate. Moreover, the micropropagated plantlets could be genetically modified to make them more resistant to some of the common plant diseases (Chen *et al.*, 1997). The induction of somaclonal variation in the micropropagated plants might also be a useful tool to improve the quality of horticulturally important plants such as *A. andreanum* (Brar and Jain, 1998). Hanan and Sherrif (2013) reported micropropagation for germplasm conservation in anthurium.

Several studies have been conducted in *in vitro* multiplication of anthurium. Microropagation of anthuriums was first reported by Pierik *et al.* (1974) through adventitious shoots formation from callus. Plantlet regeneration in anthurium was achieved with various tissues including lamina, petiole, seed, shoot tips, lateral bud, anther, spadix and spathe (Martin *et al.*, 2003, Atak and Celik, 2009, Islam *et al.*, 2010; Raad *et al.*, 2012). *In vitro* multiplication in anthurium was achieved through adventitious shoot formation from callus (Kuehnle and Sugii, 1991; Vargas *et al.*, 2004, Farsi *et al.*, 2012), direct shoot regeneration from lamina explants (Martin *et al.*, 2003), axillary buds (Kunisaki, 1980) and root explants (Chen *et al.*, 1997), somatic embryogenesis (Kuehnle *et al.*, 1992; Duquenne *et al.*, 2007; Hamidah *et al.*, 1997; Fitch *et al.*, 2011).

Swaminathan (1986) reported early seed germination (3-4 days) in Morel's modified medium but the subsequent stages were not supported by this medium. Nitsch medium was found suitable for both germination (5 days) and further growth of seedlings. NAA (0.1, 1 and 5 mg l^{-1}) had no effect on germination and subsequent growth. IAA delayed germination but promoted further growth.

Seeds of *A. parvispathum* were germinated *in vitro* and used as source of explants by Atta-Alla *et al.* (1998). The decontaminated germinated seedlings were excised and placed onto a multiplication medium containing BA 2 mg l^{-1} and NAA 0.2 mg l^{-1}. The shoots were further multiplied and rooted in IBA 0.25 mg l^{-1}.

It took 24 weeks to progress from seed to rooted plantlets ready for acclimatization.

According to Somaya *et al.* (1998), seeds of *A. andreanum* sterilized in 3 per cent sodium hypochlorite for 30 minutes produced the highest percentage germination (92.86 %), while sterilizing for 15 minutes resulted in the highest seedling height (2.25 cm) and leaf number (8.28). Seeds germinated in seven days. Seeds inoculated in MS medium with 2, 4-D (2 mg l^{-1}) produced callus in 30 days. The callus produced shoots which increased in number on a shoot proliferation media with 2, 4-D @ 0.2 mg l^{-1} + BA 1mg l^{-1}.

Prakash *et al.* (2001) cultured selfed seeds of the cv. Mauritius Orange on agarified Nitsch medium. The seeds were surface sterilized with 70 per cent ethanol for 30 seconds and then with 1 per cent sodium hypochlorite solution + 0.1 per cent teepol for five minutes. Callus was induced on petioles excised from eight week old seedlings and cultured on MS medium supplemented with 2, 4-D @ 1.0 or 0.5 mg l^{-1}.

Prabhakara *et al.* (2001) reported that quickest germination of anthurium seeds in half strength MS medium (10. 45 days). The highest germination percentage (88.5%) was recorded in Nitsch medium followed by MS medium (84.1 %).

Ravidas (2003) cultured the seeds of cv. Agnihothri and the seeds responded in modified MS medium supplemented with 2 mg l^{-1} Benzyl amino purine and 0.5 mg l^{-1} NAA in about 90 days. However, the response was slow in other media tried.

Vargas *et al.* (2004) reported *in vitro* seed germination of cv. Rubrun on a medium supplemented with 2.2 mM BA. After 2 weeks, 74 per cent of the seeds germinated and four weeks later, micro-cuttings from these plantlets were subcultured on a medium containing 4.4 mM BA and 0.05 mM NAA. Four weeks old *in vitro* plants from germinated seeds and the plantlets obtained from micro-cuttings, showed callus proliferation at the stem base.

De Freitas *et al.* (2010) reported 100 per cent germination of *A. affine* seeds in full MS media under light. Half-strength MS medium recorded a better plant development, with taller plants and larger and more roots.

Maira et al. (2010) germinated seeds of cv. Rubrun *in vitro* on MS medium supplemented with 0.5 mg l^{-1} BA. Micro-cuttings from *in vitro* germinated seedlings were subcultured on MS medium containing 2 mg l^{-1} BA and 0.5 mg l^{-1} NAA. Four week old *in vitro* plants obtained from microcuttings, showed callus proliferation at the stem base. The development of shoots and plantlets was observed from callus tissue.

Chitra *et al.* (2011) reported 100 per cent germination of cv. Temptation seeds on MS medium supplemented with 1.0 mg l^{-1} BAP after two weeks of inoculation. Four weeks later, micro-cuttings from the *in vitro* germinated seedlings were subcultured on MS medium containing 0.5 mg l^{-1} BAP.

Ancy *et al.* (2012) reported *in vitro* seed germination in modified MS medium supplemented with 2 mg l^{-1}BAP and 0.5 mg l^{-1}NAA in about 90days. Callusing was obtained in the same medium and callus was subcultured in MS full strength medium supplemented with 2 mg l^{-1}BAP and 1 mg l^{-1}IAA. They concluded that using plants from germinated seeds would eliminate the contamination problems, which were encountered using explants taken from the field.

2.6 VARIABILITY STUDIES

Success of a breeding programme depends upon the magnitude of variability present in the crop species and extent to which the desirable characters are heritable, as it provides the basis for effective selection. Variability available in a population could be partitioned into heritable and non-heritable components with the aid of genetic parameters such as genotypic and phenotypic coefficients of variation (GCV and PCV respectively), heritability (H^2) and genetic advance (GA) which serves as basis for selection (Johnson *et. al.* 1955).

According to Allard (1960), the larger the variability, the better is the chance for identifying superior genotypes. Study of variability enables the breeder to determine the crop breeding strategies. Genetic variability for yield and yield contributing traits in the base population is essential for successful crop improvement. Presence of high variability in a crop offers much scope for its improvement.

Renu (1999) reported that high PCV and GCV for the characters plant height, position of spadix, days to initiation of female phase, number of days in female phase and spathe size.

Maximum variability both at phenotypic (48.64 %) and genotypic (41.84 %) levels were observed for number of suckers per plant followed by leaf area, inclination of spadix, width of leaf blade and the minimum was recorded for number of spadices per plant per year (PCV 15.42 % and GCV 10.46 %) by Mayadevi (2001) in 100 genotypes of anthurium.

Asish *et al.* (2003) reported that maximum PCV and GCV for total anthocyanin content (PCV 57.91 % and GCV 57.83 %) followed by pollen fertility (PCV 42.42% and GCV 42.22%) and inclination of spadix to spathe (PCV 40.97 % and GCV 40.86 %). Minimum variability was recorded by days from emergence to inflorescence maturity (13.70 % for PCV and 13.58 % for GCV). High PCV combined with high GCV were obtained for total anthocyanin content, pollen fertility, inclination of spadix to spathe, days of interphase and leaf area. Total anthocyanin content recorded the highest GCV and PCV.

Variability studies revealed that high PCV along with high GCV were present for number of suckers per plant, inclination of spadix and anthocyanin content (Premna, 2003). High phenotypic and genotypic coefficients of variation for the characters number of suckers per plant, pollen fertility and duration of male phased were obtained by Pravin (2004).

Shiva and Nair (2008c) recorded high PCV and GCV for number of suckers per plant, number of leaves per plant and number of flowers per plant. Based on the genotypic and phenotypic variances, low variability was observed for leaf fresh and dry weights, spadix length, number of suckers per plant, leaf size, spathe size, number of coils per spadix, and number of leaves per plant. The values of PCV were in higher magnitude than their corresponding GCV values for all the traits. However, characters, *viz.*, leaf size, leaf area, leaf fresh and dry weight, spadix length, time taken for flowering, shelf-life of flower on plant and number of flowers per plant exhibited maximum difference between PCV and GCV, which indicated the considerable influence of environment on these characters.

According to Madhukumar (2010), maximum GCV (91.70 %) and PCV (91.86 %) were observed for anthocyanin content followed by pollen fertility (GCV 54.19 % and PCV 55.62 %), leaf size/leaf area (GCV 37.23 % and PCV 39.57 %), spathe size (GCV 33.34 % and PCV 36.65 %) and spadix length (GCV 27.05 % and PCV 29.02 %). The characters, days to initiation of female phase, duration of interphase, duration of male phase, number of leaves per plant, spathe size and plant height showed maximum differences between GCV and PCV.

Elibox and Umaharan (2012) observed wider variation in spadix colour combinations than spathe color and wide variation for the cut flower and leaf parameters with productivity and peduncle length having the smallest and largest range, respectively. Principal component analysis of 13 quantitative parameters showed that leaf length, leaf width, leaf size, petiole length, peduncle length, spadix diameter, spathe length, spathe width, spathe size, spathe showiness and productivity are the principal components which explained 75% of the variation in the accessions studied.

2.7 HERITABILITY AND GENETIC ADVANCE

Genotypic coefficient along with heritability estimates gives better idea about the amount of genetic advance in the next generation (Burton, 1952). Estimation of GCV alone is not enough to determine the amount of heritable variation. Heritable variation can be found out with greater degree of accuracy, if the heritability is coupled with genetic advance (Johnson *et al.*, 1955).

Heritability and genetic advance (GA) are important selection parameters. The ratio of genetic variance to phenotypic variance is known as heritability.

High GA indicates that additive genes govern the character and low GA shows that non-additive gene action is involved. Heritability along with GA helps us in predicting the gene action and the method of breeding to be practiced (Robinson *et al.*, 1949).

The magnitude of heritability is valuable in plant breeding programmes since it provides the basis for selection dependent on phenotypic performance. Heritability estimates the transmissibility of character from one generation to other and it provides a measure of the value of selection for different attributes, but high heritability does not necessarily mean a high genetic advance for a particular character (Allard, 1960).

Renu (1999) reported high heritability coupled with high genetic advance values for the characters plant height, spathe size, spathe/spadix ratio, position of spadix, number of flowers per spadix and days to initiation of female phase in anthurium.

Mayadevi (2001) found high heritability coupled with high genetic advance values for plant height, spathe length, spathe width, number of suckers per plant, length of leaf blade, width of leaf blade, spadix length, inclination of spadix and leaf area.

Asish (2002) reported high heritability coupled with high genetic advance values for plant height, internode length, leaf area, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, spadix length, inclination of spadix, number of flowers per spadix, life of spadix, days to initiation of female phase, days to inter phase, durtaion of male phase, pollen fertility and anthocyanin content. High heritability was recorded for anthocyanin content (99.73 %) followed by inclination of spadix to spathe (99.45 %), life of spadix (99.43 %) and pollen fertility (99.05 %). Number of spadices per plant per year recorded a low heritability of 39.34 %. Maximum genetic advance was obtained for anthocyanin content (118.98 %) followed by pollen fertility (86.55 %).

The characters leaf area, anthocyanin content, inclination of spadix, life of spadix and pollen fertility showed high heritability along with high genetic advance (Premna, 2003).

Shiva and Nair (2008c) reported genetic advance values which ranged from 0.01 for leaf dry weight to 10.21 for number of flowers per plant. However, the highest value of genetic advance as per cent of mean was obtained for number of leaves per plant, followed by number of flowers per plant, while the shelf-life of flower on plant registered the lowest value. The characters, number of flowers per plant, time taken for flowering, peduncle length, leaf area, plant spread, shelf life of flower on plant and plant height exhibited high heritability along with high genetic advance.

Madhukumar (2010) reported that plant height, leaf size/leaf area, internodal length, days from emergence to maturity of leaves, spathe size, total anthocyanin content, spadix length, inclination of spadix with spathe, number of flowers per spadix, life of spadix, days to initiation of female phase, days to inter phase, duration of male phase, pollen fertility and pollen size had high heritability estimates. Number of leaves or spadices per plant and days from emergence to maturity of inflorescence had moderate heritability.

2.8 CORRELATION STUDIES

Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection is based for genetic improvement for a particular character (Robinson *et al.*, 1949). Knowledge of correlation studies helps the plant breeder to ascertain the real components of yield and provide an effective basis of selection. The characters contributing significantly to desirable traits can be significantly identified, and can be used as alternate selection criteria in crop improvement programmes. A positive correlation between desirable characters is favorable to the plant breeder because it helps in simultaneous improvement of both the characters (Ranchana *et al.*, 2013).

Renu (1999) reported that number of flowers per spadix showed maximum positive genotypic correlation with spadix length followed by plant height and number of leaves or spadices. Phenotypic correlation was significantly positive with number of leaves/spadices per year followed by spadix length, where as it was negative with spathe- spadix ratio. Plant height positively correlated at genotypic level with number of leaves or spadices per year. Spathe size and spadix length were positively correlated at phenotypic, genotypic and environmental levels. Spadix length showed high positive genotypic correlation with position of the spadix and number of flowers per spadix.

Mayadevi (2001) reported that spadix length and leaf area exhibited significant positive genotypic correlations with plant height. Spathe length and spathe width had significant positive genotypic correlation with spadix length and leaf area both at genotypic and phenotypic level.

Asish (2002) reported a positive correlation of plant height with internodal length, leaf area and days from emergence to maturity of inflorescence. Spadix length showed positive correlation with leaf area and life of spadix. Life of spadix was found to have positive correlation with leaf area and spadix length while it showed negative correlation with days from emergence to maturity of leaves.

Premna (2003) reported that spadix length showed positive correlation with position of spadix at both genotypic and phenotypic levels. Life of spadix was found to have positive phenotypic and genotypic correlation with internodal length, leaf area, number of leaves per plant, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, number of spadices per plant, spadix length, inclination of spadix, days to initiation of female phase, duration of female phase, duration of inter phase, duration of male phase and pollen fertility.

Plant height was found to have highly significant positive phenotypic correlation with number of suckers per plant, leaf size, internode length, number of spadices per plant and pollen fertility and showed negative significant correlation with days to initiation of female phase. Plant height also showed positive genotypic correlation with most of the characters. Spadix length showed negative genotypic correlation with days to initiation of female phase, inclination of spadix, pollen fertility and pollen size (Pravin, 2004).

Chouteau *et al.* (2006) reported that pollen number was positively correlated with the inflorescence peduncle diameter. The stigma area and the pollen quantity were positively correlated with respect to the inflorescence flowering cycle and the flower morphology.

Shiva and Nair (2008a) reported that the number of suckers per plant was positively and significantly correlated with plant height, plant spread, leaf fresh weight, number of leaves per plant, leaf area and leaf dry weight. The sucker production and flower production were negatively correlated with each other.

Madhukumar (2010) reported that genotypic correlation values were higher than the phenotypic values in all most all cases. Plant height was found to have significant positive correlation with leaf size/leaf area, internodal length, total Anthocyanin content, spadix length, number of flowers per spadix and life of spadix. Leaf size/leaf area showed significant positive correlation with plant height, internodal length, total Anthocyanin content, spadix length, number of flowers per spadix, life of spadix, pollen fertility and pollen size.

Elibox and Umaharan (2012) reported that accessions with wider leaves had longer leaves and longer petioles; those with longer spathes had wider spathes; and those with longer peduncles had correspondingly longer petioles. Peduncle length also showed moderate, weak correlations with other leaf measurements and spathe parameters, respectively. Spadix diameter showed moderate correlations with leaf parameters. Spathe showiness showed moderate, weak correlations with spathe measurements and productivity, respectively.

2.9 HYBRIDIZATION

During the infancy of the anthurium industry, flowers were produced from heterogeneous plantings, due to the lack of stabilized varieties. Gradually, through selection and multiplication of superior seedling clones, commercial varieties were established. Majority of these varieties had red flowers. With the realization of the need for a systematic evaluation of available varieties and further improvement in floral attributes a breeding project on anthuriums was first initiated at the Hawaii Agricultural Experiment Station, University of Hawaii in 1950. Hybridization and selection were reported as the most common methods for improving anthuriums (Kamemoto and Nakasone, 1963).

In order to conduct a successful hybridization with anthurium it is necessary to have some understanding of the inter-relationships among different species of anthurium. Cultivated anthurium belongs to two sections *viz.*, *Calomystrium* and *Porphyrochitonium*. The section, *Calomystrium* includes the popular *A. andreanum*, the best known among the cultivated anthurium species. *A. scherzerianum* and *A. amnicola* belong to section *Porphyrochitonium* Kamemoto and Kuehnle (1996).

Hybrids were obtained only with closely related species of the section *Calomystrium.* Hybridization between *A. andreanum and A. scherzerianum* was without success. However, *A. scherzerianum* hybridized readily with *A. wendlingeri* and the hybrids were fertile. The miniature species, *A. amnicola* was able to cross easily with members of *A. andreanum and* other species of the section *Calomystrium* (Marutani *et al.*, 1988). Members of the section *Calomystrium* hybridize with only three members of the section *Porphyrochitonium* namely *A. amnicola, A. antioquiense* and *A. antrophyoides. A. amnicola*, with small, pale lavender flowers was discovered by Robert Dressler in Panama in 1972 and was introduced into cultivation in 1977, made a tremendous impact on the development of miniature, novel hybrids in anthurium (Kamemoto and Kuehnle, 1996).

Sheffer and Kamemoto (1978) evaluated the interspecific cross compatibilities among 56 species of *Anthurium* and they concluded that interspecific hybrids with *A. andreanum* and *A. scherzerianum* were not readily obtainable. However, they got hybrids of *A. andreanum* with six other closely related species.

Kaneko and Kamemoto (1978) revealed that the chromosome numbers 2n=30 for *A. andreanum* cv. Kaumana and 2n = 30 + 2B for cv. 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.

Zimmer (1986) while reviewing the problems in the development of anthurium cultivars observed that in *A. scherzerianum* first inflorescence appeared 12-15 months after sowing but began flowering regularly only after 18-24 months. The spadix seldom had full fruit set. Tissue culture from selected genotypes took, 4-5 months to become plantlets. He added that the selection of a promising genotype took 10-12 years.

Henny *et al.* (1988) obtained Southern Blush, a hybrid for foliage production through interspecific hybridization of a large pink flowered *A. andreanum* and *A. amnicola.* The hybrid was intermediate in size between its parents; spathes were about 7 cm long and 5 cm wide and medium pink with a slight lavender tint.

Wannakrairoj and Kamemoto (1990b) obtained several interspecific hybrids. First-generation hybrids between the lavender *A. Amnicola* and other species with pink-red, orange, and white spathes produced pink-red spathes. The pink-red F1 hybrid between *A. lindenianum* and *A. amnicola* backcrossed to *A.amnicola* produced a 1:1 ratio of pink-red and purple. These results suggested recessiveness of the purple phenotype.

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

Sindhu (1995) reported that a large number of combinations were incompatible. The cross 'Pink x Honeymoon Red' had the maximum percentage of fruitset (52.3 %). Among the 24 combinations obtained, 'Honeymoon Red x Pink' and 'Pink x Honeymoon Red' was found to show the highest compatibility. The duration of fruit maturity ranged from 4.5 to 8.0 months.

Henny (1999) found that the new interspecific anthurium hybrid Red Hot which was highly suitable for pot planting because of its compact growth, freely branching growth habit and production of numerous showy red spathes.

Kuehnle *et al.* (2002) described a new anthurium Waimea developed as a fast propagating, high-yielding, bright red cut flower with yield potential of 6.3 flowers per stem per year. The cultivar originated from a cross between Paradise Pink and selection 768-47 (*A. antioquiense* x Marian Seefurth).

Blight resistance was incorporated by hybridisation of *A. andreanum* types with *A. antioquiense* which enhanced resistance, but the market desired heart shaped spathe form was difficult to recover. Anthurium New Era was the first Bacterial blight resistant cultivar released from Hawaii. This selection arose from a cross between A494 (*A. andreanum* x *A. antioquiense)* and a pink selection (UH507) in an effort to breed blight-resistant varieties for the Hawaii industry (Kuhnle *et al.*, 2004a).

Kuehnle *et al.* (2004b) reported two fragrant anthurium varieties Princess Aiko and Regina. Anthurium Princess Aiko is sweet scented, multipurpose cultivar originated from a cross between white *A. antioquiense* and 'Tatsuta Pink Obake'. It is high yielding with bright, long lasting flowers carried above dark green foliage. Anthurium cv. Regina has a unique lateral tulip shape and large purple flower similar to Princess Aiko.

Kuehnle *et al.* (2007) described 'Leahi', a dualpurpose, light red and green bi-color obake plant which is an offspring of orange UH931 and pink 'Blushing Bride'. They also described the variety 'New Era' with pink spathe which is a bacterial blight resistant cut variety arose from a cross between A494 (*A. andreanum* x *A. antioquiense*) and a pink selection (UH507).

A programme on breeding novel characters in *A. ornatum* has lead to a natural mutant 'IIHR A1' at Indian Institute of Horticuliural Research, Bangalore. A mapping population comprising of 43 progenies was developed from interspecific cross between *Anthurium ornatum*, var IIHR selection A1, and

A. andreanum var 'Eternity' which is susceptible to bacterial blight (Sudarshini *et al*, 2012).

Yang *et al.* (2015) reported leaf color as one of the well sought traits in breeding programme for *A. andreanum* and also opined that knowledge of mechanisms in anthuriums to produce leaves with different shades of green would help to effectively select desirable traits for foliage anthuriums.

2.10 COMBINING ABILITY STUDIES

According to Sprague and Tatum (1942), general combining ability (GCA) is the average performance of a particular inbred in a series of hybrid combinations, whereas specific combining ability (SCA) refers to the performance of a combination of specific inbred in a particular cross. The GCA and SCA variances provide estimation for additive and non-additive gene actions, respectively thus combining ability is used in understanding the nature of gene action involved in the expression of quantitative traits and to predict the performance of the progenies (Falconer, 1989).

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

According to Mayadevi (2001), based on the GCA and SCA effects, the parent Honeymoon Red was the best general combiner for the traits plant height, width of leaf blade, length of spathe, number of spadices per plant per year, duration of female phase, days of interphase, life of spadix and carotene content. For the characters, length and width of leaf blade, leaf area, time taken for first flowering, inclination of candle, days to intiation of female phase, duration of male phase, duration of female phase, total anthocyanin content and total carotenoids, the best general combiner was Kalimpong Red. The parent Liver Red was the best general combiner for characters namely candle length, inclination of candle, internode length, length and width of leaf blade, leaf area, suckering ability, number of flowers per spadix, pollen fertility, total anthocyanin content and total carotenoids.

Materials and Methods

3. MATERIALS AND METHODS

The present study titled 'Performance analysis and combining ability studies in anthurium cultivars' was undertaken during 2010-2013 at the Department of Pomology and Floriculture, College of Agriculture, Vellayani, Thiruvananthapuram. The study comprised of two major experiments.

Details of materials used and methodologies adopted during this investigation are presented below.

3.1 EXPERIMENT 1: PERFORMANCE EVALUATION OF INTRODUCED ANTHURIUM CULTIVARS FOR GROWTH AND CUT FLOWER PRODUCTION.

3.1.1 Climate

Vellayani is located at an altitude of 29 m above mean sea level and between 76.9°E longitude and 8.5°N latitude. The meteorological data during the cropping period recorded at the meteorological observatory at the College of Agriculture, Vellayani is presented in Appendix I.

3.1.2 Experimental Material

Near flowering size plants of nine anthurium varieties *viz*., Hillary, Paradise, Marijke, Cynthia, Mozaik Fresh, Elizabeth, Anastasia, Salmon Queen and Red Amour introduced and supplied by the State Horticulture Mission, Kerala were selected for studying their performance on vegetative growth, flower yield and cut flower attributes for a period of two years from March 2011.

3.1.3 Details of Experimental Design

The selected nine varieties were raised in pots and the experiment was conducted using completely randomized design with four replications each and five plants per replication.

3.1.4 Management of Plants

The experimental plants were grown in pots with the potting mixture containing coarse sand, broken bricks, dried coconut husk pieces (3 cm size) and charcoal as per the Package of Practices (KAU, 2007). All plants received uniform cultural practices. Artificial shade of 75 per cent was provided with polypropylene agro-shade netting. Organic manuring was done by the application of FYM 20g per plant and bone meal 10g per plant once in a month. To boost up growth, NPK (19:19:19) @ 2g l^{-1} were given once a week. Plants were irrigated on alternate days. For the control of pest and diseases, Dimethoate (30 EC) @ 2ml l^{-1} and Bavistin (50 % WP) @ 2g l^{-1} or Indofil M-45@ 2 g l^{-1} was applied at fortnightly interval. Snails and slugs were handpicked and destroyed.

Observations were recorded on the following characters:

3.1.5 Morphological Characters

3.1.5.1. Plant Height

Height of the plant was measured from the collar region to the tip of the top most leaf and expressed in centimeters.

3.1.5.2. Number of Leaves per Plant

Number of leaves produced per plant was recorded at monthly interval and average number was expressed as number of leaves per plant. Young developing, diseased and old drying leaves were not counted.

3.1.5.3. Leaf Area

The maximum length and breadth of the third leaf from top were used for the estimation of leaf area. Leaf length was taken as the linear distance from the uppermost lobe border to the tip. The width was measured as the edge-to-edge perpendicular distance from the point of attachment of the petiole to the lamina. The third leaf was chosen as this would be the leaf, which will be fully unfurled and has achieved its full growth and spread of the leaf blade. Leaf area was calculated by applying the linear regression equation, $y = 9.53 + 0.64\,x$ (Mayadevi, 2001)

where y is the leaf area expressed in cm^2 and x = (maximum leaf length x maximum leaf breadth).

3.1.5.4. Number of Suckers per Plant

The number of new suckers arising from the base of the plant was recorded.

3.1.5.5. Days from Emergence to Maturity of Leaves

Days from the emergence of the leaf to the maturity of leaf was recorded.

3.1.5.6. Colour of Petiole and Young Leaf

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

3.1.5.7. Internodal Length

The length of the stem in between two nodes was measured and recorded in centimeters.

3.1.5.8. Length of Leaf Stalk

Length of leaf stalk was measured from the point of leaf emergence to the base of the leaf lamina and expressed in centimeters.

3.1.6 Floral Characters (A)

3.1.6.1. Number of Flowers or Spadices per Plant per Year

The total number of spadices produced by the plant in a year was counted and recorded.

3.1.6.2. Days from Emergence to Unfurling of Spathe

Number of days taken from the inflorescence emergence to the unfurling of the spathe was recorded.

3.1.6.3. Spathe Colour

The spathe colour of each variety was recorded by visual observation at harvestable maturity.

3.1.6.4. Spathe Length

The length of the spathe was measured from the uppermost lobe border to the tip and expressed in centimeters.

3.1.6.5. Spathe Breadth

The width of the spathe was measured as the edge-to-edge perpendicular distance directly behind the spadix and expressed in centimeters.

3.1.6.6. Spathe Size (cm^2)

The spathe size of each variety was calculated by multiplying spathe length by spathe breadth and expressed in square centimeters (cm^2).

3.1.6.7. Spathe Texture

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

3.1.6.8. Spadix Colour at Unfurling and Colour Change with Ageing

The spadix colour was noticed at unfurling to maturity by visual observation.

3.1.6.9. Spadix Length

The maximum length of the spadix of a fully unfurled flower from the point of attachment of the inflorescence at the peduncle to the tip at the time of harvestable maturity was measured and expressed in centimeters.

3.1.6.10. Spathe/spadix ratio

The spathe/spadix ratio was calculated as the ratio of the mean value of spathe size to that of spathe length.

3.1.6.11. Type of Spadix

The nature of spadix was described as short or long, thick or thin and straight or curvy based on visual observation.

3.1.6.12. Inclination of Spadix with the Spathe

The angle between the bases of the spadix to the plane of the subtending spathe at the time of harvestable maturity was measured with the help of a protractor and expressed in degrees.

3.1.6.13. Vase Life of Flowers

Uniform normal size spadices were harvested in the morning at 1/3rd maturity stage and immediately brought to the laboratory. A slanting cut was given to the stalk end under tap water. Then the flower stalk was placed in measured quantity of tap water taken in conical flasks and the mouth of the flasks were covered with cling film and kept for assessing vase life. Appearance of symptoms such as wilting, spathe blueing, spadix necrosis, discoloration of the spathe/spadix *etc.* was taken as the first sign of senescence. The number of days taken for the appearance of first symptom of senescence was recorded as vase life.

3.1.7 Floral Characters (B)

3.1.7.1 Number of True Flowers per Spadix

The total number of true flowers arranged spirally on the spadix from the base to the tip was counted and recorded.

3.1.7.2 Days to Initiation of Female Phase

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

3.1.7.3 Duration of Female Phase

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

3.1.7.4 Days of Interphase

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

3.1.7.5 Duration of Male Phase

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

3.1.7.6 Pollen Fertility

Pollen fertility was assessed using acetocarmine staining method. Pollen grains were collected during the male phase of the plant and stained with 1:1 glycerin - acetocarmine stain (2%). 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 shriveled 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.

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

3.1.7.7 Pollen Size and Shape

Pollen grains collected during the male phase of the plant and stained with 1:1 glycerin - acetocarmine stain (2%) were observed under binocular microscope, images were taken and pollen diameter measurements were made using the software Motive 2 Plus. Diameter of ten normal shaped and well stained pollen grains was measured and the mean diameter was recorded in microns.

3.1.7.8 Total Anthocyanin Content

Spathes were harvested when half of the spadix had changed the colour. Estimation of anthocyanin was done as per the method described by Rangana (1977).

The initial step was alcoholic extraction of the spathe. One gram of the spathe sample from each treatment was extracted with ethanolic hydrochloric acid, centrifuged at 100 rpm for 6 minutes and the supernatant solution was made up to 100 ml. From this 5 ml was taken and diluted with ethanolic hydrochloric acid to 50 ml and total anthocyanin content was determined by measuring the absorbance of the extract at 535 nm using a T 60 UV Visible spectrophotometer.

The anthocyanin content was then calculated using the following relationship and the quantity was expressed as mg g^{-1} of the sample.

The absorbance of a solution containing 1 mg ml^{-1} is equal to 98.2 (constant).

Therefore, Total anthocyanin in mg g^{-1} of the sample = [(Absorbance at 535nm) x (Volume made up of the extract used for colour development) x (Total volume) x 100] ÷ [Volume (ml of the extract) used x Weight of sample taken x 98.2]

3.1.8 Incidence of Pests and Diseases

Prophylactic control measures were adopted and no serious pest and diseases were noticed.

3.2 EXPERIMENT II: A. HYBRIDIZATION AND COMBINING ABILITY STUDIES IN SELECTED CULTIVARS AND EVALUATION OF HYBRID SEEDLINGS

3.2.1 Materials

Twenty one cultivars consisting of nine introduced cultivars *viz.*, Hillary (H), Paradise (P), Marijke (M), Cynthia (C), Mozaik Fresh (MF), Elizabeth (E), Anastasia (A), Salmon Queen (SQ), Red Amour (RA) and twelve cultivars found to have promising breeding attributes in earlier investigations *viz.*, Tropical Red (TR), Acropolis White (AW), Rosette (R), Liver Red (LR), Lady Jane Pink (LJ), Orange Glory (OG), Dragon's Tongue (DT), Hawaiian Orange (HO), Lima White (LW), Agnihotri Red (AR), Merengue White (MW) and Honduras (HD) were used for the hybridization study (Plate 1).

Hillary

Paradise

Marijke

Cynthia

Mozaik Fresh

Elizabeth

Salmon Queen

Anastasia

Plate 1. Different cultivars of anthurium used for the study

Red Amour

Tropical Red

Acropolis White

Rosette

Liver Red

Lady Jane Pink

Orange Glory

Dragon's Tongue

Plate 1. Different cultivars of anthurium used for the study (contd.)

Hawaiian Orange

Lima White

Agnihotri Red

Merengue White

Honduras

Plate 1. Different cultivars of anthurium used for the study (contd.)

3.2.2 Methods

3.2.2.1 Evaluation of Genotypes to Identify Suitable Parents for Hybridization

The methods used were the same as that in Experiment 1. Mature flowering plants of the selected varieties were raised in pots under completely randomized design with three replications with four plants per replication (Plate 2). Inter varietal crossing in all possible combinations (depending upon the anther emergence) were carried out. After preliminary evaluation of compatibility, further hybridization including reciprocal crossing with repeated pollination were carried out in eight selected cultivars *viz*., Paradise (P), Marijke (M), Mozaik Fresh (MF), Lady Jane Pink (LJ), Orange Glory (OG), Dragon's Tongue (DT), Lima White (LW) and Agnihotri Red (AR) in all the possible combinations (Appendix II).

3.2.2.2 Hybridization Technique in Anthurium

Flowers for hybridization were marked at the time of spathe unfurling. Individual flowers of anthurium are bisexual and are embedded in the spadix (Plate 3). The flowers show a clear protogynous condition and so no emasculation was needed. The spadices of the selected female parents were protected using polythene cover, before the commencement of the female phase, to prevent unwanted pollination. When the female phase started as indicated by the maturity of the lower flowers and viscous exudates from the lower flowers, pollen was collected from the male parent and applied on to the spadix of the female parent with wet hand, which was done in the morning hours. Repeated pollinations were done over a period of 5 to 8 days and the spadix was kept bagged. Each pollinated spadix was labeled showing the parentage and date of crossing.

3.2.3 Observations

Observations on floral characters listed under 3.1.6 and 3.1.7 of Experiment 1 was recorded from two treatment plants per replication and their mean

Plate 2. General view of the plants kept for hybridization

values were taken. After fruit set, the following observations were recorded from the treatment plants.

3.2.3.1 Percentage of Spadices Bearing Fruits

Successfully fertilized inflorescences that remained healthy with strong and green peduncles were noted and their percentage was calculated as the number of spadices bearing berries to the number of spadices pollinated.

3.2.3.2 Number of Fruits per Spadix

The number of berries in each successfully fertilized spadix was counted and recorded.

3.2.3.3 Percentage of Fruit Set

The percentage of flowers showing fruit set to the total number of flowers pollinated in a spadix was calculated and recorded as the percentage of fruit set (Renu, 1999). Hundred per cent of the flowers were assumed to be pollinated in a spadix which was pollinated four times, 90 per cent in spadices pollinated three times, 60 per cent for two and 30 per cent for one pollination. The number of pollinations done was varied as above depending upon the availability of receptive stigma and fresh pollen.

3.2.3.4 Number of Days Taken for Seed Maturity

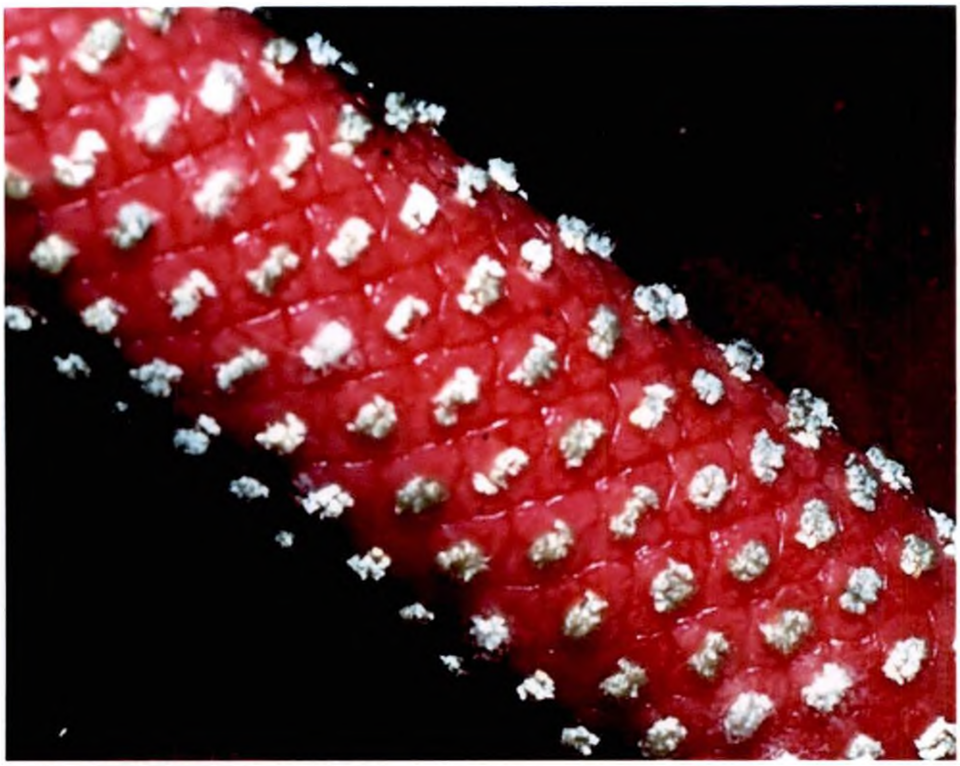
Number of days taken from pollination to ripening of seeds were recorded and expressed in days.

3.2.3.5 Number of Seeds per Fruit

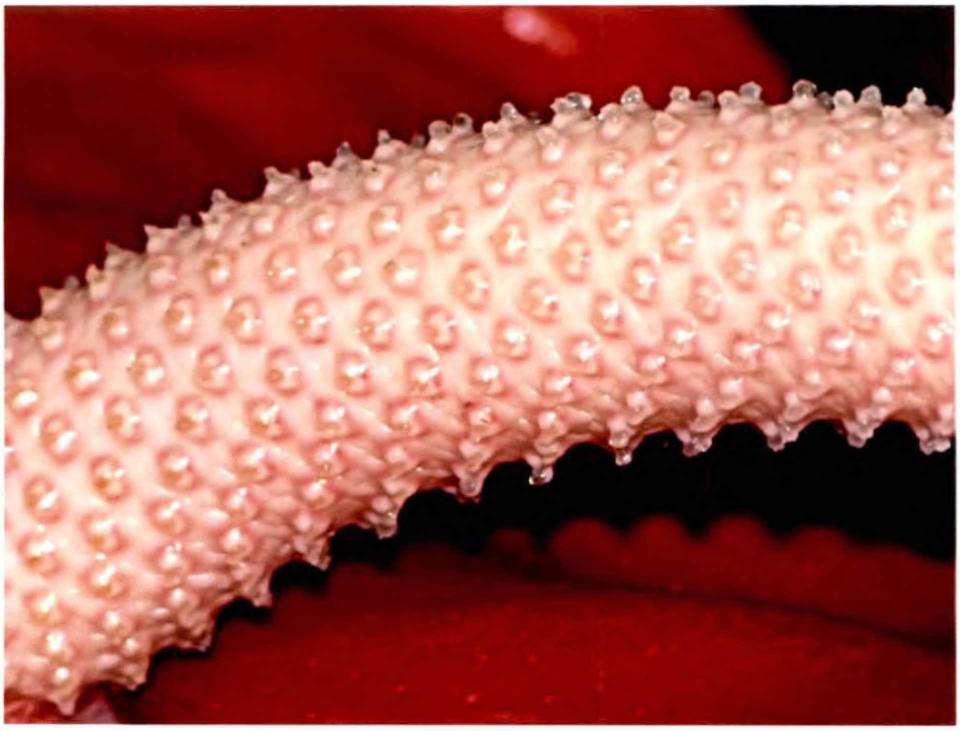
The number of seeds in each ripe berry was recorded.

3.2.3.6 Seed Size

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



Spadix in male phase



Spadix in female phase

Plate 3. Male and female phases in anthurium

3.2.3.7 Seed Germination (%)

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

3.2.3.8 Seedling Survival up to Flowering (%)

The number of seedlings survived was noted and percentage of seedling survival calculated as number of seeds survived to number of seeds germinated.

3.2.3.9 Number of Leaves per Seedling

The number of leaves per plant was noted and recorded.

3.2.3.10 Days from Emergence to Maturity of Leaves

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

3.2.3.11 Leaf Area (cm^2)

Leaf area was calculated as per the method mentioned under 3.1.5.3.

3.2.3.12 Colour of Petiole and Young Leaf

The colour of petiole and young leaf of each genotype was recorded at the time of unfurling by visual observation.

3.2.3.13 Internodal Length

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

3.2.3.14 Time Taken for Flowering

The period taken for appearance of fully unfurled flowers from planting out was observed in weeks and expressed as time taken for flowering.

3.2.3.15 Evaluation of Hybrids at Flowering Stage

When the hybrids started flowering, observations were recorded on time taken from planting to flowering, height of the plant, number of leaves, colour of spathe and spadix, length and breadth of spathe, length of spadix and inclination of spadix.

Qualitative characters of spathe and spadix were scored by a panel of 10 judges based on attractiveness of spathe colour, uniformity of spathe colour, glossiness of spathe, texture of spathe, overall appearance of spathe, attractiveness of spadix colour, shape of spadix and stand or orientation of spadix with respect to spathe. Scores provided were: Excellent (5), Good (4), Fair (3), Medium (2) and Poor (1). Based on the total score the hybrids were ranked.

3.3 EXPERIMENT II: B. *IN VITRO* SEED GERMINATION STUDIES

In vitro seed germination studies were done in the cross combination Marijke x Mozaik Fresh (M x MF) which exhibited highest percentage of fruit set. Standardization of surface sterilization techniques and basal media for seed germination were carried out.

3.3.1 Standardization of Surface Sterilization

Table 1. Surface sterilants, their concentrations and duration of treatment for *in vitro* seed culture in anthurium.

Sl. No.	Surface sterilants	Duration (minutes)
1	Mercuric chloride 0. 1%	10
2	Mercuric chloride 0. 2%	10
3	Mercuric chloride 0.1% + flaming	10
4	Mercuric chloride 0.1% + Bavistin 0.1 %	10
5	Sodium hypochlorite 1%	30
6	Sodium hypochlorite 2%	15

Berries were collected from the spadix and rinsed with tap water, labolene and distilled water. In all the treatments, the explants were submerged in the surface sterilant (Table 1) for the required period with frequent agitation in a laminar air flow chamber. The seeds, after sterilization, were washed four times with distilled water and inoculated into full MS medium containing BA 2 mg l^{-1}. All the treatments were replicated ten times. The culture vessels were labelled and kept in the culture room.

3.3.2 Standardization of Media

The basal medium used in the present study was MS (Murashige and Skoog, 1962) with or without growth regulators (Table 2).

Table 2. Different media tried for *in vitro* seed culture in anthurium.

Treatments	Media
T_1	MS + 0.5 mg l^{-1} BA
T_2	MS + 1 mg l^{-1} BA
T3	MS + 2 mg l^{-1} BA
T_4	Full MS without growth regulators
T_5	Half MS without growth regulators

To prepare the media specific quantities of stock solutions were pipetted out into a 1000 ml beaker. Sucrose and myo-inositol were freshly added and dissolved. After adding all the media components, except Agar the liquid mixture was subjected to pH checking using an electronic pH meter. The pH was adjusted to 5.7 using 0.1 N Sodium hydroxide or 0.1 N Hydrochloric acid. Agar was added to the medium while kept for boiling and stirred until it dissolved. The medium was then poured into the pre-sterilized culture bottles and autoclaved at 121°C and 1.06 kg/cm^2 pressure for 20 minutes.

Berries were collected from the spadix and rinsed with tap water, labolene and distilled water and surface sterilized with sodium hypochlorite (2%) for 15 minutes in a laminar air flow chamber. The seeds, after sterilization, were washed four times with distilled water and inoculated into different media. The composition of the media is given in Appendix III.

3.3.3 Observations

3.3.3.1 Seed Germination In Vitro

Percentage of germination was calculated as percentage of number of seeds germinated to the number of seeds inoculated.

3.3.3.2 Seedling Survival

Survival of the seedlings after one month of inoculation was observed and expressed as percentage.

3.3.3.3 Days Taken for Germination

Number of days taken from the inoculation of the seed to the germination was recorded.

3.3.3.4 Days for Callus Initiation

Number of days taken from inoculation to the initiation of callus was recorded.

3.3.3.5 Days for formation of first leaf

Number of days taken from inoculation to the appearance of first leaf was recorded.

3.4 STATISTICAL ANALYSIS

3. 4.1 Experiment 1

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

3. 4.1.1 Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) for individual character was carried out on the basis of mean value per treatment per replication in Completely Randomized Design (Panse and Sukhatme, 1985).

ANOVA

Sources of variation	df	SS	MSS	F
Treatment	(v- 1)	$\sum T_i^2 / r - CF = SST$	MST	MST/MSE
Error	v (r-1)	TSS- SST	MSE	
Total	vr-1	$\sum Y_{ij}^2$ - CF		

where, r = number of replications, v = number of treatments, SS = Sum of squares, CF = Correction factor, TSS = Total sum of squares, SST= Treatment sum of squares, MSS = mean sum of squares, MST = Treatment mean squares, MSE = Error variance, T_i = Treatment total for i^{th} genotype, Y_{ij} = observations for i^{th} genotype from j^{th} replication

$$\text{Critical difference (CD)} = t\alpha \sqrt{\frac{2\ \text{MSE}}{r}}$$

where, t_α is the student's t- table value at error degrees of freedom and α is the level of significance.

3. 4.1.2 Estimation of Variance Components

The variance components were estimated according to the method proposed by Johnson *et al.* (1955).

$$\text{I. Genotypic variance}, \sigma^2 g = \frac{\text{MST} - \text{MSE}}{r}$$

$$\text{II. Environmental variance}, \sigma^2 e = \text{MSE}$$

$$\text{III. Phenotypic variance}, \sigma^2_p = \sigma^2_g + \sigma^2_e$$

3. 4.1.3 Coefficient of Variation

To study the variability in the population, genotypic and phenotypic coefficients of variation (GCV and PCV) were worked out and expressed in percentage, by the method suggested Burton (1952).

$$\text{Phenotypic coefficient of variation, PCV} = \frac{\sigma\,\text{px}}{\overline{\text{X}}} \text{x}\,100$$

$$\text{Genotypic coefficient of variation, GCV} = \frac{\sigma\,\text{gx}}{\overline{\text{X}}} \text{x}\,100$$

where, σpx = Phenotypic standard deviation, σgx= Genotypic standard deviation, $\overline{\text{X}}$ = Population mean

Phenotypic standard deviation and genotypic standard deviation were obtained as square root of the respective variances. The PCV and GCV were classified as low (<10%), moderate (10-20%) and high (>20%) by Sivasubramanian and Madhavamenon (1973).

3. 4.1.4 Heritability

For each trait, heritability in broad sense was calculated as the ratio of genotypic variance to phenotypic variance and expressed as percentage (Jain, 1982).

$$\text{Heritability } (\text{H}^2) = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

Allard (1960) classified heritability less than 30 percent as low, 30 to 60 percent as medium and heritability more than 60 percent as high.

3. 4.1.5 Genetic Advance

$$\text{Genetic advance (GA) as percentage of mean} = \frac{\text{k.}\,\text{H}^2\sigma\text{px}}{\overline{x}} \times 100$$

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

Genetic advance as percentage were categorized into low (< 20 %) and high (>20 %) as suggested by Robinson *et al.* (1949).

3. 4.1.6 Correlation Analysis

The correlation coefficients (phenotypic, genotypic and environmental) between two characters denoted as x and y were worked out as:

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

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

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

Where σ_{gxy}, σ_{pxy} and σ_{exy} are the genotypic, phenotypic and environmental co-variances between the characters x and y. σ_{gx}, σ_{px} and σe_x are the genotypic, phenotypic and environmental standard deviations for the character x and σ_{gy}, σ_{py} and σ_{ey} are the genotypic, phenotypic and environmental standard deviations for the character y.

3.4.2 Experiment II

3.4.2.1 Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) for Completely Randomized Design (CRD) was carried out for floral characters of the parents.

3.4.2.2. Combining Ability

The data from 28 cross combinations (Appendix IV) out of the 64 possible combinations attempted were subjected to partial diallel analysis method 2 and model 1 described by Griffing (1956) to estimate the general combining effects (GCA) of parents and the specific combining ability (SCA) of crosses.

With 'n' parents and nC_2 F1s raised in CRD with 'r' replications, the ANOVA for combining ability is given as follows.

Source	Degrees of freedom	Mean square	Expected Mean Squares E(MS)
Genotypes	$n + nC_2 - 1$	M_c	$\sigma^2_e + \sigma^2_g$
gca	$n - 1$	M_g	$\sigma^2_e + \sigma^2_{sca} + (n+2)\, \sigma^2_{gca}$
sca	nC_2	M_s	$\sigma^2_e + \sigma^2_{sca}$
Error	$(n + nC_2)(r - 1)$	M_e	σ^2_e

Mg, Ms and Me are the estimates of mean squares for GCA, SCA and experimental error.

If significant differences among GCA and SCA were obtained, their effects were estimated as follows:

General combining ability effect (gi) = $\frac{1}{(n+2)}\left[\Sigma(Yi + Yii) - \frac{2Y..}{n}\right]$

Specific combining ability effect of i x j[th] cross (s_{ij}) = Y_{ij} – (Yi. + Yii + Yj. + Yjj)

$$(Sij) = Yij - \frac{(Yi. + Yii + Yj. + Yjj)}{(n+2)} + \frac{2Y..}{(n+1)(n+2)}$$

where, Y_{ij} = Mean value for P_i x P_j, Y_{ii} = Mean value for selfing P_i *ie.* for P_i x P_i, $Y_{i.}$ = Total for ith parental array, Y.. = Grand total of all the crosses.

The standard error (SE) of the combining ability effects and also for their difference is given below:

$$\text{Standard error (SE) of gi} = \sqrt{\frac{(n-1)}{n(n+2)}\sigma_e^2}$$

$$\text{SE(gi} - \text{gj)} = \sqrt{\frac{2}{(n+2)}\sigma_e^2}$$

$$\text{SE (Sij)} = \sqrt{\frac{(n^2+n+2)}{(n+1)(n+2)}\sigma_e^2}$$

$$\text{SE(Sij - Sik)} = \sqrt{\frac{2(n+1)}{(n+2)}\sigma_e^2}$$

$$\text{SE(Sij - Skl)} = \sqrt{\frac{2n}{(n+2)}\sigma_e^2}$$

The significance of gj and Sij were tested by applying student's t-test.

GCA : g_i/SE(g_i) and SCA : s_{ij}/ SE(s_{ij})

The GCA effects of parents and the SCA effects of crosses were compared with the critical difference (CD) value.

CD = t_α x SE_d where SE_d = SE of the difference of effects.

The significance of GCA effects reveals the importance of additive heritable variance for the inheritance of the character, whereas significance of SCA effect indicates the importance of non-additive variance.

Components of variances for the GCA and SCA effects were estimated as,

Error mean square = $\hat{\sigma}^2_e = M_s$

GCA variance $= \sigma^2_{gca} = \dfrac{Mg\text{-}Ms}{(n+2)}$

SCA variance $= \hat{\sigma}^2_{sca} = (M_s - M_e)$

The additive (σ^2_a) and dominant (σ^2_d) components of variance would be estimated as

The additive variance, $\sigma^2_a = 2\,\sigma^2_{gca}$

The dominance variance, $\sigma^2_d = \sigma^2_{sca}$

Additive to dominance ratio was estimated and if it is more than unity then there is predominance of additive gene action, otherwise there is predominance of non - additive gene action.

Results

4. RESULTS

The results of the investigation entitled 'Performance analysis and combining ability studies in anthurium cultivars' are presented in this chapter.

4.1 EXPERIMENT I. PERFORMANCE EVALUATION OF INTRODUCED ANTHURIUM CULTIVARS FOR GROWTH AND CUT FLOWER PRODUCTION

Performance of nine anthurium cultivars was evaluated and the data were statistically analysed. The results are presented in the following sub heads:

4.1.1 Morphological Characters

4.1.1.1 Plant Height

Plant height of nine anthurium cultivars from planting to 24 months after planting (MAP) are presented in Table 3.

The cultivars varied significantly with respect to plant height from planting to 24 MAP. At planting, the cultivar Marijke recorded the highest plant height of 26.94 cm, which was on par with Mozaik Fresh (26.66 cm), Hillary (26.28 cm), Paradise (24.63 cm) and Salmon Queen (24.23 cm). Significantly different from these was the cultivar Cynthia (22.06 cm) which was on par with Elizabeth (20.88 cm) with respect to this character. Red Amour recorded significantly lower plant height (18.16 cm) which was on par with Anastasia (18.24 cm).

The cultivar Marijke recorded the highest plant height of 29.69 cm at 3 MAP, which was on par with Hillary (28.61 cm), Mozaik Fresh (27.98 cm) and Paradise (27.65 cm). The cultivar Cynthia (25.54 cm) was on par with Salmon Queen (25.44 cm) and significantly different from the above three cultivars. Red Amour recorded significantly lower plant height (19.23 cm) which was on par with Anastasia (19.38 cm) and Elizabeth (21.96 cm).

At six MAP, the cultivar Marijke recorded the highest plant height of 33.76 cm, which was on par with Paradise (31.54 cm) and was significantly different from others. The cultivar Hillary (31.26 cm) was on par with Mozaik

Table 3. Plant height of nine anthurium cultivars

Cultivars	Plant height (cm)								
	At planting	3 MAP*	6 MAP	9 MAP	12 MAP	15 MAP	18 MAP	21 MAP	24 MAP
Hillary	26.28	28.61	31.26	34.41	37.68	40.59	43.53	46.64	50.49
Paradise	24.63	27.65	31.54	36.08	40.16	44.73	48.91	53.54	58.15
Marijke	26.94	29.69	33.76	37.89	42.16	46.21	50.11	54.40	59.24
Cynthia	22.06	25.54	27.44	30.69	33.85	37.41	40.29	43.16	46.83
Mozaik Fresh	26.66	27.98	30.04	31.95	34.13	36.09	37.98	40.14	42.79
Elizabeth	20.88	21.96	24.19	26.16	27.05	30.11	32.15	34.23	36.28
Anastasia	18.24	19.38	21.40	22.58	23.93	24.91	26.11	27.48	30.20
Salmon Queen	24.23	25.44	27.96	29.09	30.90	32.90	34.03	36.80	38.60
Red Amour	18.16	19.23	20.05	21.56	23.74	24.43	25.98	27.27	29.29
SE	1.24	1.17	0.85	1.09	1.20	1.16	1.22	1.33	1.39
CD (5%)	3.60	3.40	2.46	3.15	3.50	3.37	3.54	3.85	4.04

*MAP- Months after planting

Fresh (30.04 cm) with respect to plant height. Cynthia (27.44 cm) was on par with Salmon Queen (27.96 cm). Elizabeth recorded a plant height of 24.19 cm. Red Amour recorded significantly lower plant height (20.05 cm) which was on par with Anastasia (21.40 cm).

The cultivar Marijke recorded significantly higher plant height (37.89 cm) at nine MAP, which was on par with Paradise (36.08 cm). The cultivar Hillary (34.41 cm) was on par with Mozaik Fresh (31.95 cm) with respect to plant height. Cynthia (30.69 cm) was on par with Salmon Queen (29.09 cm). Elizabeth recorded a plant height of 26.16 cm. Red Amour recorded significantly low plant height (21.56 cm) which was on par with Anastasia (22.58 cm).

At 12 MAP, the cultivar Marijke recorded significantly higher plant height of 42.16 cm, which was on par with Paradise (40.16 cm). The cultivar Hillary recorded a plant height of 37.68 cm. Mozaik Fresh (34.13 cm) was on par with Cynthia (33.85 cm) and Salmon Queen (30.90 cm). Red Amour recorded significantly low plant height (23.74 cm) which was on par with Anastasia (23.93 cm) and Elizabeth (27.05 cm).

At 15 MAP, the cultivar Marijke recorded the highest plant height of 46.21 cm which was on par with Paradise (44.73 cm) and significantly different from the other cultivars. The cultivar Hillary recorded a plant height of 40.59 cm that was on par with Cynthia (37.41 cm). Mozaik Fresh (36.09 cm) was on par with Salmon Queen (32.90 cm). Elizabeth recorded a value of 30.11 cm. Red Amour recorded significantly lower plant height (24.43 cm), which was on par with Anastasia (24.91 cm).

The cultivar Marijke recorded significantly high plant height (50.11 cm) at 18 MAP, which was on par with Paradise (48.91 cm). The cultivar Hillary (43.53 cm) was on par with Cynthia (40.29 cm). Mozaik Fresh recorded a plant height of 37.98 cm. Salmon Queen (34.03 cm) was on par with Elizabeth (32.15 cm). Red Amour recorded significantly lower plant height (25.98 cm) which was on par with Anastasia (26.11 cm).

At 21 MAP, the cultivar Marijke recorded significantly higher plant height (54.40 cm) which was on par with Paradise (58.15 cm). The cultivar Hillary

(50.49 cm) was on par with Cynthia (46.83 cm). Mozaik Fresh recorded a plant height of 46.83 cm. Salmon Queen (38.60 cm) was on par with Elizabeth (36.28 cm). Red Amour recorded significantly lower plant height (29.29 cm) which was on par with Anastasia (30.20 cm).

At 24 MAP, cultivar Marijke recorded a plant height of 59.24 cm, which was on par with Paradise (58.15 cm) and was significantly different from other cultivars. The cultivar Hillary (50.49 cm) was on par with Cynthia (46.83 cm). Mozaik Fresh recorded a plant height of 42.79 cm while Salmon Queen recorded 38.60 cm that was on par with Elizabeth (36.28 cm). Red Amour recorded significantly lower plant height (29.29 cm) which was on par with Anastasia (30.20 cm).

4.1.1.2 Leaf Area

Leaf area of nine anthurium cultivars are presented in Table 4. The cultivars varied significantly with respect to leaf area throughout the observation period.

At planting, Marijke recorded the highest leaf area (114.09 cm^2) and was significantly different from other cultivars. The cultivar Cynthia (82.65 cm^2) was on par with Mozaik Fresh (78.64 cm^2), Elizabeth (73.36 cm^2) and Paradise (71.94 cm^2). Anastasia (60.28 cm^2), Hillary (59.42 cm^2) and Salmon Queen (58.90 cm^2) were on par with respect to this character. Red Amour recorded significantly low leaf area of 47.26 cm^2.

At three MAP, Marijke recorded significantly high leaf area (123.89 cm^2). The cultivar Cynthia (86.45 cm^2) was on par with Paradise (82.68 cm^2), Mozaik Fresh (81.57 cm^2) and Elizabeth (80.09 cm^2). Significantly different from the above cultivars were Hillary (71.54 cm^2), Anastasia (67.04 cm^2) and Salmon Queen (65.58 cm^2) which were on par with respect to this character. Red Amour recorded significantly lower leaf area of 48.29 cm^2.

The cultivar Marijke recorded significantly higher leaf area (142.85 cm^2) at six MAP. The cultivar Cynthia (105.36 cm^2) was on par with Mozaik Fresh (92.30 cm^2) and Paradise (95.81 cm^2). Elizabeth (87.25 cm^2), Hillary (84.22 cm^2), Anastasia (81.28 cm^2) and Salmon Queen (74.65 cm^2) were on par with

Table 4. Leaf area of nine anthurium cultivars

Cultivars	Leaf area (cm^2)								
	At planting	3 MAP	6 MAP	9 MAP	12 MAP	15 MAP	18 MAP	21 MAP	24 MAP
Hillary	59.42	71.54	84.22	100.97	122.93	143.07	157.86	185.45	208.05
Paradise	71.94	82.68	95.81	117.25	145.47	177.20	206.14	230.25	253.58
Marijke	114.09	123.89	142.85	159.80	168.62	182.65	195.18	214.30	239.65
Cynthia	82.65	86.45	105.36	120.99	138.57	150.76	168.50	173.26	190.70
Mozaik Fresh	78.64	81.57	92.30	96.20	102.78	107.20	111.83	119.96	134.26
Elizabeth	73.36	80.09	87.25	100.00	110.74	120.17	125.63	136.88	151.37
Anastasia	60.28	67.04	81.28	95.03	102.06	110.72	114.95	124.04	136.37
Salmon Queen	58.90	65.58	74.65	83.42	94.83	108.85	127.76	149.85	153.50
Red Amour	47.26	48.29	55.45	64.16	70.94	77.09	79.59	88.52	92.18
SE	4.06	4.24	4.86	5.42	6.85	8.75	8.97	8.95	8.43
CD (5%)	11.80	12.30	14.10	15.74	19.86	25.38	26.03	25.99	24.46

*MAP- Months after planting

respect to this character and these differed significantly from the above cultivars. The cultivar Red Amour recorded significantly low leaf area (55.45 cm^2).

At nine MAP, Marijke recorded the highest leaf area (159.80 cm^2) and differed significantly from the other cultivars. The cultivar Cynthia (120.99 cm^2) was on par with Paradise (117.25 cm^2). Red Amour recorded significantly lower leaf area of 64.16 cm^2 followed by Salmon Queen (83.42 cm^2).

The cultivar Marijke recorded significantly high leaf area (168.62 cm^2) at 12 MAP. The cultivar Paradise (145.47 cm^2) was on par with Cynthia (138.57 cm^2) and Hillary (122.93 cm^2) was on par with Elizabeth (110.74 cm^2) and differed significantly from other cultivars. Mozaik Fresh (102.78 cm^2), Anastasia (102.06 cm^2) and Salmon Queen (94.83 cm^2) were on par with respect to leaf area. The cultivar Red Amour recorded significantly low leaf area (70.94 cm^2).

At 15 MAP, the cultivar Marijke recorded the highest leaf (182.65 cm^2) area followed by Paradise (177.20 cm^2) and significantly differed from other cultivars. Cynthia (150.76 cm^2) was on par with and Hillary (143.07 cm^2). Elizabeth (120.17 cm^2) was on par with Anastasia (110.72 cm^2), Mozaik Fresh (107.20 cm^2) and Salmon Queen (108.85 cm^2). Red Amour recorded significantly low leaf area (77.09 cm^2).

At 18 MAP, the cultivar Paradise recorded significantly high leaf area (206.14 cm^2) which was on par with Marijke (195.18 cm^2). Cynthia (168.50 cm^2) was on par with Hillary (157.86 cm^2) and Salmon Queen (127.76 cm^2) was on par with Elizabeth (125.63 cm^2), Anastasia (114.95 cm^2) and Mozaik Fresh (111.83 cm^2). Red Amour recorded the lowest leaf area (79.59 cm^2).

The cultivar Paradise recorded the highest leaf area (230.25 cm^2) which was on par with Marijke (214.30 cm^2) at 21 MAP and differed significantly from the other cultivars. Hillary (185.45 cm^2) was on par with Cynthia (173.26 cm^2). Salmon Queen (149.85 cm^2) was on par with Elizabeth (136.88 cm^2) and Anastasia (124.04 cm^2). Red Amour recorded significantly low leaf area (88.52 cm^2) followed by Mozaik Fresh (119.96 cm^2).

At 24 MAP, Paradise (253.58 cm^2) and Marijke (239.65 cm^2) were on par with respect to leaf area and was significantly different from the other cultivars. Hillary and Cynthia were on par, which recorded values of 208.05 cm^2 and 190.70 cm^2 respectively. Salmon Queen recorded a leaf area of 153.50 cm^2 which was on par with Elizabeth (151.37 cm^2), Anastasia (136.37 cm^2) and Mozaik Fresh (134.26 cm^2). Red Amour recorded significantly low leaf area after two years of planting (92.18 cm^2).

4.1.1.3 Number of Leaves per Plant

The leaf number of nine anthurium cultivars is presented in Table 5. The cultivar Paradise recorded the highest number of leaves (8.75) which was on par with Marijke (8.38), Mozaik Fresh (8.00) and Salmon Queen (7.88) and differed significantly from other cultivars. The cultivars Hillary and Elizabeth produced 7.63 leaves each which were on par with Cynthia (6.88). Significantly lower number of leaves per plant was produced by the cultivar Red Amour (6.25) which was on par with Anastasia (6.50).

4.1.1.4 Number of Suckers per Plant

The data on number of suckers produced is given in Table 5. Only some of the cultivars produced suckers and hence the data could not be statistically analysed. The cultivar Salmon Queen produced the highest number of suckers (7 no.), followed by Marijke and Hillary which produced three suckers each and Mozaik Fresh and Elizabeth that produced one sucker each.

4.1.1.5 Days from Emergence to Maturity of Leaves

Data related to days from emergence to maturity of leaves of nine anthurium cultivars are presented in Table 5.

Days taken from emergence to maturity of leaves ranged from 24.55 to 35.95. The cultivar Cynthia exhibited significantly high value (35.95 days) for this character followed by Hillary (33.05 days). Mozaik Fresh and Salmon Queen were on par with a value of 29.03 days and differed significantly from other

Table 5. Variability in morphological characters of nine anthurium cultivars

Cultivars	Number of leaves per plant	Days from emergence to maturity of leaves	Internodal length (cm)	Length of leaf stalk (cm)	Total number of suckers produced
Hillary	7.63	33.05	0.86	29.58	3
Paradise	8.75	25.75	0.87	36.90	Nil
Marijke	8.38	27.85	0.99	37.50	3
Cynthia	6.88	35.95	0.77	32.25	Nil
Mozaik Fresh	8.00	29.03	0.73	38.70	2
Elizabeth	7.63	26.50	0.69	34.15	1
Anastasia	6.50	26.15	0.48	21.08	Nil
Salmon Queen	7.88	29.03	0.50	25.93	7
Red Amour	6.25	24.55	0.45	25.68	Nil
SE	0.33	0.40	0.03	1.82	*
CD (5%)	0.94	1.17	0.09	5.27	*

*Statistical analysis not done

cultivars. Marijke recorded 27.85 days for emergence to maturity of leaves. The cultivar Elizabeth recorded 26.50 days which was on par with Anastasia (26.15 days) and Paradise (25.75 days). The cultivar Red Amour recorded the lowest value (24.55 days) for days from emergence to maturity of leaves which differed significantly from the other cultivars.

4.1.1.6 Internodal Length

Data pertaining to the internodal length of nine anthurium cultivars are presented in Table 5.

Internodal length was significantly high in the cultivar Marijke (0.99 cm). Paradise (0.87 cm) was on par with Hillary (0.86 cm). The cultivar Cynthia (0.77 cm) was on par with Mozaik Fresh (0.73 cm) and Elizabeth (0.69 cm). The minimum value for internodal length was exhibited by the cultivar Red Amour (0.45cm) which was on par with Anastasia (0.48cm) and Salmon Queen (0.50 cm).

4.1.1.7 Length of Leaf Stalk

The leaf stalk length of nine anthurium cultivars is presented in Table 5.

The highest value for length of leaf stalk was exhibited by Mozaik Fresh (38.70 cm) which was on par with Marijke (37.50 cm), Paradise (36.90 cm) and Elizabeth (34.15 cm) and significantly differed from other cultivars. The cultivars Cynthia and Hillary were on par regarding length of leaf stalk with values 32.25 cm and 29.58 cm respectively. Red Amour (25.68 cm) and Salmon Queen (25.93 cm) were on par. Anastasia recorded lower leaf stalk length (21.08 cm) which differed significantly from other cultivars.

4.1.2 Floral Characters

4.1.2.1 Number of Flowers or Spadices per Plant per Year

Data on the number of flowers or spadices produced per plant per year of nine anthurium cultivars are presented in Table 6a.

Number of flowers or spadices produced per plant per year ranged from 2.67 to 6.33. Salmon Queen recorded significantly higher number of 6.33 flowers which was on par with Marijke (6.17 flowers) and Paradise (5.92 flowers). Mozaik Fresh recorded a value of 5.33 which was on par with Hillary (4.92 flowers). Elizabeth and Cynthia produced 4.58 and 4.33 flowers respectively. The cultivar Red Amour recorded significantly lower number of 2.67 flowers followed by Anastasia (3.42 flowers).

4.1.2.2 Days from Emergence to Unfurling of Spathe

Number of days taken from emergence to unfurling of spathe of nine anthurium cultivars is presented in Table 6a.

Among the nine cultivars used in the study, maximum number of days taken from emergence to unfurling of spathe was recorded by Cynthia (26.50 days) which was on par with Mozaik Fresh (26.25 days) and Elizabeth (26.00 days). The cultivars Hillary (24.75 days), Paradise (24.25 days), Salmon Queen (23.50 days) and Red Amour (23.50 days) were on par. Significantly lower number of days taken for emergence to unfurling of spathe was for the cultivar Marijke (20.75 days) followed by Anastasia (22.75 days).

4.1.2.3 Spathe Length

Data pertaining to spathe length of nine anthurium cultivars are presented in Table 6a.

Mozaik Fresh (12.80 cm) produced significantly longer spathe which was on par with Cynthia (12.05 cm), Marijke (12.03 cm), Paradise (11.58 cm) and Hillary (11.13 cm). Lowest spathe length was recorded by Red Amour (8.05 cm) which was on par with Anastasia (8.40 cm), Salmon Queen (9.03 cm) and Elizabeth (9.15 cm) which differed significantly from other cultivars in spathe length.

Table 6a. Variability in floral characters of nine anthurium cultivars

Cultivars	Number of flowers or spadices per plant per year	Days from emergence to unfurling of spathe	Spathe length (cm)	Spathe breadth (cm)	Spathe size (cm^2)	Spadix length (cm)	Spathe/ spadix ratio	Inclination of spadix with the spathe (degrees)	Vase life of flowers (days)
Hillary	4.92	24.75	11.13	9.03	101.61	4.75	21.16	62.25	7.63
Paradise	5.92	24.25	11.58	9.70	112.41	5.73	19.79	58.50	9.00
Marijke	6.17	20.75	12.03	9.05	110.94	4.48	24.72	78.25	8.50
Cynthia	4.33	26.50	12.05	8.88	98.19	4.13	23.78	75.00	6.50
Mozaik Fresh	5.33	26.25	12.80	10.65	137.98	5.28	26.17	78.33	8.38
Elizabeth	4.58	26.00	9.15	7.48	69.93	4.50	15.63	74.00	7.25
Anastasia	3.42	22.75	8.40	7.13	63.34	4.03	15.13	70.00	8.25
Salmon Queen	6.33	23.50	9.03	9.06	81.54	4.08	20.27	80.00	9.25
Red Amour	2.67	23.50	8.05	5.98	48.30	3.75	12.94	70.00	7.75
SE	0.18	0.46	0.74	0.62	12.55	0.26	2.45	1.77	0.32
CD (5%)	0.51	1.33	2.16	1.80	36.43	0.75	7.10	5.14	0.92

4.1.2.4 Spathe Breadth

Data on the spathe breadth of nine anthurium cultivars are presented in Table 6a. The cultivar Mozaik Fresh (10.65 cm) recorded the maximum spathe breadth which was on par with Paradise (9.70 cm), Salmon Queen (9.06 cm), Marijke (9.05 cm), Hillary (9.03 cm) and Cynthia (8.88 cm) and these differed significantly from other cultivars. Lowest spathe breadth was recorded by Red Amour (5.98 cm) which was on par with Elizabeth (7.48 cm) and Anastasia (7.13 cm).

4.1.2.5 Spathe Size

Spathe size of nine anthurium cultivars is presented in Table 6a. Significantly greater spathe size was observed in Mozaik Fresh (137.98 cm^2) which was on par with Paradise (112.41 cm^2), Marijke (110.94 cm^2) and Hillary (101.61 cm^2). The cultivars Cynthia (98.19 cm^2), Salmon Queen (81.54 cm^2), Elizabeth (69.93 cm^2) and Anastasia (63.34 cm^2) were on par regarding spathe size. The significantly lower spathe size was recorded for the cultivar Red Amour (48.30 cm^2).

4.1.2.6 Spadix Length

Spadix length of nine anthurium cultivars is presented in Table 6a. Significantly higher spadix length was observed for the cultivar Paradise (5.73 cm) which was on par with Mozaik Fresh (5.28 cm). The cultivar Hillary (4.75 cm) was on par with Elizabeth (4.50 cm), Marijke (4.48 cm), Cynthia (4.13 cm), Salmon Queen (4.08 cm) and Anastasia (4.03 cm) and these differed significantly from other cultivars. The minimum value was recorded for Red Amour (3.75 cm).

4.1.2.7 Spathe/spadix ratio

Data pertaining to the spathe/spadix ratio of nine anthurium cultivars are presented in Table 6a.

Significantly greater spathe/spadix ratio was observed for the cultivar Mozaik Fresh (26.17) which was on par with Marijke (24.72), Cynthia (23.78), Hillary (21.16), Salmon Queen (20.27) and Paradise (19.79). Lowest spathe/spadix ratio was observed for Red Amour (12.94) which was on par with Anastasia (15.13) and Elizabeth (15.63).

4.1.2.8 Inclination of Spadix

Data pertaining to inclination of spadix of nine anthurium cultivars are presented in Table 6a.

Inclination of spadix with the spathe was highest for the cultivar Salmon Queen (80.00°) which was on par with Mozaik Fresh (78.33°), Marijke (78.25°) and Cynthia (75.00°) which differed significantly from other cultivars. The cultivars Elizabeth (74.00°), Red Amour (70.00°) and Anastasia (70.00°) were on par. The angle between the spadix and spathe was significantly low for the cultivar Paradise (58.50°) which was on par with Hillary (62.25°).

4.1.2.9 Vase Life of Flowers

The vase life of nine anthurium cultivars is presented in Table 6a.

Among the cultivars, maximum vase life was observed for the cultivar Salmon Queen (9.25 days) which was on par with Paradise (9.00 days), Marijke (8.50 days) and Mozaik Fresh (8.38 days) which differed significantly from the other cultivars. The cultivars Anastasia (8.25 days), Red Amour (7.75 days) and Hillary (7.63 days) were on par. Significantly shorter vase life was observed for the cultivar Cynthia (6.50 days) which was on par with Elizabeth (7.25 days).

4.1.2.10 Number of True Flowers per Spadix

Data on the number of true flowers per spadix of nine anthurium cultivars are presented in Table 6b.

Significantly higher number of true flowers per spadix was observed for the cultivar Hillary (408.25). The cultivar Mozaik Fresh (342.75) was on par with

Marijke (341.67), Paradise (329.00) and Cynthia (358.34) which differed significantly from other cultivars. The minimum number of true flowers per spadix was exhibited by the cultivar Red Amour (164.33) which was on par with Elizabeth (237.00) and Salmon Queen (238.36).

4.1.2.11 Days to Initiation of Female Phase

Data related to the days to initiation of female phase of nine anthurium cultivars are presented in Table 6b.

The mean number of days to initiation of female phase ranged from 4.25 to 7.67. The cultivar Salmon Queen (7.67 days) recorded significantly high value. The cultivars Elizabeth and Cynthia recorded 6.67 days which was on par with Paradise (6.50 days), Red Amour (6.34 days) and Marijke (6.33 days). The cultivar Anastasia and Mozaik Fresh took 5.68 and 5.00 days respectively. Hillary recorded significantly lower value (4.25 days) for this character.

4.1.2.12 Duration of Female Phase

Data pertaining to the duration of female phase of nine anthurium cultivars are presented in Table 6b.

The highest mean duration of female phase was obtained for the cultivar Anastasia (12.67 days) which was on par with Cynthia (12.66 days) and Hillary (12.00 days) which differed significantly from other cultivars. Paradise recorded 11.68 days and which was on par with Mozaik Fresh (11.67 days) and Salmon Queen (11.65 days). Red Amour took 10.67 days for this character. Elizabeth recorded significantly low mean duration for female phase (7.33 days) which was on par with Marijke (8.69 days).

4.1.2.13 Days of Interphase

Data pertaining to the duration of interphase of nine anthurium cultivars are presented in Table 6b.

Table 6b. Variability in floral characters of nine anthurium cultivars

Cultivars	Number of true flowers per spadix	Days to initiation of female phase	Duration of female phase (days)	Days of interphase	Duration of male phase (days)	Total anthocyanin content (mg g^{-1})
Hillary	408.25	4.25	12.00	6.00	8.50	2.72
Paradise	329.00	6.50	11.68	5.00	4.75	16.29
Marijke	341.67	6.33	8.69	4.33	6.34	5.77
Cynthia	328.34	6.67	12.66	12.00	7.67	3.05
Mozaik Fresh	342.75	5.00	11.67	7.33	5.33	3.73
Elizabeth	237.00	6.67	7.33	5.67	7.34	5.09
Anastasia	269.33	5.68	12.67	*	*	6.79
Salmon Queen	238.36	7.67	11.65	6.68	7.33	7.47
Red Amour	164.33	6.34	10.67	*	*	20.37
SE	12.31	0.30	0.32	0.28	0.25	0.58
CD (5%)	35.72	0.87	0.94	0.83	0.72	1.99

*No pollen emergence observed

The highest mean number of days for the duration of interphase was shown by the cultivar Cynthia (12.00 days). Significantly different from this was Mozaik Fresh which recorded 7.33 days and Salmon Queen recorded 6.68 days respectively. Hillary (6.00 days) and Elizabeth (5.67 days) were on par with duration of interphase. The lowest mean number of days for the duration of interphase was shown by Marijke (4.33 days) which was on par with Paradise (5.00 days) which differed significantly from other cultivars. Interphase was not recorded in the cultivars Anastasia and Red Amour due to the non observance of pollen grains.

4. 1.2.14 Duration of Male Phase

Data on the duration of male phase of nine anthurium cultivars are presented in Table 6b.

The highest mean duration of male phase was obtained for Hillary (8.50 days) which differed significantly from other cultivars regarding this character. The cultivar Cynthia (7.67 days) was on par with Elizabeth (7.34 days) and Salmon Queen (7.33 days). Marijke recorded 6.34 days for this character. Paradise recorded significantly lower male phase (4.75 days) which was on par with Mozaik Fresh (5.33 days). Male phase was not recorded in the cultivars Anastasia and Red Amour due to the non observance of pollen grains.

4.1.2.15 Total Anthocyanin Content

Data pertaining to the total anthocyanin content of nine anthurium cultivars are presented in Table 6b.

The total anthocyanin content ranged from 2.72 mg g^{-1} to 20.37 mg g^{-1} and the cultivars differed significantly regarding the anthocyanin content. Total Anthocyanin content was highest for the cultivar Red Amour (20.37 mg g^{-1}) followed by Paradise (16.29 mg g^{-1}). The cultivars Salmon Queen (7.47 mg g^{-1}), Anastasia (6.79 mg g^{-1}) and Marijke (5.77 mg g^{-1}) were on par. The cultivar Elizabeth (5.09 mg g^{-1}) was on par with Mozaik Fresh (3.73 mg g^{-1}) in total anthocyanin content. Lowest value was recorded by Hillary (2.72 mg g^{-1}) which was on par with Cynthia (3.05 mg g^{-1}).

4.1.2.16 Pollen Fertility

Pollen fertility values of nine anthurium cultivars are presented in Table 7. The cultivar Marijke had the highest pollen fertility of 57.08 per cent. Mozaik Fresh (34.51 per cent) and Paradise (31.59 per cent) were on par and differed significantly from other cultivars. The lowest value was recorded for the cultivar Hillary (16.75 per cent) which was on par with Elizabeth (17.29 per cent), Cynthia (20.14 per cent) and Salmon Queen (20.94 per cent). Pollen fertility was not calculated in Anastasia and Red Amour due to the non observance of pollen grains.

4.1.2.17 Pollen Size and Shape

Pollen size and shape of nine anthurium cultivars is presented in Table 7. The cultivars showed significant difference regarding the pollen diameter and it ranged from 11.93 μ in Paradise to 26 μ in Cynthia. The cultivar Cynthia had the largest pollen among the cultivars studied which was on par with Hillary with a value of 25.35μ. Mozaik Fresh recorded a pollen diameter of 17.18 μ. The cultivars Salmon Queen and Marijke were on par with pollen diameters of 15.33 and 14.68 μ respectively. Significantly small pollen diameter was recorded by Paradise (11.93μ) which was on par with Elizabeth (12.15 μ).

Pollen shape varied from round to oval. The cultivar Marijke produced oval pollen and Hillary, Paradise, Cynthia, Mozaik Fresh, Elizabeth and Salmon Queen had round pollen. Pollen size and shape were not recorded in the cultivars Anastasia and Red Amour due to the non observance of pollen grains.

4.1.3 Qualitative Characters

Data related to the qualitative characters *viz*., spathe colour, spathe texture, spadix colour at unfurling and ageing, colour of young leaf and petiole are presented in Table 8.

Table 7. Fertility, size and shape of pollen grains of nine anthurium cultivars

Cultivars	Pollen fertility (%)	Pollen diameter (μ)	Pollen shape
Hillary	16.75	25.35	Round
Paradise	31.59	11.93	Round
Marijke	57.08	14.68	Oval
Cynthia	20.14	26.00	Round
Mozaik Fresh	34.51	17.48	Round
Elizabeth	17.29	12.15	Round
Anastasia	*	*	*
Salmon Queen	20.94	15.33	Round
Red Amour	*	*	*
SE	4.16	0.77	
CD (5%)	12.24	2.22	

*No pollen emergence observed

4.1.3.1 Spathe Colour

All the nine cultivars had varied spathe colour (Table 8). The cultivar Hillary had greenish white spathe with pink veins. The spathe of cultivar Paradise was light green with reddish brown tip and veins. The cultivar Marijke had diffused greenish pink spathe with pink veins. Cynthia had creamy green spathe with pink tip. The cultivar Elizabeth showed white spathe with pink blush and reddish pink veins. The spathe colour of Mozaik Fresh was off white with green lobes and edges with pink veins. Anastasia had whitish pink spathe deepening to blush pink. Spathe colour was salmon pink with green lobes in cultivar Salmon Queen. Red Amour had orange blended red with green lobes.

4.1.3.2 Spathe Texture

Spathe texture showed differences in all the cultivars studied (Table 8). Hillary had thin spathe which was shallow blistered and non glossy. Spathe of Paradise was thin, shallow blistered and medium glossy. Marijke had thin spathe which was blistered and glossy. Spathe was thin, smooth and non glossy in Cynthia. Mozaik Fresh had thin spathe which was smooth and medium glossy. The spathe of Elizabeth was thin, medium blistered and glossy. Anastasia had thin, smooth and glossy spathe. Spathe was thin, blistered and glossy in Salmon Queen. Red Amour had thin, shallow blistered and glossy spathe.

4.1.3.3 Spadix Colour at Unfurling and Colour Change with Ageing

Spadix colour varied from unfurling to maturity (Table 8). In Hillary, spadix colour was green at unfurling which changed to pinkish white at maturity. Paradise had greenish yellow spadix at unfurling which changed to white and yellow at maturity. Spadix colour was orange yellow at unfurling in Marijke which turned to light pinkish green at maturity. In Cynthia, spadix was cream coloured at unfurling which turned to light pink on maturity. Mozaik Fresh had yellowish pink spadix which turned to pink on maturity. Elizabeth had orange red spadix which turned to pink on maturity. In Anastasia, the spadix was yellow in colour which changed to pink on maturity. Salmon Queen had yellow spadix

Table 8. Qualitative characters of nine anthurium cultivars

Cultivars	Spathe colour	Spathe texture	Spadix colour		Type of spadix	Colour of petiole	Colour of young leaf
			At unfurling	At maturity			
Hillary	Greenish white with pink veins	Thin, shallow blistered, non glossy	Green	Pinkish white	Long, thick, straight	Green	Green
Paradise	Light green with reddish brown tip and veins	Thin, shallow blistered, medium glossy	Greenish yellow	White and yellow	Medium, thick, straight	Brownish green	Brownish green
Marijke	Diffused greenish pink spathe with pink veins	Thin, blistered, glossy	Orange yellow	Light pinkish green	Long, thick, straight	Brownish green	Reddish brown
Cynthia	Creamy green spathe with pink tip	Thin, smooth, non glossy	Cream	Light pink	Long, thick, slightly curved	Green	Green
Mozaik Fresh	Off white with lobes and edges green, pink veins	Thin, smooth, medium glossy	Yellowish pink	Pink	Long, thick, straight	Brownish green	Brownish green
Elizabeth	White with pink blush and reddish pink veins	Thin, medium blistered, glossy	Orange red	Pink	Long, medium thick, curved	Brownish green	Green
Anastasia	Whitish pink deepening to blush pink	Thin, smooth, glossy	Yellow	Pink	Short, thick, straight	Green	Green
Salmon Queen	Salmon pink with green lobes	Thin, blistered, glossy	Yellow	White	Medium, thick, straight	Green	Green
Red Amour	Orange blended red with green lobes	Thin, shallow blistered, glossy	Yellow	Yellow and white	Short, medium thick, straight	Green	Green

which changed to white on maturity. Spadix colour was yellow in Red Amour at unfurling which changed to yellow and white at maturity. Spadix became green at ageing.

4.1.3.4 Type of Spadix

Spadix exhibited variations in length, thickness and straightness (Table 8). Hillary, Mozaik Fresh and Marijke had long, thick and straight spadix. The cultivar Cynthia had long, thick and slightly curved spadix whereas Elizabeth had long, medium thick and curved spadix. Spadix in Paradise was medium, thick and straight. Salmon Queen had medium, thick and straight spadix and Anastasia had short, thick and straight spadix. Red Amour had short, medium thick and straight spadix.

4.1.3.5 Colour of Petiole and Young Leaf

The cultivars Hillary, Cynthia, Anastasia, Salmon Queen and Red Amour showed green petiole while the petiole colour was brownish green in Paradise, Marijke, Mozaik Fresh and Elizabeth (Table 8).

Colour of young leaf was green in the cultivars Hillary, Cynthia, Elizabeth, Anastasia, Salmon Queen and Red Amour while it was brownish green in Paradise and Mozaik Fresh. Colour of young leaf in Marijke was reddish brown.

4.1.4 Morphological description of the cultivars

Based on the results, the introduced cultivars used for performance evaluation are morphologically described as follows:

Hillary

Two years after planting, the cultivar Hillary showed an average plant height of 50.49 cm. The spathe size was 101.61 cm^2. The spadix was 4.75 cm long and inclined to the spathe at an angle of 62.25°. The cultivar had greenish white spathe with pink veins and green spadix which turned into pinkish white at maturity (Plate 4). It produced 4.92 flowers per year with a vase life of 7.63 days.

Plate 4. Variation in spathe and spadix colour in cv. Hillary with ageing

Plate 5. Variation in spathe and spadix colour in cv. Paradise with ageing

Plate 6. Variation in spathe and spadix colour in cv. Marijke with ageing

Paradise

The cultivar Paradise had an average plant height of 58.15 cm and spathe size of 112.41 cm^2. The spadix was 5.73 cm long and inclined to the spathe at an angle of 58.5°. The spathe was light green with reddish brown tip and veins. The spadix was greenish yellow which changed to white and yellow at maturity (Plate 5). It produced 5.92 flowers per year with a vase life of 9.00 days.

Marijke

This cultivar showed an average plant height of 59.24 cm and spathe size of 110.94 cm^2. Spadix length was 4.48 cm which was inclined to the spathe at an angle of 78.33°. The cultivar had diffused greenish pink spathe with pink veins and orange yellow spadix which turned to light pinkish green at maturity (Plate 6). It produced 6.17 flowers per year with a vase life of 8.5 days.

Mozaik Fresh

The cultivar Mozaik Fresh had an average plant height of 42.79 cm. The spathe size was 137.98 cm^2. The spadix was 5.33 cm long and inclined to the spathe at an angle of 78.33°. This cultivar had off white spathe with green lobes and edges, pink veins and yellowish pink spadix which turned to pink on maturity (Plate 7). It produced 5.33 flowers per year with a vase life of 8.38 days.

Cynthia

The cultivar had 46.83 cm height. The spathe size was 98.19 cm^2 and spadix was 4.13 cm long and inclined to the spathe at an angle of 75.00°. The spathe was creamy green with pink tip and spadix was cream coloured at unfurling which turned to light pink on maturity (Plate 8). It produced 4.33 flowers per year with a vase life of 6.5 days.

Elizabeth

The cultivar Elizabeth had 36.28 cm height. The spathe size was 69.93 cm^2. The spadix was 4.50 cm long and inclined to the spathe at an angle of 74°. The spathe was white with pink blush and reddish pink veins and spadix was orange red which turned to pink on maturity (Plate 9). It produced 4.58 flowers per year with a vase life of 7.25 days.

Plate 7. Variation in spathe and spadix colour in cv. Mozaik Fresh with ageing

Plate 8. Variation in spathe and spadix colour in cv. Cynthia with ageing

Plate 9. Variation in spathe and spadix colour in cv. Elizabeth with ageing

Plate 10. Variation in spathe and spadix colour in cv. Salmon Queen with ageing

Plate 11. Variation in spathe and spadix colour in cv. Anastasia with ageing

Plate 12. Variation in spathe and spadix colour in cv. Red Amour with ageing

Salmon Queen

The plant height was 38.60 cm with a spathe size of 81.54 cm^2. The spadix was 4.08 cm long and inclined to the spathe at an angle of 80°.This cultivar had salmon pink spathe with green lobes and yellow spadix which changed to white on maturity (Plate 10). It produced 6.33 flowers per year with a vase life of 9.25 days.

Anastasia

The cultivar was short with a plant height of 30.20 cm. The spathe size was 63.34 cm^2. The spadix was 4.03 cm long and inclined to the spathe at an angle of 70°.This cultivar had whitish pink spathe which deepens to blush pink and yellow spadix which changed to pink on maturity (Plate 11). It produced 3.42 flowers per year with a vase life of 8.25 days.

Red Amour

The cultivar Red Amour was short statured with a plant height of 29.29 cm. The spathe size was 48.30 cm^2. The spadix was 3.75 cm long and inclined to the spathe at an angle of 70°. Spathe was orange blended red with green lobes and spadix was yellow at opening which changed to yellow and white at maturity (Plate 12). It produced 2.67 flowers per year with a vase life of 7.75 days.

The cultivars showed variations in spathe characters (Plate 13) and shape and size of leaves (Plate 14).

4.1.5 Estimation of Variability Components

4.1.5.1 Coefficients of Variation

The phenotypic and genotypic variance and phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) are presented in Table 9.

The characters number of true flowers per spadix (5936.54), leaf area (3001.62), plant height (128.04), length of leaf stalk (47.60), inclination of spadix with the spathe (64.70) and days from emergence to maturity of leaves (14.19) recorded high phenotypic variances. The characters internodal length (0.04), number of leaves per plant (1.03), days to initiation of female phase (1.24),

Plate 13. Variation in spathe characters of the cultivars used in performance evaluation

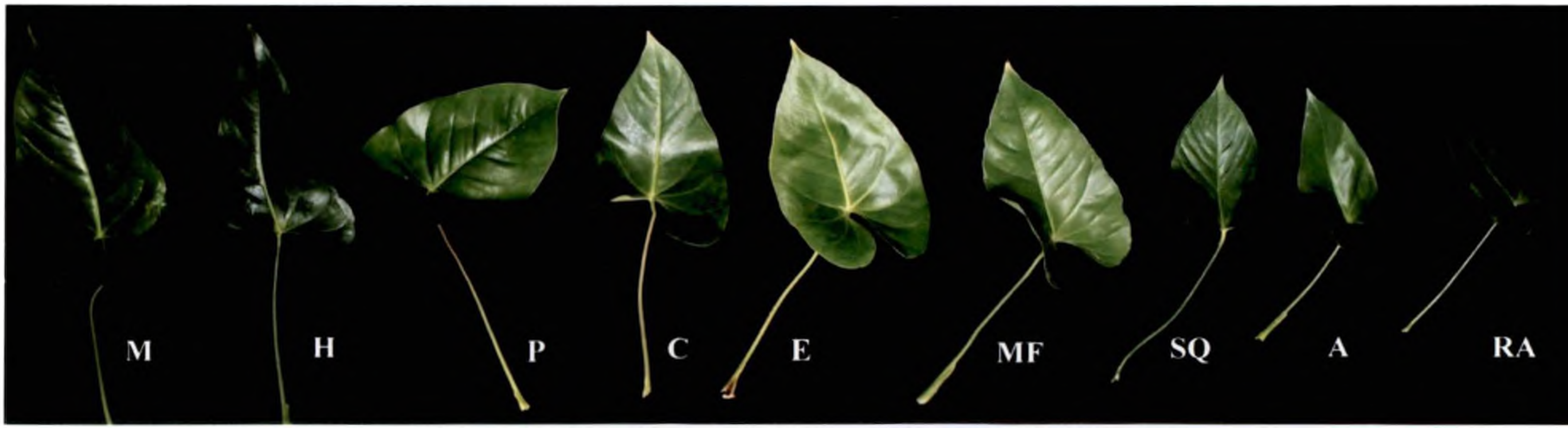


Plate 14. Variation in leaf shape and size of the cultivars used in performance evaluation

M- Marijke, H- Hillary, E- Elizabeth, C- Cynthia, P- Paradise, MF-Mozaik Fresh, SQ- Salmon Queen, A-Anastasia, RA-Red Amour

Table 9. Components of total variance for different characters in anthurium cultivars

Sl. No.	Characters	Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)
1	Plant height (cm)	128.04	120.28	25.98	25.18
2	Number of leaves per plant	1.03	0.61	13.45	10.31
3	Length of leaf stalk	47.60	34.41	22.04	18.73
4	Leaf area (cm^2)	3001.62	2709.26	31.79	30.21
5	Days from emergence to maturity of leaves	14.19	13.54	13.15	12.85
6	Internodal length (cm)	0.04	0.03	28.41	26.87
7	Number of flowers or spadices per plant per year	1.65	1.52	26.48	25.47
8	Days from emergence to unfurling of spathe	4.13	3.28	8.38	7.47
9	Spathe length(cm)	4.63	2.41	20.77	14.98
10	Spathe breadth(cm)	3.19	1.66	20.93	15.08
11	Inclination of spadix with the spathe (degrees)	64.70	52.14	11.19	10.05
12	Number of true flowers per spadix	5936.54	5330.57	26.07	24.71
13	Days to initiation of female phase	1.24	0.82	18.48	15.06
14	Duration of female phase	3.71	3.20	17.74	16.47

number of flowers or spadices per plant per year (1.65), spathe breadth (3.19), spathe length (4.63), days from emergence to unfurling of spathe (4.13) and duration of female phase (3.71) recorded low phenotypic variances.

The characters number of true flowers per spadix (5330.57), leaf area (2709.26), plant height (120.28), length of leaf stalk (34.41), inclination of spadix with the spathe (52.14) and days from emergence to maturity of leaves (13.54) recorded high genotypic variances. The characters internodal length (0.03), number of leaves per plant (0.61), days to initiation of female phase (0.82), number of flowers or spadices per plant per year (1.52), spathe breadth (1.66), spathe length (2.41), days from emergence to unfurling of spathe (3.28) and duration of female phase (3.20) recorded low genotypic variances.

Maximum phenotypic (31.79 %) and genotypic (30.21 %) coefficient of variation were observed for the character leaf area followed by internodal length (PCV 28.41 % and GCV 26.87 %). The minimum PCV and GCV were recorded by the character days from emergence to unfurling of spathe as 8.38 per cent for PCV and 7.47 per cent for GCV. Inclination of spadix with spathe, days from emergence to maturity of leaves and number of leaves per plant also registered low values of 11.19 per cent and 10.05 per cent, 13.15 per cent and 12.85 per cent, 13.45 per cent and 10.31 per cent respectively at both phenotypic and genotypic levels.

The characters spathe breadth (5.85 %), spathe length (5.79 %), days to initiation of female phase (3.42 %), length of leaf stalk (3.31 %) and number of leaves per plant (3.14 %) showed maximum differences between PCV and GCV. The characters days from emergence to maturity of leaves (0.3 %), plant height (0.8 %), days from emergence to unfurling of spathe (0.91 %) and number of flowers or spadices per plant per year (1.01 %) showed low differences between PCV and GCV.

4.1.5.2 Heritability and Genetic Advance

The heritability and genetic advance estimates of the various characters are given in Table 10.

The characters which showed highest heritability values were plant height (93.94 %), days from emergence to maturity of leaves (95.40 %), number of flowers or spadices per plant per year (92.52 %), leaf area (90.26 %), number of true flowers per spadix (89.79 %), internodal length (89.50 %), duration of female phase (86.28 %), inclination of spadix with spathe (80.59 %), days from emergence to unfurling of spathe (79.61 %), length of leaf stalk (72.27 %) and days to initiation of female phase (66.43 %).

Characters which showed moderate heritability were number of leaves per plant (58.82 %), spathe length (52.02 %) and spathe breadth (51.89 %).

Highest value for genetic advance as percentage of mean was obtained for leaf area (59.12 %) followed by internodal length (52.37 %), number of flowers or spadices per plant per year (50.48 %), plant height (50.29 %), number of true flowers per spadix (48.23 %), length of leaf stalk (32.81 %), duration of female phase (31.53 %), days from emergence to maturity of leaves (25.85 %), spathe breadth (22.37 %) and spathe length (22.25 %). The Genetic advance was low for the characters days from emergence to unfurling of spathe (13.74 %) followed by number of leaves per plant (16.29 %) and inclination of spadix with the spathe (18.59 %).

4.1.6 Correlation Studies

The results of phenotypic, genotypic and environmental correlations among the various characters were estimated and the results of the correlation analysis are presented in Tables 11, 12 and 13.

4.1.6.1 Phenotypic Correlation

Plant height was found to have significant positive correlation with number of leaves per plant (0.617), length of leaf stalk (0.621), leaf area (0.906), internodal length (0.860), number of flowers or spadices per plant per year

Table 10. Heritability and genetic advance of fourteen characters in anthurium cultivars

Sl. No.	Characters	Heritability (%)	Genetic advance (5 %)	Genetic advance as percentage of mean
1	Plant height (cm)	93.94	21.89	50.29
2	Number of leaves per plant	58.82	1.23	16.29
3	Length of leaf stalk	72.27	10.27	32.81
4	Leaf area (cm^2)	90.26	101.87	59.12
5	Days from emergence to maturity of leaves	95.40	7.41	25.85
6	Internode length (cm)	89.50	0.37	52.37
7	Number of flowers or spadices per plant per year	92.52	2.45	50.48
8	Days from emergence to unfurling of spathe	79.61	3.33	13.74
9	Spathe length (cm)	52.02	2.30	22.25
10	Spathe breadth (cm)	51.89	1.91	22.37
11	Inclination of spadix with the spathe (degrees)	80.59	13.35	18.59
12	Number of true flowers per spadix	89.79	142.51	48.23
13	Days to initiation of female phase	66.43	1.52	25.29
14	Duration of female phase	86.28	3.42	31.53

(0.666), spathe length (0.626), spathe breadth (0.563) and number of true flowers per spadix (0.702). However, no significant correlation was observed for plant height with days from emergence to maturity of leaves, days from emergence to unfurling of spathe, inclination of spadix with spathe, days to initiation of female phase and duration of female phase.

Number of leaves per plant showed significant positive correlation with plant height (0.617), length of leaf stalk (0.605), leaf area (0.588), internodal length (0.594), number of flowers or spadices per plant per year (0.737), spathe length (0.574), spathe breadth (0.593) and number of true flowers per spadix (0.415). No significant correlation was observed for number of leaves per plant with days from emergence to maturity of leaves, days from emergence to unfurling of spathe, inclination of spadix with spathe, days to initiation of female phase and duration of female phase.

Length of leaf stalk showed significant positive correlation with plant height (0.621), number of leaves per plant (0.605), leaf area (0.489), internodal length (0.645), number of flowers or spadices per plant per year (0.462), spathe length (0.724), spathe breadth (0.606) and number of true flowers per spadix (0.414). No significant correlation was observed for length of leaf stalk with all other characters under study.

Leaf area was found to have significant positive correlation with plant height (0.906), number of leaves per plant (0.588), length of leaf stalk (0.489), internodal length (0.781), number of flowers or spadices per plant per year (0.607), spathe length (0.495), spathe breadth (0.469) and number of true flowers per spadix (0.636). No significant correlation was observed for leaf area with all other characters under study.

Days from emergence to maturity of leaves showed significant positive correlation with days from emergence to unfurling of spathe (0.440), spathe length (0.384), spathe breadth (0.392), number of true flowers per spadix (0.563) and duration of female phase (0.393).

Table 11. Phenotypic correlation coefficients among fourteen characters in anthurium

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
X_1	1													
X_2	0.617**	1												
X_3	0.621**	0.605**	1											
X_4	0.906**	0.588**	0.489**	1										
X_5	0.304	0.000	0.142	0.258	1									
X_6	0.860**	0.594**	0.645**	0.781**	0.336	1								
X_7	0.666**	0.737**	0.462*	0.607**	0.159	0.568**	1							
X_8	-0.120	-0.039	0.232	-0.152	0.440*	-0.036	-0.148	1						
X_9	0.626**	0.574**	0.724**	0.495**	0.384*	0.682**	0.477**	0.134	1					
X_{10}	0.563**	0.593**	0.606**	0.469**	0.392*	0.486**	0.592**	0.194	0.868**	1				
X_{11}	-0.224	0.030	0.073	-0.342	0.130	-0.160	0.130	0.003	0.039	0.121	1			
X_{12}	0.702**	0.415*	0.414*	0.636**	0.563**	0.766**	0.467**	0.070	0.644**	0.584**	-0.238	1		
X_{13}	-0.074	0.043	0.001	-0.008	-0.190	-0.286	0.167	-0.201	-0.182	-0.069	0.279	-0.483**	1	
X_{14}	-0.056	-0.198	-0.323	-0.046	0.393*	-0.206	-0.120	0.147	0.054	0.180	-0.239	0.282	-0.191	1

* Significant at 5% ** significant at 1%

X_1 Plant height (cm)

X_2 Number of leaves per plant

X_3 Length of leaf stalk (cm)

X_4 Leaf area (cm^2)

X_5 Days from emergence to maturity of leaves

X_6 Internode length (cm)

X_7 Number of flowers or spadices per plant per year

X_8 Days from emergence to unfurling of the spathe

X_9 Spathe length (cm)

X_{10} Spathe breadth (cm)

X_{11} Inclination of spadix with the spathe (degrees)

X_{12} Number of true flowers per spadix

X_{13} Days to initiation of female phase

X_{14} Duration of female phase

Internodal length showed significant positive correlation with plant height (0.860), number of leaves per plant (0.594), length of leaf stalk (0.645), leaf area (0.781), number of flowers or spadices per plant per year (0.568), spathe length (0.682), spathe breadth (0.486) and number of true flowers per spadix (0.766).

Number of flowers or spadices per plant per year was found to have significant positive correlation with plant height (0.666), number of leaves per plant (0.737), length of leaf stalk (0.462), leaf area (0.607), internodal length (0.568), spathe length (0.477), spathe breadth (0.592) and number of true flowers per spadix (0.467).

Days from emergence to unfurling of spathe had significant positive correlation with days from emergence to maturity of leaves (0.440).

Spathe length showed significant positive correlation with spathe breadth (0.868), plant height (0.626), number of leaves per plant (0.574), length of leaf stalk (0.724), leaf area (0.495), days from emergence to maturity of leaves (0.384), internodal length (0.682), number of flowers or spadices per plant per year (0.477) and number of true flowers per spadix (0.644).

Spathe breadth showed significant positive correlation with spathe length (0.868), plant height (0.563), number of leaves per plant (0.593), length of leaf stalk (0.606), leaf area (0.469), days from emergence to maturity of leaves (0.392), internodal length (0.486), number of flowers or spadices per plant per year (0.592) and number of true flowers per spadix (0.584).

Number of true flowers per spadix had significant positive correlation with plant height (0.702), number of leaves per plant (0.415), length of leaf stalk (0.414), leaf area (0.636), days from emergence to maturity of leaves (0.563), internodal length (0.766), number of flowers or spadices per plant per year (0.467), spathe length (0.644) and spathe breadth (0.584). It showed significant negative correlation with days to initiation of female phase (-0.483).

Days to initiation of female phase had significant negative correlation with number of true flowers per spadix (-0.483).

Inclination of spadix with spathe and had no significant correlation with other characters.

4.1.6.2 Genotypic Correlation

Plant height was found to have significant positive correlation with number of leaves per plant (0.873), length of leaf stalk (0.752), leaf area (0.960), internodal length (0.961), number of flowers or spadices per plant per year (0.740), spathe length (0.917), spathe breadth (0.776) and number of true flowers per spadix (0.785). However, no significant correlation was observed for plant height with other characters.

Number of leaves per plant showed significant positive correlation with plant height (0.873), length of leaf stalk (0.820), leaf area (0.807), internodal length (0.745), number of flowers or spadices per plant per year (1.009), spathe length (0.767), spathe breadth (0.885) and number of true flowers per spadix (0.575). No significant correlation was observed with other characters.

Length of leaf stalk showed significant positive correlation with plant height (0.752), number of leaves per plant (0.820), leaf area (0.571), internodal length (0.851), number of flowers or spadices per plant per year (0.624), spathe length (0.912), spathe breadth (0.729) and number of true flowers per spadix (0.532). Length of leaf stalk showed significant negative correlation with duration of female phase (0.422). No significant correlation was observed for length of leaf stalk with all other characters under study.

Leaf area was found to have significant positive correlation with plant height (0.960), number of leaves per plant (0.807), length of leaf stalk (0.571), internodal length (0.897), number of flowers or spadices per plant per year (0.694), spathe length (0.717), spathe breadth (0.626), and number of true flowers per spadix (0.741). Leaf area showed significant negative correlation with inclination of spadix with spathe (0.386). No significant correlation was observed for leaf area with all other characters under study.

Table 12. Genotypic correlation coefficients among fourteen characters in anthurium

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
X_1	1													
X_2	0.873**	1												
X_3	0.752**	0.820**	1											
X_4	0.960**	0.807**	0.571**	1										
X_5	0.326	-0.038	0.108	0.285	1									
X_6	0.961**	0.745**	0.851**	0.897**	0.365	1								
X_7	0.740**	1.009**	0.624**	0.694**	0.172	0.576**	1							
X_8	-0.154	-0.103	0.258	-0.206	0.455*	-0.023	-0.133	1						
X_9	0.917**	0.767**	0.912**	0.717**	0.430*	0.926**	0.689**	0.200	1					
X_{10}	0.776**	0.885**	0.729**	0.626**	0.451*	0.692**	0.910**	0.274	0.890**	1				
X_{11}	-0.249	-0.117	0.065	-0.386*	0.122	-0.211	0.200	-0.073	-0.026	0.062	1			
X_{12}	0.785**	0.575**	0.532**	0.741**	0.621**	0.814**	0.503**	0.150	0.927**	0.842**	-0.261	1		
X_{13}	-0.077	0.122	-0.078	0.004	-0.238	-0.244	0.265	-0.142	-0.443*	-0.221	0.397*	-0.632**	1	
X_{14}	-0.052	-0.294	-0.422*	-0.030	0.429*	-0.229	-0.147	0.188	0.066	0.254	-0.297	0.281	-0.310	1

* Significant at 5% ** significant at 1%

X_1	Plant height (cm)	X_6	Internode length (cm)	X_{11}	Inclination of spadix with the spathe (degrees)
X_2	Number of leaves per plant	X_7	Number of flowers or spadices per plant per year	X_{12}	Number of true flowers per spadix
X_3	Length of leaf stalk (cm)	X_8	Days from emergence to unfurling of the spathe	X_{13}	Days to initiation of female phase
X_4	Leaf area (cm^2)	X_9	Spathe length (cm)	X_{14}	Duration of female phase
X_5	Days from emergence to maturity of leaves	X_{10}	Spathe breadth (cm)		

Days from emergence to maturity of leaves showed significant positive correlation with days from emergence to unfurling of spathe (0.455), spathe length (0.430), spathe breadth (0.451), number of true flowers per spadix (0.621) and duration of female phase (0.429).

Internodal length showed significant positive correlation with plant height (0.961), number of leaves per plant (0.745), length of leaf stalk (0.851), leaf area (0.897), number of flowers or spadices per plant per year (0.576), spathe length (0.926), spathe breadth (0.692) and number of true flowers per spadix (0.814).

Number of flowers or spadices per plant per year was found to have significant positive correlation with plant height (0.740), number of leaves per plant (1.009), length of leaf stalk (0.624), leaf area (0.694), internodal length (0.576), spathe length (0.689), spathe breadth (0.910) and number of true flowers per spadix (0.503).

Days from emergence to unfurling of spathe showed significant positive correlation with days from emergence to maturity of leaves (0.455).

Spathe length showed significant positive correlation with spathe breadth (0.890), plant height (0.917), number of leaves per plant (0.767), length of leaf stalk (0.912), leaf area (0.717), days from emergence to maturity of leaves (0.430), internodal length (0.926), number of flowers or spadices per plant per year (0.689) and number of true flowers per spadix (0.927). Spathe length showed significant negative correlation with days to initiation of female phase (-0.443).

Spathe breadth showed significant positive correlation with spathe length (0.890) plant height (0.776), number of leaves per plant (0.885), length of leaf stalk (0.729), leaf area (0.626), days from emergence to maturity of leaves (0.451), internodal length (0.692), number of flowers or spadices per plant per year (0.910) and number of true flowers per spadix (0.842).

Inclination of spadix with spathe had significant positive correlation with days to initiation of female phase (0.397) and significant negative correlation with leaf area (-0.386).

Number of true flowers per spadix showed significant positive correlation with plant height (0.785), number of leaves per plant (0.575), length of leaf stalk (0.532), leaf area (0.741), days from emergence to maturity of leaves (0.621), internodal length (0.814), and number of flowers or spadices per plant per year (0.503), spathe length (0.927) and spathe breadth (0.842). This character had significant negative correlation with days to initiation of female phase (-0.632).

Days to initiation of female phase showed significant positive correlation with inclination of spadix with spathe (0.397) and significant negative correlation with spathe length (-0.443) and number of true flowers per spadix (-0.632).

Duration of female phase had significant positive correlation with days from emergence to maturity of leaves (0.429) and significant negative correlation with length of leaf stalk (-0.422).

4.1.6.3 Environmental Correlation

Plant height was found to have significant negative correlation with number of flowers or spadices per plant per year (-0.356). However, no significant correlation was observed for plant height with other characters.

Number of leaves per plant showed significant positive correlation with inclination of spadix with spathe (0.389). No significant correlation was observed with other characters.

Length of leaf stalk showed significant positive correlation with days from emergence to maturity of leaves (0.462), spathe length (0.453) and spathe breadth (0.435). No significant correlation was observed for length of leaf stalk with all other characters under study.

Days from emergence to maturity of leaves showed significant positive correlation with length of leaf stalk (0.462), days from emergence to unfurling of spathe (0.455), spathe length (0.430), spathe breadth (0.451), number of true flowers per spadix (0.621) and duration of female phase (0.429).

Table 13. Environmental correlation coefficients among fourteen characters in anthurium

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
X_1	1													
X_2	-0.204	1												
X_3	0.014	0.207	1											
X_4	0.285	0.002	0.169	1										
X_5	-0.083	0.207	0.462*	-0.102	1									
X_6	-0.273	0.255	-0.232	-0.246	-0.019	1								
X_7	-0.356*	-0.041	-0.336	-0.325	-0.041	0.501**	1							
X_8	0.116	0.109	0.155	0.155	0.451*	0.113	-0.278	1						
X_9	-0.088	0.338	0.453*	0.020	0.548**	0.223	-0.002	0.017	1					
X_{10}	0.123	0.234	0.435*	0.188	0.504**	0.063	-0.205	0.055	0.844**	1				
X_{11}	-0.068	0.389*	0.098	-0.093	0.237	0.135	-0.356*	0.308	0.182	0.266	1			
X_{12}	-0.236	-0.017	-0.085	-0.312	-0.172	0.354	0.106	-0.396*	0.049	0.041	-0.111	1		
X_{13}	-0.095	-0.088	0.179	-0.062	-0.007	-0.521**	-0.259	-0.375*	0.196	0.150	-0.042	0.027	1	
X_{14}	-0.097	0.050	0.054	-0.170	0.052	-0.041	0.111	-0.057	0.038	0.039	0.054	0.296	0.201	1

* Significant at 5% ** significant at 1%

X_1 Plant height (cm)

X_2 Number of leaves per plant

X_3 Length of leaf stalk (cm)

X_4 Leaf area (cm^2)

X_5 Days from emergence to maturity of leaves

X_6 Internode length (cm)

X_7 Number of flowers or spadices per plant per year

X_8 Days from emergence to unfurling of the spathe

X_9 Spathe length (cm)

X_{10} Spathe breadth (cm)

X_{11} Inclination of spadix with the spathe (degrees)

X_{12} Number of true flowers per spadix

X_{13} Days to initiation of female phase

X_{14} Duration of female phase

Internodal length showed significant positive correlation with number of flowers or spadices per plant per year (0.501) and significant negative correlation with days to initiation of female phase (-0.521).

Number of flowers or spadices per plant per year was found to have significant positive correlation with internodal length (0.501). This character had significant negative correlation with plant height (-0.356) and inclination of spadix with spathe (-0.356).

Days from emergence to unfurling of spathe showed significant positive correlation with days from emergence to maturity of leaves(0.451) and significant negative correlation with number of true flowers per spadix (-0.396) and days to initiation of female phase (-0.375).

Spathe length showed significant positive correlation with spathe breadth (0.844), length of leaf stalk (0.453) and days from emergence to maturity of leaves (0.548).

Spathe breadth showed significant positive correlation with spathe length (0.844), length of leaf stalk (0.453), days from emergence to maturity of leaves (0.504).

Inclination of spadix with spathe had significant positive correlation with number of leaves per plant (0.389) and significant negative correlation with number of flowers / spadices per plant per year (-0.356).

Number of true flowers per spadix showed significant negative correlation with days from emergence to unfurling of spathe (-0.396).

Days to initiation of female phase showed significant negative correlation with internodal length (-0.521) and days from emergence to unfurling of spathe (-0.375).

Environmental correlation for duration of female phase was found to be non significant.

4.2 EXPERIMENT II: A. HYBRIDIZATION AND COMBINING ABILITY STUDIES IN SELECTED CULTIVARS AND EVALUATION OF HYBRID SEEDLINGS

4.2.1 Floral Characters of the Cultivars

The twenty one anthurium cultivars used for the hybridization studies were evaluated for their floral characters and the results are presented in tables 14a and 14b.

4.2.1.1 Number of Flowers or Spadices per Plant per Year

Number of flowers or spadices produced per plant per year ranged from 3.85 to 8.65 (Table 14a). Marijke recorded significantly higher number of spadices (8.65) followed by Salmon Queen (7.95) and Paradise (7.55). Cultivars Agnihotri Red (7.25), Acropolis White (7.25), Tropical Red (7.20), Mozaik Fresh (7.15) and Lima White (7.03) were on par and had significantly lesser number of spadices. The cultivar Honduras was significantly different from the above and recorded a value of 6.45 which was on par with that of Hillary (6.25). Significantly different from these was the cultivar Cynthia (6.10) which was on par with Dragon's Tongue (6.05) and Merengue White (5.95). Significantly lesser spadix numbers were found in Orange Glory (5.55) and Elizabeth (5.45) which was on par with Rosette (5.30). The cultivar Lady Jane Pink recorded a spadix number of 5.25. The cultivars Anastasia (4.65), Liver Red (4.65) and Hawaiian Orange (4.55) were on par and significantly less in number of flowers produced per plant per year. Red Amour recorded significantly low number (3.85) of spadices.

4.2.1.2 Days from Emergence to Unfurling of Spathe

The cultivars showed significant difference among themselves with respect to the trait days taken for emergence to unfurling of spathe (Table 14a). Among the cultivars, Hawaiian Orange (33.00) recorded significantly highest value for number of days taken for emergence to unfurling of spathe. Significantly different was the cultivar Acropolis White (31.67 days) which was on par with

Table 14a. Variability in floral characters of 21 anthurium cultivars

Cultivars	Number of flowers or spadices per plant per year	Days from emergence to unfurling of spathe	Spathe length (cm)	Spathe breadth (cm)	Spathe size (cm^2)	Spadix length (cm)	Spathe/ spadix ratio	Inclination of spadix with the spathe (degrees)	Vase life of flowers (days)
Hillary	6.25	25.33	14.47	9.93	143.77	7.07	20.33	60.00	7.83
Paradise	7.55	24.33	12.63	10.43	131.76	5.07	26.20	58.33	9.00
Marijke	8.65	20.33	19.53	13.67	267.90	7.57	35.59	77.67	8.68
Cynthia	6.10	27.00	18.87	13.90	262.91	6.67	40.78	75.00	6.66
Mozaik Fresh	7.15	26.67	22.23	15.63	349.61	6.50	54.57	78.33	8.50
Elizabeth	5.45	26.00	15.97	11.37	181.77	6.60	27.77	71.67	7.34
Anastasia	4.65	22.33	9.07	7.87	73.17	4.33	16.61	70.00	8.33
Salmon Queen	7.95	23.33	12.37	12.67	157.67	5.50	28.94	76.67	9.33
Red Amour	3.85	24.00	7.47	5.50	43.04	3.57	12.32	70.00	7.67
Tropical red	7.21	28.67	14.87	10.50	156.14	5.30	31.96	41.33	8.34
Acropolis White	7.25	31.67	17.00	12.70	216.25	8.10	26.64	52.67	9.00
Rosette	5.30	30.33	12.73	10.30	131.99	6.50	20.29	41.00	7.83
Liver Red	4.65	28.00	10.53	7.77	81.63	6.73	12.14	59.33	8.38
Lady Jane Pink	5.25	26.00	7.80	4.07	31.67	6.23	5.15	75.00	6.33
Orange Glory	5.55	31.00	10.70	8.07	86.39	5.57	15.61	44.67	8.50
Dragon's Tongue	6.05	25.67	16.17	12.10	195.57	9.10	21.49	71.67	8.50
Hawaiian Orange	4.55	33.00	11.10	7.03	78.02	5.70	13.74	56.33	8.65
Lima White	7.03	20.33	21.43	15.70	333.43	5.97	55.62	61.33	9.67
Agnihotri Red	7.25	26.33	17.73	13.10	233.71	7.70	30.37	66.00	8.67
Merengue White	5.95	30.00	11.10	9.40	104.43	7.00	14.92	50.00	10.00
Honduras	6.45	26.67	15.17	11.33	171.96	7.97	21.64	68.33	20.50
SE	0.09	0.61	1.04	0.56	18.27	0.47	3.47	2.19	0.34
CD (5%)	0.25	1.74	2.99	1.61	52.14	1.33	9.91	6.24	0.96

Orange Glory (31.00 days), Rosette (30.33 days) and Merengue White (30.00 days). The cultivars Tropical Red (28.67), Liver Red (28.00) and Cynthia (27.00) were on par and recorded significantly lesser number of days than the above cultivars. The cultivar Honduras (26.67 days) was on par with Mozaik Fresh (26.67 days), Agnihotri Red (26.33 days), Elizabeth (26.00 days), Lady Jane Pink (26.00 days), Dragon's Tongue (25.67 days) and Hillary (25.33 days). Paradise (24.33 days) was on par with Red Amour (24.00 days) and Salmon Queen (23.33 days). Marijke and Lima White (20.33 days each) followed by Anastasia (22.33 days) exhibited significantly lower number of days for emergence to unfurling of spathe.

4.2.1.3 Spathe Length

Spathe length of the cultivars was found to vary from 7.47 to 22.23 cm (Table 14a). Significantly high spathe length was recorded by the cultivar Mozaik Fresh (22.23 cm) which was on par with Lima White (21.43 cm) and Marijke (19.53 cm). The cultivars Cynthia (18.87 cm), Agnihotri Red (17.73 cm), Acropolis White (17.00 cm), Dragon's Tongue (16.17 cm) and Elizabeth (15.97 cm) were on par and differed significantly from the other cultivars. The cultivar Honduras (15.17 cm) was on par with Tropical Red (14.87 cm), Hillary (14.47 cm), Rosette (12.73 cm), Paradise (12.63 cm) and Salmon Queen (12.37 cm) regarding spathe length. The cultivars Merengue White and Hawaiian Orange recorded a spathe length of 11.10 cm which was on par with Orange Glory (10.70 cm), Liver Red (10.53 cm) and Anastasia (9.07 cm). Lowest spathe length was recorded by Red Amour (7.47 cm) which was on par with Lady Jane Pink (7.80 cm) and differed significantly from the other cultivars.

4.2.1.4 Spathe Breadth

Spathe breadth of the cultivars varied from 4.07 to 15.70 cm (Table 14a). Among the cultivars, significantly high spathe breadth was recorded by the cultivar Lima White (15.70 cm) which was on par with Mozaik Fresh (15.63 cm). The cultivar Cynthia (13.90 cm) was on par with Marijke (13.67 cm), Agnihotri

Red (13.10 cm), Acropolis White (12.70 cm) and Salmon Queen (12.67 cm) with respect to spathe breadth and differed significantly from the other cultivars. Dragon's Tongue (12.10 cm), Elizabeth (11.37 cm), Honduras (11.33 cm) and Tropical Red (10.50 cm) were on par. The cultivar Paradise (10.43 cm) was on par with Rosette (10.30 cm), Hillary (9.93 cm) and Merengue White (9.40 cm). The cultivars Orange Glory (8.07 cm), Anastasia (7.87 cm), Liver Red (7.77 cm), Hawaiian Orange (7.03 cm) and Red Amour (5.50 cm) were on par regarding spathe breadth. The cultivar Lady Jane Pink recorded significantly low spathe breadth (4.07 cm).

4.2.1.5 Spathe Size

Spathe size of the cultivars was observed to vary from 48.30 to 349.61 cm^2 (Table 14a). The maximum spathe size was observed for Mozaik Fresh (349.61 cm^2) which was on par with Lima White (333.43 cm^2). Marijke (267.90 cm^2), Cynthia (262.91 cm^2), Agnihotri Red (233.71 cm^2) and Acropolis White (216.25 cm^2) and differed significantly from the other cultivars. The cultivar Dragon's Tongue (195.57 cm^2) was on par with Elizabeth (181.77 cm^2), Honduras (171.96 cm^2), Salmon Queen (157.67 cm^2), Tropical Red (156.14 cm^2) and Hillary (143.77 cm^2). The cultivars Rosette (131.99 cm^2), Paradise (131.76 cm^2), Merengue White (104.43 cm^2), Orange Glory (86.39 cm^2) and Liver Red (81.63 cm^2) were on par and had significantly lesser spathe size than the above cultivars. The cultivar Lady Jane Pink (31.67 cm^2) recorded significantly lesser spathe size than all the above cultivars except Red Amour (48.30 cm^2), Anastasia (73.17 cm^2) and Hawaiian Orange (78.02 cm^2) which were on par.

4.2.1.6 Spadix Length

The cultivars exhibited significant variations in spadix length (Table 14a). Maximum spadix length was exhibited by the cultivar Dragon's Tongue (9.10 cm) which was on par with Acropolis White (8.10 cm) and Honduras (7.97 cm). Significantly less in spadix length than the above were, Agnihotri Red (7.70 cm), Marijke (7.57 cm), Hillary (7.07 cm), Merengue White (7.00 cm), Liver Red

(6.73 cm), Cynthia (6.67 cm), Elizabeth (6.60 cm), Mozaik Fresh (6.50 cm) and Rosette (6.50 cm) which were on par. The cultivars Lady Jane Pink (6.23 cm), Lima White (5.97 cm), Hawaiian Orange (5.70 cm), Orange Glory (5.57 cm), Salmon Queen (5.50 cm), Tropical Red (5.30 cm) and Paradise (5.07 cm) differed significantly from the other cultivars and were on par regarding spadix length. Red Amour (3.57 cm) recorded the minimum value with significantly lesser spadix length than all the above cultivars and was on par with Anastasia (4.33 cm).

4.2.1.7 Spathe / spadix ratio

Spathe /spadix ratio of the cultivars showed variations from 5.15 to 55.62 (Table 14a). The ratio was significantly high for the cultivar Lima White (55.62) which was on par with Mozaik Fresh (54.57). The cultivar Cynthia (40.78) was on par with Marijke (40.78) and Tropical Red (31.96). Agnihotri Red (30.37), Salmon Queen (28.94), Elizabeth (27.77), Acropolis White (26.64), Paradise (26.20), Honduras (21.64) and Dragon's Tongue (21.49) differed significantly from other cultivars and were on par for spathe-spadix ratio. Lady Jane Pink (5.15) recorded significantly lesser ratio than all other cultivars except Liver red (12.14), Red Amour (12.32), Hawaiian Orange (13.74), Merengue White (14.92), Orange Glory (15.61), Anastasia (16.61), Rosette (20.29) and Hillary (20.33) which was on par.

4.2.1.8 Inclination of Spadix with the Spathe

Inclination of spadix and spathe among the cultivars varied from 41.00 to 78.33° (Table 14a). The inclination was highest for the cultivar Mozaik Fresh (78.33°) which was on par with Marijke (77.67°), Salmon Queen (76.67°), Cynthia (75.00°) and Lady Jane Pink (75.00°). Significantly lesser inclination than the above cultivars was recorded by the cultivar Elizabeth (71.67°) was on par with Dragon's Tongue (71.67°), Anastasia (70.00°), Red Amour (70.00°), Honduras (68.33°) and Agnihotri Red (66.00°). The cultivars Lima White (61.33°), Hillary (60.00°), Paradise (58.33°), Liver Red (59.33°) and Hawaiian

Orange(56.33°) were on par regarding inclination of spadix and spathe. The cultivar Acropolis White (52.67°) was on par with Merengue White (50.00°). The angle between the spadix and the spathe was significantly lowest for the cultivar Rosette (41.00°) which was on par with Tropical Red (41.33°) and Orange Glory (44.67°).

4.2.1.9 Vase Life of Flowers

The cultivars exhibited significant variations in vase life with values ranged from 6.33 to 20.50 days (Table 14a). The cultivar Honduras had significantly greater vase life (20.50 days) than all the other cultivars. Merengue White (10.00 days) was on par with Lima White (9.67 days) for vase life. The cultivar Salmon Queen (9.33 days) was on par with Marijke and Acropolis White (9.00 days), Paradise (8.68 days), Agnihotri Red (8.67 days), Hawaiian Orange (8.65 days), Mozaik Fresh (8.50 days), Orange Glory (8.50 days), Dragon's Tongue (8.50 days) and Liver Red (8.38 days). The cultivars Tropical Red (8.34 days), Anastasia (8.33 days), Hillary (7.83 days), Rosette (7.83 days) and Red Amour (7.67 days) were on par regarding the vase life. The cultivar Lady Jane Pink had significantly lowest vase life (6.33 days) which was on par with Cynthia (6.67 days) and Elizabeth (7.34 days).

4.2.1.10 Number of True Flowers per Spadix

Number of true flowers per spadix ranged from 174.33 to 502.67 (Table 14b). The maximum number of true flowers per spadix was observed for the cultivar Honduras (502.67) which was on par with Mozaik Fresh (464.00), Lady Jane Pink (459.67) and Liver Red (454.00). The cultivars Hillary (415.00), Hawaiian Orange (414.33), Acropolis White (413.67), Merengue White (394.33), Marijke (396.00), Lima White (389.00), Rosette (368.00) and Dragon's Tongue (360.67) were on par and exhibited significantly lesser number of true flowers than the above cultivars. Cynthia (360.00) was on par with Paradise (319.67). The cultivar Orange Glory (285.00) was on par with Tropical Red (274.33), Anastasia (269.33), Agnihotri Red (265.67), Elizabeth (256.67) and Salmon

Table 14b. Variability in floral characters of 21 anthurium cultivars

Cultivars	Number of true flowers per spadix	Days to initiation of female phase	Duration of female phase (days)	Days of interphase	Duration of male phase (days)	Total anthocyanin content(mg g^{-1})
Hillary	415.00	4.67	13.33	6.00	8.69	2.72
Paradise	319.67	6.65	12.24	4.67	4.67	16.29
Marijke	396.00	6.33	8.67	4.33	6.33	5.77
Cynthia	360.00	6.67	13.31	12.00	7.68	3.05
Mozaik Fresh	464.00	4.86	12.33	7.34	5.38	3.73
Elizabeth	256.67	6.67	7.32	5.67	7.32	5.09
Anastasia	269.33	5.62	12.68	*	*	6.79
Salmon Queen	234.67	7.64	11.68	6.68	7.30	7.47
Red Amour	174.33	6.31	11.00	*	*	20.37
Tropical red	274.33	6.33	9.33	5.64	9.33	57.03
Acropolis White	413.67	5.67	11.36	6.34	8.21	2.04
Rosette	368.00	3.64	13.33	*	*	27.83
Liver Red	454.00	5.68	8.67	7.00	6.00	276.31
Lady Jane Pink	459.67	3.67	6.32	6.32	6.67	25.80
Orange Glory	285.00	7.67	8.64	4.33	7.33	13.24
Dragon's Tongue	360.67	5.33	11.65	8.00	8.00	209.78
Hawaiian Orange	414.33	7.33	10.67	*	*	15.61
Lima White	389.00	5.67	11.33	12.69	8.69	1.70
Agnihotri Red	265.67	6.00	11.00	6.00	10.65	37.34
Merengue White	394.33	5.33	11.36	4.38	7.36	2.72
Honduras	502.67	5.64	13.00	4.67	7.38	144.26
SE	18.37	0.44	0.45	0.54	0.40	2.30
CD(5%)	52.42	1.26	1.30	1.56	1.14	6.55

* No pollen emergence noticed

Queen (234.67). Significantly lower number of true flowers per spadix than all the other cultivars was exhibited by the cultivar Red Amour (174.33).

4.2.1.11 Days to Initiation of Female Phase

The mean number of days to initiation of female phase ranged from 3.64 to 7.67 (Table 14b). The significantly highest mean value for this trait was recorded for the cultivar Orange Glory (7.67 days) which was on par with the cultivars Salmon Queen (7.64 days), Hawaiian Orange (7.33 days), Paradise (6.67 days), Elizabeth (6.67 days) and Cynthia (6.65 days). The cultivars Marijke(6.33 days), Tropical Red(6.33 days), Red Amour(6.31 days), Agnihotri Red (6.00 days), Liver Red (5.68 days), Acropolis White(5.67 days), Lima White (5.67 days), Honduras(5.64 days), Anastasia (5.62 days),Merengue White (5.33 days) and Dragon's Tongue (5.33 days) were on par with respect to the number of days to initiate female phase and differed significantly from the other cultivars. The cultivar Rosette recorded the significantly lowest mean value (3.64 days) for this character which was on par with and Mozaik Fresh (4.86 days), Hillary (4.67 days) and Lady Jane Pink (3.67 days).

4.2.1.12 Duration of Female Phase

Duration of female phase ranged from 6.32 to 13.33 days (Table 14b). The highest mean duration of female phase was obtained for the cultivar Rosette and Hillary (13.33 days) which was on par with Cynthia (13.31 days), Honduras (13.00 days), Anastasia (12.68 days), Mozaik Fresh (12.33 days) and Paradise (12.24 days) which differed significantly from the other cultivars. The cultivars Salmon Queen (11.68 days), Dragon's Tongue (11.65 days), Merengue White (11.36 days), Acropolis White (11.36 days), Lima White (11.33 days), Red Amour (11.00 days), Agnihotri Red (11.00 days) and Hawaiian Orange (10.67 days) were on par. Tropical Red (9.33 days) was on par with Marijke (8.67 days), Liver Red (8.67 days) and Orange Glory (8.64 days). Lady Jane Pink recorded significantly low duration for female phase (6.32 days) which was on par with Elizabeth (7.33 days).

4.2.1.13 Days of Interphase

Duration of interphase varied from 4.33 to 12.69 days (Table 14b). The highest mean number of days for the duration of interphase was shown by Lima White (12.69 days) which was on par with Cynthia (12.00 days). Significantly differed from the above, the cultivars Dragon's Tongue (8.00 days), Liver Red (7.00 days), Salmon Queen (6.68 days) and Mozaik Fresh (5.38 days) were on par regarding duration of interphase. Elizabeth (5.67 days), Tropical Red (5.64 days), Acropolis White (6.34 days), Lady Jane Pink (6.32 days), Agnihotri Red (6.00 days) and Hillary (6.00 days) were on par with respect to days of interphase. The lowest mean number of days for the duration of interphase was shown by Marijke (4.33 days) which was on par with Paradise (4.67 days), Honduras (4.67 days), Orange Glory (4.38 days), and Merengue White (4.38 days) and differed significantly from the other cultivars.

4.2.1.14 Duration of Male Phase

The duration of male phase ranged from 4.67 to 10.65 days (Table 14b). Significantly highest mean duration of male phase was obtained for Agnihotri Red (10.65 days). Tropical Red (9.33 days), Lima White (8.69 days), Hillary (8.69 days) and Acropolis White (8.21 days) were on par with effect to duration of male phase and differed significantly from the others. The cultivar Dragon's Tongue (8.00 days) was on par with Cynthia (7.68 days), Honduras (7.38 days), Merengue White (7.36 days), Orange Glory (7.33 days), Elizabeth (7.32 days) and Salmon Queen (7.30 days). Marijke recorded a value of 6.33 days which was on par with Lady Jane Pink (6.67 days), Liver Red (6.00 days) and Mozaik Fresh (5.38 days). The cultivar Paradise recorded significantly lowest mean duration of male phase (4.67 days).

No pollen emergence was noticed for the cultivars Anastasia, Red Amour, Rosette and Hawaiian Orange during the observation period and hence duration of male phase could not be recorded.

4.2.1.15 Total Anthocyanin Content

The cultivars varied significantly with respect to the anthocyanin content of the spathe (Table 14b). The total anthocyanin content ranged from 1.70 mg g^{-1} to 276.31 mg g^{-1}. Highest value was recorded for the cultivar Liver Red (276.31 mg g^{-1}) followed by Dragon's Tongue (209.78 mg g^{-1}), Honduras (144.26 mg g^{-1}), Tropical Red (57.03 mg g^{-1}) and Agnihotri Red (37.34 mg g^{-1}). The cultivar Rosette (27.83 mg g^{-1}) was on par with Lady Jane Pink (25.80 mg g^{-1}). Red Amour (20.37 mg g^{-1}), Paradise (16.29 mg g^{-1}) and Hawaiian Orange (15.61 mg g^{-1}) were on par with respect to total anthocyanin content. The cultivar Orange Glory (13.24 mg g^{-1}) was on par with Anastasia (6.79 mg g^{-1}) and Salmon Queen (6.79 mg g^{-1}). Lowest content was recorded for Lima White (1.70 mg g^{-1}) which was on par with Acropolis White (2.04 mg g^{-1}), Hillary and Merengue White (2.72 mg g^{-1}), Cynthia (3.05 mg g^{-1}) and Mozaik Fresh (3.73 mg g^{-1}), Elizabeth (5.09 mg g^{-1}) and Marijke (5.77 mg g^{-1}).

4.2.1.16 Pollen Fertility

Data pertaining to the pollen fertility are presented in Table 15.

Marijke had the highest pollen fertility of 59 per cent which was on par with Agnihotri Red (58.59 %), Dragon's Tongue (54.11 %) and Merengue White (52.82 %). Mozaik Fresh (32.52 %) was on par with Orange Glory (44.14 %), Liver Red (38.33 %), Lima White (38.24 %) and Lady Jane Pink (34.76 %). The cultivar Paradise (31.20 %) was on par with Honduras (26.80 %), Acropolis White (26.14 %), Tropical Red (21.24 %), Salmon Queen (22.21 %) and Cynthia (19.64 %) with respect to pollen fertility. The lowest pollen fertility was recorded for Hillary (15.91 %) which was on par with Elizabeth (16.18 %).

4.2.1.17 Pollen Size and Shape

Data pertaining to the pollen size and shape are presented in Table 15.

The mean size of the pollen ranged from 12.06 μ to 26.20 μ with Hillary recorded the highest value which was on par with Cynthia (25.86 μ). Acropolis

Table 15. Pollen characters of anthurium cultivars

Sl. No.	Cultivars	Pollen fertility (%)	Pollen diameter (μ)	Pollen shape
1.	Hillary	15.91	26.20	Round
2.	Paradise	31.20	12.06	Round
3.	Marijke	59.00	15.58	Oval
4.	Cynthia	19.64	25.86	Round
5.	Mozaik Fresh	32.52	17.82	Round
6.	Elizabeth	16.18	12.14	Round
7.	Anastasia	*	*	*
8.	Salmon Queen	22.21	13.30	Round
9.	Red Amour	*	*	*
10.	Tropical Red	21.24	15.08	Round
11.	Acropolis White	26.14	20.04	Round
12.	Rosette	*	*	*
13.	Liver Red	38.33	12.86	Oval
14.	Lady Jane Pink	34.76	13.38	Oval
15.	Orange Glory	44.14	13.44	Round
16.	Dragon's Tongue	54.11	16.18	Oval
17.	Hawaiian Orange	*	*	*
18.	Lima White	38.24	19.36	Round
19.	Agnihotri Red	58.59	17.08	Round
20.	Merengue White	52.82	16.60	Round
21.	Honduras	26.80	16.84	Round
	SE	4.50	0.60	
	CD (5%)	11.90	1.69	

* No pollen emergence noticed

White (20.04 μ) was on par with Lima White (19.36 μ) whereas the cultivar Mozaik Fresh (17.82 μ) was on par with Agnihotri Red (17.08 μ), Dragon's Tongue (16.18 μ), Merengue White (16.60 μ) and Honduras (16.84 μ). Marijke (15.58 μ) was on par with Tropical Red (15.08 μ). The lowest pollen size was observed in Paradise (12.06 μ) which was on par with Elizabeth (12.14 μ), Liver Red (12.86 μ), Salmon Queen (13.30 μ), Lady Jane Pink (13.38 μ) and Orange Glory (13.44 μ).

Pollen shape ranged from round to oval and majority of the cultivars had round pollen. The cultivars Hillary, Paradise, Cynthia, Mozaik Fresh, Elizabeth, Salmon Queen, Tropical Red, Acropolis White, Orange Glory, Lima. White, Merengue White and Honduras had round pollen and Marijke, Liver Red, Lady Jane Pink and Dragon's Tongue had oval pollens (Plate 15).

4.2.1.18 Pollen Availability

Pollen emergence pattern of the cultivars from March 2011 to February 2013 is presented in Table 16.

Pollen emergence was observed in the months of July to march in 2011-12 and August to February in 2012-13. Maximum production of pollen was observed in the period of October to December. The cultivars Paradise, Marijke, Mozaik Fresh, Liver Red, Lady Jane Pink, Orange Glory, Dragon's Tongue, Lima White, Agnihotri Red and Merengue White had pollen emergence in more than half of the observation plants during the period. In the cultivars Hillary, Cynthia, Elizabeth, Salmon Queen, Tropical Red, Acropolis White and Honduras Red, the pollen emergence was low in both the years. The cultivars Anastasia, Red Amour, Rosette and Hawaiian Orange did not produce pollen during the observation period.

Table 16. Pollen emergence pattern of anthurium cultivars from March 2011 to February 2013

Period	Cultivars																				
	H	P	M	C	MF	E	A	SQ	RA	TR	AW	R	LR	LJ	OG	DT	HO	LW	AR	MW	HD
2011																					
March																					
April																					
May																					
June																					
July			++										+	+	+	+		+	+	++	
August			++							+				++	++	++			++	++	
September		+	++		+					+	+		+	++	++	++		+	++	++	+
October		++	++		+								++	++	++	++		+	++	++	+
November		++	++		++								++	++	++	++		++	++	++	
December	++	++	++		++	+		+			+		++	++	++	++		++	++	++	
2012																					
January		+	++										+	++	+	++		+	++	++	
February		+	+										+	+	+	+		+	++	+	
March																					
April																					
May																					
June																					
July																			+		
August		+	+										+	++	+	++		+	++	+	
September		+	+		+					+			++	++	+	++		++	++	++	
October		++	++	+	+	+				+	+		++	++	++	++		++	++	++	+
November	+	++	++	+	++			+		+			++	++	++	++		++	++	++	
December	+	+	++		+			+			+		++	++	++	++		++	++	++	+
2013																					
January		+	+										++	+	+	++		+	+	+	
February			+										+	+		++		+		+	

+ Less than 50 per cent of the plants/ ++ more than 50 per cent of the plants

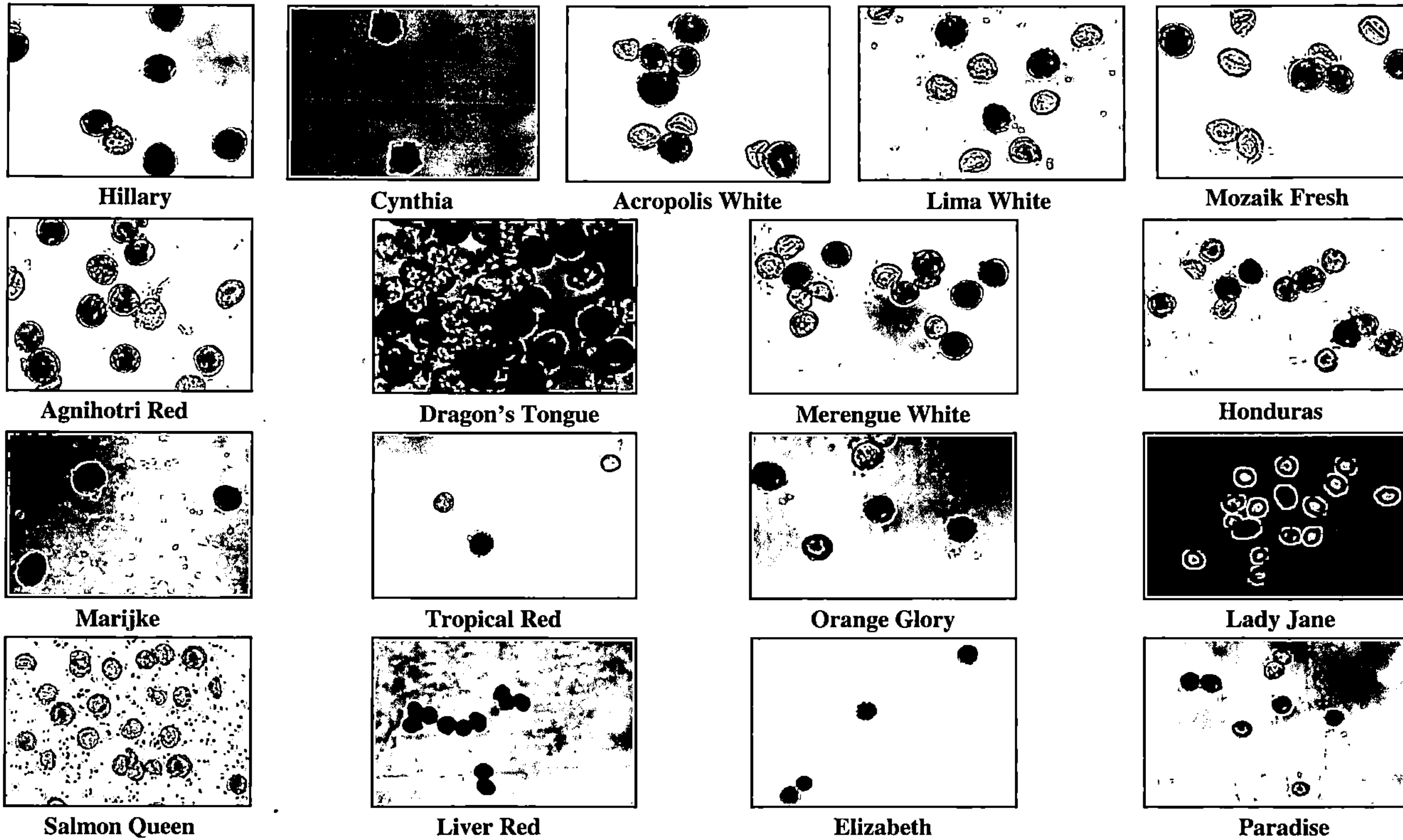


Plate 15. Pollen grains of the cultivars (40 x magnification)

4.2.1.19 Spathe Colour

Data pertaining to the spathe colour is presented in Table 17.

All the twenty one cultivars had varied spathe colour. The cultivar Hillary had greenish white spathe with pink veins. The spathe of Paradise was light green with reddish brown tip and veins. Marijke had diffused greenish pink spathe with pink veins. Cynthia had creamy green spathe with pink tip. Elizabeth showed white spathe with pink blush and reddish pink veins. The spathe colour of Mozaik Fresh was off white with green lobes and edges with pink veins. Anastasia had whitish pink spathe deepening to blush pink. Spathe colour was salmon pink with green lobes in Salmon Queen. Red Amour had orange blended red with green lobes. The cultivar Tropical Red had bright red and Acropolis White had white spathe colour. Rosette had bright pinkish orange spathe. The cultivar Liver Red had dark maroon red and Lady Jane Pink had Pink colour. Orange Glory had light orange and Dragon's Tongue had dark blood red colour. Hawaiian Orange had bright orange spathe. Lima White had white lobes occasionally turning green and Agnihotri Red had light bright red spathe. Merengue White had white and Honduras had dark dull red spathe.

4.2.1.20 Spathe Texture

Data pertaining to the spathe texture is presented in Table 17.

Spathe texture showed wide variation among the cultivars studied like thick to thin, glossy to non glossy and blistered to smooth. Hillary had thin spathe which was shallow blistered and non glossy. Spathe of Paradise was thin, shallow blistered and medium glossy. Marijke had thin spathe which was blistered and glossy. Spathe was thin, smooth and non glossy in Cynthia. Mozaik Fresh had thin spathe which was smooth and medium glossy. The spathe of Elizabeth was thin, medium blistered and glossy. Anastasia had thin, smooth and glossy spathe. Spathe was thin, blistered and glossy in Salmon Queen. Red Amour had thin, shallow blistered and glossy spathe.

Table 17. Variation in spathe colour and texture of anthurium cultivars

Cultivars	Spathe colour	Spathe texture
Hillary	Greenish white with pink veins	Thin, shallow blistered, non glossy
Paradise	Light green with reddish brown tip and veins	Thin, shallow blistered, medium glossy
Marijke	Diffused greenish pink spathe with pink veins	Thin, blistered, glossy
Cynthia	Creamy green spathe with pink tip	Thin, smooth, non glossy
Mozaik Fresh	Off white with lobes and edges green, pink veins	Thin, smooth, medium glossy
Elizabeth	White with pink blush and reddish pink veins	Thin, medium blistered, glossy
Anastasia	Whitish pink deepening to blush pink	Thin, smooth, glossy
Salmon Queen	Salmon pink with green lobes	Thin, blistered, glossy
Red Amour	Orange blended red with green lobes	Thin, shallow blistered, glossy
Tropical Red	Bright red	Thick, blistered, glossy
Acropolis White	White	Thick, shallow blistered, glossy
Rosette	Bright pinkish orange	Thin, blistered, glossy
Liver Red	Dark maroon red	Thick ,shallow blistered, glossy
Lady Jane Pink	Pink	Thin, smooth, glossy
Orange Glory	Light orange	Thick, slightly blistered, non glossy
Dragon's Tongue	Dark blood red	Thin, smooth, glossy
Hawaiian Orange	Bright orange	Thick, blistered, glossy
Lima White	White lobes occasionally turning green	Thick, shallow blistered, non glossy
Agnihotri Red	Light bright red	Thick medium blistered glossy
Merengue White	White	Medium thick, blistered, glossy
Honduras	Dark dull red	Thick, medium blistered, non glossy

Tropical Red had thick, blistered and glossy spathe and Acropolis White had thick, shallow blistered, glossy spathe. The cultivar Rosette produced thin, blistered, glossy and Liver Red with thick, shallow blistered, glossy spathe. In Lady Jane Pink the spathe was thin, smooth and glossy. Orange Glory had thick, slightly blistered, non glossy and Dragon's Tongue had thin, smooth, glossy spathe. The cultivar Hawaiian Orange produced thick, blistered and glossy spathe. Lima White had thick, shallow blistered, non glossy spathe. Agnihotri Red produced thick medium blistered and glossy spathe. Merengue White had medium thick, blistered and glossy spathe. Spathe of the cultivar Honduras was thick, medium blistered and non glossy.

4.2.1.21 Spadix Colour at Unfurling and Colour Change with Ageing

Data pertaining to spadix colour is presented in Table 18.

The spadix colour of all the cultivars showed variation at spathe unfurling and maturity. Spadix colour changed from bottom of the spadix to top of the spadix with the progress of female phase.

Spadix colour varied from unfurling to ageing. In Hillary, spadix colour was green at unfurling which changed to pinkish white at ageing. Paradise had greenish yellow spadix at unfurling which changed to white and yellow at ageing. Spadix colour was orange yellow at unfurling in Marijke which turned to light pinkish green at ageing. In Cynthia, spadix was cream coloured at unfurling which turned to light pink on ageing. Mozaik Fresh had yellowish pink spadix which turned to pink on ageing. Elizabeth had orange red spadix which turned to pink on ageing. In Anastasia, the spadix was yellow in colour which changed to pink on ageing. Salmon Queen had yellow spadix which changed to white on ageing. Spadix colour was yellow in Red Amour at unfurling which changed to yellow and white at ageing. The yellow spadix of Tropical Red, Acropolis White, Rosette, Lady Jane Pink, Orange Glory, Hawaiian Orange, Agnihotri Red and Honduras changed to yellow and white on maturity. In Liver Red, the dark pink

Table 18. Variation in spadix colour and type in anthurium cultivars

Cultivars	Spadix colour		Type of spadix
	At unfurling	At maturity	
Hillary	Green	Pinkish white	Long, thick, straight
Paradise	Greenish yellow	White and yellow	Medium, thick, straight
Marijke	Orange yellow	Light pinkish green	Long, thick, straight
Cynthia	Cream	Light pink	Long, thick, slightly curved
Mozaik Fresh	Yellowish pink	Pink	Long, thick, straight
Elizabeth	Orange red	Pink	Long, medium thick, curved
Anastasia	Yellow	Pink	Short, thick, straight
Salmon Queen	Yellow	White	Medium, thick, straight
Red Amour	Yellow	Yellow and white	Short, medium thick, straight
Tropical Red	Yellow	Yellow and white	Long, thick, straight
Acropolis White	Yellow	Yellow and white	Long, thick, straight
Rosette	Yellow	Yellow and white	Long, thick, straight
Liver Red	Dark pink	Light pink	Long, thick, straight
Lady Jane Pink	Yellow	Yellow and white	Long, thick, straight
Orange Glory	Yellow	Yellow and white	Short, thick, slightly curved
Dragon's Tongue	Light yellow	Pink and yellowish	Long, thick, straight
Hawaiian Orange	Yellow	Yellow and white	Long, medium thick, curved
Lima White	Yellowish pink	Yellow and white	Long, thick, straight
Agnihotri Red	Yellow	Yellow and white	Medium, thin, curved
Merengue White	Yellow	Pink	Long, thick, straight
Honduras	Yellow	Yellow and white	Long, thick, straight

spadix changed to light pink. The light yellow spadix of Dragon's Tongue changed to yellow and pinkish in colour. The yellowish pink spadix in Lima White changed to yellow and white. The cultivar Merengue White had yellow spadix which changed to pink on maturity.

4.2.1.22 Type of Spadix

Data pertaining to type of spadix is presented in Table 18. Type of spadix showed variations like short to long, thin to thick and curved to straight.

4.2.1.23 Colour of Petiole and Young Leaf

Data pertaining to colour of petiole and young leaf is presented in Table 19. Colour of petiole was green in most of the cultivars. Some cultivars like Paradise, Marijke, Mozaik Fresh, Elizabeth, Tropical Red and Rosette had brownish green petiole. The cultivar Liver red had reddish brown petiole.

Most of the cultivars had green colour young leaf. Colour of young leaf was brownish green in Paradise, Mozaik Fresh, Tropical Red, Orange Glory and Rosette while it was reddish brown in Marijke, Liver Red and Dragon's Tongue. Agnihotri Red had greenish brown young leaf.

4.2.2 Hybridization Studies

For selection of parental cultivars, a preliminary evaluation of compatibility was carried out by hybridization of twenty one cultivars in all possible combinations. Of the 441 possible combinations, 213 combinations were found to be practically possible depending upon the simultaneous availability of receptive spadices and fresh pollen. The data is given in table 20. From the twenty one cultivars, eight cultivars namely Paradise (P), Marijke (M), Mozaik Fresh (MF), Lady Jane Pink (LJ), Orange Glory (OG), Dragon's Tongue (DT), Lima White (LW) and Agnihotri Red (AR) were selected as parents for further hybridizations including reciprocal crossings. The results obtained for hybridizing these parents in all the possible combinations are presented below.

Table 19. Variation in colour of petiole and young leaf in anthurium cultivars

Cultivars	Colour of petiole	Colour of young leaf
Hillary	Green	Green
Paradise	Brownish green	Brownish green
Marijke	Brownish green	Reddish brown
Cynthia	Green	Green
Mozaik Fresh	Brownish green	Brownish green
Elizabeth	Brownish green	Green
Anastasia	Green	Green
Salmon Queen	Green	Green
Red Amour	Green	Green
Tropical Red	Brownish green	Brownish green
Acropolis White	Green	Green
Rosette	Brownish green	Brownish green
Liver Red	Reddish brown	Reddish brown
Lady Jane Pink	Green	Green
Orange Glory	Green	Brownish green
Dragon's Tongue	Green	Reddish brown
Hawaiian Orange	Green	Green
Lima White	Green	Green
Agnihotri Red	Green	Greenish brown
Merengue White	Green	Green
Honduras	Green	Green

Table 20. The matrix of the number of pollinations done in 21 anthurium cultivars in all possible combinations

♀ \ ♂	H	P	M	C	MF	E	A	SQ	RA	TR	AW	R	LR	LJ	OG	DT	HO	LW	AR	MW	HD
H	-	2	5	-	1	-	-	-	-	-	-	-	3	3	1	2	-	1	1	2	-
P	-	1	3	-	2	-	-	1	-	2	-	-	2	2	1	4	-	1	1	4	-
M	1	2	1	1	1	1	-	2	-	-	1	-	2	3	-	2	-	1	1	2	-
C	-	-	1	-	-	-	-	-	-	-	-	-	1	2	-	1	-	1	1	2	1
MF	1	1	3	1	1	-	-	1	-	1	1	-	1	2	2	3	-	1	2	3	1
E	-	1	2	-	1	-	-	-	-	1	-	-	1	1	-	2	-	1	2	2	-
A	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	4	-	-
SQ	-	2	2	-	1	-	-	-	-	-	-	-	2	2	2	3	-	-	1	2	-
RA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TR	-	6	2	-	1	-	-	-	-	-	-	-	1	3	1	4	-	-	3	3	-
AW	1	1	7	-	2	-	-	-	-	-	-	-	2	3	1	6	-	2	1	4	-
R	-	1	1	-	-	-	-	-	-	-	-	-	1	1	-	2	-	1	2	2	-
LR	-	2	2	-	1	-	-	-	-	-	1	-	1	2	1	1	-	2	1	2	-
LJ	-	2	2	-	1	-	-	-	-	-	-	-	1	1	1	3	-	1	2	5	-
OG	-	1	2	1	1	1	-	1	-	-	-	-	2	2	1	2	-	1	1	4	1
DT	-	1	2	-	2	1	-	1	-	-	-	-	2	1	1	1	-	2	3	3	-
HO	-	1	1	-	1	-	-	-	-	-	-	-	1	4	1	1	-	1	2	2	-
LW	-	1	1	-	1	-	-	-	-	-	-	-	1	2	1	2	-	1	2	1	-
AR	1	1	2	1	1	-	-	-	-	-	1	-	1	1	2	1	-	1	1	2	1
MW	-	1	2	-	1	-	-	-	-	-	1	-	1	2	2	1	-	1	3	1	-
HD	-	1	1	-	1	-	-	-	-	-	1	-	1	3	1	5	-	1	2	3	-

- : Cross combination not attempted. Total possible crosses: 441 Number of crosses attempted: 213

4.2.2.1 Percentage of Spadices Bearing Fruits

The matrix showing percentage of spadices bearing fruits for the successful crosses are given in Table. 21.

Paradise (P)

All the possible combinations involving this cultivar could be attempted and were successful (Plate 16). Percentage of spadix bearing fruits was highest for the crosses P x P, P x M, P x MF, P x LJ, P x DT and P x LW (100 %) and lowest for the crosses P x OG and P x AR (50 %).

Marijke (M)

All the possible combinations involving this cultivar could be attempted and were successful (Plate 17). The crosses M x MF, M x OG and M x AR showed 100 per cent success in percentage of spadix bearing fruits while M x LJ and M x DT recorded 80 per cent success. The cross M x P showed 66.66 per cent and M x M and M x LW showed 50 per cent success.

Mozaik Fresh (MF)

All the possible combinations involving this cultivar could be attempted and were successful (Plate 18). The crosses MF x M, MF x LJ and MF x LW had higher success percentage (100 %) while the crosses MF x DT recorded 80 per cent, MF x P recorded 75 per cent, MF x MF and MF x OG recorded 50 per cent and MF x AR recorded only 33.33 per cent of spadices bearing fruits.

Lady Jane Pink (LJ)

All the possible combinations involving this cultivar could be attempted and were successful (Plate 19). Percentage of spadix bearing fruits was highest for the crosses LJ x M, LJ x LJ, LJ x LW and LJ x OG (100 %) while the crosses LJ x DT recorded 75 per cent, LJ x AR recorded 66.66 per cent, LJ x P and LJ x MF recorded 50 per cent success.

Table 21. Matrix showing the percentage of spadices bearing fruits in each combination among the selected eight parents

♀ \ ♂	P	M	MF	LJ	OG	DT	LW	AR
P	100	100	100	100	50	100	100	50
M	66.66	50	100	80	100	80	50	100
MF	75	100	50	100	50	80	100	33.33
LJ	50	100	50	100	100	75	100	66.66
OG	50	100	100	100	100	50	100	66.66
DT	100	50	50	50	100	50	100	100
LW	100	100	50	100	50	100	50	66.66
AR	100	75	50	50	100	100	100	100

Table 22. Matrix showing the average number of fruits per spadix in each combination among the selected eight parents

♀ \ ♂	P	M	MF	LJ	OG	DT	LW	AR
P	31	52	92	112	22	36	43	28
M	121	54	137	132	96	128	94	32
MF	89	67	82	54	78	23	98	92
LJ	32	19	12	18	14	16	36	13
OG	38	16	13	64	16	42	31	72
DT	16	52	19	39	31	34	46	36
LW	28	34	38	62	6	37	8	41
AR	21	22	14	31	28	10	16	28


P x AR


P x DT


P x LJ


P x LW


P x M


P x MF


P x OG


P x P

Plate 16. Spadix bearing berries in different combinations with Paradise as female parent

M x AR

M x DT

M x LJ

M x LW

M x M

M x MF

M x OG

M x P

Plate 17. Spadix bearing berries in different combinations with Marijke as female parent

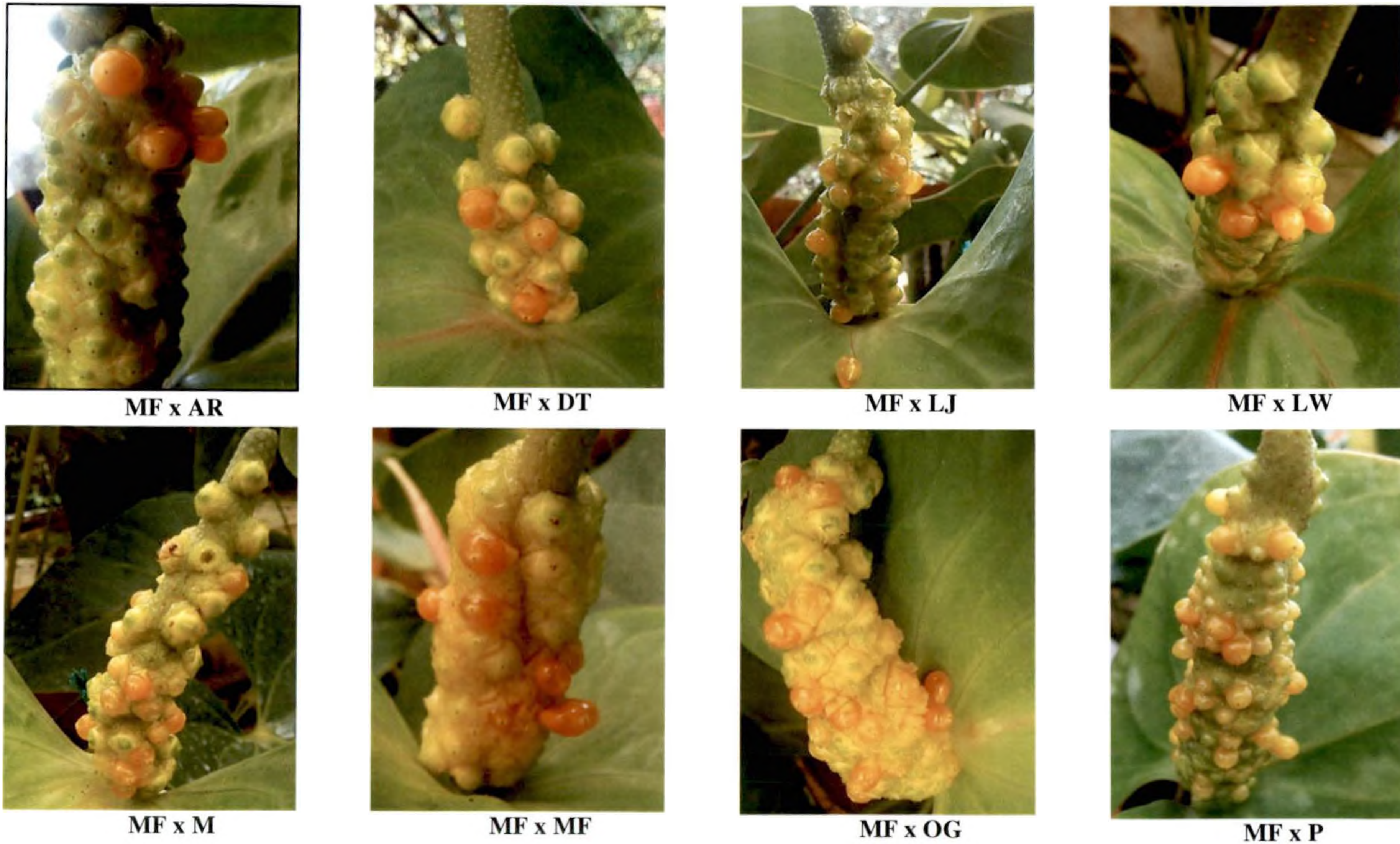


Plate 18 . Spadix bearing berries in different combinations with Mozaik Fresh as female parent

LJ x AR

LJ x DT

LJ x LJ

LJ x LW

LJ x M

LJ x MF

LJ x OG

LJ x P

Plate 19. Spadix bearing berries in different combinations with Lady Jane as female parent

Orange Glory (OG)

All the possible combinations involving this cultivar could be attempted and were successful (Plate 20). Among the crosses, 100 per cent of spadices bearing fruits were obtained for OG x M, OG x MF, OG x LJ and OG x OG followed by OG x AR (66.66 %) and OG x P and OG x DT (50 %).

Dragon's Tongue (DT)

All the possible combinations involving this cultivar could be attempted and were successful (Plate 21). The crosses DT x P, DT x OG, DT x LW and DT x AR had higher success percentage (100 %) while the crosses DT x M, DT x MF, DT x LJ and DT x DT recorded 50 per cent.

Lima White (LW)

All the possible combinations involving this cultivar could be attempted and were successful (Plate 22). The crosses LW x P, LW x M, LW x LJ and LW x DT showed 100 per cent success while the cross LW x AR had 66.66 per cent. LW x MF, LW x OG and LW x LW recorded 50 per cent success.

Agnihotri Red (AR)

All the eight possible combinations involving this cultivar could be attempted and were successful (Plate 23). Among the crosses, 100 per cent of spadices bearing fruits were obtained for AR x P, AR x OG, AR x DT, AR x LW and AR x AR while AR x M had 75 per cent and the crosses AR x MF and AR x LJ had 50 per cent success.

4.2.2.2 Number of Fruits per Spadix

The matrix showing the average number of fruits per spadix is given in Table. 22.

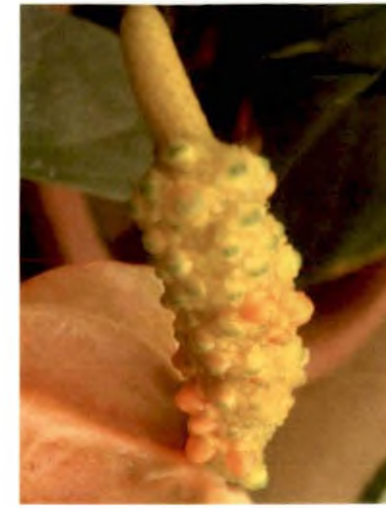
Paradise (P)

Number of fruits per spadix was highest for the cross P x LJ with 112 fruits followed by P x MF (92), P x M (52), P x LW (43), P x DT (36) and number of fruits per spadix was lowest for the crosses P x OG with 22 fruits.

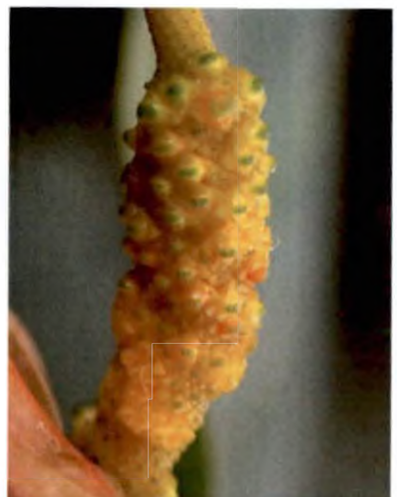

OG x AR


OG x DT


OG x LJ


OG x LW


OG x M


OG x MF


OG x OG


OG x P

Plate 20. Spadix bearing berries in different combinations with Orange Glory as female parent

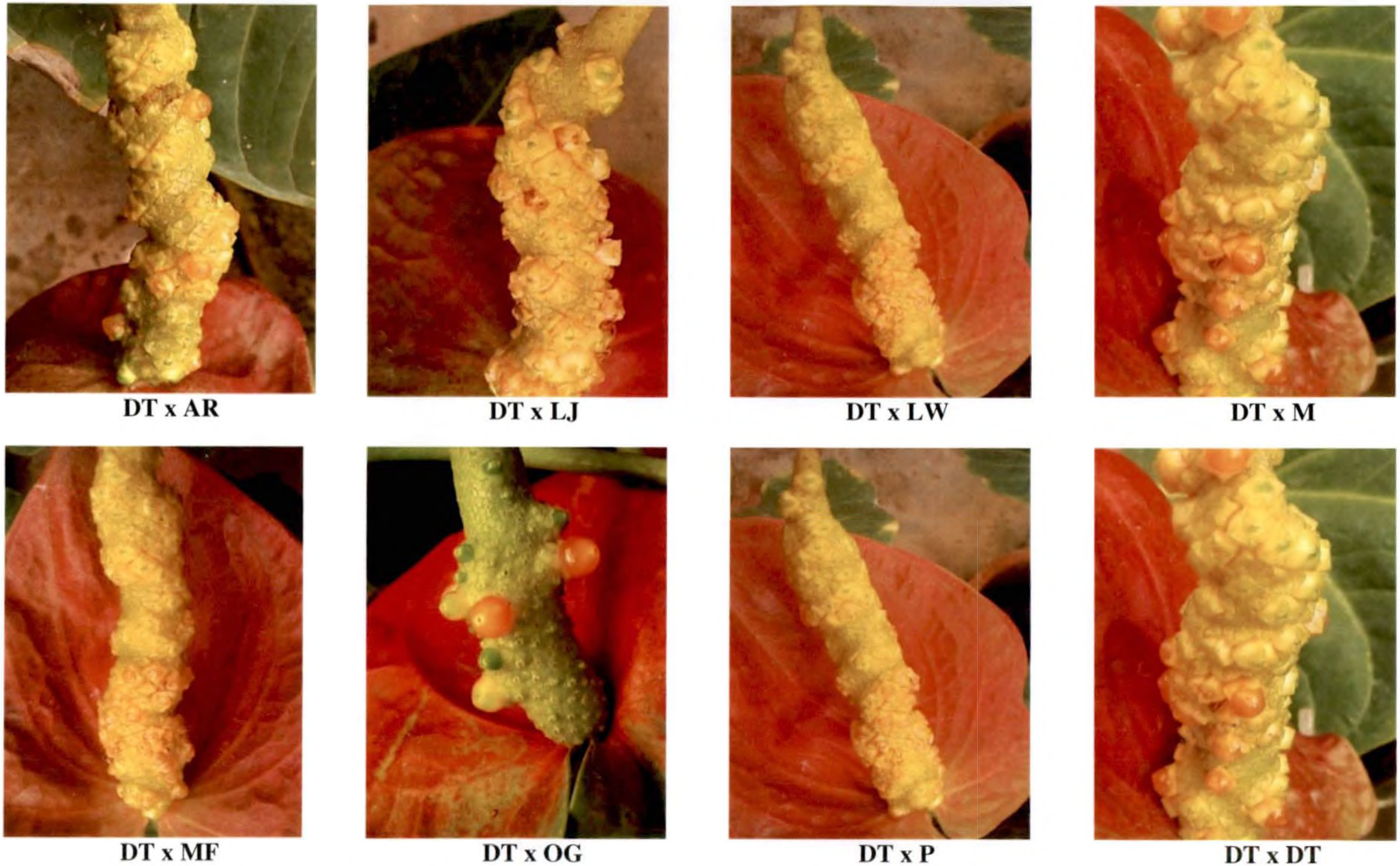


Plate 21. Spadix bearing berries in different combinations with Dragon's Tongue as female parent

LW x AR

LW x DT

LW x LJ

LW x LW

LW x M

LW x MF

LW x OG

LW x P

Plate 22. Spadix bearing berries in different combinations with Lima White as female parent

AR x AR

AR x DT

AR x LJ

AR x LW

AR x M

AR x MF

AR x OG

AR x P

Plate 23. Spadix bearing berries in different combinations with Agnihotri Red as female parent

Marijke (M)

Among the crosses M x MF recorded maximum number of fruits per spadix with a value of 137 followed by M x LJ (132), M x DT (128) and M x P (121). The cross M x OG produced 96 fruits and M x LW 94 fruits. M x M produced 54 fruits and M x AR produced 32 fruits.

Mozaik Fresh (MF)

Number of fruits per spadix was highest for the cross MF x LW (98 fruits) followed by MF x AR (92 fruits), MF x P (89 fruits), MF x MF (82 fruits), MF x OG (78 fruits), MF x M (67 fruits) and MF x LJ (54 fruits). MF x DT recorded the lowest value of 23 fruits per spadix.

Lady Jane Pink (LJ)

Among the crosses LJ x LW recorded maximum number of fruits per spadix with a value of 36 followed by LJ x P (32), LJ x M (19) and LJ x LJ (18). The cross LJ x DT produced 16 fruits and LJ x OG produced 16 fruits. LJ x AR produced 13 fruits and LJ x MF produced 12 fruits.

Orange Glory (OG)

Number of fruits per spadix was highest for the cross OG x AR (72 fruits) followed by OG x LJ (64 fruits), OG x DT (42 fruits), OG x P (38 fruits) and OG x LW (31 fruits).The crosses OG x M and OG x OG produced 16 fruits each. The cross OG x MF recorded the lowest value of 13 fruits per spadix.

Dragon's Tongue (DT)

Among the crosses DT x M recorded maximum number of fruits per spadix with a value of 52 followed by DT x LW (46), DT x LJ (39), DT x AR (36), DT x DT (34) and DT x OG (31). LJ x AR produced 13 fruits and LJ x MF produced 12 fruits. The crosses DT x MF and DT x P recorded the lowest values of 19 and 16 fruits per spadix respectively.

Lima White (LW)

Number of fruits per spadix was highest for the cross LW x LJ (62 fruits) followed by LW x AR (41 fruits), LW x MF (38 fruits), LW x DT (37 fruits), LW x M (34 fruits) and LW x P (28 fruits). The crosses LW x LW (8 fruits) and LW x OG (6 fruits) produced the lowest numbers of fruits per spadix.

Agnihotri Red (AR)

Among the crosses AR x LJ produced maximum number of fruits per spadix with a value of 31 followed by AR x OG and AR x AR, both produced 28 fruits respectively. The cross AR x M produced 22 fruits, AR x P (21 fruits), AR x LW (16 fruits) and AR x MF (14 fruits). The crosses AR x DT recorded the lowest value of 10 fruits per spadix.

4.2.2.3 Percentage of Fruit Set

The Percentage of fruit set per spadix for the successful crosses are given in Table 23.

Paradise (P)

Among the eight crosses the highest percentage of fruit set was obtained for the cross P x LJ (58.33 %) followed by P x MF (47.92 %) and P x LW (44.79 %). The crosses P x AR (14.58 %) and P x OG (11.46 %) recorded the lowest number of fruit set.

Marijke (M)

The cross M x OG recorded the highest percentage of fruit set (40.51 %) followed by M x LW (39.66 %), M x MF (34.60 %), M x P (33.99 %), M x LJ (33.33 %) and M x DT (32.32 %). The cross, and M x AR showed lowest percentage of fruit set with a value of 8.08 per cent.

Mozaik Fresh (MF)

The highest percentage of fruit set was recorded by MF x LW (30.50 %) followed by MF x MF (29.50 %), MF x OG (28.06 %), MF x AR (22.06 %),

Table 23. Matrix showing average percentage of fruit set in each combination among the selected eight parents

♀ \ ♂	P	M	MF	LJ	OG	DT	LW	AR
P	32.29	18.06	47.92	58.33	11.46	36.00	44.79	14.58
M	33.99	22.78	34.60	33.33	40.51	32.32	39.66	8.08
MF	19.18	14.44	29.50	19.42	28.06	4.96	30.50	22.06
LJ	11.59	4.59	4.35	13.04	10.14	3.48	26.09	3.14
OG	22.22	9.36	15.29	37.43	18.82	24.56	36.47	28.13
DT	14.81	24.07	8.80	18.06	28.70	15.74	21.30	16.67
LW	24.14	9.71	16.31	26.61	2.58	9.51	3.72	11.71
AR	13.21	8.27	8.81	19.50	35.44	6.29	20.25	17.61

Table 24. Matrix showing average number of days taken for seed maturity in each combination among the selected eight parents

♀ \ ♂	P	M	MF	LJ	OG	DT	LW	AR
P	147.0	141.5	134.0	151.5	148.5	146.5	145.0	140.0
M	129.0	133.5	130.5	140.0	133.5	126.0	140.0	123.5
MF	147.5	152.0	139.5	151.0	141.5	141.0	135.0	150.5
LJ	109.5	115.5	123.0	121.0	112.0	107.5	114.5	123.5
OG	204.5	201.0	192.0	209.5	218.0	220.0	202.5	239.5
DT	204.5	206.5	209.0	217.0	211.0	215.5	203.5	204.5
LW	163.5	161.5	163.0	162.0	152.5	164.0	168.0	169.5
AR	203.5	199.0	202.5	208.5	210.5	198.0	203.5	212.0

MF x LJ (19.42 %), MF x P (19.18 %) and MF x M (14.44 %) while the crosses MF x DT (4.96 %) recorded the lowest value.

Lady Jane Pink (LJ)

Among all the eight possible combinations involving this cultivar, the cross LJ x LW (26.09 %) recorded the highest percentage of fruit set followed by LJ x LJ (13.04 %), LJ x OG (10.14 %), LJ x P (11.59 %), LJ x M (4.59 %) and LJ x MF (4.35 %). The crosses LJ x DT (3.48 %) and LJ x AR (3.14 %) recorded lowest values for fruit set.

Orange Glory (OG)

Highest percentage of fruit set was obtained by the cross OG x LJ (37.43 %) followed by OG x AR (28.13 %), OG x DT (24.56 %), OG x P (22.22 %), OG x OG (18.82 %), OG x MF (15.29 %). OG x M (9.36 %) had the lowest percentage of fruit set.

Dragon's Tongue (DT)

The cross DT x OG (28.70 %) had the highest percentage of fruit set followed by DT x M (24.07 %), DT x LW (21.30 %), DT x LJ (18.06 %), DT x AR (16.67 %), DT x DT (15.74 %) and DT x P (14.81 %) while the crosses DT x MF (8.80 %) recorded the lowest value.

Lima White (LW)

Highest percentage of fruit set was obtained by the cross LW x LJ (26.61 %) followed by the crosses LW x P (24.14 %), LW x MF (16.31 %), LW x AR (11.71 %), LW x M (9.71 %), and LW x DT (9.51 %). LW x OG (2.58 %) showed the lowest value.

Agnihotri Red (AR)

Among the crosses, highest percentage of fruit set was obtained for AR x OG (35.44 %) followed by AR x LW (20.25 %), AR x LJ (19.50 %), AR x AR (17.61 %), AR x P (13.21 %) , AR x MF (8.81 %) and AR x M (8.27 %). AR x DT showed the lowest value of 6.29 per cent.

4.2.2.4 Number of Days Taken for Seed Maturity

Average number of days taken for seed maturity in the crosses is given in Table 24. The range of days taken for maturity of seeds ranged from 107.5 days (LJ x DT) to 239.5 days (OG x AR). Considering all cross combinations involving the Paradise as female parent, the days taken for seed maturity ranged from 134 to 148.5 days. Crosses with Marijke as the female parent took 123.5 to 140 days for seed maturity. In the crosses with Mozaik Fresh as the female parent recorded 135 to 152 days for maturity of seeds. Days taken for seed maturity ranged from 107.5 to 123.5 days in crosses where Lady Jane Pink was the female parent. Orange Glory showed a range of 192 to 239.5 days while Dragon's Tongue showed 203.5 to 215.5 days for seed maturity. Among the crosses in which Lima White as a female parent recorded 152.5 to 169.5 days for seed maturity where as Agnihotri Red recorded 198 to 212 days for maturity of seeds.

4.2.2.5 Number of Seeds per Fruit

The data recorded on the number of seeds per fruits for the eight anthurium parents are given in Table 25.

Paradise (P)

In the crosses where Paradise as the female parent, the percentage of fruits with single seeds was highest for the crosses P x M and P x LJ (100 %) and the percentage of fruits with double seeds was highest for the cross P x OG (27.27 %). Maximum number of seeds were produced by the cross P x LJ (112 seeds) and lowest number of seeds were produced by P x OG (28 seeds).

Marijke (M)

The cross M x M produced 100 per cent single seeds. The cross M x AR (81.25 %) had the lowest per cent of single seeds. Maximum number of double seeds were observed in the cross M x AR (18.75 %) and lowest number in the cross M x LJ (3.65 %). Considering the total number of seeds, the cross M x MF (146 seeds) and M x AR (38 seeds) highest and lowest values respectively.

Table 25. Number of seeds and seed size among the crosses

Combination	Number of berries		Total no. of seeds per spadix	Size of berries with single seed		Size of berries with two seeds	
	Single seed (%)	Two seeds (%)		Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)
P x P	90.32	9.68	34	3.12	2.45	2.56	1.75
P x M	100.00	0.00	52	3.65	2.29	0.00	0.00
P x MF	93.48	6.52	98	3.54	2.16	2.92	1.87
P x LJ	100.00	0.00	112	3.26	2.23	0.00	0.00
P x OG	72.73	27.27	28	3.57	2.46	3.01	2.11
P x DT	77.78	22.22	44	3.26	2.32	2.68	1.99
P x LW	90.70	9.30	47	3.66	2.44	2.21	1.96
P x AR	75.00	25.00	35	3.24	2.14	3.03	2.11
M x P	94.21	5.79	128	3.65	2.23	2.98	2.10
M x M	96.35	3.65	146	3.65	2.16	2.96	2.12
M x MF	100.00	0.00	54	3.61	2.36	0.00	0.00
M x LJ	93.94	6.06	140	3.61	2.25	2.69	1.64
M x OG	90.63	9.38	105	3.24	2.33	3.04	2.10
M x DT	94.37	5.63	138	3.84	2.41	2.96	1.97
M x LW	92.55	7.45	101	3.41	2.60	3.11	2.24
M x AR	81.25	18.75	38	3.12	2.08	2.85	1.68
MF x P	89.89	10.11	98	3.21	2.42	2.94	2.01
MF x M	91.04	8.96	73	3.14	2.11	2.84	1.65
MF x MF	90.24	9.76	90	3.05	2.23	2.87	1.63
MF x LJ	100.00	0.00	54	3.11	2.44	0.00	0.00
MF x OG	92.31	7.69	84	3.01	2.46	2.64	2.11

Table 25 continued

Combination	Number of berries		Total no. of seeds per spadix	Size of berries with single seed		Size of berries with two seeds	
	Single seed (%)	Two seeds (%)		Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)
MF x DT	60.87	39.13	32	3.22	2.53	2.86	1.85
MF x LW	87.76	12.24	110	3.15	2.51	2.68	1.84
MF x AR	90.22	9.78	101	3.23	2.34	2.97	2.11
LJ x P	96.88	3.13	33	2.71	1.68	2.32	1.46
LJ x M	100.00	0.00	19	2.84	1.72	0.00	0.00
LJ x MF	83.33	16.67	14	2.18	1.64	1.94	1.32
LJ x LJ	83.33	16.67	21	2.65	1.72	2.32	1.82
LJ x OG	92.86	7.14	15	2.74	1.91	2.23	1.64
LJ x DT	81.25	18.75	19	3.11	2.10	2.67	1.98
LJ x LW	94.44	5.56	38	2.87	2.04	2.14	1.63
LJ x AR	100.00	0.00	13	3.02	2.12	0.00	0.00
OG x P	84.21	15.79	44	3.24	2.65	2.84	1.98
OG x M	75.00	25.00	20	3.52	2.47	2.65	1.84
OG x MF	69.23	30.77	17	3.64	2.81	2.94	2.04
OG x LJ	87.50	12.50	72	3.32	2.45	2.68	1.93
OG x OG	75.00	25.00	20	3.21	2.57	2.78	2.11
OG x DT	85.71	14.29	48	3.78	2.61	3.04	2.24
OG x LW	77.42	22.58	38	3.45	2.53	2.65	2.14
OG x AR	90.28	9.72	79	3.41	2.36	2.69	1.95
DT x P	87.50	12.50	18	3.76	2.69	3.01	2.42
DT x M	82.69	17.31	61	3.65	2.74	2.98	2.11

Table 25 continued

Combination	Number of berries		Total no. of seeds per spadix	Size of berries with single seed		Size of berries with two seeds	
	Single seed (%)	Single seed (%)		Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)
DT x MF	68.42	31.58	25	3.81	2.68	2.96	2.04
DT x LJ	82.05	17.95	46	3.69	2.54	2.64	1.98
DT x OG	74.19	25.81	39	3.88	2.97	2.84	1.92
DT x DT	67.65	32.35	45	3.46	2.54	2.77	1.85
DT x LW	69.57	30.43	60	3.54	2.47	2.86	1.87
DT x AR	80.56	19.44	43	3.68	2.69	3.06	2.13
LW x P	82.14	17.86	33	3.54	2.61	2.64	1.86
LW x M	94.12	5.88	36	3.24	2.57	2.74	1.85
LW x MF	84.21	15.79	44	3.69	2.66	2.85	1.97
LW x LJ	87.10	12.90	70	3.74	2.96	2.82	1.74
LW x OG	83.33	16.67	7	3.74	2.91	2.81	1.62
LW x DT	94.59	5.41	39	3.54	2.76	2.94	2.14
LW x LW	100.00	0.00	8	3.61	2.77	2.82	2.10
LW x AR	92.68	7.32	44	3.42	2.73	3.01	2.18
AR x P	90.48	9.52	23	2.64	1.62	2.20	1.24
AR x M	95.45	4.55	23	2.53	1.74	2.31	1.52
AR x MF	85.71	14.29	16	2.67	1.69	2.10	1.36
AR x LJ	90.32	9.68	34	2.21	1.54	2.06	1.36
AR x OG	96.43	3.57	29	2.78	1.65	2.36	1.52
AR x DT	100.00	0.00	10	2.91	1.59	0.00	0.00
AR x LW	87.50	12.50	18	2.22	1.76	1.98	1.52
AR x AR	96.43	3.57	29	2.34	1.68	2.02	1.44

Mozaik Fresh (MF)

Among the crosses, MF x LJ produced 100 percent single seeds while the cross MF x DT (60.87 %) produced the lowest. Percentage of double seeds were maximum for the cross MF x DT (39.13 %). The cross MF x LW produced maximum number of seeds (110 seeds) and MF x DT (32 seeds) produced the lowest.

Lady Jane Pink (LJ)

Among all the eight possible combinations involving this cultivar, the crosses LJ x M and LJ x AR produced all single seeds. LJ x DT produced maximum number of double seeds (18.75 %). While considering the total number of seeds, LJ x P (34 seeds) had highest number of seeds and LJ x MF (14 seeds) had the lowest number.

Orange Glory (OG)

All the eight crosses produced both single and double seeds. Highest percentage of single seeds were observed for the cross OG x AR (90.28 %) and lowest for the cross OG x MF (69.23 %). Number of double seeds were highest for the cross OG x MF (30.77 %) and lowest for OG x AR (9.72 %). Maximum number of seeds were produced by OG x AR (79 seeds) and minimum number by OG x MF (17 seeds).

Dragon's Tongue (DT)

All the crosses produced both single and double seeds. The cross DT x P (87.5 %) produced maximum number of single seeds and DT x DT (67.65 %) produced the minimum. Maximum number of double seeds were observed for DT x DT (32.35 %) and minimum number for the cross DT x P (12.5 %). Considering the total number of seeds, the cross DT x M (61seeds) recorded the highest value where as DT x P (18 seeds) recorded the lowest.

Lima White (LW)

Highest percentage of single seeds were produced in the cross LW x LW (100 %). Maximum number of double seeds were produced by the cross LW x P (17.86 %) and minimum number for LW x DT (5.41 %). Total number of seeds were highest for the cross LW x LJ (70 seeds) and lowest for LW x DT (7seeds).

Agnihotri Red (AR)

Highest percentage single seeds were obtained for AR x DT (100 %).The cross AR x MF (14.29 %) produced maximum number of double seeds.

Considering all the 64 cross combinations together, seven combinations produced all single seeds (P x M, P x LJ, M x MF, MF x LJ, LJ x M, LJ x AR, LW x LW and AR x DT). The female parents DT and OG produced single and double seeds in all the combinations. The cross MF x DT produced the lowest percentage of single seeds (60.87) and highest percentage of double seeds (39.3 %). Considering the total number of seeds, the cross M x MF produced maximum number of seeds (146 seeds) followed by M x LJ (140 seeds) and M x DT (138 seeds). Lowest number of seeds were produced in the cross LW x OG (7 seeds).

4.2.2.6 Seed Size

The data recorded on the seed size of the eight parents are given in Table 25. Size of seeds from the fruits of same cross combination showed variation depending on whether the fruits contained one or two seeds. As the number of seeds in the berry increased the average size of seeds decreased. When the fruits with single seeds are considered, maximum seed size was observed for the cross DT x OG with 3.88 mm length and 2.97 mm width. The crosses DT x MF (3.81 x 2.68 mm) and DT x P (3.76 x 2.69 mm) also had larger seeds. The cross LJ x MF (2.18 x 1.64 mm) produced smallest seed among single seeded fruits followed by AR x LJ (2.21 x 1.54 mm) and AR x LW (2.22 x 1.76 mm).

Among the fruits with two seeds, the cross M x LW (3.11 x 2.24 mm) produced the largest seed followed by DT x AR (3.06 x 2.13 mm) and LW x AR

(3.01 x 2.18 mm). Smallest seed in the single seeded as well as two seeded fruits was seen in the cross LJ x LW (1.94 x 1.32).

4.2.2.7 Seed Germination (%)

The data on percentage of seed germination is given in Table 26. The percentage of seed germination ranged from 29.17 percent in the cross OG x DT to 92.96 per cent in M x MF. The results of seed germination per cent of different parents are given below. Various stages of seed germination are given in Plate 24.

Paradise (P)

In the crosses where Paradise as the female parent, the percentage of seed germination was highest for the cross P x AR (85.71 %) followed by P x LW (76.60 %), P x OG (75.00 %), P x DT (72.73 %), P x P (70.59 %) and P x LJ (61.61 %). Lowest percentage of seed germination was observed in the crosses P x MF (38.78 %) and P x MF (42.31 %).

Marijke (M)

The cross M x MF recorded the highest germination percent of 92.96 followed by M x LJ (91.43 %), M x OG (89.52 %), M x P (88.28 %), M x DT (88.00 %), M x M (85.19 %) and Lowest germination percent was observed in the cross M x AR (76.32 %).

Mozaik Fresh (MF)

Among the crosses, MF x M recorded the highest germination (83.56 %) followed by MF x LJ (83.33 %), MF x MF (81.11 %), MF x OG (72.62 %), MF x LW (69.09 %), MF x AR (67.33 %) and MF x P (65.31 %). The cross MF x DT recorded the lowest germination percent (50.00 %).

Lady Jane Pink (LJ)

Among all the eight possible combinations involving this cultivar, the cross LJ x MF (76.19 %) recorded the highest germination per cent followed by LJ x LJ (71.43 %), LJ x AR (69.23 %), LJ x DT (68.42 %), LJ x OG (60.00 %),

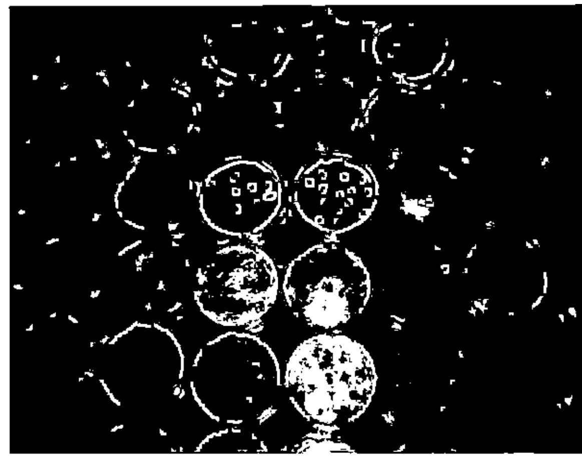
Table 26. Matrix showing the percentage of seed germination in each combination among the selected eight parents

♀ \ ♂	P	M	MF	LJ	OG	DT	LW	AR
P	70.59	42.31	38.78	61.61	75.00	72.73	76.60	85.71
M	88.28	85.19	92.96	91.43	89.52	88.00	83.17	76.32
MF	65.31	83.56	81.11	83.33	72.62	50.00	69.09	67.33
LJ	54.55	57.89	76.19	71.43	60.00	68.42	42.11	69.23
OG	47.73	60.00	64.71	54.17	60.00	29.17	42.18	35.44
DT	55.56	36.07	68.00	45.65	41.03	36.67	31.11	53.49
LW	42.42	47.22	43.18	44.29	57.14	66.67	53.85	61.36
AR	60.87	52.17	43.75	32.35	34.48	60.00	33.33	37.93

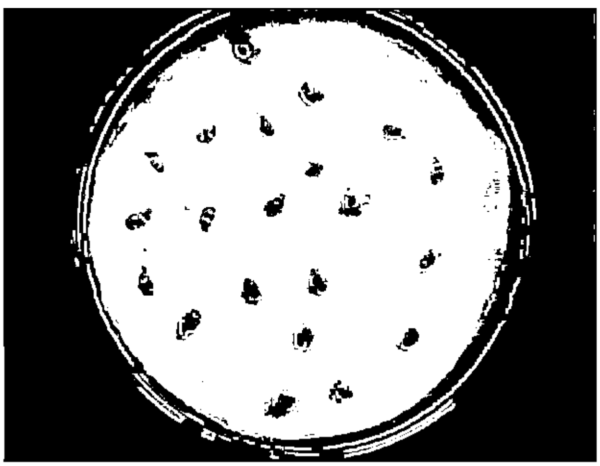
Table 27. Matrix showing the average number of days taken for seed germination in each combination among the selected eight parents

♀ \ ♂	P	M	MF	LJ	OG	DT	LW	AR
P	10.40	8.80	12.00	7.20	7.80	14.60	7.60	5.60
M	5.00	4.40	7.80	5.40	7.40	3.40	4.00	7.20
MF	5.60	5.20	7.40	8.60	8.40	6.20	8.40	5.60
LJ	9.00	4.40	4.60	6.20	7.00	7.20	6.00	5.60
OG	6.60	8.80	9.40	11.40	8.40	7.80	8.60	9.60
DT	10.00	6.00	5.80	8.20	5.00	7.60	10.00	6.60
LW	7.40	8.40	6.00	7.00	8.80	6.20	7.40	5.20
AR	6.40	7.80	10.20	13.60	11.80	9.40	7.40	9.00

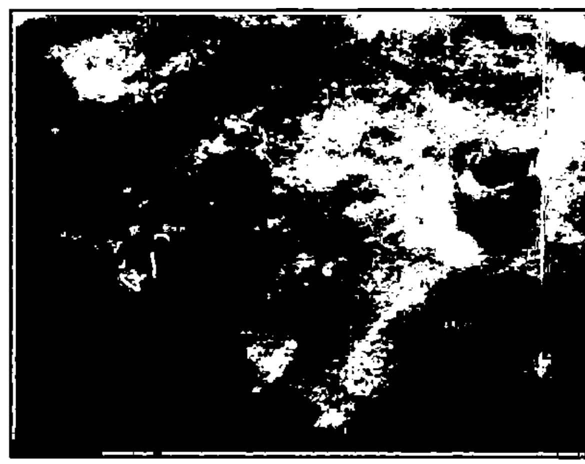
Fully mature fruits



Seeds kept for germination



Germinating seeds in petridish



Germinating seeds with mucilage

Seeds after 3 weeks of germination

A germinating seed

Plate 24. Fruits and germination stages of seeds

LJ x M (57.89 %) and LJ x P (54.55 %). The cross LJ x LW (42.11 %) recorded the lowest value.

Orange Glory (OG)

Among the crosses, OG x MF (64.71 %) recorded the highest germination per cent followed by OG x M and OG x OG (60.00 %), OG x LJ (54.17 %). The cross OG x DT (29.17 %) recorded the lowest germination per cent followed by OG x AR (35.44 %), OG x LW (42.18 %) and OG x P (47.73 %).

Dragon's Tongue (DT)

The cross DT x M recorded the highest germination percent of 68.00 followed by DT x P (55.56 %) and DT x AR (53.49 %). Other crosses recorded germination percentages of DT x LJ (45.65 %), DT x OG (41.03 %), DT x DT (36.67 %), DT x M (36.07 %) and DT x LW (31.11 %) respectively.

Lima White (LW)

Highest percentage of germination was observed in the cross LW x DT (66.67 %) followed by LW x AR (61.36 %), LW x OG (57.14 %) and LW x LW (53.85 %). The cross LW x P (42.42 %) recorded the lowest germination per cent followed by LW x MF (43.18 %), LW x LJ (44.29 %) and LW x M (47.22 %).

Agnihotri Red (AR)

Among the crosses, highest percentage of germination was obtained for AR x P (60.87 %) followed by AR x DT (60.00 %) and AR x M (52.17 %). The cross AR x LJ (32.35 %) recorded the lowest germination per cent followed by AR x LW (33.33 %), AR x OG (34.48 %), AR x AR (37.93 %) and AR x MF (43.75 %).

4.2.2.8 Days Taken for Seed Germination

The data on average number of days taken for seed germination is given in Table 27. Maximum number of days taken for seed germination was in the cross P x DT (14.60 days) and minimum was in M x DT (3.4 days).

Paradise (P)

Among the crosses, P x DT (14.60 days) took maximum days for seed germination followed by P x MF (12.00 days). Lowest days for seed germination was observed in the cross P x AR (5.60 days).

Marijke (M)

The cross M x MF recorded maximum days for seed germination with a value of 7.80 days where as M x DT (3.4 days) took the least number of days.

Mozaik Fresh (MF)

Among the crosses, MF x LJ (8.60 days) maximum days for seed germination followed by MF x OG (8.40 days). MF x M (5.20 days) took minimum number of days for seed germination

Lady Jane Pink (LJ)

Among all the eight possible combinations involving this cultivar, the cross LJ x P (9.00 days) recorded maximum days for seed germination and the cross LJ x M (4.40 days) recorded the lowest value.

Orange Glory (OG)

The cross OG x LJ (11.40 days) recorded maximum days for seed germination where as OG x P (6.60 days) recorded minimum number of days for seed germination.

Dragon's Tongue (DT)

Maximum number of days for seed germination was obtained for the crosses DT x P and DT x LW with a value of 10.00 days. The cross DT x OG (5.00 days) took the least number of days.

Lima White (LW)

The cross LW x OG (8.80 days) recorded maximum days for seed germination where as LW x AR (5.20 days) recorded minimum number of days for seed germination.

Agnihotri Red (AR)

Maximum number of days for seed germination was obtained for the cross AR x LJ with a value of 10.60 days. The cross AR x P (6.40 days) took the least number of days.

4.2.2.9 Seedling Survival

The data on survival (%) of hybrid seedlings at 6 and 12 MAP is given in Table 28. At 6 MAP, highest seedling survival was recorded by the cross LW x OG (51.23 %) and lowest survival by M x OG (5.32 %). At 12 MAP, highest seedling survival was recorded by the cross AR x DT (33.33 %) and lowest survival was exhibited by the cross M x OG (1.06 %).

4.2.2.10 Number of Leaves

The data on number of leaves of the seedlings is given in Table 28. Maximum number of leaves was produced by the cross M x LJ (9.60) followed by M x OG and OG x AR (9.20) while the lowest for the cross DT x LW (4.90) followed by DT x P (5.30).

4.2.2.11 Days from Emergence to Maturity of Leaves

The data on emergence to maturity of the leaves of the seedlings is given in Table 28. The maximum number of days taken for emergence to maturity of the leaves was by the cross AR x DT and OG x M (34.75) followed by DT x P (34.25). The least number of days for emergence to maturity of the leaves was taken by M x AR (24.75).

4.2.2.12 Leaf Area (cm^2)

The data on leaf area of the seedlings is given in Table 28. The leaf area was maximum for the cross P x MF (45.06 cm^2) followed by DT x DT (42.09 cm^2) and P x P (40.90 cm^2). The minimum leaf area observed for the cross LJ x P (24.89 cm^2).

Table 28. Seedling survival and performance of hybrids

Combination	Seedling survival (%)		Number of leaves per seedling (12 MAP)	Days from emergence to maturity of leaves	Leaf area (cm^2) (12 MAP)	Internodal length (cm)
	6 MAP	12 MAP				
P x P	12.50	8.33	7.20	28.00	40.90	0.27
P x M	18.18	4.55	7.10	30.25	38.85	0.23
P x MF	10.53	2.63	7.30	30.00	45.06	0.28
P x LJ	5.80	1.45	8.20	26.75	39.25	0.26
P x OG	14.29	9.52	7.10	30.50	38.92	0.28
P x DT	12.50	9.38	8.20	25.75	36.49	0.28
P x LW	8.33	5.56	7.60	28.25	37.01	0.26
P x AR	16.67	3.33	8.50	25.00	32.57	0.23
M x P	6.19	4.42	7.30	27.50	31.96	0.26
M x M	8.70	4.35	6.70	26.00	32.09	0.27
M x MF	6.06	4.55	7.90	29.25	33.38	0.31
M x LJ	7.81	5.47	9.60	31.00	34.72	0.23
M x OG	5.32	1.06	9.20	27.75	33.38	0.29
M x DT	8.33	6.82	6.80	29.75	33.15	0.28
M x LW	5.95	2.38	9.10	25.50	32.86	0.28
M x AR	10.34	3.45	8.20	24.75	30.77	0.27
MF x P	7.81	3.13	6.80	29.00	31.05	0.29
MF x M	9.84	3.28	8.10	28.50	32.90	0.29
MF x MF	6.85	1.37	6.70	32.00	34.55	0.28
MF x LJ	15.56	2.22	8.90	30.75	37.27	0.26
MF x OG	8.20	6.56	7.30	31.00	33.99	0.26

Table 28 continued.

Combination	Seedling survival (%)		Number of leaves per seedling (12 MAP)	Days from emergence to maturity of leaves	Leaf area (cm^2) (12 MAP)	Internodal length (cm)
	6 MAP	12 MAP				
MF x DT	12.50	6.25	7.80	32.25	37.15	0.30
MF x LW	7.89	5.26	9.30	27.50	34.72	0.30
MF x AR	5.88	2.94	7.30	30.00	30.26	0.30
LJ x P	16.67	5.56	6.80	26.75	24.89	0.30
LJ x M	27.27	18.18	7.10	27.00	27.00	0.29
LJ x MF	30.00	20.00	5.90	29.00	28.74	0.22
LJ x LJ	25.00	12.50	6.60	31.00	31.57	0.23
LJ x OG	33.33	22.22	7.50	31.75	30.27	0.27
LJ x DT	23.08	7.69	7.40	32.00	33.15	0.29
LJ x LW	25.00	6.25	7.60	27.75	33.18	0.27
LJ x AR	22.22	22.22	6.10	28.75	31.30	0.28
OG x P	19.05	4.76	7.10	33.25	31.57	0.29
OG x M	25.00	16.67	8.20	34.75	31.83	0.30
OG x MF	36.36	18.18	7.20	30.50	32.34	0.29
OG x LJ	7.69	5.13	8.20	31.75	28.74	0.26
OG x OG	25.00	16.67	7.00	30.25	31.84	0.31
OG x DT	21.43	14.29	7.10	28.75	36.50	0.27
OG x LW	25.00	18.75	8.10	28.75	34.80	0.26
OG x AR	17.86	14.29	9.20	31.00	31.31	0.26
DT x P	40.00	20.00	5.30	34.25	40.74	0.28
DT x M	13.64	9.09	6.20	32.75	38.91	0.29

Table 28 continued.

Combination	Seedling survival (%)		Number of leaves per seedling (12 MAP)	Days from emergence to maturity of leaves	Leaf area (cm^2) (12 MAP)	Internodal length (cm)
	6 MAP	12 MAP				
DT x MF	23.53	5.88	7.80	30.25	34.41	0.32
DT x LJ	19.05	9.52	7.50	29.50	32.79	0.28
DT x OG	25.00	18.75	6.30	30.50	38.07	0.27
DT x DT	28.57	14.29	5.20	32.00	42.09	0.27
DT x LW	13.64	13.64	4.90	31.75	32.26	0.27
DT x AR	17.39	8.70	6.20	34.25	33.29	0.24
LW x P	21.43	14.29	6.30	27.00	30.93	0.28
LW x M	23.53	11.76	9.20	25.00	32.28	0.28
LW x MF	15.79	10.53	7.30	29.50	28.08	0.26
LW x LJ	12.90	12.90	7.10	27.00	27.25	0.26
LW x OG	51.23	25.00	7.20	30.50	28.01	0.28
LW x DT	28.57	9.52	5.20	29.75	39.56	0.30
LW x LW	50.00	25.00	5.80	27.75	34.34	0.27
LW x AR	11.11	7.41	6.70	25.25	36.82	0.24
AR x P	21.43	14.29	6.20	33.50	32.88	0.26
AR x M	25.00	8.33	7.30	31.00	31.17	0.29
AR x MF	42.86	28.57	6.40	31.50	31.34	0.27
AR x LJ	27.27	9.09	7.80	29.50	33.36	0.26
AR x OG	20.00	10.00	7.20	31.75	34.41	0.22
AR x DT	33.33	33.33	7.90	34.75	40.15	0.29
AR x LW	33.33	16.67	6.70	30.75	36.50	0.28
AR x AR	18.18	18.18	6.10	29.25	34.01	0.27

4.2.2.13 Internodal Length

The data on internodal length of the seedlings is given in Table 28. The internodal length was maximum for the cross DT x MF (0.32 cm) followed by M x MF (0.31 cm). The internodal length was least for the crosses LJ x MF and AR x OG (0.22 cm).

4.2.3 Combining Ability Analysis

The analysis of variance for combining ability was carried out for eleven characters studied. The general combining ability effects (GCA) of the parents and specific combining ability effects (SCA) of the hybrids are given in Tables 29 and 30 respectively. The results are described for each character separately as follows:

4.2.3.1 Number of Fruits per Spadix

Significant GCA effects were observed for the eight parents under study. GCA effects ranged from -11.475 to 28.192. The parents P (-4.075), LJ (-5.542), OG (-9.242), DT (-8.408), LW (-9.642) and AR (-11.475) had significant negative GCA effects whereas M (28.192) and MF (20.192) had significant positive GCA effects.

The values of SCA effects of 28 hybrids for number of fruits per spadix ranged from -39.941to 61.793. Among them ten hybrids recorded significantly high positive SCA effects for this character. The cross combinations with positive significant SCA effects were P x LJ (61.793), M x LJ (56.859), M x DT (45.726), M x MF (36.459), OG x AR (33.293), MF x LW (21.559), MF x AR (18.459), M x OG (16.293), M x LW (14.559) and P x MF (13.393).

The cross combinations with significant negative SCA effects were MF x DT (-39.941), M x AR (-34.874), P x M (-23.941), LJ x DT (-20.541), MF x LJ (-19.474), LJ x OG (-19.307), P x OG (-15.774), LJ x AR (-13.807) and P x AR (-10.607).

Table 29. General combining ability effects of the parents

Genotypes	Number of fruits per spadix	Percentage of fruit set	Days for seed maturity	Number of seeds	Seed germination (%)	Days for germination	Seedling survival (%)	Number of leaves per seedling	Days from emergence to maturity of leaves	Leaf area (cm^2)	Internodal length (cm)
P	-4.075**	0.775*	-5.593	-5.767**	4.821	1.825**	-1.992**	-0.052	-1.008**	3.155**	-0.007
M	28.192**	6.746**	-13.826**	27.100**	10.167**	-1.408**	-3.040**	0.228	-1.275**	-0.172	0.001
MF	20.192**	3.270**	-9.859*	20.633**	7.342*	0.258	-3.796**	0.201	1.258**	0.053	0.014*
LJ	-5.542**	-2.053**	-22.059**	-8.367**	-2.963	-0.942	0.343	0.061	0.692**	-0.155	-0.011
OG	-9.642**	-1.622**	27.074**	-9.333**	-0.091	0.525**	3.137**	0.328**	0.858**	-0.827	0.007
DT	-8.408**	-2.011**	8.344	-5.700**	-9.970**	0.425**	1.560**	-0.442**	1.392**	0.040	0.004
LW	-9.242**	-2.724**	1.654	-8.633**	-4.327	-0.175	2.939**	-0.066	-1.275**	-0.498	-0.002
AR	-11.475**	-2.380**	14.264**	-9.933**	-4.978	-0.508**	0.849	-0.256	-0.642**	-1.596*	-0.006
SE(gi)	1.293	0.347	4.701	1.703	2.859	0.134	0.458	0.136	0.168	0.484	0.006
SE(gi-gj)	1.955	0.524	7.107	2.575	4.323	0.203	0.692	0.206	0.254	0.732	0.009
CD(0.05)	2.534	0.680	9.214	3.338	5.604	0.263	0.898	0.267	0.329	0.949	0.012

* Significant at 5%; ** significant at 1%

4.2.3.2 Percentage of Fruit Set

GCA effects for the character percentage of fruit set ranged from -2.724 to 6.746. The parents LJ (-2.053), OG (-1.622), LW (-2.724), DT (-2.011) and AR (-2.380) showed significant negative GCA for percentage of fruit set. P (0.775), M (6.746) and MF (3.270) had significant positive GCA effects with respect to this character.

SCA effects for percentage of fruit set ranged from -9.948 to 19. 859. Positively significant SCA effects were shown by the crosses P x LJ (19.859), M x LJ (14.633), OG x AR (12.488), M x DT (11.056), M x MF (10.657), P x MF (7.453), MF x LW (3.840), M x LW (3.688), OG x DT (3.464), M x OG (2.922) and MF x AR (2.347).

Significantly negative SCA effects were recorded for the crosses MF x DT (-9.948) and M x AR (-9.703), LJ x OG (-6.349), P x OG (-6.093), LJ x DT (-5.959), P x M (-5.190), MF x LJ (-4.877), LJ x AR (-4.793) and P x AR (-4.293).

4.2.3.3 Days for Seed Maturity

GCA effects for the character days of seed maturity ranged from-22.059 to 27.074. Significant negative GCA effects were observed for the parents P (-5.593), M (-13.826), MF (-9.859) and LJ (-22.059). The parents OG (27.074), DT (8.344), LW (1.654) and AR (14.264) had positive GCA effects.

The range of SCA effects for days of seed maturity was -44.525 to 46.151. The cross combinations with significant positive SCA effects were OG x AR (46.151), OG x DT (33.071), MF x LJ (31.408) and P x LJ (28.808).

LJ x OG (-44.525), DT x AR (-36.885), M x OG (-30.452), M x AR (-30.282), LJ x DT (-29.462) and MF x OG (-27.392) recorded significant negative SCA effects for this character.

Table 30. Specific combining ability effects of hybrids

Genotypes	Number of fruits per spadix	Percentage of fruit set	Days for seed maturity	Number of seeds	Seed germination (%)	Days for germination	Seedling survival (%)	Number of leaves per seedling	Days from emergence to maturity of leaves	Leaf area (cm^2)	Internodal length (cm)
P x M	-23.941**	-5.190**	9.241	-24.259**	-12.036	0.500	2.176	-0.644	3.163**	0.524	-0.029
P x MF	13.393**	7.453**	-1.059	15.874**	-15.962	2.167**	0.514	0.049	0.630	1.543	0.003
P x LJ	61.793**	19.859**	28.808*	54.207**	7.352	-1.300**	-4.556**	0.089	-2.137**	5.673**	0.005
P x OG	-15.774**	-6.093**	-24.659	-15.159**	-0.337	-1.767**	1.605	-0.111	1.696**	2.133	0.009
P x DT	-4.674	-1.849	-6.929	-6.459	17.191*	5.000**	0.336	0.326	-3.837**	-3.365*	0.013
P x LW	2.493	0.843	-1.905	2.141	9.252	-1.400**	-3.153*	0.349	1.163*	-5.057**	-0.004
P x AR	-10.607**	-4.293**	-18.182	-10.226	1.055	-3.067**	-1.717	0.272	-2.470**	-0.161	-0.022
M x MF	36.459**	10.657**	3.508	29.674**	-0.362	1.400**	3.427*	0.136	0.230	-1.431	0.028
M x LJ	56.859**	14.633**	24.375	46.674**	11.464	0.267	-0.468	0.709	2.130**	-0.471	-0.025
M x OG	16.293**	2.922**	-30.452*	19.641**	7.425	1.133**	-5.387**	0.776	-0.704	0.449	0.013
M x DT	45.726**	11.056**	-20.029	50.674**	9.080	-3.100**	-0.278	-0.121	0.430	-2.322	0.005
M x LW	14.559**	3.688**	0.661	15.941**	10.781	-1.833**	-4.360**	0.669	-1.237*	0.878	0.010
M x AR	-34.874**	-9.703**	-30.282*	-33.426**	8.050	1.500**	-2.914*	-0.274	-2.870**	-0.285	0.004
MF x LJ	-19.474**	-4.877**	31.408*	-19.859**	7.614	1.600**	-1.874	0.336	-0.404	1.787	-0.016
MF x OG	5.293	-0.854	-27.392*	6.774	2.367	-0.533	-1.587	-0.364	0.096	1.792	-0.034

Table 30 continued.

Genotypes	Number of fruits per spadix	Percentage of fruit set	Days for seed maturity	Number of seeds	Seed germination (%)	Days for germination	Seedling survival (%)	Number of leaves per seedling	Days from emergence to maturity of leaves	Leaf area (cm^2)	Internodal length (cm)
MF x DT	-39.941**	-9.948**	-8.995	-42.859**	-6.350	-2.100**	0.608	-0.439	0.230	3.321*	0.014
MF x LW	21.559**	3.840**	-8.305	22.074**	5.010	0.833*	-3.667**	0.696	-1.104**	-0.218	0.019
MF x AR	18.459**	2.347*	-5.582	21.374**	2.738	-1.500**	-1.171	-0.281	0.263	-2.439	0.024
LJ x OG	-19.307**	-6.349**	-44.525**	-19.226**	-11.363	-0.333	3.902**	-0.424	0.996	-2.382	0.001
LJ x DT	-20.541**	-5.959**	-29.462*	-20.526**	-7.194	0.100	-2.220	0.246	0.463	-3.462*	0.027
LJ x LW	-0.707	-1.116	-16.772	-0.593	-21.201*	0.033	-5.474**	0.269	-0.870	-0.135	0.010
LJ x AR	-13.807**	-4.793**	-21.049	-6.293	13.063	-0.633	6.240**	-0.174	-0.504	-2.107	0.026
OG x DT	5.559	3.464**	33.071*	2.441	0.558	-0.367	-0.660	-0.354	-2.704**	0.211	-0.013
OG x LW	-2.274	1.136	23.095	-1.626	-6.985	1.233**	2.779*	0.202	-0.037	1.492	-0.019
OG x AR	33.293**	12.488**	46.151**	35.674**	-1.683	1.567**	1.130	0.592	1.663**	0.121	-0.014
DT x LW	8.493	2.683*	-25.042	11.407*	-8.813	2.333**	4.388**	-0.328	1.763**	-1.774	-0.004
DT x AR	5.393	0.862	-36.885*	5.041	-10.764	-0.667	-2.915*	0.029	4.130**	-0.772	-0.022
LW x AR	5.226	1.025	1.905	1.974	8.084	-1.733**	-4.194**	-0.114	-1.870**	3.349*	-0.016
SE(ij)	3.910	1.048	14.215	5.150	8.646	0.406	1.385	0.412	0.508	1.464	0.018
SE(ij-ik)	5.865	1.573	21.322	7.725	12.968	0.609	2.078	0.618	0.763	2.196	0.027
SE(ij-skl)	5.530	1.483	20.103	7.283	12.227	0.574	1.959	0.582	0.719	2.070	0.026

* Significant at 5%; ** significant at 1%

4.2.3.4 Number of Seeds

GCA effects ranged from -9.933 to 27.100. The parents P (-5.767), LJ (-8.367), OG (-9.333), DT (-5.700), LW (-8.633) and AR (-9.933) had significant negative GCA effects whereas M (27.100) and MF (20.633) had significant positive GCA effects for number of seeds.

SCA effects ranged from -42.859 to 54.207. The crosses P x LJ (54.207), M x DT (50.674), M x LJ (46.674), OG x AR (35.674), M x MF (29.674), MF x LW (22.074), MF x AR (21.374), M x OG (19.641), M x LW (15.941), P x MF (15.874) and DT x LW (11.407) exhibited significant positive SCA effects.

Significant negative SCA effects were obtained for the crosses MF x DT (-42.859), M x AR (-33.426), P x M (-24.259), LJ x DT (-20.526), MF x LJ (-19.859), LJ x OG (-19.226) and P x OG (-15.159).

4.2.3.5 Seed Germination Percentage

Significant GCA effects were shown by three parents in which, M (10.167) and MF (7.342) had positive effects and DT (-9.970) had negative effect.

The SCA effects for seed germination ranged from -21.201 to 17.191. The cross combination P x DT (17.191) had significant positive SCA effect and LJ x LW (-21.201) had significant negative SCA effect.

4.2.3.6 Days for Germination

The parents M (-1.408) and AR (-0.508) showed significant negative GCA effects and P (1.825), OG (0.525) and DT (0.425) had significant positive GCA effects.

The SCA effects ranged from -3.100 to 5.000. The cross combinations P x DT (5.000), DT x LW (2.333), P x MF (2.167), MF x LJ (1.600), OG x AR (1.567), MF x AR (1.500), M x MF (1.400), OG x LW (1.233), M x OG (1.133) and MF x LW (0.833) showed significant positive SCA effects.

The crosses M x DT (-3.100), P x AR (-3.067), MF x DT (-2.100), M x LW (-1.833), P x OG (-1.767), LW x AR (-1.733), MF x AR (-1.500), P x LW (-1.400) and P x LJ (-1.300) had significant negative SCA effects.

4.2.3.7 Seedling Survival

The parents P (-1.992), M (-3.040) and MF (-3.796) had significant negative GCA effects whereas OG (3.137), DT (1.560) and LW (2.939) had significant positive GCA effects.

The SCA effects ranged from -5.474 to 6.240. The cross combinations with significant positive SCA effects for seedling survival were LJ x AR (6.240), DT x LW (4.388), LJ x OG (3.902), M x MF (3.427) and OG x LW (2.779).

Significantly low SCA effects were obtained for the crosses LJ x LW (-5.474), M x OG (-5.387), P x LJ (-4.556), M x LW (-4.360) LW x AR (-4.194), MF x LW (-3.667), P x LW (-3.153), DT x AR (-2.915), and M x AR (-2.914).

4.2.3.8 Number of Leaves per Seedling

Significant GCA effects were shown by the parents OG (0.328) and DT (-0.442).

SCA effects for number of leaves per seedling were not significantly different and the values ranged from -0.644 to 0.776.

4.2.3.9 Days from Emergence to Maturity of Leaves

The parents P (-1.008), M (-1.275), LW (-1.275) and AR (-0.642) had significant negative GCA effects. MF (1.258), LJ (0.692), OG (0.858) and DT (1.392) had significant positive GCA effects.

The values of SCA effects for days from emergence to maturity of leaves ranged from -3.837 to 4.130.The crosses with significant positive SCA effects for this character were DT x AR (4.130), P x M (3.163), M x LJ (2.130), DT x LW (1.763), P x OG (1.696), OG x AR (1.663) and P x LW (1.163).

Significant negative SCA effects were obtained for the crosses P x DT (-3.837), M x AR (-2.870), OG x DT (-2.704), P x AR (-2.470), P x LJ (-2.137), LW x AR (-1.870), M x LW (-1.237) and MF x LW (-1.104).

4.2.3.10 Leaf Area

A significant positive GCA effect was shown by the parent P (3.155) and a significant negative GCA by AR (-1.596).

The SCA effects for leaf area ranged from -5.057 to 5.673. The crosses P x LJ (5.673), LW x AR (3.349) and MF x DT (3.321) had positive significant SCA effects.

The crosses P x LW (-5.057), LJ x DT (-3.462), and P x DT (-3.365) had negative significant SCA effects.

4.2.3.11 Internodal Length

The parent MF (0.014) had significant positive GCA effects.

The SCA effects for intermodal length were not significantly different. The values ranged from -0.034 to 0.028.

4.2.4 Components of Genetic Variance

Additive and dominance components of genetic variance corresponding to GCA and SCA were calculated and presented in table 31. Compared to additive variances, high dominance variances were observed for the characters number of fruits per spadix (807.786), percentage of fruit set (64.714), days for seed maturity (473.682), number of seeds (728.763), days for seed germination (3.189), days from emergence to maturity of leaves (3.101), leaf area (3.648) and internodal length. Additive variance to dominance variance ratio was more than one for the characters *viz.*, number of leaves per seedling (15.167), percentage of seed germination (5.490) and seedling survival (1.104).

Table 31. Components of genetic variance for various characters in anthurium cultivars

Sl. No	Characters	σ^2_{gca}	σ^2_{sca}	Additive variance $\sigma^2_a = 2\,\sigma^2_{gca}$	Dominance variance $\sigma^2_d = \sigma^2_{sca}$	σ^2_a / σ^2_d
1.	Number of fruits per spadix	150.244	8070.786	300.487	807.786	0.372
2.	Percentage of fruit set	4.932	64.714	9.863	64.714	0.152
3.	Days for seed maturity	186.671	473.682	373.341	473.682	0.788
4.	No. of seeds	146.123	728.763	292.246	728.763	0.401
5.	Seed germination (%)	36.774	13.396	73.549	13.396	5.490
6.	Days for germination	0.662	3.189	1.325	3.189	0.415
7.	Seedling survival (%)	5.769	10.451	11.538	10.451	1.104
8.	Number of leaves per seedling	0.045	0.006	0.091	0.006	15.167
9.	Days from emergence to maturity of leaves	1.002	3.101	2.005	3.101	0.647
10.	Leaf area	1.295	3.648	2.589	3.648	0.710
11.	Internodal length	-	-	-	-	--

4.2.5 Vegetative and floral characters of the hybrids

Data pertaining to the vegetative and floral characters (Table 32) and qualitative characters (Table 33) of 35 hybrids which flowered (32 hybrids of the selected parental combinations and three hybrids from the preliminary compatibility evaluation) are given below (Plate 25).

AR x DT: Plant height at flowering was 42.3 cm. The hybrid flowered 28 months after planting. Inclination of spadix to spathe is 50°. Average spathe length is 12.3 cm with a breadth of 9.4 cm. Spadix length is 7.2 cm. Spathe colour is red and spadix colour is pinkish yellow.

AR x LJ: Spathe colour is coral with light pink spadix. The hybrid flowered 22 MAP. Inclination of spadix to spathe is 85°. Plant height at flowering was 39.4 cm. Average spathe length is 8.4 cm with a breadth of 5.9 cm. Spadix length is 6.8 cm.

AR x M: Plant height at flowering was 40.1 cm. The hybrid flowered 24 MAP. Inclination of spadix to spathe is 40°. Average spathe length is 8.2 cm with a breadth of 6.4 cm. Spadix length is 6.2 cm. Spathe colour is pinkish red with yellow spadix.

AR x OG: Plant height at flowering was 36.3 cm. The hybrid flowered 21 MAP. Inclination of spadix to spathe is 75°. Average spathe length is 6.2 cm with a breadth of 5.3 cm. Spadix length is 5.1 cm. Spathe colour is red with yellow spadix.

AW x DT: Spathe colour is dark pink with creamy yellow spadix. The hybrid flowered 19 MAP. Inclination of spadix to spathe is 80°. Plant height at flowering was 43.8 cm. Average spathe length is 9.6 cm with a breadth of 8.3 cm. Spadix length is 4.8 cm.

AW x OG: Spathe colour is orange with yellow spadix. The hybrid flowered 25 MAP. Inclination of spadix to spathe is 70°. Plant height at flowering was 44.2 cm. Average spathe length is 5.2 cm with a breadth of 4.9 cm. Spadix length is 5.3 cm.

Table 32. Vegetative and floral characters of hybrids

Hybrids	Time taken for flowering (months)	Number of leaves	Plant height (cm)	Spathe length (cm)	Spathe breadth (cm)	Spadix length (cm)	Inclination of spadix to spathe (degrees)
AR x DT	28	10	42.3	12.3	9.4	7.2	45
AR x LJ	22	9	39.4	8.4	5.9	6.8	85
AR x M	24	10	40.1	8.2	6.4	6.2	40
AR x OG	21	10	36.3	6.2	5.3	5.1	75
AW x DT	19	11	43.8	9.6	8.3	4.8	80
AW x OG	25	12	44.2	5.2	4.9	5.3	70
DT x AR	24	9	40.4	7.6	6.1	5.1	45
DT x LW	23	10	42.8	8.4	6.4	6.1	45
DT x M	22	10	40.1	6.2	5.8	4.6	85
LJ x DT	25	9	39.9	6.8	5.1	4.8	50
LJ x LW	24	8	42.4	7.3	4.8	6.1	50
LJ x M	23	18	41.3	6.3	5.2	5.5	70
LJ x MF	26	11	42.6	7.4	5.4	5.6	75
LW x AR	27	9	41.8	6.4	5.3	4.9	40
LW x DT	21	6	35.4	6.1	7.3	6.1	85
LW x M	24	8	43.2	7.6	6.1	5.3	60
LW x P	26	11	45.3	6.4	5.1	4.4	35
M x DT	21	13	32.8	6.8	5.1	4.8	60
M x LJ	19	14	42.6	6.3	3.9	4.8	40
M x LW	20	9	36.3	7.1	6.8	6.6	90
M x MF(1)	22	15	46.7	6.5	7.2	6.1	75
M x MW	18	6	32.4	6.8	5.4	4.9	80
M x OG	24	6	44.5	5.8	4.6	4.6	80
MF x AR(1)	20	8	46.3	7.2	5.9	6.8	40
MF x AR(2)	26	10	41.4	7.6	5.7	6.8	90
MF x DT	25	10	41.2	8.4	6.6	5.9	50
MF x LJ	21	8	44.5	8.2	5.7	6.2	45
OG x DT	26	10	38.4	6.3	5.2	4.6	85
OG x LJ	25	11	41.3	7.4	4.9	5.5	85
OG x MF	24	9	39.3	5.2	4.2	4.2	60
P x AR (1)	23	10	42.2	6.6	5.3	5.6	45
P x AR (2)	22	7	36.3	6.4	5.1	4.1	40
P x DT	27	12	44.5	7.8	6.9	5.6	60
P x LJ	22	10	36.2	6.5	6.4	4.8	80
P x M	20	9	41.2	6.7	6.1	4.4	50

X

Agnihotri Red | Dragon's Tongue | AR x DT

X

Agnihotri Red | Lady Jane | AR x LJ

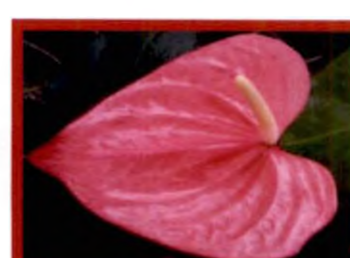
X

Agnihotri Red | Marijke | AR x M

X

Agnihotri Red | Orange Glory | AR x OG

X



Acropolis White | Dragon's Tongue | AW x DT

Plate 25. Parental cultivars and their hybrids

DT x AR: Spathe colour is bright red with red spadix. The hybrid flowered 24 MAP. Inclination of spadix to spathe is 45°. Plant height at flowering was 40.4 cm. Average spathe length is 7.6 cm with a breadth of 6.1 cm. Spadix length is 5.1 cm.

DT x LW: Spathe colour is red with pink spadix. The hybrid flowered 23 MAP. Inclination of spadix to spathe is 45°. Plant height at flowering was 42.8 cm. Average spathe length is 8.4 cm with a breadth of 6.4 cm. Spadix length is 6.1 cm.

DT x M: Spathe colour is bright red with pinkish red spadix. The hybrid flowered 22 MAP. Inclination of spadix to spathe is 85°. Plant height at flowering was 40.1 cm. Average spathe length is 6.2 cm with a breadth of 5.8 cm. Spadix length is 4.6 cm.

LJ x DT: Spathe colour is coral with light pink spadix. The hybrid flowered 25 MAP. Inclination of spadix to spathe is 50°. Plant height at flowering was 39.9 cm. Average spathe length is 6.8 cm with a breadth of 5.1 cm. Spadix length is 4.8 cm.

LJ x LW: Spathe colour is coral with pink spadix. The hybrid flowered 24 MAP. Inclination of spadix to spathe is 50°. Plant height at flowering was 42.4 cm. Average spathe length is 7.3 cm with a breadth of 4.8 cm. Spadix length is 6.1 cm.

LJ x M: Spathe colour is light pink with reddish pink spadix. The hybrid flowered 23 MAP. Inclination of spadix to spathe is 70°. Plant height at flowering was 41.3 cm. Average spathe length is 6.3 cm with a breadth of 5.2 cm. Spadix length is 5.5 cm.

LJ x MF: Spathe colour is light pink with yellow spadix. The hybrid flowered 26 MAP. Inclination of spadix to spathe is 75°. Plant height at flowering was 42.6 cm. Average spathe length is 7.4 cm with a breadth of 5.4 cm. Spadix length is 5.6 cm.

Acropolis White

X

Orange Glory

AW x OG

Dragon's Tongue

X

Agnihotri Red

DT x AR(1)

Dragon's Tongue

X

Lima White

DT x LW

Dragon's Tongue

X

Marijke

DT x M

Lady Jane

X

Dragon's Tongue

LJ x DT

Plate 25. Parental cultivars and their hybrids (contd.)

Table 33. Colour of spathe, spadix, petiole and young leaf of hybrids

Hybrids	Colour of spathe	Colour of spadix	Colour of petiole	Colour of young leaf
AR x DT	Red	Pinkish yellow	Brownish green	Brownish green
AR x LJ	Coral	Light pink	Green	Green
AR x M	Pinkish red	Yellow	Green	Green
AR x OG	Red	Yellow	Greenish brown	Greenish brown
AW x DT	Dark Pink	Creamy yellow	Green	Green
AW x OG	Orange	Yellow	Green	Green
DT x AR	Bright red	Red	Brownish green	Brownish green
DT x LW	Red	Light pink	Brownish green	Brownish green
DT x M	Bright Red	Creamy yellow	Green	Green
LJ x DT	Coral	Light pink	Green	Green
LJ x LW	Coral	Pink	Green	Green
LJ x M	Light Pink	Reddish Pink	Green	Green
LJ x MF	Light pink	Yellow	Green	Green
LW x AR	Bright pink	Yellow	Green	Green
LW x DT	Light Pink	Yellow	Greenish brown	Greenish brown
LW x M	White with light blush in lobes	Light yellow	Greenish brown	Green
LW x P	Coral	White and yellow	Green	Green
M x DT	Coral Pink	Yellow	Brownish green	Brownish green
M x LJ	Light Pink	Yellow	Greenish brown	Green
M x LW	Pink with light green veins	pink	Green	Green
M x MF(1)	Reddish Pink	Reddish Pink	Brownish green	Brownish green
M x MW	Light Pink	Dark Pink	Green	Green
M x OG	Pink	Dark Pink	Greenish brown	Green
MF x AR(1)	Red	Red	Green	Green
MF x AR(2)	Coral Pink	Pink	Green	Green
MF x DT	Pink	Orange- yellow	Brownish green	Brownish green
MF x LJ	Dark Pink	yellow	Green	Green
OG x DT	Coral	Pink	Brownish green	Brownish green
OG x LJ	Light pink	yellow	Green	Green
OG x MF	Light pink	Light yellow	Green	Green
P x AR (1)	Dark pink	Pink	Brownish green	Brownish green
P x AR (2)	Dark Pink	yellow	Brownish green	Brownish green
P x DT	Red	red	Green	Green
P x LJ	Light pink	Yellow	Brownish green	Brownish green
P x M	Dark pink	yellow	Green	Green

Lady Jane

X

Lima White

LJ x LW

Lady Jane

X

Marijke

LJ x M

Lady Jane

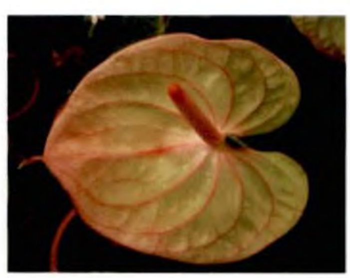
X

Mozaik Fresh

LJ x MF

Lima White

X



Marijke

LW x M

Lima White

X

Agnihotri Red

LW x AR

Plate 25. Parental cultivars and their hybrids (contd.)

LW x DT: Spathe colour is light pink with yellow spadix. The hybrid flowered 21 MAP. Inclination of spadix to spathe is 85°. Plant height at flowering was 35.4 cm. Average spathe length is 6.1 cm with a breadth of 7.3 cm. Spadix length is 6.1 cm.

LW x P: Spathe colour is coral with white and yellow spadix. The hybrid flowered 26 MAP. Inclination of spadix to spathe is 35°. Plant height at flowering was 45.3 cm. Average spathe length is 6.4 cm with a breadth of 5.1 cm. Spadix length is 4.4 cm.

LW x AR: Spathe colour is bright pink with yellow spadix. The hybrid flowered 27 MAP. Inclination of spadix to spathe is 40°. Plant height at flowering was 41.8 cm. Average spathe length is 6.4 cm with a breadth of 5.3 cm. Spadix length is 4.9 cm.

LW x M: Spathe colour is white with light blush in lobes and light yellow spadix. The hybrid flowered 24 MAP. Inclination of spadix to spathe is 60°. Plant height at flowering was 43.2 cm. Average spathe length is 7.6 cm with a breadth of 6.1 cm. Spadix length is 5.3 cm.

M x DT: Spathe colour is coral with yellow spadix. The hybrid flowered 21 MAP. Inclination of spadix to spathe is 60°. Plant height at flowering was 32.8 cm. Average spathe length is 6.8 cm with a breadth of 5.1 cm. Spadix length is 4.8 cm.

M x LJ: Spathe colour is light pink with yellow spadix. The hybrid flowered 19 MAP. Inclination of spadix to spathe is 40°. Plant height at flowering was 42.6 cm. Average spathe length is 6.3 cm with a breadth of 3.9 cm. Spadix length is 4.8 cm.

M x LW: Spathe is pink with light green veins and pink spadix. The hybrid flowered 20 MAP. Inclination of spadix to spathe is 90°. Plant height at flowering was 36.3 cm. Average spathe length is 7.1 cm with a breadth of 6.8 cm. Spadix length is 6.6 cm.

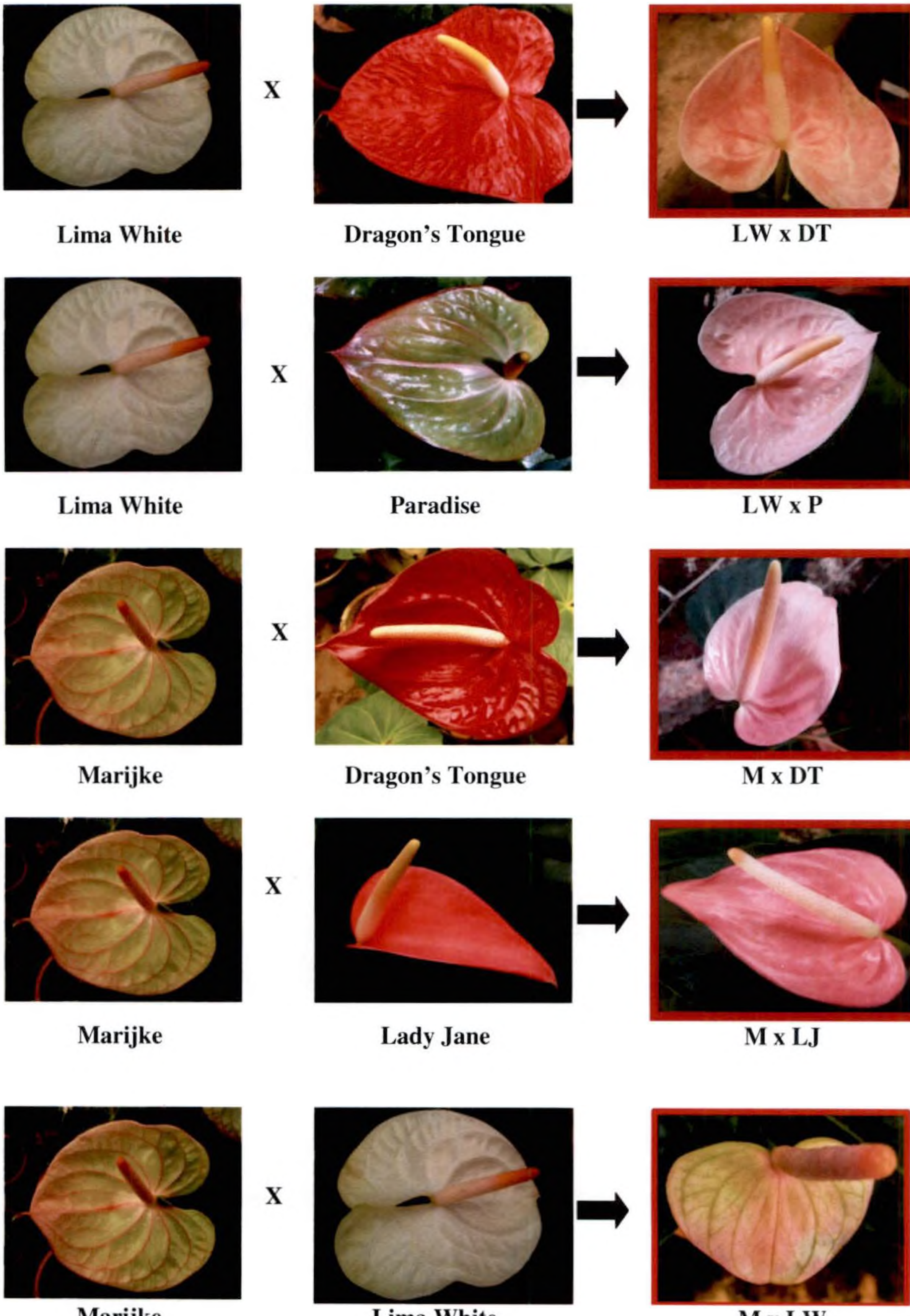


Plate 25. Parental cultivars and their hybrids (contd.)

M x MF (1): Spathe colour is reddish pink with reddish pink spadix. The hybrid flowered 22 MAP. Inclination of spadix to spathe is 75°. Plant height at flowering was 46.7 cm. Average spathe length is 6.5 cm with a breadth of 7.2 cm. Spadix length is 6.1 cm.

M x MW: Spathe colour is light pink with dark pink spadix. The hybrid flowered 18 MAP. Inclination of spadix to spathe is 80°. Plant height at flowering was 32.4 cm. Average spathe length is 6.8 cm with a breadth of 5.4 cm. Spadix length is 4.9 cm.

M x OG: Spathe colour is pink with dark pink spadix. The hybrid flowered 24 MAP. Inclination of spadix to spathe is 80°. Plant height at flowering was 44.5 cm. Average spathe length is 5.8 cm with a breadth of 4.6 cm. Spadix length is 4.6 cm.

MF x AR (1): Spathe colour is red with red spadix. The hybrid flowered 20 MAP. Inclination of spadix to spathe is 40°. Plant height at flowering was 46.3 cm. Average spathe length is 7.9 cm with a breadth of 6.9 cm. Spadix length is 6.7 cm.

MF x AR (2): Spathe colour is coral pink with pink spadix. The hybrid flowered 26 MAP. Inclination of spadix to spathe is 90°. Plant height at flowering was 41.4 cm. Average spathe length is 7.6 cm with a breadth of 5.7 cm. Spadix length is 6.8 cm.

MF x DT: Spathe colour is pink with orange-yellow spadix. The hybrid flowered 25 MAP. Inclination of spadix to spathe is 50°. Plant height at flowering was 41.2 cm. Average spathe length is 8.4 cm with a breadth of 6.6 cm. Spadix length is 5.9 cm.

MF x LJ: Spathe colour is dark pink with yellow spadix. The hybrid flowered 21 MAP. Inclination of spadix to spathe is 45°. Plant height at flowering was 44.5 cm. Average spathe length is 8.2 cm with a breadth of 5.7 cm. Spadix length is 6.2 cm.

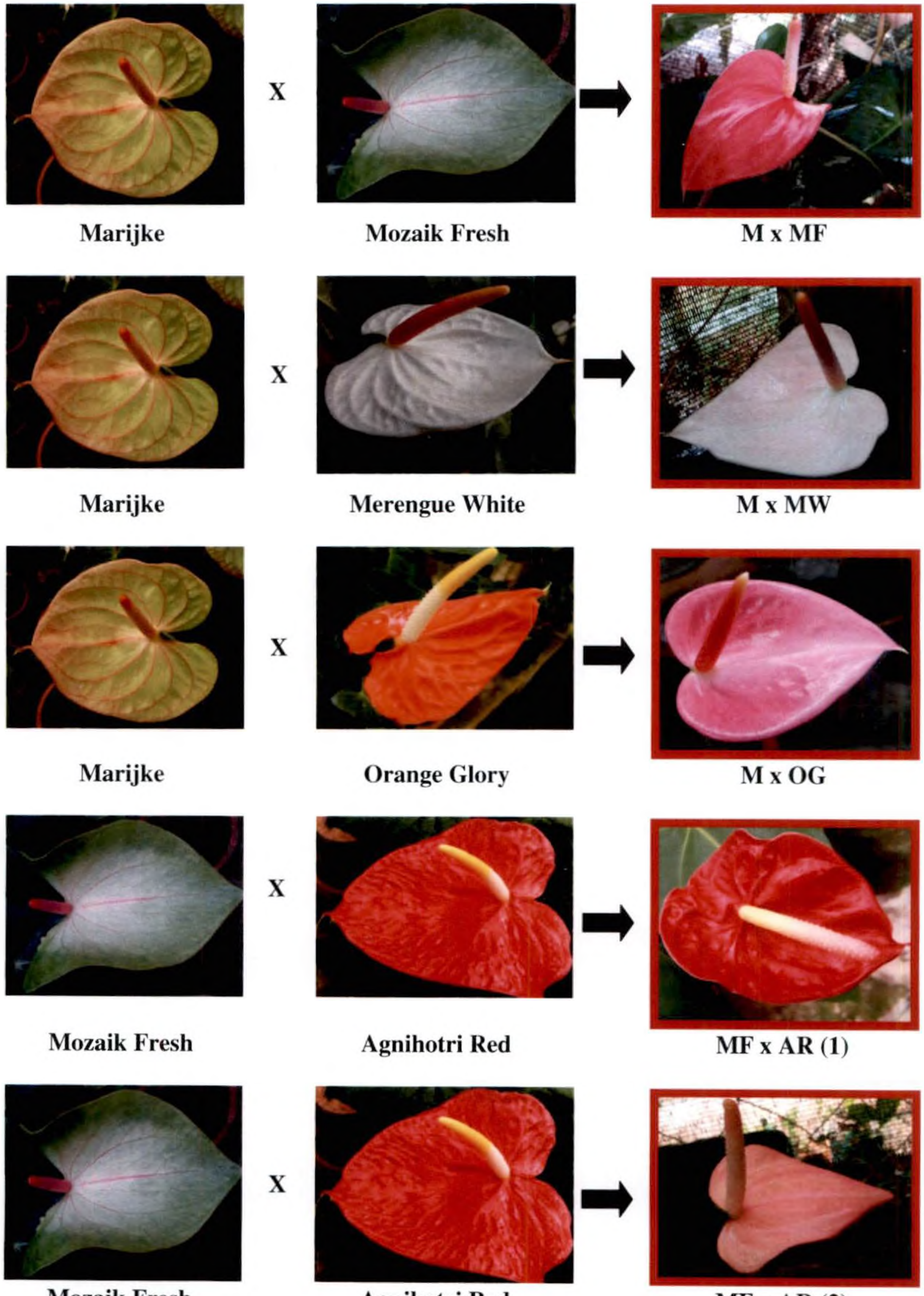


Plate 25. Parental cultivars and their hybrids (contd.)

OG x DT: Plant height at flowering was 38.4 cm. The hybrid flowered 26 MAP. Inclination of spadix to spathe is 85°. Average spathe length is 6.3 cm with a breadth of 5.2 cm. Spadix length is 4.6 cm. Spathe colour is coral with pink spadix.

OG x LJ: Plant height at flowering was 41.3 cm. The hybrid flowered 25 MAP. Inclination of spadix to spathe is 85°. Average spathe length is 7.4 cm with a breadth of 4.9 cm. Spadix length is 5.5cm. Spathe colour is light pink with yellow spadix.

OG x MF: Plant height at flowering was 39.3 cm. The hybrid flowered 24 MAP. Inclination of spadix to spathe is 60°. Average spathe length is 5.2 cm with a breadth of 4.2 cm. Spadix length is 4.2 cm. Spathe colour is light pink with light yellow spadix.

P x AR (1): Spathe colour is dark pink with red spadix. The hybrid flowered 23 MAP. Inclination of spadix to spathe is 45°. Plant height at flowering was 42.2 cm. Average spathe length is 6.6 cm with a breadth of 5.3 cm. Spadix length is 5.6 cm.

P x AR (2): Spathe colour is dark pink with yellow spadix. The hybrid flowered 22 MAP. Inclination of spadix to spathe is 40°. Plant height at flowering was 36.3 cm. Average spathe length is 6.4 cm with a breadth of 5.1 cm. Spadix length is 4.1 cm.

P x DT: Spathe colour is red with red spadix. The hybrid flowered 27 MAP. Inclination of spadix to spathe is 60°. Plant height at flowering was 44.5 cm. Average spathe length is 7.8 cm with a breadth of 6.9 cm. Spadix length is 5.6 cm.

P x LJ: Spathe colour is light pink with yellow spadix. The hybrid flowered 22 MAP. Inclination of spadix to spathe is 80°. Plant height at flowering was 36.2 cm. Average spathe length is 6.5 cm with a breadth of 6.4 cm. Spadix length is 4.8 cm.

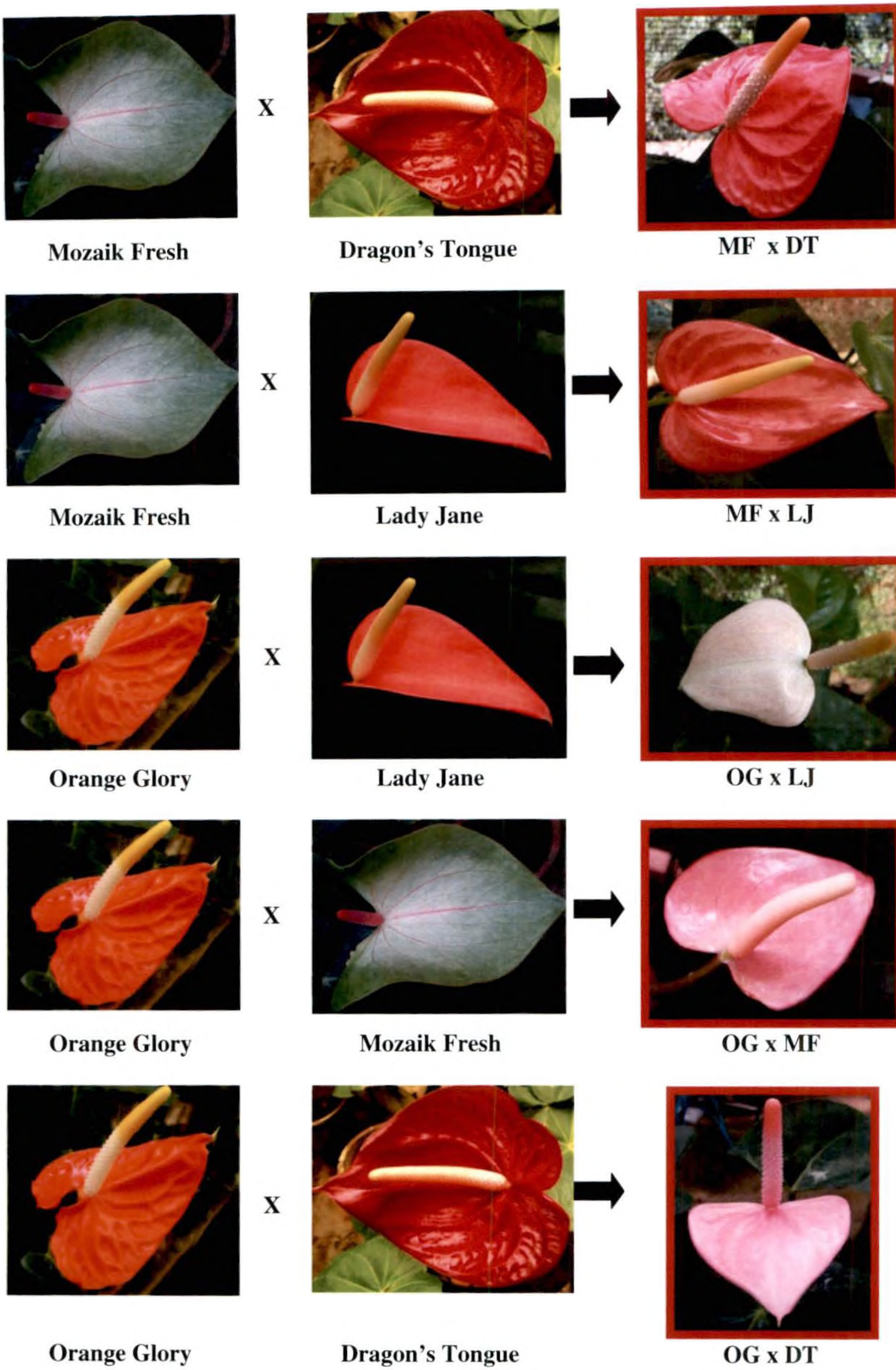


Plate 25. Parental cultivars and their hybrids (contd.)

P x M: Spathe colour is dark pink with yellow spadix. The hybrid flowered 20 MAP. Inclination of spadix to spathe is 50°. Plant height at flowering was 41.2 cm. Average spathe length is 6.7 cm with a breadth of 6.1 cm. Spadix length is 4.4 cm.

The colour of young leaf and petiole of the hybrids showed variations like reddish brown, greenish brown and green.

4.2.6 Qualitative Evaluation of the Hybrids

The 35 hybrids which flowered were scored for qualitative characters (Table 34). The hybrids were ranked from 1 to 35 according to the total score value obtained. The hybrids which obtained the top ten ranks were DT x AR (1), P x DT, M x OG, LW x P, MF x AR (1), MF x DT, LW x AR, LW x M, AR x DT and DT x M.

4.3 EXPERIMENT II: B. *IN VITRO* SEED GERMINATION STUDIES

Fully matured seeds from the cross, 'Marijke x Mozaik Fresh' was used for the *in vitro* seed germination studies.

4.3.1 Standardization of Surface Sterilization

The results of the experiment on standardization of surface sterilization of anthurium seeds are presented in Table 35.

Maximum survival percentage with less incidence of contamination was obtained with the combination in which the seeds were treated with Sodium hypochlorite 2 per cent for 15 minutes. This treatment recorded a survival percentage of 93.33. This was followed by the treatment with Sodium hypochlorite 1.0 per cent for 30 minutes which recorded 90 per cent survival. Lowest survival per cent was obtained for the treatment with mercuric chloride 0.1 per cent for 10 minutes with flaming of the fruits. Among the different treatments tried, none recorded total survival.

4.3.2 Standardization of Media for *In Vitro* Seed Germination

The surface sterilized seeds were cultured in different media treatments. The data on days taken for germination, days for callus initiation and days for

Table 34. Scores obtained for the hybrids for spathe and spadix characters

Hybrids	Spathe characters					Spadix characters			Total	Rank
	Attractiveness of colour	Uniformity of colour	Glossiness	Texture	Overall appearance	Attractiveness of colour	Shape	Stand/ Orientation with respect to spathe		
AR x DT	40	42	34	36	36	38	42	30	298	9
LW x DT	26	24	34	28	24	36	38	22	232	26
P x DT	48	46	44	36	46	42	40	40	342	2
MF x AR (2)	40	36	34	24	30	36	34	30	264	15
P x AR (1)	32	26	28	32	30	30	24	26	228	29
P x M	36	36	34	30	32	36	38	22	264	15
LW x P	46	46	38	42	44	36	36	36	324	4
MF x DT	40	38	40	42	40	42	40	38	320	6
AW x OG	32	34	30	34	24	30	26	24	234	25
M x AR	34	34	32	32	24	32	32	22	242	23
LW x M	44	38	40	38	34	38	38	30	300	8
AR x OG	34	26	28	28	28	28	32	44	248	21
AR x M	32	36	38	30	32	32	32	28	260	18
P x LJ	38	36	34	34	38	30	32	36	278	13
DT x LW	42	34	36	34	38	30	36	32	282	12
AW x DT	36	38	32	36	32	32	34	22	262	17
OG x DT	36	32	32	30	30	28	30	26	244	22
LJ x M	30	28	34	22	28	28	28	34	232	26
LW x AR	46	40	36	38	42	36	36	36	310	7
M x LJ	28	30	26	28	30	28	28	30	228	29
M x DT	28	30	32	24	30	30	30	26	230	27

Table 34 continued.

Hybrids	Spathe characters					Spadix characters			Total	Rank
	Attractiveness of colour	Uniformity of colour	Glossiness	Texture	Overall appearance	Attractiveness of colour	Shape	Stand/ Orientation with respect to spathe		
DT x AR(1)	44	44	44	42	42	42	42	44	344	1
DT x M	42	36	34	40	42	40	36	28	298	9
LJ x DT	36	36	32	30	36	38	28	34	270	14
LJ x LW	34	32	32	28	30	36	32	34	258	19
M x LW	26	24	20	24	22	24	20	16	176	34
M x MF (1)	44	44	40	30	36	26	18	16	254	20
M x MW	34	28	30	24	28	32	24	18	218	31
OG x LJ	26	22	26	22	24	20	16	14	170	35
OG x MF	34	34	30	24	24	20	18	16	200	33
P x AR (2)	42	40	38	38	38	34	28	28	286	11
AR x LJ	34	34	28	22	28	24	18	14	202	32
LJ x MF	36	36	34	24	34	26	24	26	240	24
M x OG	46	42	42	40	46	42	40	30	328	3
MF x AR (1)	46	46	38	38	46	34	34	40	322	5

formation of first leaf were subjected to statistical analysis and the results are presented along with the data on germination percent and survival of seedlings (Table 36).

4.3.2.1 Effect of Different Media on Days Taken for Germination

Maximum number of days taken for seed germination was recorded in the treatment full MS + BA 2.0 mg l^{-1} with a value of 8.96 followed by 8.50 days in the treatment MS + BA 0.5 mg l^{-1}. Early germination (8.19 days) was obtained in the treatment with half MS without growth regulators, which was on par with the treatment with full MS without growth regulators (8.31 days) and the treatment MS + BA 1.0 mg l^{-1}(8.38 days).

4.3.2.2 Days Taken for callus Initiation

Maximum number of days taken for callus initiation was in the treatment MS + BA 0.5 mg l^{-1}, which took 37.74 days. The minimum number of days taken for callus initiation was in the treatment MS + BA 2.0 mg l^{-1} with a value of 26.62 days. The treatment MS + BA 1.0 mg l^{-1} took 33.72 days for callus initiation. The treatments without growth regulators did not produce callus.

4.3.2.3 Days Taken for Formation of First Leaf

All the media selected showed significant difference in the formation of first leaf in the plants. Days taken for formation of first leaf were highest in MS + BA 0.5 mg l^{-1}, which took 45.38 days which showed significant difference with that of MS + BA 1.0 mg l^{-1} with 42.50 days. The lowest number of days taken for formation of first leaf (22.25 days) was in the treatment full MS without growth regulators which was on par with the treatment half MS without growth regulators with a value of 23 days.

4.3.2.4 Germination Percentage

Highest germination per cent (90.00) was obtained in the treatment full MS without growth regulators followed by 83.33 per cent in the treatment half MS without growth regulators. Lowest germination per cent was obtained in the treatment MS + BA 2.0 mg l^{-1} with 63.33 per cent germination. The other

Table 35. Details of surface sterilization of anthurium seeds

Treatment	Concentration (%)	Duration	Contamination (%)	Survival (%)
Mercuric chloride	0. 1	10 minutes	43.33	56.67
Mercuric chloride	0.2	10 minutes	13.33	86.67
Mercuric chloride + flaming	0.1	10 minutes	53.33	46.67
Mercuric chloride + Bavistin 0.1 %	0.1	10 minutes	16.67	83.33
Sodium hypochlorite	1	30 minutes	10.00	90.00
Sodium hypochlorite	2	15 minutes	6.67	93.33

Table 36.Effect of different media on germination of hybrid seeds of anthurium

Media	Days taken for germination	Days for callus initiation	Days for formation of first leaf	Germination (%)	Survival after one month (%)
MS + BA 0.5 mg l^{-1}	8.50	37.74	45.38	66.67	80.00
MS + BA 1.0 mg l^{-1}	8.38	33.72	42.50	70.00	85.71
MS + BA 2.0 mg l^{-1}	8.96	26.62	36.88	63.33	84.21
Full MS without growth regulators	8.31	No callus	22.25	90.00	96.30
Half MS without growth regulators	8.19	No callus	23.00	83.33	92.00
SE	0.17	0.39	0.59		
CD (5%)	0.49	1.15	1.68	*	*

*Statistical analysis not done

treatments viz., MS + BA 0.5 mg l^{-1} and MS + BA 1.0 mg l^{-1} showed germination percentage of 66.67 and 70.00 per cent respectively.

4.3.2.5 Survival Percentage of the Seedlings After One Month

Seedling survival after one month of germination was highest in the treatment full MS without growth regulators (96.30 %) followed by the treatment half MS without growth regulators (92.00 %). Lowest value was recorded by the treatment MS + BA 0.5 mg l^{-1} with 80.00 per cent survival. Treatments MS + BA 2.0 mg l^{-1} recorded 84.21 per cent and MS + BA 1.0 mg l^{-1} recorded 85.71 per cent survival respectively.

Discussion

5. DISCUSSION

The present study was undertaken with the aim to evaluate introduced cultivars of anthurium for growth, flowering and floral attributes, assessment of their compatibility with cultivars having breeding potential and production of novel anthurium cultivars through inter-varietal hybridization. Performance evaluation, variability studies and combining ability analysis were carried out among the selected cultivars.

In experiment I, performance evaluation of nine introduced anthurium cultivars was carried out and morphological and floral characters were assessed for a period of two years. Differential responses were exhibited by the cultivars in the vegetative characters during the period of study. The cultivar Marijke exhibited significantly higher plant height throughout the observation period (Fig. 1). The cultivar Paradise was found to be on par with Marijke in plant height at 24 months after planting (58.15 and 59.24 cm respectively). Significantly lesser plant height was exhibited by the cultivar Red Amour with a value of 29.29 cm and Anastasia with a value of 30.20 cm after 24 months of planting. Plant height was reported as a varietal character (Bindu and Mercy, 1994) influenced by nutrients supplied to plants (Salvi, 1997; Abdussammed, 1999; Basheer and Thekkayam, 2012). Similar to the results, significant variation in plant height among different cultivars of anthurium was reported by Sindhu (1995), Renu (1999), Asish (2002), Ravidas (2003) and Madhukumar (2010).

In leaf area, the cultivars exhibited a similar variation during the period of study with Marijke and Paradise recording significantly higher leaf area (253.58 cm^2 and 239.65 cm^2 respectively) and Red Amour recording significantly lower leaf area of 92.18 cm^2 (Fig. 2). Persistent variation in leaf area among anthurium genotypes including hybrids have been reported by several workers. Asish (2002) observed differences ranging from 92.20 to 183.40 cm^2 among fifty genotypes, Premna (2003)

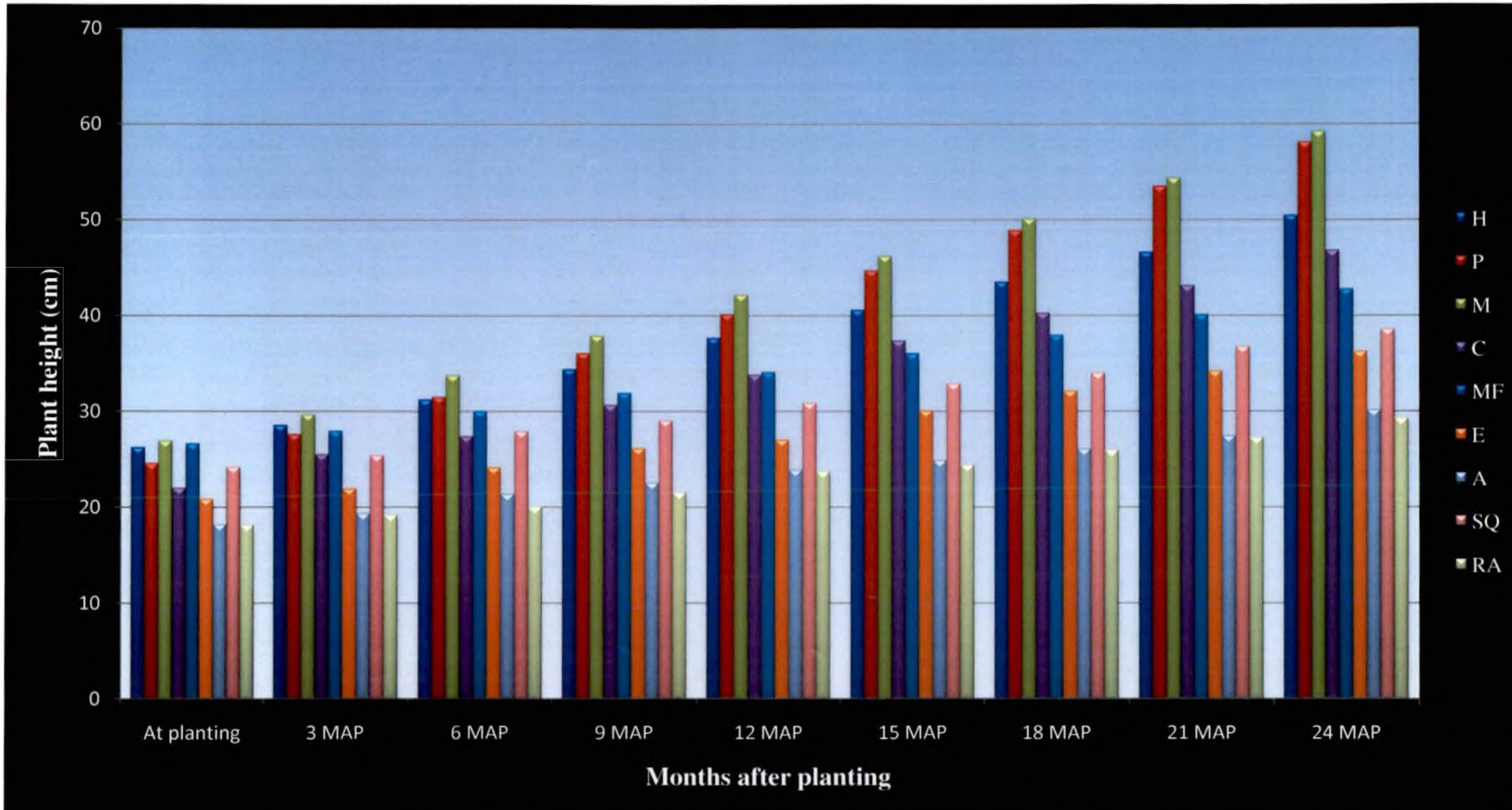


Fig. 1 Plant height of introduced anthurium cultivars

reported values ranging from 113.62 to 301.10 cm^2 in fourteen genotypes and Pravin (2004) recorded a range from 91.97 to 287.76 cm^2 and observed that the variations were based on difference in leaf size of the cultivars. Madhukumar (2010) and Agasimani *et al.* (2011a) reported similar leaf area differences among anthurium cultivars.

Anthuriums were reported to grow slowly and produce only 6 to 8 new leaves and vegetative buds on a stem axis per year (Criley, 1989). Among the cultivars, significantly highest leaf number ranging from 7.88 to 8.75 was observed in Paradise, Marijke, Mozaik Fresh and Salmon Queen with cultivars Hillary, Elizabeth and Cynthia being on par. The leaf number was significantly low in Red Amour and Anastasia that recorded 6.25 and 6.50 leaves respectively. The variation in leaf production among anthurium cultivars was reported as a genetic character (Agasimani *et al.*, 2011a).

In the present study, greater sucker production was observed in Salmon Queen (7 suckers) followed by Marijke and Hillary (3 suckers each) and Mozaik Fresh and Elizabeth (one sucker each). As observed in this study, varietal difference in sucker production was reported by Higaki and Rasmussen (1979). Kamemoto and Nakasone (1963) reported that suckering was a genetically transmitted trait aiding in propagation. However, extreme proliferation of suckers was found to affect flower production. Most of the good commercial and hybrid cultivars were found to be shy suckering or did not sucker at all (Mercy and Dale, 1994). They also reported that propagation of hybrid cultivars using suckers was a slow process due to their poor suckering.

The time taken from emergence to maturity of leaves varied among the cultivars from 24.55 to 35.95 days. In anthurium, attainment of maturity of leaves and development of dark green foliage colour is reported to be associated with high rate of photosynthesis (Dai and Paull, 1990). In this study this period was the period from

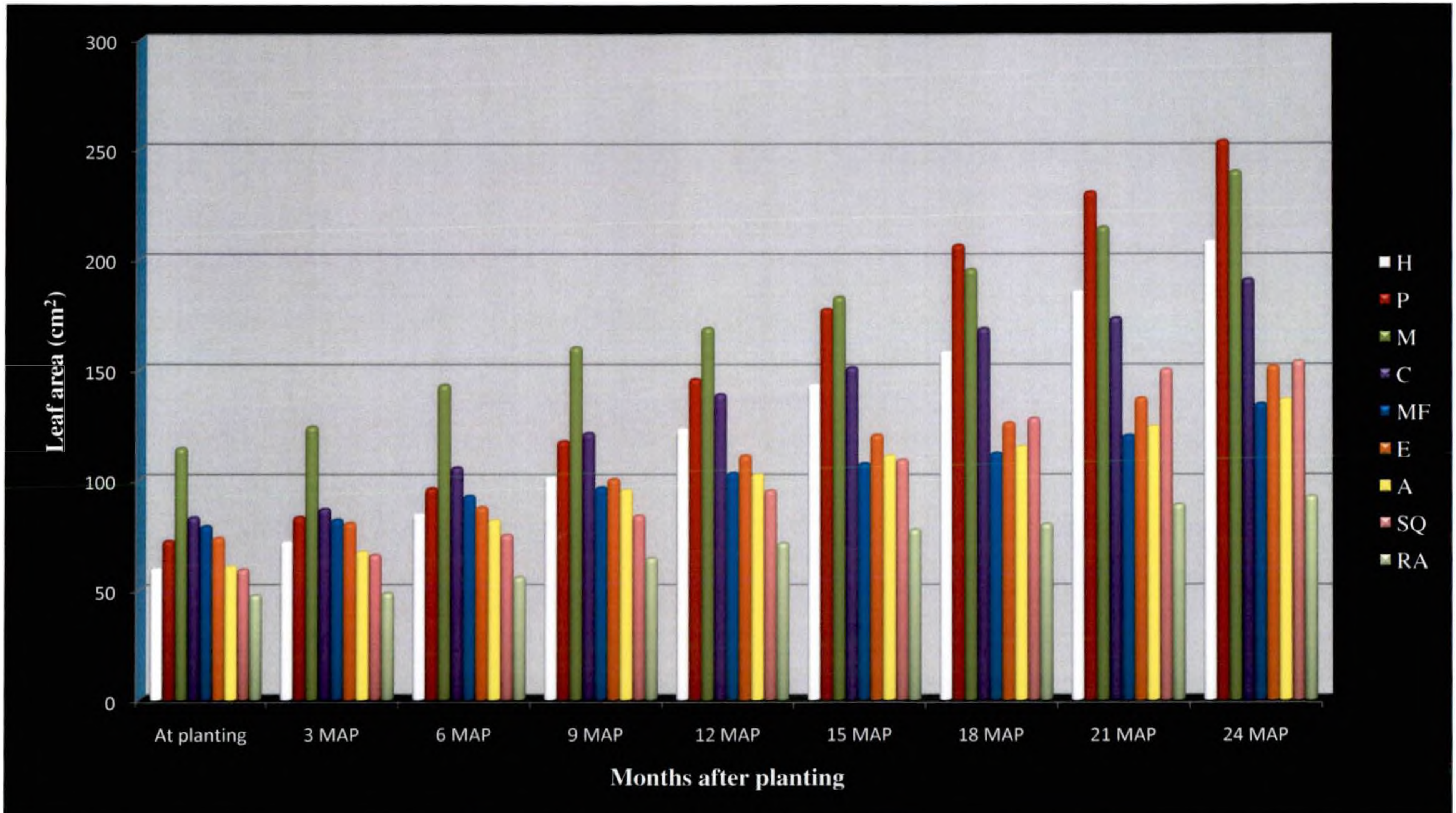


Fig. 2 Leaf area of introduced anthurium cultivars

emergence to maturity which was significantly lowest in the cultivar Red Amour (24.55 days) followed by Elizabeth, Anastasia and Paradise with 26.50, 26.15 and 25.75 days respectively, while it was 35.95 days in cultivar Cynthia. Periods of leaf maturity ranging from 41.40 days in the cultivar 'Honeymoon Red' to 44.40 days in the cultivar 'Pink' was reported by Mayadevi (2001). Madhukumar (2010) reported a range of 25.89 to 36.60 days for attainment of leaf maturity in anthurium.

In internodal length, the taller cultivars Marijke (0.99 cm) and Paradise (0.87 cm) recorded greater values and the shorter cultivars Red Amour (0.45 cm) and Anastasia (0.48 cm) registered the lowest values. In anthurium, higher light intensities were reported to produce shorter internodes and greater shade in the growing environment was reported to promote longer internodes (Higaki *et al.*, 1984). Cultivar and environment differences were observed to influence the length of internodes in the short and thick stems of anthuriums. Shorter internodes in anthurium were reported to be a desirable character resulting in compact habit (Singh, 1987) and delayed transplanting frequency (Kamemoto and Kuehnle, 1996).

Length of the leaf stalk among the cultivars ranged from 21.08 to 38.70 cm with Mozaik Fresh, Marijke, Paradise and Elizabeth (38.70, 37.50, 36.90 and 34.15 cm respectively) recording longer stalk lengths. Along with other characters, long leaf stalk and short internodes with a compact bushy appearance were reported to be desirable attributes of commercial anthurium cultivars by Mercy and Dale (1994).

With respect to the morphological characters of plant height, leaf area, leaf number, length of leaf stalk and internodal length, the cultivars Marijke and Paradise were found to show greater vegetative vigour and the cultivars Hillary, Cynthia, Mozaik Fresh, Elizabeth and Salmon Queen were observed to be moderate in vegetative vigour. The cultivars Red Amour and Anastasia were observed to be lower in vegetative vigour.

Greater flower production was recorded in Salmon Queen, Marijke and Paradise that produced respectively 6.33, 6.17 and 5.92 spadices per year. Significantly lesser flower production was found in Red Amour (2.67) and Anastasia (3.42). Kamemoto *et al* (1986) reported that in anthurium flower yield was influenced by temperature and solar radiation and it varied from 3.4 to 7.6 flowers per plant per year. Several workers evaluating different anthurium genotypes reported significant differences in flower yield (Sindhu, 1995; Renu, 1999; Mayadevi, 2001; Praneetha *et al.*, 2002; Ehrenberger *et al.*, 2003; Madhukumar, 2010 and Islam *et al.*, 2013).

The time taken from emergence to unfurling of spadices was found to be a varietal character influencing the maturity of flowers. From emergence to unfurling of spathe, significantly lowest number of days were recorded in cultivar Marijke (20.75 days) followed by Anastasia (22.75 days). The highest flower production of the cultivar Marijke may be due to the lower time taken by its spadices from emergence to unfurling. However, in the cultivar Anastasia that recorded a shorter period for emergence to unfurling, flower production was found to be equally low. Differences in the duration for emergence to unfurling of spathe varying from 19.00 to 25.33 days was reported by Ravidas (2003).

In the cultivars, differences in spathe length and breadth contributed to differences in spathe size and shape. In spathe length and breadth, the cultivars Mozaik Fresh (12.08 and 10.65 cm), Marijke (12.03 and 9.05 cm), Paradise (11.58 and 9.70 cm), Hillary (11.13 and 9.03 cm) and Cynthia (11.05 and 8.88 cm) were found to record significantly higher values. Red Amour (8.05 and 5.98 cm), Elizabeth (9.15 and 7.48 cm) and Anastasia (8.40 and 7.13 cm) were found to record lower values. The difference between the length and breadth was more distinct in Mozaik Fresh, Marijke, Hillary, Cynthia, Red Amour and Elizabeth, which contributed to their ovate to elongated spathes, and less distinct differences between spathe length and breadth in the cultivars Paradise and Anastasia contribute towards their less ovate spathes. In cultivar Salmon Queen, where spathe breadth (9.06 cm) was greater than spathe length (9.03 cm), the shape was distinctively rounded to broad. In the cultivars Mozaik Fresh, Marijke and Paradise the days from spathe emergence to unfurling was found to be the lowest. In spathe size and spathe/spadix ratio, Mozaik Fresh, Paradise, Marijke and Hillary were found to record higher values. Red Amour and Anastasia recorded lower values.

Spadices curving towards the tip of the spathe at an angle less than 45° is a desirable attribute for commercial anthurium cultivars (Kamemoto and Kuehnle, 1996) aiding in compact packing of flowers in cartons. Among the cultivars of the performance evaluation study, none was found to have such a desirable angle of inclination of spathe and spadix. The lowest angle was observed in Paradise (58.50°) and Hillary (62.25°) followed by Elizabeth (74.00°), Red Amour (70.00°) and Anastasia (70.00°). Salmon Queen, Mozaik Fresh, Marijke and Cynthia had an inclination of 80.00°, 78.33°, 78.25° and 75.00° respectively.

As in the case of vegetative vigour, during the initial years, Marijke and Paradise were found to have higher flower production along with Salmon Queen. However, Marijke also recorded relatively longer days from emergence to unfurling of spathe. The cultivars Mozaik Fresh, Cynthia, Elizabeth and Hillary were found to be moderate in flower production. The cultivars Red Amour and Anastasia, which were observed to be low in vegetative vigour, were found to produce the lowest number of flowers or spadices per plant per year. The latter cultivar also recorded the lowest period from emergence to unfurling of spathe. The more vigourous cultivars Marijke and Paradise recorded higher spathe size along with the moderately vigourous cultivars Mozaik Fresh and Hillary. The moderately vigorous Cynthia, Salmon Queen and Elizabeth were found to be next in spathe size. Red Amour, which was lower in vigour, recorded the lowest spathe size.

The flower stems of Salmon Queen, Paradise, Marijke and Mozaik Fresh placed in tap water without re-cutting the stalk bases recorded a greater vase life of

9.25, 9.00, 8.50 and 8.38 days respectively. The cultivars Anastasia, Red Amour and Hillary were on par with a vase life of 8.25, 7.75 and 7.63 days respectively. Vase life was found to be the lowest in the cultivars Cynthia and Elizabeth (6.50 and 7.25 days respectively). In intact flower stems of anthuriums, vascular occlusions resulting in reduced hydraulic conductivity at the peduncle base was observed to contribute water stress induced senescence symptoms (van Doorn, 1999).

The number of true flowers per spadix was reported to show considerable variation in different genotypes. Bindu and Mercy (1994) reported differences ranging from 50 to 150, Sindhu (1995) observed values ranging from 175 to 325, Renu (1999) recorded a range from 254 to 450, Mayadevi (2001) reported values ranging from 372 to 600 and Madhukumar (2010) observed a range of 196 to 518.6 in the number of true flowers per spadix. In the present study, the number of true flowers per spadix was significantly highest in the cultivar Hillary (408.25). Mozaik Fresh, Marijke, Paradise and Cynthia were on par with flower number ranging from 329 to 358. The number was lowest in Red Amour (164.33), Elizabeth (237) and Salmon Queen (238.36).

In anthurium, the true flowers are generally protogynous and flower opening progress from the base of the spadix upwards. The female phase is usually followed by a short interphase and a male phase. The duration and progress of the female phase is associated with longevity of the spathes and spadices. The maximum post harvest longevity of anthurium flowers is obtained when harvested at 1/3 rd, half or 3/4th progression of the female phase (KAU, 2007). Cultivars with earlier initiation of female phase and shorter duration of the phase tend to attain earlier harvestable maturity. The mean number of days to initiation of female phase in the cultivars ranged from 4.25 to 7.67 days with the cultivar Salmon Queen recording the highest and the cultivar Hillary recording the lowest number of days.

Duration of the female phase in the cultivars varied from 7.33 to 12.67 days and Anastasia, Cynthia and Hillary were on par (12.67, 12.66 and 12.00 days respectively). The lowest mean duration for female phase was recorded by the cultivars Elizabeth (7.33 days) and Marijke (8.69 days).The duration of the interphase varied from 4.33 to 12.00 days in the cultivars, which were observed to have male phase. The cultivar Cynthia which was found to record a higher duration of female phase is found to have the greatest duration of interphase. Marijke, which recorded a lower duration of the female phase, was also found to have the lowest duration of interphase. The cultivar Red Amour which had recorded the lowest number of true flowers among the cultivars (164.33) was not found to have a male phase and pollen production. The cultivar Anastasia too did not find to have a male phase and pollen production. However, it recorded the highest mean duration of the female phase which seemed to indicate functional femaleness during the period of study.

The duration of the male phase in the cultivars ranged from 4.75 to 8.50 days. The highest duration was observed in cultivar Hillary which was also found to have greater duration of the female phase and the highest recorded number of true flowers per spadix. The lowest duration of male phase was found in the cultivar Paradise which had also recorded the lesser duration of interphase (4.75 days) and a medium high duration of the female phase (11.68 days).

Wide variation was observed among the anthocyanin content among the cultivars, which ranged from 2.72 mg g^{-1} to 20.37 mg g^{-1}. The cultivar Red Amour which had orange red spathe recorded the highest value. Next in the content of total anthocyanin was the cultivar Paradise (16.29 mg g^{-1}) which had reddish brown veins and tip, with light green spathes. Salmon Queen which had a pink spathe with green lobes, Anastasia with whitish pink spathes deepening to blush pink and Marijke with diffused greenish pink spathe and pink veins were on par in total anthocyanin content (7.47 mg g^{-1}, 6.79 mg g^{-1} and 5.77 mg g^{-1} respectively). The cultivar Elizabeth with white-blushed pink spathe and reddish pink veins and the cultivar Mozaik Fresh with green lobes and off-white spathe edged with pink veins were on par (5.09 mg g^{-1} and 3.73 mg g^{-1} respectively). The cultivar Hillary having a greenish white spathe and Cynthia having a creamy green spathe colour recorded the lowest values of 3.05 mg g^{-1} and 2.72 mg g^{-1} respectively. Reddish colouration observed on a greater portion of the spathe and reddish brown colouration seen on a lesser portion of the spathe was found to be associated with higher anthocyanin content in the cultivars. Pinkish colouration on the spathe and veins were found to be associated with relatively lower anthocyanin content while white and green colouration on a greater portion of the spathe was found to be associated with the lowest anthocyanin contents.

Pollen fertility of the cultivars during the period of study ranged from 16.75 to 57.08 per cent. The cultivar Marijke had the highest pollen fertility. The lowest pollen fertility was recorded in Hillary, Elizabeth, Cynthia and Salmon Queen, which had a relatively greater duration of male phase. Mercy and Dale (1994) reported pollen fertility varying from 20.40 per cent to 28.80 per cent. Premna (2003) recorded a range of 9.26 to 50.80 percentage. Pravin (2004) reported the highest pollen fertility of 41.67 per cent and most of the genotypes had low fertility values. According to Madhukumar (2010), pollen fertility values ranged from 4.58 to 43.01 per cent.

Pollen shape varied from round to oval in the cultivars and pollen diameter from 11.93 μ in the cultivar Paradise to 26 μ in cultivar Cynthia. Pravin (2004) noticed that the pollen size ranged from 16.80 to 24.97μ. Mean size of the pollen ranged from 14.67 to 25.18 μ in a study conducted by Madhukumar (2010) in 40 genotypes.

Spathe texture differed widely in the cultivars. Blistered nature and glossiness were observed in Marijke and Salmon Queen. Glossiness coupled with shallow blistering was observed in the cultivars Elizabeth and Red Amour. Shallow blistering together with medium glossiness was observed in the cultivar Paradise. The cultivars

Anastasia, Mozaik Fresh and Cynthia had smooth spathe without any blistering. However, the former two also had glossy and medium glossy textures. The cultivar Hillary and Cynthia had non-glossy spathes.

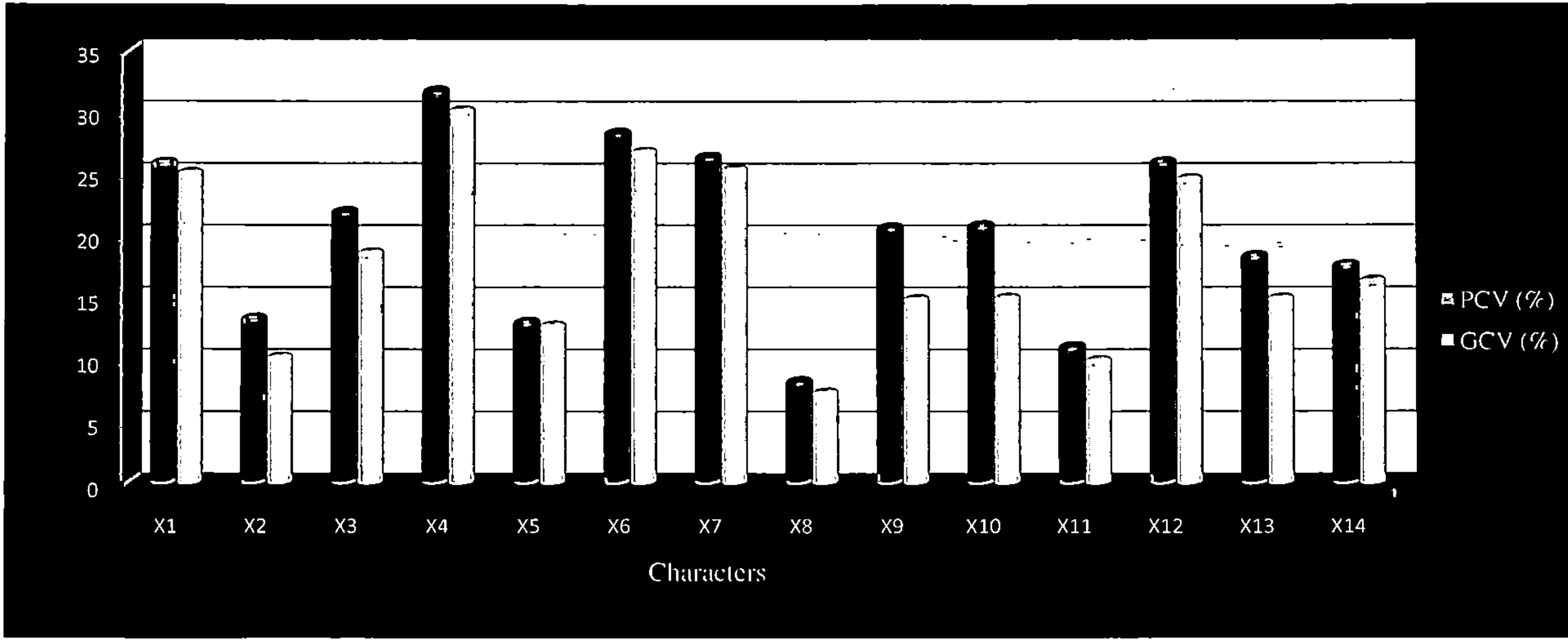
In the cultivars, spadix color varied from the time of unfurling up to attainment of harvestable maturity. In Anastasia, Salmon Queen and Red Amour the spadix colour at unfurling was yellow and changed to pink, white or white and yellow respectively. The cultivars Marijke and Elizabeth in which the spadix was orange yellow or orange red, the color turned to light pinkish green and pink respectively. In Hillary and Paradise, which had green and greenish yellow color at unfurling, spadices became pinkish white and white and yellow respectively. The distinctive color change of the spadices was found to be an index of maturity that was easily observed for harvesting flowers. The greater contrast of spadix color with spathe color observed at this stage also contributed to greater attractiveness in the cultivars.

The young leaves were colored green along with the petioles in the cultivar Hillary, Cynthia, Anastasia, Salmon Queen and Red Amour. In the cultivar Elizabeth, though the young leaves were green, the petioles were brownish green. In the cultivars, Paradise and Mozaik fresh, which had brownish green young leaves and in Marijke, which had reddish brown young leaves, the petioles were coloured brownish green. Colour of young leaves were reported to vary from deep reddish brown to light green (Mercy and Dale, 1994), light green to brown (Sindhu, 1995), brown to reddish brown and greenish brown to green (Premna, 2003) and brown to reddish brown and greenish brown to green and to light green (Madhukumar, 2010). The colour of petiole was reported to vary from purple to green (Sindhu, 1995) and brown to reddish brown to greenish brown to green (Madhukumar, 2010).

Based on the morphological and floral characters of two year old plants, the cultivars were grouped. The cultivars Paradise and Maijke, which were better performers with respect to morphological characters, were found to be higher yielders and had a greater vase life. The cultivars, Salmon Queen, Mozaik Fresh, Hillary, Cynthia and Elizabeth that were moderate in vegetative vigor were also found to be higher yielders and the first two had greater vase life. The cultivars, Red Amour and Anastasia were short in stature and lower in vegetative vigor were found to be lower yielders.

In the variation and correlation study carried out in this experiment, the total variability was partitioned into heritable and non-heritable components with the help of genetic parameters like genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance, for aiding in selection. GCV was reported to provide a valid basis for comparing and assessing the range of genetic diversity for quantitative characters and PCV was observed to measure the extent of total variation in population. In the cultivars, PCV was slightly higher than GCV (Fig. 3) in most of the characters indicating the influence of environment. The variation apparent in the cultivars can thus be attributed to not only due to genotypes but also due to the influence of environment. In most of the characters, the differences between GCV and PCV were very low indicating that these small differences due to the environment on these characters were less. Ravidas (2003) also obtained similar results.

Maximum phenotypic (31.79 %) and genotypic (30.21 %) coefficient of variation were observed for the character leaf area followed by internodal length (PCV 28.41 % and GCV 26.87 %). This indicated a great extent of variability for these characters, thereby suggesting good scope for improvement of these characters through selection. Similar to these results, Asish *et al.* (2003) and Madhukumar (2010) reported high PCV and GCV for leaf area along with total anthocyanin content, pollen fertility, inclination of spadix to spathe and days of interphase. However, high PCV and GCV were reported for the characters plant height, position of spadix, days to initiation of female phase, number of days in female phase and



X1 Plant height (cm)
X2 Number of leaves per plant
X3 Length of leaf stalk (cm)
X4 Leaf area (cm^2)
X5 Days from emergence to maturity of leaves
X6 Internode length (cm)
X7 Number of flowers or spadices per plant per year
X8 Days from emergence to unfurling of the spathe
X9 Spathe length (cm)
X10 Spathe breadth (cm)
X11 Inclination of spadix with the spathe
X12 Number of true flowers per spadix
X13 Days to initiation of female phase
X14 Duration of female phase

Fig. 3 PCV and GCV for fourteen traits in anthurium cultivars

spathe size (Renu, 1999) and number of suckers per plant, number of leaves per plant and number of flowers per plant (Shiva and Nair, 2008c).

The minimum PCV and GCV were recorded by the character days from emergence to unfurling of spathe as 8.38 per cent for PCV and 7.47 per cent for GCV. Inclination of spadix with spathe, days from emergence to maturity of leaves and number of leaves per plant also registered low values of 11.19 per cent and 10.05 per cent, 13.15 per cent and 12.85 per cent, 13.45 per cent and 10.31 per cent respectively at both phenotypic and genotypic levels. Therefore, improvement of these characters has only a limited scope. Asish *et al.* (2003) reported minimum variability for the character days from emergence to inflorescence maturity, number of spadices per plant per year and internodal length.

The characters, spathe breadth (5.85 %), spathe length (5.79 %), days to initiation of female phase (3.42 %), length of leaf stalk (3.31 %) and number of leaves per plant (3.14 %) showed maximum differences between PCV and GCV which indicates that the influence of environment on these characters was considerable. Madhukumar (2010) reported maximum differences between PCV and GCV for the character number of leaves per plant along with days to initiation of female phase, duration of interphase, duration of male phase, spathe size and plant height.

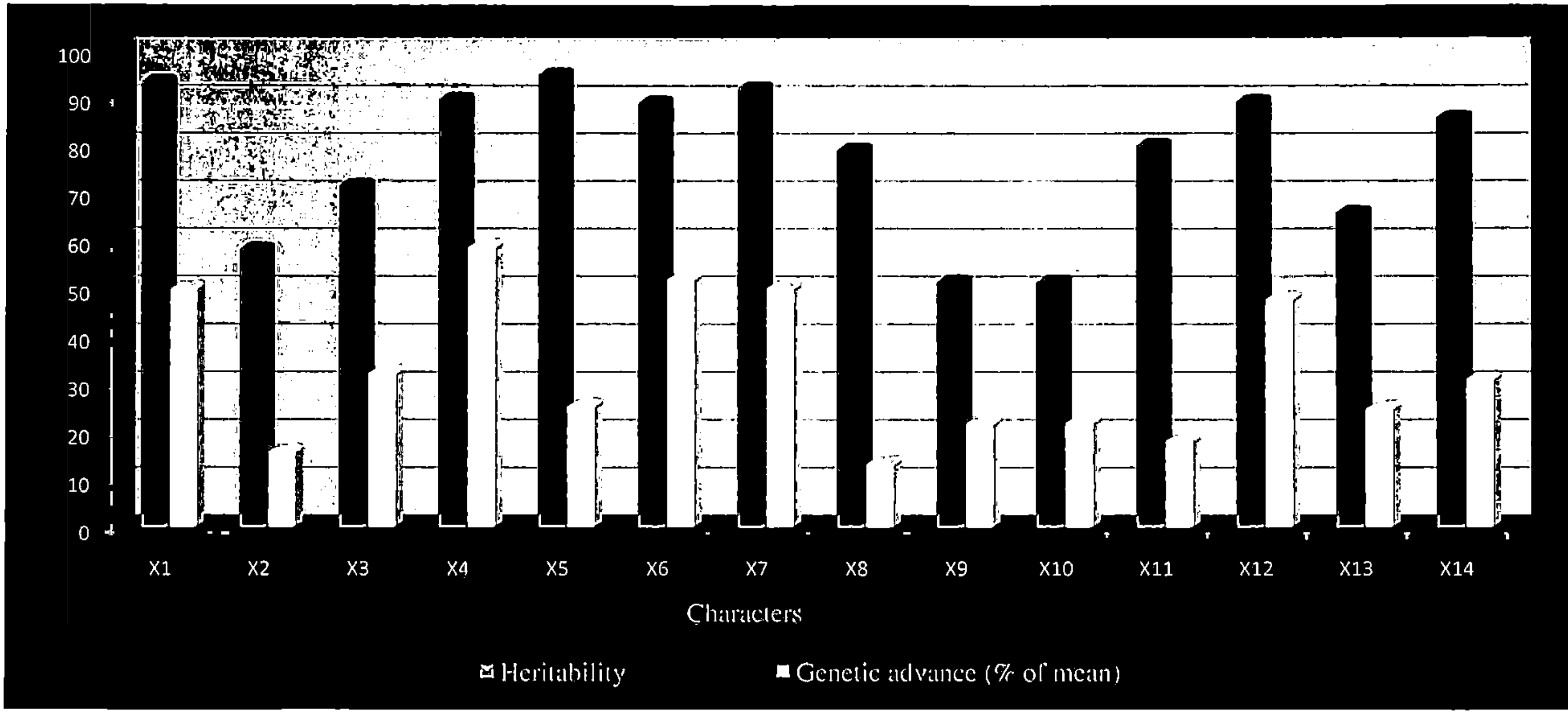
The characters days from emergence to maturity of leaves (0.3 %), plant height (0.8 %), days from emergence to unfurling of spathe (0.91 %) and number of spadices per plant per year (1.01 %) showed low differences between PCV and GCV which indicated environmental influence on these characters was less and selection on phenotypic basis will be suitable. However, Madhukumar (2010) obtained low differences between GCV and PCV for the characters *viz*., total anthocyanin content, pollen size, life of spadix and pollen fertility.

Based on the genotypic and phenotypic variances, low variability was observed for internodal length, number of leaves per plant, number of flowers or spadices per plant per year and days to initiation of female phase. High variability was observed for the characters *viz.*, number of true flowers per spadix, leaf area and plant height. Though Shiva and Nair (2008c) obtained low variability for number of leaves per plant, they obtained low variability for other characters *viz.*, leaf fresh and dry weights, spadix length, number of suckers per plant, leaf size, spathe size and number of coils per spadix.

Allard (1960) has pointed out that genotypic coefficient along with heritability estimates gives better idea about the amount of genetic advance in the next generation. Estimation of GCV alone is not enough to determine the amount of heritable variation. However, high heritability does not necessarily mean a high genetic advance for a particular character. Johnson *et al.* (1955) reported that heritable variation could be estimated with greater degree of accuracy, if heritability is coupled with genetic advance. The assessment of the heritability along with genetic advance was suggested to aid effective selection based on phenotypic performance.

The characters days from emergence to maturity of leaves, plant height, number of flowers/spadices per plant per year, leaf area, internodal length and number of true flowers per spadix recorded high heritability and genetic advance (Fig. 4). High heritability and genetic advance observed for these characters indicated that they may be controlled by additive gene action and their genetic improvement could be possible through selection (Panse and Sukhatme, 1985). Similar to the present study, high heritability coupled with high genetic advance values were reported in anthurium for the characters plant height, leaf area and internodal length by several workers (Mayadevi, 2001; Asish, 2002; Pravin, 2004 and Madhukumar, 2010). Renu (1999) and Asish (2002) reported high heritability and genetic advance for plant height along with number of flowers per candle and Shiva and Nair (2008c) reported high heritability and genetic advance for plant height along with leaf area.

In the present study, the character plant height recorded the highest heritability value along with days from emergence to maturity of leaves, number of



X1 Plant height (cm)
X2 Number of leaves per plant
X3 Length of leaf stalk (cm)
X4 Leaf area (cm^2)
X5 Days from emergence to maturity of leaves
X6 Internode length (cm)
X7 Number of flowers or spadices per plant per year
X8 Days from emergence to unfurling of the spathe
X9 Spathe length (cm)
X10 Spathe breadth (cm)
X11 Inclination of spadix with the spathe
X12 Number of true flowers per spadix
X13 Days to initiation of female phase
X14 Duration of female phase

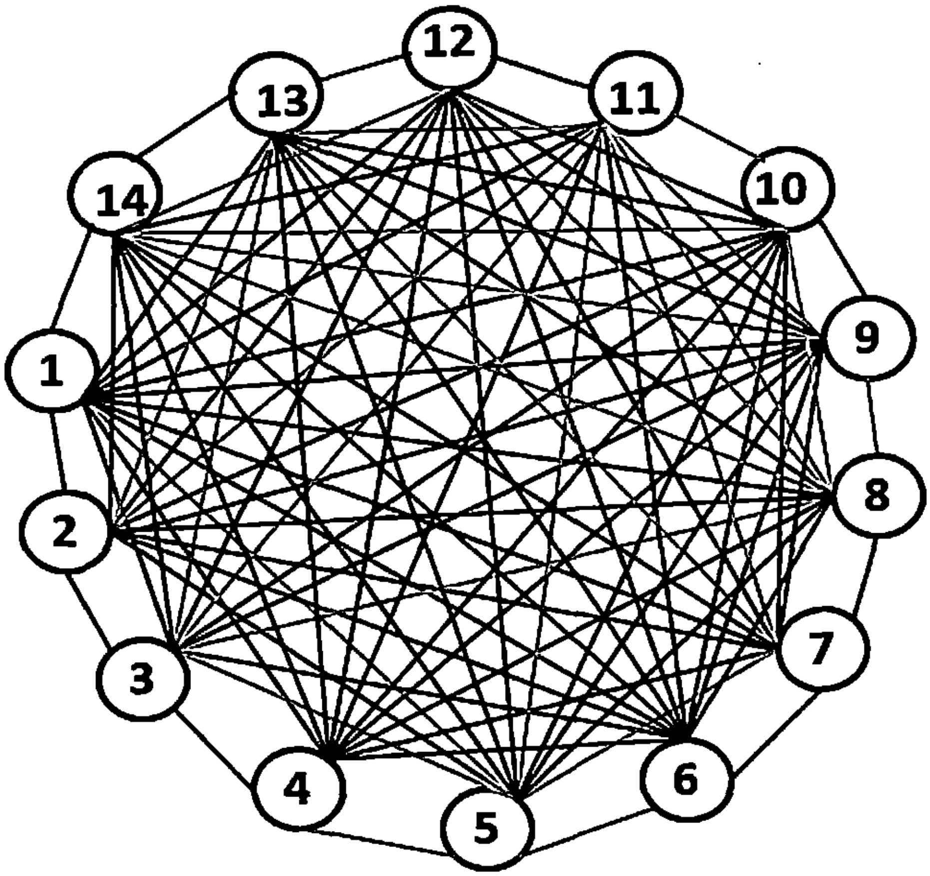
Fig. 4 Heritability and genetic advance as percentage of mean for different characters

spadices per plant per year, leaf area, number of true flowers per spadix, internodal length, duration of female phase, inclination of spadix with spathe, days from emergence to unfurling of spathe, length of leaf stalk and days to initiation of female phase. Similar to this, Sindhu (1995) recorded high heritability for the character plant height along with days to initiation of female phase and Ravidas (2003) reported high heritability value for plant height along with length of flower stalk, length and width of spathe, longevity of spadix on plant and duration of male phase. High to very high heritability for most of the characters might be governed by additive gene action and large proportion of phenotypic variance was due to genotypic variance (less governed by environmental factors) and hence, reliable selection could be made for these traits based on phenotype, which would result in significant improvement in the next generation.

The character leaf area (59.12 %) recorded the highest value for genetic advance as percentage of mean followed by internodal length (52.37 %), number of spadices per plant per year (50.48 %), plant height (50.29 %), number of true flowers per spadix (48.23 %), length of leaf stalk (32.81 %), duration of female phase (31.53 %), days from emergence to maturity of leaves (25.85 %), spathe breadth (22.37 %) and spathe length (22.25 %). High genetic advance was observed for spathe length and breadth, which are economically important characters in anthurium. However, for these characters the heritability percentage was relatively low indicating that selection alone might not result in improvement of these characters. The lowest genetic advance was obtained for days from emergence to unfurling of spathe (13.74 %) followed by number of leaves per plant (16.29 %) and inclination of spadix with the spathe (18.59 %).

Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection is based for genetic improvement for a particular character (Robinson *et al.*, 1949). When selection is applied on a trait, the population under selection is reported to be improved for not only that trait but also in respect of other associated characters (Sharma, 1994). Genetically related characters were observed to move in the same direction under selection favouring any one of such related traits. Such correlated response to selection is the basic property of quantitative traits under the control of polygenic system. The quantitative traits governed by one or a few genes do not exhibit correlated changes on selection. Correlation studies help the plant breeder to ascertain the real components of yield and provide an effective basis of selection. The characters contributing significantly to desirable traits can be identified, and can be used as alternate selection criteria in crop improvement programmes (Cyprien and Kumar, 2011).

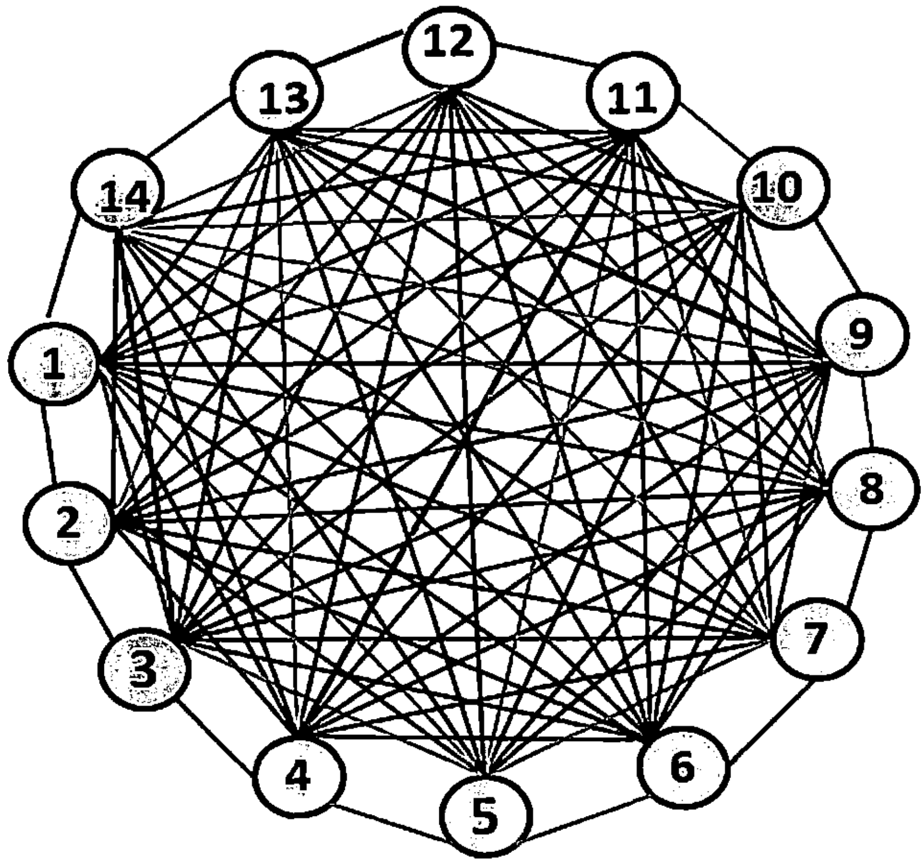
In the present study, phenotypic correlation coefficients (Fig. 5) were observed to be lower than genotypic correlation coefficients (Fig. 6) for most of the characters indicating that in spite of the inherent association between the characters, their phenotypic expressions were lessened. Morphological traits of plant height, number of leaves, leaf area, length of leaf stalk and internodal length were found to be correlated with each other. Positive genotypic and phenotypic correlation thus observed indicate that improvement in any one of this character could bring about a corresponding improvement in the other associated character. Selection for greater plant height could ensure greater internodal length, number of leaves, length of leaf stalk and leaf area in these cultivars. The association of these characters with economic traits such as number of spadices per year, spathe length, and spathe breadth shows that morphological traits are linked with yield contributing or economic traits. However, the strong inherent association between the number of spadices per year and plant height was found to be lessened to an extent under environmental influence as seen by the negative environment correlation observed with it (Fig. 7). Several workers reported significant positive genotypic correlation of plant height with other characters. Mayadevi (2001), Asish (2002) and Madhukumar (2010) reported significant positive genotypic correlation of plant height with leaf



1. Plant height (cm)
2. Number of leaves per plant
3. Length of leaf stalk (cm)
4. Leaf area (cm^2)
5. Days from emergence to maturity of leaves
6. Internode length (cm)
7. Number of flowers/ spadices per plant per year
8. Days from emergence to unfurling of the spathe
9. Spathe length (cm)
10. Spathe breadth (cm)
11. Inclination of spathe with spadix (degrees)
12. Number of true flowers per spadix
13. Days to initiation of female phase
14. Duration of female phase

Positive significant
Positive
Negative
Negative significant

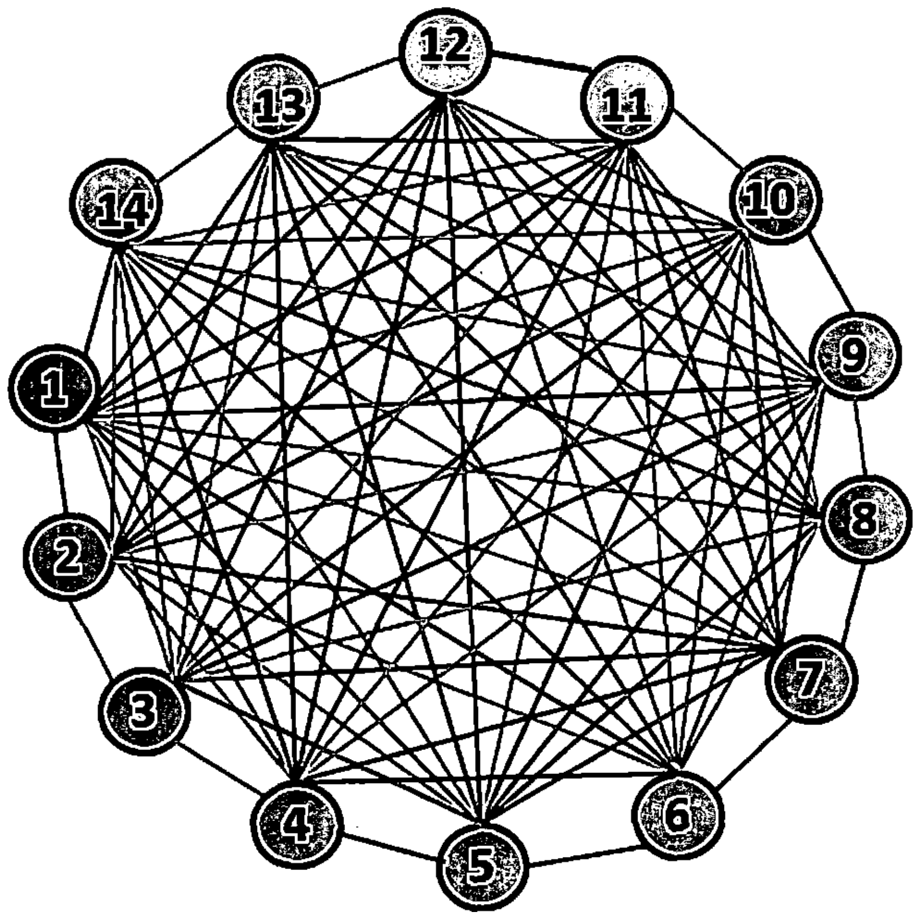
Fig. 5 Phenotypic correlation coefficients among the characters



1. Plant height (cm)
2. Number of leaves per plant
3. Length of leaf stalk (cm)
4. Leaf area (cm^2)
5. Days from emergence to maturity of leaves
6. Internode length (cm)
7. Number of flowers/ spadices per plant per year
8. Days from emergence to unfurling of the spathe
9. Spathe length (cm)
10. Spathe breadth (cm)
11. Inclination of spathe with spadix (degrees)
12. Number of true flowers per spadix
13. Days to initiation of female phase
14. Duration of female phase

Positive significant
Positive
Negative
Negative significant

Fig. 6 Genotypic correlation coefficients among the characters



1. Plant height (cm)
2. Number of leaves per plant
3. Length of leaf stalk (cm)
4. Leaf area (cm^2)
5. Days from emergence to maturity of leaves
6. Internode length (cm)
7. Number of flowers/ spadices per plant per year
8. Days from emergence to unfurling of the spathe
9. Spathe length (cm)
10. Spathe breadth (cm)
11. Inclination of spathe with spadix (degrees)
12. Number of true flowers per spadix
13. Days to initiation of female phase
14. Duration of female phase

Positive significant
Positive
Negative
Negative significant

Fig. 7 Environmental correlation coefficients among the characters

area whereas, Premna (2003) reported positive correlation of plant height with internodal length, leaf area and number of leaves per plant.

The character *viz.*, days from emergence to maturity of leaves was found to have positive genotypic and phenotypic correlation with days from emergence to unfurling of spathe, their length and breadth. Developmental maturity of leaves and spathe as well as spathe size was thus found to be correlated in these cultivars. However, the positive environmental correlations observed between days to maturity of leaves and days from emergence to unfurling of spathe, its length and breadth indicated that positive environmental effect was modifying this association. However, the characters *viz.*, spathe length and breadth were found to have positive phenotypic and genotypic correlation, the dependence of these characters on each other were positively influenced by the environment. This indicated that improvements in these traits are to be considered with respect to the influence of environment on them.

Number of true flowers per spadix was found to have negative phenotypic and genotypic correlation with days to initiation of female phase. This influence indicated that the greater the number of flowers on a spadix, the lesser was the time taken for the initiation of the female phase on the spadix. Thus greater flower number is conducive to greater chances for higher fruit set and seed yield for breeding purpose. So also, a shorter time for initiation of female phase provides a better advantage for earlier attainment of harvestable maturity of spadices.

In experiment II, hybridization and combining ability studies were carried out. The 21 cultivars used for the hybridization studies were evaluated for their floral characters. The annual production of spadices per plant ranged from 3.85 to 8.65 numbers. Significantly higher number of spadices were produced by the cultivar Marijke (8.65) followed by Salmon Queen (7.95) and Paradise (7.55). Red Amour recorded the least number (3.85) of spadices. Flower yield is an important commercial aspect of anthurium cultivars and it is reported to be dependent on

(Kamemoto and Kuehnle, 1996) various parameters like hereditary factors in addition to temperature, light and nutrition.

The time taken for emergence to unfurling of the spathe was found to differ significantly among the cultivars. Among the cultivars, Hawaiian Orange recorded the maximum value (33.00 days) and this period was significantly lower for Marijke and Lima White (20.33 days). In accordance with these results, Ravidas (2003) reported the lowest number of days from emergence to unfurling of the spathe (19.00 days) in cultivar Lima White.

Spathe size is an important commercial aspect in grading anthuriums for determining the price of flowers. Spathe length ranged from 7.47 to 22.23 cm and spathe breadth ranged from 4.07 to 15.70 cm among the cultivars studied. Significantly larger spathe sizes were observed in the cultivars Mozaik Fresh (349.61 cm^2), Lima White (333.43 cm^2), Marijke (267.90 cm^2), Cynthia (262.91 cm^2), Agnihotri Red (233.71 cm^2) and Acropolis White (216.25 cm^2). The cultivars, Lady Jane (31.67 cm^2) recorded significantly smaller spathe size along with Red Amour (48.30 cm^2), Anastasia (73.17 cm^2) and Hawaiian Orange (78.02 cm^2). Similar varietal differences in spathe sizes of anthuriums were reported by Bindu and Mercy (1994), Sindhu (1995), Henny (1999), Renu (1999), Ravidas (2003) and Madhukumar (2010).

Spadix length shorter than spathe and a slight downward curve with lesser angle of inclination with spathe are desirable characters for post harvest handling of anthuriums (Kamemoto and Kuenhle, 1996). Among the cultivars studied, significantly higher spadix length was exhibited by the cultivar Dragon's Tongue (9.10 cm) which was on par with Acropolis White (8.10 cm) and Honduras (7.97 cm). Red Amour (3.57 cm) and Anastasia (4.33 cm) recorded significantly lower values. The cultivars Rosette (41.00°), Tropical Red (41.33°) and Orange Glory (44.67°) had the desirable angle of inclination (Fig. 8) whereas, inclination was significantly

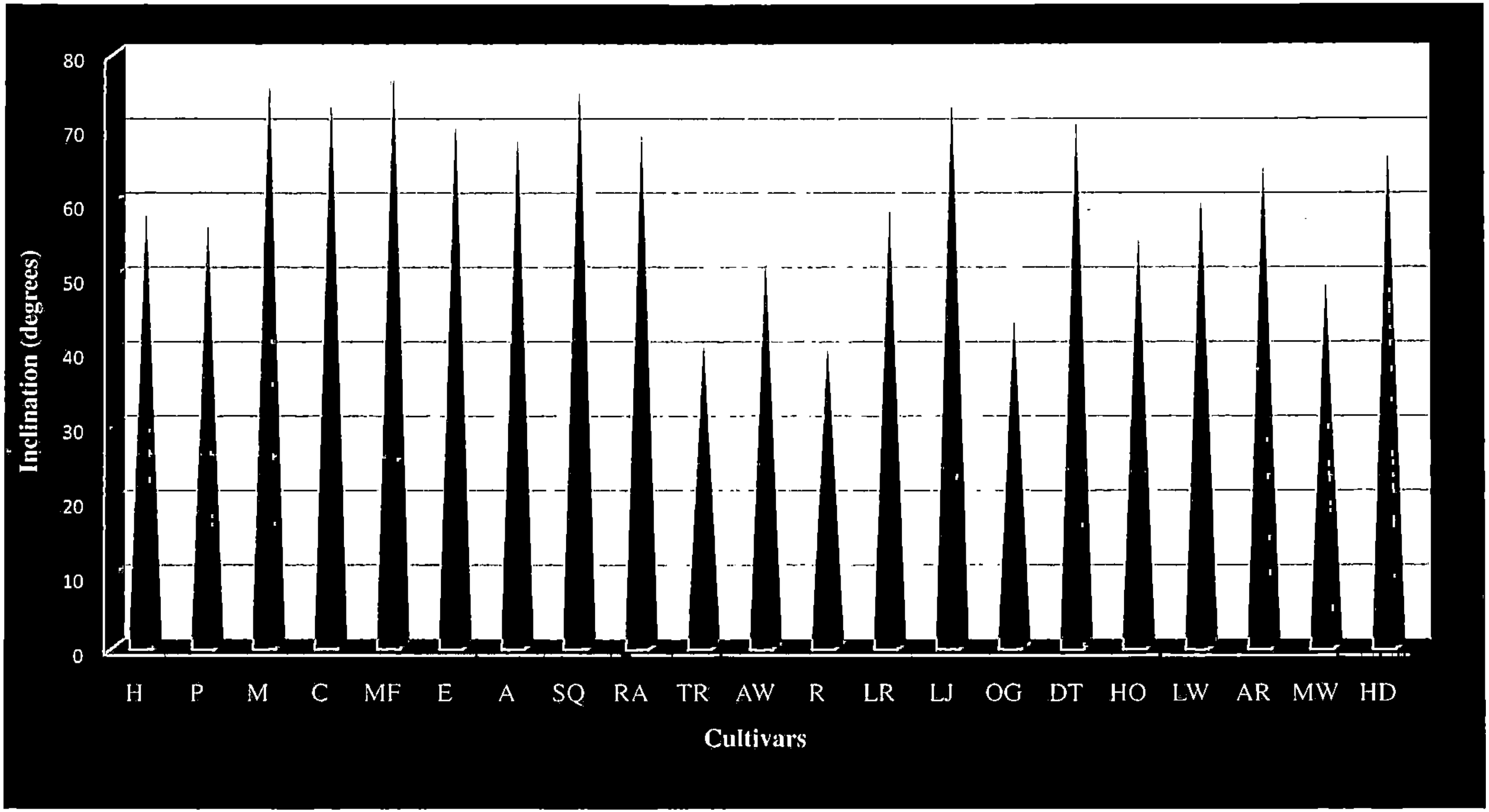


Fig. 8 Inclination of spadix to spathe in anthurium cultivars

higher for the cultivars Mozaik Fresh (78.33°), Marijke (77.67°), Salmon Queen (76.67°), Cynthia (75.00°) and Lady Jane (75.00°). The spathes that are perpendicular to the flower stalk are not convenient for packing and not fully visible in flower arrangements.

High spathe/spadix ratio was reported to be a desirable character by Ravidas (2003) in the evaluation of anthurium cultivars. Spathe/spadix ratio was significantly higher for the cultivar Lima White (55.62) which was on par with Mozaik Fresh (54.57). Significantly lower spathe/spadix ratio was observed in Lady Jane (5.15), Liver Red (12.14), Red Amour (12.32), Hawaiian Orange (13.74), Merengue White (14.92), Orange Glory (15.61), Anastasia (16.61), Rosette (20.29) and Hillary (20.33). However, in the cultivars Tropical Red, Agnihotri Red, Elizabeth and Acropolis White which recorded the values of 31.96, 30.37, 27.77 and 26.64 respectively, there was greater visual appeal of flowers proportionate to their length of spathe and spadix.

Vase life of the flowers kept in tap water ranged from 6.33 to 20.50 days (Fig. 9). Among the cultivars, significantly greater vase life was observed for Honduras (20.50 days). Merengue White recorded the next highest vase life (10.00 days) which was on par with Lima White (9.67 days). The commercially grown cultivars Tropical Red and Acropolis White had a vase life of 8.34 and 9.00 days. Significantly, lesser vase life was observed for the cultivar Lady Jane (6.33 days) which was on par with Cynthia (6.67 days) and Elizabeth (7.34 days). The cultivar Honduras recorded a longer vase life of 45 days in sterile distilled water (Elibox and Umaharan, 2010) and the delayed symptoms of water stress by this cultivar is attributed to its ability to maintain above average water uptake rate over a longer period of time. They proposed that a balance between the factors that affect water uptake in anthurium is determined by the timing, extent and duration of vascular occlusion and factors affect stomatal regulation may contribute to cut-flower senescence in anthurium.

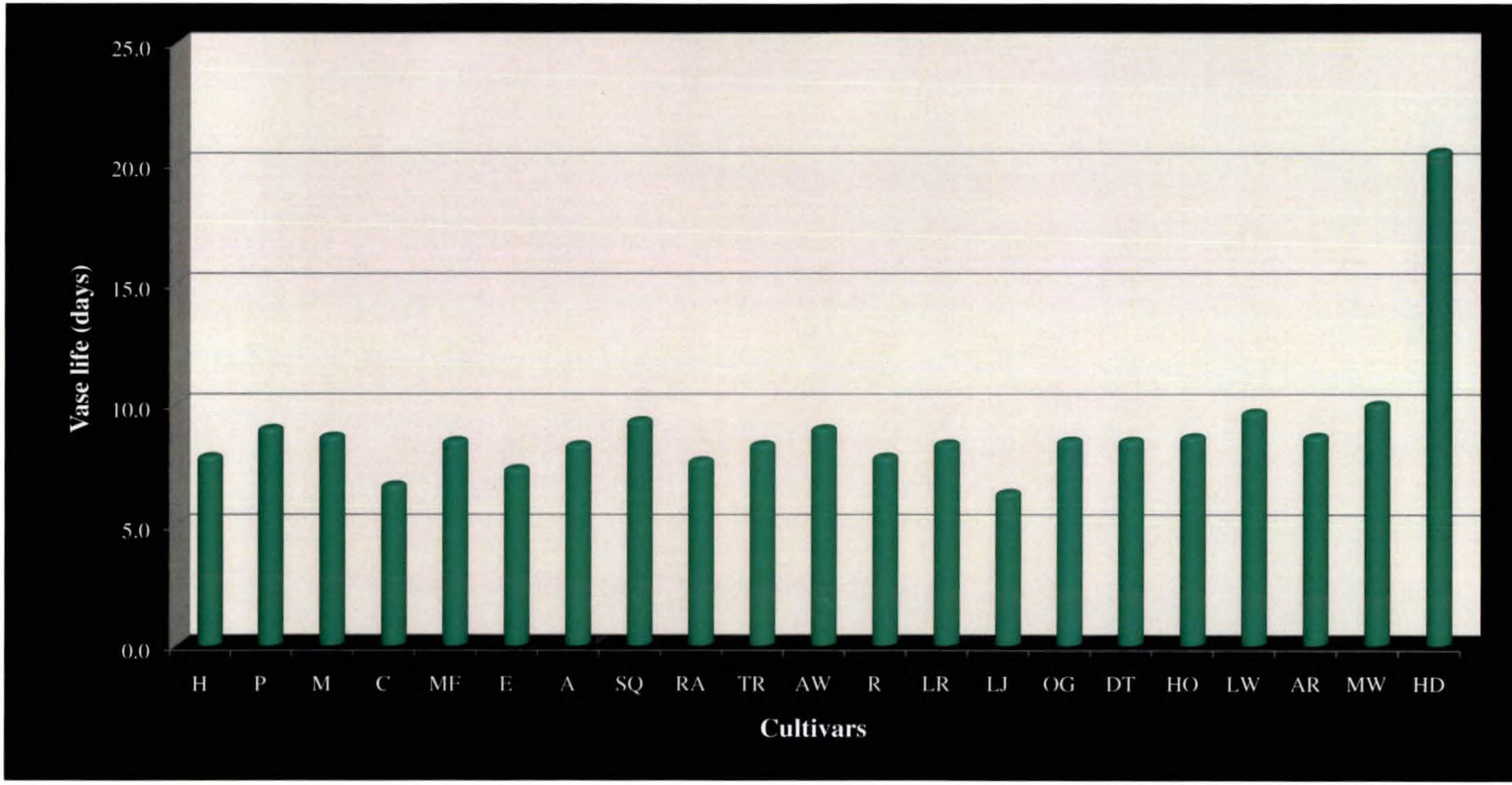


Fig. 9 Vase life of anthurium cultivars

The cultivars varied significantly with respect to the anthocyanin content of the spathe and with variation in the intensity of spathe colour a gradation in the content of anthocyanin was observed. The total anthocyanin content ranged from 1.70 mg g^{-1} to 276.31 mg g^{-1}. In the red coloured cultivars an increase in anthocyanin content with deepening of the red colouration of the spathe was observed.The cultivar Liver Red which had intense dark maroon- red coloration uniformly on the spathe had the highest total anthocyanin content (276.31 mg g^{-1}). The next highest anthocyanin content was observed in Dragon's Tongue (209.78 mg g^{-1}) which had a blood red coloured spathe. The cultivar Honduras with dark dull red spathe had an anthocyanin content of 144.26 mg g^{-1}. Tropical Red and Agnihotri Red with spathe colours ranging from bright red to light bright red showed significant differences and came next with values of 57.03 and 37.39 mg g^{-1} respectively. However, these two had lower anthocyanin content than Liver Red, Dragons Tongue and Honduras, the cultivars showing more intense red coloration on spathe. In cultivars Rosette having bright pinkish orange spathe and Lady Jane having dark pink spathe, the anthocyanin content was on par and nine to ten times lesser than that of Liver Red. Red Amour with orange blended red spathe with green lobes (20.37 mg g^{-1}), Paradise with light green spathe with reddish brown tip and veins (16.29 mg g^{-1}) and Hawaiian Orange with orange spathe (15.61 mg g^{-1}) were on par with respect to total anthocyanin content. The orange cultivar Orange Glory (13.24 mg g^{-1}) was on par with Anastasia having whitish pink spathe that deepens to blush pink (6.79 mg g^{-1}) and Salmon Queen having salmon pink spathe with green lobes (6.79 mg g^{-1}). The cultivar Lima White with white spathes and occasionally green lobes recorded significantly lowest anthocyanin content (1.70 mg g^{-1}). It was on par with the white cultivar Acropolis White, Hillary (greenish white spathe with pink veins), Merengue White (white spathe), Cynthia (creamy green spathe with pink tip) and Mozaik Fresh (off-white spathe with green lobes), Elizabeth (white spathe with pink blush and reddish pink veins) and Marijke (diffused greenish pink spathe with pink veins).

The five major colour groups reported to be associated with spathes of anthurium cultivars are red, pink, orange, coral, and white (Iwata *et al.* 1979). The presence of colourless flavone C glycosides and the absence of anthocyanins were reported in white cultivars (Williams *et al.*, 1981). However, Iwata *et al.* (1985) observed that the colour of anthurium flowers was determined by the concentration and ratio of two anthocyanins, cyanidin 3-rutinoside and pelargonidin 3-rutinoside. These anthocyanins alone or in combination in varying concentrations were found responsible for the expression of the major spathe colours. It was also reported that distinguishing between shades of red and pink or orange and coral was difficult due to variations in concentrations of pigments in different environments and seasons (Kamemoto and Kuehnle, 1996). They also reported that green colour was due to the presence of chlorophyll and brown due to the co-pigmentation of orange and green. Li *et al.* (2013) also reported that the content of the anthocyanin cyanidin 3-rutinoside, and the ratio of cyanidin 3-rutinoside content to pelargonidin 3-rutinoside content were negatively correlated with spathe lightness.

The differences in concentration of the dominant pigments in red, pink and orange cultivars may be exerting influences on colour expression observed in this study. The results suggest that the intensity of red spathe colour expression in red cultivars is related to their higher anthocyanin levels. The findings of Iwata *et al* (1985), that cyanidin 3-rutinoside was observed at nearly ten times the level of absorbance when compared to pelargonidin 3-rutinoside per gram of fresh weight of the tissue in cultivars belonging to the red group endorse these results.

Comparatively pink cultivars were reported to have lesser cyanidin and pelargonidin content than red cultivars. It was further proposed that orange cultivars have both pelargonidin and cyanidin anthocyanins but their relative content of pelargonidin is less when compared to red cultivars. The more intense colour expression of orange cultivars was suggested to be due to pelargonidins having a more pronounced effect on colour expression when compared to cyanidins. In cv. Lady Jane, which is an interspecific hybrid of *Anthurium andreanum* and *A.*

amnicola, the anthocyanin content was significantly greater than the orange cultivars and significantly lesser than in the red cultivars. This may be due to the presence of peonidin 3-rutinoside of the *A. amnicola* parent along with the two other anthocyanins as reported by Marutani *et al.* (1987).

In anthurium, the true flowers are located in the spadix and their number was found to vary from 174 flowers in Red Amour to 502 flowers in Honduras. Significantly greater number of true flowers were recorded by Honduras, Lady Jane and Liver Red followed by Hillary, Hawaiian Orange, Acropolis White, Meringue White, Marijke, Lima White, Rosette, Dragon's Tongue, Cynthia and Paradise. Significantly lower number of true flowers per spadix was exhibited by the cultivar Red Amour.

The mean number of days to initiation of female phase ranged from 3.64 to 7.67. The highest mean value was recorded for the cultivar Orange Glory (7.67 days), Salmon Queen (7.64 days), Hawaiian Orange (7.33 days), Paradise (6.67 days), Elizabeth (6.67 days) and Cynthia (6.65 days). The cultivar Rosette recorded significantly lower value (3.64 days) for this character, which was on par with Mozaik Fresh (4.86 days), Hillary (4.67 days) and Lady Jane (3.67 days). Mercy and Dale (1994) reported significant variation in number of days taken for initiation of female phase, which ranged from 4 to 7 days. Ravidas (2003) reported initiation of female phase in the same day of spathe unfurling in the cultivar Nitta. Madhukumar (2010) also reported a lower duration for initiation of female phase in the cultivar Lady Jane (3.55 days).

The female phase in anthurium proceeds from the base to tip of the spadix and is visible by slight protrusion of stigmas and presence of viscous exudates. Duration of female phase ranged from 6.32 to 13.33 days with significantly high mean duration obtained for the cultivars Rosette and Hillary (13.33 days each), Cynthia (13.31 days), Honduras (13.00 days), Anastasia (12.68 days), Mozaik Fresh (12.33 days) and Paradise (12.24 days). The cultivars Tropical Red and Orange Glory that had relatively lesser number of true flowers exhibited a shorter duration of female phase. The lowest mean duration for female phase was recorded by the cultivars Lady Jane (6.32 days) and Elizabeth (7.33 days). Ravidas (2003) also reported a wide range in female phase from 12.00 to 20.33 days in a study using six anthurium cultivars.

A short interphase between stigma receptivity and pollen emergence was found in the anthurium spadices. In the present study, duration of interphase varied from 4.33 to 12.69 days. Significantly, high duration for interphase was shown by the cultivars Lima White (12.69 days) and Cynthia (12.00 days). The cultivars Marijke (4.33 days), Paradise (4.67 days), Honduras (4.67 days), Orange Glory (4.38 days) and Merengue White (4.38 days) had significantly low duration of interphase. Ravidas (2003) obtained a range of 3.67 to 20 days and Madhukumar (2010) reported a range of 3.55 days to 9.22 days regarding this character.

Male phase was visible by the emergence of pollen grains and like female phase, it proceeded from base to apex of the spadix. The highest mean duration of male phase was obtained for Agnihotri Red (10.65 days). Tropical Red (9.33 days), Lima White (8.69 days), Hillary (8.69 days) and Acropolis White (8.21 days) were on par with respect to duration of male phase. The duration of male phase was the lowest in Paradise (4.67 days). Anastasia, Red Amour, Rosette and Hawaiian Orange did not exhibit male phase. Ravidas (2003) reported a male phase of 9.33 days duration in the cultivar Lima White. Madhukumar (2010) reported a male phase of 10.36 days in the cultivar Acropolis White and observed a range of 3.37 to 10.89 days in the 40 cultivars evaluated.

Pollen emergence pattern observed from March 2011 to February 2013 showed that peak emergence was observed from October to January when mean minimum temperature were low. During this period, the relative humidity differences between the morning and evening hours ranged from 28 to 38 per cent. Poor to absence of pollen production was associated with the months of March to May during which the highest daily minimum temperature was observed. As in the present study, pollen production was observed to be suppressed during the hot months of March to June by Renu (1999), Ravidas (2003) and Madhukumar (2010).

Pollen fertility values ranged from 15.91 to 59.00 per cent. Significantly high pollen fertility values were observed for the cultivars Marijke (59 %), Agnihotri Red (58.59 %), Dragon's Tongue (54.11 %) and Merengue White (52.82 %). The cultivars Hillary (15.91 %) and Elizabeth (16.18 %) had significantly low pollen fertility values. Reduction in pollen fertility suggests genetic divergence of the species (Marutani *et al.*, 1993). The mean size of the pollen ranged from 12.06 μ to 26.20 μ. The cultivars Hillary and Cynthia, which had significantly larger pollen (26.20 and 25.86 μ respectively), were found to be low in pollen fertility. High pollen fertility indicating feasibility as male parents along with greater pollen size in process was found in the cultivars Agnihotri Red, Dragon's Tongue and Meringue White. Significantly lower pollen size was observed in the cultivars Paradise (12.06 μ), Elizabeth (12.14 μ), Liver Red (12.86 μ), Salmon Queen (13.30 μ), Lady Jane (13.38 μ) and Orange Glory (13.44 μ). Pollen shape ranged from round to oval and majority of the cultivars had round pollen except Marijke, Liver Red, Lady Jane and Dragon's Tongue.

Considering all the cultivars evaluated in experiment 2, greater numbers of spadices were produced by the cultivar Marijke which also had greater spathe size, longer spadices and showed a quicker unfurling of spathe. The vase life of the cultivar was 8.68 days. However, the angle of inclination of its spadix was 77. 67°. This cultivar had greater number of true flowers and a relatively shorter duration of female phase, inter phase and male phase. Its anthocyanin content was low as the spathes were coloured diffused greenish pink with pink veins. The cultivar also showed high pollen fertility. The cultivar Red Amour persisted as a low yielder, recording lesser days for days from emergence to unfurling of spathe, spathe size, spadix length, spathe/spadix ratio, vase life and lowest number of true flowers. This cultivar was seemed to be functionally female without a male phase.

The cultivars exhibited variations among the qualitative characters spathe texture, spadix colour and type, colour of young leaf and petiole. Varying degrees of smoothness, blistering and glossiness were observed with respect to the spathe texture of the cultivars. Spadix colour varied from unfurling to ageing and the colour change was observed from base of the spadix to the tip. Maturity of true flowers from the base to apex of the spadix was attributed to the colour change of spadix (Dufour and Guerin, 2003). Carotenoid pigments were reported to be responsible for the bright yellow colour and flavonoids for the other spadix colours (Kamemoto and Kuehnle, 1996). Type of spadix showed variations like short to long, thin to thick and curved to straight. Most of the cultivars had green colour young leaf. Colour of young leaf was brownish green in Paradise, Mozaik Fresh, Tropical Red, Orange Glory and Rosette while it was reddish brown in Marijke, Liver Red and Dragon's Tongue. Agnihotri Red had greenish brown young leaf. Though the colour of petiole in most of the cultivars was green, the colour was found to darken with increase in red colour of the cultivar. Some cultivars like Paradise, Marijke, Mozaik Fresh, Elizabeth, Tropical Red and Rosette had brownish green petiole while the cultivar Liver Red had reddish brown petiole.

Among the eight parents selected for hybridization, 34 crosses showed 100 per cent spadices bearing fruits. Relatively higher cross combinations were obtained by Paradise, Agnihotri Red and Orange Glory as female parents followed by Lady Jane. Similar findings were reported by Pravin (2004), who obtained 100 per cent fruit set for six crosses among 12 successful cross combinations and Madhukumar (2010) recorded 100 per cent fruit set in 41 crosses among 80 successful combinations of anthurium genotypes.

In cultivars showing fruit set, the number of fruits per spadix ranged from six to 137. In crosses with Paradise as the female parent, fruit set was highest with Lady Jane (112 fruits per spadix) and lowest number with Orange Glory (22 fruits per spadix). Among the crosses of Marijke as female parent the values ranged from 32 in the cross M x AR to 137 in the cross M x MF. Considering Mozaik Fresh as a female parent, the cross MF x LW recorded highest number of 98 fruits per spadix and the lowest number of 23 fruits in MF x DT. Among the crosses of Lady Jane as a female parent the number ranged from 13 fruits in LJ x MF to 36 fruits in LJ x LW. Orange Glory as a female parent recorded values ranging from 13 (OG x MF) to 72 fruits (OG x LJ). Dragon's Tongue when used as a female parent recorded a range of 16 (DT x P) to 52 (DT x M) fruits per spadix. Lima White as a female parent recorded a range of six fruits in the cross LW x OG to 62 fruits in the cross LW x LJ whereas Agnihotri Red recorded 10 fruits in the cross AR x DT and 31 fruits in AR x LJ. Variations in number of fruits per spadix was reported to range from 100 to 200 (Mercy and Dale, 1994), 2 to 170 (Sindhu, 1995) and 5 to 85 (Madhukumar, 2010).

Average percentage of fruit set varied from 2.58 per cent in the cross LW x OG to 58.33 per cent in the cross P x LJ. Paradise as a female parent recorded 11. 46 per cent fruit set in the cross P x OG and 58.33 per cent in the cross with Lima White. Marijke as a female parent recorded a range of 8.08 per cent in M x AR to 40.51 per cent in M x OG. In the crosses where Mozaik Fresh as a female parent recorded 4.96 per cent fruit set in MF x DT to 30.50 per cent in MF x LW. Lady Jane as a female parent showed 3.14 per cent fruit set in the cross LJ x AR and 26. 09 per cent in the cross with Lima White. Orange Glory recorded a fruit set of 9.36 per cent in OG x M and 37. 43 per cent in OG x LJ. Dragon's Tongue recorded 8.80 per cent fruit set in the cross DT x MF to 28.70 per cent in DT x OG. Lima White had a fruit set of 2.58 per cent in the combination LW x OG to 26.61 per cent in the combination with Lady Jane. Agnihotri Red in combination with Dragon's Tongue as male parent recorded 6.29 per cent fruit set while with Orange Glory it recorded 35.44 per cent fruit set. Madhukumar (2010) recorded a lowest fruit set of 1.75 per cent in the cross 'Esmeralda x (Pompon Red x Orange Glory)' and highest fruit set of 21.14 per cent in the cross '(Pompon Red x Orange Glory) x (Orange Glory x

Dragon's Tongue)'. Zimmer (1986) reported that absence of full fruit set in anthurium spadix as the major problem in the improvement of anthurium cultivars.

Number of days taken for maturity of seeds ranged from 107.5 days in the cross LJ x DT to 239.5 days in the cross OG x AR. Considering all cross combinations involving Paradise as female parent, the days taken for seed maturity ranged from 134 to 148.5 days. Crosses with Marijke as the female parent took 123.5 to 140 days for seed maturity. In the crosses with Mozaik Fresh as the female parent recorded 135 to 152 days for maturity of seeds. Days taken for seed maturity ranged from 107.5 to 123.5 days in crosses where Lady Jane was the female parent. Orange Glory showed a range of 192 to 239.5 days while Dragon's Tongue showed 203.5 to 215.5 days for seed maturity. Among the crosses in which Lima White as a female parent recorded 152.5 to 169.5 days for seed maturity whereas Agnihotri Red recorded 198 to 212 days for maturity of seeds. In general, shortest seed maturity period was observed in Lady Jane and longest in Orange Glory and Dragon's Tongue. Renu (1999) also reported the lowest seed maturity period in Lady Jane Red (4.4 months) among the 10 cultivars studied. Variations in seed maturity periods were reported in anthurium as 5 to 12 months (Zimmer, 1986), 6-8 months (Singh, 1987), 4 to 7.5 months (Mercy and Dale, 1994), 5 to 6.8 months (Sindhu, 1995) and 4.5 to 7 months (Madhukumar, 2010).

In anthurium, the seeds inside the berries were found to be either single or double. Considering the entire cross combinations together, seven combinations produced all single seeds (P x M, P x LJ, M x MF, MF x LJ, LJ x M, LJ x AR, and AR x DT). The female parents Dragon's Tongue and Orange Glory produced single and double seeds in all the combinations. The cross MF x DT produced the lowest percentage of single seeds (60.87) and highest percentage of double seeds (39.3 %). Percentage of single seeded berries was observed to be higher than double seeded berries. Similar observations were recorded by Sindhu (1995) and Madhukumar (2010). Considering the total number of seeds, the cross M x MF produced maximum number of seeds (146 seeds) followed by M x LJ with 140 seeds and M x DT with 138 seeds. Lowest number of seeds were produced in the crosses LW x OG (7 seeds) and AR x DT (10 seeds).

Size of seeds from the fruits of same cross combination showed variation depending on whether the fruits are double seeded or single seeded. As the number of seeds in the berry increased the average size of seeds decreased. When the fruits with single seeds are considered, maximum seed size was observed for the cross DT x OG with 3.88 mm length and 2.97 mm width. The crosses DT x MF (3.81 x 2.68 mm) and DT x P (3.76 x 2.69 mm) also had larger seeds. The cross LJ x MF (2.14 x 1.64 mm) produced smallest seed among single seeded fruits followed by AR x LJ (2.21 x 1.54 mm) and AR x LW (2.22 x 1.76 mm). Among the fruits with two seeds, the cross M x LW produced the largest seeds (3.11 x 2.24 mm) followed by DT x AR (3.06 x 2.13 mm) and LW x AR (3.01 x 2.18 mm). Smallest seed in the single seeded as well as two seeded fruits were seen in the cross LJ x LW (1.94 x 1.32). Madhukumar (2010) reported maximum seed size of 3.53 x 2.27 mm among the two seeded berries and 4.17 x 3.45 mm in single seeded berries for the cross 'Acropolis White x (Pompon Red x Orange Glory)'.

The percentage of seed germination ranged from 29.17 per cent in the cross OG x DT to 92.96 per cent in M x MF. In the crosses where Paradise as the female parent, the percentage of seed germination ranged from 38.78 per cent in the cross P x MF to 85.71 per cent in P x AR. With respect to the crosses of Marijke, the cross M x AR (76.32 %) recorded the lowest while M x MF recorded the highest germination per cent of 92.96. Among the crosses of Mozaik Fresh, MF x M recorded the highest germination of 83.56 per cent and the cross MF x DT recorded the lowest germination of 50.00 per cent. Among all the eight possible combinations involving Lady Jane, LJ x MF (76.19 %) recorded the highest germination per cent and LJ x LW (42.11 %) recorded the lowest value. Among the crosses of Orange Glory, germination per cent ranged from 35.44 in OG x AR to 64.71per cent in OG x MF.

Dragon's Tongue as a female parent recorded a range of 31.11 per cent in the combination DT x LW to 68.00 per cent in DT x M. Considering Lima White, highest percentage of germination was observed in the cross LW x DT (66.67 %) and lowest in LW x P (42.42 %). Agnihotri Red recorded 33.33 per cent germination in the cross AR x LW and 60.87 per cent in AR x P. Renu (1999) recorded the highest germination of 6.9 per cent while Madhukumar (2010) recorded a range from 19.05 to 71.67 per cent.

Number of days taken for seed germination varied from 3.4 to 14.60. Among the crosses of Paradise, it varied from 5.60 days in P x AR to 14.60 days in P x DT. Marijke recorded 3.4 days in M x DT and 7.80 days in M x MF. Among the crosses of Mozaik Fresh, number of days for seed germination ranged from 5.20 days in MF x M to 8.60 days in MF x LJ. Among all the eight possible combinations involving Lady Jane, the cross LJ x M (4.40 days) recorded the lowest value and the cross LJ x P (9.00 days) recorded the highest value. In the combinations where Orange Glory as a female parent, days for seed germination varied from 6.60 days in OG x P to 11.40 days in the cross OG x LJ. Among the crosses of Dragon's Tongue, the cross DT x OG (5.00 days) took the least number of days for germination while the crosses DT x P and DT x LW took maximum number of days (10.00 days). Lima White as a female parent recorded 5.20 days in LW x AR to 8.80 days in LW x OG. In the cross combinations where Agnihotri Red as the female parent, days for seed germination ranged from 6.40 days in AR x P to 10.60 days in the cross AR x LJ. It was observed that the green tip of the radicle was visible outside the seed in some fruits when extracted from the ripe berries and such seeds took fewer days for germination. Madhukumar (2010) also recorded a similar observation and a seed germination period that ranged from four to nine days.

At six MAP, highest seedling survival was recorded by the cross LW x OG (51.23 %). Lowest seedling survival among the hybrids was observed in the cross M x OG (5.32 %). At 12 MAP, highest seedling survival was recorded by the cross

AR x DT (33.33 %) and lowest survival was exhibited by the cross M x OG (1.06 %). None of the crosses had 100 per cent survival. Out of 34 cross combinations germinated in a trial by Renu (1999), only 31 cross combinations survived for more than four months and Pravin (2004) reported that seedlings of nine out of 12 crosses that germinated survived for more than four months. However, relatively higher survival rates ranged from of 37.50 per cent in 'Lady Jane x (Pompon Red x Orange Glory)' to 81.25 per cent in the cross '(Kalympong Red x Liver Red) x Dragon's Tongue' were obtained by Madhukumar (2010) in similar studies.

Number of leaves in the one year old hybrid seedlings varied from 4.90 in the cross DT x LW to 9.60 in the cross M x LJ (4.90). Madhukumar (2010) recorded leaf numbers ranged from 4.50 in 'Dragon's Tongue x Fla Red' to 6.33 in '(Pompon Red x Orange Glory) x (Orange Glory x Dragon's Tongue)'. Number of days taken for emergence to maturity of the leaves ranged from 24.75 days in M x AR to 34.75 days in the crosses AR x DT and OG x M. Internodal length of the hybrid seedlings varied from 0.22 cm for the crosses LJ x MF and AR x OG to 0.32 cm for the cross DT x MF. Leaf area of the seedlings varied from 24.89 cm^2 for the cross LJ x P to 45.06 cm^2 for the cross P x MF. Similar findings were obtained by Shiva and Nair (2008 b) with a leaf area range of 5.33 to 16.43 cm^2 and by Madhukumar (2010) with a range of 15.16 to 21.05 cm^2 in anthurium hybrid seedlings.

Combining ability analysis has been reported as an important method of plant breeding for identifying parents for hybridization (Sprague and Tatum, 1942). In the present study, eight parental genotypes and their hybrids were assessed for their general combining ability (GCA) and specific combining ability (SCA) based on 11 characters. GCA and SCA variances for the characters were also calculated. A comparison of GCA effects of parents and SCA effects of crosses for different characters are represented in Fig. 10 (a, b and c) and 11 (a, b, c, d and e).

Among the characters studied, dominance variance was found to be greater for eight characters such as number of fruits per spadix, percentage of fruit set, days for seed maturity, number of seeds, days for seed germination, days from emergence to maturity of leaves, leaf area and internodal length indicating predominance of non additive gene action for these characters. However, for the characters number of leaves per seedlings, percentage of seed germination and seedling survival, additive variance was higher than the dominance variance and the ratio of additive to dominance variance showed values greater than unity indicating the predominance of additive gene action. Large additive variance component relative to that of dominance variance suggested that the cultivars which had good GCA values in a particular trait had the greatest chance of producing superior progeny (Dar, 2007).

Among the hybrids, positive SCA effects for the character number of fruits per spadix was observed in the hybrid M x MF in which both parents were good general combiners and in the hybrids M x LJ, M x DT, MF x LW, MF x AR, M x OG, M x LW and P x MF in which one of the parent Marijke or Mozaik Fresh was a positive general combiner.

In percentage of fruit set, the hybrids M x MF and P x MF were found to have positive SCA effects and both the parents were observed to be good general combiners. As in the case of the above trait, positive SCA effects were also observed in the hybrids M x LJ, M x DT, MF x LW, MF x AR, M x OG and M x LW in which one of the parents was a positive general combiner. However, for number of fruits per spadix and percentage of fruit set, the highest values for SCA were observed for the hybrid P x LJ in which both parents (Paradise and Lady Jane) were negative general combiners and it was followed by the hybrid M x LJ in which the parent Marijke was a good general combiner.

For the trait days to seed maturity, the highest value was obtained for the hybrid LJ x OG in which the parent Orange Glory was a good general combiner. In

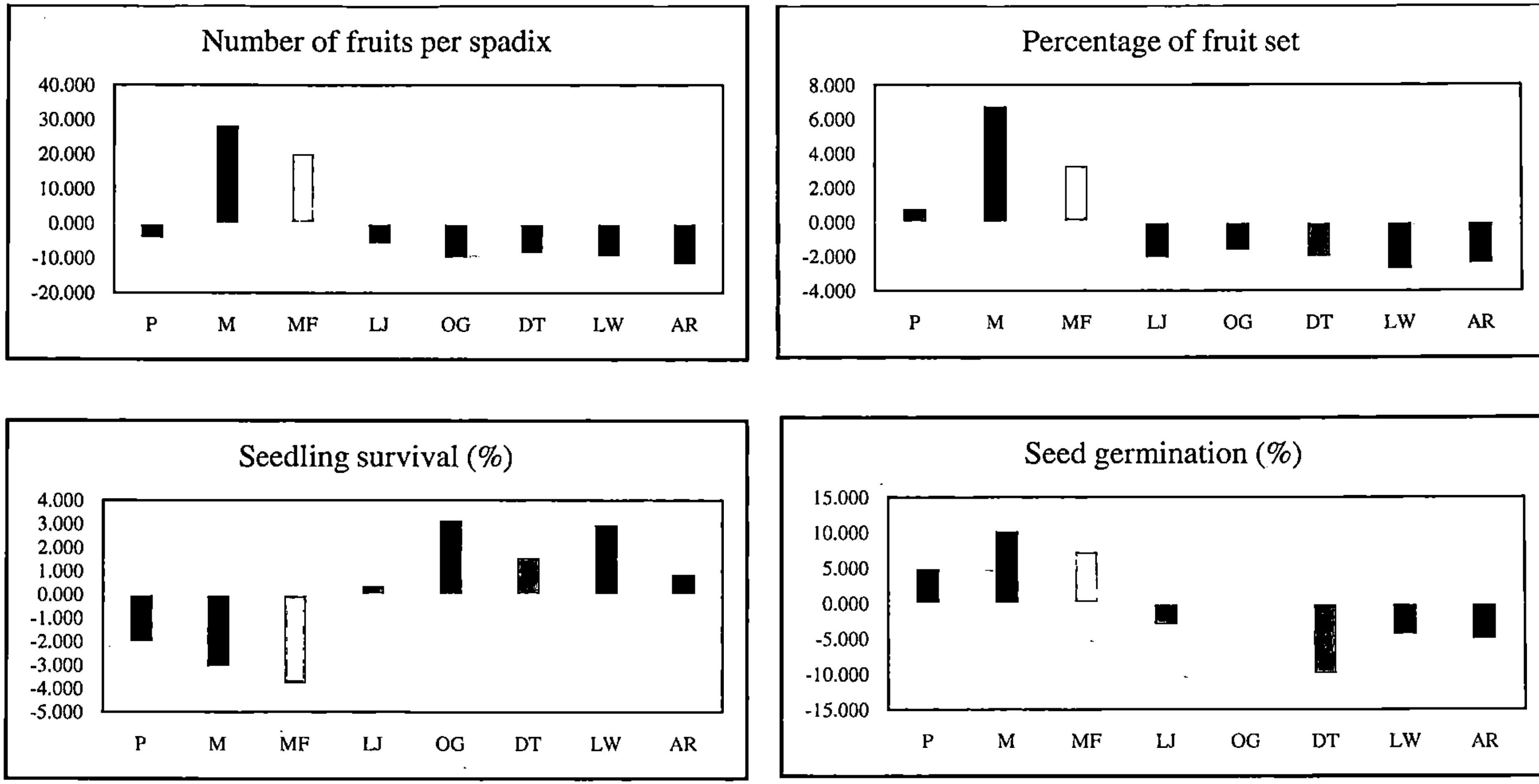


Fig. 10a. General combining ability of the parents

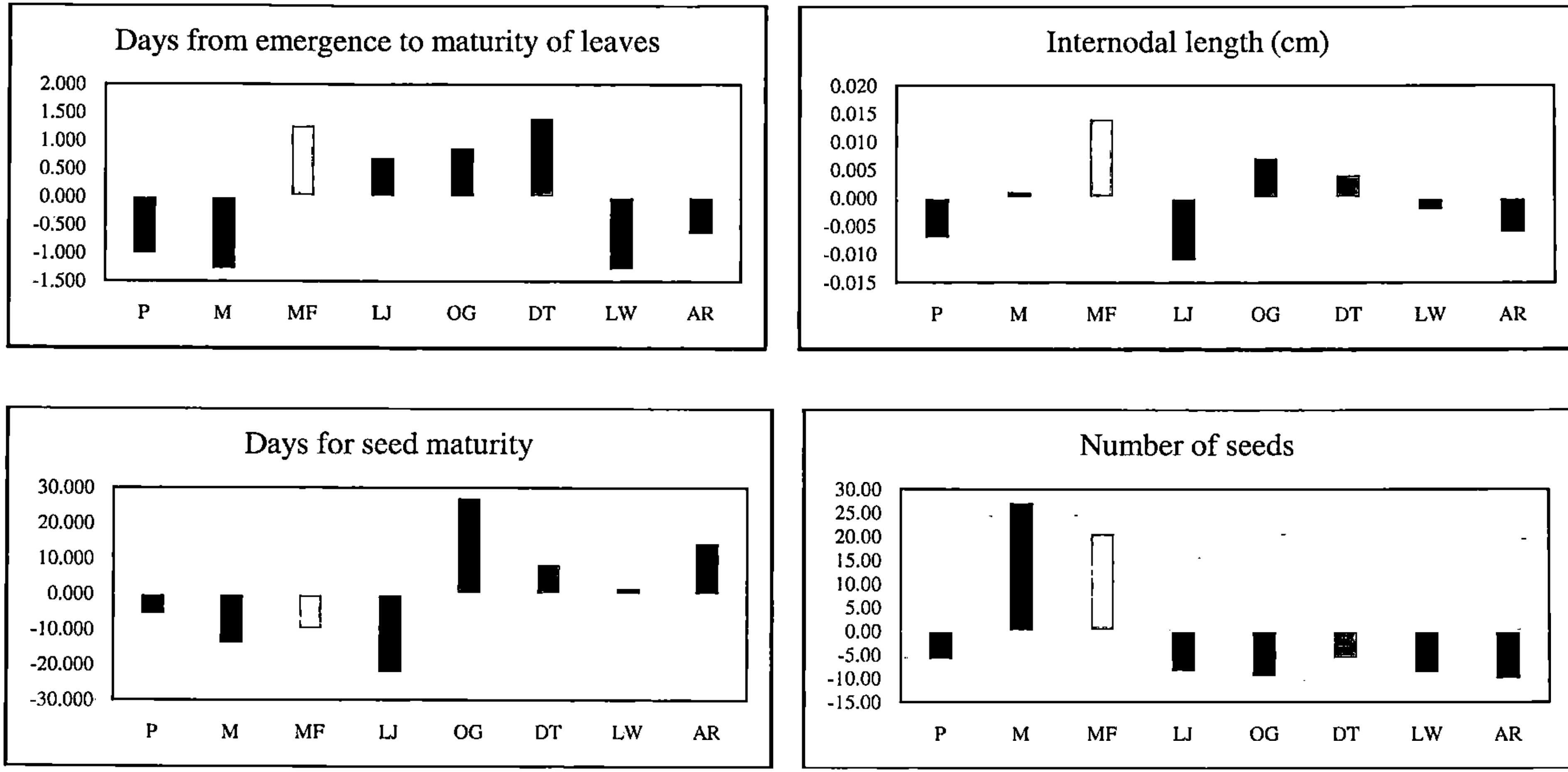


Fig. 10b. General combining ability of the parents (contd.)

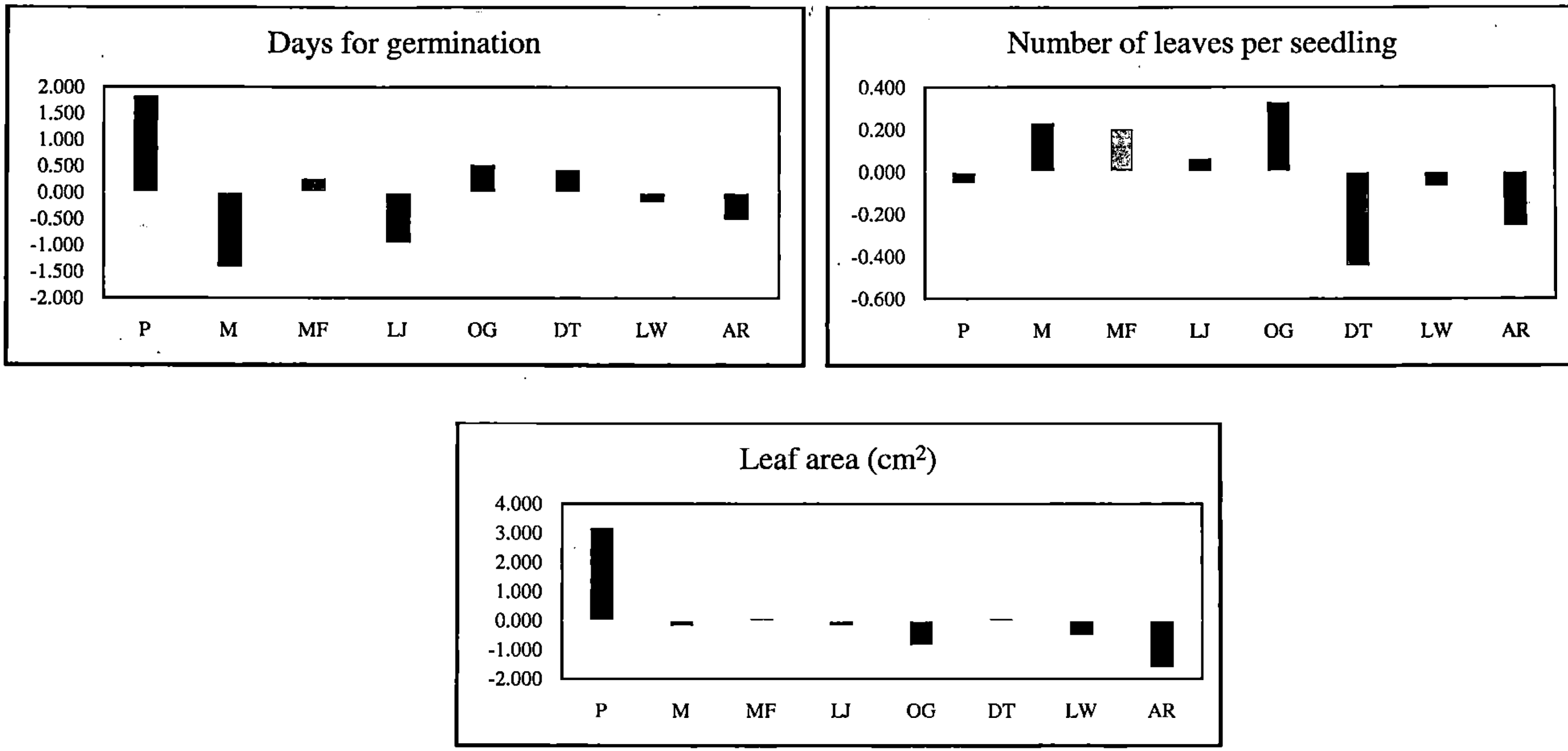
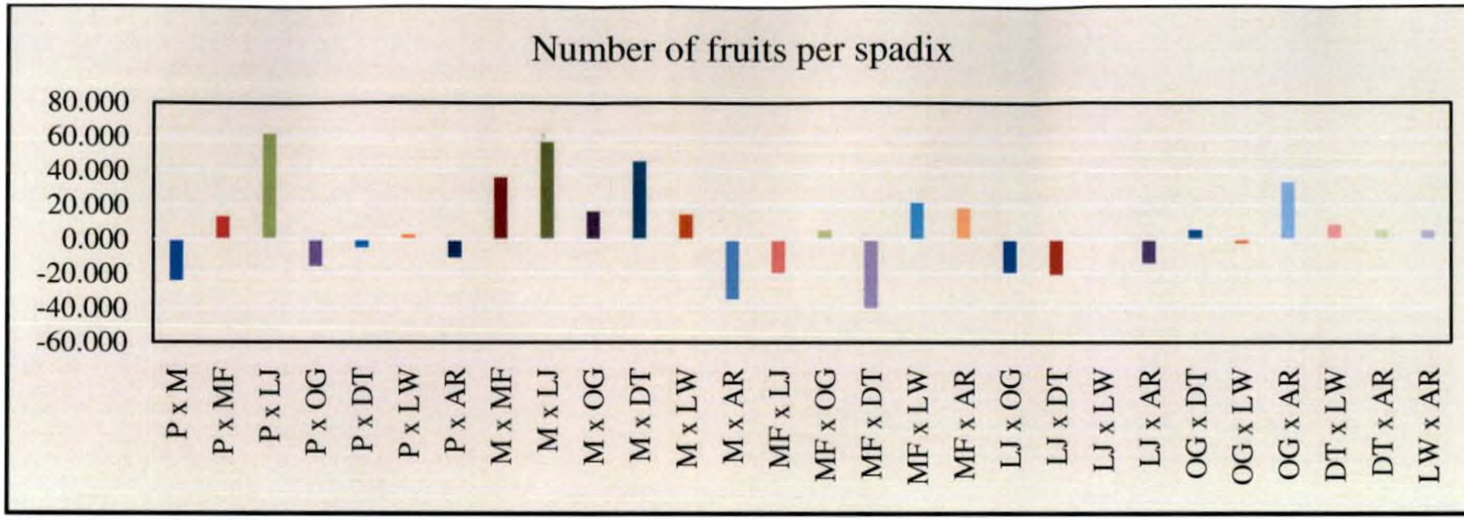


Fig. 10c. General combining ability of the parents (contd.)

the hybrids P x LJ, M x DT and M x LJ high values for SCA effects for the character number of seeds was observed. In the first hybrid both the parents Paradise and Lady Jane showed negative GCA effects while in the other two, one of the parents Marijke showed positive GCA effects and the other parent Dragon's Tongue/Lady Jane showed negative GCA effect. However, the parental genotype Mozaik Fresh was also found to have positive GCA effects for this character.

For the trait seed germination per cent, positive SCA effects were observed in the hybrid P x DT in which the parent Dragon's Tongue showed to be a negative general combiner. However, the parental genotypes Marijke and Mozaik Fresh were found to have positive GCA effects with respect to this character as in the case of number of seeds. The highest value for the days for seed germination was observed in the hybrid M x DT and P x AR in which one of the parents Paradise and Dragon's Tongue were positive general combiners and the parents Marijke and Agnihotri Red were negative general combiners with respect to days for seed germination.

In the case of seedling survival, the parents Orange Glory, Dragon's Tongue and Lima White were found to be positive general combiners while the parents Paradise, Marijke and Mozaik Fresh were found to be negative general combiners. The cultivar Orange Glory showed to be a positive general combiner for number of leaves per seedling while Dragon's Tongue was observed to be a negative general combiner for the trait. For the character leaf area, the hybrid P x LJ gave the highest values for SCA effects in which the parent Paradise was found to be high in positive general combining ability. All other parents showed negative GCA effects and the GCA variance was lower than SCA variance. Mayadevi (2001) in a combining ability analysis of five parental genotypes of anthurium found that leaf area was influenced by non-additive gene action. Compactness in plant height is associated with shorter internodal length and it is a desirable trait in anthurium. Positive GCA effect conducive to impart tallness to hybrids was observed in the parent Mozaik Fresh. Negative GCA effects obtained for the parents Lady Jane, Paradise and Agnihotri



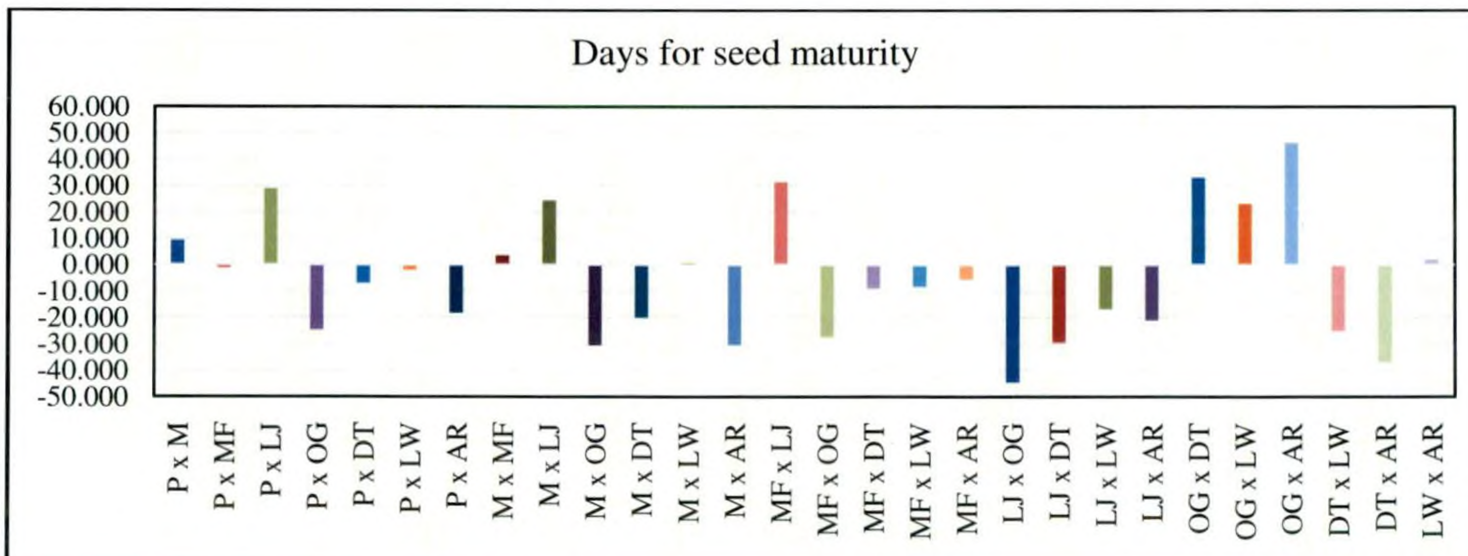
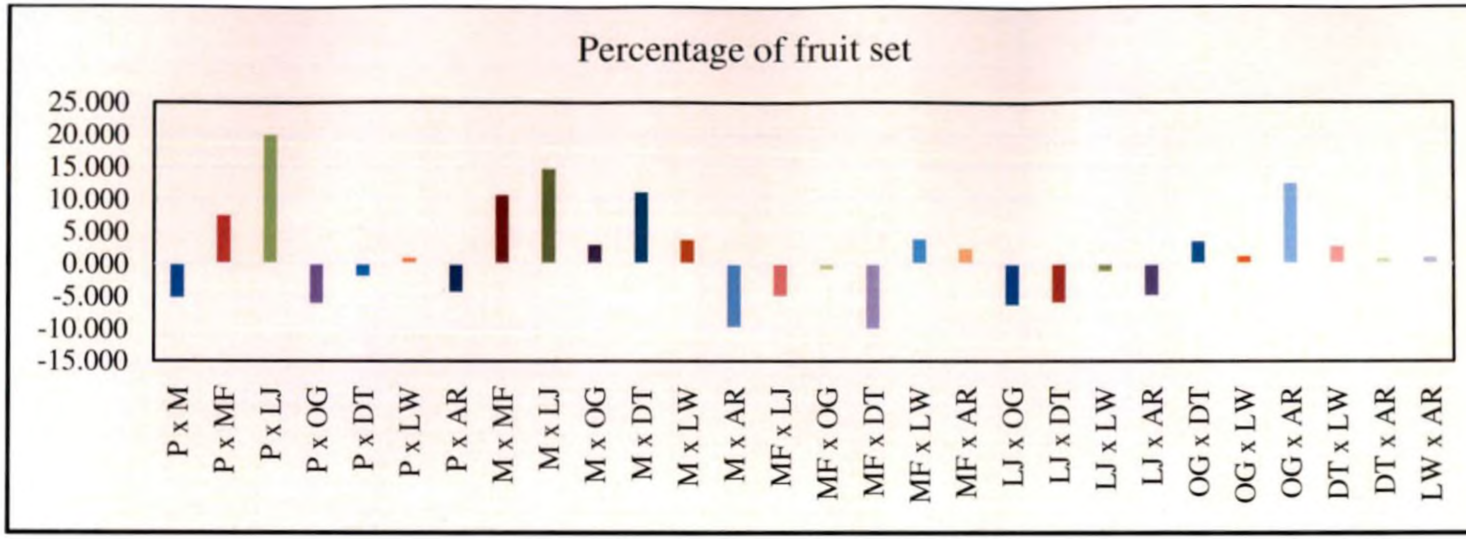


Fig. 11a. Specific combining ability of the crosses



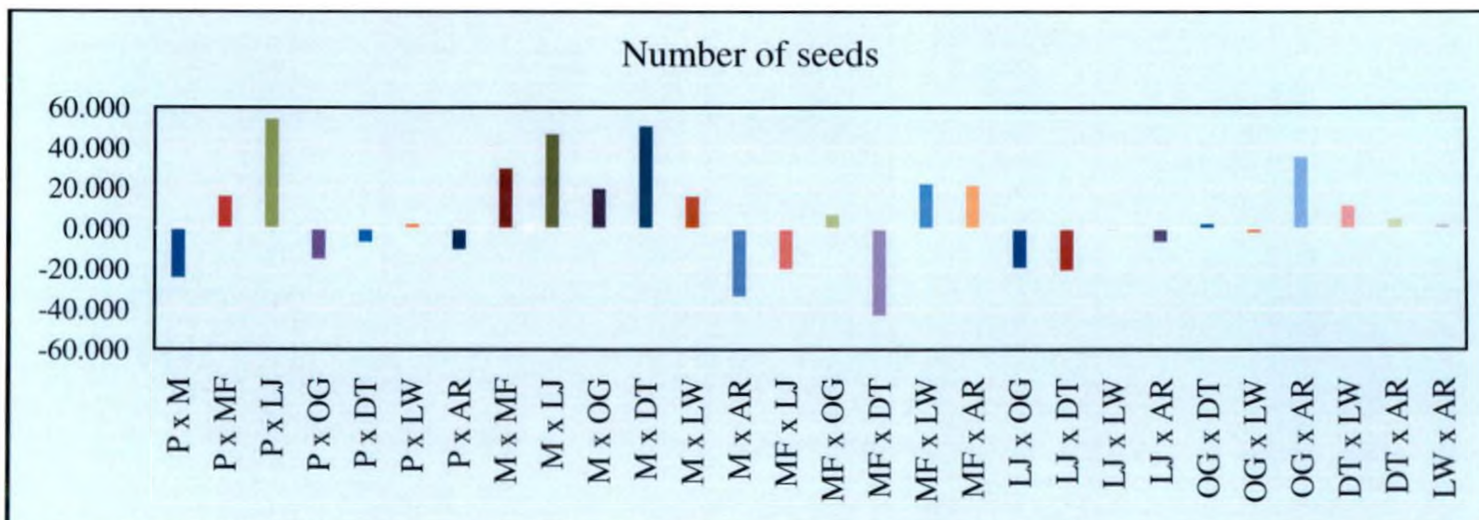
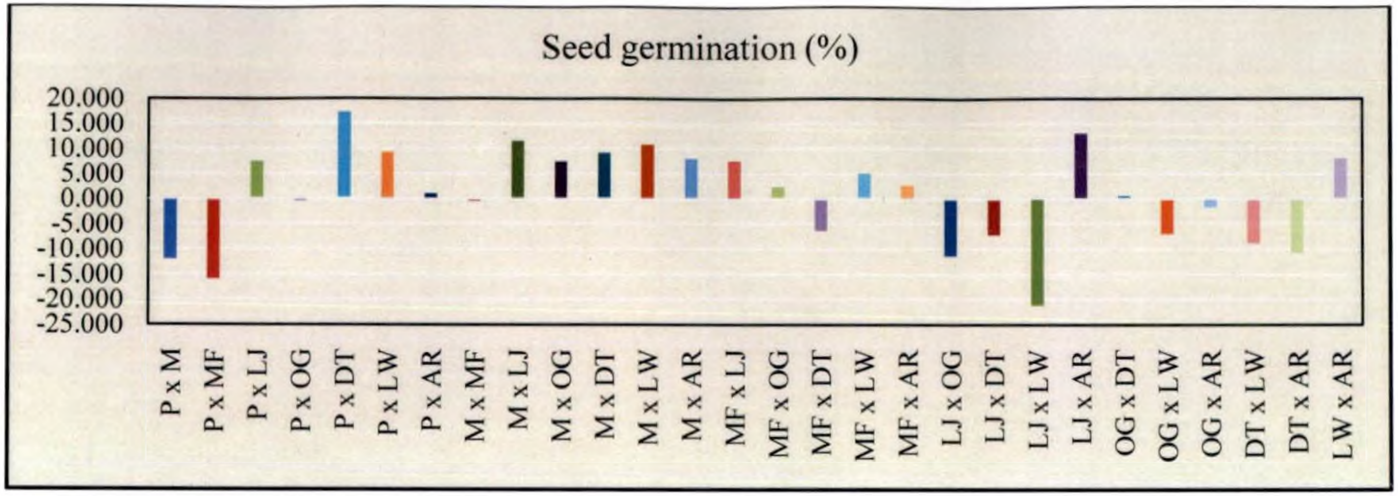


Fig. 11b. Specific combining ability of the crosses (contd.)



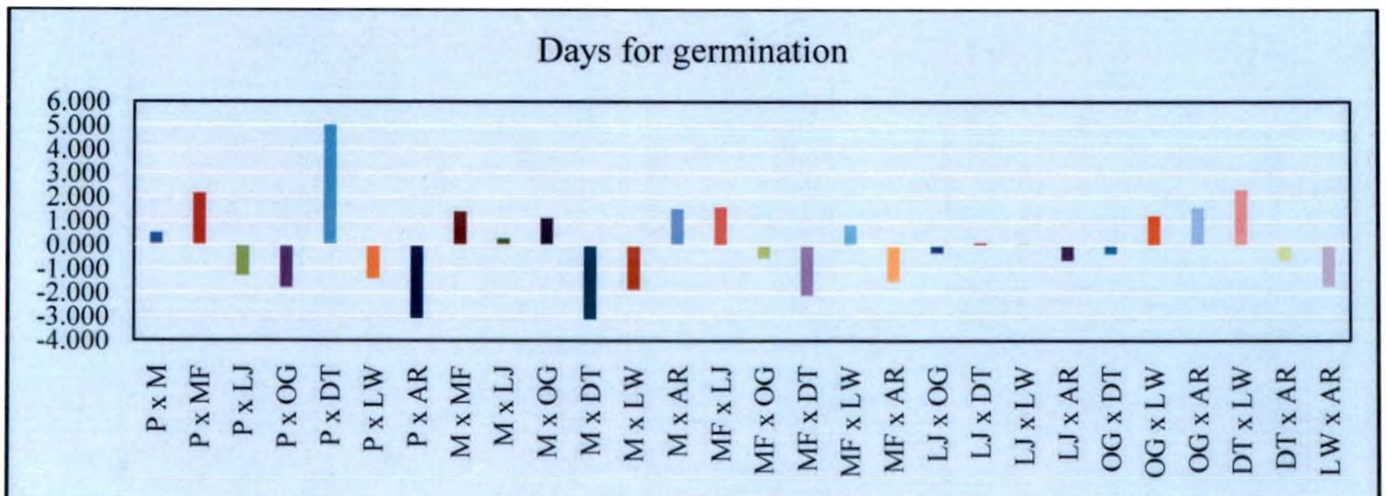
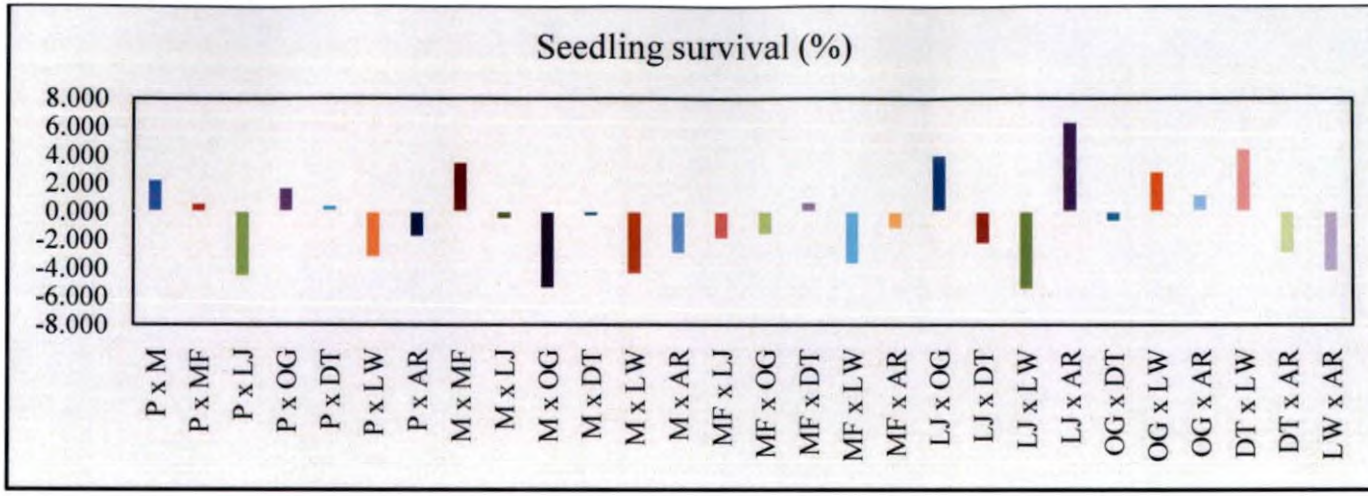


Fig. 11c . Specific combining ability of the crosses (contd.)



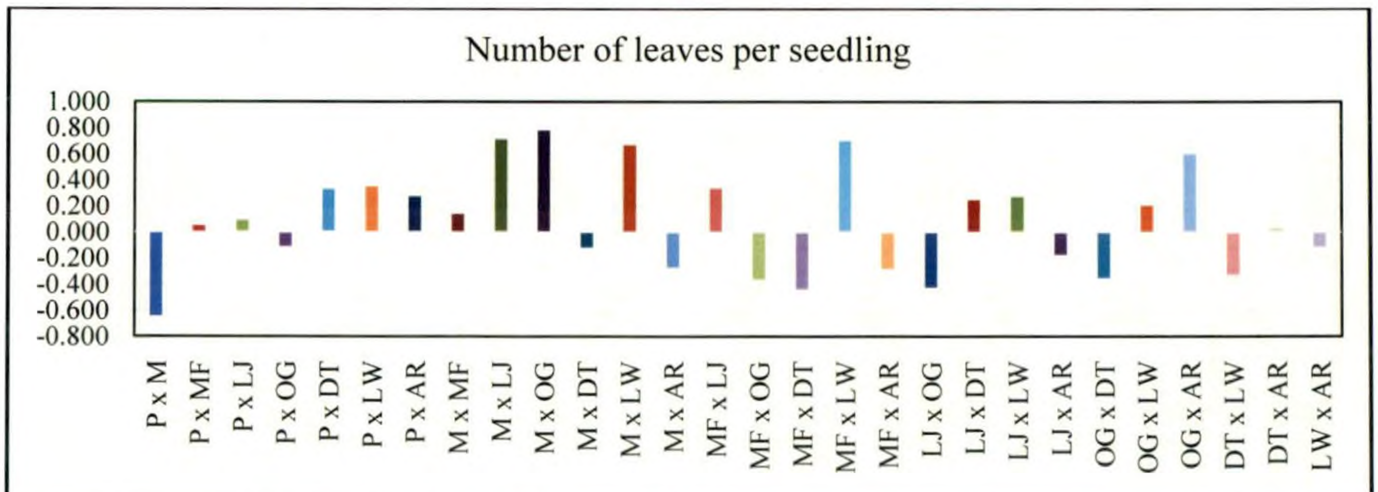
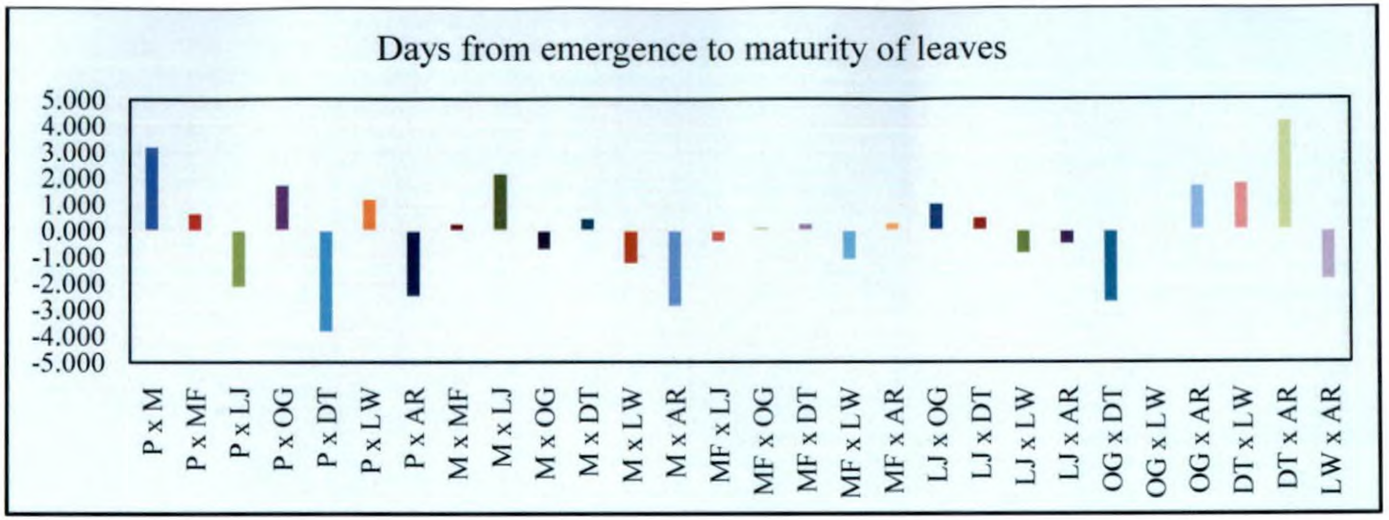


Fig. 11d. Specific combining ability of the crosses (contd.)



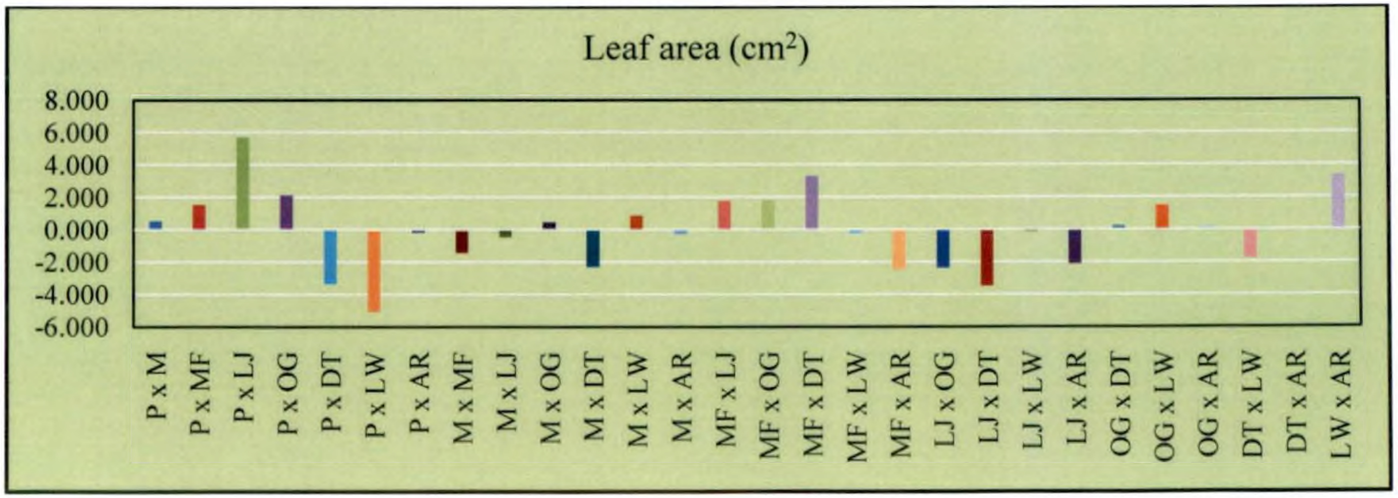


Fig. 11e. Specific combining ability of the crosses (contd.)

Red indicated that they were desirable parents for producing hybrids with less internodal length.

Based on the effects with respect to the characters number of fruits per spadix, percentage of fruit set, number of seeds and percentage of seed germination, the parental genotypes Marijke and Mozaik Fresh were found to be good general combiners. This indicates the suitability of these as better general combiners for obtaining higher fruit set and seed germination. Mozaik Fresh was also found to be a good general combiner for the traits emergence to maturity of leaves and internodal length. The parents Orange Glory and Dragon's Tongue were found to be good general combiners for days to seed maturity, days to seed germination, seedling survival and days from emergence to maturity of leaves. However, for the trait number of leaves, Orange Glory was found to be a good general combiner. With respect to percentage of fruit set, days for germination and leaf area, the parent Paradise also was found to be a good general combiner and for days to seed maturity and seedling survival Lima White was found to be a good general combiner.

The involvement of both additive and non-additive gene action in the inheritance of characters suggests that selection as well as hybridization may be effective for improvement of these characters.

The hybrid plants in the field are in flowering, near flowering and pre flowering stage. Comparison of vegetative and floral characters of the hybrids with their parents revealed variations in parameters studied, even though the floral characters of the initial flowers may not be indicative of the actual performance of the plant. Height of the hybrids at flowering ranged from 32.4 cm in M x MW to 46.7 cm in M x MF (1) and number of leaves at flowering varied from six to 18. The time taken from planting to flowering varied from 18 months in the hybrid M x MW to 28 months in AR x DT. Inclination of spadix to spathe was equal to or below the ideal angle of 45° in the hybrids AR x DT, AR x M, DT x AR, DT x LW, LW x AR, LW x P, M x LJ, MF x AR (1), MF x LJ, P x AR (1) and P x AR (2). In all the other hybrids, it was above 45°.

Spathe colour ranged from coral to pinkish red and red in the hybrids having Agnihotri Red, Dragon's Tongue, Marijke, Mozaik Fresh and Paradise as female parents. In the hybrid with Marijke as female parent, the spathe colour ranged from coral to light pink and dark pink to reddish pink.

Among the four hybrids with Agnihotri Red as the female parent, the spadix was coloured yellow in AR x M and AR x OG, pinkish yellow in AR x DT and light pink in AR x LJ. In the three hybrids with Dragon's Tongue as female parent, the spadix colour ranged from pink to red. In the six hybrids with Marijke as female parent, the spadices were coloured pink to red in four hybrids (M x LW, M x MF, M x MW and M x OG). In the other two hybrids M x DT and M x LJ, the spadix was yellow. Among the four hybrids with Mozaik Fresh as female parent, spadix colour was orange yellow in MF x DT and yellow in MF x LJ. In the two hybrids with the parentage MF x AR, the hybrid with red spathe colour had a red spadix and the hybrid with coral spathe had pink spadix. In the two hybrids with P x AR as parents, the spathe was coloured red in both while the spadix was yellow in one hybrid and red in other. In the other three hybrids with Paradise as female parents, the spadix was coloured red in the hybrid having red spathe colour (P x DT) and the spadix was coloured yellow in P x LJ which had light pink and P x M which had dark pink spathe.

The spadix colour in the four hybrids with Lady Jane Pink as the female parent, varied from light pink, pink, reddish pink and yellow and spathe colour from coral to light pink. In the four hybrids with Lima White as female parent, the spathe was coloured light pink to coral with yellow spadices in LW x DT, LW x P and LW x AR and spathe was off white with a contrastingly red spadix in LW x M. Among the three hybrids with Orange Glory as female parent, the spathe colour was coral and spadix was coloured pink in OG x DT. In the other two hybrids with light

DT x AR (1)

P x DT

M x OG

LW x P

MF x AR (1)

MF x DT

LW x AR

LW x M

AR x DT

DT x M

Plate 26. Promising hybrids identified

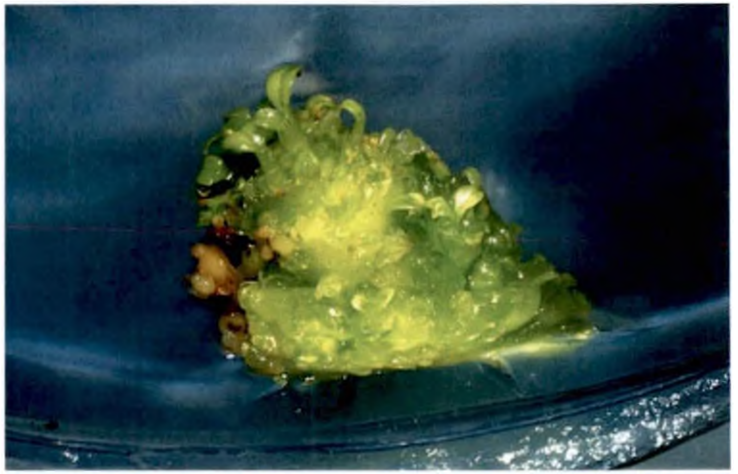
pink (OG x LJ) and dark pink (OG x MF) spathe colour, the spadix was coloured yellow.

Based on the ranks obtained during the qualitative evaluation, 10 hybrids with total scores ranging from 298 to 344 were found to be promising with respect to spathe and spadix characters (Plate 26). The promising hybrids identified in the study were DT x AR (1), P x DT, M x OG, LW x P, MF x AR (1), MF x DT, LW x AR, LW x M, AR x DT and DT x M.

In vitro seed germination study (Plate 27) using seeds from the cross Marijke x Mozaik Fresh revealed that highest survival percentage (93.33 %) with the lowest incidence of contamination was obtained in surface sterilization with sodium hypochlorite 2 % for 15 minutes. Early germination (8.19 days) and was obtained in seeds cultured with half MS or full MS without growth regulators (8.31 days) and full MS with BA 1.0 mg l^{-1} (8.38 days). A similar high per cent of germination (92.86%) in anthurium was observed by Somaya *et al.* (1998) on surface sterilization of the seeds in 3.0 per cent sodium hypochlorite for 30 minutes.

Callus initiation and multiple shoot production were found in basal medium containing BA and the shortest period for the same (26.62 days) was observed in MS medium containing 2 mg l^{-1} BA. Somaya *et al.* (1998) reported that anthurium seeds inoculated in MS medium with growth regulator (2, 4-D @ 2 mg l^{-1}) produced callus in 30 days. Highest germination per cent and earlier leaf development were seen in full MS (90 % and 22.25 days respectively) and half MS medium without BA (83.33 % and 23 days respectively). Late leaf development and lowest survival per cent was found in full or half MS with BA 0.5 mg l^{-1}. Lowest germination per cent was observed in full MS + BA 2 mg l^{-1}. Ravidas (2003) reported early leaf formation in the combination MS + BA 0.5 mg l^{-1} and early callus development in MS + BA 1 mg l^{-1}. Chitra *et al.* (2011) reported 100 per cent germination of seeds of the anthurium cultivar Temptation on MS medium supplemented with 1.0 mg l^{-1} BAP after two weeks of inoculation.

In vitro seed germination in MS medium without growth regulators



Callus production *in vitro* in MS medium with BA 2 mg l^{-1}

Multiple shoot production from *in vitro* germinated seed in MS medium with BA 2 mg l^{-1}

In vitro grown plant with flower bud, two years after planting out

Plate 27. Stages of *in vitro* seed germination and field established plant

In vitro germination in plant growth regulator free media in this study was comparative to the germination per cent obtained in the petri dishes. It is an ideal alternative to ensure contamination free germination of seeds. Multiple shoot production obtained in the media containing plant growth regulators in the study can be refined and used for multiplication of hybrids. Conventional propagation in anthurium using suckers is a slow process and some are poor in suckering habit. Seed germination *in vitro* and its further multiplication could reduce the time taken to develop new hybrids in large numbers. Several workers reported the use of seeds of anthurium germinated *in vitro* as a source of explant for micro propagation (Atta-Alla *et al.,* 1998; Prakash *et al.*, 2001; Ravidas, 2003; Vargas *et al.*, 2004; Maira *et al.*, 2010; Chitra *et al.*, 2011 and Ancy *et al.*, 2012).

In this investigation, performance evaluation of introduced cultivars revealed that the cultivars Marijke and Paradise are dual purpose cultivars suited for flower production and for growing as potted foliage plants. Salmon Queen with its distinct dark salmon pink spathe and green basal lobes had good flower quality and vase life and was compact in size with high sucker production making it a medium sized cultivar suited for cut flower production. Among the introduced cultivars, better breeding attributes of cultivars Marijke, Mozaik Fresh and Paradise make them suitable as parents in hybridization. The 35 hybrids that flowered had the above three introduced cultivars and the cultivars Dragon's Tongue, Lady Jane Pink, Agnihotri Red, Lima White and Orange Glory in their parentage. From these hybrids based on preliminary observations of spathe and spadix characters, 10 hybrids could be selected as promising. The performance and cut flower attributes of the remaining hybrids that have flowered and which are yet to flower can be further assessed and improved if necessary. The 10 promising hybrids can be further evaluated for flower yield and other cut flower attributes and selected for cultivation.

Summary

6. SUMMARY

Investigation on performance analysis and combining ability studies in anthurium cultivars were carried out at the Department of Pomology and Floriculture, College of Agriculture, Vellayani during 2010- 2013. The objectives of the experiment were to evaluate introduced cultivars of anthurium for growth, flowering and floral attributes and assessment of their compatibility with cultivars having breeding potential and production of novel anthurium cultivars through inter-varietal hybridization. The study was conducted in two experiments. Performance evaluation of introduced anthurium cultivars for growth and cut flower production was carried out under experiment-I and hybridization and combining ability studies in selected cultivars, *in vitro* seed germination studies and evaluation of hybrid seedlings were carried out under experiment-II. The results and salient findings are summarized here.

- In experiment 1, near flowering size plants of nine anthurium cultivars *viz*., Mozaik Fresh, Elizabeth, Anastasia, Hillary, Cynthia, Red Amour, Salmon Queen, Paradise and Marijke introduced and supplied by the Kerala State Horticulture Mission were evaluated for vegetative growth, flower yield and cut flower attributes for a period of two years. The results revealed significant variation with respect to the morphological and floral characters.
- The cultivar Marijke exhibited significantly higher plant height (59.24 cm), leaf area (239.65 cm^2) and internodal length (0.99 cm) and was on par with the cultivar Paradise. The cultivar Red Amour recorded lowest plant height (29.29 cm), leaf area (92.18 cm^2) and internodal length (0.45 cm) 24 months after planting.
- The cultivar Paradise (8.75) recorded the highest number of leaves and Red Amour and Anastasia recorded significantly lower numbers (6.25 and 6.50 respectively). Greater sucker production was observed in Salmon Queen (7 suckers) followed by Marijke and Hillary (3 suckers each) and Mozaik Fresh and Elizabeth (one sucker each).

- The time taken from emergence to maturity of leaves varied from 24.55 to 35.95 days. This period was lowest in the cultivar Red Amour and highest in Cynthia. Length of the leaf stalk among the cultivars ranged from 21.08 to 38.70 cm with Anastasia produced significantly shortest leaf stalk and Mozaik Fresh produced the longest.
- Greater flower production was recorded in Salmon Queen, Marijke and Paradise that produced 6.33, 6.17 and 5.92 spadices respectively per year. Significantly, lesser flower production was found in Red Amour (2.67) and Anastasia (3.42). For the character time taken from emergence to unfurling of spadices the lowest number of days were recorded in Marijke (20.75 days) followed by Anastasia (22.75 days) and highest in Cynthia (26.50).
- In spathe length and breadth, Mozaik Fresh (12.08 and 10.65 cm) recorded significantly higher values and Red Amour (8.05 and 5.98 cm) recorded lowest values. In cultivar Salmon Queen, spathe breadth (9.06 cm) was greater than spathe length (9.03 cm). In spathe size and spathe/spadix ratio, Mozaik Fresh, Paradise, Marijke and Hillary were found to record higher values. Red Amour and Anastasia recorded lower values.
- The lowest angle of inclination of spadix with spathe was observed in Paradise (58.50°) and highest in Salmon Queen (80°). Vase life was found to be the lowest in the cultivars Cynthia (6.50 days) and highest in Salmon Queen (9.25 days).
- The number of true flowers per spadix ranged from 164.33 numbers in Red Amour to 408.25 numbers in cultivar Hillary. The mean number of days to initiation of female phase in the cultivars ranged from 4.25 to 7.67 days with the cultivar Salmon Queen recorded the highest and Hillary recorded the lowest. Duration of the female phase in the cultivars varied from 7.33 days in Elizabeth to 12.67 days in Anastasia. The duration of the interphase varied from 4.33 days in Marijke to 12.00 days in Cynthia. The duration of male phase in the cultivars ranged from 4.75 to 8.50 days with Paradise recorded the lowest and Hillary recorded the highest duration.

- Wide variation was observed for the anthocyanin content among the cultivars which ranged from 2.72 mg g^{-1} to 20.37 mg g^{-1}. The cultivar Red Amour which had orange red spathe recorded the highest value and the cultivar Cynthia having a creamy green spathe colour recorded the lowest value.
- Pollen fertility of the cultivars ranged from 16.75 to 57.08 per cent with Marijke recorded the highest value and Hillary recorded the lowest. Pollen shape varied from round to oval in the cultivars and pollen diameter ranged from 11.93 µ in the cultivar Paradise to 26 µ in cultivar Cynthia.
- Colour of spathe, spadix, petiole and young leaves, spathe texture and type of spadix exhibited variations among the cultivars.
- In the cultivars, phenotypic coefficient of variation (PCV) was slightly higher than genotypic coefficient of variation (GCV) for most of the characters and the differences between GCV and PCV were very low. Maximum PCV (31.79 %) and GCV (30.21 %) were observed for the character leaf area followed by internodal length. The characters, spathe breadth (5.85 %), spathe length (5.79 %), days to initiation of female phase (3.42 %), length of leaf stalk (3.31 %) and number of leaves per plant (3.14 %) showed maximum differences between PCV and GCV.
- Based on the genotypic and phenotypic variances, less variability was observed for internodal length, number of leaves per plant, number of flowers or spadices per plant per year and days to initiation of female phase. High variability was observed for the characters number of true flowers per spadix, leaf area and plant height.
- Among the cultivars, high heritability values were observed for the characters plant height, days from emergence to maturity of leaves, number of flowers or spadices per plant per year, leaf area, number of true flowers per spadix, internodal length, duration of female phase, inclination of spadix with spathe, days from emergence to unfurling of spathe, length of leaf stalk and days to initiation of female phase. Highest value for genetic advance as percentage of mean was obtained for leaf area

(59.12 %) followed by internodal length (52.37 %), number of flowers or spadices per plant per year (50.48 %), plant height (50.29 %), number of true flowers per spadix (48.23 %), length of leaf stalk (32.81 %), duration of female phase (31.53 %), days from emergence to maturity of leaves (25.85 %), spathe breadth (22.37 %) and spathe length (22.25 %). The characters days from emergence to maturity of leaves, plant height, number of flowers/spadices per plant per year, leaf area, internodal length and number of true flowers per spadix recorded high heritability and genetic advance.

- The genotypic correlation coefficients were observed to be higher than phenotypic correlation coefficients for most of the characters. Morphological traits of plant height, number of leaves, leaf area, length of leaf stalk and internodal length were found to be correlated with each other. The character days from emergence to maturity of leaves was found to have positive genotypic and phenotypic correlation with days from emergence to unfurling of spathe, their length and breadth. Number of true flowers per spadix was found to have negative phenotypic and genotypic correlation with days to initiation of female phase.
- In experiment II, hybridization and combining ability studies were carried out. Twenty one cultivars were evaluated for their floral characters and the annual production of spadices per plant ranged from 3.85 to 8.65 numbers. Significantly higher number of spadices was produced by the cultivar Marijke (8.65) followed by Salmon Queen (7.95) and Paradise (7.55) and Red Amour recorded the least number (3.85) of spadices. Hawaiian Orange recorded the longest period (33.00 days) for time taken for emergence to unfurling of the spathe and this period was significantly lower for Marijke and Lima White (20.33 days).
- Spathe length ranged from 7.47 to 22.23 cm and spathe breadth ranged from 4.07 to 15.70 cm among the cultivars studied. Significantly larger spathe sizes were observed in the cultivar Mozaik Fresh (349.61 cm^2) and smaller spathe size in Lady Jane (31.67 cm^2). Spathe/spadix ratio was

significantly higher for the cultivar Lima White (55.62) which was on par with Mozaik Fresh (54.57). Significantly lower spathe/spadix ratio was observed for Lady Jane (5.15).

- The cultivars Rosette (41°), Tropical Red (41.33°) and Orange Glory (44.67°) had the desirable angle of inclination where as inclination was significantly higher for all other cultivars with Mozaik Fresh (78.33°) recorded the highest value. Vase life of the flowers varied significantly from 6.33 to 20.50 days with Honduras recorded the highest values and Lady Jane recorded the lowest.
- The cultivars varied significantly with respect to the anthocyanin content of the spathe and with variation in the intensity of spathe colour a gradation in the content of anthocyanin was observed. The total anthocyanin content ranged from 1.70 mg g^{-1} to 276.31 mg g^{-1} with cultivar Lima White having white spathes and lobes which occasionally turn green recorded the lowest and Liver Red with dark maroon red spathe recorded the highest values.
- In the cultivars, the number of true flowers located in the spadix was found to vary from 174 flowers in Red Amour to 502 flowers in Honduras. The mean number of days to initiation of female phase ranged from 3.64 to 7.67 in the cultivars Rosette and Orange Glory respectively. Duration of female phase ranged from 6.32 days in Lady Jane to 13.33 days in the cultivars Rosette and Hillary. Duration of interphase varied from 4.33 to 12.69 days with the cultivar Marijke recorded the lowest and Lima White recorded the highest values. The highest mean duration of male phase was obtained for Agnihotri Red (10.65 days) and lowest in Paradise (4.67 days). The cultivars Anastasia, Red Amour, Rosette and Hawaiian Orange did not exhibit male phase.
- Peak pollen emergence was observed from October to January when mean minimum temperature was low. Poor to absence of pollen production was associated with the months of March to May. Pollen fertility showed a range from 15.91 per cent in cultivar Hillary to 59.00 per cent in Marijke.

The mean size of the pollen ranged from 12.06 μ in Paradise to 26.20 μ in Hillary. Pollen shape ranged from round to oval and majority of the cultivars had round pollen except Marijke, Liver Red, Lady Jane and Dragon's Tongue.

- The cultivars exhibited variation in the qualitative characters of spathe texture, spadix colour and type, colour of young leaf and petiole. Varying degrees of smoothness, blistering and glossiness were observed with respect to the spathe texture of the cultivars. Spadix colour varied from unfurling to ageing and the colour change was observed from base of the spadix to the tip. Spadices varied from short to long, thin to thick and curved to straight. Most of the cultivars had green coloured young leaves. Colour of the young leaf was brownish green in Paradise, Mozaik Fresh, Tropical Red, Orange Glory and Rosette while it was reddish brown in Marijke, Liver Red and Dragon's Tongue. Agnihotri Red had greenish brown young leaf. Colour of petiole in most of the cultivars was green except Paradise, Marijke, Mozaik Fresh, Elizabeth, Tropical Red and Rosette, which had brownish green petiole and Liver red which had reddish brown petiole.
- For selection of parental cultivars, a preliminary evaluation of compatibility was carried out by hybridization of the 21 cultivars in all possible combinations. Of the 441 possible combinations, 213 combinations were found to be practically possible depending upon the simultaneous availability of receptive spadices and fresh pollen. From the 21 cultivars, eight cultivars namely Paradise (P), Marijke (M), Mozaik Fresh (MF), Lady Jane (LJ), Orange Glory (OG), Dragon's Tongue (DT), Lima White (LW) and Agnihotri Red (AR) were selected as parents for further hybridizations including reciprocal crossings.
- Among all the possible combinations of the eight parents selected for hybridization, 34 crosses showed 100 per cent spadices bearing fruits. Relatively higher cross combinations were obtained by Paradise, Agnihotri Red and Orange Glory as female parents followed by Lady Jane.

- In cultivars showing fruit set, the number of fruits per spadix ranged from six in the cross LW x OG to 137 in M x MF. Average percentage of fruit set varied from 2.58 per cent in the cross LW x OG to 58.33 per cent in the cross P x LJ. Number of days taken for maturity of seeds ranged from 107.5 days in the cross LJ x DT to 239.5 days in the cross OG x AR. In general shortest seed maturity period was observed in Lady Jane and longest in Orange Glory and Dragon's Tongue.
- The fruits were either single or double seeded. Dragon's Tongue and Orange Glory as female parents produced single and double seeds in all the combinations. The cross MF x DT produced the lowest percentage of single seeds (60.87) and highest percentage of double seeds (39.3). Percentage of single seeded berries was observed to be higher than double seeded berries.
- The size of seeds from fruits of the same cross combination showed variation depending on whether the fruits were double or single seeded. In fruits with single seed, maximum seed size was observed for the cross DT x OG with 3.88 mm length and 2.97 mm width. The cross LJ x MF (2.14 x 1.64 mm) produced the smallest seed among single seeded fruits followed by AR x LJ (2.21 x 1.54 mm) and AR x LW (2.22 x 1.76 mm). Among the fruits with two seeds, the cross M x LW (3.11 x 2.24 mm) produced the largest seed followed by DT x AR (3.06 x 2.13 mm) and LW x AR (3.01 x 2.18 mm). Smallest seed in the single seeded as well as two seeded fruits was seen in the cross LJ x LW (1.94 x 1.32 mm).
- The percentage of seed germination ranged from 29.17 per cent in the cross OG x DT to 92.96 per cent in M x MF. Number of days taken for seed germination varied from 3.4 days in M x DT to 14.60 days in P x DT.
- At six MAP, highest seedling survival was recorded by the cross LW x OG (51.23 %). Lowest seedling survival among the hybrids was observed in M x OG (5.32 %). At 12 MAP, highest seedling survival was recorded by the cross AR x DT (33.33 %) and lowest survival was

exhibited by the cross M x OG (1.06 %). None of the crosses had 100 per cent survival.

- Number of leaves in the one year old hybrid seedlings varied from 4.90 in the cross DT x LW to 9.60 in the cross M x LJ (4.90). Number of days taken for emergence to maturity of the leaves ranged from 24.75 days in M x AR to 34.75 days in the crosses AR x DT and OG x M. Internodal length of the hybrid seedlings varied from 0.22 cm for the crosses LJ x MF and AR x OG to 0.32 cm for the cross DT x MF. Leaf area of the seedlings varied from 24.89 cm^2 for LJ x P to 45.06 cm^2 for P x MF.
- The eight parental genotypes and their hybrids were assessed for their general combining ability (GCA) and specific combining ability (SCA) based on 11 characters. GCA and SCA variances for the characters were also calculated.
- Among the characters studied, dominance variance was found to be greater for eight characters such as number of fruits per spadix, percentage of fruit set, days for seed maturity, number of seeds, days for seed germination, days from emergence to maturity of leaves, leaf area and internodal length indicating predominance of non additive gene action for these characters. However, for the characters number of leaves per seedlings, percentage of seed germination and seedling survival, additive variance was higher than the dominance variance and the ratio of additive to dominance variance showed values greater than unity indicating the predominance of additive gene action.
- Based on the GCA effects with respect to the characters number of fruits per spadix, percentage of fruit set, number of seeds and percentage of seed germination, the parental genotypes Marijke and Mozaik Fresh were found to be good general combiners. The parents Orange Glory and Dragon's Tongue were found to be good general combiners for days to seed maturity, days to seed germination, seedling survival and days from emergence to maturity of leaves. The cultivar Orange Glory showed to be a positive general combiner for number of leaves per seedling while

Dragon's Tongue was observed to be a negative general combiner for the trait. With respect to percentage of fruit set, days for germination and leaf area, the parent Paradise also was found to be a good general combiner and for days to seed maturity and seedling survival Lima White was found to be a good general combiner. Mozaik Fresh was found to have positive GCA effect with respect to internodal length and negative GCA effect for internodal length was obtained for the parents Lady Jane, Paradise and Agnihotri Red. This indicated that these are desirable parents for producing hybrids with less internodal length. Paradise, Marijke and Mozaik Fresh were found to be negative general combiners for seedling survival.

- Among the hybrids, positive SCA effects for the character number of fruits per spadix was observed in the hybrid M x MF in which both parents were good general combiners. In percentage of fruit set, the hybrids M x MF and P x MF were found to have positive SCA effects and both the parents were observed to be good general combiners. As in the case of the above trait, positive SCA effects were also observed in the hybrids M x LJ, M x DT, MF x LW, MF x AR, M x OG and M x LW in which one of the parents was a positive general combiner. However, for number of fruits per spadix and percentage of fruit set, the highest values for SCA were observed for the hybrid P x LJ in which both parents were negative general combiners and it was followed by the hybrid M x LJ in which the parent Marijke was a good general combiner.
- For the character days to seed maturity, the highest value was obtained for the hybrid LJ x OG in which the parent Orange Glory was a good general combiner. In the hybrids P x LJ, M x DT and M x LJ high values for SCA effects for the character number of seeds was observed.
- For the trait seed germination percentage, positive SCA effects were observed in the hybrid P x DT in which the parent Dragon's Tongue showed to be a negative general combiner. The highest value for the days for seed germination was observed in the hybrid M x DT and P x AR in

which one of the parents Paradise and Dragon's Tongue were positive general combiners and the parents Marijke and Agnihotri Red were negative general combiners.

- *In vitro* seed germination studies were carried out in the cross combination Marijke x Mozaik Fresh which exhibited highest percentage of fruit set. Standardization of surface sterilization techniques and basal media for seed germination were carried out. Highest survival percentage (93.33 %) with the lowest incidence of contamination was obtained in surface sterilization with sodium hypochlorite 2 % for 15 minutes. Early germination (8.19 days) and was obtained in seeds cultured with half MS or full MS without growth regulators (8.31 days) and full MS with BA 1.0 mg l^{-1} (8.38 days).
- Callus initiation and multiple shoot production were found in basal medium containing BA and the shortest period for the same (26.62 days) was observed in MS medium containing 2 mg l^{-1} BA. Highest germination per cent and earlier leaf development were seen in full MS (90 % and 22.25 days respectively) and half MS medium without BA (83.33 % and 23 days respectively). Late leaf development and lowest survival per cent was found in full or half MS with BA 0.5 mg l^{-1}. Lowest germination per cent was observed in full MS + BA 2.0 mg l^{-1}.
- The hybrid plants in the field are in flowering, near flowering and pre flowering stages. Comparison of floral characters of the 35 hybrids that flowered with their parents revealed variations in flower number and spathe-spadix colours. Height of the hybrids at flowering ranged from 32.4 cm in M x MW to 46.7 cm in M x MF (1) and number of leaves at flowering varied from six to 18. The time taken from planting to flowering varied from 18 months in the hybrid M x MW to 28 months in AR x DT. Ten hybrids found promising based on preliminary evaluation of spathe and spadix characters were DT x AR (1), P x DT, M x OG, LW x P, MF x AR (1), MF x DT, LW x AR, LW x M, AR x DT and DT x M.

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* Orginals not seen.

Appendices

APPENDIX- I

Weather data during the study period

Year	Month	Temperature (^0C)		Relative Humidity (%)	
		Maximum	Minimum	Morning	Evening
2011	March	33.0	25.6	86.8	73.2
2011	April	31.8	24.6	88.1	68.5
2011	May	31.1	25.2	88.8	73.8
2011	June	30.3	24.9	91.4	76.6
2011	July	29.6	24.1	91.5	75.2
2011	August	29.8	24.3	89.6	73.8
2011	September	29.7	24.1	92.5	75.2
2011	October	32.4	24.6	90.7	70.8
2011	November	30.3	23.0	97.7	69.4
2011	December	30.5	22.9	96.5	65.0
2012	January	30.3	20.9	98.5	60.2
2012	February	31.2	22.3	96.8	60.6
2012	March	31.7	23.5	93.5	65.5
2012	April	32.1	25.0	90.7	69.7
2012	May	31.2	25.8	90.6	72.5
2012	June	30.4	24.4	91.6	73.6
2012	July	29.7	24.2	92.8	75.6
2012	August	29.8	23.8	91.6	75.8
2012	September	30.2	24.1	90.1	73.3
2012	October	30.5	23.7	91.6	73.9
2012	November	30.3	23.1	97.4	71.8
2012	December	30.7	22.7	96.7	65.3
2013	January	30.3	22.0	96.0	74.2
2013	February	31.4	22.1	91.8	73.4

APPENDIX - II

Matrix showing the possible pollinations attempted in the selected eight parents

♀ \ ♂	P	M	MF	LJ	OG	DT	LW	AR
P	P x P	P x M	P x MF	P x LJ	P x OG	P x DT	P x LW	P x AR
M	M x P	M x M	M x MF	M x LJ	M x OG	M x DT	M x LW	M x AR
MF	MF x P	MF x M	MF x MF	MF x LJ	MF x OG	MF x DT	MF x LW	MF x AR
LJ	LJ x P	LJ x M	LJ x MF	LJ x LJ	LJ x OG	LJ x DT	LJ x LW	LJ x AR
OG	OG x P	OG x M	OG x MF	OG x LJ	OG x OG	OG x DT	OG x LW	OG x AR
DT	DT x P	DT x M	DT x MF	DT x LJ	DT x OG	DT x DT	DT x LW	DT x AR
LW	LW x P	LW x M	LW x MF	LW x LJ	LW x OG	LW x DT	LW x LW	LW x AR
AR	AR x P	AR x M	AR x MF	AR x LJ	AR x OG	AR x DT	AR x LW	AR x AR

P- Paradise, M – Marijke, MF – Mozaik Fresh, LJ- Lady Jane Pink, OG- Orange Glory, DT – Dragon's Tongue, LW – Lima White, AR-Agnihotri Red

APPENDIX – III

Composition of Murashige and Skoog (1962) medium

Particulars	Weight taken	Volume made up	Volume pipetted
Solution A 1) NH_4NO_3 2) KNO_3 3) $MgSO_4 . 7 H_2O$ 4) KH_2PO_4	16.5 g 19.0 g 3.7 g 1.7 g	250 mg (10 x)	25 ml
Solution B 1) $CaCl_2 . 2H_2O$	8.00 g	100 ml (20 x)	5 ml
Solution C 1) H_3BO_3 2) $MnSO_4 . 4 H_2O$ 3) $ZnSO_4 . 7 H_2O$ 4) KI 5) $Na_2MoO_4 . 2 H_2O$	920 mg 1.69 g 860 mg 83 mg 25 mg	100 ml (100 x)	1 ml
Solution D 1) $FeSO_4 . 7H_2O$ 2) Na_2EDTA	745 mg 556 mg	100 ml (20 x)	5 ml
Solution E 1) $CoCl_2 . 6 H_2O$ 2) $CuSO_4 . 5H_2O$	12.5 mg 12.5 mg	250 ml (500 x)	0.5 ml
Solution F 1) Glycine 2) Nicotine acid 3) Pyridoxine HCl 4) Thiamine HCl	200 mg 50 mg 50 mg 10 mg	100 ml (100 x)	1 ml

Inositol 100 g Sucrose 30 g Agar 8 g

APPENDIX- IV

Cross combinations selected for partial diallel analysis

♀ \ ♂	P	M	MF	LJ	OG	DT	LW	AR
P		P x M	P x MF	P x LJ	P x OG	P x DT	P x LW	P x AR
M			M x MF	M x LJ	M x OG	M x DT	M x LW	M x AR
MF				MF x LJ	MF x OG	MF x DT	MF x LW	MF x AR
LJ					LJ x OG	LJ x DT	LJ x LW	LJ x AR
OG						OG x DT	OG x LW	OG x AR
DT							DT x LW	DT x AR
LW								LW x AR
AR								

PERFORMANCE ANALYSIS AND COMBINING ABILITY STUDIES IN ANTHURIUM CULTIVARS

by

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(2010-22-101)

ABSTRACT OF THE THESIS

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ABSTRACT

The investigation on "Performance analysis and combining ability studies in anthurium cultivars" was conducted at Department of Pomology and Floriculture, College of Agriculture, Vellayani during 2010 - 2013. The objectives were to evaluate introduced cultivars of anthurium for growth, flowering and floral attributes, to assess their compatibility with cultivars having breeding potential and to produce novel anthurium cultivars through inter-varietal hybridization. The study was conducted in two experiments and the results and salient findings are abstracted here.

In experiment I, performance evaluation of nine introduced anthurium cultivars for growth and cut flower production was carried out. The cultivars exhibited differential responses in vegetative and floral characters. With respect to morphological characters the cultivars Marijke and Paradise had greater vegetative vigour, higher yields, larger spathes and greater vase life. Salmon Queen, Mozaik Fresh, Hillary, Cynthia and Elizabeth were moderate in vegetative vigour. Red Amour and Anastasia were short statured, lower in vegetative vigour and low yielders with smaller spathes. Variability studies indicated that phenotypic coefficient of variation was slightly higher than genotypic coefficient of variation for most of the characters indicating the greater influence of environment. Genotypic correlation coefficients were higher than phenotypic correlation coefficients for most of the characters.

In experiment II, twenty one anthurium cultivars including the introduced ones were evaluated for their floral characters and from these, eight cultivars namely Paradise, Marijke, Mozaik Fresh, Lady Jane Pink, Orange Glory, Dragon's Tongue, Lima White and Agnihotri Red were selected as parents for further hybridization. Significant differences in floral characters were noticed among the cultivars. The cultivars exhibited variations in the qualitative characters of spathe colour, texture, spadix colour and type and colour of the young leaf and petiole. Anthocyanin content of the spathe showed a gradation with variation in the intensity of spathe colour. Vase life of the cultivars ranged

from 6.33 to 20.50 days. Peak pollen emergence was observed from October to January and absence of pollen was found from March to May.

Combining ability analysis was carried out for 11 traits in which eight traits exhibited higher dominance variance and three traits had higher additive variance which indicated involvement of both additive and non-additive gene action in the inheritance of characters and suggested the importance of selection as well as hybridization for improvement of these characters. Marijke and Mozaik Fresh were good general combiners with respect to the characters number of fruits per spadix, percentage of fruit set, number of seeds and percentage of seed germination, Orange Glory and Dragon's Tongue for days to seed maturity, days to seed germination, seedling survival and days from emergence to maturity of leaves and Paradise for percentage of fruit set, days for germination and leaf area.

In vitro seed germination study revealed that surface sterilization with sodium hypochlorite 2 % for 15 minutes recorded the lowest incidence of contamination and highest survival percentage. Highest germination per cent and earlier leaf development were seen in full MS media without growth regulators. Seed germination *in vitro* and its further multiplication could reduce the time taken to develop new hybrids in large numbers.

The hybrid plants in the field are in flowering, near flowering and pre flowering stages. Vegetative and floral characters of the 35 hybrids that flowered when compared with their parents, revealed variations in the parameters studied. Ten hybrids found promising based on qualitative evaluation of spathe and spadix characters in the present study can be further assessed for flower yield and cut flower attributes and selected for cultivation.