PALYNOLOGICAL AND CROSS COMPATIBILITY STUDIES IN ANTHURIUM (*Anthurium andreanum* Linden)

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(2018-11-054)

DEPARTMENT OF PLANT BREEDING AND GENETICS

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM - 695522

KERALA, INDIA

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by

SMERA G. SANTHOSH

(2018-11-054)

THESIS

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2020

DECLARATION

I, hereby declare that this thesis entitled **"Palynological and Cross compatibility studies in anthurium (*Anthurium andreanum* Linden)"** 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 the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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(**2018 - 11- 054)**

CERTIFICATE

Certified that this thesis, entitled **"Palynological and Cross compatibility studies in anthurium (*Anthurium andreanum* Linden)"** is a record of research work done independently by **Ms.Smera G. Santhosh (2018-11-054)** 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 him.

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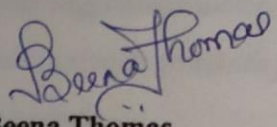
We, the undersigned members of the advisory committee of **Ms. Smera G. Santhosh (2018-11-054)**, a candidate for the degree of **Master of Science in Agriculture** with major in Plant Breeding and Genetics, agree that the thesis **"Palynological and Cross compatibility studies in anthurium (*Anthurium andreanum* Linden)"** may be submitted by **Ms. Smera G. Santhosh (2018-11-054)**, in partial fulfilment of the requirement for the degree.



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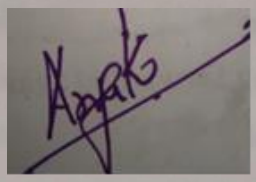

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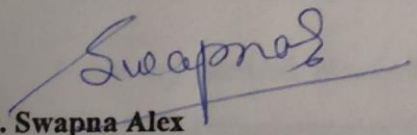

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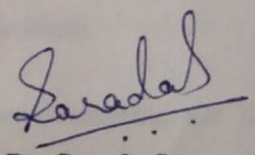

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Smera G. Santhosh

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LIST OF ABBREVIATIONS AND SYMBOLS USED

°	Degree
°C	Degree Celsius
<	Less than
>	Greater than
%	Per cent
µ	Micrometre
CD	Critical Difference
cm	Centimetre
CR	Ceylon Red
CRD	Completely Randomised Design
cv	Cultivar
d.f	Degrees of freedom
DT	Dragon's Tongue
et al.	And others
Fig.	Figure
g	Gram
GCV	Genotypic coefficient of variation
HO	Hawaiian Orange
HoR	Hounduras Red
HR	Honeymoon Red
i.e.	That is
KAU	Kerala Agricultural University
Kg	Kilo gram
KR	Kalympong Red

LJ	Lady Jane
LR	Liver Red
LW	Lima White
mg	Milligram
MR	Miniature Red
NO	Nitta Orange
No.	Number
OG	Orange Glory
PCV	Phenotypic coefficient of variation
PR	Pompon Red
Sl.	Serial
sp. or spp.	Species (Singular and Plural)
TP	Tropical Pink
TR	Tropical Red
Via	Through
viz.	Namely

Introduction

1. INTRODUCTION

Anthurium is one of the most popular cutflower in demand across the globe. It belongs to the family Araceae with diploid chromosome number 30. Its name is derived from two Greek words '*anthos'*, meaning flower, and '*oura'*, meaning tail, which indicates the spadix. The other names for anthurium are flamingo flower, tailflower, painter's palette and laceleaf. The attractive heart shaped spathe and the longlasting nature and wide range of beautiful colours of anthurium flowers contribute towards its demand in the cutflower industry.

Anthuriums add beauty to outdoors as well as to indoors. The anthurium plants have been found as indoor purifying plants as their leaves remove ammonia, formaldehyde, toluene and xylene from air. Hence anthuriums have achieved a place in the list of NASA's air purifying plants.

The genus anthurium include about thousand species of flowering plants. The most important cultivated species of anthurium are *Anthurium andreanum* and *Anthurium scherzianum,* out of which *Anthurium andreanum* is the commercially exploited species.

Anthuriums are semi terrestrial, perennial and epiphytic in nature. The place of origin is South-West Columbia, from where these were later brought to Europe in 1876 (Singh, 1987). Later the anthuriums were introduced to India as the climatic condition prevailing here was suitable for its cultivation.

The popularity of anthurium as cutflower has increased greatly, Netherlands is the largest producer of anthurium in the world. In India, anthuriums are cultivated in Karnataka, Tamil Nadu, Kerala, Andhra Pradesh and North-Eastern States.

The anthurium flower consists of a modified leaf called "spathe" and an inflorescence in which hundreds of flowers are arranged in acropetal succession called as "spadix". The flowers are bisexual and protogynous in nature. The spathe is brightly coloured viz., white, pink, red, light-red, dark-red, brown, green, lavender, cream or even multi-coloured which adds to its enduring beauty.

Two phases are present in the growth stages of anthurium. One is the long juvenile phase in which the growth and development of the plant takes place. Another

is the generative phase in which the plant starts producing flowers (Christensen, 1971).

Anthuriums are naturally cross pollinated in nature. Bees, beetles, flies and ants facilitate the cross pollination. Fruits are fleshy called as ‘berries’ and develop in the spadix within around 6 months after pollination. Propagation through the seeds creates high variability. So, the commonly used method of propagation in anthurium are through suckers. Micropropagation in anthurium is gaining importance as it increases the market potential.

Floriculture is one of the expanding fields in agri-business. The increasing demand for the anthuriums in the cutflower industry has led many farmers towards anthurium cultivation. The promising part of anthurium cultivation is that it provides flowers all the year around.

The climatic conditions of Kerala are well suited for exploration of anthuriums. The basic cultural requirements of anthurium is a warm green house with 75 percent shade and atmospheric humidity and a temperature of 18-28°C (Madhukumar,2010). The major constraints of anthurium cultivation are lack of availability of quality planting materials and a stable market (Gopi,2016).

The abundance of genetic variability present in anthurium due to the heterozygous nature needs to be exploited so that novel hybrids with more desirable characters can be developed.

Hybridisation followed by selection is the most appropriate method for the genetic improvement of anthuriums (Kamemoto and Nakasone, 1955; Sheffer and Kamemoto, 1976).The practice of hybridisation between selected genotypes having good combining ability helps to create anthurium hybrids with commercially desirable characters (Mercy and Dale,1994).So, analysing the cross compatibility of the genotypes becomes a pre- requisite for successful hybridization programmes.

Considering the above facts, the present study is to evaluate the floral and pollen attributes of 10 genotypes of anthurium and to analyse compatibility of the genotypes in hybridization.

Review of Literature

2. REVIEW OF LITERATURE

Anthurium is one of the most demanded cutflower in the world. The increasing demand is due to the beautiful and longlasting flowers. The heart shaped spathe seeks the main attraction of the flower. *Anthurium andreanum* Linden is the one that have commercial value in the tropical regions. The climatic conditions of Kerala are well suited for the cultivation of anthurium.

The best method for the genetic improvement of anthurium is hybridization followed by selection. Anthurium is a crop having high genetic potential because of its heterozygous nature, and hence there is a large scope for crop improvement. The present investigation is to evaluate the floral and pollen characteristics of parents and further more improvement of characters through hybridization. A brief review of works relevant to the present study is presented below

2.1 CULTURAL REQUIREMENTS

According to Mercy and Dale (1994), the optimum requirements for anthurium are warm greenhouse with 75 percent shading, 70 -80 percent atmospheric humidity. The anthurium growing media include sand, cow dung, brick pieces, charcoal and coconut husk. These provide 100 per cent drainage to the anthurium plants.

The weekly application of 1 percent 17:17:17 complex NPK fertilizer resulted in increased height and other biometrical characters of cultivar Hawaiian Red (Salvi,1997). For proper and better growth and flowering of anthurium, a low to medium range of light intensity (2,000 to 6,000 lux) and shade of 60-80 percent are optimum. (Prasad *et al*. 2001)

Srinivasa (2006b) conducted a field trial to observe the effect of different shade levels on the growth and flowering of *Anthurium andreanum* cv. Honduras. It was observed that shade level of 80 per cent provided maximum values for all the vegetative and reproductive characters.

Prasad *et al*. (2001) and Prakash *et al*. (2006) claimed that a temperature range between 21 to 24°C during day time and 18.3°C during night time with an atmospheric humidity of 50- 80 percent is required for the proper and better growth

and development of anthurium. Dhaduk *et al.* (2007) observed enhanced growth and flowering in the anthurium varieties on foliar application GA3 (500 ppm).

Anthurium plants are partially epiphytic in nature. During summer, about 20-30 per cent is the tolerable level of light in the tropical region. Excessive light may result in the yellowing and scorching of leaves while very low light intensity may lead to excessive vegetative growth and low flowering. Hence, for the anthurium plants it is preferable to grow under open condition, providing artificial shade structures for better and proper growth and yield. Anthurium plants do not prefer to grow under a temperature more than 30°C (KAU,2007).

Keshav and Prashant (2008), conducted study in anthurium and observed that upon using FYM + Brick piece in the growing media, the total number of leaves produced was 5.00 which increased to 7.66 when FYM + cocofibre was used. It was also observed that the FYM + cocofibre growth medium produced maximum value for leaf lamina diameter, leaf sheath length, plant height, early flower initiation, maximum number of spadices, largest flower and longest flower stalk.

Growth medium having wood shaving and organic compost in 1:1 ratio produced better flower quality in anthurium plants (Cuquel *et al*., 2012). Well decomposed coconut husk with cow dung, sand and small stones in the ratio of 2: 1: 1: 1 can be used as a growing media for anthurium (Islam *et al.*,2013).

Fertilizer application is an important aspect regarding the growth and development of the crop. The deficiency of nitrogen in anthurium plants can lead to reduction in the yield and flower quality (Dufour and Guerin, 2005).

Split application of 30:20:40 g NPK in the anthurium plants, improved values of the plant characters such as number of suckers (1.88), number of spadices (2.25), leaf length (17.63 cm), leaf width (8.52 cm), spadix length (5.00cm) and spadix girth (6.04 cm).Split application of 20:15:30 g NPK also resulted in the improvement of characters spathe length (9.88 cm) and spathe width (7.81 cm).No significant difference was observed with differing fertilizer levels in the physiological traits like anthocyanin content, carotenoid, wax and chlorophyll content (Srinivasa ,2006a).

Waheeduzzama *et al*. (2007) applied 4 per cent panchagavya + 5 per cent RDF in anthurium variety Meringue inorder to study the effect of integrated nutrient management (INM) practice in enhancing the flower yield. It was observed that the

floral characters such as days to first flowering (206.50), flower yield per plant (5.90) was improved. There was also an increase in the vegetative traits like plant height (32.40 cm), number of leaves per plant (6.20), number of suckers per plant (4.20) and number of aerial roots per plant (2.60), number of primary roots per plant (12.50) and root length (15.30 cm).

Seasonal variations have very much influence on yield and quality of anthurium flowers. Significant difference was shown by ten anthurium varieties in the two seasons i.e. summer and winter. (Agasimani *et al*., 2011 b)

Regular phytosanitation measures in anthurium on weekly basis and the removal of the infected plant materials and weeds is required for the proper growth of anthurium. The infected plant materials should be burnt inorder to control the further spread of pest and diseases. Timely flower harvest of the anthurium should be practiced at three-fourths ripe stage of the flowers (Elibox and Umaharan 2012).

Khawlhring *et al*. (2012) observed that on comparison with the anthurium plants grown at natural tree shade those grown at 75 percent shade house showed better growth and development.

According to Anand (2019), anthuriums require an optimum atmospheric temperature of 22° to 25°C with a range between 25 and 28°C during the daytime and between 18 and 22°C during the night time.

2.2. Floral characters

2.2.1 Spathe size (cm^2)

According to the United States Department of Agricultural Standards, anthurium flowers can be graded inaccordance with the average length and width of spadix, as miniature (under 8 cm), small (8-10 cm), medium (10-13 cm), large (13-15 cm) and extra-large (15 cm) (Singh, 1987). Sindhu (1995) observed that the variety Pink and Kalympong Red produced flowers with maximum spathe size and Miniature White produced minimum sized spathe. The miniature variety Red Hot has a spathe size of 10 to 12 cm (Henny, 1999).

Renu (2000) observed maximum spathe size (width + length) in the variety Dragon’s Tongue Red (30.74cm) followed by Midori Green (26.90cm). Mayadevi

(2001) conducted a study in 100 genotypes of anthurium and observed a wide variation in spathe size. The average spathe length observed was 10.80 cm and average width was 7.76 cm. On analysing the performance of 14 anthurium genotypes, Shiva and Nair (2008) observed that the spathe size ranged from 5.8 to 8.52 cm with variety Mauritius having maximum spathe size.

Madhukumar (2010) studied the performance of 40 genotypes of anthurium and observed that the genotype Acropolis White (123.43 cm^2) has maximum spathe size followed by Geisha white (118.18 cm^2).On comparing 9 exotic anthurium varieties, Sheena (2015) observed maximum spathe size in the cultivar Mozaik Fresh (137.98 cm^2) followed by Paradise (112.41 cm^2).The cultivar Red Amour (48.30 cm^2) was recorded with minimum spathe size.

Gopi (2016) evaluated 25 genotypes of anthurium and found variation in spathe size from 42.88 cm^2 to 101 cm^2. The genotype Boroque (101 cm^2) was observed with maximum spathe size followed by Tropical Peach (97.2 cm^2) and the variety Lady Jane (42.88 cm^2) with minimum spathe size. Anand *et al*. (2017) recorded highest spathe length (12.67 cm) and highest spathe width (13.50 cm) in the variety Fantasia.

Anand (2019) conducted variability study in 20 anthurium hybrids and recorded maximum spathe size in the hybrid HoR x KR (112.30 cm^2) followed by HR x LR (96.55 cm^2). The minimum spathe size was observed in HR x MR (27.60 cm^2).

2.2.2 Spadix length (cm)

Short slender candles having anthuriums are more preferred in the commercial market than the anthurium with thick candles. According to Mercy and Dale (1994), the spadix was long and fleshy in ordinary varieties of ‘Red’, ‘Pink’ and ‘White’ while shorter and more slender in the case of hybrids and exotics. Renu (2000) recorded maximum spadix length in the variety Dragon’s Tongue Red (8.02 cm) and minimum in the variety Tropical Red with spadix length of 5.74 cm.

Ravidas (2003) in his study observed that the variety Lima (9.11cm) had maximum spadix length and the variety Red Dragon (6.22cm) had minimum spadix length. According to Srinivasa and Reddy (2005), among the five cut flower

genotypes of anthurium, the genotype Honduras reported the maximum spadix length (6.57 cm) and girth (7.93 cm).

Madhukumar (2010) observed the highest spadix length for the hybrid OG x DT and the lowest spadix length in the hybrid LR x PR. In a study conducted by Agasimani *et al*. (2011a), maximum spadix length was observed in the genotype Esmeralda (8.24 cm) and minimum in the genotype Grace (3.35 cm). Anand *et al.* (2013) reported maximum spadix length in variety Temptation (11.5 cm) and minimum spadix length in variety Mearague Red (5.67 cm).

Islam *et al*. (2013) reported the highest spadix length in genotype Titicaca (8.1 cm) and lowest spadix length in the genotype Ivory (4.5 cm). Anand *et al* (2015) evaluated thirteen anthurium cultivars and found that the spadix length ranged between 4 to 6.5 cm. Sheena (2015) reported the longest candles in the variety Paradise (5.73 cm) and shortest candles in variety Anastasia (4.03 cm).

The cultivar Chikoos (8.76 cm) showed the highest spadix length of followed by Cascade White (7.18 cm) and the shortest spadix with a length of 2.2 cm was reported in cultivar Honeymoon Red (Gopi, 2016). Anand (2019) analysed 20 hybrids of anthurium and observed maximum spadix length in the hybrid HR x KR with 8.58 cm and minimum spadix length in the hybrid KR x LR with 3.64 cm.

2.2.3 Life of spadix in plant (days)

Mercy and Dale (1994) reported that the fertilized inflorescence (4-7 months) have greater shelf life than the unfertilized spadix (2 months). Yellowing of peduncle followed by withering of spathe and candle indicates the senescence in anthurium.

The life of fertilized spadix ranges from four and a half to eight months. The unfertilized spadix in the variety Kalympong Orange remained in the plant for about one and half months and in Honeymoon Red for about two to three and a half months (Sindhu,1995).Foliar application of GA3 at a concentration of 1000 ppm resulted in the increased longevity of spadix in the cultivar Agnihotri (Valsalakumari *et al*., 1998).

Renu (2000) recorded that the life of fertilized spadices ranged from 3.8 to 7.5 months. Premna (2003) studied the performance of various anthurium varieties and

hybrids and observed that the hybrid PR x DT had the highest spadix life of 101.50 days and the cultivar Carrie had lowest spadix life of 59.50 days.

Shiva and Nair (2008) on studying the 14 genotypes of anthurium concluded that the maximum life span varied widely among the genotypes. Maximum life span of spadix was shown by the varieties Wrinkled Orange and Honey. Madhukumar (2010) reported much variation among varieties and hybrids in life of spadix. Maximum spadix life span of 101.33 days was reported in the hybrid PR x DT and minimum spadix life of 46.83 days was reported in the variety Gold Spark.

Gopi (2016) conducted variability study and noted that Tropical Red (91.2 days) had the maximum spadix life span followed by Liver Red (88.4 days). The lowest spadix life was found in the variety Vezuvious Red (48.2 days). Anand (2019) found that the hybrid OG X NO had maximum spadix life with 95 days. The minimum spadix life was observed in the hybrid HR x P with 58.8 days.

2.2.4 Inclination of candle with spathe (degrees)

An ideal anthurium flower should have its inclination of candle with the spathe less than an angle of 45° for more demand in the market (Mercy and Dale,1994). Sindhu (1995) observed that ideal angle less than 45° is present in Chilli Red, Kalympong Orange and Kalympong Red.

On analysing 10 varieties of anthurium, Renu (2000) reported that the varieties like Pompon Red, Chilli Red, Tropical Red, Mauritius Orange, Nitta Orange, Merengue White and Midori Green have inclination with spathe at an angle less than 45°. Mayadevi (2001) reported that the angle of inclination of candle with spathe ranged from lowest 21° in Kalympong Red to highest 78.20° in Honeymoon Red. Ashish (2002) reported that the hybrid MO X KR (89.33°) had the maximum angle of inclination and minimum angle of inclination was observed in PR X MO (10.67°).

Pravin (2004) analyzed 14 hybrids of anthurium and observed that the hybrid MO x KR (1) (70.07°) has the highest candle to spathe angle and lowest in PR x MO (26.10°). Madhukumar (2010) observed a range from 35.33° in Orange Glory to 75.67° in Vezuvious Red on calculating the inclination angle with the spathe. Islam *et*

al. (2013) observed maximum angle of inclination (60°) in variety Jewel and minimum in superior variety Aymara (30°).

Sheena (2015) on comparing 9 exotic anthuriums found lowest angle of inclination in the variety Paradise (58.50°) and the highest angle of inclination in the cultivar Salmon Queen (80°) followed by Mozaik Fresh (78.33°).The optimum angle of inclination desirable for the market were observed in the cultivars like Rosette (41°), Tropical Red (41.33°) and Orange Glory (44.67°).

Gopi (2016) found maximum angle of inclination in the variety Vezuvious Red (72.6°) followed by Chikoos (70.4°) and minimum angle of inclination was found in variety Mauritius Orange followed by Honeymoon Red (44.8°). Anand (2019) in the variability study using 20 hybrids of *Anthurium andreanum,* observed maximum inclination of candle with spathe in the hybrid LR x DT (103.2°) and the minimum angle of inclination of candle with the spathe was observed in the hybrid P x LR (37.2°).

2.2.5 Vase life

The harvest of flowers is done after the complete unfolding of their spathe (Kamemoto, 1962). Ho and Nicholus (1975) reported that the higher sugar intake that takes place in the petal cells from the vase solution resulted in the enhanced water uptake due to osmotic pull in cut flowers.

Shriram (2008) reported vase life maximum in the variety Esmeralda (21days) and the variety Ivory (10 days) had the minimum vase life. Agasimani et al. (2011b) observed that there is significantly difference among the anthurium varieties in the vase life of flowers. Anand *et al*. (2013) in the variability study observed that the variety Honduras (24 days) had the maximum vase life followed by Temptation (23 days) and Ria Bamboo Red (22 days). The cultivar Lambada (14 days) was reported with minimum vase life.

Harish shivalingappa *et al*. (2013) observed significant difference in the vase life of the varieties upon effect of different holding solutions. Significant differences were also found among the varieties. The least vase life was reported in cultivar Marysia with 10 days when kept in distilled water.

Islam *et al*. (2013) the vase life was the maximum in the variety Titicaca (16 days) and the minimum vase life was recorded in Caesar (10 days). All the other varieties studied were significantly different from each other. Sahare and Alka (2015) when kept cut flowers in water, a vase life of 11.86 days was observed. Sheena (2015) reported maximum vase life in the cultivar Salmon Queen (9.25 days) followed by cultivar Paradise (9.00 days) and minimum vase life was observed in the cultivar Cynthia (6.50 days)

Anand *et al.* (2017) claimed that for the ultimate requirement of any successful flower production technology, post-harvest life or vase life of cut flower is important. The vase life of anthurium was found to be a genetically controlled trait and influenced very much by the stage of flower harvest and size of flowers.

Anand (2019) reported the maximum vase life in the hybrid HoR x KR (24.4 days) followed by the genotype LJ x OG with 23.4 days. The minimum vase life was observed for the genotype KR x LR with 10 days.

2.2.6 Spathe colour

Spathe is the most attractive part of the anthurium. The 5 major colours of anthurium spathe are red, pink, orange, coral and white (Kamemoto *et al*., 1988). Forsyth and Simmonds (1954) identified the presence of 1- pelargonidin glycoside and 3-cyanidin glycoside in the spathes of *Anthurium andreanum* and they reported spathe colours like red, orange, pink, green and white.

Iwata *et al.* (1979) reported the presence of anthocyanin in the spathes of anthurium. They identified pigments pelargonidin 3- rutinoside and cyanidine 3-rutinoside responsible for the spathe colour. Analysing the genetics of spathe colour, they found that in the red coloured cultivars both the pigments are present. They observed that the coral and orange coloured spathe are contributed by pelargonidin 3-rutinoside. The white coloured spathe contains either pelargonidin or both the pelargonidin and cyanidine are absent.

The two genes which are responsible for anthocyanin production in anthurium are M and O. Here recessive epistasis of the O locus exists over the M locus. The production of cyanidin 3-rutinoside is controlled by the M gene and the production of

pelargonidin 3-rutinoside is controlled by gene O. Many other genes also contribute to give the diversity of flower colours. The production of red, orange, pink, coral and white colours are controlled by genes M and O. The presence of both gene M and O give rise to red and pink colours. Double heterozygote is responsible for the pink colour. The combination of 'OO' with M and also double recessive 'mmoo' give rise to white colour. White and orange colours breed true (Kamemoto *et al*., 1988).

With the increase in age of the flower, the spathe colour gradually decreases. After fertilization of the flower, the spathe colour changes to green in colour and become photosynthetic in nature. This is to provide nutrition to the growing berries (Mercy and Dale, 1994)

Sindhu (1995) observed that dark and bright coloured spathe, which are of commercial importance in the cultivars Chilli Red and Kalympong Red. Renu (2000) reported significant variation in the spathe colour. The red varieties showed spathe colour variation from dark red to bright red to red.

Mayadevi (2001) observed a range from deep maroon to light pink in the spathe colour of 100 anthurium genotypes studied. The red varieties exhibited variation from deep red (Chilli Red) to red (Honeymoon Red).

Ashish (2002) conducted variability study in 50 genotypes of anthurium, and observed significant difference in the spathe colour ranging from deep maroon to white.

Asish and Mayadevi (2006) claimed that high concentration of anthocyanins is responsible for deep maroon colour of the spathe and lower concentration is responsible for the pink colour of spathe.

Madhukumar (2010) observed double coloured spathe in addition to the deep maroon to white colour variation of spathe. Gopi (2016) observed wide variation in the spathe colour among the 25 genotypes of anthurium. The spathe colours ranged from deep maroon to green.

Anand *et al*. (2017) conducted variability study among various anthurium cultivars and observed colour variations in spathe like pure white in cultivar Acropolis, white in Angel, red in Calisto, pink in Cheers, deep orange in DO 32, greenish in Fantasia, red in Fire, pale white in Lumina, creamy yellow in Marysia, green in Midori, whitish pink in Rosa, white with green margins in Titicaca and red in

Xavia. Anand (2019) observed wide variation in the spathe colour of the anthurium ranged from dark to light colours of red, orange and pink.

2.2.7 Spadix colour

The most common spadix colour was yellow at young stage and when the flowers become mature it changes to white (Kamemoto and Nakasone, 1963).Usually anthurium varieties have single colour for spadix like red, pink and green while hybrids exhibited different colours like yellow, pink or red in two or more bands (Mercy and Dale, 1994).

Renu (2000) observed different spadix colours like pink, light pink, yellow, light yellow, green and light green in the ten varieties of anthurium. Asish (2002) reported variations in spadix colour such as red to light red, reddish pink, pink, light pink, pinkish yellow, pinkish white, yellow, yellowish white and cream.

Madhukumar (2010) reported spadix colours in anthurium varieties like pink, light yellow, yellow, maroon, yellowish white, creamish white and greenish yellow. Sheena (2015) concluded that according to the cultivars, the colour of the spadix also varies.

Anand *et al.* (2017) reported spadix colours like creamy yellow in genotype Acropolis, whitish and greenish tinge in Angel, whitish and greenish tinge at the tip of spadix in Calisto, Peach with green in Cheers, creamy yellow in DO 32, green in Fantasia, creamy yellow in Fire, Violet in Lumina, whitish and greenish tinge at the tip of spadix in Marysia, green in Midori, pinkish with yellowish tinge at the tip of spadix in Rosa, green in Titicaca and red in genotype Xavia.

Anand (2019) reported wide variation in the spadix colours of 20 genotypes of anthurium. The spadix colours observed were yellowish red, whitish red, greenish red, whitish yellow, yellowish green, yellowish white, reddish white, and white.

2.3. Pollen characteristics

2.3.1 Pollen fertility (%)

The pollen sterility present in the anthurium species is about 70-75 per cent (Lalithambika,1978). Bindu and Mercy (1994) claimed that it may be the high degree of meiotic abnormalities that resulted in high pollen sterility of anthurium.

Renu (2000) studied ten genotypes of anthurium and observed maximum pollen fertility in the genotype Liver Red 42 per cent followed by cultivar Tropical Red with 29 per cent. The minimum pollen fertility was recorded in cultivar Lady Jane Red with 13.7 per cent.

Mayadevi (2001) found the highest pollen fertility in the genotype Liver Red (40.90 percent) and lowest was recorded in the genotype Chilli Red (20.12 percent). Asish (2002) observed an average pollen fertility of 24.24 per cent in almost all the cultivars studied.

Premna (2003) recorded pollen fertility the highest in the cultivar Carrie with 35.70 per cent followed by cultivar Honduras with 35.13 per cent. Pravin (2004) observed low pollen fertility in almost all varieties studied.

Madhukumar (2010) conducted variability studies and observed highest pollen fertility 43.01 per cent in the cultivar Liver Red and the lowest pollen fertility 2.59 per cent in the cultivar Diva Pink.

Sheena (2015) conducted variability study in 9 exotic varieties of anthurium and observed maximum pollen fertility in the cultivar Marijke with 57.08 percent followed by Mozaik Fresh (34.51 percent). The minimum pollen fertility was observed in cultivar Hillary (16.75 percent) followed by 17.29 percent in Elizabeth. Gopi (2016) recorded the highest pollen fertility in the genotype Chikoos with 42.58 per cent and lowest was recorded in the variety Tropical Peach (3.63 percent).

2.3.2 Pollen viability

Staining with nonvital stains like acetocarmine, iodine in potassium iodide, and aniline blue in lactophenol can be used to determine the degree of pollen sterility, but it is not useful for assessing pollen viability (Shivanna and Rangaswamy,1992).

Marutani *et al.* (1993) conducted pollen viability test using tetrazolium salt in *Anthurium andreanum*, its closely related species and their hybrids.

2.3.3 Pollen size

Bindu (1992) observed pollen size from a range 87.2 x 86.4 µ in the cultivar Lady Jane to 81.8 x 68.0 µ in the variety Pink. Premna (2003) conducted study using 14 genotypes of anthurium and recorded pollen size from a range of 22.6µ to 28µ.

Ravidas (2003) observed the highest pollen size in the genotype Agnihotri (25µ). Pravin (2004) observed varied size of pollen from 16.80 µ to 24.97µ. Madhukumar (2010) observed the highest pollen size in the genotype Lady Jane (25.18 µ) and lowest pollen size was recorded in the genotype Arun Gold (14.67µ).

Sheena (2015) observed wide variation in the pollen size of the anthurium studied. Largest pollen size of 26 µ was observed in the cultivar Cynthia followed by cultivar Hillary (25.35µ).The smallest pollen size of 11.93 µ was observed in cultivar Paradise.

Gopi (2016) studied 25 genotypes of anthurium and observed maximum pollen size in the genotype Liver Red (24.42µ) and minimum pollen size was recorded in Vezuvious Red (14.32µ).

2.3.4 Pollen emergence pattern

The anther dehiscence in *Anthurium andreanum* was observed during 8 to 10 am on sunny days and was found to be delayed during the rainy and cloudy days (Mercy and Dale 1994). Renu (2000) found no pollen emergence in the cultivars like Pompon Red, Nitta Orange and Midori Green. Except for the variety Merengue White, regular pattern of pollen emergence was observed for other varieties.

Madhukumar (2010) observed the highest pollen emergence in the months from October to December and lowest pollen emergence was recorded from March to June. Sheena (2015) recorded maximum pollen emergence in the months from October to January and minimum pollen emergence was recorded from March to May months.

Similarly, Gopi (2016) observed high emergence of pollen in November to February months and low emergence was observed from March to June month. A retarding effect in the pollen emergence was observed due to the increasing atmospheric temperature during the summer month.

Anand (2019) stated that there was a high pollen emergence in the winter months and low pollen emergence was observed during the summer months.

2.3.5 Pollen shape

Croat (1980) observed variable texture and shape of pollen in anthurium. Madhukumar (2010) conducted variability study in 40 anthurium genotypes and observed round pollen in most of the genotypes.

Gopi (2016) after studying 25 anthurium genotypes observed the occurrence of round to oval pollen. Sheena (2015) observed that the pollen shape varied from round to oval. Oval shape of pollen was found in cultivar Marijke and round pollen found in cultivars like Paradise, Cynthia, Elizabeth, Salmon Queen, Hillary and Mozaik Fresh.

Anand (2019) conducted study in 20 hybrids of anthurium and observed round to oval pollen shape. The hybrids like LJ x OG, HR x LJ and OG x DT were found to have oval pollen shape and others round in shape.

2.3.6 Pollen colour

Croat (1980) observed recorded that there was a wide variation in the pollen colour that ranged from orange, yellow, purple and white. It was revealed that the colour of the pollen decreases as the age of the flower increases.

Gopi (2016) studied 25 genotypes of anthurium and observed that the pollen colour ranged from cream to white. Anand (2019) conducted study using 20 genotypes of anthurium and observed that most of the genotypes have white pollen colour.

2.4 STATISTICAL ANALYSIS

2.4.1 Estimation of Genetic Parameters

2.4.1.1 Variability Studies

The prime important thing for the crop improvement programme is variability. Hence, the variability study provides the basis for selection. In a population, the variability available can be divided into heritable and non-heritable components. The analysis of the components is achieved with the help of genetic parameters like phenotypic and genotypic component of variation (PCV and GCV respectively), heritability(H^2) and genetic advance (GA) (Johnson *et al.*,1955).

According to Allard (1960) variability study enables the plant breeder to develop new crop improvement strategies. The presence of a high variability in crop provides a chance for the improvement of the crop.

In a study with 10 genotypes of anthurium, Renu (2000) observed highest PCV and high GCV for the characters like inclination of candle with spathe and spathe size. Mayadevi (2001) conducted variability study using 100 genotypes of *Anthurium andreanum*, high PCV and GCV was observed in the character inclination of candle with spathe.

Asish (2002) recorded high PCV and GCV for the characters like pollen fertility and inclination of candle to the spathe. Premna (2003) in the variability study of anthurium observed high PCV and GCV for the character inclination of candle with spathe.

Pravin (2004) obtained high PCV combined with high GCV in the character like pollen fertility. High variability was observed in the characters like pollen fertility, spathe size and spadix length (Madhukumar,2010).

Tamuli *et al*. (2015) observed that in all vegetative and floral characters the Phenotypic coefficient of variation (PCV) value was found to be higher than genotypic coefficient of variation (GCV) value which indicates the influence of environment over these characters.

Gopi (2016) observed high PCV, along with high GCV for the character like pollen fertility which could be improved by direct selection. Anand (2019) recorded

high PCV along with high GCV for the character spathe size and the character life of spadix was marked with low value of PCV and GCV.

2.4.1.2 Heritability and Genetic Advance

Heritability coupled with genetic advance provides a clear accurate picture of the heritable variation (Johnson *et al.*,1955). Heritability provides measure of the transmissibility of a character from one generation to another and gives the value of selection for each character. As heritability provides the basis of selection based on phenotypic performance (Allard,1960).

Renu (2000) observed high heritability along with high genetic advance in the characters like spathe size, spathe size and inclination of candle with spathe. Mayadevi, (2001) observed high heritability coupled with high genetic advance in the floral characters like spathe length, spathe width, spadix length and inclination of spadix.

Asish (2002) reported the highest genetic advance for the character anthocyanin content with 118.98 per cent followed by pollen fertility with 86.55 per cent. High heritability coupled with high genetic advance was reported for the characters like leaf area, inclination of spadix, life of spadix, anthocyanin content and pollen fertility (Premna, 2003). These characters can hence be improved by selection.

Madhukumar (2010) also observed high heritability combined with high genetic advance in character like pollen fertility. Anand *et al.* (2013) in the variability study recorded high heritability coupled with high genetic advance in the floral characters like spathe. So, these characters in anthurium were controlled by additive gene action and thereby further improvement can be brought by selection.

According to Sheena (2015) the floral character like inclination of spadix with the spathe showed high heritability in anthurium. Tamuli *et al*. (2015) observed that in the floral characters like spadix length, vase life there was high heritability with low genetic advance which indicates the presence of non-additive gene action.

Gopi *et al*. (2016) recorded high heritability coupled with high genetic advance for the floral characters namely spathe size, spadix length, life of spadix and inclination of candle with the spathe.

Anand (2019) observed that the floral characters like spathe size, spadix length, inclination of candle with spathe and vase life have high heritability combined with high genetic advance.

2.5 COMPATIBILITY STUDIES

2.5.1 Percentage of Candle Bearing Fruits

Sheffer and Kamemoto (1976) conducted huge number of pollinations in *Anthurium andreanum* and observed self-pollination gave 81 percent of candle bearing fruits. The percent of fruiting spadices in intraspecific and interspecific crosses were 65.4 and 28 percent respectively. Sindhu (1995) claimed percent of candle bearing fruits highest in variety White (93 per cent) and lowest of 50 per cent in the cultivar Kalympong Red.

Renu (2000) observed the highest fruiting spadices in the genotype Nitta Orange (51.93 per cent) and the lowest fruiting spadices in the genotype Mauritius Orange. Premna (2003) observed highest candle bearing fruits (100 percent) in 9 crosses of anthurium.

Pravin (2004) conducted hybridization with fourteen genotypes of anthurium and found six crosses with 100 percent candle bearing fruits. Madhukumar (2010) observed a range from 50 to 100 per cent in the percentage of candle bearing fruits. Of the 80 cross combinations that were successful, 100 percent fruiting spadices were found in 41 crosses and 50 percent spadices bearing fruits were found in 39 crosses. The highest percentage of fruiting spadices was observed in the hybrid, Pompon Red x Orange Glory with 90.0 per cent followed by genotype Acropolis White with 66.67 per cent. The lowest percentage of 5 per cent for fruiting spadices was shown by the genotype Esmeralda.

Sheena (2015) conducted around 213 crosses, in which100 percent spadix bearing berries were shown by 34 crosses. When the genotypes such as Orange glory, Paradise and Agnihotri Red were used as the female parent, more successful crosses were obtained.

Gopi (2016) observed the range from zero to 100 in the percentage of candle bearing fruits. The maximum percentage of fruiting spadices were found in the genotypes like Liver Red, Tropical Peach and Pistache.

2.5.2 Number of fruits per spadix

Sindhu (1995) observed the highest number of fruits per spadix in the cross Pink x Honeymoon Red (170). The lowest number of fruits per spadix was reported in the cross Kalympong Red x Kalympong Red. Renu (2000) reported maximum number of fruits per spadix in the genotype Pompon Red. The minimum number of fruits per spadix was observed in the genotype Lady Jane.

Madhukumar (2010) reported maximum average number of fruits per spadices in the genotype Liver Red and the minimum was observed in the genotype Esmeralda. It was observed that all the crosses showed fruit set below 50 per cent. The genotype Ceasor Violet was found to have the lowest fruit set and highest was observed in the genotype Liver Red.

Sheena (2015) reported the maximum number of fruits per spadix in the cross M x MF (137) and minimum was observed in the cross LW x OG (6). The genotype Pompon Red was marked with the highest average number of fruits per spadix and lowest recorded in genotype Lady Jane.

Gopi (2016) conducted cross compatibility study and observed maximum number of fruits per spadix in the cross DT x C and the minimum number of fruits per spadix in the crosses CK x DT and VR x DT.

2.5.3 Percentage of fruit set per spadix

Sindhu (1995) recorded the highest percentage of fruit set with 52.30 per cent in the cross Pink x Honeymoon Red followed by the cross Honeymoon Red x Pink with 44.3 per cent fruit set. Renu (2000) recorded the highest fruit set percentage in the crosses where Pompon Red was used as female parent.

Premna (2003) recorded the maximum per cent fruit set for the cross (Ordinary Orange x Kalympong Red) x Carrie with 34.29 percent. Among the female parents

that were used in the hybridization, maximum average fruit set was observed in (Ordinary Orange x Kalympong Red) with 29.03%. Pravin (2004) noticed the highest percentage of fruit set in the cross Liver Red x Pompon Red and the lowest in the cross Pompon Red x Fla Red.

Madhukumar (2010) obtained percentage of fruit set in almost successful crosses as below 50 per cent. The cross (Pompon Red x Orange Glory) x (Orange Glory x Dragon's Tongue) was reported with the highest fruit set of 21.14 per cent and the cross Esmeralda x (Pompon Red x Orange Glory) had the lowest fruit set per cent (1.75 percent).

Sheena (2015) observed the range of fruit set percentage from 2.58 percent in (LW x OG) to 58.33 percent in (P x LJ). The maximum fruit set was shown by the cross, LR x DT with 52.63 per cent and the minimum fruit set was observed in the cross C x LR with 1.17 percent. The genotype Liver Red showed highest average percentage of fruit set and the lowest was shown by the genotype Chekas. Gopi (2016) recorded a maximum fruit set in the cross LR x DT with 52.63 per cent and minimum fruit set of 1.17 per cent was observed in C x LR.

2.5.4 Number of seeds per berry

Mercy and Dale (1994) claimed that in the commercial varieties of anthurium, each berry contains one or two seeds. Sindhu (1995) observed the percentage of single seeds from 37 to 100 per cent and the percentage of double seeds was found to be 63 per cent.

Renu (2000) observed the range of single seeded berries from 34.30 to 100 percent and the range of double seeded berries ranged from 0 to 62.50 percent. Pravin (2004) noticed that the percentage of single seeded berries were higher in all the successful crosses expect the cross (Liver Red x Pompon Red) x Orange Glory.

Madhukumar (2010) reported the highest percentage of double seeded berries in the cross Fla Red x Liver Red while all other crosses exhibited single seeded berries. Based on compatibility analysis using six genotypes of *Anthurium andreanum*, Sheena (2015) found that in all the cross combinations where the genotype Dragon's Tongue and Orange Glory were used as female parents, both

single and double seeds were produced in all. Gopi (2016) observed both double and single seeded berries in almost all the crosses other than C x DT, CK x DT and VR x DT and TP x C.

2.5.5 Seed size (mm)

Sindhu (1995) observed that when the genotypes like Pink and Honeymoon Red were used as the female parents, the crosses produced larger sized seeds. Smaller sized seeds were produced by the Kalympong varieties.

Renu (2000) reported that the crosses like 'Pompon Red x Liver Red', 'Merengue White x Liver Red' and 'Pompon Red x Dragon's Tongue' produced larger seeds in double seeded berries. In the single seeded berries having crosses, the cross 'Tropical Red x Merengue White' produced larger seeds.

Premna (2003) observed maximum sized seeds in the single seeded berries for the cross (Pompon Red x Liver Red) x Tropical and in the case of double seeded berries large size seeds was recorded in the cross (Ceylon Red x Liver Red) x Honduras.

Madhukumar (2010) reported that in the berry with 2 seeds i.e., double seeded berry, large sized seeds with seed size of 3.53 mm x 2.27 mm was observed in the cross Acropolis White x (Pompon Red x Orange Glory).

Sheena (2015) in the cross compatibility study using 6 genotypes of anthurium, observed the cross DT x OG had the maximum seed size (3.88 mm x 2.97 mm) and the cross LJ x MF had minimum seed size of (2.14 mm x 1.64 mm).Gopi (2016) observed maximum seed size in the cross (Hawaiian Orange x Dragon's Tongue) among the single seeded berries and in case of the double seeded berries, the cross (Hawaiian Orange x Chikoos) was reported with maximum seed size.

2.5.6 Number of days taken for seed maturity

Geir (1989) observed that for *Anthurium andreanum* the taken for seed maturity ranged from 6-7 months (180 to 210 days) while for *Anthurium scherzerianum* it ranged from 10-12 months (300-360 days).

Mercy and Dale (1994) reported that for the maturation of the berries it takes about 4 to 7.5 months i.e., 120 to 225 days. Sheena (2015) observed maximum time for seed maturity as 6.1 months (183 days). Gopi (2016) reported that for the maturity of the berries it took about 4 to 7 months i.e., 120 to 210 days.

Materials and Methods

3. MATERIALS AND METHODS

The current investigation was carried out at College of Agriculture in the Department of Plant Breeding and Genetics during 2018 – 2020. The current study was carried out to assess the pollen characteristics and to study the cross compatibility of commercially important anthurium genotypes and hybrids maintained in the Department. The two experiments of the research investigation are given below.

Experiment I a: Floral characters analysis of parents

b: Pollen analysis of parents

Experiment II: Hybridization and compatibility analysis

The detailed materials and methods used for the conduct of these experiments are presented below.

3.1 EXPERIMENT I

3.1.1 Materials

Five commercially important genotypes and five superior hybrids of anthurium generated through hybridisation in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani that differ in commercial qualities were utilized for the current study.

The five commercially important genotypes used in the study are listed below:

1. Hawaiian Orange (HO)
2. Lima White (LW)
3. Liver Red (LR)
4. Tropical Pink (TP)
5. Tropical Red (TR)

The five superior hybrids of anthurium used in the study are given below:

1. Lady Jane x Orange Glory (LJ x OG)
2. Hounduras Red x Kalympong Red (HoR x KR)
3. Honeymoon Red x Miniature Red (HR x MR)

4. Pompon Red x Honeymoon Red (PR x HR)
5. Orange Glory x Nitta Orange (OG x NO)

3.1.2 Methods

3.1.2.1 Floral characters analysis of parents

The floral characteristics including five quantitative traits and two qualitative traits of the five commercially important genotypes and five superior hybrids were observed from the five replications, recorded and their mean values were taken for study.

3.1.2.1.1 Spathe Size

Spathe size was taken using the standard graphical method and calculated in centimetre squares.

3.1.2.1.2 Spadix Length

Spadix length was taken from the base to the tip of the candle using scale and was recorded in centimetres.

3.1.2.1.3 Life of Spadix in plant

The time from the first day of emergence of inflorescence to the time of shrivelling of candle through the stages like yellowing and withering of spathe was observed and recorded in number of days.

3.1.2.1.4 Inclination of Candle with the Spathe

The angle between the base of the candle to the plane of subtending spathe was taken with the help of a protractor and the inclination angle was recorded in degrees.

3.1.2.1.5 Vase Life

After the harvest of flower, a slanting cut in the stalk was made under the tap water and placed in a 250 ml conical flask containing 100 ml tap water. The tap water was changed every alternate day. Wilting, discolouration of spadix/spathe, spadix necrosis were the signs of senescence. The number of days for the first symptom of senescence was marked as the vase life of the genotype.

3.1.2.1.6 Spathe Colour

Spathe colour of each commercial variety and hybrid was observed visually and was recorded.

3.1.2.1.7 Spadix Colour

Spadix (candle) colour of each genotype was identified by visual observation and recorded.

3.1.2.2 Pollen analysis of parents

The pollen of the parents was collected and different observations including three quantitative traits and two qualitative traits were made with the help of microscope.

3.1.2.2.1 Pollen Fertility

The pollen fertility of all the commercial varieties and hybrids were assessed using acetocarmine staining method. Pollen grains from each were collected during its male phase and then stained with 1:1 glycerine-acetocarmine stain (2 percent). Five slides were prepared for each and then the scoring of microscopic fields was done. The data recorded were then used for the calculation of pollen fertility.

The uniformly stained and properly filled ones were scored as the fertile pollen grains and the unstained, undersized, partially stained and shrivelled pollen grains were scored as sterile pollen grains.

The pollen fertility was calculated using the equation,

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

3.1.2.2.2 Pollen viability

2,3,5-Triphenyltetrazolium chloride (TTC) 0.2-0.5% in sucrose solution was used for pollen viability assessment. Pollen grains with a drop of TTC-sucrose solution was taken in glass slide and then incubated in dark for some hours. The glass slide was observed under microscope and scoring were done for percentage of viable pollen grains, i.e., pollen grains that have turned red due to accumulation of formazan.

$$\text{Pollen viability (\%)} = \frac{\text{Number of pollen grains red in colour}}{\text{Total number of pollen grains}} \times 100$$

3.1.2.2.3 Pollen Size

The pollen size was measured using ocular micrometer after caliberation. Inorder to obtain the measurement of ocular micrometer division caliberation was done using stage micrometer and then it was converted it to µ.

After measuring the pollen grain diameter, the standard deviation and standard error were calculated based on the mean inorder to obtain the average pollen size.

Average diameter = Mean ± standard error.

3.1.2.2.4 Pollen Emergence Pattern

The pollen emergence pattern of all the commercial varieties and hybrids under study were observed for a period of one year. The seasonal effect on pollen emergence was also studied.

3.1.2.2.5 Pollen Shape

The pollen grains of each were collected and tapped on the glass slide. The pollen grains were made moist by adding few drops of water. Then the glass slide was observed under the microscope without staining the pollen. The pollen shape was visually observed and recorded.

3.1.2.2.6 Pollen Colour

The pollen colour of the each were observed through microscope and visually recorded.

3.1.3 Statistical Analysis

3.1.3.1 Analysis of Variance

Analysis of variance (ANOVA) was performed using the with Completely Randomized Design (Panse and Sukhatme,1985). The ANOVA for the two characters X and Y measured in ‘g’ genotypes with ‘r’ replications and grown in completely randomized design is given below

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

3.1.3.2 Coefficient of Variation

The estimation of genotypic and phenotypic coefficients of variation was done using the formula proposed by Singh and Chowdhury (1977). The formula

for the estimation of phenotypic and genotypic coefficients of variation (PCV and GCV) for a trait X given below.

$$GCV = \frac{\sigma gx}{\overline{X}} \quad X\ 100$$

$$PCV = \frac{\sigma_{px}}{\overline{X}} \quad X\ 100$$

Where,

σ_{gx} = genotypic standard deviation

σ_{px} = phenotypic standard deviation

$\overline{X}$ = mean of the character under study

3.1.3.3 Heritability and Genetic Advance

Heritability (H^2) in broad sense was estimated as the proportion of heritable component of variation. Broad sense heritability for each character was calculated as a percentage based on the formula given by Jain (1982).

$$\text{Heritability coefficient (in broad sense), } H^2 = \frac{\sigma}{\sigma_{px}^2} \quad X\ 100$$

Where,

σ_{gx}^2 = genotypic variance of the character X

σ_{px}^2 = phenotypic variance of the character X

According to classification of Heritability by Allard (1960),

< 30 percent - Low heritability

30-60 percent - Medium heritability

>60 percent - High heritability

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

Where,

k = Selection differential whose value is 2.06 if 5% selection is to be practiced (Miller *et. al*., 1958).

H^2 = Heritability in broad sense

σ_{px} = Phenotypic standard deviation

$\overline{X}$ = Mean of the character over all varieties

Robinson *et al*. (1949) classified Genetic advance as percentage of mean into three categories i.e.

< 20 % - Low genetic advance

> 20 % - High genetic advance

3.2 EXPERIMENT II

3.2.1. Hybridization

Based on the pollen availability and receptivity of stigma, intervarietal cross in all possible combination were attempted between the five commercially important genotypes and five superior hybrids.

3.2.1.1 Hybridization Technique in Anthurium

Anther dehiscence occurs during morning at a time between 8 to 10am.The pollen was collected with fine brush or wet hands. The receptivity of stigma was identified by the presence of stickiness and viscous exudate. As the anthurium flower is protogynous in nature, there was no need of emasculation. The pollen collected is passed through the sticky stigma. The pollinated flower was covered using butter paper and was removed after some days. After pollination, the colour of spathe gradually fades and becomes greenish in colour. Berries take about 4 to 6 months to get matured. The pollinated spadix was marked for identification of parentage and date of crossing.

3.2.1.2 Plant Protection

1. To control the anthracnose caused by *Colletotrichum gloeosporioides* regular application of the one of these chemicals were carried out.

a. Bavistin 50 per cent WP @ $2gl^{-1}$

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

c. Nativo @ 0.5 g l^{-1}

2. Inorder to control the bacterial blight caused by *Xanthomonas axonopodis pv. Dieffenbachiae, Pseudomonas fluorescens* at a rate of 2 per cent were applied at weekly intervals.

3. Application of Metacid (2g l^{-1}) or Nuvacron (2g l^{-1}) were done to control the leaf eating caterpillars.

4. For the control of bacterial fungal attack bacteriomycin were sprayed in the field at a rate of 6g/20L.

5.To control the snails, hand picking was practised and also salt was dropped at the borders of the green house.

3.2.2. Compatibility Studies

3.2.2.1 Percentage of Spadix Bearing Berries

The successfully fertilized inflorescence which remained strong and those having green peduncles were noted and its percentage was calculated using the formula

$$\frac{\text{The number of spadices bearing berries}}{\text{Number of spadices pollinated}} \times 100$$

3.2.2.2 Number of Fruits per Candle

The number of fruits or berries in each successfully fertilised candle was counted and recorded.

3.2.2.3 Percentage of Fruit Set per Candle

The percentage of flowers showing fruit set to the total number of flowers pollinated in a spadix were recorded as the percentage of fruit set. If the spadix is pollinated four times, hundred percentage of the flowers were assumed to be pollinated, 3 times means 90 percent, two for 60 percent and one for 30 percent. The number of pollination done varies depending on the availability of receptive stigma and fresh pollen.

3.2.2.4 Number of Seeds per Berry

The number of seeds present in each berry was noted and recorded.

3.2.2.5 Seed Size

The size of the seeds was measured by taking its length and breadth in millimetres and noted.

3.2.2.6 Number of days for maturity

The number of days after pollination to the complete maturation of berries were recorded and expressed in days.

Results

4. RESULTS

The results of the two experiments of the recent study are presented as two experimental results

1. Floral and pollen character analysis of the ten *Anthurium andreanum* parents for hybridization programme

2. Cross compatibility analysis

4.1 FLORAL AND POLLEN CHARACTER ANALYSIS OF THE TEN ANTHURIUM PARENTS FOR HYBRIDIZATION PROGRAMME

The floral and pollen characteristics of the *Anthurium andreanum* Linden and their performance were studied. The genotypes were maintained in the green house with five replications each. The data were recorded and statistical analysis was computed and the results of the present study are presented under the following subheads.

4.1.1Floral and pollen character study of the anthurium genotypes

4.1.2 Estimation of variability components i.e., PCV and GCV

4.1.3 Estimation of Heritability and Genetic Advance

4.1.1 Floral and pollen character study of the anthurium genotypes

Significant variations were observed among the ten anthurium i.e., five commercially important anthurium varieties and five superior hybrids after analysis of variance (Table 1) were performed on the basis of the floral and pollen characteristics. The mean performance of the ten anthurium genotypes (quantitative and qualitative traits of floral and pollen characters) are furnished in Table 2.

Table 1. Analysis of variance of floral and pollen characters in *Anthurium andreanum* genotypes

Sl. No	Characters	Mean square	
		Genotypes	Error
1	Spathe size (cm^2)	4439.351*	15.64
2	Spadix length (cm)	2.503*	0.146
3	Life of spadix in plant (days)	609.553*	16.777
4	Inclination of candle with spathe (degrees)	410.809*	24.64
5	Vase life (days)	79.576*	6.83
6	Pollen fertility (percent)	534.593*	7.753
7	Pollen viability (percent)	454.616*	2.196
8	Pollen size (µ)	71.448*	3.663

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

Liver Red (LR)

Tropical Red (TR)

Tropical Pink (TP)

Lima White (LW)

Plate 1. Genotypes (commercial varieties and hybrids) used in the study

Hawaiian Orange (HO)

Lady Jane x Orange Glory (LJ x OG)

Honeymoon Red x Miniature Red (HR x MR)

Hounduras Red x Kalympong Red (HoR x KR)

Plate 1. (Continued) List of genotypes (commercial varieties and hybrids) used in the study

Orange Glory x Nitta Orange
(OG x NO)

Pompon Red x Honeymoon Red
(PR x HR)

Plate 1. (Continued) List of genotypes (commercial varieties and hybrids) used in the study

Plate 2. General view of the experimental plot

4.1.1.1 Floral characters

4.1.1.1.1 Spathe Size

The hybrid HoR x KR was recorded with the maximum spathe size (115.79 cm^2) followed by variety Tropical Pink (96.8 cm^2), Lima White (91.94 cm^2) and hybrid OG x NO (89.02 cm^2). The minimum spathe size was observed in the hybrid PR x HR (26.82 cm^2).

4.1.1.1.2 Spadix Length

The highest mean spadix length was observed in the hybrid HoR x KR (6.24cm) which was significantly on par with variety Liver Red (6 cm),Lima White (5.82 cm)and hybrid OG x NO (5.76 cm).The lowest mean spadix length was recorded for the hybrid PR x HR (3.86 cm).

4.1.1.1.3 Life of Spadix in plant

The maximum mean value for the life of spadix was observed in the hybrid OG x NO (93.3 days) which was significantly on par with variety Tropical Red (90.3 days),hybrid HoR x KR (92.2 days) and Liver Red(89.2 days).The minimum life of spadix was recorded for the hybrid PR x HR (65.4 days) which was on par with hybrid LJ x OG(66.3 days).

4.1.1.1.4 Inclination of Candle with the Spathe

The highest mean value for inclination of candle with the spathe was recorded for hybrid HoR x KR (72°). The angle between the candle and the spathe was the lowest in the hybrid PR x HR (41.4°) which was on par with hybrid OG x NO (44.8°), variety Tropical Red (45.4°) and Tropical Pink (46.2°).

4.1.1.1.5 Vase life

The genotype Tropical Red was recorded with the highest vase life (25.60 days) which significantly on par with hybrid HoR x KR (24.80 days) and HR x MR (23.20 days).The lowest mean vase life was recorded for LJ x OG (13.20 days) which was on par with PR x HR (15.60 days).

Table 2a. Mean performance of quantitative floral characters in *Anthurium andreanum* genotypes.

Sl. No.	Genotypes	Spathe size($cm^{2)}$	Spadix length (cm)	Life of spadix in plant (days)	Inclination of candle with spathe (degrees)	Vase life (days)
1	HO	76.1	5.64	69.3	58.6	19.4
2	LW	91.94	5.82	77.4	57.4	18
3	LR	74.42	6	89.2	56.6	19.2
4	TP	96.8	5.46	75.4	46.2	17.6
5	TR	75.7	5.74	90.3	45.4	25.6
6	(LJ x OG)	34.04	5.68	66.3	50.6	13.2
7	(HoR x KR)	115.79	6.24	92.2	72	24.8
8	(HR x MR)	36.6	4.64	73.4	50.2	23.2
9	(PR x HR)	26.82	3.86	65.4	41.4	15.6
10	(OG x NO)	89.02	5.76	93.3	44.8	21.6
	Mean	71.723	5.484	79.22	52.32	19.82
	CD (0.05)	5.05	0.48	5.23	6.35	3.34

Table 2b. Qualitative floral characters of *Anthurium andreanum* genotypes

Sl. No.	Genotypes	Spathe colour	Spadix colour
1	HO	Orange	Yellow
2	LW	White	Yellowish white
3	LR	Deep maroon	Light pink
4	TP	Light pink	Yellow
5	TR	Bright red	Yellow
6	(LJ x OG)	Pink	White
7	(HoR x KR)	Light red	Reddish white
8	(HR x MR)	Light red	Whitish pink
9	(PR x HR)	Dark red	Yellowish red
10	(OG x NO)	Light orange	Yellow

4.1.1.1.6 Spathe Colour

The spathe colour of the varieties and hybrids studied varied from deep maroon, dark red, light red, orange, light orange, pink, light pink and white.

4.1.1.1.7 Spadix Colour

Wide variation was observed among the genotypes studied in the spadix colour. The different colours were listed in Table 2b.

4.1.1.2 Pollen characters

4.1.1.2.1 Pollen Fertility

The maximum pollen fertility was recorded for the genotype Liver Red (44.04 percent) followed by Tropical Red (28.20percent) and Lima White (24.74 percent). The genotype Hawaiian Orange (4.61 percent) was observed with the lowest pollen fertility.

4.1.1.2.2 Pollen viability

The variety Liver Red was observed with highest pollen viability (38.22 percent) followed by Tropical Red (22.77 percent) and Tropical Pink (19.20 percent). The lowest pollen viability was recorded for Hawaiian Orange (2.94 percent).

4.1.1.2.3 Pollen Size

The mean pollen size was recorded the maximum in the hybrid PR x HR (25.4 µ) which was found significantly on par with variety Liver Red (24.65 µ).The minimum pollen size was observed in the hybrid LJ x OG (14.11 µ) which was found significantly on par with the variety Tropical Pink (15.76 µ).

Table 2c. Mean performance of quantitative pollen characters in *Anthurium andreanum* genotypes.

Sl. No.	Genotypes	Pollen fertility (%)	Pollen viability (%)	Pollen size (µ)
1	HO	4.61	2.94	20.86
2	LW	24.74	16.70	18.21
3	LR	44.04	38.22	24.65
4	TP	22.91	19.20	15.76
5	TR	28.20	22.77	17.19
6	(LJ x OG)	13.74	9.96	14.11
7	(HoR x KR)	21.64	15.10	21.90
8	(HR x MR)	18.80	13.00	16.69
9	(PR x HR)	16.80	11.81	25.40
10	(OG x NO)	16.74	10.21	18.04
	Mean	21.22	15.99	19.28
	CD (0.05)	3.56	1.89	2.44

Table 2d. Qualitative pollen characters of *Anthurium andreanum* genotypes

Sl. No.	Genotypes	Pollen shape	Pollen colour
1	HO	Round	White
2	LW	Round	White
3	LR	Round	Cream
4	TP	Oval	White
5	TR	Round	White
6	(LJ x OG)	Oval	Cream
7	(HoR x KR)	Round	Cream
8	(HR x MR)	Round	White
9	(PR x HR)	Round	White
10	(OG x NO)	Round	White

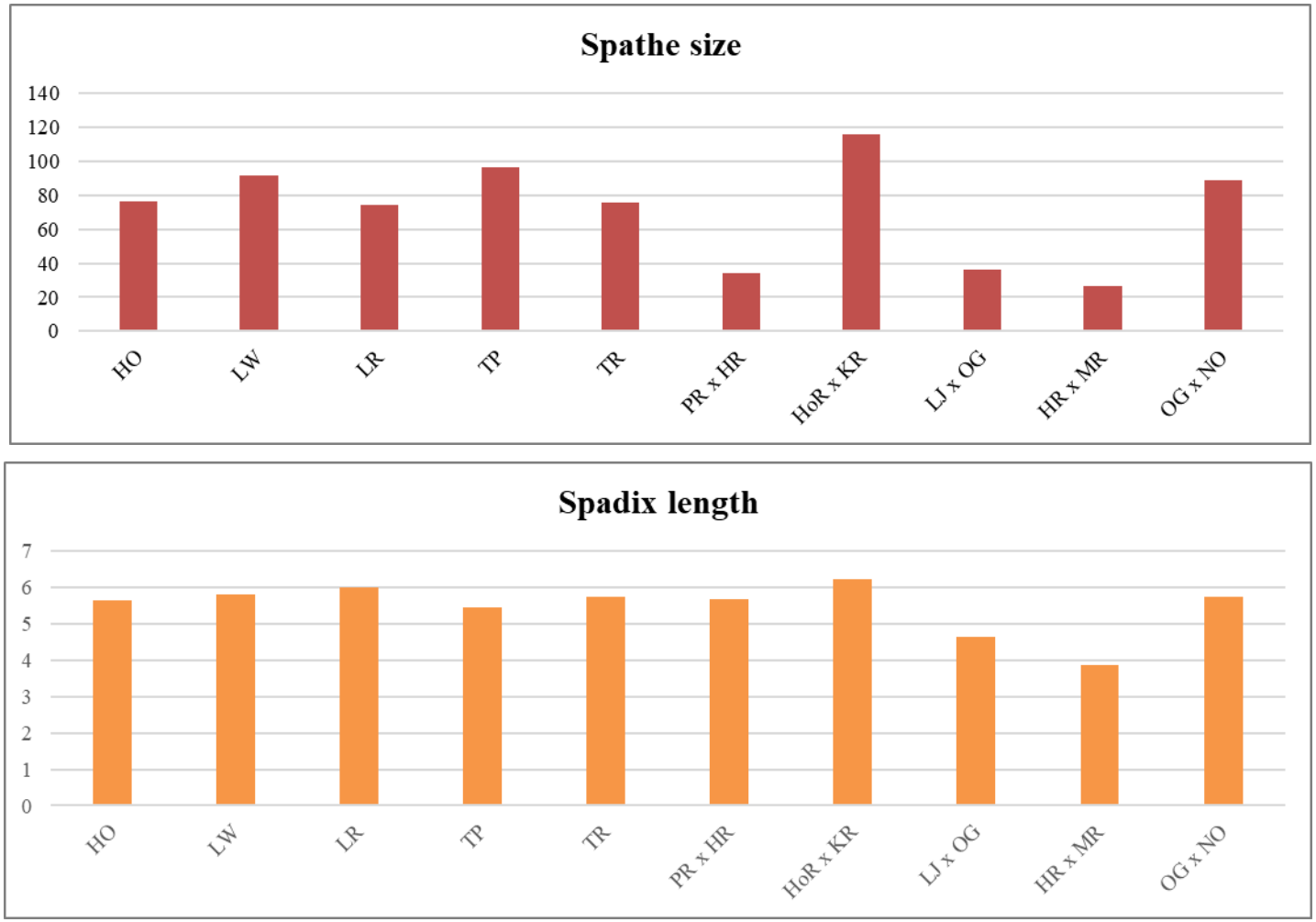


Fig. 1a. Mean performance of 10 *Anthurium andreanum* genotypes

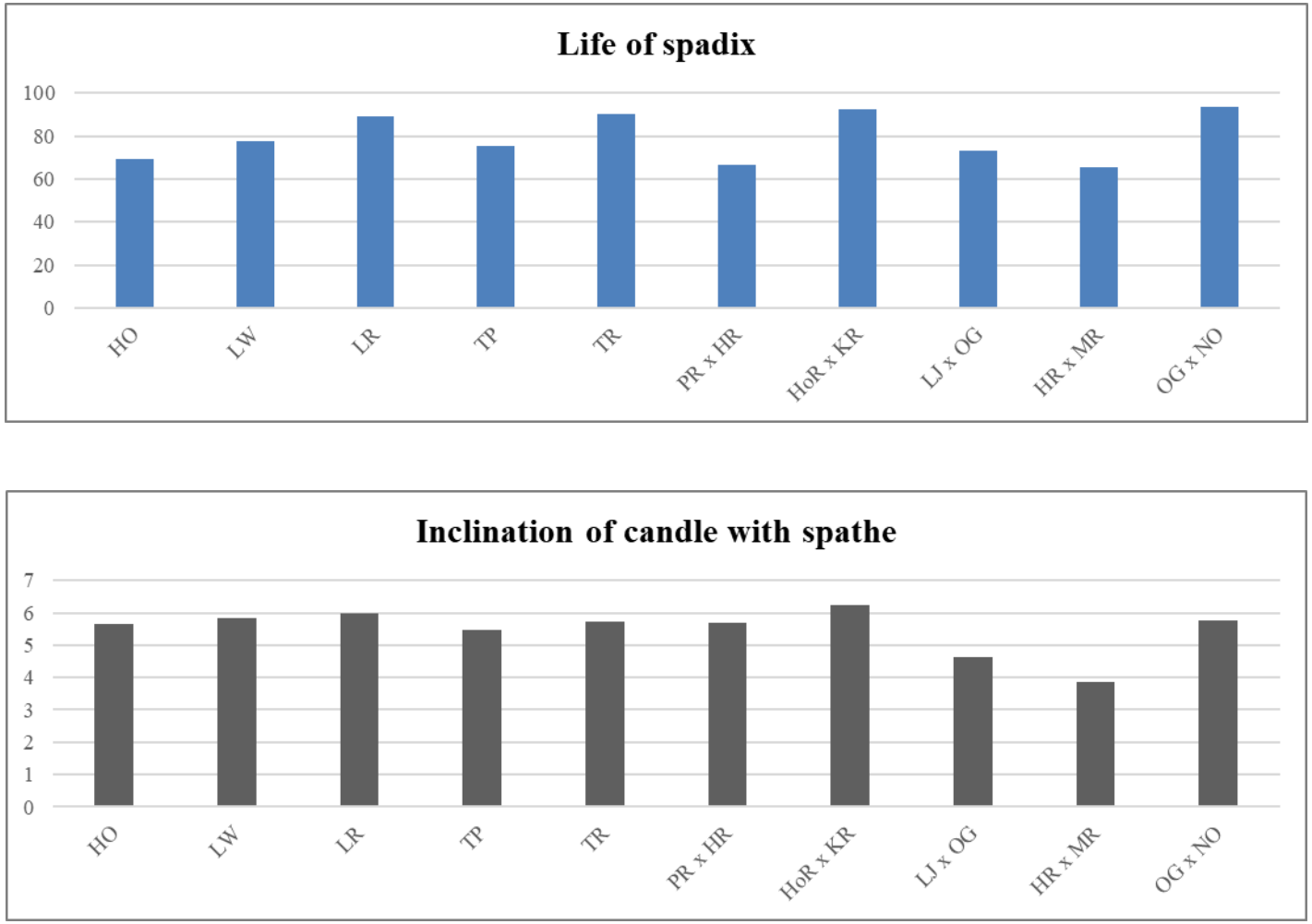
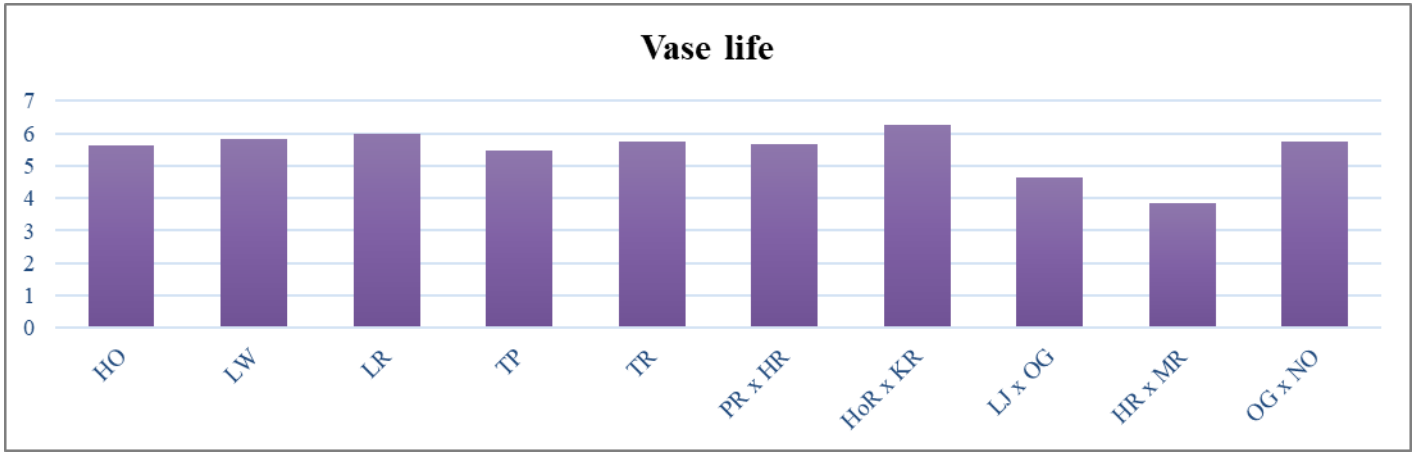


Fig. 1b. Mean performance of 10 *Anthurium andreanum* genotypes



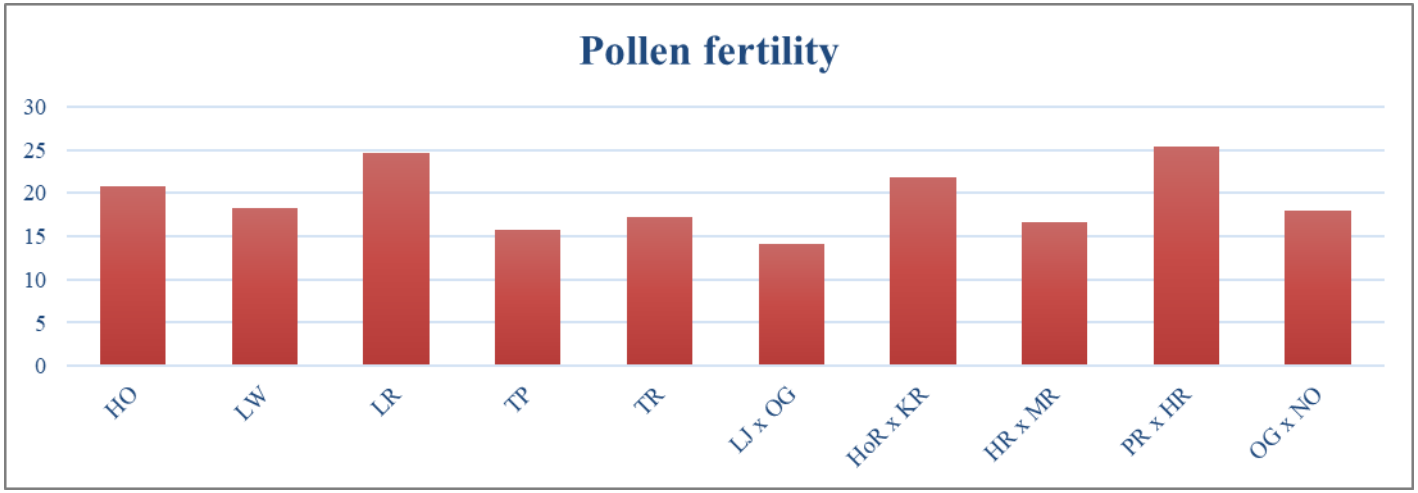


Fig. 1c. Mean performance of 10 *Anthurium andreanum* genotypes

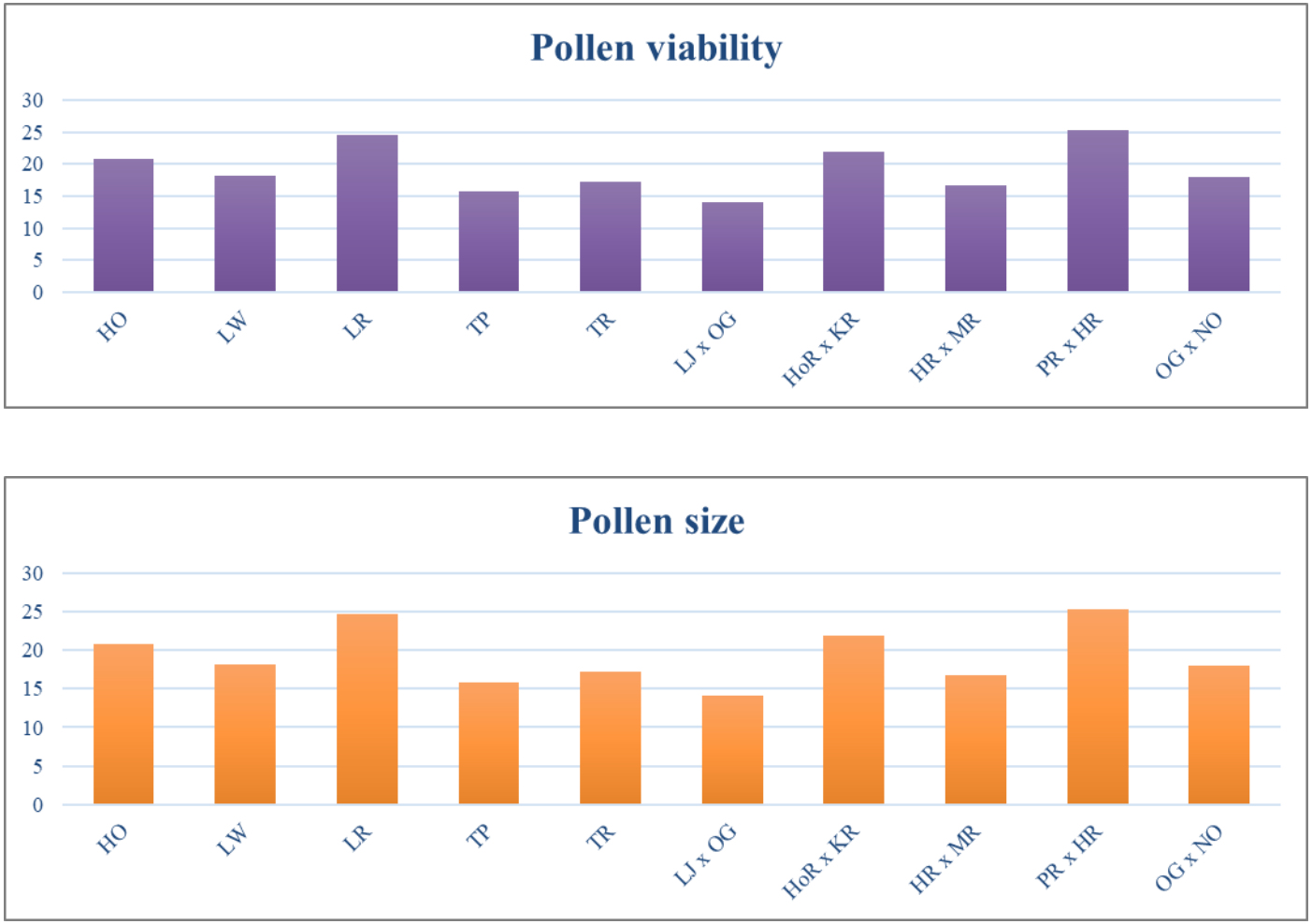


Fig. 1d. Mean performance of 10 *Anthurium andreanum* genotypes

4.1.1.2.4 Pollen Emergence Pattern

High emergence of pollen was observed the months of October to January and low pollen emergence during the summer months. The highest pollen emergence was recorded in the genotypes Liver Red, Tropical Red and HoR x KR. The lowest pollen emergence was recorded in Hawaiian Orange and LJ x OG.

4.1.1.2.5 Pollen Shape

The pollen shape of the five varieties and five hybrids studied ranged from oval to round. Most of the genotypes exhibited round pollen while the Tropical Red and LJ x OG was observed with oval pollen.

4.1.1.2.6 Pollen Colour

The pollen colour of the studied genotypes varied from cream to white. The variety Liver Red, hybrids LJ x OG and HoR x KR were observed with cream pollen colour.

4.1.2 Estimation of variability components i.e., PCV and GCV

The value of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were computed for the characters and presented in the Table 3.The phenotypic coefficient of variation (PCV) was found to be higher than the genotypic coefficient of variation (GCV) in all the characters indicating the influence of environment in expression of these characters.

All the characters studied showed high PCV and GCV. The maximum phenotypic (70.93 percent) and genotypic (70.82 percent) coefficient of variation was recorded for the character life of spadix in plant followed by inclination of candle with spathe(GCV 70.40 percent and PCV 70.67 percent),vase life (GCV 65.32 percent and PCV 66.10 percent), spadix length (GCV 63.58 percent and PCV 65.40 percent), spathe size (GCV 62.40 percent and PCV 64.71 percent), pollen fertility (GCV 62.59 percent and PCV 62.75 percent), pollen size (GCV 56.20 percent and PCV 56.70 percent) and pollen viability (GCV 53.49 percent and PCV 55.12 percent).

Table 3. Phenotypic coefficient of variation and genotypic coefficient of variation of 8 characters in *Anthurium andreanum* genotypes

Sl. No	Characters	PCV (percent)	GCV (percent)
1	Spathe size (cm^2)	64.71	62.40
2	Spadix length (cm)	65.40	63.58
3	Life of spadix in plant (days)	70.93	70.82
4	Inclination of candle with spathe (degrees)	70.67	70.40
5	Vase life (days)	66.10	65.32
6	Pollen fertility (percent)	62.75	62.59
7	Pollen viability (percent)	55.12	53.49
8	Pollen size (µ)	56.70	56.20

PCV -Phenotypic coefficient of variation

GCV -Genotypic coefficient of variation

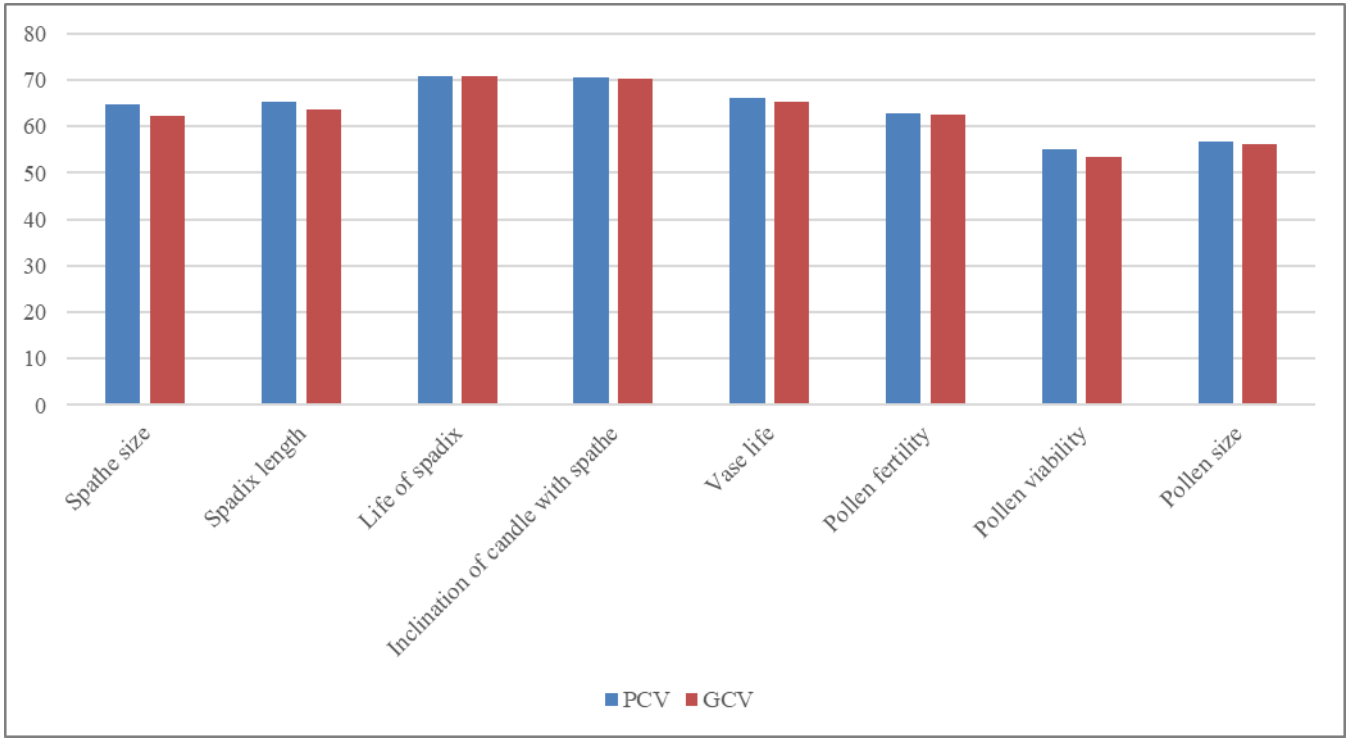


Fig. 2. PCV and GCV for 8 characters in *Anthurium andreanum* genotypes

The difference between PCV and GCV was found to be the lowest in the characters like life of spadix, inclination angle, pollen fertility and pollen size. This indicates that there is negligible effect of environment and the expression of these characters is mainly due to genetic factors.

4.1.3 Estimation of Heritability and Genetic Advance

Estimates of heritability and genetic advance are the important selection parameters. The values of heritability and genetic advance of the different characters studied are depicted in Table 4. High heritability (above 60 per cent) was observed for the characters such as vase life (63.87 percent), inclination of candle with spathe (63.86 percent) and life of spadix in plant (62.97 percent). Medium heritability (30- 60 percent) was exhibited by the characters like spathe size (55.30 percent), spadix length (54.15 percent), pollen fertility (52.15 percent), pollen size (49.05 percent) and pollen viability (43.20 percent).

High genetic advance as percentage of mean (>20 per cent) was exhibited by all the characters studied, of which the highest was found in inclination of candle with spathe (115.89 percent) and life of spadix in plant (115.76 percent).

According to Johnson *et al*. (1955), heritability along with genetic advance expressed in percentage of mean provides a better picture than heritability alone. High heritability coupled with high genetic advance was found in the characters like inclination of candle with spathe, vase life and life of spadix in plant indicating the presence of additive gene action effect.

Table 4. Heritability and genetic advance of 8 characters in *Anthurium andreanum* genotypes.

Sl. No	Characters	Heritability (per cent)	Genetic advance (percentage of mean)
1	Spathe size (cm^2)	55.30	95.60
2	Spadix length (cm)	54.15	96.39
3	Life of spadix in plant (days)	62.97	115.76
4	Inclination of candle with spathe (degrees)	63.86	115.89
5	Vase life (days)	63.87	107.54
6	Pollen fertility (percent)	52.15	93.11
7	Pollen viability (percent)	43.20	72.43
8	Pollen size (µ)	49.05	81.10

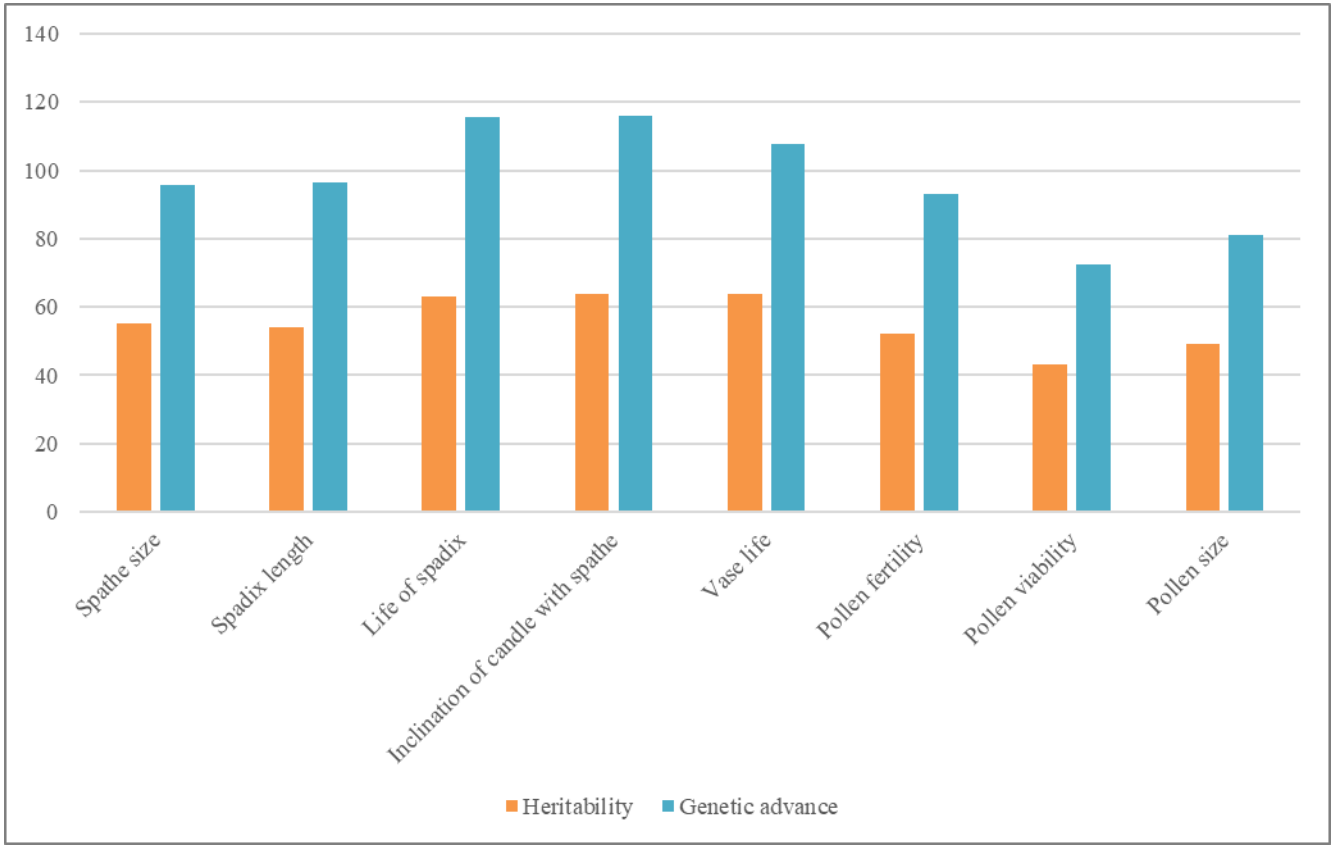


Fig. 3. Heritability and genetic advance as percentage mean for 8 characters in *Anthurium andreanum* genotypes

Table 5: Matrix showing the number of pollinations done in *Anthurium andreanum* genotypes.

	HO	LW	LR	TP	TR	PR x HR	HoR x KR	LJ x OG	HR x MR	OG x NO
HO								1		1
LW						1			1	
LR						1	1			
TP						2		1	1	1
TR						1	1		2	1
PR x HR		2	1				1			
HoR x KR	1	1	1	1	1					
LJ x OG		2	1		2					
HR x MR	1							1		
OG x NO		1				1			1	

4.2 COMPATIBILITY STUDIES

Hybridization involving the five commercially important varieties and five superior hybrids in all possible combination were done shown in Table 5. The list of female and male parents used for the hybridization is furnished in Table 6. The results of cross compatibility analysis are presented below.

4.2.1 Percentage of Spadix Bearing Berries

The percentage of the spadix bearing berries is furnished in the Table 7.

4.2.1.1 Hawaiian Orange

Out of the two crosses attempted, none of the cross was observed with spadix bearing berries.

4.2.1.2 Lima White

None of the cross attempted was found with candle bearing fruits.

4.2.1.3 Liver Red

Two crosses were attempted, but none of the cross showed candle bearing berries.

4.2.1.4 Tropical Pink

Out of the five combinations, only two were successful. The highest percentage of candle bearing fruits (100 percent) was observed for the combination Tropical Pink x (Lady Jane x Orange Glory). The cross combination Tropical Pink x (Pompon Red x Honeymoon Red) was found to have 50 percent spadix bearing fruits.

(HoR x KR) x LW

TP x (PR x HR)

TR x (PR x HR)

(LJ x OG) x LR

Plate 3. Spadix with fruit set in different crosses

TP x (LJ x OG)

(LJ x OG) x LW

(PR x HR) x LW

(LJ x OG) x TR

Plate 3. (Continued) Spadix with fruit set in different crosses

(HoR x KR) x TP

(HoR x KR) x HO

(HoR x KR) x TR

(HoR x KR) x LR

Plate 3. (Continued) Spadix with fruit set in different crosses

TR x (HR x MR)

TR x (HoR x KR)

Plate 3. (Continued) Spadix with fruit set in different crosses

Table 6: List of the successful crosses obtained through hybridization

Sl. No	**Female parent**	**Male parent**	**Cross**
1	Tropical Red	Pompon Red x Honeymoon Red	TR x (PR xHR)
2	Lady Jane x Orange Glory	Liver Red	(LJ x OG) x LR
3	Hounduras Red x Kalympong Red	Lima White	(HoR x KR) x LW
4	Tropical Pink	Pompon Red x Honeymoon Red	TP x (PR x HR)
5	Hounduras Red x Kalympong Red	Tropical Pink	(HoR x KR) x TP
6	Hounduras Red x Kalympong Red	Hawaiian Orange	(HoR x KR)x HO
7	Hounduras Red x Kalympong Red	Liver Red	(HoR x KR) x LR
8	Hounduras Red x Kalympong Red	Tropical Red	(HoR x KR)x TR
9	Pompon Red x Honeymoon Red	Lima White	(PR x HR) x LW
10	Lady Jane x Orange Glory	Tropical Red	(LJ x OG) x TR
11	Tropical Red	Honeymoon Red x Miniature Red	TR x (HR x MR)
12	Tropical Red	Hounduras Red x Kalympong Red	TR x (HoR x KR)
13	Lady Jane x Orange Glory	Lima White	(LJ x OG) x LW
14	Tropical Pink	Lady Jane x Orange Glory	TP x (LJ x OG)

4.2.1.5 Tropical Red

Among the three successful cross combinations, 100 percent candle bearing berries were observed in the cross combinations Tropical Red x (Pompon Red x Honeymoon Red) and Tropical Red x (Hounduras Red x Kalympong Red). The average percentage of candles in this variety was found to be 50 per cent.

4.2.1.6 Pompon Red x Honeymoon Red

Out of the four cross combinations, only one cross was found to be successful. The average percentage of candles in this hybrid was found to be 16.6 per cent. The cross combination (Pompon Red x Honeymoon Red) x Lima White was observed with 50 percent candle bearing berries.

4.2.1.7 Hounduras Red x Kalympong Red

Six cross combinations were attempted of which five were found to be successful. The highest percentage candle bearing berries (100 percent) were observed in all five the cross combinations *viz*.,(Hounduras Red x Kalympong Red) x Hawaiian Orange, (Hounduras Red x Kalympong Red) x Lima White, (Hounduras Red x Kalympong Red) x Tropical Red, (Hounduras Red x Kalympong Red) x Liver Red and (Hounduras Red x Kalympong Red) x Tropical Pink. The average percentage of candle bearing fruits in this hybrid was found to be 83.3 per cent.

4.2.1.8 Lady Jane x Orange Glory

Out of the five cross combinations, only three were found to be successful. The average percentage of candles in this hybrid was 40 per cent. The cross combination (Lady Jane x Orange Glory) x Liver Red was observed with the maximum percentage of candle bearing berries (100 percent). The cross combinations like (Lady Jane x Orange Glory) x Lima White and (Lady Jane x Orange Glory) x Tropical Red were found to have 50 percent candle bearing fruits.

4.2.1.9 Honeymoon Red x Miniature Red

None of the crosses were found to be successful.

4.2.1.10 Orange Glory x Nitta Orange

Out of the three crosses attempted, none of the crosses were successful.

4.2.2 Number of Fruits per Spadix

The number of fruits per spadix for the successful crosses are presented in the Table 8.

4.2.2.1 Tropical Pink

The maximum of fruits (23) was observed in the cross Tropical Pink x (Pompon Red x Honeymoon Red) followed by Tropical Pink x (Lady Jane x Orange Glory) with 16 berries.

4.2.2.2 Tropical Red

Out of the three successful spadix bearing fruits, the highest number of fruits (62) was found in the cross Tropical Red x (Pompon Red x Honeymoon Red) followed by Tropical Red x (Honeymoon Red x Miniature Red) with 45 berries and Tropical Red x (Hounduras Red x Kalympong Red) with 25 berries.

4.2.2.3 Pompon Red x Honeymoon Red

The cross (Pompon Red x Honeymoon Red) x Lima White was found to have 36 berries.

4.2.2.4 Hounduras Red x Kalympong Red

Out of the five spadix bearing berries, the highest numbers of fruits were observed in the cross combinations, (Hounduras Red x Kalympong Red) x Liver Red with 43 berries, (Hounduras Red x Kalympong Red) x Tropical Red with 37 berries, (Hounduras Red x Kalympong Red) x Lima White with 33 berries and (Hounduras Red x Kalympong Red) x Tropical Pink with 28 berries. The lowest number of berries was found in the (Hounduras Red x Kalympong Red) x Hawaiian Orange with 5 berries.

Table 7: Matrix showing spadix bearing fruits in each cross combination

	HO	LW	LR	TP	TR	PR x HR	HoR x KR	LJ x OG	HR x MR	OG x NO	Av
HO								0		0	0
LW						0			0		0
LR						0	0				0
TP						50		100	0	0	30
TR						100	100		50	0	50
PR x HR		50	0				0				16.6
HoR x KR	100	100	100	100	100					0	83.3
LJ x OG		50	100		50						40
HR x MR	0							0			0
OG x NO		0				0			0		0

Table 8: Matrix showing number of fruits per spadix in each cross combination

	HO	LW	LR	TP	TR	PR X HR	HoR X KR	LJ X OG	HR X MR	OG X NO	Average
HO											0
LW											0
LR											0
TP						23		16			19.5
TR						62	25		45		44
PR x HR		36									36
HoR x KR	5	33	43	28	37						29.2
LJ x OG		55	75		26						52
HR x MR											0
OG xNO											0

4.2.2.5 Lady Jane x Orange Glory

Out of the 3 successful spadix bearing fruits, the maximum numbers of berries were found in the cross combination (Lady Jane x Orange Glory) x Liver Red with 75 berries followed by (Lady Jane x Orange Glory) x Lima White with 55 berries. The minimum number of fruits was observed in the cross (Lady Jane x Orange Glory) x Tropical Red with 26 berries.

4.2.3 Percentage of Fruit Set per Spadix

The percentage of fruit set per spadix for the successful crosses obtained are presented in the Table 9.

4.2.3.1 Tropical Pink

Among the two successful crosses, the maximum per cent of fruit set (9.5 percent) was found in the cross Tropical Pink x (Pompon Red x Honeymoon Red). The minimum per cent of fruit set (5 percent) was observed in the cross Tropical Pink x (Lady Jane x Orange Glory).

4.2.3.2 Tropical Red

Out of the three successful spadix bearing fruits, the highest fruit set per candle was observed in the cross Tropical Red x (Pompon Red x Honeymoon Red) with 46.5 percent followed by Tropical Red x (Honeymoon Red x Miniature Red) with 33.5 percent. The lowest fruit set per candle was found in the cross Tropical Red x (Hounduras Red x Kalympong Red) with 12.5 percent.

4.2.3.3 Pompon Red x Honeymoon Red

The cross (Pompon Red x Honeymoon Red) x Lima White was found to have 26.5 percent fruit set per spadix.

Table 9: Matrix showing average percentage of fruit set in each cross combination

	HO	LW	LR	TP	TR	PR x HR	HoR x KR	LJ x OG	HR x MR	OG x NO	Average
HO											0
LW											0
LR											0
TP						9.5		5			7.25
TR						46.5	12.5		33.5		30.83
PR x HR		26.5									26.5
HoR x KR	0.75	22	30.5	16.5	27.5						19.45
LJ x OG		40.5	51		15.5						35.67
HR x MR											0
OG x NO											0

4.2.3.4 Hounduras Red x Kalympong Red

Among the five successful crosses, the maximum percent fruit set per spadix was observed in the cross combinations, (Hounduras Red x Kalympong Red) x Liver Red with 30.5 percent followed by (Hounduras Red x Kalympong Red) x Tropical Red with 27.5 percent, (Hounduras Red x Kalympong Red) x Lima White with 22 percent and (Hounduras Red x Kalympong Red) x Tropical Pink with 16.5 percent. The minimum percentage of fruit set (0.75 percent) was found in the (Hounduras Red x Kalympong Red) x Hawaiian Orange.

4.2.3.5 Lady Jane x Orange Glory

Among the 3 successful spadix bearing fruits, the percentage fruit set was found to be the highest in cross combination (Lady Jane x Orange Glory) x Liver Red having 51 percent followed by (Lady Jane x Orange Glory) x Lima White with 40.5 percent. The lowest percentage fruit set was observed in the cross (Lady Jane x Orange Glory) x Tropical Red with 15.5 percent.

4.2.4 Number of Seeds per Berry

The number of seeds per berry in each successful combination is furnished in the Table 10.

4.2.4.1 Tropical Pink

Among the obtained two successful cross combinations, the highest per cent of single seeded berries (100 percent) was obtained in the cross, Tropical Pink x (Lady Jane x Orange Glory) followed by Tropical Pink x (Pompon Red x Honeymoon Red) having 66.67 percent single seeded berries. The maximum double seeded berries (33.33 percent) was observed in the cross Tropical Pink x (Pompon Red x Honeymoon Red).

4.2.4.2 Tropical Red

Out of the three successful spadix bearing fruits, the cross Tropical Red x (Honeymoon Red x Miniature Red)was found to have 100 percent single seeded berries which was followed by the cross Tropical Red x (Hounduras Red x

Kalympong Red) having 75 percent and cross Tropical Red x (Pompon Red x Honeymoon Red) with 60 percent single seeded berries. The maximum percentage of double seeded berries (40 percent) was recorded in the cross, Tropical Red x (Pompon Red x Honeymoon Red) followed by Tropical Red x (Hounduras Red x Kalympong Red) with 25 percent double seeded berries.

4.2.4.3 Pompon Red x Honeymoon Red

The only successful cross (Pompon Red x Honeymoon Red) x Lima White had 100 percent single seeded berries.

4.2.4.4 Hounduras Red x Kalympong Red

Out of the five successful crosses, the maximum percentage (94.46 percent) of single seeded berries was recorded in the cross (Hounduras Red x Kalympong Red) x Hawaiian Orange followed by (Hounduras Red x Kalympong Red) x Tropical Pink with 91.76 percent, (Hounduras Red x Kalympong Red) x Lima White with 86.40 percent, (Hounduras Red x Kalympong Red) x Liver Red with 85 percent and (Hounduras Red x Kalympong Red) x Tropical Red with 64 percent.

The maximum percentage (36 percent) of double seeded berries was found in the cross (Hounduras Red x Kalympong Red) x Tropical Red followed by (Hounduras Red x Kalympong Red) x Liver Red (15 percent), (Hounduras Red x Kalympong Red) x Lima White with 13.6 percent and (Hounduras Red x Kalympong Red) x Tropical Pink with 8.24 percent. The minimum percentage (5.54 percent) of double seeded berries was observed in the cross (Hounduras Red x Kalympong Red) x Hawaiian Orange.

4.2.4.5 Lady Jane x Orange Glory

Out of the three successful crosses, the highest percentage of single seeded berries (90 percent) was observed in the cross combination (Lady Jane x Orange Glory) x Tropical Red followed by (Lady Jane x Orange Glory) x Lima White with 86 percent. The minimum per cent of single seeded berries number of berries were obtained in the cross, (Lady Jane x Orange Glory) x Liver Red with 70 percent. In the case of double seeded berries, the highest per cent was obtained in the cross (Lady

Jane x Orange Glory) x Liver Red with 30 percent followed by the cross (Lady Jane x Orange Glory) x Lima White with 14 percent.

4.2.5 Seed size

The seed size in each successful combination is furnished in the Table 11.

4.2.5.1 Tropical Pink

Out of the two successful cross combinations, the cross Tropical Pink x (Lady Jane x Orange Glory) had both single seeded and double seeded berries whereas Tropical Pink x (Pompon Red x Honeymoon Red) had only single seeded berries with 3.19 x 1.90 mm seed size. The cross, Tropical Pink x (Lady Jane x Orange Glory) had seed size of 3.28 x 2.12 mm for single seeded and 2.50 x 1.90 mm for double seeded berries.

4.2.5.2 Tropical Red

Out of the three successful spadix bearing fruits, the maximum seed size of 3.25 x 2.15 mm for single seeded berries was found in the cross Tropical Red x (Honeymoon Red x Miniature Red) followed by Tropical Red x (Hounduras Red x Kalympong Red) having seed size of 3.19 x 2.10 mm and Tropical Red x (Pompon Red x Honeymoon Red) with seed size of 3.00 x 2.30 mm. In case of the double seeded berries, maximum seed size was observed in the cross Tropical Red x (Hounduras Red x Kalympong Red) having seed size of 2.32 x 1.60 mm followed by the cross Tropical Red x (Pompon Red x Honeymoon Red) with seed size of 2.45 x 1.20 mm.

4.2.5.3 Pompon Red x Honeymoon Red

The only cross (Pompon Red x Honeymoon Red) x Lima White had 100 percent single berries having seed size of 3.10 x 2.20 mm.

Table 10: Number of seeds per berry among the crosses successful

Sl. No	Crosses	Number of seeds per berry (Per cent)	
		Single seeded	Double seeded
1	TP x (PR x HR)	66.67	33.33
2	TP x (LJ x OG)	100	0
3	TR x (PR x HR)	60	40
4	TR x (HR x MR)	100	0
5	TR x (HoR x KR)	75	25
6	(PR x HR) x LW	100	0
7	(HoRx KR) x LW	86.4	13.6
8	(HoR x KR) x TP	91.76	8.24
9	(HoRx KR)x HO	94.46	5.54
10	(HoR x KR) x LR	85	15
11	(HoRx KR) x TR	64	36
12	(LJ x OG) x LR	70	30
13	(LJ x OG) x TR	90	10
14	(LJ x OG) x LW	86	14

4.2.5.4 Hounduras Red x Kalympong Red

Among the five successful crosses, the maximum seed size in the single seeded berries was observed in the cross combination, (Hounduras Red x Kalympong Red) x Liver Red with seed size of 3.55 x 2.49 mm followed by (Hounduras Red x Kalympong Red) x Hawaiian Orange with seed size 3.42 x 2.50 mm , (Hounduras Red x Kalympong Red) x Tropical Pink with seed size of 3.50 x 2.30 mm, (Hounduras Red x Kalympong Red) x Tropical Red with seed size of 3.12 x 2.35 mm and (Hounduras Red x Kalympong Red) x Lima White with seed size of 3.48 x 2.00 mm.

In case of the double seeded berries, the maximum seed size was observed in the cross (Hounduras Red x Kalympong Red) x Tropical Red with seed size of 2.80 x 1.90 mm followed by (Hounduras Red x Kalympong Red) x Liver Red with seed size of 2.45 x 1.80 mm, (Hounduras Red x Kalympong Red) x Hawaiian Orange with seed size of 2.10 x 1.79 mm and (Hounduras Red x Kalympong Red) xLima White with seed size of 2.12 x1.70 mm. The minimum seed size among the double seeded berries was found in the cross (Hounduras Red x Kalympong Red) x Hawaiian Orange with seed size of 2.10 x 1.79 mm.

4.2.5.5 Lady Jane x Orange Glory

Among the 3 successful spadix bearing fruits, the maximum seed size in case of single seeded berries was found in the cross combination (Lady Jane x Orange Glory) x Lima White having seed size of 2.45 x 1.54 mm followed by (Lady Jane x Orange Glory) x Liver Red with seed size 2.99 x 1.90 mm and (Lady Jane x Orange Glory) x Tropical Red with 2.99 x 1.80 mm seed size.

In the case of double seeded berries, the maximum seed size (2.45 x 1.54 mm) was observed in the cross (Lady Jane x Orange Glory) x Lima White followed by (Lady Jane x Orange Glory) x Tropical Red with seed size of 2.13 x 1.70 mm. The minimum seed size in the double seeded berries was observed in the cross (Lady Jane x Orange Glory) x Liver Red with seed size 2.35 x 1.45 mm.

Table 11: Seed size of the successful crosses obtained

Sl. No	Crosses	Seed size (mm)	
		Single seeded	Double seeded
1	TP x (PR x HR)	3.28 x 2.12	2.50 x 1.90
2	TP x (LJ x OG)	3.19 x 1.90	-
3	TR x (PR x HR)	3.00 x 2.30	2.45 x 1.20
4	TR x (HR x MR)	3.25 x 2.15	-
5	TR x (HoR x KR)	3.19 x 2.10	2.32 x 1.60
6	(PR x HR) x LW	3.10 x 2.20	-
7	(HoRx KR) x LW	3.48 x 2.00	2.12 x1.70
8	(HoR x KR) x TP	3.50 x 2.30	2.15 x 1.45
9	(HoRx KR) x HO	3.42 x 2.50	2.10 x 1.79
10	(HoR x KR) x LR	3.55 x 2.49	2.45 x 1.80
11	(HoR x KR) x TR	3.12 x 2.35	2.80 x 1.90
12	(LJ x OG) x LR	2.99 x 1.90	2.35 x 1.45
13	(LJ x OG) x TR	2.99 x 1.80	2.13 x 1.70
14	(LJ x OG) x LW	3.00 x 2.00	2.45 x 1.54

4.2.6 Number of days taken for seed maturity

The number of days taken for seed maturity for the successful crosses are presented in the Table 12.

4.2.6.1 Tropical Pink

Among the two successful crosses, the cross Tropical Pink x (Pompon Red x Honeymoon Red) took 180 days for the maturity of seed while the cross Tropical Pink x (Lady Jane x Orange Glory) took 170 days for maturity.

4.2.6.2 Tropical Red

Out of the three successful spadix bearing fruits, the highest number of days taken for seed maturity (164 days) was observed in the cross Tropical Red x (Pompon Red x Honeymoon Red) followed by 155 days in cross Tropical Red x (Hounduras Red x Kalympong Red) and 136 days in Tropical Red x (Honeymoon Red x Miniature Red).

4.2.6.3 Pompon Red x Honeymoon Red

The cross (Pompon Red x Honeymoon Red) x Lima White took 175 days for the seed maturity.

4.2.6.4 Hounduras Red x Kalympong Red

Among the five successful crosses, the number of days taken for seed maturity (150 days) was found the maximum in cross, (Hounduras Red x Kalympong Red) x Tropical Pink followed by (Hounduras Red x Kalympong Red) x Tropical Red,(Hounduras Red x Kalympong Red) x Lima White and (Hounduras Red x Kalympong Red) x Hawaiian Orange. The minimum number of days for seed maturity was found in the (Hounduras Red x Kalympong Red) x Liver Red.

4.2.6.5 Lady Jane x Orange Glory

Among the 3 successful spadix bearing fruits, the highest number of days (180 days) for seed maturity was found in the cross (Lady Jane x Orange Glory) x Lima

White followed by (Lady Jane x Orange Glory) x Liver Red and the cross (Lady Jane x Orange Glory) x Tropical Red with 169 and 165 days respectively.

Table 12: Matrix showing number of days for seed maturity in each cross combination

	HO	LW	LR	TP	TR	PR x HR	HoR x KR	LJ x OG	HR x MR	OG x NO	Average
HO											0
LW											0
LR											0
TP						180		170			175
TR						164	155		136		151.66
PR x HR		175									175
HoR x KR	143	145	129	150	147						142.80
LJ x OG		180	169		165						171.33
HR x MR											0
OG x NO											0

Discussion

5. DISCUSSION

Anthuriums are gaining importance as an important economic flower of export potential. The quality of flowers is more considered than the quantity; hence production of anthurium flowers with desirable market qualities ensures the place of anthuriums in global floriculture trade.

The current investigation was to assess the floral and pollen characteristics of the anthurium parental genotypes and improve them through hybridization. Statistical analysis was carried out and also cross compatibility analysis was done based on the fruit set. The findings from the present study, based on analysis of genetic parameters and cross compatibility analysis are discussed in this chapter.

5.1 MEAN PERFORMANCE

The floral as well as the pollen characteristics showed wide variation among the five commercially important varieties and five superior hybrids studied. The spathe size of the anthurium genotypes showed wide variation ranging from 26.82 cm^2 in hybrid PR x HR to 115.79 cm^2 in hybrid HoR x KR. Similar wide variation were reported in the studies conducted by Mayadevi (2001), Pravin (2004), Madhukumar (2010), Agasimani *et al*. (2011a), Islam et al. (2013), Sheena (2015) and Anand (2019).

The spadix length of the anthurium genotypes in the present investigation ranged from 3.86 cm (PR x HR) to 6.24 cm (HoR x KR). The genotypes like Lima White, Liver Red and Hybrid OG x NO were found to be on par with the highest spadix length having HoR x KR. The desirable length of spadix in the market is short and slender. Mercy and Dale (1994) also reported spadix length ranging from 4 cm to 9.5 cm. Similar findings were reported by Renu (2000), (Pravin (2004), Agasimani *et al*. (2011a), Sheena (2015), Gopi (2016) and Anand (2019).

The life of spadix in the plant ranged from 93.3 days to 66.3 days. The highest life span was shown by the hybrid OG x NO which was on par with variety Tropical Red (90.3 days), hybrid HoR x KR (92.2 days) and Liver Red (89.2 days). According to Mercy and Dale (1994), the fertilized candles have more life span (4-7 months)

than the unfertilized candles (2 months). The maximum spadix life span of 95.0 days was reported in the hybrid OG x NO, among 20 anthurium hybrids studied by Anand (2019). Similar results were obtained by Madhukumar (2010) and Sheena (2015) and Gopi (2016).

The present investigation revealed that the inclination of candle with the spathe ranged from 41.4° to 72°. For suitable packing, the ideal anthurium genotypes should have an inclination angle less than 45° (Mercy and Dale, 1994). In the present investigation, the ideal angle less than 45° was found in (PR x HR) and (OG x NO). The highest inclination angle was found in hybrid HoR x KR which is less desirable for packing. Islam *et al*. (2013) in his study observed a variety Aymara having very less inclination angle of 30°. The results of present study were also in accordance with the findings by Mayadevi (2001), Sheena (2015), Gopi (2016) and Anand (2019).

The vase life of the anthurium genotypes in the present study ranged from 13.20 days in LJ x OG to 25.60 days in Tropical Red which was significantly on par with hybrid HoR x KR (24.80 days) and HR x MR (23.20 days). Anand *et al*. (2017) stated that the vase life is the most important or ultimate requirement of the production technology of a cut flower. Shriram (2008) reported similar variation in the vase life of anthurium genotypes ranging from 10 to 21 days. Similar findings were reported by Islam *et al*. (2013) and Harishshivalingappa *et al.* (2013).

In the present study, wide variation in the spadix colour were reported ranging from yellow, white to double colours. The genotypes like Hawaiian Orange, Tropical Pink, Tropical Red, OG x NO showed yellow colour spadix. Similar variations were also reported by Mayadevi (2001), Asish (2002), Sheena (2015), Gopi (2016) and Anand (2019).

Spathe colour is the most important qualitative character that seeks primary attention in consumer's eyes. The detailed genetics of spathe colour was explained by Kamemoto *et al.* (1988). He reported the presence of two major genes that controls the inheritance of spathe colour. These genes were responsible for expression of major colours namely pink, red, coral, white and orange. The presence of both M and O genes together causes the expression of pink to red colour. M gene is responsible for the cyanidin 3-rutinoside production while O gene is responsible for the pelargonidin 3-rutinoside production. The colour variations in red ranging from maroon to dark red

and to red and pink results due to the incremental effect of M gene over O gene, thereby a decrease in colour intensity was observed form MMOO, MMOo, MmOO and MmOo. The ‘mmOO’ genotype showed a light orange colour i.e., coral coloured spathe. The genotype ‘mmOO’ i.e., true breeding is responsible for the orange colour of spathe. True white coloured spathe was expressed as recessive ‘oo’ was epistatic to M, the spathe colour of recessive (mmoo) genotypes or genotypes with M in combination with ‘oo’ (Mmoo and MMoo) resulting the expression. The spathe was purple due to recessive epistasis having genotype ‘MO pp’. The P allele which was dominant found to have no effect on spathe colour in any combinations.

In the present study, wide variations in spathe colour such as deep maroon, dark red, light red, orange, light orange, pink, light pink and white. Asish (2002) reported wide variations in spathe colour ranging from deep maroon to white. Gopi (2016) reported spathe colour variations deep maroon, dark red, bright red, red, pink, peach, green, bright orange, orange and chocolate brown in the 25 genotypes of anthurium. Similar variations in spathe colour among anthurium genotypes was reported by Sheena (2015) and Anand *et al*. (2017) and Anand (2019).

For the success of hybridization programmes, pollen fertility is the prime important factor. The present study revealed the highest pollen fertility in the genotype Liver Red with 44.04 percent followed by Tropical Red and Lima White. The lowest pollen fertility was reported in Hawaiian Orange with 4.61 percent. Similar results were reported with the highest pollen fertility in the genotype Chikoos with 42.58 percent and the lowest in Tropical Peach (3.63 percent). Lalithambika (1978) stated that the pollen sterility in anthurium is about 70-75 per cent. The high pollen sterility in anthurium was due to meiotic abnormalities that occur during anaphase (Bindu and Mercy, 1994). Similar results of pollen fertility were reported by Renu (2000), Madhukumar (2010), Sheena (2015) and Gopi (2016).

In the present study, the highest pollen viability was recorded in Liver Red with 38.22 percent and the lowest was recorded in Hawaiian Orange with 2.94 percent. The use of vital stains provides more accurate value of pollen viability (Shivanna and Rangaswamy,1992). Marutani *et al.* (1993) reported that the tetrazolium test discriminates among the pollen grains having specific oxidative

metabolism and hence the values of pollen viability were less than the pollen fertility using acetocarmine stain.

The pollen size among the anthurium genotypes studied showed wide variation ranging from 25.4 µ in the hybrid PR x HR to 14.11 µ in hybrid LJ x OG. Similar results of pollen size were reported from 14.03µ (Can Can) to 24.42µ (Liver Red) by Gopi (2016). Significant results were reported by Premna (2003), Pravin (2004), Sheena (2015) and Gopi (2016).

Pollen shape of the ten anthurium genotypes studied ranged from oval to round and the pollen colour ranged from cream to white. Similar results were obtained by Sheena (2015), Gopi (2016) and Anand (2019).

5.2 VARIABILITY COMPONENTS

Variability is considered as the prime requisite for the basis of selection. Through analysis of variance the absolute assessment of variability cannot be done. It can only be calculated by genotypic and phenotypic coefficients of variability. The computation of genotypic (GCV) and phenotypic (PCV) coefficients of variation helps to identify the environmental influence out of total variability. PCV provides the extent of total variation while GCV is effective in measuring the genetic diversity of quantitative traits. Moreover, GCV and PCV are the better indices for comparison of quantitative traits having different units of measurement.

In the present study, the PCV was found to have higher magnitude than GCV for all the analysed characters like life of spadix in plant, inclination of candle with spathe, vase life, spadix length, spathe size, pollen fertility, pollen size and pollen viability. In the study conducted by Madhukumar (2010) the highest GCV and PCV for the traits such as pollen fertility, spathe size and spadix length. In the variability study using 20 anthurium hybrids, the highest PCV and GCV were shown by inclination of candle with spathe, spathe size, vase life and spadix length. Similar results were reported by Pravin (2004), Sheena (2015) and Gopi (2016).

5.3 HERITABILITY AND GENETIC ADVANCE

Heritability helps effective selection and thereby attaining maximum genetic gain in less time. Heritability alone fails to indicate the response to selection. So, estimates of heritability along with the estimates of genetic advance as percentage mean are used in predicting the final effect which can be used for selection of superior genotypes.

High heritability in the present study was recorded in the characters like vase life, inclination of candle with spathe and life of spadix in plant. Medium heritability was recorded in spathe size, spadix length, pollen fertility, pollen size and pollen viability. Similar findings were recorded in the study by Pravin (2004), Madhukumar (2010) and Sheena (2015) and Gopi (2016).

In the present study, high genetic advance was recorded for life of spadix in plant, inclination of candle with spathe, vase life, spadix length, spathe size, pollen fertility, pollen size and pollen viability. Gopi (2016) also reported high genetic advance in the characters like pollen fertility, pollen size, spathe size and inclination of candle with the spathe. Anand (2019) also observed high genetic advance in spathe size, spadix length, inclination of candle with spathe and vase life. These findings are in line the findings reported by Premna (2003), Pravin (2004) and (Sheena, 2015).

High heritability coupled with high genetic advance in the present study was observed in life of spadix in plant, inclination angle of candle with the spathe and the vase life. This indicates that these characters are controlled by additive gene action and thus the direct selection of these characters can be effective (Panse and Sukhatme, 1967). Similar findings were also reported by Anand (2019) in which inclination angle of candle with the spathe and the vase life had high heritability coupled with high genetic advance. The results of the present study were also in accordance with the findings of Sheena (2015), Tamuli *et al.* (2015) and Gopi *et al*. (2016).

5.4 COMPATIBILITY STUDIES

Hybridization followed by selection is the common method accepted for the genetic improvement in anthurium (Kamemoto and Nakasone, 1955). Hybridization

between the selected parents having good combining ability provides desirable and novel hybrids (Mercy and Dale, 1994). The flowers of anthurium are protogynous, therefore large scope for out crossing is present in the plants.

In the present study, the compatibility analysis was carried out on basis of percentage of fruit set. Out of the thirty five crosses attempted, fourteen crosses were found to be successful. The maximum percentage of candle bearing fruits (83.3 percent) was found in the hybrid (HoR x KR) followed by Tropical Red and hybrid (LJ x OG). The minimum zero percentage candle bearing fruits was recorded in Hawaiian Orange, Lima White, Liver Red, (HR x MR) and (OG x NO). These findings are in line with the findings of Sindhu (1995), Renu (2000), Premna (2003), Pravin (2004), Madhukumar (2010) and Sheena (2015).

In the present study, among the 14 successful cross combination, the highest number of fruits per spadix was found in the cross, (LJ x OG) x LR followed by TR x (PR x HR) and (LJ x OG) x LW and the lowest in the cross (HoR x KR) x HO. Mecy and Dale (1994) observed that completely fertilized spadix consists of 100 to 200 berries. Findings similar to present study were reported by Renu (2000), Pravin (2004) and Sheena (2015).

The fruit set percentage in the present study was the highest in (LJ x OG) x LR followed by TR x (PR x HR) and the lowest percentage of fruit set was found in (HoR x KR) x HO. The average percentage of fruit set was recorded the highest in the hybrid LJ x OG. Similar findings were reported by Renu (2000), Premna (2003), Pravin (2004), Madhukumar (2010) and Gopi (2016).

Two to three seeds are found in the berries of anthurium (Zimmer et al, 1986). The cross combinations (PR x HR) x LW, TR x (HR x MR) and TP x (LJ x OG) were found to have 100 percent single seeded berries and all others exhibited both single and double seeded berries. Similar results were obtained by Sindhu (1995), Mayadevi (2001), Premna (2003) Pravin (2004) and Gopi (2016). The number of days taken for the seed maturity was found to be the maximum in TP x (PR x HR) and (LJ x OG) x LW with 180 days and the minimum in (HoR x KR) x LR with 129 days. The findings of the present study were in line with the studies conducted by Sindhu (1995), Renu (2000), Premna (2003), Pravin (2004), Madhukumar (2010), Sheena (2015) and Gopi (2016).

Summary

6. SUMMARY

The present investigation, “Palynological and cross compatibility studies in anthurium (*Anthurium andreanum* Linden)” was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, during 2018-20. The study was undertaken to assess the floral and pollen characteristics and to study the cross compatibility of commercially important anthurium genotypes. The investigation consisted of two experiments. Experiment I involved the study of floral and pollen characteristics of the five commercially important anthurium genotypes and five superior anthurium hybrids from the previous study. Experiment II involved the hybridization and cross compatibility analysis based on fruit set.

Five commercially important genotypes and five superior hybrids obtained from the previous study conducted in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani were utilised for the present study. The five commercially important genotypes utilised were Hawaiian Orange, Lima White, Liver Red, Tropical Pink and Tropical Red. The five superior hybrids utilised from the previous study were Lady Jane X Orange Glory (LJ x OG), Hounduras Red X Kalympong Red (HoR x KR), Honeymoon Red X Miniature Red (HR x MR), Pompon Red X Honeymoon Red (PR x HR) and Orange Glory X Nitta Orange (OG x NO).

The genotypes were raised in green house under completely randomized design with five replications. Observations were made on floral and pollen quantitative as well as qualitative characteristics of the parents. Analysis of variance showed significant variation for quantitative characters among the 10 anthurium genotypes studied. The floral characteristics studied were spathe size, spadix length, life of spadix in plant, inclination of candle with spathe, vase life, spathe colour and spadix colour. The pollen traits studied includes pollen fertility, pollen viability, pollen size, pollen emergence pattern, pollen shape and pollen colour.

Among the five commercially important anthurium varieties and five hybrids studied, the spathe size ranged from 115.79 cm^2 in Tropical Pink to 26.82 cm^2 in

hybrid PR x HR. The highest spadix length was noticed for the hybrid HoR x KR (6.24cm) and the lowest in the hybrid PR x HR (3.86 cm). The maximum life of spadix in plant was exhibited by hybrid OG x NO and the minimum in hybrid PR x HR.

Ideal inclination angle of candle to the spathe less than 45° was observed in the hybrid PR x HR (41.4°) and OG x NO (44.8°). The vase life of the anthurium genotypes ranged from 25.60 days in Tropical Red to 13.20 days in hybrid LJ x OG. The qualitative floral characters like spathe colour and spadix colour exhibited wide variation among the anthurium genotypes. The spathe colour ranged from deep maroon, dark red, light red, orange, light orange, pink, light pink and white. The spadix colour ranged from yellow, white and various shades these colours.

The pollen fertility among the genotypes was observed from a range between 44.04 percent in Liver Red to 4.61 percent in Hawaiian Orange. The pollen viability was recorded from the maximum 38.22 percent in genotype Liver Red to 2.94 percent in Hawaiian Orange. The highest pollen size was recorded in hybrid PR x HR with 25.4 µ and the lowest in hybrid LJ x OG with 14.11 µ which was found significantly on par with the variety Tropical Pink. The pollen emergence was recorded the highest during the winter months from October to January and the lowest pollen emergence was recorded during the summer months. The qualitative trait pollen shape ranged from oval to round. The genotypes like Tropical Red and LJ x OG was observed with oval pollen while all the others were observed with round pollen. The pollen colour of the genotypes varied from cream to white.

The components of variation, genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were computed. High PCV and GCV were observed for all the characters studied. The highest PCV and GCV was observed for the character life of spadix in plant (PCV 70.93 percent, GCV 70.82 percent). The characters like life of spadix in plant, inclination angle of candle with the spathe, pollen fertility and pollen size had the lowest difference between the PCV and GCV values.

High heritability coupled with high genetic advance was observed in characters like life of spadix in plant, inclination angle of candle with the spathe and the vase life. This indicates additive gene action effect.

Hybridization was performed in all possible combinations among the five commercially important anthurium genotypes and five superior hybrids from previous study. Cross compatibility analysis was conducted based on the percentage fruit set. Based on the availability of pollen and receptive stigma, crosses ere attempted. Out of the thirty five crosses attempted, fourteen crosses were found to be successful.

The percentage of spadix bearing fruits ranged from 0 to 83.3 percent. The hybrid HoR x KR had the highest spadix bearing fruits percentage of 83.3. The maximum number of fruits per spadix was expressed by the cross (LJ x OG) x LR followed by TR x (PR x HR) and (LJ x OG) x LW. The average number of fruits per spadix was the highest (52) in the hybrid (LJ x OG) and the lowest in genotype Tropical Pink (19.5). The fruit set percentage was the highest in (LJ x OG) x LR (51 per cent) followed by TR x (PR x HR) (46.5 percent). The lowest percentage of fruit set was found in (HoR x KR) x HO (0.75 per cent). Complete single seeded berries were found in the cross combinations (PR x HR) x LW, TR x (HR x MR) and TP x (LJ x OG). The maximum seed size among the single seeded berries was found in the cross (HoR x KR) x LR and the minimum in (LJ X OG) X TR. Among the double seeded berries, the cross (HoR X KR) X TR was found to have the maximum seed size and (HoR X KR) X HO had the minimum seed size. The number of days for seed maturity was the maximum (180 days) in crosses TP x (PR x HR) and (LJ x OG) x LW and the minimum in (HoR x KR) x LR (129 days). Among the 14 successful crosses, based on the fruit set the best cross was found to be (LJ x OG) x LR.

References

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PALYNOLOGICAL AND CROSS COMPATIBILITY STUDIES IN ANTHURIUM (*Anthurium andreanum* Linden)

by

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ABSTRACT

The study entitled “Palynological and cross compatibility studies in anthurium (*Anthurium andreanum* Linden)” was conducted at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2018-2020.The research programme was undertaken to assess the floral and pollen characteristics and to study the cross compatibility of commercially important anthurium genotypes.

In experiment I, five commercially important varieties viz., Hawaiian Orange(HO), Lima White(LW), Liver Red(LR), Tropical Pink(TP) and Tropical Red(TR) and five superior hybrids maintained in the Department of Plant Breeding and Genetics viz., Lady Jane x Orange Glory (LJ x OG), Hounduras Red x Kalympong Red (HoR x KR), Honeymoon Red x Miniature Red (HR x MR), Pompon Red x Honeymoon Red (PR x HR) and Orange Glory x Nitta Orange (OG x NO) were assessed in completely randomized design with five replications. The important floral and pollen traits were evaluated and their mean values were calculated. The statistical analysis was carried out including analysis of variance (ANOVA) and estimation of genetic parameters such as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (H^2) and genetic advance (GA).

Palynological studies revealed that Liver Red was the highest pollen producing genotype with the maximum values of pollen fertility, viability and size. The highest genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were recorded for character life of spadix in plant. All the characters studied exhibited high genetic advance. High heritability (>60%) coupled with high genetic advance (>20%) were observed in characters like life of spadix in plant, inclination of candle with spathe and vase life. This indicates that these characters are controlled by additive gene action.

In experiment II, hybridization was done among the five commercially important varieties and five superior hybrids based on the pollen availability as well as the receptivity of stigma. Thirty five crosses were attempted, out of which fourteen were successful. The successful crosses obtained were TR x (PR x HR), (LJ x OG) x LR, (HoR x KR) x LW, TP x (PR x HR), (HoR x KR) xTP, (HoR x KR)x HO, (HoR

x KR) x LR, (HoR x KR)x TR, (PR x HR) x LW, (LJ x OG) x TR and TR x (HR x MR).The compatibility analysis of these crosses were done based on the fruit set.

Spadix bearing berries ranged from 0 to 100 percentage. The highest percentage of spadix bearing fruits was found in the hybrid (HoR x KR). The cross (LJ x OG) x LR was observed with the maximum number of fruits per spadix and fruit set per candle and the lowest was recorded in the cross (HoR x KR) x HO. The crosses (PR x HR) x LW, TR x (HR x MR) and TP x (LJ x OG) expressed 100 % single seeded berries.The cross (HoR x KR) x TR exhibited the maximum seed size among the double seeded berries and in single seeded berries, (HoR x KR) x LR had the highest seed size. The maximum days for maturity was observed by the crosses (LJ x OG) x LW and TP x (PR x HR) and the minimum recorded for cross (HoR x KR) x LR.

The results of the present study revealed that there is variation among the anthurium genotypes in the floral and pollen characteristics. The best pollen producing parents were found to be Liver Red, Tropical Red and Lima White. The best female parents were found to be (HoR x KR), (LJ x OG) and Tropical Red. The most compatible cross obtained from the study was (LJ x OG) x LR followed by TR x (PR x HR). The best hybrid combinations obtained in the present study can be utilised for further crop improvement programmes in the future.