HETEROSIS BREEDING AND *IN VITRO* MUTAGENESIS IN PINEAPPLE (*Ananas comosus* [L] Merr.)

By

KURIAKOSE, K. P.

THESIS

Submitted in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Agriculture

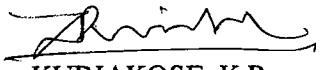
Faculty of Agriculture
Kerala Agricultural University

Department of Plant Breeding and Genetics
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680656
KERALA, INDIA

2004

DECLARATION

I hereby declare that this thesis entitled "HETEROSIS BREEDING AND *IN VITRO* MUTAGENESIS IN PINEAPPLE (*Ananas comosus* [L] Merr.)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.



Vellanikkara
19.3.2004

KURIAKOSE, K.P.

Dr. K. PUSHKARAN
Director (Academic)
Kerala Agricultural University

Kerala Agricultural University
Vellanikkara
Date: 19.3.2004

CERTIFICATE

Certified that this thesis entitled "HETEROSIS BREEDING AND *IN VITRO* MUTAGENESIS IN PINEAPPLE (*Ananas comosus* [L] Merr.)" is a record of research work done independently by Mr. Kuriakose, K.P., 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.

Dr. K. PUSHKARAN
Chairman, Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of Mr. Kuriakose, K.P., a candidate for the degree of Doctor of Philosophy in Agriculture with major in Plant Breeding and Genetics, agree that the thesis entitled "HETEROSIS BREEDING AND *IN VITRO* MUTAGENESIS IN PINEAPPLE (*Ananas comosus* [L] Merr.)" may be submitted by Mr. Kuriakose, K.P., in partial fulfillment of the requirements for the degree.

Dr. K. PUSHKARAN
(Chairman, Advisory Committee)
Director (Academic)
Kerala Agricultural University
Vellanikkara, Thrissur

Dr. ACHAMMA OOMMEN
(Member, Advisory Committee)
Professor & Head
Dept. of Plant Breeding & Genetics
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur

Dr. P.A. NAZEEM
(Member, Advisory Committee)
Associate Professor & Head
Centre for Plant Biotechnology &
Molecular Biology
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur

Dr. V.V.RADHAKRISHNAN
(Member, Advisory Committee)
Associate Professor
Dept. of Plant Breeding & Genetics
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur

27/7/04

Dr. V.S. DEVADAS
(Member, Advisory Committee)
Associate Professor & Head
Agronomic Research Station
Kerala Agricultural University
Chalakudy, Thrissur

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

I am extremely thankful and indebted to Dr. K.Pushkaran, Director (Academic), Kerala Agricultural University and Chairman of my Advisory Committee for the deep interest, technical advice for the formulation of the research programme, sustained and valuable guidance throughout the period of investigation and preparation of the manuscript.

I express my heartfelt thanks to Dr. Achamma Oommen, Professor & Head, Department of Plant Breeding & Genetics and member of my Advisory Committee for the encouragement, valuable guidance and timely advice throughout the period of the work.

I have great pleasure to place on record my deep sense of gratitude and indebtedness to Dr. V.V. Radhakrishnan, Associate Professor, Department of Plant Breeding & Genetics and member of my Advisory Committee for the constant inspiration, advice and guidance throughout the period of the work and also during the statistical analysis and interpretation of the results.

With great pleasure, I wish to express my respectful gratitude to Dr. P.A. Nazeem, Associate Professor & Head, Centre for Plant Biotechnology and Molecular Biology and member of my Advisory Committee for the keen interest, sharp comments and encouragement given during the investigation. I am extremely thankful for providing the excellent facilities at the Centre to carry out the studies on in vitro mutagenesis.

I wish to express my sincere thanks to Dr. V.S. Devadas, Associate Professor & Head, Agronomic Research Station, Chalakudy (former Head of Pineapple Research Station, Vazhakulam) and member of my Advisory Committee for the deep interest, timely help and encouragement rendered during the investigation, especially during the field studies at Pineapple Research Station, Vazhakulam.

My sincere thanks are due to Dr. V.K.G. Unnithan, Associate Professor & Head, Department of Agricultural Statistics for the timely and valuable suggestions rendered in statistical analysis of data and interpretation of the results.

I am greatly indebted to Mr. S. Krishnan, Assistant Professor, Department of Agricultural Statistics for the keen interest and encouragement during the investigation and the help rendered with unfailing patience during the statistical analysis of data and interpretation of the results.

I am grateful to Dr. K. Mohanakumaran, Director of Research (Retd.) for the keen interest and valuable advice during the formulation and implementation of the research programme.

I am indebted to the Associate Dean and all other faculty members of the College of Horticulture for providing all facilities and encouragement during the entire period of the study.

My sincere thanks are due to all the staff members, field assistants and workers of the Centre for Plant Biotechnology and Molecular Biology, College of Horticulture and Pineapple Research Station, Vazhakulam for all the help and cooperation rendered for all the field and laboratory studies.

I am indebted to Kerala Agricultural University for granting study leave, part-time research facility and to take up the investigation as a part of the University research programme at Pineapple Research Station, Vazhakulam.

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Introduction

INTRODUCTION

Pineapple (*Ananas comosus* [L.] Merr.) under the family Bromiliaceae is a xerophytic, succulent, herbaceous, perennial monocotyledonous plant whose terminal inflorescence develops into a multiple fruit. The place of origin of pineapple is considered to be the south-eastern Brazil, Paraguay and northern Argentina (Baker and Collins, 1939 and Cabot, 1992). Pineapple was domesticated in tropical America (Collins, 1948).

Pineapple is grown for its excellent fruit. The ripe fruit is juicy, sweet and contains sugar, minerals, vitamins and proteins. A blend of citric acid, sugar and other natural flavouring agents give the pineapple its own delicious taste. Oviedo (1535) stated that "there are no other fruit in the world to equal pineapple for its beauty of appearance, delicate fragrance and excellent flavour". The travellers and missionaries took pineapple to all parts of the world. The leading pineapple producing countries are Thailand, Philippines, Brazil and India in the order of quantity produced (Ti, 2000).

The Portuguese introduced pineapple in south India during 1550 (Laufer, 1929). Pineapple was described as *Kapa-tsjakka* in *Horti Malabarici* published by Rhede (1685). Varieties like Giant Kew, Kew, Queen and Mauritius were cultivated in Malabar area (Gandhi, 1949; Bhattacharya and Sarma, 1949 and Bhattacharjee, 1957). Its cultivation in Travancore-Cochin area was mentioned by Pruthi and Lal (1955) and reported that Kew and Giant Kew varieties are suitable for canning whereas Mauritius was uneconomical though it yields good quality juice. In India it is cultivated in all the north-eastern states, Andhra Pradesh, Bihar, Goa, Karnataka, Kerala, Orissa, Tamilnadu and West Bengal (Chadha *et al.*, 1998). In Kerala pineapple is grown in 11159 ha. (Ecostatkerala, 2003).

Presently in Kerala, pineapple production and marketing is centered mainly around Vazhakulam area in Ernakulam district. However, it is spreading to all parts of the state. It is mainly grown as an intercrop in rubber and coconut and also as pure

crop in garden land and reclaimed paddy fields. The Kerala Agricultural University had established a Pineapple Research Station at Vazhakulam in 1995 for research and development support to the farmers. More than 95 percent of the area under pineapple cultivation in Kerala is occupied by Mauritius variety. It is dependant on fresh fruit market due to its better quality of fruit, economical pricing and low damage during post harvest handling and storage. However, the processing industry prefers Kew variety due to its bigger size, cylindrical shape, high juice content and low eye depth. But its cultivation in Kerala declined due to its seasonal demand, uneconomic pricing and high damage during post harvest handling and storage.

For the sustained production of pineapple, the processing industry should also develop, otherwise a market glut can be expected especially if the present trend of area expansion is continued. In this situation a dual purpose variety, suitable for both fresh fruit market and processing industry, will be a better choice. Such a variety, an ideal pineapple, can have the desirable growth characters like short duration, less height, spineless leaves and high response to management; fruit characters like medium weight (1500-2000 g), cylindrical shape, high sugar and TSS content, low acidity and bright yellow crisp pulp and post harvest features like better storage and keeping quality and low damage during post harvest handling and storage. Such a variety may be able to replace both Kew and Mauritius variety.

However, pineapple being an asexually propagated and introduced crop to India with limited varietal variability, there is little scope for selection among the available varieties. Hence the alternative is to develop new varieties or improve the existing varieties. As the objectives in pineapple breeding are mainly quality improvement rather than yield improvement, several characters are to be considered simultaneously since the quality is influenced by a number of attributes. Pineapple being a vegetatively propagated crop, though amenable to sexual reproduction, is highly heterozygous. Collins (1951) reported that the genotype of the Cayenne variety introduced to France from French Guiana in 1820 was highly heterozygous. There were also reports suggesting that differentiation among *Ananas* species could be due to

ecological isolation rather than genetic divergences (Cabot, 1992 and Aradhya *et al.*, 1994).

Among the plant breeding tools, clonal selection may help only to maintain the qualities of the present varieties at its best. The application of genetic transformation depends on the identification of genes to be transformed. Intervarietal hybridizations are expected to produce wide genetic variability because of the high heterozygosity in pineapple. High genetic variability can also be expected through induced mutation. *In vitro* mutagenesis will be a better option due to its easiness to effect large number of mutants in a short time for selection.

With an objective to create maximum genetic variability for selecting ideal pineapple genotype, with most of the desirable characters mentioned earlier, the following investigations were carried out.

- Evaluation of pineapple genotypes.
- Study of the floral biology.
- Hybridization and production of hybrids.
- Evaluation of hybrids.
- *In vitro* mutagenesis.

The field studies were done at the Pineapple Research Station, Vazhakulam. *In vitro* mutagenesis was taken up at the Centre for Plant Biotechnology and Molecular Biology, College of Horticulture, Vellanikkara.

Review of Literature

REVIEW OF LITERATURE

The pineapple was selected and domesticated by peoples of prehistoric times. The first recorded history of pineapple started in 1493 by Columbus in his visit to an island named Guadeloupe in West Indies (Collins, 1960). Collins has explained the parthenocarpic development of pineapple fruit. The multiple fruit was made up of 100 to 200 berry-like fruitlets fused together on a central axis or core. The present type of multiple fruit was formed during the phylogenetic evolution by almost complete fusion of the fruitlets and subtending leafy bract. According to Coombe (1976), the peduncle was associated with core formation and accessory tissues with the formation of fruitlets in pineapple. Purseglove (1975) considered pineapple fruitlets as berries and stated that cell division in pineapple was completed by flowering period and the later increase in size took place in development stage. The relevant literature on various aspects of the present investigation was reviewed below.

2.1. Evaluation of Pineapple Genotypes

Girdhari and Singh (1955) observed that the ascorbic acid content of three varieties of pineapple grown in South India, namely Kew, Giant Kew and Mauritius varied from 14 to16.6, 6.1 to 10.2 and 19.3 to 24.6 mg/100 g of juice.

Hayes (1957) opined that the general quality of fruits varied from variety to variety and from place to place. Collins (1960) studied the effect of environment on the quality of pineapple fruit. He observed that sunshine and temperature had direct effect on quality of pineapple. Plants growing at 670 m altitude produced fruits with high acidity and poor flavour. Very low intensity of sunshine resulted in fruits low in sugar content. Too much sunshine caused sunburn. Hope (1963) found that sugar content of fruit increased throughout the life period of pineapple, especially in summer as compared to that in winter.

According to Dull (1971) the general composition of pineapple fruit reflected a broad range of ripeness and agronomic as well as environmental factors. The general analysis of ripe pineapple fruit given by him (on fresh weight basis) was

Brix	- 0.8-17.5%
Titrable acid (as citric)	- 0.6-1.62%
Ash	- 0.30- 0.42%
Water	- 81.2-86.2%
Fibre	- 0.30-0.61%
Nitrogen	- 0.045-0.115%
Pigments (carotene)	- 0.2-2.5%
Ether extract	- 0.2%

The chemical constituents of ripe Smooth Cayenne pineapple fruits were reported as 86.5 % moisture, 0.6% protein, 0.1% fat, 12% carbohydrate and 0.5% mineral matter (C.S.I.R., 1948). Similar values were reported by Purseglove (1975) also.

Gopimony *et al.* (1978) evaluated 20 pineapple varieties and found that Kew and Smooth Cayenne having maximum fruit weight whereas the variety Valera Balanga was found to have a superior sugar-acid blend and suggested to use it as a parent in breeding for improvement of Kew variety. Based on the constituents present in the fruit, they classified Mauritius, McGregor, Alexandra, Queen, Ripley Queen and Valera Balanga as good table varieties and Kew as the best commercial variety for canning.

Valsamma *et al.* (1979) reported that in a study involving 19 genotypes, number of leaves per plant was highly influenced by environmental effects. High heritability for fruit weight without crown and TSS was also observed. Nayar *et al.* (1981a) found varietal level variation in morphological and nutritional characters of pineapple at harvest stage. Evaluation of nutritive characters of various pineapple varieties revealed that among the varieties studied, Queen and Charlotte Rothschild had the highest T.S.S.

content. Total sugar, reducing and non-reducing sugars as well as acidity were the highest in Kew variety.

Brazil, which is one of the most important centers of genetic diversity of *Ananas comosus* and its wild relatives, is having more than 500 accessions from several species (Ferreira and Cabral, 1993).

In a study involving 89 clones of the main cultivated groups and three wild species, the Cayenne, Queen and Pernambuco groups appear clearly distinct and homogenous (Duval and Coppens, 1993). In a comparative study of two cultivars of pineapple, the local Smooth Cayenne showed a better adaptation to Cuban conditions (Benega *et al.* 1997).

Duval *et al.* (2000) studied the variability in the genera *Ananas* and *Pseudananas* using RFLP, the results of which supported the hypothesis of a northern center of origin and domestication for the pineapple. A set of 313 clones was sampled from the collections of CIRAD-FLHOR (Martinique, FWI) and EMBRAPA-CNPMF (Crus das Almas, Brazil). Most of them were recently collected in Venezuela, Brazil, French Guyana and Paraguay. DNAs were restricted with four endonucleases: Eco RV, Sst I, Eco RI and Hind III. A partial Pst I genomic library was established as a source of RFLP markers. A subset of 25 probes proved to be both polymorphic and to represent low copy number sequences. Data from probe hybridizations were analysed using multiple correspondence analysis and hierarchial cluster analysis on dice index. First results show continuous variation. Species as defined by Smith and Downs (1979) do not appear as separate entities and show large intraspecific variation, especially in *Ananas ananassoides*. Within *Ananas comosus*, clones presenting the same leaf margin phenotype such as piping or spiny tip do not constitute uniform clusters.

2.2. Study of the Floral Biology

The morphological changes accompanying the origin and growth of the pineapple inflorescence and the fruit by histological analysis of the apex were reported

by Kerns *et al.* (1936). They recorded the time interval required for various stages of inflorescence development from early initiation to harvest of the fruit in Smooth Cayenne. Collins (1960) reported the average duration of the developmental changes from planting to harvesting of ripe fruits of pineapple as shown below:

From planting to beginning of inflorescence	- 427 days
From beginning to end of formation of inflorescence	- 37 "
From end of inflorescence formation to first open flower	- 43 "
Period of flowering	- 26 "
Period from the opening of the last flower to the ripening of the fruit	- 109 "
Total period of fruit development	- 215 "
From planting to ripe fruits	- 642 "

The flower initiation and early developmental changes of pineapple fruit was studied by Gifford (1969) after treating Smooth Cayenne plants with acetylene for induction of flowering. Purseglove (1975) recorded that the flowering period of pineapple extended upto 10-20 days. Gopimony *et al.* (1976) reported that under Kerala conditions, the time required for the developmental change was much shorter than those observed under Hawaii conditions.

Collins (1960) and Purseglove (1975) describing the flowers of Smooth Cayenne variety reported that individual fruitlets developed from perfect trimerous flowers having one subtending floral bract, three fleshy sepals, three petals, six stamens in two whorls of three, and one tricarpellary ovary with three stigmatic lobes. The style is slightly longer than the stamens and a little shorter than the petals of the tube-like corolla. Petals of the tubular corolla were white at the base, bluish-purple above the calyx and liguliform in shape.

Datta (1970) while describing the general characters of the family Bromeliaceae stated that in *Ananas* genus, the ovary of flower was inferior. A sketch of the longitudinal section of a pineapple flower showing various floral parts were outlined by Simmonds (1976).

Collins (1960) and Purseglove (1975) reported that 5 to 10 flowers opened in a pineapple inflorescence in one day. Gopimony *et al.* (1976) observed that under Kerala conditions, the rate of flowering in Kew variety was 4 to 11 and even upto 15 flowers. The average number worked out by them was 6.54 per day.

Studies conducted by Collins (1960) revealed that the average number of flowers produced in Smooth Cayenne inflorescence was 150 and it varied widely under different environments. When Purseglove (1975) reported a range of 100 to 200 flowers per inflorescence, Gopimony *et al.* (1976) recorded a range of 100 to 180 flowers per inflorescence under Kerala conditions.

Collins (1960) observed that flowers were oriented in a regular spiral pattern on the fruit axis and opened in the sequence of their origin, starting with the whorls of flowers at the base of the inflorescence. Opening of flowers from the base of the inflorescence upwards was reported by Purseglove (1975) also.

Collins (1960) reported that in pineapple the flowers opened and anthers dehisced in the early forenoon, began to wither in late afternoon and closed by sundown. Purseglove (1975) was of opinion that flowers opened and shed pollen in the morning, began to wither in the late afternoon and were closed by sunset. Gopimony *et al.* (1976) found that under Kerala conditions, flowers opened early in the morning and withered in the evening. Anther dehiscence was reported to coincide with flower opening.

Collins (1960) reported that in pineapple the stylar canal which is an open tube to the carpel before and during anthesis is closed shortly after the flower opening. This finding was supported by Purseglove (1975). Gopimony *et al.* (1976) reported that under Kerala conditions the stigma of pineapple flowers were receptive in the early morning hours and receptivity period extended upto 10.45 am.

Variation in the pollen size of pineapple varieties were reported by Collins (1960) and Nayar *et al.* (1981). They found that pollen diameter varied depending on

the varieties. Collins (1960) was of opinion that the average pollen diameter of Cayenne was 49.5 microns and that of Queen was 46.5 microns. Bhowmik and Bhagabati (1975) found that Kew variety had larger pollen grains as compared to the other varieties studied and the Kew variety was having 27.85 to 89.5 % and Queen 37.17 to 60.54 % of fertile pollen.

Ramirez (1966) suggested pollen fertility as a means for selecting male parents in pineapple breeding and revealed that among the varieties tested, Baon Rothschild had the highest percentage of viable pollen grains followed by Smooth Cayenne. To test the viability of pollen grains, Stanley and Linskens (1974) suggested germination test and non-germination assays. To study the fertility of pollen grains, staining technique was adopted by Zirkle as early as in 1937. He introduced the acetocarmine staining technique and explained that properly stained, plumpy and well developed pollen grains as viable and shriveled ones as non-viable.

Collins (1960) stated that the linear petals of pineapple flowers were so close at their outer end that only small insects could enter the flowers. Since the nectar was exudated between the petals at the base of the flowers, bees went directly to the base while visiting the inflorescence. In Hawaii, no natural agencies capable of effecting cross pollination were reported even when compatible varieties were grown in adjacent rows. Purseglove (1975) reported that in Brazil different species of humming birds acted as pollinating agents.

Collins (1960), Marr (1964) and Purseglove (1975) reported that all varieties of *Ananas comosus* produced functional germ cells, but could not be self-fertilized. Most of them were cross compatible and set seeds when cross-pollinated. Simmonds (1976) reported that *Ananas comosus* was the self-incompatible species known in the genus, others were at least partly self-fertile.

Brewbaker and Gorrez (1967) studied the genetics of self-incompatibility in *Ananas* and found that a single 'S' locus with multiple alleles and gametophytic control of pollen phenotype were implicated. Inhibition of pollen tube growth in the upper

third of pineapple style occurs. They also reported the existence of self-fertile mutants in Cayenne. These mutants were assumed as SfSt types. Sf pollens would be uninhibited in all crosses and selfs resulting in seeded fruit. Marr (1964) found that self-fertile mutants could be induced by x-ray radiation of the pollen during meiosis.

Singh and Dutta (1965) observed male sterility in some varieties of *Ananas comosus*. Of the five varieties investigated, Smooth Cayenne had the lowest percentage of non-viable pollen (17 to 22 %), while Sarawak had the highest percentage (83 to 90 %). In Singapore Spanish, Selangore Green and Mauritius, sterility ranged from approximately 40 to 65 %.

Cross-compatibility studies in pineapple varieties conducted by Bhowmik and Bhagabati (1975) revealed that 39.09 % of bold seeds were formed when Kew was the female parent and 73.88 % when Queen was the female parent. But self-pollination produced no seeds.

Cross compatibility among Kew, Alexandra, Mauritius and Ripley Queen was studied by Gopimony *et al.* (1976). Mean seed set per cross was highest in Kew x Alexandra cross (2.20) followed by Alexandra x Kew (2.14), Kew x Mauritius (2.01), Mauritius x Kew (2.00) and Kew x Ripley Queen (1.54). Mean seed set per cross was the lowest in Ripley Queen x Kew combination (0.54).

Majumder *et al.* (1964) applied a callose fluorescence technique in studies of pollen growth in pineapple styles and found that Smooth cayenne and three other varieties were highly self-incompatible while results with one variety were variable. Brewbaker and Gorrez (1967) stained the pollen tubes in style for similar studies.

Gopimony et al. (1976) found that the time of flower opening and anther dehiscence in Kew pineapple was between 4.15 and 5 am. The anther dehiscence coincides with the time of flower opening. The time interval between various stages of flower development was studied and found to be much shorter than those observed under Hawaii conditions. Hand pollination in Kew variety of pineapple using pollen

from three other compatible varieties can be successfully done at any time between 4.15 and 10.45 am.

Diploid chromosome number (2n) of 50 has been observed in Kew and Queen varieties of pineapple (Bhowmik, 1977). Allopolyploidy and various chromosomal irregularities have played an important role in evolving the present diploid number in pineapple. Pollen fertility and size variation was found correlated with meiotic irregularities.

Bhowmik (1982) found that self-incompatibility in Kew and Queen varieties was based on the gametophytic 'S' allele system. Kew was assigned the genotype SaSa and Queen SbSb. The genotype of the hybrid clones (K x Q) and (Q x K) is SaSb. Artificial self-pollination within four clones (Kew, Queen, Hybrid Kew x Queen and hybrid Queen x Kew) and reciprocal crosses between hybrids as well as backcrosses did not produce any seed.

2.3. Hybridization and Production of Hybrids

The first ever pineapple breeding work in scientific basis was started by Webber (1905) in Florida, USA. Holt started pineapple breeding at The Federal Station in Honolulu in 1914 and by Doty at the Hawaiian Sugar Planters Association Experiment Station on behalf of the Association of Hawaiian Pineapple Canners in 1916 (William and Fleisch, 1993). Seeds from Cayenne fruits at the canneries in Honolulu and from crosses made between Cayenne and Queen were germinated in 1916 (Doty, R.E., 1923).

Mendiola (1951), Collins (1960), Gopimony *et al.* (1976) and Samson (1980) described the method of hybridization between pineapple varieties. According to them, it was unnecessary to emasculate and protect the pistillate plant of a cross, to cover the staminate parent or to cover or protect the pistillate parent after pollination. Hand pollination can be done by rubbing an anther on the stigma. The process of selection and development of hybrids was described by Cabot (1987).

Gopimony *et al.* (1976a) found that sterilization of the medium for germination of pineapple seeds was most essential and seed treatment with conc. Sulphuric acid is not essential if kept under incubation. They observed that seeds treated with conc. Sulphuric acid for 30 seconds or incubated at 32°C germinated mostly in the second week after sowing.

Pickersgill (1976) observed production of a large number of seeds upto 3000 from fruits produced through cross-pollination. Chan (1986) described the methodology in hybridization including the choice of parents and the direction of the cross, the crossing procedure, seed set, extraction, treatment and storage as well as seed germination, nursery maintenance and evaluation of the F_1 progenies. In hybridization of Cayenne with Queen or Spanish, larger number of seeds can be obtained by using Cayenne as the pollen donor. Though crossing may be done during the entire length of the day, seed set may be variable depending on the time of the day at which pollination was effected. Successful pollination and seed set may be temperature related with higher seed set obtained from pollination done during the early morning or cooler evening. Poorer seed set was recorded when pollination was done at noon or in the early afternoon. In general, the results showed that fertilization and seed set occur satisfactorily throughout the entire length of the day with some slight variation possibly due to temperature influence. Pollen is collected early in the morning by excising and collecting flowers at anthesis from the paternal blocks. These flowers are removed from the inflorescences by making three deep triangular incisions into the base of the flower and then gorging them out from the inflorescence. This method of collecting pollen in excised flowers is superior to that of removing only the stamens and collecting them in petri-dishes. Pollen in the excised flowers remained longer and dehydrate less rapidly. The excised flowers are stored in cool chests and when pollen is required, one is taken out and its petals removed to expose the freshly dehisced anthers with an abundance of pollen. The pollen on the anthers was then brushed onto the stigma of the flowers of the maternal parent. Since the flowers are self-incompatible, there is no necessity to emasculate the maternal flowers prior to the introduction of the pollen. Depending on varieties the number of flowers in an inflorescence ranged between 75 and 150. About three to seven flowers anthesize daily, in which case, a

period of about two to three weeks may be necessary to complete pollination of the whole inflorescence. Pollinated fruits can be harvested at the two eyes riped stage. Seeds develop in the ovarian cavities (eyes) and the cavities can be exposed by peeling the shell of the fruit from a depth of about 1.5 cm. The exposed seeds in the cavities are scraped out and washed. A 2% solution of Thiram is used to treat the seeds to prevent fungal growth. The treated seeds are allowed to air-dry under normal room temperature after which they are labeled and sealed in plastic bags. These are stored under refrigeration at temperature of 8 to 10 degrees Celsius. Kept in this condition, the seeds retain their viability for at least six months. The hard coat of the pineapple seed requires scarification in order to obtain more uniform and quicker germination. Treatment with concentrated sulphuric acid for about 30 seconds was found to give good results. The scarified seeds are sown in shallow sand boxes covered with clear polythene sheets to retain high humidity important for good germination. The seeds are sprinkled thinly over the sterilized sand media and remained unburied. Germination occurs normally after 10-14 days. When the seedlings reach the sixth to eighth leaf stage after three months, they are carefully transplanted at a spacing of 8 cm x 8 cm in peat beds in the nursery. At the nursery stage, some preliminary selection may be permitted to cull off the obviously undesirable characters such as poor vigour, albinism and spiny leaves. The seedlings are kept in the nursery for about a year before they are transplanted in the field for evaluation. The small seedlings (about 12 to 15 cm tall) take about 15 months to grow to a stage when they can be hormoned. In the F_1 population each individual plant is unique and the segregation is very wide. Evaluation is carried out on each plant and this may be exceedingly tedious considering the large F_1 populations that are normally grown. Hybridization presents an extremely valuable method in generating widely variable genotypes through gene recombination.

Selection among 30000 hybrids produced every year by hybridizing Cayenne and Perolera was done in Ivory Coast to develop new cultivars for fresh and processed market with improved fruit quality (Cabot and Lacoeuilhe, 1990).

In a study involving 71 pineapple clones, comparison of cross and self-fertility indicated that all genotypes were self incompatible, except A. *bracteatus* var. *typicus*

clones and as the proportion of aborted seeds was the same after self and open pollinations, there seemed to be no inbreeding effect at the zygotic and embryonic levels (Coppens *et al.*, 1993).

2.4. Evaluation of Hybrids

Backcrossing Cayenne x Queen selections on Cayenne gave vigorous plants (Wendt, 1926). Kerns (1929) found that the wild pineapple (*Ananas ananassoides*) when crossed onto Cayenne gave unusually uniform seedlings that favoured Cayenne type.

Collins and Kerns (1946) reported the inheritance of three leaf types- spiny tips characteristic of Cayenne cultivar: spiny, a character typical of many cultivars in which the entire leaf margin bears spines; and the type known as piping, a completely spineless leaf form. A large number of mutants have been reported in Cayenne like white flowers etc.

Chan (1986a) reported a complete diallel, involving the Cayenne, Spanish, Queen and an F_1 selection from a hybrid between Spanish and Cayenne, carried out to study the differential seed set and compatibility between the crosses. All genotypes were self-incompatible while the crosses showed differential seed set influenced by female and male sources and their interaction. Depending on the cross, seed set ranged from six seeds to 478 seeds/kg of fruit. Further, one-way compatibility was found for two sets of crosses involving the Hybrid female with Queen and with the Spanish. Application of the results in terms of ascertaining the direction of cross between two parents in pineapple hybridization as well as the danger of mixed cropping of highly compatible varieties which may produce seedy fruits were discussed.

Chan (1989) observed that a cross between two pineapple cultivars, Gandul and Hybrid 36, belonging to the spanish group, generated a very wide spectrum of recombinants in the F_1. The C.V. for 13 characters in the F_1 were very large, in many cases exceeding by two fold that of the clonal parents. For all the characters, the ranges

covered by the F_1 segregants transgressed those of both the parents combined. Pineapple is usually self sterile but crosses between cultivars often set seed. The degree of fertility depends on the groups of pineapple used for the crosses as well as the direction of their cross i.e., reciprocal or otherwise. Hybridization between cultivars is expected to bring about segregation among the F_1 progenies because each pineapple cultivar is heterozygous in genetic makeup but homogenous in phenotype due to asexual propagation. This variation may be exploited in selection and development of new improved varieties. About 5000 hybrid seeds sown in shallow peat trays covered with clear plastic sheets to retain moisture. About 20% of the seeds germinated and the seedlings were transferred six months later from the germination trays to the nursery peat beds. The seedlings were nurtured in the nursery for about 14 months before field transplanting. On evaluating the F_1's (mean, range and coefficient of variation), flesh color, TSS and acid content, where the mean values of the hybrids found to be intermediate between the two parents suggesting that these characters were probably governed by additive genes. For other characters, ie, fruit weight, length and diameter, number of fruitlets, core diameter, crown weight, marble eye and sucker and slip production, where the mean values of the F_1 were close to or exceeded the means of either parents, dominance or over dominance gene effects may be implicated. The hybrids showed an increased tendency towards production of vegetative propagules such as slips, aerial suckers and ground suckers. This is to be expected because pineapple is not normally seed propagated and a proliferation of vegetative propagules may be natural reaction for dissemination of the species. The low occurrence of such vegetative growth in the two parents is evidence of the selection pressure against such characters to obtain a high harvest index for these cultivars. The range of values for each character in the F_1 showed that the segregation was transgressive, ie, the minimum and maximum values of the F_1 progenies in all cases exceeded the lowest and highest values of either parents. This resulted in very high coefficients of variance in the F_1. The coefficients were at least twice that of the parents in many cases. Very few F_1's came near to the mean of Hybrid 36 and fewer or none may be expected to have high acid with the desired combination of other characters that qualify them for selection. For TSS, the F_1 was normal and transgressive with a wide range far exceeding those of the parents. It is unlikely that all favourable characters would be found in one

individual plant, therefore, some form of selection index and weighing must be imposed for picking progenies with an acceptable balance of desirable characters.

A complete diallel cross in pineapple using four parents from three diverse groups by Chan (1991) showed wide variation of the F_1 population for eight characters often exceeding twice that of the parents and this represents scope for selection and improvement. Identifying the parents most likely to generate the best F_1 population was relatively straight forward when characters were considered one at a time. For each character, more promising F_1 populations may be produced by using the parent with the best mean if there was no female parent x male parent interaction, or by using the best combination of parents when interaction was significant. Estimation of breeding value of parents was more complicated when all the characters were considered simultaneously for selection.

In a hybridization involving three groups of pineapple, crosses between groups showed differential seed set but all cultivars were self-incompatible and analysis of the F_1 populations for 8 characters showed wide variation, often exceeding twice that of the clonal parents (Chan, 1993).

F_1 plants from a cross between smooth leaf margin "Maipure" and "spiny" segregated 1 to 1 with the parent's phenotype suggesting the expression of a single pair of allele whereas the cross between Cayenne to different Cayenne types resulted in the expression of "few", "scallop", "spiny" and "spineless" phenotypes suggesting triple pair of alleles (Kinjo, 1993).

Radha *et al.* (1994) reported maximum seed set in crosses in Mauritius x Kew and lowest survival of seedlings (2.5 %) after six months in Kew x Ripley Queen.

Coppens and Duval (1995) observed that intervarietal and interspecific hybridization produced a much wider genetic variability because of the high heterozygosity of progenitors and the high recombination rate. However most varieties bring more negative traits than positive traits. Selected traits are very numerous and the

hybrids exhibiting good combinations are extremely rare. Consequently, a generation of breeding is not sufficient and backcrosses or inter hybrid crosses are needed.

Chan and Lee (1996) reported a systematic hybridization programme for improving pineapple started at the MARDI Integrated Peat Research Station in Pontian in 1984. Four cultivars representing the three major groups of pineapple i.e., Sarawak (Cayenne), Moris (Queen), Johor (Spanish) and Masmerah (Spanish) were crossed in a complete diallel to generate about 50000 F_1 progenies. This hybrid population was evaluated and 300 selections were subsequently made. These selections were further evaluated, trimmed down to 13 in 1989 and further reduced to six in 1991. These six potential hybrids were tested over three environments i.e., Pontian, Bukit Tangga and Kluang from 1991-1994, to establish the hybrid's performance and stability. The result of the trial showed that one of the hybrids, A25-34, has good yield and its strong aroma and high, stable TSS % are suited for table fruit. Further, its attractive fruit cosmetics, improved storage life and tolerance to black heart disorder also make it a good candidate for export. This hybrid was named JOSAPINE because it was derived from Johore and Sarawak parents and was officially released by MARDI on 5 August 1996.

Cayenne x Perolera hybrids were subjected to individual analysis first based on external and internal observations and on juice analysis and later a more comprehensive field evaluation is made on grouped plants grown on small plots, resulting in identification of one outstanding clone (Yapi and d'Eeckenbrugge, 1997).

Chan and Lee (1999) opinioned that for improving early fruit bearing there seemed to be limited prospects in telescoping the periods for inflorescence emergence and fruit maturation. The best avenue for obtaining early fruit bearing appeared to be in shortening the period of plant growth for hormoning. This requires the selection of genotypes with high fruit-to-plant weight ratio.

Chan and Lee (2000) studied the possibility for developing earliness in pineapple and located a hybrid genotype coded as AO4-16, which could be forced at seven month stage economically, but it cannot be directly used as a variety due to its

weaknesses and suggested that early fruiting lie in the ability to reduce the growing period from planting to forcing and early fruiting progenies should have the capacity to bear economic sized fruit on small plant mass.

Marie *et al.* (2000) described their evaluation process of pineapple hybrids in which they had transferred 700 preselected Smooth Cayenne x Manzana hybrid clones from the breeding programme in Cote d'Ivoire to Martinique, where a general objective of diversification and specialization was emphasised, selecting either for the fresh fruit market or for processing. First evaluations, conducted along with multiplication, allowed to discard many clones on the basis of major defects, such as insufficient vigour, multiple crowns, fruit fasciations, recurrent spininess, fruit and fruitlet shape defects, fruit size and lodging, collar-of-slips and knobs and pulp taste and quality. The remaining 205 clones were evaluated in 20 plant plots and compared with Smooth Cayenne and an elite clone that was identified early in the selection process. Most of them showed good vigour and a shorter cultivation cycle with high sugar content. However variation was still very important and many unfavourable traits were still observed. Twentynine clones presenting interesting character combination were selected. They generally showed good vegetative vigour and productivity with good yield and earlier fruiting than Smooth Cayenne. Slip production was reduced by selection while suckering was comparable to that of Smooth Cayenne. Shell and flesh maturation is uniform within the fruit. External colour is highly variable. Gustative quality has been improved in most hybrids, as their sugar content is higher than in Smooth Cayenne while acidity is lower or equivalent. Ascorbic acid is also higher, with wide variation, upto three or four times the values observed for Smooth Cayenne. Hybrids often produce heavy fruits on long peduncles, which makes them susceptible to lodging. Most hybrids are susceptible to *Penicillium funiculosum*.

2.5. *In vitro* Mutagenesis

Collins and Kerns (1938) described 30 mutant types of the cv. Cayenne of which some of them reproduce sexually. Since a large number of plants of the same clone was grown, even less frequently occurring spontaneous mutations can be found.

Marr (1964) induced self fertile mutants by X-radiation of pollen during meiosis. From Queen, morphological mutants including spineless plants were produced using chemical mutagens on slips (Singh and Iyer, 1974). Singh *et al.* (1976) reported the occurrence of chimera and gene mutations in pineapple cultivar Kew for leaf characters. Kew variety appears to be heterozygous for smooth spiny tip character wherein a mutation leading to homozygous recessive leads to spininess, the loci being highly mutable. Nayar *et al.* (1978) observed that when three month old pineapple suckers were irradiated at 4-6 Kr, suckers that were irradiated at 4 Kr dose has induced 100 % flowering in sixteen months whereas none of the unirradiated suckers flowered, indicating a stimulant action of radiation at 4 Kr dose for flowering in pineapple.

Aghion and Beauchesne (1960) attempted micropropagation of pineapple using buds situated on pineapple stem fragments and reported the first successful *in vitro* culturing of pineapple.

Terminal buds have been shown to produce only one plantlet per culture whereas auxins and cytokinins have been found to influence induction and development of multiple shoots. Pineapple terminal buds will regenerate when cut into four or more segments and this could be used for rapid proliferation. The *in vitro* techniques are more attractive for the purpose of the quick production of thousands of plants in pineapple (Pannetier, C. and Lanaud, C. 1976). Drew (1980) reported production of one lakh plants from one shoot in less than 12 months.

Scow and Wee (1970) regenerated *in vitro* plants from leaf buds, from callus by Wee (1979) and from apex or axillary buds from crown by Fitchet (1985). Shaken cultures induce rapid proliferation of single shoot apices of bromeliads (Mapes, 1973). The technique of cutting shoot apices for regeneration could be used in pineapple for rapid proliferation of clones with desirable characteristics (Teo, 1974).

Lakshmi *et al.* (1974) observed that terminal buds have been shown to produce only one plantlet per culture whereas auxins and cytokinins have been found to influence induction and development of multiple shoots. The morphogenetic potential

of normally dormant lateral buds of pineapple for production of multiple plantlets *in vitro* has been confirmed (Mathews *et al.* 1976).

Mathews and Rangan (1979) reported that plantlets were obtained from usually dormant axillary buds, excised from the crown of pineapple (*Ananas comosus* L. Merr.) and grown in culture. Multiple shoots arose from single buds grown on MS medium supplemented with auxins and kinetin. Shaking culture flasks during growth increased the number of multiple shoots formed, when compared with stationary liquid cultures. Leaf explants excised from *in vitro* plantlets developed into a callus capable of plantlet regeneration. Subjecting developing buds to surgical segmentation also resulted in multiple shoot formation. Such shoots when excised and grown on MS medium supplemented with auxins, developed roots and grew into complete plantlets capable of being grown in soil.

Wakasa (1979) in a detailed study of tissue culture of syncarp, slip, crown and axillary bud of *Ananas comosus* (L.) Merr., cultivar Smooth Cayenne, 448 plants were established. To examine the two possible merits of this technique on self-incompatible plants of vegetative propagation, mass production of non-variants and induction of variants useful in breeding, the variation among the redifferentiated plants were investigated. Many variants regarding spine, leaf color, wax secretion on leaf surface and foliage density were found among the established plants. There were a few variants with narrow leaves or albino strips. Organ-to-organ differences were found in the frequencies and the modes of distribution of these variations. Syncarps and a slip developed variants in high frequencies, while crowns and axillary buds did only in low frequencies. The variants from syncarps included the characters on leaf color, spine, wax and foliage density, but the ones from a slip, crown and axillary buds were almost confined in spine characters. From these present findings, it is considered possible to apply the tissue culture technique on the rapid propagation of nonvariant plantlets and the induction of useful variants, if proper kinds of organs are chosen for the respective purpose.

Mathews and Rangan (1981) could establish callus cultures from the basal region of *in vitro* obtained shoot buds on MS medium supplemented with casein hydrolysate, coconut water and NAA. Such callus cultures when grown on MS medium devoid of any growth regulators, regenerated shoot buds and optimum regeneration was obtained on MS + coconut water (5% v/v) medium. Addition of BA did not enhance shoot bud regeneration, but two variants (albino types) were observed among the BA induced regenerants. The callus regenerated shoot buds produced multiple shoots when transferred to MS+NAA+IBA+Kinetin medium. The plantlets were induced to root on a modified Whites' medium+ NAA+IBA and subsequently transferred to soil.

Pineapple propagation by *in vitro* culture of crown and lateral buds has been shown to be feasible (Zepeda and Sagawa, 1981). Callus has been established from *in vitro* grown plantlets from crown and lateral buds with subsequent regeneration of plants via adventitious organogenesis (Rangan, 1984). Callus has also been established from hybrid embryos with the subsequent regeneration of plants via adventitious organogenesis (Rao *et al.*, 1981). De Wald *et al.* (1988) used lateral buds from crowns for micropropagation.

Fitchet (1990) reported induction of callus from the crown apical region of Queen pineapples on Murashige and Tucker medium with casein hydrolysate (400 mg/L), coconut water (15 %) and NAA (40 mg/L). Callus did not become organogenic unless it passed through a stage where the color changed from yellow to green. By investigating the anatomical changes in the green callus it was possible to determine that the regeneration of plants was by indirect adventitious organogenesis and not the result of somatic embryogenesis. Areas of meristematic activity were easily discernible and developing shoot buds could be seen on the periphery of the callus as well as within the callus mass.

Fitchet (1993) described a technique for maximum production of pineapple (*Ananas comosus* [L] Merr.) plants from minimal propagation material. The *in vitro* culture of lateral buds obtained from the crowns of pineapple need not be limited to

those buds that are easily visible. Undeveloped buds can also be used successfully for cloning by sectioning the crown apical dome region and culturing these sections on Murashige and Tucker medium with NAA, IBA and KIN (2 mg/L each). Developing plantlets were multiplied in liquid MT medium with NAA (2 mg/L) and Kin (2 mg/L).

Kiss *et al.* (1995) introduced a novel micropropagation method for pineapple (*A. comosus* L.) based on shoot elongation induced *in vitro* for two cultivars. Decapitated *in vitro* plantlets were used as explants. Shoot etiolation was induced by placing explants in a MS medium containing NAA (10 μm) and incubating in darkness at 28°C for 30-40 days. The mean number of the regenerated etiolated shoots per explant was 2.6±0.29. The etiolated shoots were placed into N6 medium supplemented with kinetin or BA (25 or 20 μm, respectively). After 4-6 weeks, shoots regenerated along the nodes. The highest regeneration rate was 15 and 13 plantlet per node with 25 μm kinetin and 20 μm BA respectively. Regenerated plantlets were rooted on a growth regulator free MS medium. Residual shoots of the initial explant could be recycled by rooting on a growth regulator free MS medium. This procedure enables the regeneration of several thousand plantlets per year.

Recently the alternative propagation method of pineapple through nodule culture have been developed (Teng, 1997). Nodules are cell clusters that display a consistant internal cell and tissue differentiation pattern and generally have a high capacity for plant or organ regeneration via organogenesis. They can also proliferate into more nodules, and plant material can be maintained long-term at the nodule stage.

Higher multiplication rates for Perola were obtained with BAP concentrations of 2.0 and 1.0 mg 1-1 for the establishment and proliferation stages respectively, while for Primivera the best results were obtained with BAP concentrations of 3.0 and 2.0 mg I-1 respectively (Almeida *et al.* 1997)

Micropropagation produces plants without disease but also suppresses endomycorrhiza formation. Endomicorrhization of pineapple vitroplants at outplanting

from *in vitro* conditions positively affected their mineral nutrition, growth and contents of photosynthetic pigments (Guillemin *et al.* 1997).

Pineapple (*Ananas comosus* Merr.) regeneration from *in vitro* leaf culture was achieved in 2 steps (Dolgov *et al.* 1998). The first step involved the formation of callus. Callus was observed on 23-30 % of explants. Its frequency depended upon plant age and which part of the leaf was cultured. At the second stage, callus formed plantlets at a frequency of 50-100%. Crumbly-globular callus with nodules produced more plantlets than firm-compact callus on MS media supplemented with 2ip, Kin, NAA and IBA. The best regeneration and callus formation were observed on leaf explants taken from *in vitro* plants 8-9 weeks old. Pineapple takes 4 years to flower from seed.

In an evaluation of phenotypic and genotypic variation among pineapple plantlets at different stages of *in vitro* regeneration, acclimatization and growth in the field, Vesco *et al.* (2000) found that the phenotypically observed somaclonal variation frequency among 2421 micropropagated plants was only 0.12%. Analysis of isoenzyme systems detected ten variants out of 390. Evaluation of the first production cycle showed that micropropagation allowed the production of healthy plantlets, which produced adult plants with normal morphological and agronomic traits, similar to plants propagated conventionally. The high number of suckers per plant was the only trait which diverged from the varietal pattern. The efficiency of the *in vitro* regeneration protocol was demonstrated through the large scale production of healthy plantlets with a low rate of somaclonal variation.

Graham *et al.* (2000) attempted to control blackheart by inhibiting expression of polyphenol oxidase in genetically engineered pineapple plants. PPO genes have been isolated from various pineapple tissues. Pineapple has been transformed using *Agrobacterium* mediated gene delivery.

Botella *et al.* (2000) isolated and characterized the gene that is responsible for production of ACC synthase enzyme, the key regulatory enzyme for the biosynthesis of

ethylene. Ethylene is responsible for natural flowering in pineapple. Transgenic pineapple plants are produced which carry sense and antisense copies of the flowering related ACC synthase gene in order to down regulate the expression of the gene and therefore suppress natural flowering.

Materials and Methods

MATERIALS AND METHODS

The present investigations were carried out under the Department of Plant Breeding & Genetics at the College of Horticulture, Vellanikkara of the Kerala Agricultural University during the period from 1998 to 2003. The field investigations were conducted at the Pineapple Research Station, Vazhakulam, Muvattupuzha, of the Kerala Agricultural University, which was located at 76° 36 ' east longitude and 9° 57 ' north latitude at an elevation of 105 m above MSL. The studies on *in vitro* mutagenesis was done at the Centre for Plant Biotechnology and Molecular Biology at the College of Horticulture, Vellanikkara. The irradiation of the *in vitro* culture was done at the Radio-tracer Laboratory at Vellanikkara, Kerala Agricultural University.

3.1. Evaluation of Pineapple Genotypes

3.1.1. Materials

The parental materials used for hybridization consisted of six genotypes of which five genotypes, viz., Mauritius (M), Kew (K), Selection-1 (S-1), Pampakuda local (PKDA) and Kakkoor local (KKR), were obtained from the Pineapple Research Station, Vazhakulam and one genotype, ie., Ripley Queen (RQ), was received from the Pineapple Research Centre at Vellanikkara.

3.1.2. Methods

The six parental genotypes were evaluated at the research plots of the Pineapple Research Station, Vazhakulam. Ten suckers were planted for each genotype in paired rows with five plants in each row. Planting was done at a spacing of 30 cm. between plants, 45 cm. between two rows and 150 cm. between paired rows. The treatments were replicated in four plots. All the management operations were carried out as per the Package of Practices Recommendations of Kerala Agricultural University (KAU,

1996). Observations on both quantitative and qualitative characters were recorded from the parental genotypes.

3.1.2.1. Growth characters

The following growth characters were recorded from six plants in each plot avoiding the border plants and the mean values worked out.

1. *Height of the plant*

Height of the plant at the time of harvest of the fruit was measured in centimeter from the ground level to the tip of the longest leaf.

2. *Number of leaves per plant*

All the leaves present on the plant at the time of harvest was counted and recorded.

3. *Number of suckers per plant*

Number of suckers present on the leaf axils of the plant at the time of harvest of the fruit was recorded.

4. *Number of slips per plant*

Number of slips present on the peduncle of the fruit at the time of harvest was recorded.

5. *Length of peduncle*

Length of the peduncle was measured in centimeter from the axil of the upper most leaf to the base of the fruit.

6. *Duration from planting to beginning of inflorescence development*

The number of days from planting of the sucker in the field to the change of colour in the heart of the plant was counted as duration from planting to beginning of inflorescence development.

7. *Duration from beginning to full development of inflorescence*

The number of days from the day of change of colour in the heart of the plant to the full emergence of the inflorescence was counted as the duration from beginning to full development of inflorescence.

8. *Duration from full development of inflorescence to first flower opening*

The number of days from the full emergence of inflorescence to the day of the opening of the first flower was counted and recorded as duration from full development of inflorescence to first flower opening.

9. *Duration from opening of first flower to last flower*

The number of days from opening of the first flower in the base to the last flower at the tip of the inflorescence was counted as duration from opening of first flower to last flower.

10. *Duration from opening of last flower to harvest*

The number of days from opening of the last flower at the tip of the inflorescence to the ripening of the fruit was counted as duration from opening of last flower to harvest.

11. *Duration of fruit development*

The number of days from the change of colour in the heart of the plant to the ripening of the fruit was counted as duration of fruit development.

12. *Duration of the crop*

The number of days from planting of suckers to ripening of the fruit was counted as duration of crop.

3.1.2.2. Fruit characters

1. *Fruit weight with crown*

The weight of the fruit including the crown was recorded, in grams, immediately

after harvest.

2. *Fruit weight without crown*

The weight of the fruit after removing the crown was recorded in grams.

3. *Fruit length*

Length of the fruit was measured from the base of the fruit to the point of attachment of the crown to the fruit, in centimeter using a vernier caliper.

4. *Mean fruit breadth*

Breadth of the fruit was measured in centimeter using a vernier caliper at three regions, viz., lower $1/4^{th}$, middle $2/4^{th}$ and upper $3/4^{th}$ length of the fruit and the average of the three measurements were recorded as mean fruit breadth.

5. *Girth of fruit*

Girth at the middle of fruit was measured in centimeter.

6. *Canning ratio*

Canning ratio was estimated by dividing the length of fruit by breadth at the middle of fruit.

7. *L/B ratio*

L/B ratio was estimated by dividing the length of fruit by the mean breadth of the fruit.

8. *Taper ratio*

The breadth of the fruit at the upper $3/4^{th}$ region was divided by the breadth of the fruit at the lower $1/4^{th}$ region to get the value of taper ratio.

9. *Crown weight percentage*

Weight of the crown was taken separately and the percentage of the crown weight out of the total weight of the fruit was calculated.

10. *Peel weight percentage*

The peel of the fruit was carefully removed, its weight recorded and the percentage of the peel weight out of the weight of fruit without crown determined.

11. *Pulp weight percentage*

Weight of the pulp, after removing the peel and core of the fruit, was expressed as percentage of pulp weight out of the weight of the fruit without crown.

12. *Peel/pulp ratio*

Peel/pulp ratio was estimated by dividing the weight of the peel by the weight of the pulp.

13. *Core weight percentage*

The core of the fruit was carefully taken out and its weight expressed as percentage of core weight out of the weight of fruit without crown.

14. *Juice weight percentage*

The juice of the fruit after removing the peel and core was extracted using a juicer, filtered through a fine closely knitted nylon cloth and its weight expressed as percentage of juice weight out of the weight of the fruit without crown.

15. *Total soluble solids*

Total soluble solids (TSS) of the juice extracted was measured with an ERMA hand refractometer and expressed as degree brix.

16. *Acidity of the juice*

Acidity of the juice was estimated (Ranganna, S. 1977) by titrating against standard alkali using phenolphthalein as indicator and expressed as gram of citric acid per 100 gram of juice (percentage).

17. *Ascorbic acid content*

Ascorbic acid was estimated (Ranganna, S. 1977) by titrating against 2, 6

Dichlorophenol indophenol dye and expressed as milligram per 100 gram of fruit.

18. *Reducing sugar*

Reducing sugar was estimated (Ranganna, S. 1977) as gram of reducing sugar required to reduce cupric salt to cuprous oxide and expressed as gram of glucose per 100 gram of juice (percentage).

19. *Total sugar*

The non-reducing sugar in the fruit was hydrolysed to reducing sugar and the total sugar was estimated by titration and expressed as gram of glucose per 100 gram of juice (percentage) (Ranganna, S. 1977).

20. *Non-reducing sugar*

The difference between the total sugar and the reducing sugar was estimated as non-reducing sugar and expressed as gram of sucrose per 100 gram of juice (percentage).

21. *p*H *of the juice*

*p*H of the juice was measured using an Elico *p*H meter.

22. *Sugar/acid ratio*

Sugar/acid ratio was estimated by dividing the value of total sugar by the value of acidity.

23. *Brix/acid ratio*

Brix/acid ratio was estimated by dividing the value of brix by the value of acidity.

3.1.2.3. Qualitative characters

The following qualitative characters were recorded from the six parental genotypes.

1. *Presence of spine on the leaf.*
2. *Colour of leaf.*
3. *Depth of fruit eyes.*
4. *Fruit colour at ripening.*
5. *Pulp colour at ripening.*

3.1.2.4. Statistical analysis

Analysis of variance

The mean values of the six sample plants from each replication were used for the Analysis of Variance (Singh and Choudhary, 1985) for all the characters.

3.2. Study of the Floral Biology

In any hybridization programme, study of the floral biology of the various parents with respect to the location where it is to be implemented is of very much important. Hence the floral biology of the six parental genotypes were studied at the conditions of the Pineapple Research Station, Vazhakulam.

3.2.1. Flower production and anthesis

Flower production and the process of the opening of flowers in the pineapple inflorescence were studied. The following observations were recorded.

1. *Number of flowers opened per day*

The number of flowers opened on each day in an inflorescence was counted from the first day of flower opening to the last day of flower opening and the total number of flowers opened was divided by the number of days taken for completion of flower opening to get the number of flowers opened per day. This was observed every day in the morning between 7 am to 9 am on four inflorescences for each genotype with four replications and the mean values worked out.

2. *Number of flowers per inflorescence*

The total number of flowers opened was taken as number of flowers per inflorescence.

3. *Number of days for completion of flower opening*

The number of days from the opening of the first flower to the opening of the last flower in an inflorescence was taken as the number of days for completion of flower opening.

4. *Mean number of flowers opened on each day*

The number of flowers opened on each day from the day of opening of the first flower to the last flower was counted and the mean for each day was taken as the number of flowers opened on each day.

5. *Percentage of flowers opened on each day*

Percentage of flowers opened on each day out of the total number of flowers opened was worked out.

6. *Sequence of flower opening*

The sequence of the opening of the flowers in the inflorescence on each day was observed on five inflorescences for each genotype.

7. *Time of flower opening*

The total number of flowers opened on each day was observed for four consecutive days in five inflorescence in each genotype from 4 pm on the previous day to 12 noon in the next day at one hour interval for their time of opening. Total number of flowers observed on five inflorescences was taken as number flowers observed on each day for each genotype.

8. *Time of anther dehiscence*

The total number of flowers that are to open on each day was forced open with a pair of forceps at 3 am on five inflorescence in each genotype for four days and

observed for anther dehiscence from 3 am, till the anther dehisce, at one hour interval using a hand lens.

3.2.2. Pollen fertility and viability

Pollen fertility was ascertained by acetocarmine staining (Zirkle, 1937). Viability of the pollen was tested by germinating in 10 % sucrose solution.

3.2.3. Duration of receptivity of stigma

The duration of receptivity of stigma was studied by pollinating at different time intervals.

1. *Percentage of flowers with seed set when pollinated at different time intervals*

To find out the duration of receptivity of stigma, thirty flowers in each genotype was crossed in 15 time intervals at one hour time interval from 3 am to 6 pm. At full ripening, seeds were collected from each flower at each time interval and the success in seed set at each time interval was taken as receptivity of stigma. Pollen from Mauritius was used for crossing with Kew, Selection-1, Pampakuda local and Kakkoor local and the pollen from Kew was used for crossing with Mauritius and Ripley Queen. Before the opening of flowers started, the inflorescence were bagged using muslin cloth as a protection against any chance for cross pollination by bees as there was very high bee activity at the time of anthesis. The cloth bags were removed from the inflorescence the next day after the completion of flower opening. Spraying of insecticides was also done in the entire breeding plot and also on the plants at frequent intervals to prevent ants which are also found to be very active during anthesis.

To compare the percentage of flowers with seed set when pollinated at different time intervals, seed set at open pollinated and self pollinated conditions were also observed. For self pollination, five inflorescences of each genotype were bagged before the initiation of flower opening and the bagging was removed after all the flowers were opened. For open pollination, five inflorescence of each genotype were

left as such. The seeds, if any, from all the fruits in both the cases were collected. The mean value was worked out and the percentage of the mean value over the mean number of flowers per inflorescence of each genotype was estimated.

2. *Number of seeds per pollinated flower when pollinated at different time intervals*

The value of the number of seeds produced when pollinated at each time interval was divided by the value of the total number of flowers pollinated at the respective time interval to get the number of seeds per pollinated flower at different time intervals. This value was compared with number of seeds per flower produced at open pollinated and self pollinated situation. The number of seeds per flower at open and self pollinated condition was estimated by dividing the mean number of seeds per inflorescence by the mean number of flowers per inflorescence.

3. *Number of seeds per successful cross when pollinated at different time intervals*

The value of the number of seeds produced when pollinated at different time intervals were divided by the value of the number of flowers with seeds at the respective time interval to get the number of seeds per successful cross at different time intervals. This value was compared with number of seeds per flower with seed produced at open pollinated and self-pollinated situation. The number of seeds per flower with seed at open and self pollinated condition was estimated by dividing the number of seeds obtained by the number of flowers with seed in an inflorescence and the mean worked out.

3.3. Hybridization and Production of Hybrids

3.3.1. Hybridization

The hybridization programme was planned with six genotypes to be crossed in all possible combinations to produce thirty cross combinations. For this purpose 20 plants in each genotype were induced to flower by applying ethephon. The Kew and Selection-1 were induced one week prior to the rest for synchronization of flowering as they are late by about one week in flowering. Additional plants in sufficient numbers

in all the genotypes were induced in a staggered manner to meet the requirements of pollen and also to meet the eventuality of missing any proposed plants for hybridization. All the plants were observed for the development of inflorescence and one day prior to the initiation of flower opening all the pistillate inflorescences were bagged using muslin cloth fitted in a frame (Plate 1). All the pistillate plants were labeled for their cross combinations.

On the day of pollination, pollen was collected from the plants kept apart for the purpose during early morning between 5 am and 6 am. Pollen was collected by cutting the entire flower, sufficient in number for the day, and the excised flowers were collected in petri-dishes and covered. For crossing, emasculation was not done as there was self-incompatibility in pineapple. Pollination was done during 6 am to 10 am and all the flowers opened on each day in an inflorescence were pollinated for all the genotypes. After 6 am the petals would have sufficiently opened and there was no need to force open the flower. Moreover the stigma would have protruded out above the stamens and will be visible. At the time of pollination, the bagging of the pistillate plant was opened on the top. Then one anther for crossing the respective pistillate plant was taken from the petridish using a pair of narrow forceps and rubbed against the stigma and the anther was allowed to remain on the stigma. Similarly all the flowers in an inflorescence opened on that day were pollinated. After pollination, the bag was closed again at the top.

In this way all the inflorescences were pollinated for all the flowers in the thirty cross combinations and the number of flowers pollinated in each inflorescence were recorded.

3.3.2. Seed set and seed production

When the fruit was fully ripe, it was harvested. To collect the seeds from the fruit, first a thin layer of the peel was removed in such a way that the eyes or the borders of each fruitlet was continued to be visible. Then each fruitlet was taken out separately using a blunt narrow knife and the seeds were pressed out of it. This

Plate 1. Bagging of inflorescence for hybridization

procedure helped to observe the number of flowers having seeds after pollination. After collection of seeds, the seeds were washed thoroughly several times to remove the sticky matters from the seed. Then it was spread over an absorbent paper and kept for one to two hours. Then the seeds were graded into bold and shriveled seeds and sown separately. The following observations were recorded.

1. *Percentage of flowers with seed set*

The number of flowers having seeds out of the total number of flowers pollinated was expressed as percentage of flowers with seed set.

2. *Number of seeds per pollinated flower*

Number of seeds per pollinated flower was estimated by dividing the value of the total number of seeds obtained by the value of the total number of flowers pollinated.

3. *Number of seeds per successful cross*

Number of seeds per successful cross was estimated by dividing the value of the total number of seeds obtained by the value of the total number of flowers having seeds after pollination.

4. *Percentage of bold seeds*

The total number of bold seeds out of the total seeds obtained was expressed as percentage of bold seeds.

5. *Percentage of shriveled seeds*

The total number of shriveled seeds out of the total seeds obtained was expressed as percentage of shriveled seeds.

3.3.3. Germination of hybrid seeds

The seeds were sown on the same day of its collection. For sowing seeds, sterilized river sand were used in plastic trays. The seeds were sown as a thin layer

over the sand, gently pressed and a thin layer of fine sand was spread over it. The seeds were moistened with sterile water as and when required. When the seedlings attain about one month old they were transplanted to plastic cups filled with sterile river sand. As the seedlings grow to form new leaves and roots, a thin layer of well powdered and well mixed top soil and cow dung was spread over the sand in the cups around the seedlings. And as the seedlings further grow and attain about 8-10 cm height they were transplanted to polybags filled with potting mixture. Later when the seedlings attain 18-20 cm height, they were transplanted to main field. The following observations were recorded.

1. *Percentage of bold seeds germinated*

The number of seeds germinated out of the total number of bold seeds sown was expressed as percentage of bold seeds germinated.

2. *Percentage of shriveled seeds germinated*

The number of seeds germinated out of the total number of shriveled seeds sown was expressed as percentage of shriveled seeds germinated.

3. *Percentage of germination of total seeds*

The number of seeds germinated out of the total number of seeds sown was expressed as percentage of germination of total seeds.

4. *Duration for completion of germination*

After sowing the hybrid seeds, germination was observed at weekly intervals and the number of weeks taken from the day of sowing to the completion of the germination was counted as duration for completion of germination.

5. *Percentage of the total seeds germinated at weekly intervals*

The germination counts of the hybrid seeds after sowing were taken at weekly intervals till the completion of germination and the percentage of the total seeds germinated in each week was worked out.

6. *Percentage of bold seeds germinated at weekly intervals*

The bold seeds were sown separately and the germination of seeds were recorded at weekly intervals till the completion of germination and the percentage of the total bold seeds germinated in each week was worked out.

7. *Percentage of shriveled seeds germinated at weekly intervals*

The shriveled seeds were sown separately and the germination of seeds were recorded at weekly intervals till the completion of germination and the percentage of the total shriveled seeds germinated in each week was worked out.

3.3.4. Percentage of albino seedlings

The number of albino seedlings germinated out of the total seeds sown in each cross was expressed as percentage of albino seedlings.

3.3.5. Self-incompatibility and cross-compatibility studies

From the 30 possible crosses involving six parents, the extent of compatibility of different crosses in terms of seed production and incompatibility among different crosses were studied.

3.4. Evaluation of Hybrids

The hybrid seedlings grown in poly-bags were transplanted to main field as and when they reach 18 to 20 cm height. Planting was done in paired rows at the spacing of 30 cm between plants, 45 cm between rows and 180 cm between paired rows. The seedlings that were transplanted during summer months were given partial shading to prevent sun scorching. All efforts were made at all stages of growth of the hybrids so that maximum number of hybrids survived to attain full growth. Fungicidal application was done from the primary nursery stage onwards. Application of Farm Yard Manure was done in adequate quantities. Irrigation was done to maintain sufficient moisture in the soil always.

All the seedlings were transplanted as and when they reached sufficient growth. The hybrids were allowed to flower naturally and not induced to flower so as to allow them to express all their characters naturally. This has resulted in staggered flowering and harvest facilitating quality analysis of the fruits of all hybrids harvested. Observations on the hybrids harvested upto 2003 were included in this study.

During the evaluation, the following observations were recorded

1. *Percentage of seedlings survived at the stage of planting out and at intervals of 6, 12, 18 and 24 months after planting out.*

Seedlings that were about one month old were transplanted to plastic cups from the primary nursery. The number of seedlings planted out, out of the total seeds germinated in a cross, was expressed as percentage of seedlings survived at the stage of planting out. Similarly the number of seedlings survived at the stage of 6, 12, 18 and 24 months after plant out were also recorded.

Out of the 22 cross combinations studied up to the survival of hybrids, only sixteen cross combinations were included for the following observations. All the crosses involving Ripley Queen as pollen parent and the cross PKDA x KKR and its reciprocal were excluded due to the lack of sufficient number of hybrids reaching harvest stage during the period of evaluation, either by mortality or by slow growth.

2. *Duration from planting to beginning of inflorescence development*

The number of days from sowing of seeds to the date of change of colour at the heart of the plant was counted and recorded as duration from planting to initiation of flowering.

3. *Duration of the crop*

The number of days from sowing of seeds to the date of harvest on ripening of fruit was counted and recorded as duration of crop.

The following observations were recorded from the hybrids, as described for the evaluation of the parental genotypes.

1. *Height of the plant*
2. *Number of leaves per plant*
3. *Number of suckers per plant*
4. *Number of slips per plant*
5. *Length of peduncle*
6. *Duration from beginning to full development of inflorescence*
7. *Duration from full development of inflorescence to first flower opening*
8. *Duration from opening of first flower to last flower*
9. *Duration from opening of last flower to harvest*
10. *Duration of fruit development*
11. *Fruit weight with crown*
12. *Fruit weight without crown*
13. *Fruit length*
14. *Mean fruit breadth*
15. *Girth of fruit*
16. *Canning ratio*
17. *L/B ratio*
18. *Taper ratio*
19. *Crown weight percentage*
20. Peel weight percentage
21. *Pulp weight percentage*
22. *Peel/pulp ratio*
23. *Core weight percentage*
24. *Juice weight percentage*
25. *Total soluble solids*
26. *Acidity of the juice*
27. *Ascorbic acid content*
28. *Reducing sugar*
29. *Total sugar*

30. *Non-reducing sugar*

31. *p*H *of the juice*

32. *Sugar/acid ratio*

33. *Brix/acid ratio*

3.4.1. Statistical analysis

The data on the evaluation of hybrids for thirty five characters were analysed to derive the following information, for all the cross combinations.

3.4.1.1. Genetic variability between and within cross combinations

To have a preliminary assessment of the nature of all the observed characters of the progenies, summary statistics like mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion were computed using MS Excel.

3.4.1.2. Multivariate analysis

After the preliminary assessment of the progenies of all the cross combinations using the summary statistics, further evaluation of the hybrids for their performance were done by selecting the five commercially important characters of pineapple, viz., fruit weight without crown, TSS, total sugars, pulp weight percentage and juice weight percentage. Based on the above five characters, the following multivariate analysis were done to find out the relative position of the progenies in a cross.

3.4.1.2.1. *Determinant of the covariance matrix*

The determinant of the covariance matrix based on five characters were computed for all the cross combinations so as to have a composite variability index for each cross combinations.

3.4.1.2.2: *Principal Component Analysis*

The Principal Component Analysis (Chatfield and Collins, 1980) aims at reduction in the diamensionality of the problem as it will take into consideration all the characters at a time. The first two components were taken into consideration for figurative representation of the progenies. The Principal Components were computed based on correlation matrix using SPSS package.

3.4.1.2.3. *Euclidean distance*

The Euclidean distance (Chatfield and Collins, 1980) is the most familiar measure of dissimilarity when observations on 'p' variables for each of 'n' individuals are given. It is a measure of the distance between two plants with respect to a number of characters. The Euclidean distance of a progeny from another progeny, based on five characters, were computed using SPSS package. After computing the distance matrix, the mean distance of a progeny from the rest were computed to find out the relative distance of the progenies. The progeny having the maximum mean distance in each cross combinations were derived.

3.4.1.3. Selection of desirable hybrids

From among all the hybrids, desirable ones were selected based on the principle of heterosis. All the hybrids in all cross combinations were screened to identify hybrids that expressed higher values than mid parent, better parent and standard parent (Mauritius) for the five important commercially viable characters, viz., fruit weight without crown, TSS, total sugar, pulp weight percentage and juice percentage, taken simultaneously.

Heterosis

The selected hybrids were subjected to estimation of heterosis in five selected characters following the procedure of Hayes *et al.* (1955).

Relative heterosis

Relative heterosis was estimated by dividing the difference between the value of hybrids and mid parent by mid parental value, expressed in percentage.

Heterobeltiosis

Heterobeltiosis was estimated by dividing the difference between the value of hybrids and better parent by the value better parent, expressed in percentage.

Standard heterosis

Standard heterosis was estimated by dividing the difference between the value of hybrids and the standard parent (Mauritius) by the value of standard parent, expressed in percentage.

3.4.2. Spine character of the hybrids

The expression of spines on the leaf of all the hybrid plants were recorded as spiny, non-spiny and sparsely spiny.

3.4.3. Hybrids with distinct or abnormal characters

Hybrids with variation in colour, chlorophyll content, plants with piping character and any other features observed among the hybrid progenies obtained were recorded.

3.5. *In vitro* Mutagenesis

In vitro mutagenesis was done to induce variability in Mauritius genotype. Young suckers of healthy plants were used as source. The growing tips of the selected suckers were pretreated in 0.1 % Emisan for 30 minutes followed by 0.1 % mercuric chloride for 10 minutes. The treated explants were washed thoroughly in sterile water, sized to about 0.5 mm and inoculated in Murashige and Skoog (MS) medium (1962) supplemented with Benzyl adenine (BA) 5.0 mg 1^{-1}. Established explants were

transferred to MS medium supplemented with BA 5 mg l^{-1} and Naphthalene acetic acid (NAA) 1 mg l^{-1} for proliferation of globular structures.

Uniform masses of globular structures were irradiated with gamma rays at the dose of 10, 15, 20, 25, 30, 35 and 40 Gray (Gy). and again inoculated in MS medium supplemented with BA 5 mg l^{-1} and NAA 1 mg l^{-1} for further proliferation. It was subcultured three times at 3-4 weeks interval for further proliferation of globular structures to get maximum number of shoots. Then for development of shoots, the culture was transferred to MS basal medium. Subculturing was done at 3-4 weeks interval.

When maximum number of shoots were developed and are about 2 cm height, the plantlets were taken out, washed, dipped in fungicide, again washed and planted in sterilized sand filled in plastic cups. All the plantlets with or without roots were planted out. Each individual cup with plantlets was covered with a transparent polythene cover to develop sufficient moisture inside to prevent drying of the plantlets. After one week the polythene cover was removed. The plantlets were irrigated with sterile water as and when required. When hardened, the plantlets started growing by forming new leaves and roots. A mixture of dried cowdung and top soil were added around each plantlets, in the cup. When the plantlets attained about 7-8 cm height, they were transplanted to polybags filled with potting mixture and at about 18-20 cm height, at the age of about 14-15 months, they were transplanted to main field.

Observations on height and number of leaves were recorded at the stages of plant out, and at intervals of 30 days up to 120 days.

Results

RESULTS

The results of the various field experiments, viz., evaluation of the six parental genotypes used for hybridization, study of the floral biology of the six genotypes, study of the pollination aspects, hybridization and production of hybrids, evaluation of hybrids and hardening and evaluation of the *in vitro* mutants, taken up at the Pineapple Research Station at Vazhakulam are presented below.

4.1. Evaluation of Pineapple Genotypes

The six parental genotypes were evaluated for 12 growth characters (Table 1) and 23 yield and quality characters (Table 2) to study their performance. It was found that out of the total thirty five characters studied, the six genotypes differ significantly in thirty four characters and there was no significant difference between the genotypes with regard to the number of leaves per plant. The ANOVA for growth and yield and quality characters are presented in Appendix-I and Appendix-II respectively.

The genotype Mauritius was having high values for number of suckers per plant at the time of harvest (0.9), length of peduncle (23.5 cm), duration from full development of inflorescence to first flower opening (6.7 days), length of fruit (15.4 cm), canning ratio (1.51), L/B ratio (1.49), core weight % (8.77), T.S.S. (14.9 ° brix), total sugar (13.48 %), non-reducing sugar (10.61 %), sugar/acid ratio (21.67) and brix/acid ratio (24.74).

Kew was having higher values for duration from planting to beginning of inflorescence development (colour change at the heart of the plant) (348.2 days), duration from beginning to full development of inflorescence (full emergence of inflorescence) (12.4 days), duration from full development of inflorescence to first flower opening (9.2 days), duration from opening of last flower to harvest (87.7 days), fruit development period (125.2 days), total duration of crop (473.4 days), girth of fruit at middle (35.1 cm), mean breadth of fruit (10.3 cm)), taper ratio (0.96), crown weight

Table 1. Mean values of growth characters of six pineapple genotypes selected for hybridization

Sl.. No.	Genotypes	Height of the plant (cm)	Number of leaves per plant	Number of suckers per plant	Number of slips per plant	Length of peduncle (cm)	Duration						
							from planting to beginning of inflore-scence develop-ment (days)	from beginning to full develop-ment of infloresc-ence (days)	from full develop-ment of inflore-scence to first flower opening (days)	from opening of first flower to last flower (days)	from opening of last flower to harvest (days)	of fruit develop ment (days)	of the crop (days)
1.	Mauritius	84.6 ^{c}	39.2	0.9 ^{a}	1.3 ^{c}	23.5 ^{a}	266.7 ^{c}	9.7 ^{bcd}	6.7 ^{ab}	17.0 ^{b}	74.6 ^{c}	108.0 ^{c}	374.7 ^{c}
2.	Kew	92.6 ^{b}	40.1	0.2 ^{b}	0.0 ^{d}	19.5 ^{bc}	348.2 ^{a}	12.4 ^{a}	9.2 ^{a}	16.0 ^{b}	87.7 ^{a}	125.2 ^{a}	473.4 ^{a}
3.	Selection-1	97.7 ^{b}	42.7	0.1 ^{b}	0.0 ^{d}	17.7 ^{c}	338.7 ^{ab}	11.6 ^{ab}	4.5 ^{b}	20.3 ^{a}	89.9 ^{a}	126.3 ^{a}	465.0 ^{a}
4.	Pampakuda local	106.9 ^{a}	36.2	0.7 ^{a}	2.3 ^{b}	20.5 ^{b}	330.1 ^{ab}	9.3 ^{cd}	7.3 ^{ab}	15.2 ^{b}	86.6 ^{ab}	118.2 ^{b}	448.4 ^{ab}
5.	Kakkoor local	107.0 ^{a}	34.8	0.8 ^{a}	3.6 ^{a}	20.4 ^{b}	305.9 ^{b}	8.5 ^{d}	8.2 ^{ab}	16.8 ^{b}	81.7 ^{b}	115.1 ^{b}	421.1 ^{b}
6.	Ripley Queen	80.8 ^{c}	43.9	0.3 ^{b}	0.0 ^{d}	19.1 ^{bc}	264.4 ^{c}	10.9 ^{abc}	8.4 ^{ab}	16.3 ^{b}	61.5 ^{d}	97.3 ^{d}	361.7 ^{c}
	CD (0.05)	7.14	n. s.	0.33	0.86	2.684	36.29	2.19	4.55	2.35	5.40	4.93	35.86

Values having different superscripts differ significantly

Table 2. Mean values of fruit characters of six pineapple genotypes selected for hybridization

Sl. No.	Genotypes	Fruit weight with crown (g)	Fruit weight without crown (g)	Fruit length (cm)	Mean fruit breadth (cm)	Girth at middle (cm)	Canning Ratio	L/B Ratio	Taper ratio	Crown weight (%)	Peel weight (%)	Pulp weight (%)	Peel-pulp ratio
1.	Mauritius	1223.4 ^{de}	1061.3 ^{cd}	15.4 ^{ab}	9.7 ^{b}	31.9 ^{bc}	1.51 ^{a}	1.49 ^{ab}	0.93 ^{bc}	13.52 ^{c}	13.68 ^{b}	78.0 ^{b}	0.19 ^{b}
2.	Kew	1697.0 ^{b}	1443.4 ^{b}	14.4 ^{b}	10.3 ^{ab}	35.1 ^{ab}	1.29 ^{bc}	1.39 ^{b}	0.96 ^{abc}	17.59 ^{ab}	8.76 ^{d}	82.7 ^{a}	0.11 ^{c}
3.	Selection-1	2059.1 ^{a}	1765.7 ^{a}	16.9 ^{a}	11.0 ^{a}	37.4 ^{a}	1.40 ^{ab}	1.53 ^{ab}	0.92 ^{bc}	14.97 ^{bc}	9.76 ^{cd}	82.1 ^{ab}	0.12 ^{c}
4.	Pampakuda local	1377.6 ^{cd}	1084.5 ^{cd}	12.2 ^{c}	10.1 ^{ab}	33.1 ^{bc}	1.16 ^{c}	1.21 ^{c}	1.07 ^{a}	19.98 ^{a}	12.33 ^{bc}	79.7 ^{ab}	0.17 ^{bc}
5.	Kakkoor local	1558.9 ^{bc}	1278.4 ^{bc}	14.5 ^{b}	10.3 ^{ab}	33.4 ^{bc}	1.35 ^{b}	1.41 ^{b}	1.02 ^{ab}	17.60 ^{ab}	10.67 ^{bcd}	79.5 ^{ab}	0.14 ^{bc}
6.	Ripley Queen	1058.7 ^{e}	916.3 ^{d}	15.0 ^{b}	9.7 ^{b}	30.8 ^{c}	1.53 ^{a}	1.62 ^{a}	0.90 ^{c}	14.92 ^{bc}	18.63 ^{a}	71.2 ^{c}	0.27 ^{a}
	CD (0.05)	291.24	250.13	1.46	0.88	3.36	0.14	0.14	0.11	2.92	3.28	4.46	0.06

Values having different superscripts differ significantly

Table 2 (contd.)

Table 2. (concl.)

Sl. No.	Genotypes	Core weight (%)	Juice weight (%)	T.S.S. (°Brix)	Acidity (%)	Ascorbic acid (mg/100 g)	Total sugar (%)	Non-reducing sugar (%)	Reducing sugar (%)	p^H of the juice	Sugar/ acid ratio	Brix/ acid ratio
1.	Mauritius	8.77 ^{ab}	47.1 ^{bc}	14.9 ^{a}	0.61 ^{cd}	41.11 ^{b}	13.48 ^{a}	10.61 ^{a}	2.78 ^{b}	3.75 ^{bc}	21.67 ^{a}	24.74 ^{a}
2.	Kew	8.50 ^{ab}	49.1 ^{ab}	13.7 ^{b}	0.81 ^{a}	21.64 ^{c}	11.88 ^{b}	7.83 ^{b}	4.05 ^{a}	3.53 ^{d}	14.45 ^{c}	17.25 ^{c}
3.	Selection-1	8.30 ^{ab}	51.5 ^{a}	13.4 ^{b}	0.70 ^{bc}	20.94 ^{c}	11.82 ^{b}	7.90 ^{b}	3.95 ^{a}	3.62 ^{bcd}	18.37^{ab}	20.82 ^{b}
4.	Pampakuda local	7.17 ^{bc}	44.0 ^{c}	10.1 ^{c}	0.52 ^{d}	60.73 ^{a}	8.39 ^{c}	5.68 ^{c}	2.75 ^{b}	3.96 ^{a}	16.60 ^{bc}	20.13 ^{bc}
5.	Kakkoor local	5.98 ^{c}	45.2 ^{bc}	9.8 ^{c}	0.60 ^{cd}	57.86 ^{a}	8.41 ^{c}	5.56 ^{c}	2.86 ^{b}	3.71 ^{bcd}	14.42 $_{c}$	17.21 ^{c}
6.	Ripley Queen	10.23 ^{a}	36.8 ^{d}	15.0 ^{a}	0.78 ^{ab}	49.49 ^{ab}	12.00 ^{ab}	10.01 ^{a}	2.02 ^{c}	4.05 ^{a}	15.57 ^{bc}	19.50 ^{bc}
	CD (0.05)	2.18	4.24	1.16	0.10	11.91	1.49	1.36	0.46	0.19	3.57	3.09

Values having different superscripts differ significantly

% (17.59), core weight % (8.5), pulp weight % (82.7), juice weight % (49.1), acidity (0.81 %) and reducing sugar (4.05 %).

The genotype Selection-1 was having higher values for duration from planting to beginning of inflorescence development (338.7 days), duration from beginning to full development of inflorescence (11.6 days), duration from opening of first to last flower (20.3 days), duration from opening of last flower to harvest (89.9 days), fruit development period (126.3 days), total duration of crop (465 days), fruit weight with and without crown (2059.1 and 1765.7 days respectively), girth of fruit at middle (37.4 cm), length of fruit (16.9 cm), mean breadth of fruit (11 cm), canning ratio (1.4), L/B ratio (1.53), core weight % (8.3), pulp weight % (82.1), juice weight % (51.5), reducing sugar (3.95%) and sugar/acid ratio (18.37 %).

Pampakuda local was having high values for height of the plant (106.9 cm), number of suckers (0.7), duration from planting to beginning of inflorescence development (330.1 days), duration from full development of inflorescence to first flower opening (7.3 days), duration from opening of last flower to harvest (86.6 days), total duration of crop (448.4 days), mean breadth of fruit (10.1 cm), taper ratio (1.07), crown weight % (19.98), pulp weight % (79.7), ascorbic acid content (60.73 mg per 100 g of fruit) and *p*H of the juice (3.96).

Kakkoor local was having higher values for height of the plant (107 cm), number of suckers (0.8), number of slips (3.6), duration from full development of inflorescence to first flower opening (8.2 days), taper ratio (1.02), crown weight % (17.6), mean breadth of fruit (10.3 cm), pulp weight % (79.5) and ascorbic acid content (57.86 mg per 100 g of fruit).

Ripley Queen expressed higher values for duration from beginning to full development of inflorescence (10.9 days), duration from full development of inflorescence to first flower opening (8.4 days), canning ratio (1.53), L/B ratio (1.62), peel weight % (18.63), peel/pulp ratio (0.27), core weight % (10.23), T.S.S. (15 °brix),

acidity (0.78 %), ascorbic acid content (49.49 mg per 100 g of fruit), total sugar (12 %), non-reducing sugar (10.01 %) and *p*H of juice (4.05).

The six genotypes were further evaluated for five qualitative characters (Table 3). Among the six genotypes, only Kew was having spineless leaves and all others are having spiny leaves. The colour of the leaves was green for Mauritius, Kew, Selection-1 and Ripley Queen, pale green for Pampakuda local and reddish green for Kakkoor local (Plate 2). The colour in the heart of the plant at the time of inflorescence development was deep red in KKR, creamy white in PKDA and has different intensities of red in Kew, S-1, RQ and Mauritius (Plate 3). The fruit eyes were deep for Mauritius and Ripley Queen, shallow for Kew and Selection-1 and medium deep for Pampakuda local and Kakkoor local. Shell colour of 'green fruit' was black for Kew and S-1, grey black for Mauritius and RQ, green for PKDA and reddish pink for KKR (Plate 4). Fruit colour at ripening was golden yellow for Mauritius, yellow for Kew, Selection-1 and Ripley Queen, bright yellow for Pampakuda local and reddish yellow for Kakkoor local (Plate 5). Colour of pulp at ripening was golden yellow for Mauritius and Ripley Queen, yellow for Pampakuda local and Kakkoor local and pale yellow for Kew and Selection-1.

4.1.1. Desirable characters of parents

The six parental genotypes for hybridization were compared based on the desirable expression of fifteen characters (Table 4), viz., less height, low number of suckers, low or absence of slips, short duration, high TSS, low acidity, high fruit weight, optimum taper ratio, low peel weight, low core weight, high ascorbic acid content, spineless leaves, high juice content, attractive colour of fruit at ripening and golden yellow and pale yellow colour of pulp at ripening.

Mauritius was having the desirable characters such as less height of the plant (84.6 cm), short duration (374.7 days), high T.S.S. (14.9 °brix) and golden yellow colour of pulp. Kew was having the desirable characters like low sucker (0.2) and slip production (0.0), optimum taper ratio (0.96), low peel weight % (8.76), high juice %

Table 3. Qualitative characters of leaf and fruit of six pineapple genotypes selected for hybridization

Sl. No.	Genotypes	Presence of spine on leaf	Colour of leaf	Fruit eye depth	Fruit colour at ripening	Pulp colour at ripening
1.	Mauritius	Spiny	Green	Deep	Golden yellow	Golden yellow
2.	Kew	No spines	Green	Shallow	Yellow	Pale yellow
3.	Selection-1	Spiny	Green	Shallow	Yellow	Pale yellow
4.	Pampakuda local	Spiny	Pale green	Medium deep	Bright yellow	Yellow
5.	Kakkoor local	Spiny	Reddish green	Medium deep	Reddish yellow	Yellow
6.	Ripley Queen	Spiny	Green	Deep	Yellow	Golden yellow

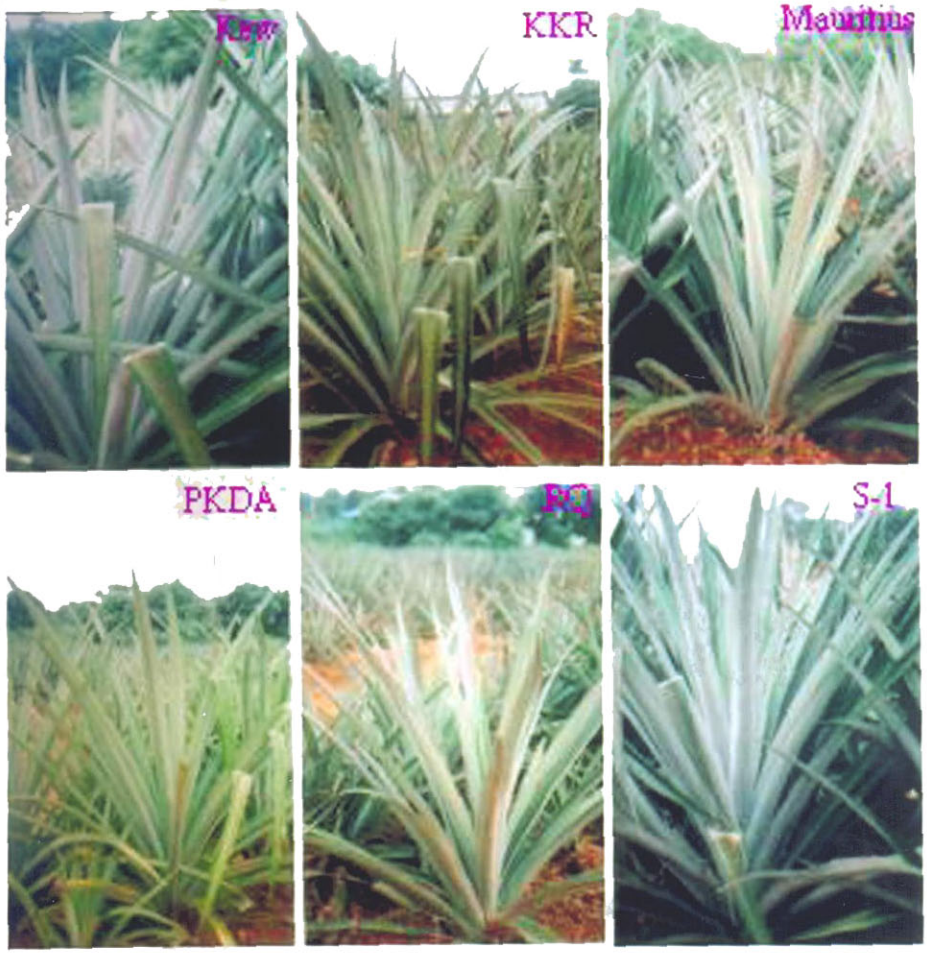


Plate 2. Six parental genotypes used for hybridization

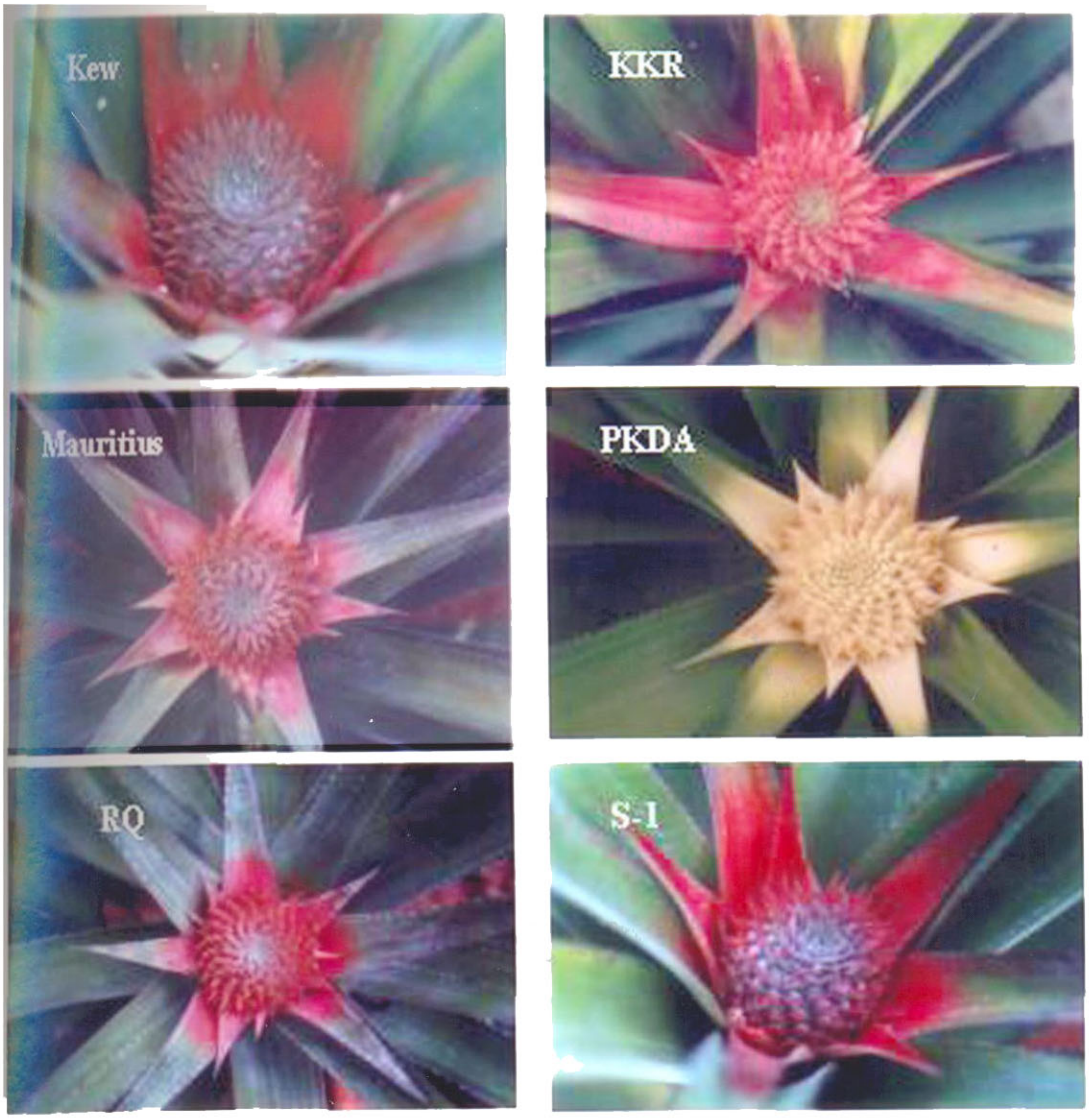


Plate 3. Colour variation in the heart of the six pineapple genotypes used for hybridization at the time of inflorescence development

Plate 4. Green fruits of the six pineapple genotypes used for hybridization

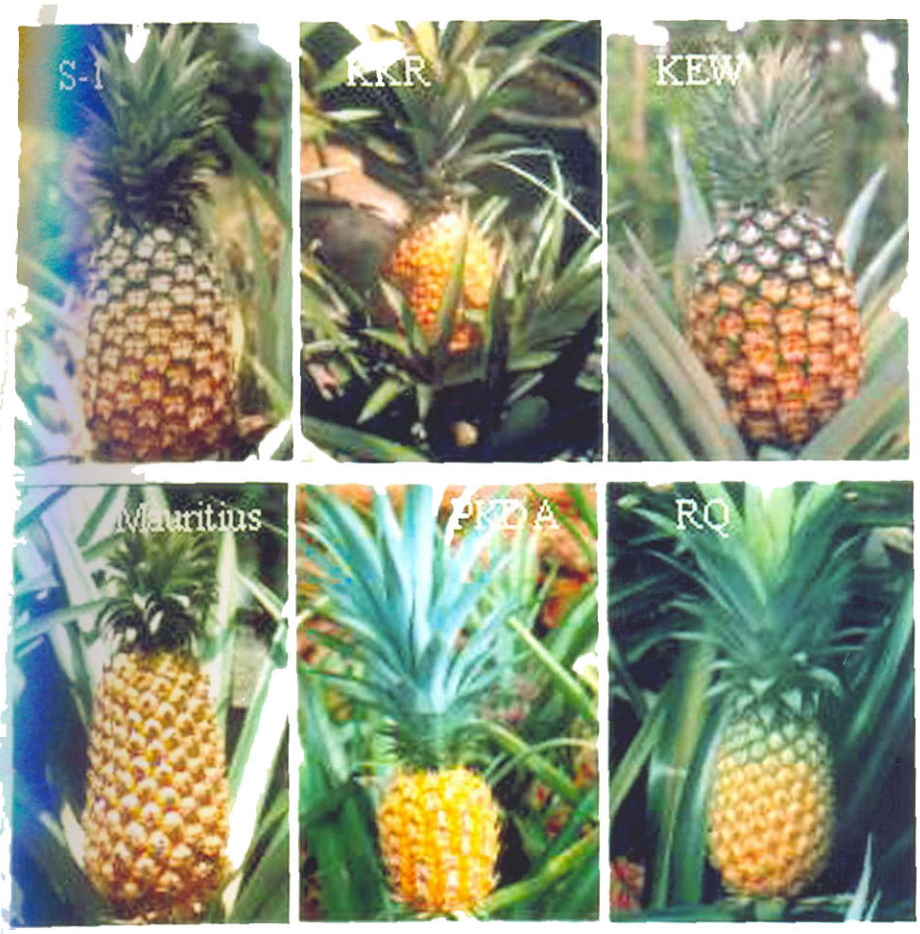


Plate 5. Ripe fruits of the six pineapple genotypes used for hybridization

Table 4. Mean values of the desirable characters of the six pineapple genotypes selected for hybridization

Sl. No.	Desirable characters	Mauritius	Kew	Selection-1	Pampakuda local	Kakkoor local	Ripley queen
1.	Less height of plant	84.6					80.8
2.	Low sucker production		0.20	0.10			
3.	Low slip production		Nil	Nil			
4.	Short duration of crop	374.7					361.7
5.	High T.S.S.	14.9					15.0
6.	Low acidity				0.52	0.60	
7.	High fruit weight			2059.10			
8.	Optimum taper ratio		0.96				
9.	Low peel weight %		8.76	9.76			
10.	Low core weight %				7.17	5.98	
11.	High ascorbic acid				60.73	57.86	
12.	Spineless leaves		Spineless				
13.	High juice content (%)		49.10	51.50			
14.	Colour of fruit at ripening				Bright yellow	Reddish yellow	
15.	Colour of pulp at ripening	Golden yellow	Pale yellow	Pale yellow			Golden yellow

(49.1), spineless leaves and pale yellow colour of pulp. The Selection-1 was having the desirable characters like low sucker (0.1) and slip (0.0) production, high fruit weight (2059.1 g), low peel weight % (9.76), high juice content (51.5%) and pale yellow colour of pulp. The Pampakuda local was having the desirable characters such as low acidity (0.52 %), low core weight % (7.17), high ascorbic acid content (60.73 mg per 100 g of fruit) and an attractive bright yellow colour of fruit. The desirable characters of Kakkoor local are low acidity (0.6 %), low core weight % (5.98), high ascorbic acid content (57.86 mg per 100 g of fruit) and an attractive reddish yellow colour of fruit. The genotype Ripley Queen was having the desirable characters like less height of the plant (80.8 cm), short duration of crop (361.7 days), high T.S.S. (15 °brix) and golden yellow colour of pulp.

It was observed that none of the six genotypes were having all the desirable characters and at the same time all were having four to seven desirable characters for which they were compared.

4.2. Study of the Floral Biology

The flowers of pineapple are arranged spirally on the axis of the compact inflorescence and it can be considered as the continuation of the spiral arrangement of the leaves on the stem (Collins, 1960 and Purseglove, 1975). The flowers of pineapple are hermaphrodite, trimerous, have one subtending floral bract; 3 fleshy sepals; 3 petals with purplish blue colour above and whitish below; six stamens in two whorls of three; ovary inferior, 3 carpels with thick fleshy septa, ovules 14-20 per carpel in 2 rows, style longer than stamens and stigma 3 lobed. Petals, stamens and style wither after anthesis and the rest remain attached to the developing fruit. The fruit of pineapple is a sorosis, ie., a fleshy fruit formed from a number of crowded flowers, developing from numerous sessile flowers including their subtending bracts which have become fused with one another during development to form the collective syncarpus fruit (Okimoto, 1948).

The six parental genotypes were studied for the flower production, anthesis and receptivity of stigma and the results are presented below.

4.2.1. Flower production and anthesis

1. *Number of flowers opened per day*

The number of flowers opened per day (Table 5) was maximum for Ripley Queen (8.72) and was on par with Mauritius (8.02), Kew (7.85) and Selection-1 (8.22) and significantly superior to Pampakuda local (5.6) and Kakkoor local (5.62).

2. *Number of flowers per inflorescence*

Ripley Queen was having the maximum number of flowers per inflorescence (Table 5) (149.38) and was on par with Mauritius (140.15), Kew (140.54) and Selection-1 (146.73) and significantly superior to Pampakuda local (97.08) and Kakkoor local (101.19).

3. *Number of days for completion of flower opening*

There was no significant difference between the six genotypes with regard to the number of days for completion of flower opening (Table 5). However, maximum number of days was taken by Selection-1 (18.23 days).

4. *Number of flowers opened on each day*

The study on the number of flowers opened on each day (Table 6) showed that the maximum number of flowers opened during the second week after the beginning of flower opening by a gradual increase in the number of flowers opened on each day from the first day and the rate of flower opening decreased in the third week.

5. *Percentage of the total flowers opened on each day*

The values for the percentage of flowers opened on each day (Table 7) were high during the second week and thereafter a gradual decrease was observed during the third week for all the genotypes.

Table 5. Mean values of flowering characters of six pineapple genotypes selected for hybridization

Variety	Number of flowers opened per day	Number of flowers per inflorescence	Number of days for completion of flower opening
Mauritius	8.02 [a]	140.15 [a]	17.51
Kew	7.85 [a]	140.54 [a]	18.08
Selection-1	8.22 [a]	146.73 [a]	18.23
Pampakuda local	5.60 [b]	97.08 [b]	17.17
Kakkoor local	5.62 [b]	101.19 [b]	18.09
Ripley Queen	8.72 [a]	149.38 [a]	17.13
CD.(0.05)	1.152	28.224	n.s

Values having different superscripts differ significantly

Table 6. Mean number of flowers opened on each day in six pineapple genotypes selected for hybridization

Days	Mean number of flowers opened on each day in					
	Mauritius	KEW	S – 1	KKR	PKDA	RQ
1	2.1	3.1	4.3	2.0	1.9	1.3
2	4.0	5.1	5.5	3.3	2.3	3.2
3	4.0	4.8	5.8	4.0	3.9	4.0
4	3.9	5.1	6.2	4.2	4.3	4.0
5	4.8	7.1	7.5	5.7	4.6	5.0
6	5.8	8.7	8.0	6.0	5.7	6.2
7	7.9	7.1	8.0	5.9	6.8	7.7
8	8.4	10.4	8.5	6.6	6.6	9.8
9	10.1	10.4	9.0	6.2	7.1	8.5
10	11.4	9.8	10.9	7.6	7.3	12.5
11	11.0	10.2	11.3	7.5	7.6	13.8
12	11.5	11.5	11.5	7.6	7.2	13.7
13	11.0	12.9	9.7	6.7	7.9	12.5
14	12.1	9.8	9.3	6.8	6.4	13.3
15	10.4	7.9	7.4	6.8	6.6	14.3
16	7.3	7.3	6.7	6.5	6.0	10.5
17	6.4	4.2	5.5	4.7	4.9	6.5
18	4.5	3.0	3.7	2.7	3.5	1.7
19	2.2	1.3	1.8	1.7	1.5	0.2
20	1.4	0.6	1.2	0.7	0.6	
21	0.3	0.4	0.9	0.8	0.1	
22	0.1		0.1	0.3		
23				0.3		
24				0.3		

Table 7. Percentage of the total flowers opened on each day in six pineapple genotypes selected for hybridization

Days	Percentage of the total flowers opened on each day in					
	Mauritius	KEW	S – 1	PKDA	KKR	RQ
1	1.5	4.3	3.0	1.9	2.0	0.9
2	3.0	3.6	3.9	2.2	3.1	2.2
3	3.0	3.4	8.1	3.9	3.9	2.7
4	2.9	3.9	4.5	4.3	4.0	2.7
5	3.6	5.1	5.2	4.6	5.4	3.4
6	4.3	6.2	5.6	5.8	5.7	4.2
7	5.7	5.1	5.7	6.7	5.6	5.2
8	6.1	7.4	6.0	6.5	6.3	6.6
9	7.3	7.5	6.2	7.0	6.1	5.9
10	8.3	7.0	7.4	7.4	7.3	8.4
11	7.9	7.2	7.8	7.6	7.1	9.3
12	8.3	8.2	8.1	7.2	7.3	9.2
13	8.0	9.3	6.7	7.7	6.4	8.4
14	8.9	7.0	6.4	6.3	6.6	8.9
15	7.4	5.5	5.5	6.4	6.6	9.6
16	9.9	5.2	4.6	5.6	6.0	7.1
17	4.1	3.0	4.0	4.4	4.3	4.4
18	2.9	2.2	2.7	3.1	2.3	1.1
19	1.4	0.9	1.4	1.4	1.5	0.1
20	0.9	0.5	0.9	0.5	0.7	
21	0.2	0.3	0.8	0.4	0.8	
22	0.1		0.1		0.3	
23					0.3	
24					0.1	

6. *Sequence of flower opening*

The flowers open from the base of inflorescence upwards spirally, in sequence of its formation.

7. *Time of flower opening*

The flowers of Mauritius, Kew, Selection-1 and Ripley Queen open during 4 am to 5 am and those of Pampakuda local and Kakkoor local open during 5 am to 6 am (Table 8).

8. *Time of anther dehiscence*

The anther dehiscence occurred during 4 am to 5 am for Mauritius, Kew, Selection-1 and Ripley Queen and during 5 am to 6 am for Pampakuda local and Kakkoor local (Table 8).

4.2.2. Pollen fertility and viability

Fertility of the pollen, tested by acetocarmine staining method (Zirkle, 1937), showed that PKDA was having 94 % fertile pollen and the least was for S-1 (29%) (Table 9). Pollen of all the six genotypes germinated in 10 % sucrose solution.

4.2.3. Duration of receptivity of stigma

To study the duration of receptivity of stigma, the percentage of flowers with seed set, number of seeds per pollinated flower and number of seeds per successful cross when pollinated at different time intervals were used as criteria for the receptivity of stigma. The results of the study are given below.

1. *Percentage of flowers with seed set when pollinated at different time intervals.*

Percentage of flowers with seed set when pollinated at different time intervals was estimated and presented in Table 10. When pineapple flowers were pollinated during 3-4 am, only 37.9 % of flowers were having seed set in the genotype Mauritius. During 4-6 am there was seed set in 100 % of flowers and during 6 am to 3 pm there

Table 8. Time of flower opening and anther dehiscence in six pineapple genotypes selected for hybridization

Genotypes	Number of flowers observed on each day										Time of	
	1st day for		2nd day for		3rd day for		4th day for		Total			
	Flr. op.	Anther dehisc.	Flr. op	Anther dehisc.	Flr. op.	Anther dehisc.	Flr. op.	Anther dehisc.	Flr. op.	Anther dehisc.	Flr. op.	Anther dehisc.
Mauritius	33	28	57	30	46	34	49	34	185	126	4-5 am	4-5 am
Kew	34	33	40	36	35	34	46	34	155	137	4-5 am	4-5 am
S-1	43	39	43	36	35	37	42	35	163	137	4-5 am	4-5 am
PKDA	31	22	14	24	41	27	30	26	116	99	5-6 am	5-6 am
KKR	31	23	28	24	27	26	27	26	116	99	5-6 am	5-6 am
RQ	36	31	33	32	37	37	36	34	142	134	4-5 am	4-5 am

Flr.= Flower. Op. = opening. Dehisc. = dehiscence.

Table 9. Fertility of pollen of the six genotypes used for hybridization

Genotype	Pollen fertility (%)
Kew	32
S-1	29
Mauritius	93
Pampakuda local	94
Kakkoor local	93
Ripley Queen	87

Table 10. Percentage of flowers with seed set when pollinated at different time intervals

Time interval	Genotypes					
	Mauritius	KEW	S-1	PKDA	KKR	RQ
3-4 am	37.9	100.0	100.0	100.0	100.0	13.9
4-5 am	100.0	100.0	70.4	100.0	100.0	15.4
5-6 am	100.0	100.0	100.0	100.0	100.0	100.0
6-7 am	90.0	100.0	92.3	100.0	100.0	97.1
7-8 am	96.7	100.0	100.0	100.0	100.0	100.0
8-9 am	90.0	100.0	100.0	100.0	100.0	100.0
9-10 am	90.0	92.1	100.0	100.0	100.0	100.0
10-11 am	93.3	70.0	100.0	100.0	100.0	100.0
11-12 pm	86.7	40.0	81.6	100.0	100.0	100.0
12-1 pm	83.3	45.4	100.0	100.0	100.0	100.0
1-2 pm	93.3	32.1	73.5	100.0	66.7	100.0
2-3 pm	93.3	100.0	100.0	100.0	96.8	100.0
3-4 pm	76.7	79.2	100.0	100.0	63.3	100.0
4-5 pm	76.0	85.0	35.7	100.0	59.1	100.0
5-6 pm	61.0	91.7	93.9	100.0	58.3	95.0
Self pollinated	2.9	0.7	0.0	25.8	11.9	0.0
Open pollinated	3.6	0.7	0.0	87.6	11.9	0.0

was a slight decrease in seed set. There was further fall in seed set during 3-5 pm and by 5-6 pm there was only 61 % of the flowers with seed set.

In the genotype Kew, there was 100 % seed set during 3-9 am, there after the number of flowers with seed set continued to decrease reaching up to 32.1 % by 2 pm. During 2-6 pm the number of flowers with seed set showed a higher level. In the genotype Selection-1, seed set occurred in more than 80 % of the flowers during the entire time interval of the study except during 4-5 am, 1-2 pm and 4-5 pm. All the flowers showed seed set during the entire time interval of 3 am to 6 pm in the genotype Pampakuda local. In the genotype Kakkoor local, all the flowers showed seed set during 3 am to 1 pm after which it continued to decrease reaching up to 58.30 % by 6 pm. In the genotype Ripley Queen, the percentage of flowers with seed set was only 13.90 during 3-4 am and 15.40 during 4-5am. From 5 am to 5 pm all the flowers showed seed set except during 6-7 am during which it was only 97.10 %. During 5-6 pm only 95 % of the flowers showed seed set.

There was no seed set at all in Selection-1 and Ripley Queen under self-pollinated or open pollinated conditions. In Pampakuda local, the percentage of flowers with seed set was very high under both self and open pollinated conditions with 25.80 and 87.60 percent respectively. In Kew, Mauritius and Kakkoor local there was slight seed set under both self (2.9%, 0.7% and 11.9% respectively) and open pollinated conditions (3.5 %, 0.7 % and 11.9 % respectively).

2.*Number of seeds per pollinated flower when pollinated at different time intervals.*

The number of seeds per pollinated flower when pollinated at different time intervals was estimated and presented in Table 11. Except Selection-1, all the other genotypes produced maximum number of seeds per pollinated flower during the early morning hours of 3–8 am. PKDA produced maximum number of seeds (12.2) during 4-5 am followed by KKR (11.4) during 3-4 am. For Selection-1 maximum seeds (6.8) was obtained when pollinated during 10-11 am. However, all the six genotypes produced maximum seeds when pollinated during forenoon hours.

Table 11. Mean number of seeds per pollinated flowers when pollinated at different time intervals

Time interval	Genotypes					
	Mauritius	KEW	S-1	PKDA	KKR	RQ
3-4 am	1.4	10.1	5.8	10.3	11.4	0.3
4-5 am	6.2	6.9	1.8	12.2	5.8	0.3
5-6 am	6.6	8.9	6.2	9.7	6.0	6.8
6-7 am	4.6	4.2	3.5	9.0	5.5	8.6
7-8 am	6.7	9.8	4.0	5.4	6.2	7.8
8-9 am	4.5	2.5	4.6	5.7	6.1	7.2
9-10 am	5.8	2.7	3.5	5.2	3.5	3.8
10-11 am	6.1	1.1	6.8	6.9	5.7	3.6
11-12 am	5.4	1.5	2.2	5.5	4.8	6.8
12-1 pm	4.7	1.9	4.7	6.3	4.5	7.9
1-2 pm	6.4	0.4	3.3	8.9	2.9	6.9
2-3 pm	5.1	4.0	5.3	9.6	3.3	7.3
3-4 pm	2.9	3.4	6.0	8.5	2.4	8.2
4-5 pm	3.6	4.3	0.6	4.8	3.0	5.8
5-6 pm	2.2	3.3	5.4	7.1	3.0	4.7
Self pollinated	0.03	0.01	0.0	0.69	0.15	0.0
Open pollinated	0.04	0.01	0.0	3.20	0.14	0.0

3. *Number of seeds per successful cross when pollinated at different time intervals.*

The number of seeds per successful cross was of the same pattern (Table 12) as that of the number of seeds per pollinated flower. All the genotypes produced maximum number of seeds per successful cross during the fore noon hours.

The study of the duration of the receptivity of stigma indicated that the stigma of all the six genotypes remained receptive from 3 am to 6 pm.

4.3. Hybridization and Production of Hybrids

4.3.1. Hybridization

The six parental genotypes, viz., Mauritius, Kew, Selection-1, Pampakuda local, Kakkoor local and Ripley Queen were crossed in all possible combinations. However, due to crop failure, inspite of all precautions taken, the crosses involving RQ as female parent could not be made use of in these studies, but the crosses utilizing it as male parent was included. Further, the parental crosses K x S-1 and M x RQ and their reciprocals were found to be incompatible. Thus the remaining 22 cross combinations out of the total 30 possible combinations were included. For this study all the flowers produced in an inflorescence were involved. After hybridization, the fruits were harvested at fully ripe stage. The seeds were collected from individual flowers and counts recorded. The seeds were washed thoroughly, graded into bold and shriveled seeds. The results of the study are as follows:

4.3.2. Seed set and seed production

For each cross, percentage of flowers with seed set, number of seeds per pollinated flower, number of seeds per successful cross, percentage of bold seeds out of total seeds produced and percentage of shriveled seeds out of total seeds produced were studied and presented in Table 13. A view of pineapple seeds are shown in Plate 6.

Table 12. Mean number of seeds per successful cross when pollinated at different time intervals

Time interval	Genotypes					
	Mauritius	KEW	S-1	PKDA	KKR	RQ
3-4 am	3.7	10.1	5.8	10.3	11.4	2.2
4-5 am	6.2	6.9	2.6	12.2	5.8	2.2
5-6 am	6.6	8.9	6.2	9.7	6.0	6.8
6-7 am	5.1	4.2	3.8	9.0	5.5	8.9
7-8 am	6.9	9.8	4.0	5.4	6.2	7.8
8-9 am	5.0	2.5	4.6	5.7	6.1	7.2
9-10 am	6.4	2.9	3.5	5.2	3.5	3.8
10-11 am	6.5	1.6	6.8	6.9	5.7	3.6
11-12 pm	6.2	3.7	2.6	5.5	4.8	6.8
12-1 pm	5.6	4.2	4.7	6.3	4.5	7.9
1-2 pm	6.8	1.3	4.5	8.9	4.4	6.9
2-3 pm	5.5	4.0	5.3	9.6	3.4	7.3
3-4 pm	3.8	4.3	6.0	8.5	3.7	8.2
4-5 pm	4.8	5.1	1.8	4.8	5.1	5.8
5-6 pm	3.7	3.5	5.8	7.1	5.1	5.0
Self pollinated	1.0	1.0	0.0	2.7	1.3	0.0
Open pollinated	1.0	1.0	0.0	3.6	1.2	0.0

Plate 6. Hybrid seeds of pineapple

1. *Percentage of flowers with seed set*

Seed setting in all the flowers was not observed in any of the crosses involved. There was no significant difference between the 22 cross combinations with regard to the percentage of flowers with seed set on cross pollination. However, all the crosses involving Mauritius as female parent and the cross PKDA x K produced maximum seed set with above 90%. The lowest percentage of seed set was observed in the cross KKR x PKDA local with 39.75 %.

2. *Number of seeds per pollinated flower*

Number of seeds produced based on the number of flowers pollinated was found to be varying significantly between the 22 cross combinations. The crosses involving Mauritius as female parent (7 to 8.45) and PKDA x M (8.45) showed maximum seed set and they are on par. The crosses M x PKDA (8.45) and its reciprocal and M x KKR (8.35) are significantly superior to all other crosses. The crosses KKR x PKDA (1.2) and K x M (1.55) are found to be having the lowest value with regard to the number of seeds per flower produced when pollinated.

3. *Number of seeds per successful cross*

The 22 crosses vary significantly when the number of seeds produced in flowers with actual seed set occurred only was taken into consideration. The cross PKDA x M was having the maximum number of seeds per successful cross (9.38) and was on par with M x PKDA local (8.69) and M x KKR (8.51). All the crosses involving Mauritius as female parent were having high number of seeds per flower with seed set and are on par. The lowest values were recorded by K x M (2.87) and KKR x PKDA (2.99).

4. *Percentage of bold seeds produced*

Seeds produced in pineapple are either bold and plump or shriveled and flat in appearance. The 22 crosses differ significantly with regard to the percentage of bold seeds produced. The cross PKDA x M was having the highest percentage of bold seeds (91.05) which was on par with 14 other crosses. The lowest percentage of bold seeds was observed in the cross S-1 x M (40.2) and was on par with S-1 x RQ (45.75) and K x RQ (54.45).

Table 13. Mean values of the seed set and seed obtained in twenty two Compatible crosses involving six pineapple genotypes

Sl. No.	Cross combination	Percentage of flowers with seed set	Number of seeds per pollinated flower	Number of seeds per successful cross	Percentage of bold seeds out of total seeds	Percentage of shriveled seeds out of total seeds
1	KKR x K	53.38	2.40 ^{de}	4.18 ^{fgh}	86.75 ^{abc}	13.25 ^{fg}
2	KKR x M	58.23	3.48 ^{de}	6.19 ^{cdef}	81.90 ^{abcd}	18.10 ^{efg}
3	KKR x RQ	67.90	3.95 ^{cde}	5.57 ^{defg}	79.60 ^{abcde}	20.40 ^{defg}
4	KKR x PKDA	39.75	1.20 ^{e}	2.99 ^{h}	74.85 ^{bcde}	25.15 ^{cdefg}
5	KKR x S-1	68.50	3.10 ^{de}	4.52 ^{fgh}	86.40 ^{abc}	13.60 ^{fg}
6	K x M	55.35	1.55 ^{e}	2.87 ^{h}	82.15 ^{abcd}	17.85 ^{efg}
7	K x RQ	85.30	2.90 ^{de}	3.27 ^{gh}	54.45 ^{fg}	45.55 ^{abc}
8	K x PKDA	58.95	2.40 ^{de}	4.01 ^{fgh}	71.35 ^{cde}	28.65 ^{cdef}
9	K x KKR	68.05	3.25 ^{de}	3.46 ^{gh}	64.45 ^{ef}	35.55 ^{bcd}
10	M x K	95.35	7.15 ^{ab}	7.45 ^{abcde}	89.15 ^{ab}	10.85 ^{g}
11	M x PKDA	97.00	8.45 ^{a}	8.69 ^{ab}	87.75 ^{ab}	12.25 ^{g}
12	M x KKR	98.10	8.35 ^{a}	8.51 ^{abc}	86.35 ^{abc}	13.65 ^{fg}
13	M x S-1	90.25	7.00 ^{abc}	7.75 ^{abcd}	85.80 ^{abc}	14.20 ^{fg}
14	S-1 x M	76.00	3.35 ^{de}	4.45 ^{fgh}	40.20 ^{g}	59.80 ^{a}
15	S-1 x RQ	73.95	4.70 ^{bcd}	5.62 ^{defg}	45.75 ^{g}	54.25 ^{ab}
16	S-1 x PKDA	64.25	2.05 ^{de}	3.20 ^{h}	87.25 ^{abc}	12.75 ^{fg}
17	S-1 x KKR	75.95	2.80 ^{de}	3.69 ^{gh}	76.20 ^{abcde}	23.80 ^{defg}
18	PKDA x K	94.20	4.80 ^{bcd}	5.14 ^{ef}	85.70 ^{abc}	14.35 ^{fg}
19	PKDA x M	88.65	8.45 ^{a}	9.38 ^{a}	91.05 ^{a}	9.00 ^{g}
20	PKDA x RQ	78.15	2.25 ^{de}	2.91 ^{h}	68.10 ^{def}	31.90 ^{bcde}
21	PKDA x KKR	51.30	2.05 ^{de}	3.44 ^{gh}	66.45 ^{def}	38.70 ^{bc}
22	PKDA x S-1	81.50	4.10 ^{bcde}	4.82 ^{fgh}	89.50 ^{ab}	10.50 ^{g}
	CD (0.05)	n.s	3.105	2.348	16.115	16.074

Values having different superscripts differ significantly

5. *Percentage of shriveled seeds produced*

The crosses differ significantly in the production of shriveled seeds. The cross S-1 x M produced maximum shriveled seeds (59.8) and was on par with S-1 x RQ (54.25) and K x RQ (45.55). The lowest percentage was observed in the cross PKDA x M (9) and was on par with 14 other crosses.

4.3.3. Germination of hybrid seeds

The collected seeds after grading into bold and shriveled were sown within 24 hours in sterilized sand. The germination counts were recorded at weekly intervals and the results of the study are presented below.

1. *Percentage of bold seeds germinated*

There was no significant difference between the crosses with regard to the percentage of bold seeds germinated (Table 14). However, maximum germination of bold seeds was observed in S-1 x M (83.5%) followed by M x KKR (69.4%).

2. *Percentage of shriveled seeds germinated*

The germination of shriveled seeds (Table 14) was maximum in S-1 x M (31.25%) and was on par with S-1 x KKR (29.8%), K x KKR (23.25%), PKDA x S-1 (22.4) and KKR x S-1 (19.88%). The lowest value was recorded in KKR x R Q (2.25%) and was on par with 15 other crosses. In the cross PKDA x RQ, there was no germination at all for the shriveled seeds.

3. *Percentage of germination of the total seeds*

There was no significant difference between the crosses with regard to the percentage of germination of the total seeds (Table 14). Maximum germination was observed in M x KKR (61.23%).

4. *Duration for completion of germination*

The seeds of the cross M x S-1 took the maximum period of 15.50 weeks for the completion of germination (Table 14) and was on par with M x K (14.5 weeks), M x

Table 14. Mean values of seed germination in the twenty two cross combinations

Sl. No.	Cross combinations	Percentage of bold seeds germinated	Percentage of shriveled seeds germinated	Percentage of germination of total seeds	Duration for completion of germination (weeks)
1	KKR x K	60.30	5.45 ^{e}	52.35	9.75 ^{efgh}
2	KKR x M	44.20	13.10 ^{bcde}	39.20	7.25 ^{h}
3	KKR x RQ	32.10	2.25 ^{e}	25.20	7.50 ^{h}
4	KKR x PKDA	44.85	6.05 ^{de}	35.20	8.00 ^{g}
5	KKR x S-1	56.00	19.88 ^{abcd}	50.20	9.50 ^{fgh}
6	K x M	34.95	10.90 ^{bcde}	31.00	10.50 ^{defg}
7	K x RQ	53.25	12.92 ^{bcde}	35.03	8.50 ^{fgh}
8	K x PKDA	23.45	13.75 ^{bcde}	18.91	9.50 ^{fgh}
9	K x KKR	43.35	23.25 ^{ab}	37.77	9.50 ^{fgh}
10	M x K	45.50	4.20 ^{e}	41.06	14.50 ^{ab}
11	M x PKDA	55.72	9.55 ^{bcde}	49.88	13.50 ^{abc}
12	M x KKR	69.40	9.35 ^{cde}	61.23	13.00 ^{abcd}
13	M x S-1	51.85	4.20 ^{e}	44.76	15.50 ^{a}
14	S-1 x M	83.50	31.25 ^{a}	51.02	13.50 ^{abc}
15	S-1 x RQ	34.15	8.20 ^{de}	20.03	9.00 ^{fgh}
16	S-1 x PKDA	43.30	15.55 ^{bcde}	39.18	8.50 ^{fgh}
17	S-1 x KKR	49.90	29.80 ^{a}	45.71	8.50 ^{fgh}
18	PKDA x K	34.10	10.80 ^{bcde}	30.21	8.50 ^{fgh}
19	PKDA x M	39.40	11.10 ^{bcde}	29.73	9.50 ^{fgh}
20	PKDA x RQ	46.75	3.70 ^{e}	24.83	11.00 ^{cdef}
21	PKDA x KKR	20.25	0.00	13.05	7.00 ^{h}
22	PKDA x S-1	50.70	22.40 ^{abc}	47.78	12.50 ^{bcde}
	CD (0.05)	n.s	13.833	n.s	2.931

Values having different superscripts differ significantly

PKDA (13.5 weeks), S-1 x M (13.5 weeks) and M x KKR (13 weeks). The germination process was completed in the shortest period by PKDA x KKR (7 weeks) and was on par with 13 other crosses. All the crosses involving Mauritius as pistillate parent, took maximum period for completion of germination.

5. *Percentage of the total seeds germinated at weekly intervals after sowing*

There was no seed germination during the first week after sowing (Table 15). Germination started in the second week (0.53%) and increased to a maximum of 29.91 percent during the fourth week and thereafter it decreased and continued up to seventeenth week (0.01%). However, out of the total 22 cross combinations germination in second week was observed only in six combinations, viz., KKR x RQ, KKR x PKDA, KKR x S-1, K x RQ, PKDA x M and PKDA x S-1. Out of the remaining 16 cross combinations, the seed germination started in the third week for fifteen crosses and for S-1 x RQ the germination started in the fourth week after sowing. The seeds of the cross PKDA x RQ started germination in the third week and completed in the seventh week taking the shortest duration for completion of germination. For M x S-1, the germination started in the third week and continued up to seventeenth week taking the longest period for completion of germination.

6. *Percentage of the bold seeds germinated at weekly intervals after sowing*

There was no seed germination during the first week after sowing (Table 16). Germination started in the second week (0.55%) and increased to a maximum of 31.05 percent during the fourth week and thereafter it decreased and continued up to seventeenth week (0.01%). However, out of the total 22 cross combinations germination in second week was observed only in six combinations, viz., KKR x RQ, KKR x PKDA, KKR x S-1, K x RQ, PKDA x M and PKDA x S-1. Out of the remaining 16 cross combinations, the seed germination started in the third week for fifteen crosses and for S-1 x RQ the germination started in the fourth week after sowing. The seeds of the cross KKR x PKDA started germination in the second week and completed in the sixth week taking the shortest duration for germination where as the seeds of the cross M x S-1 took the longest duration of 17 weeks.

Table 15. Percentage of the total seeds germinated at weekly intervals in the 22 cross combinations

Sl. No.	Cross Combinations	Number of weeks after sowing																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	KKR x K	0.00	0.00	29.40	30.77	14.56	0.44	8.79	4.12	0.55	1.10	0.27	0.00	0.00	0.00	0.00	0.00	0.00
2	KKR x M	0.00	0.00	36.73	37.24	16.84	2.55	2.55	4.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	KKR x RQ	0.00	0.65	3.27	29.41	41.83	16.34	3.92	4.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	KKR x PKDA	0.00	4.12	26.80	43.30	12.37	11.34	1.03	0.00	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	KKR x S-1	0.00	4.46	33.09	30.48	20.45	4.09	2.97	2.60	0.37	0.00	0.37	0.74	0.37	0.00	0.00	0.00	0.00
6	K x M	0.00	0.00	7.20	31.20	18.93	16.00	10.13	5.07	6.13	1.60	3.73	0.00	0.00	0.00	0.00	0.00	0.00
7	K x RQ	0.00	1.32	6.58	19.74	38.16	13.16	11.84	7.89	1.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	K x PKDA	0.00	0.00	41.10	36.30	2.05	2.05	1.37	13.01	3.42	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	K x KKR	0.00	0.00	0.99	39.66	12.07	11.08	19.46	5.42	0.49	10.10	0.00	0.74	0.00	0.00	0.00	0.00	0.00
10	M x K	0.00	0.00	1.56	23.30	24.74	16.70	12.52	5.55	3.61	2.18	1.93	4.55	2.24	0.44	0.69	0.00	0.00
11	M x PKDA	0.00	0.00	4.51	22.03	21.46	11.59	6.72	18.60	9.30	3.22	0.00	1.79	0.14	0.57	0.07	0.00	0.00
12	M x KKR	0.00	0.00	4.16	23.93	15.07	27.27	12.79	4.22	3.58	6.92	1.64	0.29	0.06	0.06	0.00	0.00	0.00
13	M x S-1	0.00	0.00	9.51	29.85	18.91	10.46	3.45	4.52	2.62	9.16	6.90	1.43	1.19	1.66	0.00	0.24	0.12
14	S-1 x M	0.00	0.00	13.31	20.56	24.60	14.92	4.84	3.63	5.24	2.42	8.06	1.61	0.00	0.40	0.40	0.00	0.00
15	S-1 x RQ	0.00	0.00	0.00	13.16	38.16	15.79	13.16	7.89	10.53	1.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	S-1 x PKDA	0.00	0.00	4.62	70.00	14.62	6.92	0.77	2.31	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	S-1 x KKR	0.00	0.00	13.69	38.69	29.17	7.14	6.55	1.79	2.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	PKDA x K	0.00	0.00	11.30	23.77	23.19	14.78	6.09	10.14	4.35	1.16	0.58	1.45	3.19	0.00	0.00	0.00	0.00
19	PKDA x M	0.00	0.81	27.27	21.75	7.95	20.94	8.77	5.52	5.52	0.16	1.30	0.00	0.00	0.00	0.00	0.00	0.00
20	PKDA x KKR	0.00	0.00	1.15	26.44	26.44	16.09	5.75	12.64	8.05	1.15	0.00	2.30	0.00	0.00	0.00	0.00	0.00
21	PKDA x RQ	0.00	0.00	2.08	10.42	39.58	25.00	22.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	PKDA x S-1	0.00	0.28	17.68	35.91	25.69	10.50	1.93	2.21	3.04	1.93	0.00	0.28	0.55	0.00	0.00	0.00	0.00
	Mean	0.00	0.53	13.45	29.91	22.13	12.96	7.65	5.72	3.31	1.96	1.13	0.69	0.35	0.14	0.39	0.01	0.01

Table 16. Percentage of the bold seeds germinated at weekly intervals in the 22 cross combinations

Sl. No.	Cross combinations	Number of weeks after sowing																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	KKR x K	0.00	0.00	29.64	31.02	14.13	10.53	8.59	4.16	0.55	1.11	0.28	0.00	0.00	0.00	0.00	0.00	0.00
2	KKR x M	0.00	0.00	37.99	36.31	16.20	2.23	2.79	3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	KKR x RQ	0.00	0.67	3.33	21.33	41.33	16.00	4.00	4.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	KKR x PKDA	0.00	4.30	27.96	43.01	12.90	11.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	KKR x S-1	0.00	4.74	34.78	30.83	20.16	3.16	2.77	1.98	0.00	0.00	0.40	0.79	0.40	0.00	0.00	0.00	0.00
6	K x M	0.00	0.00	7.38	31.69	19.13	15.57	10.11	5.19	5.74	1.37	3.83	0.00	0.00	0.00	0.00	0.00	0.00
7	K x RQ	0.00	1.45	5.80	21.74	37.68	13.04	11.59	7.25	1.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	K x PKDA	0.00	0.00	47.32	43.75	0.00	1.79	1.79	1.79	2.68	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	K x KKR	0.00	0.00	1.14	44.57	10.29	8.00	18.86	4.86	0.57	11.43	0.00	0.29	0.00	0.00	0.00	0.00	0.00
10	M x K	0.00	0.00	1.50	23.32	24.76	16.80	12.48	5.52	3.57	2.13	1.94	4.58	2.26	0.44	0.69	0.00	0.00
11	M x PKDA	0.00	0.00	4.53	22.13	21.62	11.47	6.72	18.55	9.13	3.29	0.00	1.75	0.15	0.58	0.07	0.00	0.00
12	M x KKR	0.00	0.00	4.25	23.82	15.14	26.93	12.81	4.31	3.65	7.06	1.68	0.24	0.06	0.06	0.00	0.00	0.00
13	M x S-1	0.00	0.00	9.64	30.12	19.04	10.24	3.49	4.46	2.65	9.16	6.75	1.45	1.08	1.57	0.00	0.24	0.12
14	S-1 x M	0.00	0.00	19.64	26.19	26.19	14.29	1.79	4.17	2.38	1.79	3.57	0.00	0.00	0.00	0.00	0.00	0.00
15	S-1 x RQ	0.00	0.00	0.00	16.67	46.67	15.00	10.00	8.33	1.67	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	S-1 x PKDA	0.00	0.00	4.80	72.80	14.40	6.40	0.00	0.80	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	S-1 x KKR	0.00	0.00	15.60	43.26	26.95	6.38	4.96	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	PKDA x K	0.00	0.00	10.29	24.12	23.53	15.00	6.18	10.29	4.12	1.18	0.59	1.47	2.35	0.00	0.00	0.00	0.00
19	PKDA x M	0.00	0.67	27.62	21.63	7.99	21.13	8.82	5.49	5.16	0.17	1.33	0.00	0.00	0.00	0.00	0.00	0.00
20	PKDA x KKR	0.00	0.00	1.20	27.71	27.71	16.87	6.02	9.64	7.23	1.20	0.00	2.41	0.00	0.00	0.00	0.00	0.00
21	PKDA x RQ	0.00	0.00	2.08	10.42	39.58	25.00	22.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	PKDA x S-1	0.00	0.29	17.44	36.63	26.16	10.76	1.45	1.74	2.62	2.03	0.00	0.29	0.58	0.00	0.00	0.00	0.00
	Mean	0.00	0.55	14.27	31.05	22.34	12.66	7.19	4.84	2.58	2.02	0.93	0.60	0.31	0.12	0.03	0.01	0.01

7. *Percentage of the shriveled seeds germinated at weekly intervals after sowing*

There was no seed germination during the first week after sowing (Table 17). Germination started in the second week (0.3%) and it increased up to a maximum of 19.73 percent during the fifth week after which it deceased and completed by fifteenth week (0.06%). However, out of the total 22 cross combinations, germination in second week was observed only in the cross PKDA x M and in the third week germination started in nine cross combinations. During the fourth week germination was initiated in six crosses. In five crosses germination was initiated in the fifth week and in the remaining cross PKDA x KKR the seed germination was initiated only in the eighth week.

4.3.4. Percentage of albino seedlings

Out of the total 22 cross combinations, sixteen cross combinations produced albino seedlings (Table 18). All the four crosses involving Kew as female parent did not produce any albino seedlings. Crosses involving S-1 as female parent with Mauritius and RQ did not produce any albino seedlings. The highest percent of albino was observed in the cross PKDA x KKR (28.74) followed by M x PKDA (22.75). Primary nursery showing albino seedlings is depicted in Plate 7.

4.3.5. Self-incompatibility and cross-compatibility studies

Seed set and seed production under self and cross pollination was taken as the criteria to understand the self-incompatibility and cross compatibility in the present study.

The genotypes, Selection-1 and Ripley Queen were self-incompatible as there were no flowers with seed set under self-pollinated conditions (Table 10). Very low seed set under self-pollinated conditions was observed in Mauritius (2.9 %) and Kew (0.7%), indicating that self-incompatibility existed in these two genotypes also. Seed set was observed in 25.8% flowers in PKDA and 11.9 % flowers in KKR under self-pollination indicating some amount of self-compatibility in these two genotypes.

Table 17. Percentage of the shriveled seeds germinated at weekly intervals in the 22 cross combinations

Sl. No.	Cross Combinations	Number of weeks after sowing																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	KKR x K	0.00	0.00	0.00	0.00	66.67	0.00	33.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	KKR x M	0.00	0.00	23.53	47.06	23.53	5.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	KKR x RQ	0.00	0.00	0.00	0.00	66.67	33.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	KKR x PKDA	0.00	0.00	0.00	50.00	0.00	0.00	25.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	KKR x S-1	0.00	0.00	6.25	25.00	25.00	18.75	6.25	12.50	6.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	K x M	0.00	0.00	0.00	11.11	11.11	33.33	11.11	0.00	22.22	11.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	K x RQ	0.00	0.00	14.29	0.00	42.86	14.29	14.29	14.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	K x PKDA	0.00	0.00	20.59	11.76	8.82	2.94	0.00	50.00	5.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	K x KKR	0.00	0.00	0.00	8.93	23.21	30.36	23.21	8.92	0.00	1.79	0.00	3.57	0.00	0.00	0.00	0.00	0.00
10	M x K	0.00	0.00	10.00	20.00	20.00	0.00	20.00	10.00	10.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	M x PKDA	0.00	0.00	3.45	17.24	13.79	17.24	6.90	20.69	17.24	0.00	0.00	3.45	0.00	0.00	0.00	0.00	0.00
12	M x KKR	0.00	0.00	0.00	29.41	11.76	44.12	11.76	0.00	0.00	0.00	0.00	2.94	0.00	0.00	0.00	0.00	0.00
13	M x S-1	0.00	0.00	0.00	9.09	9.09	27.27	0.00	9.09	0.00	9.09	18.18	0.00	9.09	9.09	0.00	0.00	0.00
14	S-1 x M	0.00	0.00	0.00	8.75	21.25	16.25	11.25	2.50	13.75	3.75	17.50	5.00	0.00	1.25	1.25	0.00	0.00
15	S-1 x RQ	0.00	0.00	0.00	0.00	6.25	18.75	25.00	6.25	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	S-1 x PKDA	0.00	0.00	0.00	0.00	20.00	20.00	20.00	40.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	S-1 x KKR	0.00	0.00	3.70	14.81	40.74	11.11	14.81	11.11	3.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	PKDA x K	0.00	0.00	100.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	PKDA x M	0.00	6.67	13.33	26.67	6.67	13.33	6.67	6.67	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	PKDA x KKR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	75.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	PKDA x RQ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	PKDA x S-1	0.00	0.00	22.22	22.22	16.67	5.56	11.11	11.11	11.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mean	0.00	0.30	9.88	13.73	19.73	14.21	10.94	12.64	9.27	1.62	1.62	0.68	0.41	0.47	0.06	0.00	0.00

Table 18. Percentage of albino seedlings produced out of the total seeds germinated in the 22 cross combinations

Sl. No.	Cross Combinations	Percentage of albino seedlings
1	KKR x K	1.67
2	KKR x M	15.82
3	KKR x RQ	7.19
4	KKR x PKDA	14.43
5	KKR x S-1	0.37
6	K x M	0.00
7	K x RQ	0.00
8	K x PKDA	0.00
9	K x KKR	0.00
10	M x K	0.45
11	M x PKDA	22.75
12	M x KKR	19.06
13	M x S-1	0.48
14	S-1 x M	0.00
15	S-1 x RQ	0.00
16	S-1 x PKDA	3.08
17	S-1 x KKR	1.19
18	PKDA x K	10.72
19	PKDA x M	17.86
20	PKDA x KKR	28.74
21	PKDA x RQ	5.56
22	PKDA x S-1	1.38

Plate 7. Albino seedlings among hybrids in the primary nursery

Four crosses involving four genotypes (Table 19) were found to be incompatible. The crosses K x S-1, M x RQ and their respective reciprocal crosses were incompatible. The cross RQ x M was totally incompatible whereas its reciprocal M x RQ was having 3.5 percent flowers with seed set. The cross S-1 x K with 4.1 percent and its reciprocal K x S-1 with 1.45 percent flowers with seed set was observed. There was no bold seeds in the cross M x RQ and only the seeds in S-1 x K germinated.

The genotype Mauritius expressed maximum compatibility as a pistillate parent with all the other five genotype as pollen parent by showing more than 90 percent flowers with seed set (Table 13). M x PKDA and its reciprocal was the most compatible cross among all the cross tried as it showed high percentage of flowers with seed set, with 97 percent and 88.65 percent respectively.

The genotype KKR as a pistillate parent with PKDA as pollen parent was less compatible as it showed only 39.75 percent flowers with seed set. None of the seedlings in PKDA x KKR survived up to 18 months and highest percentage of albino seedlings (28.74%) was also observed in this cross. This might be probably due to incompatibility. The cross S-1 x M was considered less compatible as it produced lowest percentage of bold seeds (40.2%) and highest shriveled seeds (59.8%).

4.4. Evaluation of Hybrids

The seedlings in the primary nursery (Plate 8) were transplanted to secondary nursery in plastic cups (Plate 9) at about one month old stage. When the seedlings attained about 8 to 10 cm height (Plate 10), they were transplanted to tertiary nursery (Plate 11) in poly bags. When the seedlings reached 18 to 20 cm height they were transplanted to main field. The following observations were recorded in the hybrid population in the early stages of the growth of the seedlings.

Table 19. Mean values for seed production and seed germination pattern in four incompatible crosses involving four pineapple genotypes

Cross combination	Percentage of flowers with seed set	Number of seeds per pollinated flower	Number of seeds per successful cross	Percentage of bold seeds out of total seeds	Percentage of shriveled seeds out of total seeds	Percentage of bold seeds germinated	Percentage of shriveled seeds germinated	Percentage of germination of total seeds	Duration for completion of germination (weeks)
K x S-1	1.45	0.02	1.00	50.00	50.00	0.00	0.00	0.00	0.00
S-1 x K	4.10	0.15	3.92	86.85	13.15	5.55	0.00	16.08	7.00
M x RQ	3.50	0.04	1.00	0.00	100.00	0.00	0.00	0.00	0.00
RQ x M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Plate 8. Pineapple hybrid seedlings in the primary nursery

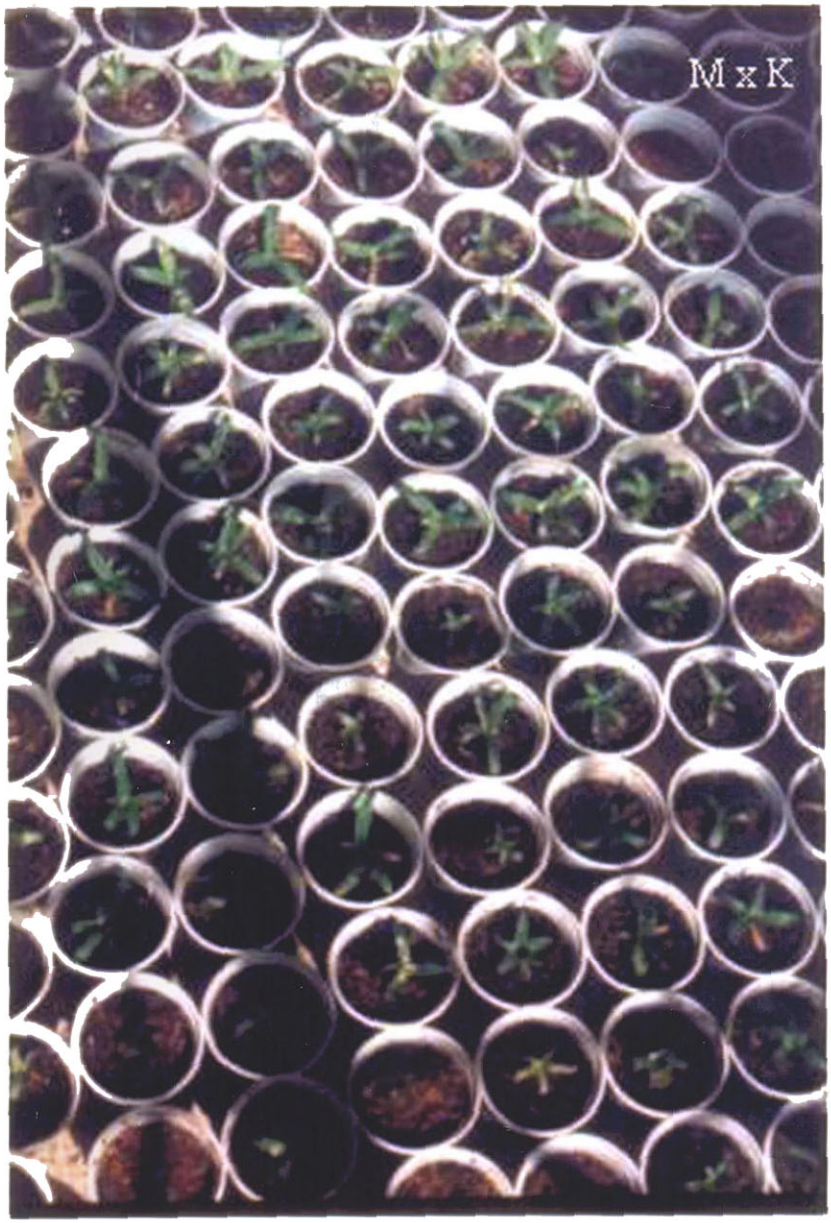


Plate 9. Pineapple hybrid seedlings in the secondary nursery

Plate 10. Pineapple hybrid seedlings ready for planting in the tertiary nursery

Plate 11. Pineapple hybrid seedlings in the tertiary nursery

Percentage of seedlings survived at the stage of planting out and at intervals of 6, 12, 18 and 24 months after planting out

The hybrid seedlings that are about one month old were planted out in plastic cups. During the period from germination to plant out, more than 90 percent of the seedlings in eleven cross combinations survived (Table 20). But during the period up to 6 months, more than 50 percent of the seedlings did not survive in 9 cross combinations. In the case when Ripley Queen was used as pollen parent with Kew and Selection-1, none of the seedlings survived up to 6 months and in the remaining two crosses, with KKR and PKDA, none of the seedlings survived up to one year. At the stage of 18 months growth, survival of more than 50 percent of the seedlings was observed in KKR x M, KKR x S-1, S-1 x M and PKDA x S-1 only. In the crosses M x S-1 and S-1 x PKDA, more than 40 percent of the seedlings survived. Maximum survival of 76.31 percent was observed in PKDA x S-1 followed by 62.45 percent in KKR x S-1. None of the seedlings in PKDA x KKR survived up to 18 months. No mortality was observed in any cross combinations after 18 months.

4.4.1. Genetic variability between and within cross combinations

A view of the hybrids in the field is shown in Plate 12. To estimate the extent of variability between and within cross combinations, the mean, range, percentage of variation of range over mean, mode, mean deviation from mode and the coefficient of dispersion of the observed characters were studied for each of the cross combinations. Being a vegetatively propagated crop, any selected hybrid can be made use of directly.

The hybrids in the sixteen cross combinations were studied individually for the following characters.

1. *Height of the plant*

For height of the plant (Table 21), lowest value of mean (108.97 cm) and mode (100) was in M x S-1 and highest in S-1 x KKR (137.62 cm and 140 respectively). The highest value of range (52-191) and percentage of variation (107.38) was in PKDA x S-1 and lowest (100-150 and 40.25 respectively) in PKDA x K. Mean deviation from

Table 20. Percentage of seedlings survived at the stage of planting out and at intervals of 6, 12, 18 and 24 months after planting out.

Cross Combinations	Number of seeds germinated	Percentage of seedlings survived up to				
		Planting out	6 months	12 months	18 months	24 months
KKR x K	359	93.59	80.5	47.63	25.35	25.35
KKR x M	196	84.18	63.78	58.16	54.59	54.59
KKR x PKDA	97	86	38.14	27.84	14.43	14.43
KKR x S- 1	269	93.31	72.12	70.26	62.45	62.45
KKR x RQ	153	75.82	0.65	0	0	0
K x M	375	97.6	55.2	22.67	22.67	22.67
K x PKDA	146	52.05	30.14	24.66	20.55	20.55
K x KKR	406	92.61	70.94	46.55	25.12	25.12
K x RQ	76	84.21	0	0	0	0
M x K	1605	99.56	66.6	36.95	32.77	32.77
M x PKDA	1398	99.21	58.3	21.67	7.65	7.65
M x KKR	1699	99.71	67.98	42.55	27.19	27.19
M x S – 1	841	90.25	66.47	48.51	41.38	41.38
S – 1 x M	248	91.13	79.44	60.89	52.42	52.42
S – 1 x PKDA	130	84.62	52.31	50	45.38	45.38
S – 1 x KKR	168	97.02	63.1	48.21	33.33	33.33
S – 1 x RQ	76	80.26	0	0	0	0
PKDA x K	345	83.19	49.86	18.55	9.86	9.86
PKDA x M	616	85.55	42.21	22.89	21.75	21.75
PKDA x KKR	87	47.13	28.74	17.24	0	0
PKDA x S – 1	363	97.52	87.33	82.92	76.58	76.05
PKDA x RQ	54	55.56	1.85	0	0	0

Plate 12. A view of hybrids in the field

Table 21. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of height of the plant in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	129	124.85	80 -161.5	65.27	125	13.15	10.52
2	KKR x M	89	120.28	88 - 167	57.15	124	12.72	10.26
3	KKR x K	52	118.86	84 - 163	66.46	118	15.67	13.28
4	M x S -1	242	108.97	75 - 137	56.66	100	12.30	12.30
5	M x K	302	110.65	72.5 -148	68.24	104	11.81	11.35
6	M x KKR	308	116.17	56 - 169	97.26	126	16.04	12.73
7	M x PKDA	92	120.44	63 - 186	102.12	129	15.76	12.22
8	K x M	62	113.99	78 - 145	58.78	130	18.65	14.34
9	K x KKR	52	126.47	92 - 157	51.39	115	14.94	12.97
10	K x PKDA	23	131.43	104 - 158	41.09	139	16.40	11.80
11	S -1 x M	89	117.46	77.5 -152	62.72	108	14.66	13. 58
12	S-1 x KKR	29	137.62	90 - 176	62.49	140	13.41	9.58
13	S-1 x PKDA	48	134.39	90 - 170	58.29	128	14.35	11.21
14	PKDA x S-1	206	128.81	52 - 191	107.38	125	14.56	11.65
15	PKDA x M	92	125.27	70 - 161	72.64	130	17.14	13.18
16	PKDA x K	13	124.23	100 - 150	40.25	112	14.00	12.50

mode was low in M x K (11.81) and high in K x M (18.65). Coefficient of dispersion was high in K x M (14.34) and low in S-1 x KKR (9.58).

2. *Number of leaves per plant*

Mean value for number of leaves per plant (Table 22) was high in K x M (45.63) followed by M x K (45.25) and low in K x KKR (37.08). Mode was high in S-1 x PKDA (48) and low in S-1 x KKR (30). Highest value of range (22-135) and percentage of variation (294.59) was in M x PKDA and lowest in PKDA x K (32-48 and 41.43). Mean deviation from mode was high in K x M (10.21) and low in PKDA x K (3.15). Coefficient of dispersion was high in S-1 x KKR (29.54) and low in PKDA x K (8.52).

3. *Number of suckers per plant*

Lowest mean value for number of suckers per plant (Table 23) was observed in K x KKR (0.26) and highest in KKR x M (0.75). Highest value of range (0-7) and percentage of variation (1247.83) was in PKDA x S-1 and lowest range in K x PKDA (0-1) and PKDA x K (0-1). Percentage of variation was also lowest (255.56) in K x PKDA.

4. *Number of slips per plant*

Lowest mean value was observed in M x K (0.92) and highest in S-1 x KKR (4.41) for number of slips per plant (Table 24). Maximum range was in M x KKR (0-18) and lowest in PKDA x K (0-7). Percentage of variation was high in K x M (1600) and lowest in PKDA x K (216.67).

5. *Length of peduncle*

Mean value for length of peduncle (Table 25) was lowest in M x K (18.2 cm) and highest in K x KKR (22.62cm). The maximum range was in KKR x M (8-46 cm) and lowest in PKDA x K (12-30cm). The percentage of variation was high in M x S-1 (185.78) and low in PKDA x K (93.98). The mode value was high in S-1 x KKR (28) and lowest in M x S-1 (16) and M x KKR (16). Mean deviation from mode was high in

Table 22. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of number of leaves per plant in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	129	39.31	24 - 68	111.93	34	7.06	20.77
2	KKR x M	89	37.57	25 - 57	85.17	38	5.08	13.37
3	KKR x K	52	37.44	25 - 54	77.45	38	5.33	14.02
4	M x S -1	242	42.44	24 - 75	120.18	38	7.28	19.16
5	M x K	302	45.25	16 - 92	167.95	38	9.71	25.55
6	M x KKR	308	38.22	17 - 64	122.96	38	6.28	16.53
7	M x PKDA	92	38.36	22-135	294.59	38	8.03	21.14
8	K x M	62	45.63	28 - 74	100.81	38	10.21	26.87
9	K x KKR	52	37.08	25 - 62	99.79	40	6.04	15.10
10	K x PKDA	23	39.61	31 - 54	58.07	39	4.26	10.93
11	S -1 x M	89	45.13	27 - 88	135.15	38	8.26	21.73
12	S-1 x KKR	29	38.79	29 - 55	67.02	30	8.86	29.54
13	S-1 x PKDA	48	41.19	30 - 60	72.84	48	6.08	12.67
14	PKDA x S-1	206	39.56	24 - 80	141.56	38	6.04	15.90
15	PKDA x M	92	39.09	26 - 78	133.04	35	6.65	19.01
16	PKDA x K	13	38.62	32 - 48	41.43	37	3.15	8.52

Table 23. Mean, range and percentage of variation of range over mean of number of suckers per plant in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation
1	KKR x S -1	127	0.49	0 - 6	1229.03
2	KKR x M	89	0.75	0 - 4	531.34
3	KKR x K	52	0.60	0 - 4	670.97
4	M x S -1	242	0.64	0 - 3	471.43
5	M x K	302	0.53	0 - 4	755.00
6	M x KKR	306	0.65	0 - 4	618.18
7	M x PKDA	92	0.54	0 - 4	736.00
8	K x M	62	0.48	0 - 3	620.00
9	K x KKR	53	0.26	0 - 2	757.14
10	K x PKDA	23	0.39	0 - 1	255.56
11	S -1 x M	89	0.64	0 - 3	468.42
12	S -1 x KKR	29	0.52	0 - 2	386.67
13	S-1 x PKDA	48	0.67	0 - 2	300.00
14	PKDA x S-1	205	0.56	0 - 7	1247.83
15	PKDA x M	92	0.65	0 - 3	460.00
16	PKDA x K	13	0.38	0 - 1	260.00

Table 24. Mean, range and percentage of variation of range over mean of number of slips per plant in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation
1	KKR x S-1	126	2.87	0 - 16	556.91
2	KKR x M	87	3.95	0 - 16	404.65
3	KKR x K	51	2.80	0 - 16	570.63
4	M x S -1	242	1.02	0 - 13	1268.55
5	M x K	300	0.92	0 - 14	1521.74
6	M x KKR	305	2.68	0 - 18	672.79
7	M x PKDA	90	2.30	0 - 14	608.70
8	K x M	60	1.00	0 - 16	1600.00
9	K x KKR	53	1.09	0 - 9	822.41
10	K x PKDA	23	3.78	0 - 12	317.24
11	S -1 x M	85	1.20	0 - 13	1083.33
12	S-1 x KKR	29	4.41	0 - 13	294.53
13	S-1x PKDA	48	3.71	0 - 12	323.60
14	PKDA x S-1	205	3.01	0 - 17	563.92
15	PKDA x M	91	3.84	0 - 13	338.97
16	PKDA x K	13	3.23	0 - 7	216.67

Table 25. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of length of peduncle in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	126	22.26	5 - 39	152.73	22	5.77	26.23
2	KKR x M	87	21.03	8 - 46	180.71	20	5.41	27.04
3	KKR x K	51	21.47	11 - 43	149.04	21	3.69	17.55
4	M x S -1	242	18.30	6 - 40	185.78	16	5.07	31.66
5	M x K	300	18.20	8 - 36	153.87	18	4.00	22.44
6	M x KKR	305	20.58	6 - 41	170.11	16	6.42	40.11
7	M x PKDA	90	20.75	5.6 - 39	160.96	20	4.88	24.41
8	K x M	60	19.45	9 - 31	113.11	18	4.55	25.28
9	K x KKR	53	22.62	12 - 36	106.09	25	4.87	19.47
10	K x PKDA	23	22.35	12 - 36	107.39	20	5.22	26.09
11	S -1 x M	85	18.67	8 - 31	123.19	22	5.21	23.69
12	S -1 x KKR	29	22.52	10 - 34	106.59	28	6.72	24.02
13	S-1x PKDA	48	19.90	9 - 40	155.82	22	5.81	26.42
14	PKDA x S-1	205	22.40	7 - 40	147.31	20	6.17	30.87
15	PKDA x M	91	19.67	8 - 39	157.60	17	4.80	28.25
16	PKDA x K	13	19.15	12 - 30	93.98	18	3.92	21.80

S-1 x KKR (6.72) and low in KKR x K (3.69). Coefficient of dispersion was high in M x KKR (40.11) and lowest in KKR x M (17.55).

6. *Duration from planting to beginning of inflorescence development*

The mean value for duration from planting to beginning of inflorescence development (Table 26) was lowest in PKDA x M (862.75 days) and high in K x M (1129.65 days). The mode was lowest in PKDA x K (939) and high in K x M (1058). The range was maximum in KKR x K (625-1335) and lowest in S-1 x KKR (824-999). Percentage of variation was high in KKR x K (78.84) and low in S-1 x KKR (18.14). Mean deviation from mode was high in M x KKR (134.47) and low in S-1 x KKR (22.03). Coefficient of dispersion was high in PKDA x M (13.35) and low in S-1 x KKR (2.24).

7. *Duration from beginning to full development of inflorescence*

For duration from beginning to full development of inflorescence (Table 27), the mean value was high in PKDA x K (10.85 days) and low in S-1 x KKR (7.86 days). Range was high in M x KKR (5-21) and M x K (6-22) and low in S-1 x KKR (6-10). Percentage of variation was high in M x KKR (176.13) and low in S-1 x KKR (50.88). Value of mode was high (10) in S-1 x M, KKR x K, K x M, M x K, K x PKDA, PKDA x K, M x PKDA and PKDA x K and low (8) in all other crosses. Mean deviation from mode was high in PKDA x K (1.92) and low in S-1 x KKR (0.76). Coefficient of dispersion was high in M x S-1 (20.11) and low in S-1 x KKR (9.48).

8. *Duration from full development of inflorescence to first flower opening*

The mean value for duration from full development of inflorescence to first flower opening (Table 28) was high in S-1 x M (15.99 days) and low in M x PKDA (12.54 days). Range was high in M x KKR (4-36) and K x M (8-40) and low in S-1 x KKR (10-19) and K x PKDA (10-19). Percentage of variation was high in M x KKR (223.93) and low in K x PKDA (60.88). Mode was high in S-1 x M (15) and S-1 x PKDA (15) and low in K x KKR (12), K x M (12), M x K (12) and M x PKDA (12). Highest value of mean deviation from mode (3.71) and coefficient of dispersion (30.91) was in K x M and low in S-1 x KKR (1.66 and 11.82 respectively).

Table 26. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of duration from planting to beginning of inflorescence development in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	128	944.05	631 - 1329	73.94	1007	69.74	6.93
2	KKR x M	89	895.88	661 - 1023	40.41	1000	106.48	10.65
3	KKR x K	51	900.53	625 - 1335	78.84	1004	132.61	13.21
4	M x S -1	243	940.91	656 - 1074	44.43	1033	93.89	9.09
5	M x K	301	1100.96	828 - 1500	61.04	1046	86.18	8.24
6	M x KKR	310	885.67	552 - 1241	77.79	1013	134.47	13.27
7	M x PKDA	92	968.21	663 - 1323	68.17	960	82.90	8.64
8	K x M	62	1129.65	830 - 1455	55.33	1058	125.84	11.89
9	K x KKR	52	1019.37	854 - 1325	46.21	997	61.48	6.17
10	K x PKDA	23	969.87	735 - 1196	47.53	986	40.65	4.12
11	S -1 x M	86	968.19	754 - 1046	30.16	1034	66.61	6.44
12	S -1 x KKR	29	964.69	824 - 999	18.14	983	22.03	2.24
13	S-1x PKDA	48	948.23	727 - 1022	31.11	990	45.19	4.56
14	PKDA x S-1	206	955.80	679 - 1095	43.52	1016	62.92	6.19
15	PKDA x M	92	862.75	622 - 1034	47.75	991	132.27	13.35
16	PKDA x K	13	968.77	765 - 1139	38.61	939	72.85	7.76

Table 27. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of duration from beginning to full development of inflorescence in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	128	8.84	6 - 16	113.17	8	1.37	17.09
2	KKR x M	89	9.11	6 - 16	109.74	8	1.61	20.08
3	KKR x K	51	9.53	6 - 16	104.94	10	1.45	14.51
4	M x S -1	243	9.20	6 - 18	130.47	8	1.61	20.11
5	M x K	300	10.79	6 - 22	148.24	10	1.87	18.67
6	M x KKR	309	9.08	5 - 21	176.13	8	1.56	19.54
7	M x PKDA	92	9.96	6 - 16	100.44	10	1.54	15.44
8	K x M	62	10.26	6 - 16	97.48	10	1.55	15.48
9	K x KKR	52	8.56	6 - 14	93.48	8	1.33	16.59
10	K x PKDA	23	8.74	5 - 14	102.99	10	1.78	17.83
11	S -1 x M	86	8.85	6 - 13	79.11	10	1.50	15.00
12	S -1 x KKR	29	7.86	6 - 10	50.88	8	0.76	9.48
13	S-1x PKDA	48	8.85	6 - 14	90.35	8	1.48	18.49
14	PKDA x S-1	206	8.64	6 - 18	138.88	8	1.18	14.81
15	PKDA x M	92	9.84	6 - 19	132.15	10	1.75	17.50
16	PKDA x K	13	10.85	8 - 18	92.20	10	1.92	19.23

Table 28. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of duration from full development of inflorescence to first flower opening in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	128	14.96	6 – 24	120.31	14	2.02	14.45
2	KKR x M	89	13.67	3 – 22	138.95	14	1.76	12.60
3	KKR x K	51	14.08	5 – 24	134.96	14	2.04	14.57
4	M x S -1	243	15.63	7 – 36	185.50	14	2.32	16.55
5	M x K	299	13.47	2 – 23	155.92	12	2.27	18.92
6	M x KKR	307	14.29	4 – 36	223.93	14	2.23	15.89
7	M x PKDA	92	12.54	5 – 21	127.56	12	2.07	17.21
8	K x M	62	15.29	8 – 40	209.28	12	3.71	30.91
9	K x KKR	52	14.31	10 – 23	90.86	12	2.62	21.80
10	K x PKDA	23	14.78	10 – 19	60.88	14	1.91	13.67
11	S –1 x M	86	15.99	10 – 34	150.11	15	2.59	17.29
12	S –1 x KKR	28	14.57	10 – 19	61.76	14	1.66	11.82
13	S-1x PKDA	48	13.63	8 – 20	88.07	15	2.33	15.56
14	PKDA x S-1	206	14.27	9 – 23	98.13	13	1.87	14.38
15	PKDA x M	92	13.47	5 – 21	118.81	13	1.92	14.80
16	PKDA x K	13	12.85	9 – 19	77.84	13	1.85	14.20

9. *Duration from opening of first flower to last flower*

For duration from opening of first flower to last flower (Table 29), mean value was high in S-1 x KKR (24.82 days) and low in M x KKR (18.32 days). Range was maximum in K x M (10-61) and lowest in PKDA x K (13-32). Percentage of variation was high in M x KKR (251.1) and lowest in PKDA x K (91.48). Value for mode was high in PKDA x K (21) and low in KKR x M (14), M x KKR (14) and K x M (14). Highest value of mean deviation from mode (9.68) and coefficient of dispersion (69.12) was in K x M and low in PKDA x K (3.92 and 18.68).

10. *Duration from opening of last flower to harvest*

Mean value for duration from opening of last flower to harvest (Table 30) was high (92.07 days) in S-1 x KKR and low (75.13 days) in M x PKDA. Range was high (31-165) in M x KKR and low (41-93) in PKDA x K. Percentage of variation was high (169.77) in M x KKR and low (64.08) in S-1 x KKR. Mode was high (101) in S-1 x KKR and low (72) in PKDA x M. Mean deviation from mode was high (16) in PKDA x K and low (9.51) in PKDA x M. Coefficient of dispersion was high (17.58) in PKDA x K and low (11) in S-1 x PKDA.

11. *Duration of fruit development*

Mean value for duration of fruit development (Table 31) was high (138.82 days) for S-1 x KKR and low (118.34 days) in M x PKDA. Range was maximum (72-221) in M x KKR and minimum (95-137) in PKDA x K. Percentage of variation was high (123.49) in M x KKR and low (35.04) in PKDA x K. Mode was high (149) in S-1 x KKR and low (113) in PKDA x K. High values of mean deviation from mode (15.73) and coefficient of dispersion (13.33) was recorded in KKR x K and low (8.58 and 7.15 respectively) in PKDA x M.

12. *Duration of crop*

Duration of the crop (Table 32) was shortest in PKDA x M (977.66 days) and longest in K x M (1259.28 days) followed by M x K (1231.02 days). Mode value was highest in PKDA x K (1252) followed by M x K (1190) and lowest in KKR x K (782). Range was maximum in M x K (782-1603) and lowest in S-1 x KKR (948-1157). High

Table 29. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of duration from opening of first flower to last flower in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	128	21.80	9 - 44	160.57	16	7.20	45.02
2	KKR x M	89	21.07	8 - 50	199.36	14	7.67	54.82
3	KKR x K	51	20.31	12 - 44	157.53	16	5.37	33.58
4	M x S -1	243	20.51	9 - 51	204.73	17	5.65	33.21
5	M x K	299	19.47	10 - 48	195.12	16	4.99	31.17
6	M x KKR	307	18.32	6 - 52	251.10	14	5.49	39.23
7	M x PKDA	92	20.71	9 - 44	169.02	16	6.19	38.66
8	K x M	62	23.19	10 - 61	219.89	14	9.68	69.12
9	K x KKR	52	18.58	8 - 51	231.47	16	5.35	33.41
10	K x PKDA	23	18.83	10 - 32	116.86	19	4.44	23.34
11	S -1 x M	85	22.24	9 - 55	206.88	15	8.08	53.88
12	S -1 x KKR	28	24.82	13 - 52	157.12	18	8.46	47.02
13	S-1x PKDA	48	21.04	7 - 44	175.84	15	6.92	46.11
14	PKDA x S-1	206	21.07	9 - 56	223.04	18	5.70	31.69
15	PKDA x M	92	18.85	10 - 41	164.48	18	4.35	24.16
16	PKDA x K	13	20.77	13 - 32	91.48	21	3.92	18.68

Table 30. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of duration from opening of last flower to harvest in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	128	88.12	34 - 140	120.29	90	13.26	14.73
2	KKR x M	88	79.38	36 - 122	108.35	75	12.06	16.08
3	KKR x K	51	87.92	35 - 116	92.13	98	13.53	13.81
4	M x S -1	241	81.85	35 - 127	112.39	88	13.39	15.22
5	M x K	298	85.91	21 - 133	130.36	96	15.31	15.95
6	M x KKR	305	78.93	31 - 165	169.77	76	11.13	14.65
7	M x PKDA	92	75.13	44 - 103	78.53	76	9.87	12.99
8	K x M	62	80.13	44 - 120	94.85	81	12.87	15.89
9	K x KKR	52	91.37	25 - 118	101.79	92	11.06	12.02
10	K x PKDA	23	91.30	62 - 125	69.00	92	10.61	11.53
11	S -1 x M	85	80.94	49 - 114	80.31	85	11.21	13.19
12	S -1 x KKR	28	92.07	63 - 122	64.08	101	14.43	14.29
13	S-1x PKDA	48	91.69	57 - 127	76.35	89	10.15	11.00
14	PKDA x S-1	206	86.14	38 - 125	101.00	79	12.76	16.15
15	PKDA x M	92	76.62	36 - 100	83.53	72	9.51	13.21
16	PKDA x K	13	75.38	41 - 93	68.98	91	16.00	17 58

Table 31. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of duration of fruit development in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	128	133.69	87 - 171	62.83	134	11.25	8.40
2	KKR x M	88	123.30	94 - 158	51.91	125	9.91	7.93
3	KKR x K	51	131.65	94 - 158	48.61	118	15.73	13.33
4	M x S -1	241	127.24	94 - 169	58.94	124	11.55	9.32
5	M x K	298	129.67	63 - 177	87.92	131	12.02	9.17
6	M x KKR	305	120.66	72 - 221	123.49	115	10.33	8.98
7	M x PKDA	92	118.34	87 - 152	54.93	115	8.84	7.68
8	K x M	62	128.92	89 - 169	62.05	120	13.80	11.57
9	K x KKR	52	132.81	79 - 164	64.00	135	10.62	7.86
10	K x PKDA	23	133.65	105 - 179	55.37	135	12.04	8.92
11	S –1 x M	85	127.93	98 - 170	56.28	124	10.12	8.16
12	S –1 x KKR	28	138.82	112 - 171	42.50	149	14.89	10.00
13	S-1x PKDA	48	135.21	113 - 169	41.42	143	10.83	7.58
14	PKDA x S-1	206	130.12	89 - 165	58.41	133	10.01	7.53
15	PKDA x M	92	118.66	86 - 143	48.04	120	8.58	7.15
16	PKDA x K	13	119.85	95 - 137	35.04	113	12.08	10.69

Table 32. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of duration of crop in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	127	1074.91	626 - 1172	50.79	1146	75.17	6.56
2	KKR x M	86	1020.90	772 - 1157	37.71	1132	114.13	10.08
3	KKR x K	47	1022.11	763 - 1458	68.00	782	242.02	30.95
4	M x S -1	243	1069.93	791 - 1304	47.95	1165	99.61	8.55
5	M x K	309	1231.02	782 - 1603	66.69	1190	86.36	7.26
6	M x KKR	304	1007.56	683 - 1356	66.80	1134	134.70	11.88
7	M x PKDA	90	1098.76	846 - 1450	54.97	1076	85.82	7.98
8	K x M	64	1259.28	949 - 1579	50.03	1188	120.88	10.18
9	K x KKR	51	1160.75	982 - 1559	49.71	1133	66.37	5.86
10	K x PKDA	21	1106.19	841 - 1339	45.02	1131	50.05	4.43
11	S –1 x M	85	1102.07	868 - 1193	29.49	1143	56.95	4.98
12	S-1 x KKR	28	1103.61	948 - 1157	18.94	1133	32.68	2.88
13	S-1x PKDA	47	1085.92	871 - 1145	25.23	1118	42.30	3.78
14	PKDA x S-1	190	1083.67	811 - 1177	33.77	1133	66.57	5.88
15	PKDA x M	86	977.66	727 - 1146	42.86	998	101.94	10.22
16	PKDA x K	11	1093.73	863 - 1252	21.10	1252	158.27	12.64

values of percentage of variation (68), mean deviation from mode (242.02) and coefficient of dispersion (30.95) was in KKR x K and lowest (18.94, 32.68 and 2.88 respectively) in S-1 x KKR.

13. *Fruit weight with crown*

Mean value of fruit weight with crown (Table 33) was high in S-1 x PKDA (2088.95 g) and lowest in M x KKR (1323.08 g). Range was maximum in PKDA x M (467-5950) and low in PKDA x K (692-2605). Mode was high in K x PKDA (2216) and low in K x M (1081). Percentage of variation was high in KKR x K (252.97) and low in PKDA x K (130.47). Mean deviation from mode was high in S-1 x M (673.31) and low in KKR x M (401.72). Coefficient of dispersion was high in K x M (57.53) and low in K x PKDA (24.31).

14. *Fruit weight without crown*

For fruit weight without crown (Table 34) mean value was maximum for S-1 x PKDA (1781.61 g) and low in M x KKR (1125.88 g). High values of range (340-3817) and percentage of variation (245.53) was recorded in KKR x S-1 and low in PKDA x K (624-1833 and 101.89 respectively). Mode was high in KKR x M (2034) and low in M x S-1 (632). Mean deviation from mode was high in KKR x M (915.77) and low in PKDA x K (276.82). Coefficient of dispersion was high in M x S-1 (105.88) and low in PKDA x K (24.54).

15. *Length of fruit*

Maximum mean value for length of fruit (Table 35) was observed in S-1 x KKR (17.19 cm) followed by S-1 x M (16.73 cm) and lowest in K x KKR (14.18 cm). Range was high in M x KKR (4.7-28.5) and M x S-1 (7.7-31.5) and low in PKDA x K (12.2-17.8). Percentage of variation was high in M x KKR (162.08) and low in PKDA x K (36.45). Mode was high in PKDA x K (16.2) and low in K x KKR (11.4). High values of mean deviation from mode (3.72) and coefficient of dispersion (31.26) was observed in M x PKDA and low in PKDA x K (1.38 and 8.53 respectively).

Table 33. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of fruit weight with crown in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	127	1693.41	407.5-4300	229.86	1275	538.91	42.27
2	KKR x M	86	1352.04	497 - 3059	189.49	1193	401.72	33.67
3	KKR x K	49	1760.89	686-5140.5	252.97	1306	590.40	45.21
4	M x S -1	225	1561.99	367 - 3618	208.13	1342	417.29	31.09
5	M x K	304	1563.54	366 - 3318	188.80	1137	523.32	46.03
6	M x KKR	311	1323.08	289.5-3410	235.85	1449	415.45	28.67
7	M x PKDA	94	1433.18	536 - 2652	147.64	1558	426.95	27.40
8	K x M	63	1651.18	672-3933.5	197.53	1081	621.85	57.53
9	K x KKR	52	1644.96	703 - 3051	142.77	1805	443.19	24.55
10	K x PKDA	22	1857.05	624 - 3443	151.80	2216	538.77	24.31
11	S-1 x M	80	1839.58	742-4861.5	223.94	2009	673.31	33.52
12	S-1 x KKR	28	2002.52	911-3660.5	137.30	2008	508.16	25.31
13	S- 1x PKDA	47	2088.95	1053 -3835	133.18	1888	532.35	28.20
14	PKDA x S-1	191	1797.36	469 - 4396	218.49	1720	510.86	29.70
15	PKDA x M	86	1548.63	467 - 5950	224.91	1130	535.79	47.42
16	PKDA x K	11	1466.27	692 - 2605	130.47	1386	417.91	30.15

Table 34. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of fruit weight without crown in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	127	1416.12	340 - 3817	245.53	792	651.26	82.23
2	KKR x M	86	1152.25	452 - 2851	208.20	2034	915.77	45.02
3	KKR x K	49	1448.65	386- 3416.5	209.19	1611	485.71	30.15
4	M x S -1	225	1291.16	324 - 2890	198.74	632	669.14	105.88
5	M x K	304	1297.69	239 - 3201	228.25	1281	374.59	29.24
6	M x KKR	311	1125.88	199 - 2623	215.30	717	480.17	66.97
7	M x PKDA	94	1245.56	336 - 2343	161.13	1072	390.42	36.42
8	K x M	63	1432.40	477 - 3324	198.76	916	570.40	62.27
9	K x KKR	51	1328.42	353 - 2832	186.61	1436	434.03	30.23
10	K x PKDA	22	1500.07	406 - 2697	152.73	1883	533.93	28.36
11	S-1 x M	80	1504.20	624- 3797.5	210.98	1412	494.38	35.01
12	S-1 x KKR	28	1675.14	724.5-3142.5	144.35	1131	640.18	56.60
13	S-1 x PKDA	47	1781.61	858 - 3541	150.59	1872	538.34	28.76
14	PKDA x S-1	190	1427.54	421 - 3527	217.58	824	647.18	78.54
15	PKDA x M	86	1344.31	309 - 3558	241.68	1336	460.87	34.50
16	PKDA x K	11	1186.55	624 - 1833	101.89	1128	276.82	24.54

Table 35. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of length of fruit in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	127	15.39	6.1 - 26	129.32	13.2	3.03	22.97
2	KKR x M	86	15.38	9 - 30	136.58	14.1	3.13	22.23
3	KKR x K	49	15.41	8.2 - 25	109.00	15.2	2.39	15.74
4	M x S -1	225	15.93	7.7 - 31.5	149.40	14.5	2.88	19.87
5	M x K	304	15.51	7.5 - 28	132.19	15.4	2.69	17.46
6	M x KKR	311	14.68	4.7 - 28.5	162.08	15.1	2.96	19.57
7	M x PKDA	94	15.02	6.1- 25.2	127.16	11.9	3.72	31.26
8	K x M	63	16.07	9.6 - 24	89.62	14.0	3.13	22.37
9	K x KKR	52	14.18	5.9 - 22	113.52	11.4	3.24	28.46
10	K x PKDA	22	14.95	8.4- 20.1	78.24	11.8	3.57	30.28
11	S-1 x M	81	16.73	9.7- 27.8	108.17	15.2	3.13	20.57
12	S-1 x KKR	28	17.19	11.5-25.5	81.45	15.0	3.28	21.88
13	S-1x PKDA	47	16.53	8.5 - 27.3	113.70	15.3	2.96	19.36
14	PKDAx S-1	191	15.54	9 - 30	135.14	12.8	3.48	27.20
15	PKDA x M	86	16.19	5.8 - 26	124.76	15.4	3.37	21.88
16	PKDA x K	11	15.36	12.2-17.8	36.45	16.2	1.38	8.53

16. *Breadth of fruit*

Mean value for breadth of fruit (Table 36) was highest in S-1 x PKDA (10.95 cm) and lowest in KKR x M (9.46 cm). High values of range (6.87-15.27) and percentage of variation (85.55) was recorded in M x K and low in PKDA x K (8.37-10.83 and 25.63 respectively). Mode value was high in K x PKDA (11.37) and low in K x M (8.67). High values of mean deviation from mode (1.37) and coefficient of dispersion (15.8) was in K x M and low in PKDA x K (0.61 and 6.57 respectively).

17. *Girth of fruit*

For girth of fruit (Table 37) mean value was high in S-1 x KKR (36.34 cm) followed by S-1 x PKDA (36.16 cm) and low in M x KKR (31.35 cm). High values of range (14.1-52.1), percentage of variation (112.44), mean deviation from mode (5.34) and coefficient of dispersion (18.29) was in KKR x S-1. Mode was high in PKDA x S-1 (36.1) and low in PKDA x K (28.9). Lowest range (27.9-36.4) and percentage of variation (26.56) was in PKDA x K. Lowest mean deviation from mode (2.73) was in M x K and coefficient of dispersion (7.97) was in K x KKR.

18. *Canning ratio*

The mean value of canning ratio (Table 38) was highest in PKDA x M (1.55) and lowest (1.28) in K x KKR. Maximum range (0.16-2.65) and percentage of variation (167.63) was in K x M and lowest (1.33-1.77 and 25.17 respectively) in PKDA x K. The mode was high in PKDA x K (1.59) and M x KKR (1.59) and low in K x KKR (1.01). Mean deviation from mode was high in KKR x M (0.29), K x KKR (0.29) and PKDA x M (0.29) and low in PKDA x K (0.11). Coefficient of dispersion was high (29.14) in K x KKR and low (6.75) in PKDA x K.

19. L/B *ratio*

For L/B ratio (Table 39) the values for mean and mode was high (1.72 and 1.76 respectively) in S-1 x KKR and low (1.35 and 1.04 respectively) in K x KKR. The range and percentage of variation was high (0.44-2.87 and 153.66 respectively) in M x K and low in PKDA x K (1.45-1.88 and 26.84 respectively). High value for mean

Table 36. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of breadth of fruit in 16 cross combinations

Sl. No	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	128	10.23	0 – 15.53	51.88	10.10	1.15	11.37
2	KKR x M	86	9.46	7.03 - 13	63.09	8.73	0.99	11.33
3	KKR x K	47	10.23	7.9 – 13.9	58.66	10.33	0.96	9.28
4	M x S -1	224	10.09	6.73 – 13.03	34.84	9.30	1.05	11.33
5	M x K	304	9.82	6.87 – 15.27	85.55	9.53	0.85	8.96
6	M x KKR	311	9.42	5.53 – 11.97	68.35	9.40	0.87	9.28
7	M x PKDA	94	9.80	6.57 – 12.67	62.26	9.30	0.94	10.03
8	K x M	61	9.97	7.8 – 13.2	54.17	8.67	1.37	15.80
9	K x KKR	49	10.41	7.07 – 13.63	62.99	10.50	0.85	8.08
10	K x PKDA	22	10.85	7.97 – 12.77	44.24	11.37	1.09	9.58
11	S –1 x M	81	10.55	7.93 – 16	76.48	9.87	1.18	11.93
12	S –1 x KKR	27	10.44	7.67 – 13.73	58.03	10.93	1.23	11.25
13	S-1x PKDA	47	10.95	8.33 – 13.7	49.02	10.50	0.98	9.32
14	PKDA x S-1	191	10.29	7.1 – 14.2	68.99	10.37	0.91	8.78
15	PKDA x M	86	9.85	5.83 – 13.2	74.81	10.10	0.92	9.08
16	PKDA x K	11	9.60	8.37 – 10.83	25.63	9.33	0.61	6.57

Table 37. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of girth of fruit in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	127	33.79	14.1- 52.1	112.44	29.2	5.34	18.29
2	KKR x M	86	31.36	21.5- 42.7	67.60	30.5	2.80	9.44
3	KKR x K	47	34.30	27.6- 44.6	100.00	29.8	4.66	15.64
4	M x S -1	225	32.90	22.3- 41.4	58.05	30.1	3.38	11.24
5	M x K	303	32.84	23.2- 50.6	83.43	33.6	2.73	8.11
6	M x KKR	311	31.35	19.5- 40.2	66.04	32.0	2.74	8.56
7	M x PKDA	94	32.68	23.6 -40.2	50.80	34.9	3.31	9.48
8	K x M	63	33.25	23.2- 45.5	67.08	30.1	4.08	13.54
9	K x KKR	48	34.41	25.1 -44.3	55.80	35.2	2.81	7.97
10	K x PKDA	22	35.42	27.3- 42.7	43.47	34.2	3.32	9.72
11	S-1 x M	81	34.97	27.3- 58.3	88.65	32.0	4.23	13.21
12	S-1 x KKR	26	36.34	25.1- 44.3	52.84	32.0	3.84	12.01
13	S-1x PKDA	47	36.16	29.5- 44.3	40.93	32.7	4.01	12.27
14	PKDA x S-1	190	33.89	14.6- 46.2	93.25	36.1	3.57	9.89
15	PKDA x M	86	32.72	22.9 -42.4	59.61	31.4	2.89	9.21
16	PKDA x K	11	32.00	27.9 -36.4	26.56	28.9	3.28	11.36

Table 38. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of Canning ratio in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	127	1.42	0.83 – 2.5	117.34	1.21	0.26	21.27
2	KKR x M	86	1.54	1 – 2.88	122.39	1.58	0.29	18.28
3	KKR x K	47	1.38	0.85 – 1.97	80.93	1.21	0.22	18.41
4	M x S -1	225	1.52	0.94 – 3.05	138.92	1.45	0.24	16.80
5	M x K	304	1.48	0.72 – 2.65	130.08	1.38	0.25	17.84
6	M x KKR	311	1.46	0.64 – 2.57	131.78	1.59	0.28	17.69
7	M x PKDA	94	1.45	0.77 – 2.96	151.49	1.50	0.26	17.30
8	K x M	63	1.49	0.16 – 2.65	167.63	1.36	0.26	18.75
9	K x KKR	49	1.28	0.74 – 2.29	121.27	1.01	0.29	29.14
10	K x PKDA	22	1.33	0.94 – 1.95	76.23	1.16	0.23	19.55
11	S –1 x M	81	1.52	1.04 – 2.55	99.49	1.49	0.23	15.64
12	S –1 x KKR	27	1.54	1.02 – 2.42	90.78	1.42	0.25	17.27
13	S-1x PKDA	47	1.43	0.79 – 2.21	99.08	1.33	0.23	17.61
14	PKDA x S-1	191	1.43	0.91 – 2.4	104.08	1.33	0.23	16.90
15	PKDA x M	86	1.55	0.71 – 2.47	113.25	1.57	0.29	18.64
16	PKDA x K	11	1.51	1.33 – 1.71	25.17	1.59	0.11	6.75

Table 39. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of L/B ratio in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	127	1.50	0.86 – 2.69	122.21	1.33	0.26	19.44
2	KKR x M	86	1.63	0.96 – 3.25	140.59	1.69	0.32	19.18
3	KKR x K	47	1.49	0.94 – 2.16	81.95	1.47	0.19	13.17
4	M x S –1	225	1.61	0.97 – 3.28	143.43	1.31	0.34	26.06
5	M x K	304	1.58	0.44 – 2.87	153.66	1.43	0.28	19.45
6	M x KKR	311	1.55	0.69 – 2.75	132.58	1.59	0.28	17.28
7	M x PKDA	93	1.55	0.81 – 2.83	130.11	1.20	0.37	31.02
8	K x M	63	1.60	0.32 – 2.29	123.27	1.50	0.28	18.71
9	K x KKR	49	1.35	0.83 – 2.44	119.21	1.04	0.33	31.71
10	K x PKDA	22	1.38	1.01 – 2.16	83.39	1.06	0.33	30.62
11	S –1 x M	81	1.59	1.05 – 2.71	104.22	1.08	0.51	47.55
12	S –1 x KKR	26	1.72	1.09 – 2.82	100.72	1.76	0.31	17.47
13	S-1x PKDA	46	1.54	0.8 – 2.34	100.03	1.33	0.26	19.76
14	PKDA x S-1	191	1.51	0.9 – 2.69	118.37	1.29	0.28	22.01
15	PKDA x M	86	1.64	0.73 – 2.67	118.31	1.46	0.33	22.24
16	PKDA x K	11	1.60	1.45 – 1.88	26.84	1.51	0.11	7.29

deviation from mode (0.51) and coefficient of dispersion (47.55) was in S-1 x M and low (0.11 and 7.29 respectively) in PKDA x K.

20. *Taper ratio*

The mean value of taper ratio (Table 40) was highest (0.96) in K x KKR and low (0.88) in S-1 x KKR. Range and percentage of variation was high (0.11-1.94 and 193.73 respectively) in M x K and low (0.8-1.09 and 31.09 respectively) in PKDA x K. Mode was high (1.03) in KKR x M and low (0.86) in PKDA x S-1. Mean deviation from mode was high (0.13) in S-1 x PKDA and low (0.07) in KKR x K and K x KKR. Coefficient of dispersion was high (12.96) in PKDA x S-1 and low (6.93) in KKR x K.

21. *Crown weight percentage*

For crown weight percentage (Table 41) lowest mean value (13.85) was obtained in M x PKDA and highest (19.92) in K x KKR. In M x KKR mode was lowest (6.63) and was highest in S-1 x PKDA (22.02). The range and percentage of variation was high (1.07-66.04 and 418.55 respectively) in M x KKR. Mean deviation from mode and coefficient of dispersion were high (13.27 and 188.72 respectively) in PKDA x S-1. Lowest value for range (4.5-37.95), percentage of variation (204.6), mean deviation from mode (5.48) and coefficient of dispersion (33.28) were found in PKDA x K.

22. *Peel weight percentage*

For peel weight percentage (Table 42) the mean and mode was high in S-1 x M (15.11 and 15.22 respectively) and low (12.74 and 8.5 respectively) in KKR x K. Range was high (5.77-42.55) in M x K and low (6.06-16.32) in S-1 x PKDA. Percentage of variation was high (284.79) in M x K and low (79.61) in PKDA x K. Mean deviation from mode was high (4.31) in KKR x K and low in KKR x S-1 (2.18) and M x PKDA (2.18). Coefficient of dispersion was high (50.7) in KKR x K and low (15.24) in S-1 x M.

23. *Pulp weight percentage*

The mean values of pulp weight percentage (Table 43) were highest (81.1 %) in

Table 40. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of taper ratio in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	127	0.94	0.66 – 1.13	49.79	0.98	0.08	7.69
2	KKR x M	86	0.93	0.57 – 1.16	63.41	1.03	0.12	11.20
3	KKR x K	47	0.93	0.72 – 1.09	39.73	0.97	0.07	6.93
4	M x S -1	225	0.94	0.63 – 1.23	64.13	0.89	0.09	10.00
5	M x K	304	0.94	0.11 – 1.94	193.73	0.97	0.10	9.77
6	M x KKR	311	0.95	0.62 – 1.34	75.48	0.92	0.09	9.69
7	M x PKDA	94	0.95	0.71 – 1.13	44.21	0.98	0.08	7.66
8	K x M	63	0.92	0.64 – 1.2	60.62	0.99	0.10	10.05
9	K x KKR	49	0.96	0.64 – 1.12	50.23	0.95	0.07	7.41
10	K x PKDA	22	0.95	0.73 – 1.11	39.83	0.99	0.08	7.58
11	S –1 x M	81	0.94	0.65 – 1.78	120.56	0.89	0.10	11.28
12	S –1 x KKR	27	0.88	0.58 – 1.12	61.42	0.95	0.10	10.88
13	S-1x PKDA	47	0.90	0.67 – 1.15	53.12	1.02	0.13	12.29
14	PKDA x S-1	190	0.94	0.59 – 1.24	68.87	0.86	0.11	12.96
15	PKDA x M	86	0.92	0.57 – 1.15	62.85	0.91	0.08	9.02
16	PKDA x K	11	0.93	0.8 – 1.09	31.09	0.92	0.08	8.30

Table 41. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of crown weight % in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	127	16.71	3.47 – 41.95	230.31	11.23	7.83	69.69
2	KKR x M	86	15.45	2.35 – 45.63	280.05	6.80	9.34	137.39
3	KKR x K	49	18.02	4.65 – 43.73	216.82	8.27	10.01	121.09
4	M x S -1	225	16.84	1.03 – 57.09	332.98	8.48	9.57	112.86
5	M x K	304	17.14	0 – 50.12	292.33	15.04	7.59	50.45
6	M x KKR	311	15.52	1.07 – 66.04	418.55	6.63	9.51	143.49
7	M x PKDA	94	13.85	1.67 – 42.77	296.72	18.21	7.98	43.80
8	K x M	63	14.07	0 – 40.58	288.42	16.79	6.92	41.20
9	K x KKR	51	19.92	4.81 – 49.79	225.85	21.39	8.82	41.24
10	K x PKDA	22	19.75	4.78 – 56.16	260.19	15.03	8.31	55.28
11	S –1 x M	80	17.68	2.34 – 56.64	307.15	17.60	8.75	49.62
12	S –1 x KKR	28	17.44	1.17 – 38.66	214.91	12.81	8.24	64.28
13	S-1x PKDA	47	15.03	0 – 51.18	340.49	22.02	10.16	46.15
14	PKDA x S-1	190	19.75	0 – 55.95	283.23	7.03	13.27	188.72
15	PKDA x M	86	14.66	0 – 45.27	308.86	14.16	7.10	50.16
16	PKDA x K	11	16.35	4.5 – 37.95	204.60	16.47	5.48	33.28

Table 42. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of peel weight % in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	124	13.93	8.47 – 28.32	142.53	13.01	2.18	16.76
2	KKR x M	83	14.74	6.36 – 28.21	148.21	14.79	2.57	17.37
3	KKR x K	46	12.74	7.25 – 25.07	139.91	8.50	4.31	50.70
4	M x S -1	150	14.14	8.91 – 28.48	138.42	15.13	2.36	15.56
5	M x K	290	12.92	5.77 – 42.55	284.79	11.37	2.46	21.65
6	M x KKR	243	14.29	5.16 – 30.39	176.61	14.04	2.30	16.39
7	M x PKDA	93	14.29	7.71 – 21.84	98.85	13.41	2.18	16.25
8	K x M	61	13.10	2.95 – 29.34	201.47	11.14	3.04	27.32
9	K x KKR	45	13.41	5.9 – 19.56	101.88	13.35	2.22	16.65
10	K x PKDA	22	15.01	6.99 – 22.15	100.97	13.79	2.54	18.39
11	S –1 x M	78	15.11	8.25 – 27.2	125.46	15.22	2.32	15.24
12	S –1 x KKR	27	14.83	9.91 – 26.35	110.88	14.95	2.52	16.85
13	S-1x PKDA	47	12.81	6.06 – 16.32	80.10	10.04	3.02	30.12
14	PKDA x S-1	114	12.96	6.57 – 27.22	159.28	12.36	2.25	18.19
15	PKDA x M	85	14.30	8.25 – 27.51	134.67	14.97	2.47	16.49
16	PKDA x K	11	13.04	7.73 – 18.11	79.61	14.46	2.94	20.30

Table 43. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of pulp weight % in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	121	78.35	65.55 – 88.03	28.69	82.85	4.92	5.94
2	KKR x M	83	78.51	60.88 – 87.59	34.02	79.18	3.27	4.13
3	KKR x K	46	80.59	65.84 – 87	26.26	80.23	3.95	4.92
4	M x S -1	150	77.13	45.15 – 88.36	56.03	80.41	4.00	4.98
5	M x K	289	79.39	51.69 – 86.16	43.42	79.20	2.71	3.42
6	M x KKR	243	79.30	52.1 – 89.09	46.65	81.26	3.46	4.26
7	M x PKDA	93	79.35	68.01 – 87.99	25.18	82.49	3.94	4.70
8	K x M	61	78.98	59.84 – 88.25	35.97	80.02	3.39	4.23
9	K x KKR	44	79.56	71.17 – 87.33	20.31	79.92	3.25	4.06
10	K x PKDA	22	77.45	70.79 – 87.08	21.03	77.91	3.12	4.01
11	S -1 x M	78	75.13	66.15 – 85.60	25.90	78.42	4.15	5.29
12	S -1 x KKR	27	78.08	66.91 – 84.74	22.84	76.71	3.15	4.11
13	S-1 x PKDA	47	78.49	68.11 – 85.36	21.98	83.38	4.99	5.98
14	PKDA x S-1	114	79.39	61.28 – 88.95	34.85	80.72	3.39	4.21
15	PKDA x M	85	78.93	49.36 – 88.41	49.48	79.53	3.54	4.45
16	PKDA x K	11	81.10	74.84 – 88.38	16.70	79.64	3.73	4.68

PKDA x K and lowest (75.13 %) in S-1 x M. Range and percentage of variation was high (45.15-88.36 and 56.03 respectively) in M x S-1 and low (74.84-88.38 and (16.7) in PKDA x K. The cross S-1 x PKDA expressed high values of mode (83.38), mean deviation from mode (4.99) and coefficient of dispersion (5.98). Low values were expressed by S-1 x KKR for mode (76.71) and by M x K for mean deviation from mode (2.71) and coefficient of dispersion (3.42).

24. *Peel/pulp ratio*

The values of mean for peel/pulp ratio (Table 44) was high (0.2) in S-1 x M and K x PKDA and low (0.16) in S-1 x PKDA, KKR x K, M x K and PKDA x K. Range and percentage of variation were high (0.07-0.82 and 456.7 respectively) in M x K and low (0.09-0.24 and 92.18 respectively) in PKDA x K. Mode was high (0.2) in K x PKDA and low (0.15) in PKDA x S-1 and KKR x K. Mean deviation from mode was high (0.05) in PKDA x K and low (0.03) in M x S-1, S-1 x PKDA, K x KKR and M x K. Coefficient of dispersion was high (27.33) in KKR x M and low (15.99) in S-1 x PKDA.

25. *Core weight percentage*

The mean value of core weight percentage (Table 45) was lowest (5.86%) in PKDA x K and high (9.84%) in S-1 x M. The mode was lowest (5.24) in M x PKDA and high (9.49) in S-1 x M. The range was maximum (3.17-37.54) in PKDA x M and low (3.62-8.99) in PKDA x K. Percentage of variation was high (507.55) in PKDA x M and low (87.18) in K x PKDA. Mean deviation from mode was high in S-1 x PKDA (3.41) and low in M x KKR (1.48). Coefficient of dispersion was high (62.73) in S-1 x PKDA and low (19.97) in M x K.

26. *Juice weight percentage*

Mean value for juice weight percentage (Table 46) was highest (48.58) in KKR x K followed by PKDA x S-1 (48.53) and lowest (41.41) in S-1 x M. Range was maximum in KKR x K (38.08-83.68) and lowest (31.85-56.62) in S-1 x PKDA. Mode was high (53.42) in PKDA x S-1 and low (37.81) in M x S-1. Percentage of variation was high (102.66) in M x K and low (53.2) in S-1 x PKDA. Mean deviation from

Table 44. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of peel/pulp ratio in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	121	0.18	0.1 – 0.43	183.25	0.17	0.04	20.37
2	KKR x M	83	0.19	0.07 – 0.46	205.00	0.16	0.04	27.33
3	KKR x K	46	0.16	0.08 – 0.38	188.00	0.15	0.04	24.64
4	M x S -1	150	0.19	0.11 – 0.44	178.12	0.17	0.03	19.49
5	M x K	289	0.16	0.07 – 0.82	456.70	0.16	0.03	20.37
6	M x KKR	243	0.18	0.06 – 0.54	263.83	0.16	0.04	23.84
7	M x PKDA	93	0.18	0.09 – 0.31	120.85	0.16	0.04	22.51
8	K x M	61	0.17	0.03 – 0.49	272.43	0.16	0.04	25.41
9	K x KKR	44	0.17	0.07 – 0.27	117.80	0.17	0.03	19.65
10	K x PKDA	22	0.20	0.08 – 0.3	112.30	0.20	0.04	19.32
11	S –1 x M	79	0.20	0.1 – 0.41	151.92	0.19	0.04	19.65
12	S –1 x KKR	26	0.19	0.12 – 0.39	140.96	0.17	0.04	23.08
13	S-1x PKDA	39	0.16	0.07 – 0.23	97.96	0.17	0.03	15.99
14	PKDA x S-1	114	0.17	0.07 – 0.44	223.17	0.15	0.04	23.04
15	PKDA x M	85	0.18	0.09 – 0.43	184.19	0.18	0.04	20.72
16	PKDA x K	11	0.16	0.09 – 0.24	92.18	0.19	0.05	23.92

Table 45. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of core weight % in 16 cross combinations

Sl. No.	Cross Combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation From mode	Coefficient of dispersion
1	KKR x S-1	121	7.84	3.14 – 21.07	228.62	5.49	2.71	49.41
2	KKR x M	83	6.75	3.5 – 14.19	158.36	6.71	1.74	25.93
3	KKR x K	46	6.58	2.16 – 18.39	246.71	5.72	2.15	37.57
4	M x S –1	150	8.56	3.69 – 17.33	159.31	8.01	2.03	25.28
5	M x K	289	7.63	2.13 – 13.72	151.82	8.53	1.70	19.97
6	M x KKR	243	6.16	2.14 – 16.84	238.77	5.75	1.48	25.75
7	M x PKDA	93	6.11	2.47 – 17.01	237.84	5.24	1.83	34.86
8	K x M	61	7.92	2.84—14.00	140.92	7.87	1.67	21.25
9	K x KKR	44	7.11	3.06 – 11.90	124.39	6.10	2.05	33.56
10	K x PKDA	22	7.54	4.72 – 11.29	87.18	7.33	1.52	20.70
11	S –1 x M	78	9.84	4.41 – 17.79	135.92	9.49	2.49	26.19
12	S –1 x KKR	27	7.08	3.79 – 13.26	133.74	7.26	1.71	23.50
13	S-1x PKDA	47	8.70	3.69 – 16.64	148.86	5.43	3.41	62.73
14	PKDA x S-1	114	7.63	2.02 – 16.39	188.29	9.39	2.89	30.81
15	PKDA x M	85	6.77	3.17 – 37.54	507.55	7.49	2.50	33.38
16	PKDA x K	11	5.86	3.62 – 8.99	91.58	7.05	1.55	21.93

Table 46. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of juice weight % in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	121	44.89	26.22 – 4.37	84.99	48.15	5.51	11.45
2	KKR x M	83	43.21	27.83 – 56.19	65.63	40.68	5.26	12.94
3	KKR x K	46	48.58	38.08 – 83.68	93.86	47.37	6.05	12.78
4	M x S -1	150	42.83	21.75 – 56.78	81.79	37.81	6.31	16.68
5	M x K	288	44.26	22.77 – 68.03	102.66	44.87	4.99	11.12
6	M x KKR	243	44.62	15.86 – 59.79	98.46	50.79	6.84	13.47
7	M x PKDA	93	45.63	27.17 – 58.84	69.40	44.02	4.85	11.01
8	K x M	61	46.17	24.79 – 64.36	85.70	45.52	5.26	11.55
9	K x KKR	44	46.86	22.95 – 61.76	82.82	47.67	5.30	11.13
10	K x PKDA	22	44.01	29.56 – 54.4	56.44	38.25	7.00	18.30
11	S -1 x M	78	41.41	25.75 – 59.83	82.31	41.08	5.23	12.73
12	S -1 x KKR	27	46.87	30.21 – 56.15	55.35	46.23	4.30	9.30
13	S-1x PKDA	47	46.56	31.85 – 56.62	53.20	46.08	3.80	8.25
14	PKDA x S-1	103	48.53	23.38 – 57.39	70.09	53.42	9.37	17.53
15	PKDA x M	85	44.93	26.21 – 60.52	76.36	44.00	5.12	11.64
16	PKDA x K	11	43.10	27.08 – 53.35	60.95	48.44	6.38	13.16

mode was high (9.37) in PKDA x S-1 and low (3.8) in S-1 x PKDA. Coefficient of dispersion was high (18.3) in K x PKDA and low (8.25) in S-1 x PKDA.

27. *TSS*

The mean value for TSS (Table 47) was high (14.71) in M x K followed by M x S-1 (14.38) and K x M (14.28) and low (10.93) in PKDA x K. Range and percentage of variation was high (7-23.8 and 137.28 respectively) in M x KKR and low (8.2-16.8 and 72.6 respectively) in M x PKDA. Mode was high (15.2) in K x M and low (9.6) in PKDA x K. Mean deviation from mode was high (2.76) in PKDA x K and low (1.53) in KKR x M. Coefficient of dispersion was high (28.79) in PKDA x K and low (12.2) in M x K.

28. *Acidity of the juice*

High mean value for acidity of juice (Table 48) was observed in M x K (0.59) and low in K x PKDA (0.47). Mode was high in M x S-1 (0.65) and low in PKDA x S-1 (0.28). Range and percentage of variation was high (0.15-1.15 and 206.22 respectively) in KKR x S-1 and low (0.28-0.78 and 101.08 respectively) in S-1 x KKR. Mean deviation from mode and coefficient of dispersion was high (0.25 and 90.55 respectively) in PKDA x S-1 and low (0.1 and 20.2 respectively) in M x PKDA.

29. *Ascorbic acid content*

High mean value of ascorbic acid content (Table 49) was observed in PKDA x M (56.3) and low (31.11) in M x K. Mode was high (74.65) in M x PKDA and low (13.43) in K x KKR. Range was high (0.51-171) in M x KKR and low (4.28-73.69) in K x KKR. Percentage of variation was high (416.63) in M x K and low (154.63) in K x PKDA. Mean deviation from mode was high (29.27) in M x KKR and low (12.87) in KKR x S-1. Coefficient of dispersion was high (192.98) in K x KKR and low (31.35) in K x PKDA.

30. *Reducing sugar*

For reducing sugar (Table 50) maximum values for mean (3.17), range (0.44-11), percentage of variation (333.09), mean deviation from mode (1.12) and coefficient

Table 47. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of TSS in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	126	11.59	4.2 - 19	127.71	12.4	1.96	15.77
2	KKR x M	85	11.70	6.6 - 18	97.42	12.0	1.53	12.78
3	KKR x K	49	11.84	5- 15.8	91.19	10.0	2.17	21.69
4	M x S -1	225	14.38	8- 21.6	94.56	14.0	2.05	14.63
5	M x K	303	14.71	7- 21.6	99.22	15.0	1.83	12.20
6	M x KKR	308	12.24	7- 23.8	137.28	11.0	1.97	17.91
7	M x PKDA	94	11.85	8.2- 16.8	72.60	10.6	1.68	15.87
8	K x M	63	14.28	8.6 - 20.8	85.45	15.2	2.21	14.51
9	K x KKR	49	11.79	7 - 20	110.30	10.0	2.45	24.47
10	K x PKDA	22	11.19	6 - 16	89.39	10.2	1.81	17.69
11	S-1 x M	82	13.37	5.3- 20.2	111.42	12.0	2.29	19.11
12	S-1 x KKR	28	11.46	6.8- 15.4	75.06	12.0	1.97	16.43
13	S-1x PKDA	47	11.65	7.2 - 16	75.54	12.0	1.69	14.06
14	PKDA x S-1	190	12.39	6.6 - 23	132.41	12.0	2.11	17.55
15	PKDA x M	86	11.78	6 - 18	101.89	11.0	1.74	15.83
16	PKDA x K	11	10.93	6.4- 16.6	93.34	9.6	2.76	28.79

Table 48. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of acidity of juice in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	120	0.48	0.15- 1.15	206.22	0.51	0.14	26.80
2	KKR x M	83	0.51	0.28 - 0.93	127.48	0.38	0.14	37.41
3	KKR x K	48	0.51	0.19- 0.94	146.94	0.58	0.14	24.64
4	M x S -1	150	0.57	0.16 - 0.96	139.58	0.65	0.14	21.77
5	M x K	289	0.59	0.16-1.13	165.06	0.58	0.14	24.09
6	M x KKR	243	0.51	0.16- 0.96	156.75	0.51	0.12	22.71
7	M x PKDA	93	0.52	0.19- 0.89	135.37	0.51	0.10	20.20
8	K x M	61	0.57	0.33- 0.97	111.83	0.51	0.13	24.75
9	K x KKR	47	0.52	0.21- 0.92	137.04	0.56	0.14	24.13
10	K x PKDA	22	0.47	0.24- 0.81	122.58	0.32	0.15	48.15
11	S -1 x M	78	0.56	0.25- 1.06	145.58	0.51	0.13	25.99
12	S-1 x KKR	28	0.49	0.28 - 0.78	101.08	0.61	0.15	24.77
13	S-1x PKDA	47	0.48	0.23- 0.83	125.78	0.60	0.16	26.88
14	PKDAx S-1	113	0.53	0.21 - 1.1	168.49	0.28	0.25	90.55
15	PKDA x M	85	0.54	0.24 -1.01	143.44	0.38	0.17	45.91
16	PKDA x K	11	0.55	0.26 -0.94	123.03	0.55	0.13	23.64

Table 49. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of ascorbic acid content in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	121	40.87	10.45-105.93	233.59	37.67	12.87	34.16
2	KKR x M	83	44.99	14.49 - 134	265.63	33.32	18.08	54.26
3	KKR x K	48	39.12	8.95- 79.5	180.37	46.28	16.18	34.96
4	M x S -1	150	36.60	14.28-107.22	253.90	31.87	13.28	41.67
5	M x K	281	31.11	1.49 - 131.12	416.63	23.88	14.51	60.78
6	M x KKR	241	52.87	0.51 - 171	322.48	25.38	29.27	115.32
7	M x PKDA	88	50.88	4.47 - 122.42	231.83	74.65	28.37	38.00
8	K x M	60	32.98	4.03 - 128.39	377.09	14.93	19.45	130.26
9	K x KKR	47	38.83	4.28- 73.69	178.75	13.43	25.92	192.98
10	K x PKDA	22	45.96	15.93 - 87	154.63	49.28	15.45	31.35
11	S -1 x M	78	36.10	14.62- 118.5	287.75	25.34	13.69	54.03
12	S-1 x KKR	28	40.01	16.89 - 98.53	204.05	46.36	15.01	32.37
13	S-1x PKDA	47	45.18	18.83 – 89.83	157.17	60.85	19.69	32.35
14	PKDAx S-1	112	50.57	9.99 - 130.41	238.11	43.47	17.45	40.15
15	PKDA x M	85	56.30	13.81- 140.6	225.19	49.26	20.85	42.32
16	PKDA x K	10	39.60	14.49 - 87.75	185.02	44.79	21.89	48.88

Table 50. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of reducing sugar in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	121	2.42	0.53 – 5.67	212.25	2.20	0.55	25.05
2	KKR x M	83	2.39	1.16 – 5.14	166.38	2.24	0.50	22.41
3	KKR x K	48	2.67	1.43 – 4.17	102.55	2.46	0.52	21.05
4	M x S –1	150	2.48	1.3 – 6.02	190.10	2.88	0.63	21.86
5	M x K	289	3.17	0.44 - 11	333.09	2.12	1.12	52.75
6	M x KKR	241	2.53	1.18 – 5.5	170.73	2.24	0.53	23.43
7	M x PKDA	93	2.67	1.4 – 5.5	153.69	2.12	0.71	33.64
8	K x M	61	3.13	1.51 – 7.33	185.65	3.57	0.82	22.84
9	K x KKR	47	3.02	1.35 – 7.53	204.84	2.76	0.75	27.14
10	K x PKDA	22	2.46	1.77 – 3.12	54.82	2.39	0.35	14.49
11	S –1 x M	78	2.30	0.96 – 3.51	110.74	2.80	0.60	21.27
12	S –1 x KKR	28	2.28	1.12 – 3.6	108.89	2.12	0.48	22.39
13	S-1x PKDA	47	2.27	1.16 – 3.53	104.56	2.54	0.52	20.35
14	PKDA x S-1	113	2.41	1.23 – 4.44	132.97	2.16	0.54	25.08
15	PKDA x M	85	2.21	0.77 – 4.06	148.77	2.11	0.44	20.89
16	PKDA x K	11	2.55	1.66 – 4.37	106.12	2.50	0.46	18.26

of dispersion (52.75) was in M x K whereas mode was high (3.57) in K x M. Lowest values for range (1.77-3.12), percentage of variation (54.82), mean deviation from mode (0.35) and coefficient of dispersion (14.49) was in K x PKDA. Mean and mode was low (2.21 and 2.11 respectively) in PKDA x M.

31. *Total sugar*

The mean value of total sugar (Table 51) was maximum (11.22) for M x K and lowest (6) in S-1 x KKR. Range was high (2.96-18.58) for M x K and low (3.23-10.1) in S-1 x KKR. Percentage of variation was high (193.48) in KKR x S-1 and low (65.05) in M x KKR. Mode was high (12.5) in M x K and low (5.3) in KKR x S-1. Mean deviation from mode was high (3.91) in S-1 x M and low (1.27) in S-1 x KKR. Coefficient of dispersion was high (36.97) in KKR x S-1 and low (15.48) in M x K.

32. *Non-reducing sugar*

For non-reducing sugar (Table 52) mean and range was maximum (8.03 and 1.5-15.33 respectively) in M x K and low (3.81 and 0.1-7.09 respectively) in S-1 x KKR. Percentage of variation was high (257.44) in KKR x S-1 and low (139.35) in M x S-1. Mode was high (8.93) in K x M followed by M x K (8.55) and low (2.09) in K x KKR. Mean deviation from mode was high (2.49) in K x M and low (1.45) in S-1 x PKDA. Coefficient of dispersion was high (107.78) in K x KKR and low (18.97) in M x K.

33. *pH of the juice*

Mean value of pH of the juice (Table 53) was high (4.09) in KKR x M and KKR x S-1 and low (3.9) in K x M. Range and percentage of variation was maximum (1.86-5.02 and 78.64 respectively) in M x PKDA and low (3.27-4.34 and 26.77 respectively) in PKDA x K. Mode was high (4.31) in KKR x M and low (3.66) in PKDA x S-1. Mean deviation from mode and coefficient of dispersion was high (0.42 and 11.43 respectively) in PKDA x S-1 and low (0.17 and 4.31 respectively) in K x M.

34. *Sugar/acid ratio*

For sugar/acid ratio (Table 54) mean and range was high (21 and 7.4-58.63) in

Table 51. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of total sugars in 16 cross combinations

Sl. No	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	121	6.77	2.25- 13.11	193.48	5.30	1.96	36.97
2	KKR x M	83	7.11	1.7 -10.93	129.73	7.30	1.48	20.29
3	KKR x K	48	8.00	3.15 -14.78	145.42	7.66	1.46	19.07
4	M x S -1	149	9.46	3.87- 13.86	105.59	10.60	1.84	17.35
5	M x K	289	11.22	2.96- 18.58	139.18	12.50	1.94	15.48
6	M x KKR	241	8.38	3.82 -12.85	65.05	7.46	1.54	20.69
7	M x PKDA	93	8.41	2.71- 13.33	126.27	8.13	1.69	20.79
8	K x M	61	10.19	4.14 -15.63	112.76	12.33	2.72	22.05
9	K x KKR	47	7.11	2.65- 13.28	149.52	8.03	2.25	27.98
10	K x PKDA	22	7.00	3.45- 11.47	114.65	6.39	1.70	26.62
11	S-1 x M	78	7.35	2.73- 13.33	144.15	11.04	3.91	35.43
12	S-1 x KKR	28	6.09	3.23- 10.1	112.82	6.46	1.27	19.64
13	S-1x PKDA	47	6.48	2.15 -12.04	152.68	6.97	1.61	23.16
14	PKDAx S-1	113	7.71	3.11- 14.58	148.68	8.88	2.06	23.14
15	PKDA x M	85	7.60	1.86 -12.33	137.85	8.48	1.65	19.26
16	PKDA x K	11	7.64	4.27- 14.25	130.58	8.04	2.37	29.43

Table 52. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of non-reducing sugar in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	121	4.36	0.07 – 11.29	257.44	3.67	1.50	40.90
2	KKR x M	83	4.72	0.48 – 8.31	165.80	3.39	1.78	52.49
3	KKR x K	48	5.39	0.57 – 11.07	194.81	4.07	1.70	41.78
4	M x S -1	150	6.98	1.95 – 11.68	139.35	8.48	1.97	23.23
5	M x K	289	8.03	1.5 – 15.33	172.15	8.55	1.62	18.97
6	M x KKR	241	5.85	1.49 – 10.32	150.90	4.40	1.72	39.16
7	M x PKDA	93	5.72	1.07 – 10.25	160.49	5.78	1.53	26.38
8	K x M	61	7.06	2.63 – 12.61	141.44	8.93	2.49	27.83
9	K x KKR	47	4.08	0.2 – 9.16	219.54	2.09	2.25	107.78
10	K x PKDA	22	4.53	1.1 – 8.35	159.92	3.54	1.84	51.98
11	S -1 x M	78	5.05	0.43 – 10.39	197.22	5.98	2.21	37.03
12	S -1 x KKR	28	3.81	0.1 – 7.09	183.36	6.11	2.40	39.25
13	S-1x PKDA	47	4.21	0.45 – 9.3	210.04	4.40	1.45	32.90
14	PKDA x S-1	113	5.30	1.68 – 11.71	189.30	3.52	2.00	56.89
15	PKDA x M	85	5.38	0.66 – 9.25	159.53	6.33	1.53	24.14
16	PKDA x K	11	5.09	1.77 – 11.74	195.91	5.17	1.96	37.95

Table 53. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of *p*H of the juice in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	121	4.09	3.2 – 4.85	40.35	4.04	0.23	5.72
2	KKR x M	83	4.09	3.34 – 4.81	35.92	4.31	0.26	6.06
3	KKR x K	48	3.93	3.47 – 4.71	31.54	3.72	0.31	8.26
4	M x S –1	150	4.01	3.59 – 4.85	31.40	3.94	0.19	4.70
5	M x K	289	3.92	3.19 – 4.99	45.91	3.95	0.18	4.55
6	M x KKR	243	4.03	3.53 – 4.87	33.29	3.92	0.19	4.91
7	M x PKDA	93	4.02	1.86 – 5.02	78.64	3.75	0.32	8.56
8	K x M	61	3.90	3.17 – 4.4	31.52	3.97	0.17	4.31
9	K x KKR	47	3.99	3.16 – 4.66	37.61	4.04	0.22	5.49
10	K x PKDA	22	3.95	3.18 – 4.38	30.37	4.25	0.32	7.59
11	S –1 x M	78	4.04	3.24 – 4.64	34.67	3.97	0.25	6.28
12	S –1 x KKR	27	4.04	3.27 – 4.54	31.45	4.01	0.25	6.22
13	S-1x PKDA	47	4.06	3.36 – 5.06	41.90	3.91	0.27	7.00
14	PKDA x S-1	113	4.07	3.54 – 4.77	30.19	3.66	0.42	11.43
15	PKDA x M	85	4.06	3.15 – 4.87	42.38	3.99	0.22	5.53
16	PKDA x K	11	4.00	3.27 – 4.34	26.77	4.16	0.21	4.98

Table 54. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of sugar/acid ratio in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	121	15.86	5.4 – 39.94	217.80	8.03	8.10	100.81
2	KKR x M	83	14.72	3.54 – 26.6	156.67	13.41	4.00	29.82
3	KKR x K	46	17.16	8.35 – 44.57	211.09	11.55	6.17	53.43
4	M x S -1	150	17.85	7.28 – 45.96	216.65	13.30	5.74	43.14
5	M x K	289	21.00	7.4 – 58.63	243.96	20.19	5.77	28.55
6	M x KKR	241	17.92	7.39 – 54.31	261.89	13.52	5.71	42.24
7	M x PKDA	93	17.48	5.21 – 50.42	258.63	17.74	5.02	28.28
8	K x M	61	19.10	4.31 – 43.42	204.72	16.73	5.30	31.69
9	K x KKR	44	15.59	4.64 – 43.43	248.83	13.37	6.51	48.65
10	K x PKDA	22	16.41	5.66 – 44.17	234.74	13.60	5.30	38.95
11	S -1 x M	78	14.15	4.63 – 34.2	208.95	11.28	5.07	44.94
12	S -1 x KKR	27	13.16	6.22 – 28.76	171.23	14.64	4.06	27.73
13	S-1x PKDA	47	14.91	5.45 – 28.67	155.69	14.52	5.35	36.87
14	PKDA x S-1	113	16.94	4.19 – 44.83	239.95	18.00	6.10	33.89
15	PKDA x M	85	15.01	2.91 – 28.79	172.45	22.06	7.57	34.31
16	PKDA x K	11	15.11	7.49 – 29.08	142.93	11.16	5.52	49.44

M x K and low (13.16 and 6.22-28.76) in S-1 x KKR. Percentage of variation was high (261.89) in M x KKR and low (142.93) in PKDA x K. Mode was high (22.06) in PKDA x M and low (8.03) in KKR x S-1. Mean deviation from mode was high (8.1) in KKR x S-1 and low (4) in KKR x M. Coefficient of dispersion was high (100.81) in KKR x S-1 and low (27.73) in S-1 x KKR.

35. *Brix/acid ratio*

The mean value of brix/acid ratio (Table 55) was high (27.47) in M x K and low (22.06) in PKDA x K. Maximum values of range (9.56-100.67), percentage of variation (333.11), mean deviation from mode (9.55) and coefficient of dispersion (47.74) was in KKR x S-1. Mode was high (30) in M x S-1, KKR x M and M x PKDA and low (17.67) in PKDA x K. Low values were observed for range (9.79-41.08) in PKDA x K, percentage of variation (139.11) and mean deviation from mode (5.8) in PKDA x M and coefficient of dispersion (25.62) in KKR x M.

The study of the hybrids using the parameters mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion showed wide variability between cross combinations for all characters. None of the cross combinations were found to express high values for all characters or most of the important characters. The characters are found to segregate independently. This trend was found in all cross combinations.

4.4.2. Multivariate analysis

4.4.2.1. *Determinant of the covariance matrix*

To estimate the extent of variability between cross combinations based on important characters, five economically important characters, viz., fruit weight without crown, TSS, total sugars, pulp % and juice % were selected. An index of variability for each cross combinations when all the five selected characters were taken together was found out by computing the covariance matrix and the determinant of the covariance matrix.

Table 55. Mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion of brix/acid ratio in 16 cross combinations

Sl. No.	Cross combinations	Number of hybrids	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
1	KKR x S-1	121	27.35	9.56 – 100.67	333.11	20.00	9.55	47.74
2	KKR x M	83	24.36	11.61 – 46.15	141.77	30.00	7.69	25.62
3	KKR x K	46	25.36	12.66 – 56.19	171.66	26.36	6.76	25.66
4	M x S -1	150	26.01	13.12 – 68.75	213.87	30.00	7.70	25.68
5	M x K	289	27.47	10.21 – 72.5	226.78	23.33	7.34	31.44
6	M x KKR	243	24.96	7.66 – 88.75	324.94	20.00	6.97	34.87
7	M x PKDA	93	24.42	12.73 – 61.05	197.89	30.00	8.12	27.06
8	K x M	61	26.64	10.83 – 50.59	149.22	24.55	6.47	26.37
9	K x KKR	44	25.66	12.61 – 57.14	173.53	21.64	8.06	37.22
10	K x PKDA	22	25.86	11.36 – 54.17	165.53	21.70	6.38	29.40
11	S –1 x M	78	26.16	12.08 – 68.8	216.80	20.00	8.04	40.20
12	S –1 x KKR	27	24.79	13.33 – 47.85	139.22	23.91	6.15	25.71
13	S-1x PKDA	47	26.75	10.51 – 52.17	155.71	26.67	7.18	26.92
14	PKDA x S-1	113	25.69	8 – 56.19	218.75	27.65	8.19	29.60
15	PKDA x M	85	23.41	10.3 – 42.86	139.11	19.66	5.80	29.50
16	PKDA x K	11	22.06	9.79 – 41.08	141.86	17.67	7.80	44.16

The result of the estimation of variance (Table 56) and covariance (Table 57) showed highly variable values for fruit weight without crown and for all other characters relatively low values were observed. The covariance of the five characters showed a negative relationship between fruit weight without crown vs. TSS and total sugar and positive relationship between fruit weight without crown vs. pulp weight percentage and juice weight percentage.

The values of the determinant of covariance matrix (Table 58) showed wide variability between cross combinations. The values of the determinants vary from 0.60×10^{10} of M x KKR to 1.19×10^{10} of S-1 x M, indicating very high variability between cross combinations.

To identify any hybrid having desirable combination of characters from any of the cross combinations, the following parameters were studied using the five characters selected viz., fruit weight without crown, TSS, total sugar, pulp weight percentage and juice weight percentage.

4.4.2.2. *Principal component analysis*

Percentage cumulative variance explained by the first two components were estimated and presented in Table 59. Maximum value of percentage cumulative variance was expressed by the cross PKDA x K (79.74) followed by K x M (72.46) and K x KKR (71.06). The lowest value was in the cross S-1 x M (58.16). The variance of first and second components of all hybrids was presented in Appendix –III. The scatter diagram of the principal components is given in Figure 1.

4.4.2.3. *Euclidean distance.*

Variability between hybrids within a cross combination when all the five characters were taken together was found out by estimating the Euclidean distances. In all the sixteen cross combinations, Euclidean distances were worked out and the average Euclidean distance was estimated for all the hybrids in all cross combinations. The average Euclidean distance (Appendix IV) showed very high variability between hybrids in all cross combinations.

Table 56. Variance of five characters in 16 cross combinations of pineapple

Crosses	Fruit weight without crown (g)	TSS	Total sugar	Pulp weight %	Juice weight %
KKR x S- 1	323352.0	5.46	5.14	17.87	45.01
S-1 x KKR	454863.5	5.71	2.42	14.77	32.81
M x S- 1	166975.5	5.58	4.41	21.18	32.43
S- 1 x M	483171.1	7.43	6.85	17.08	46.29
PKDA x S- 1	248583.7	4.60	4.64	17.08	43.22
S-1 x PKDA	436853.9	4.46	4.41	12.19	24.02
KKR x M	238930.6	3.85	3.63	18.46	33.91
M x KKR	197478.0	3.23	3.03	19.42	40.39
KKR x K	358658.8	3.83	3.86	23.51	71.81
K x KKR	237269.4	7.7	6.62	17.25	47.72
K x M	395017.1	6.7	7.22	19.75	47.76
M x K	236777.5	5.1	4.56	15.29	42.14
K x PKDA	293749.3	4.84	5.12	16.2	42.94
PKDA x K	132349.8	11.71	9.8	21.59	59.7
M x PKDA	229712.4	3.23	4.35	19.65	37.15
PKDA x M	346655.3	4.35	4.02	29.97	42.05

Table 57. Covariance of five characters in 16 cross combinations of pineapple

Crosses	Fruit weight without crown vs TSS	Fruit weight without crown vs Total sugar	Fruit weight without crown vs Pulp weight %	Fruit weight without crown Vs Juice weight %	TSS vs Total sugar	TSS vs Pulp weight %	TSS vs Juice weight %	Total sugar vs Pulp weight %	Total sugar vs Juice weight %	Pulp weight % vs Juice weight %
KKR x S1	-257.17	-196.02	406.91	1442.57	2.88	1.35	0.11	1.51	1.01	5.31
S-1x KKR	-404.63	-421.04	816.39	1737.66	1.82	-2.26	-0.61	-0.41	-2.51	6.68
M x S-1	-154.97	-76.31	215.76	781.73	2.82	1.22	1.58	1.44	1.35	6.86
S-1x M	-420.75	-307.76	863.53	1413.74	2.84	-1.67	-2.47	-0.26	-3.49	-2.09
PKDAx S-1	-294.55	-238.33	764.6	851.84	2.55	0.11	1.42	2.32	1.95	10.14
S-1xPKDA	-295.29	-339.78	516.66	1240.71	1.95	1.40	-1.10	1.31	-1.44	5.58
KKR x M	-110.99	-57.79	621.7	975.62	1.29	0.59	-0.81	2.79	0.55	7.37
M x KKR	-132.07	-140.11	329.81	563.53	2.21	-0.71	-0.27	0.98	0.15	5.41
KKR x K	-222.11	-34.31	695.94	620.68	2.34	-1.61	5.64	2.48	7.63	12.39
K x KKR	-164.64	-140.67	699.58	1967.31	3.93	-1.1	-3.21	4.21	-3.38	7.05
K x M	-797.51	-1012.8	-42.77	1771.57	5.42	-1.76	-7.92	0.43	-5.24	3.96
M x K	-204.58	-151.12	241.74	1158.93	3.55	0.20	-2.08	0.58	-0.73	4.2
K x PKDA	195.35	-89.43	815.82	1048.27	1.97	2.46	4.83	2.51	4.19	9.21
PKDA x K	304.13	434.64	923.13	1638.77	7.22	0.11	11.63	1.98	9.11	12.75
M x PKDA	-50.06	2.11	714.15	1185.61	1.43	-0.75	-2.61	2.94	1.56	9.24
PKDA x M	-319.21	-139.85	1044.24	2205.47	1.92	-1.11	-0.75	2.39	2.09	13.6

Table 58. Determinant of the covariance matrix of 16 cross combinations with respect to five characters

Crosses	Number of hybrids	Determinant of the covariance
KKR x S-1	127	0.38×10^{10}
KKR x M	86	0.11×10^{10}
KKR x K	49	0.28×10^{10}
S-1 x KKR	28	0.11×10^{10}
S-1 x M	80	1.19×10^{10}
S-1 x PKDA	47	0.12×10^{10}
M x S-1	225	0.15×10^{10}
M x KKR	311	0.06×10^{10}
M x K	304	0.12×10^{10}
M x PKDA	94	0.10×10^{10}
PKDA x S-1	191	0.18×10^{10}
PKDA x K	11	0.34×10^{10}
PKDA x M	86	0.26×10^{10}
K x KKR	52	0.24×10^{10}
K x M	63	0.29×10^{10}
K x PKDA	22	0.23×10^{10}

Table 59. Percentage cumulative variance explained by the first two components together for the 16 cross combinations

Cross Combinations	% cumulative variance
KKR x S-1	63.63
KKR x M	62.79
KKR x K	68.95
M x S-1	63.49
M x K	64.92
M x KKR	62.89
M x PKDA	65.21
K x M	72.46
K x KKR	71.06
K x PKDA	66.03
S-1 x M	58.16
S-1 x KKR	66.13
S-1 x PKDA	66.10
PKDA x S-1	68.23
PKDA x M	69.54
PKDA x K	79.74

To compare the variability between the sixteen cross combinations, the highest value of the average Euclidean distances was taken out from all the sixteen cross combinations and compared (Fig 2). The values showed that the hybrid combinations vary in average distance from 711.23 in PKDA x K to 2425.90 in KKR x S-1 indicating very high variability.

4.4.3. Selection of desirable hybrids

The results of the summary statistics and multivariate analysis showed that the hybrids in all cross combinations and also between cross combinations express very high variability for all characters. The result further indicated that there is much scope for selection among the hybrids based on few economically important characters.

The hybrid number 214 of the cross K x M was having the appearance of a dual type. It is having the plant characters of Kew (leaves without spines) and fruit characters of Mauritius (deep eyes), but it's TSS is only 12.8.

To exploit the variability among the hybrids for achieving the objective of developing genotypes suitable for the dual purpose of processing and fresh fruit, all the hybrids were screened for identifying hybrids with relative heterosis, heterobeltiosis and standard heterosis based on five economically important characters, viz., fruit weight without crown, TSS, total sugars, pulp % and juice % simultaneously.

Relative heterosis

Out of the 16 cross combinations, F_1's with relative heterosis (Table 60) could be located in seven cross combinations, viz., KKR x K, M x KKR, M x PKDA, M x K, K x PKDA, PKDA x K and PKDA x M. Thirteen hybrids from among all the seven cross combinations showed relative heterosis. Hybrids in the cross KKR x K (number 1975) showed maximum relative heterosis for fruit weight without crown (111.77 %) whereas for TSS (34.45%) it was in K x PKDA (Hybrid No. 7637), for total sugar (20.02%) it was in PKDA x K (Hybrid No. 2092), for pulp percentage (8.69) it was in

Table 60. Relative heterosis of selected hybrids in five characters.

Cross	Hybrid No.	Relative heterosis of				
		Fruit weight without crown (g)	TSS ^{0} brix	Total sugar %	Pulp weight %	Juice weight %
KKR x K	1970	46.59	14.04	7.49	6.62	25.54
	1975	111.77	10.64	12.81	3.32	21.12
M x KKR	2348	27.54	24.70	0.27	0.17	0.93
	4381	22.75	5.26	1.10	8.69	2.60
M x PKDA	2252	96.76	8.80	0.91	3.63	20.11
M x K	341	43.25	18.88	3.23	0.39	0.25
	464	5.80	14.69	3.23	1.39	13.68
	575	48.36	13.29	0.87	0.67	16.92
	656	27.88	9.09	6.86	1.79	9.44
	894	23.53	4.20	2.68	1.28	8.05
K x PKDA	7637	4.12	34.45	13.12	7.24	15.40
PKDA x K	2092	10.13	14.29	20.02	3.42	3.24
PKDA x M	6030	34.77	15.20	12.71	6.39	9.77

M x KKR (Hybrid No. 4381) and for juice percentage (25.54%) it was in KKR x K (Hybrid No. 1970). However, considering all five characters together, hybrid Nos. 7637 of K x PKDA and 464 of M x K were considered superior based on relative heterosis.

Heterobeltiosis

When all the hybrids in the sixteen cross combinations were screened simultaneously for five selected characters to identify hybrids having heterobeltiosis, none of the hybrids with heterobeltiosis for all the five characters could be located.

Standard heterosis

All the hybrid combinations were screened for identifying hybrids with standard heterosis (Table 61) for all the selected five economically important characters, viz., fruit weight without crown, TSS, total sugar, juice percentage and pulp percentage, when taken simultaneously. Only seven hybrids in three cross combinations, viz., KKR x S-1, M x S-1 and M x K, showed standard heterosis when all the five characters were taken simultaneously.

Hybrid No. 257 of M x K showed maximum standard heterosis for fruit weight (67.62%), TSS (28.86%), total sugar (10.83%) and pulp percentage (5.79%). Standard heterosis was high for juice percentage (14.97 %) in hybrid No. 891 of the cross M x K.

4.4.3.1. Characters of the twenty hybrids showing heterosis

The performance of the thirteen hybrids that showed relative heterosis and seven hybrids that showed standard heterosis was compared with the parental genotypes and presented in Table 62. The hybrid No. 257 was having highest TSS (19.2 ^{0} Brix) and total sugar (14.94 %). It was having medium fruit weight (1779 g).

Table 61. Standard heterosis of selected hybrids for five characters

Cross	Hybrid No.	Standard heterosis of				
		Fruit weight without crown (g)	TSS ^{0} brix	Total sugar %	Pulp weight %	Juice weight %
KKR x S-1	8622	18.35	15.44	2.37	1.36	1.08
M x S-1	3523	1.10	15.44	2.82	3.00	2.51
M x K	257	67.62	28.86	10.83	5.79	2.04
	614	32.29	8.72	0.96	1.91	2.53
	656	50.90	4.70	0.52	4.86	11.76
	800	57.73	8.72	0.82	4.95	1.70
	891	33.47	20.81	8.75	1.10	14.97

Table 62. Characters of twenty selected hybrids compared with parents.

Cross	Hybrid No.	Fruit weight without crown (g)	TSS ^{o} brix	Total Sugar %	Pulp weight %	Juice weight %
KKR x S-1	8622	1256.0	17.2	13.80	79.06	47.61
KKR x K	1970	1995.0	13.4	10.91	86.47	59.19
	1975	2882.0	13.0	11.45	83.79	57.11
M x S-1	3523	1073.0	17.2	13.86	80.34	48.28
M x K	257	1779.0	19.2	14.94	82.52	48.06
	614	1404.0	16.2	13.61	79.49	48.29
	656	1601.5	15.6	13.55	81.79	52.64
	800	1674.0	16.2	13.59	81.86	47.90
	891	1416.5	18.0	14.66	78.86	54.15
	341	1794.0	17.0	13.09	80.66	48.22
	464	1325.0	16.4	13.09	84.47	54.68
	575	1858.0	16.2	12.79	80.89	56.24
	656	1601.5	15.6	13.55	81.79	52.64
	894	1547.0	14.9	13.02	81.38	51.97
M x KKR	2348	1492.0	15.4	10.98	78.88	46.58
	4381	1436.0	13.0	11.07	85.59	47.35
M x PKDA	2252	2111.0	13.6	11.04	81.71	54.71
K x PKDA	7637	1316.0	16.0	11.47	87.08	53.72
PKDA x K	2092	1392.0	13.6	12.17	83.98	48.06
PKDA x M	6030	1446.0	14.4	12.33	83.89	50.00
MAURITIUS		1061.3	14.9	13.48	78.00	47.10
KEW		1443.4	13.7	11.88	82.70	49.10
KKR		1278.4	9.8	8.41	79.50	45.20
PKDA		1084.5	10.1	8.39	79.70	44.00
S-1		1765.7	13.4	11.82	82.10	51.50

4.4.4. Spine character of the hybrids

Hybrids in the sixteen cross combinations were screened for the expression of spine character and the result presented in Table 63. All the crosses where Kew was used as one of the parent, produced progenies with spiny, sparsely spiny and spineless leaves whereas in the case of other parents, the progeny in general are spiny. In two crosses, viz., M x S-1 and PKDA x M where both the parents are spiny, one progeny from each cross was found to have spineless leaves.

4.4.5. Hybrids with distinct or abnormal characters

Among the hybrids of various cross combinations, plants with distinct or abnormal characters that are not normally found in pineapple populations were observed.

4.4.5.1. *Hybrids with leaf colour variation*

All cross combinations expressed variability in the leaf colour exhibiting colours like pale green, green, deep green, green with reddish tinge and green with violet tinge.

4.4.5.2. *Hybrid with low chlorophyll content*

The hybrid number 6170 of the cross PKDA x M was found to have low chlorophyll content and the leaves are yellowish in colour with slight greenish tinge (Plate 13).

4.4.5.3. *Hybrids with piping character*

Plants with piping character of leaves was observed in four crosses (Table 64), viz., PKDA x K, PKDA x M, PKDA x S-1 and KKR x PKDA. Plants with piping character have leathery leaves without spines even at the leaf tip and the leaf margins

Table 63. Expression of spine character in the sixteen cross combinations of pineapple

Cross combination	Presence of spines			
	Spiny leaves	Non spiny leaves	Sparsely spiny leaves	Total
KKR x S-1	132	0	0	132
KKR x M	89	0	0	89
KKR x K	31	13	7	51
M x S-1	250	1	0	251
M x K	226	155	33	414
M x KKR	317	0	0	317
M x PKDA	91	0	1	92
K x M	32	23	10	65
K x KKR	34	21	1	56
K x PKDA	15	7	1	23
S-1 x M	91	0	0	91
S-1 x KKR	30	0	0	30
S-1 x PKDA	53	0	0	53
PKDA x S-1	177	0	0	177
PKDA x M	110	1	0	111
PKDA x K	8	2	3	13

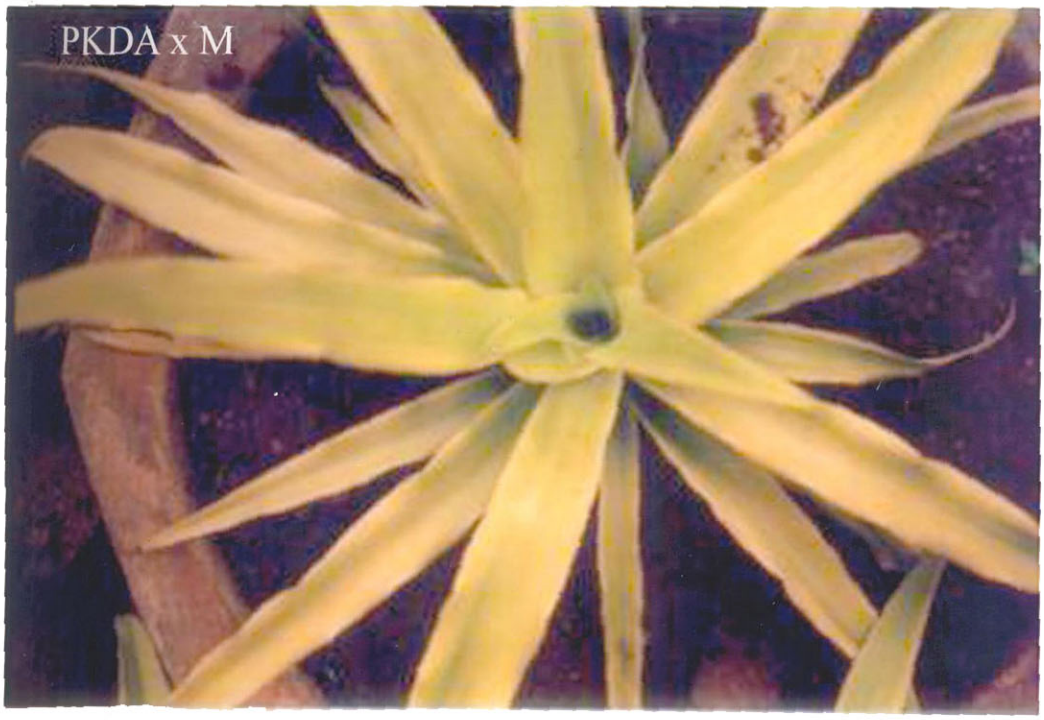


Plate 13. Hybrid number 6170 with low chlorophyll content

Table 64. Cross combinations showing plants with piping character

Cross combination	Number of plants with piping character	% of plants with piping character out of the	
		total seeds germinated	total seedlings survived
PKDA x K	5	1.4	45.5
PKDA x M	1	0.2	1.2
PKDA x S-1	1	0.3	0.5
KKR x PKDA	3	3.1	23.1

are soft and smooth. Maximum percentage of plants with piping character was produced in KKR x PKDA followed by PKDA x K (Plate 14). However, maximum number of plants with piping character out of the total seedlings survived was in PKDA x K followed by KKR x PKDA. Among the five genotypes whose cross combinations were evaluated, the genotype PKDA was involved as one of the parent in all the crosses, whose progeny expressed the piping character.

4.4.5.4. *Colour of heart at the beginning of inflorescence development*

The colour development in the heart of the plant at the time of inflorescence development expressed variability in all crosses. The hybrids showed a range of deep red to creamy white colour. Hybrids of the crosses S-1 x M and PKDA x K developed a range of red to creamy white colour in the heart of the plant at the time of inflorescence development.

4.4.5.5. *Hybrid with white flower*

The colour of the petals of pineapple flower was normally purplish blue. But in the hybrid numbers 2095 (Plate 15) and 2106 of the cross PKDA x K was having white coloured petals.

4.4.5.6. *Hybrid with extra long and cylindrical fruit*

The fruit of the hybrid No. 3005 of the cross M x S-1 was found to have 31.5 cm length and was perfectly cylindrical in shape (Plate 16).

4.4.5.7. *Fruit that ripened uniformly*

Ripening of pineapple fruit normally starts from the base of the fruit with yellowing of lower most eyes first and continued upwards till all the eyelets turn yellow. However in the hybrid No. 1048 of the cross K x M, this process was not

Plate 14. Piping character in pineapple hybrids

Plate 15. Hybrid number 2095 with white flower

Plate 16. Hybrid number 3005 with extra long cylindrical fruit

observed but instead, all the eyes in the fruit were found to turn yellow simultaneously. But the intensity of yellowing, when fully ripe, was found to be more in the lower eyes.

4.5. *In vitro* Mutagenesis

The greening of the explants started within 4-7 days. The plantlets, without roots when planted out, developed roots *ex situ*. The mean height of plants at 120 days after plant out was 19.79 cm whereas that of control was only 9.22 cm (Table 65). Number of leaves at 120 days after plant out was 28.49 and that of control was 10.4 only. Variability in growth between different doses of irradiation is shown in Plate 17. Chlorophyll mutants were observed which did not have any chlorophyll (Plate 18) and hence did not survive. Chimera was also observed. The plantlets ready for plant out is shown in Plate 19. The plantlets started flowering after one year, naturally.

Table 65. Mean height and number of leaves of *in vitro* mutant plants at different intervals of growth

Treats	Days of interval														
	0			30			60			90			120		
	No. of plts	Ht. (cm)	No. of lves.	No. of plts	Ht (cm)	No. of lves	No. of plts	Ht (cm)	No. of lves	No. of plts	Ht (cm)	No. of lves	No. of plts	Ht (cm)	No. of lves
10 Gy.	107	3.84	6.99	97	4.34	7.39	95	5.35	8.26	94	6.13	9.46	94	7.08	9.97
15 Gy	217	3.07	6.62	193	3.89	7.41	188	4.88	8.09	187	5.43	9.00	180	6.52	9.63
20 Gy	582	2.82	6.85	488	3.71	7.77	486	4.56	8.29	474	5.49	8.61	456	6.93	8.68
25 Gy	92	3.36	7.17	87	4.35	7.53	87	5.30	7.66	85	5.72	8.74	79	6.57	9.66
30 Gy	267	7.39	16.27	183	11.87	20.55	173	15.13	22.13	161	16.94	25.35	152	19.79	28.49
35 Gy	162	2.65	6.85	137	3.52	7.39	135	4.65	7.81	133	5.40	8.41	130	6.34	8.27
40 Gy	37	3.49	7.00	36	4.71	7.94	35	6.08	9.26	33	6.92	10.48	33	7.55	10.53
Control	56	3.17	7.11	52	4.80	8.88	52	6.98	9.96	52	8.40	10.50	52	9.22	10.40

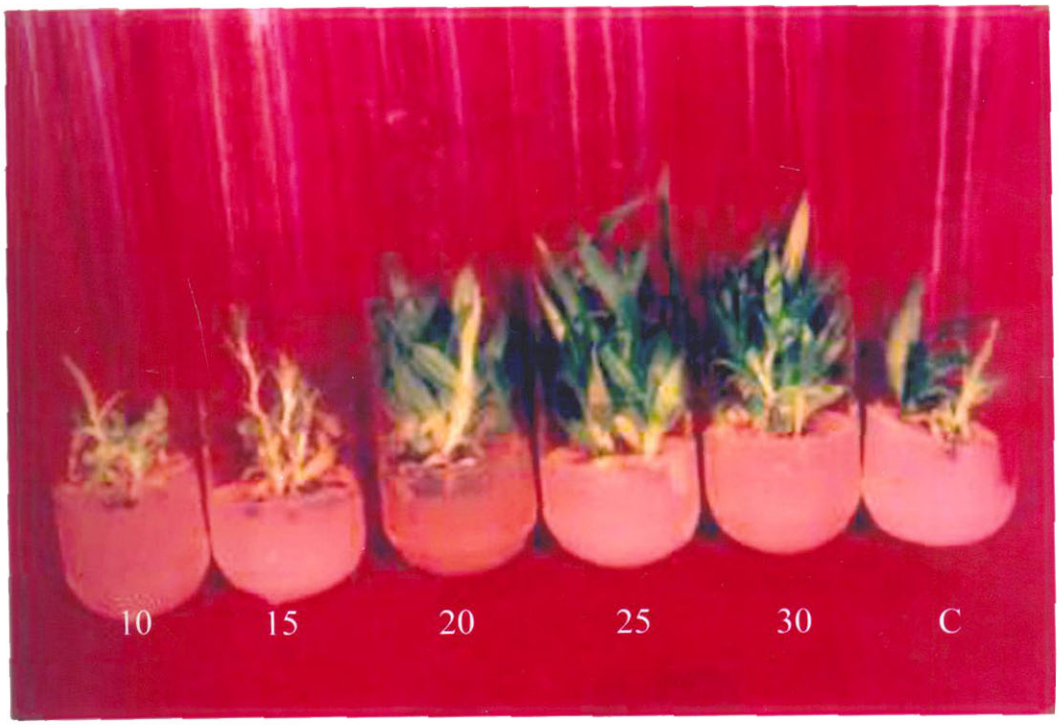
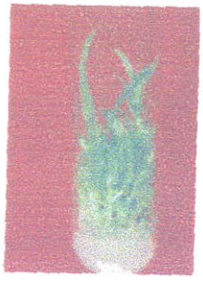


Plate 17. Variability in the growth of irradiated *in vitro* plants

Plate 18. Albino plant among irradiated *in vitro* plants

Plate 19. Irradiated *in vitro* plants ready for planting out



Discussion

DISCUSSION

Information about the genetic variability in the available germplasm is essential for any crop improvement programme. This information will give an idea about the possibility of character combinations that can be expected in a hybridization programme. This will also give an idea about the genotype that is having maximum number of desirable characters and the characters that are to be integrated in the hybridization programme.

Usually in a hybridization programme maximum genetic diversity among the parents are expected to result in high heterotic effect. This aspect is of more importance when the objective is to improve one or two characters especially if the yield improvement is the prime consideration. But in the case where priority is given to the quality aspects, several characters are to be considered simultaneously in a hybridization and selection programme.

In the present case of breeding in pineapple, priority is given for quality improvement than to the yield considering the fact that the genotype has average yield potential with standard fruit size and normal duration. The problem becomes more complex due to the difference in the requirement of the end users. The requirement of fresh fruit consumers and processing industry are different. The fresh fruit market demands a fruit with high quality, flavour and low damage during post harvest handling and storage. Whereas, the processing industry prefers a fruit having bigger size, cylindrical shape, high juice content and low eye depth. Hence the present research programme aims to develop a dual purpose variety to meet the requirements of both, the processing industry and the fresh fruit market.

5.1. Evaluation of Pineapple Genotypes

Among the six genotypes used in the study, Kew and Mauritius are popular varieties grown preferentially for processing and fresh fruit purpose respectively.

Pampakuda local and Kakkoor local are not grown commercially but are hardy types found to grow in neglected lands, poor soil, shaded conditions etc., but still performs well. Hence some amount of resistance is expected in these two types. The Selection-1 have some similarities with Kew but it was having short duration and higher fruit weight than Kew. It's leaves are spiny and the fruits are ideal for processing. The Ripley Queen and Mauritius were ideal for table purpose (Gopimony *et al.* 1978).

The six genotypes were evaluated for 12 growth characters and 23 fruit yield and quality characters. They differ significantly in thirty four out of the total thirty five characters studied (Table 1 and 2) and there was no significant difference between the genotypes with regard to the character number of leaves per plant. The six genotypes also differ in five qualitative characters studied (Table 3). Nayar *et al.* (1981a) reported varietal level variation in morphological and nutritional characters of pineapple at harvest stage. Queen was having higher TSS whereas total sugar, reducing sugar and acidity were higher in Kew. Variation in general quality of fruit depending on variety and place was found by Hayes (1957). Effect of sunlight, temperature, altitude and period of fruit development on quality of pineapple fruit were reported (Collins, 1960 and Hope, 1963). Chemical constituents of pineapple fruit were studied and reported earlier (C.S.I.R., 1948 and Purseglove, 1975). The general composition was reported by Dull (1971) giving a range of each of the constituents wherein the acidity ranged from 0.6 to 1.62 % and brix from 10.8 to 17.5 %.

In the present study, the six genotypes were compared for fifteen favourable characters, viz., less height, low number of suckers, low or absence of slips, short duration, high TSS, low acidity, high fruit weight, optimum taper ratio, low peel weight, low core weight, high ascorbic acid content, spineless leaves, high juice content, attractive colour of fruit at ripening and golden yellow and pale yellow colour of pulp at ripening.

Less height and spineless leaves favour easy management operations. Low sucker and slip production favour development of bigger fruit. Short duration helps to get early income. High TSS and low acidity leads to better flavour. High fruit weight

gives better income. Favourable taper ratio, low peel weight and core weight and high juice content is advantageous for the purpose of processing. High ascorbic acid content is advantageous in terms of nutrient status. Bright attractive colours are ideal for marketing of the fruits in the fresh fruit market. Colour of pulp is very much considered in both fresh fruit market and in the processing industry.

The comparative study showed that there was no two similar genotypes when several favourable characters were considered simultaneously (Table 4). None of the types were having all the desirable characters but all are having four or more desirable characters.

These results showed that the genotypes selected for hybridization were genetically diverse and all the desirable characters are available among the six genotypes, but distributed in different genotypes in various proportions. Hence it was expected that hybrids with maximum number of desirable characters could be obtained by crossing the six parental genotypes in all possible combinations. According to Chan (1986), with clear objectives and judicious selection of the parents, the F_1 population would present a spectrum of variation within which the desired improved genotypes may be found. Hybridization presents an extremely valuable method in generating widely variable genotypes through gene recombination in pineapple.

5.2. Study of the Floral Biology

The investigations on floral biology provide the basic information for the successful hybridization programme. As a first step, the number of flowers opened per day, number of flowers per inflorescence and the number of days for completion of flower opening were studied in the six genotypes.

5.2.1. Flower production and anthesis

Among the six genotypes, the mean number of flowers opened per day varied from 5.60 in Pampakuda local to 8.72 in Ripley Queen. Collins (1960) and Purseglove

(1975) reported 5 to 10 flowers opened in pineapple inflorescence in one day whereas Gopimony *et al.* (1976) observed 4 to 11 flowers opening per day in Kew.

The results of the present study and the reported findings indicated that the number of flowers opened per day was a varietal character and it did not vary much depending on the environmental factors.

The mean number of flowers per inflorescence ranged from 97.08 in Pampakuda local to 149.38 in Ripley Queen. According to the earlier studies reported, the number of flowers per inflorescence was 150 in Smooth Cayenne (Collins, 1960), 100 to 200 (Purseglove, 1975), 100 to 180 (Gopimony *et al.* 1976) and 75 to 150 (Chan, 1986). The highly variable value for number of flowers per inflorescence observed in the present study and reported by various studies earlier indicated that this character was highly dependant on both varieties and environmental conditions.

The significant difference between the genotypes with regard to the number of flowers opened per day and the number of flowers per inflorescence and the non-significance among the genotypes with regard to the number of days for completion of flower opening showed that the rate of flower opening was slow in Pampakuda local (5.60) and Kakkoor local (5.62). The fastest rate was observed in Ripley Queen as it was having the maximum number of flowers opening per day (8.72) and number of flowers per inflorescence (149.38), but it was statistically on par with Mauritius, Kew and Selection-1 (Table 5).

In the present study, the mean number of days for completion of flower opening ranged from 17.13 in Ripley Queen to 18.23 in Selection-1 and there was no significant difference between the six genotypes in this character. Purseglove (1975) recorded 10 to 20 days period whereas Gopimony *et al.* (1976) observed 10 to 15 days and consider it as much shorter than under Hawaiian conditions. The results of the present study and previous reported studies indicated that the number of days for completion of flower opening in pineapple was independent of the varieties, environment, number of flowers opened per day and the total number of flowers in an inflorescence.

The number of flowers opened on each day and the percentage of the total number of flowers opened on each day showed that maximum number of flowers opened during the second week and in any breeding programme, the second week after the initiation of flower opening was more important as maximum number of flowers for crossing will be obtained during this period.

The sequence of opening of flower from the base to upwards spirally suggest that it was a continuation of the spiral arrangement of the leaves on the stem (Collins, 1960 and Purseglove, 1975). The older flowers are on the base of the inflorescence and the younger flowers formed in continuation are arranged towards the upper portion and hence the older flowers will open first followed by the younger ones.

The flowers open during 4 am to 5 am in the case of Mauritius, Kew, Selection-1 and Ripley Queen and during 5 am to 6 am in the case of Pampakuda local and Kakkoor local. Thus there was variability with regard to the time of flower opening among the genotypes.

The anthers dehisce during 4 am to 5 am in the case of Mauritius, Kew, Selection-1 and Ripley Queen and during 5 am to 6 am in the case of Pampakuda local and Kakkoor local. Hence there was variability with regard to the time of anther dehiscence among the genotypes.

The study on the time of flower opening and anther dehiscence showed that flower opening and anther dehiscence occur simultaneously and the flowers opened during 4 am to 6 am, started withering by 4 pm and started closing by 6 pm (Plate 20). Gopimony *et al.* (1976) reported that flower opening in Kew was between 4.15 am and 5 am and the anther dehiscence coincides with the time of flower opening. Collins (1960) and Purseglove (1975) described that pineapple flowers opened and anther dehisced in the early forenoon, began to wither in late afternoon and closed by sunset. The result of the present study further confirms that the flower opening and anther dehiscence occur simultaneously even if there was variation in the time of flower

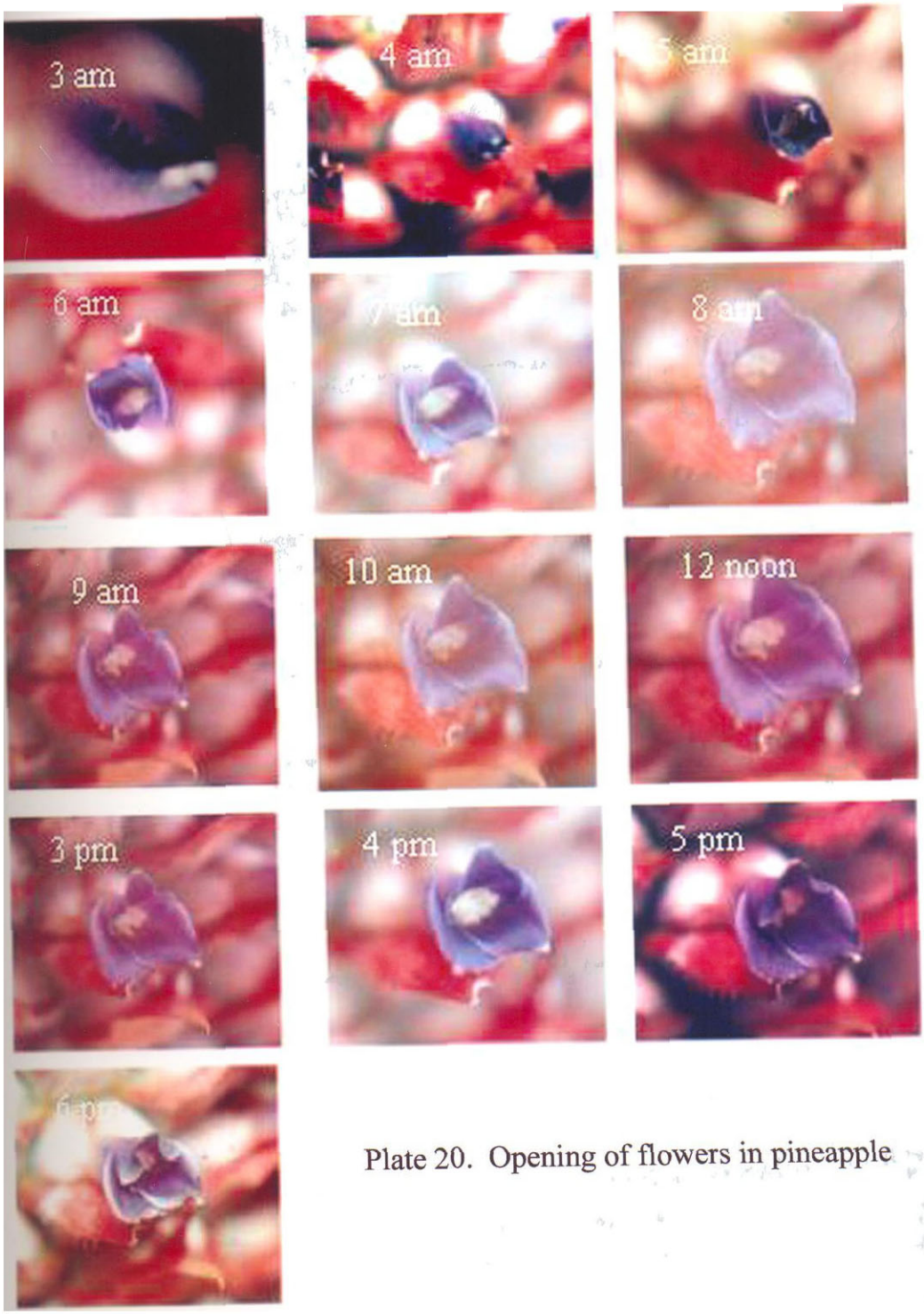


Plate 20. Opening of flowers in pineapple

opening in one genotype from the other. The Pampakuda local and Kakkoor local are distinct from the rest four with regard to anthesis.

5.2.2. Pollen fertility and viability

Staining of pollen using acetocarmine showed that the genotypes PKDA, KKR, Mauritius and RQ were having higher level of fertile pollen whereas Kew and S-1 were having very low pollen fertility. Zirkle (1937) described that properly stained plumpy and well developed pollen grains as viable and the shriveled ones as non viable. Singh and Dutta (1965) observed that Smooth Cayenne was having only 17 to 22 % non-viable pollen. Ramirez (1966) suggested pollen fertility as a means for selecting male parents in pineapple breeding. Bhowmik and Bhagabati (1975) reported the presence of 27.85 to 89.5% fertile pollen in Kew variety.

5.2.3. Duration of receptivity of stigma

Percentage of flowers with seed set, number of seeds per pollinated flower and number of seeds per successful cross when pollinated at different time intervals were taken as a measure of the duration of the receptivity of stigma and fertility of the flowers. Hence pollination was done at hourly interval in all the six genotypes from 3 am to 6 pm. Seed set was observed in all the genotypes during the entire time interval from 3 am to 6 pm. However, comparatively low number of flowers with seed set was observed during 3 am to 4 am in Mauritius and Ripley Queen and during 5 pm to 6 pm in Mauritius and Kakkoor local. This showed that there might be varietal variation in the time of receptivity of the stigma. The result of the present study proved that seed set could occur in all the six genotypes during the entire time interval of 3 am to 6 pm with slight variation between genotypes and with variation at different time intervals probably due to variation in temperature.

In general all the six genotypes produced maximum seeds when pollinated during forenoon hours. There was a decreasing trend during afternoon with regard to the number of flowers with seed set, number of seeds per pollinated flower and number

of seeds per successful cross indicating that hybridization in the forenoon hours was more effective than during afternoon hours. This may be due to the increased day temperature in the afternoon hours and subsequent wilting of the flower. The number of seeds per successful cross was of the same pattern as that of the number of seeds per pollinated flower.

Chan (1986) reported that fertilization and seed set could occur satisfactorily throughout the entire length of the day with slight variation possibly due to temperature influences. It was further explained that seed set might be variable depending on the time of day the pollination was effected. Successful pollination and seed set may be temperature related with higher seed set obtained per pollination done during early morning or cooler evening. Poorer seed set was recorded when pollination was done at noon or in the early afternoon. But the results of the present study showed that successful pollination could be done from early morning at 3 am and continued up to 6 pm. Gopimony *et al.* (1976) found that hand pollination in Kew can be done conveniently at any time during morning hours from 4.15 am to 10.45 am for maximum seed production in Vellanikkara condition.

The receptivity of the stigma in the six genotypes was compared with open pollinated and self pollinated conditions. It was found that Selection-1 and Ripley Queen are completely self incompatible as there was no seed set at all. But Pampakuda local showed high (25.8 %)and very high (87.6%) seed set under self and open pollinated conditions respectively indicating that some amount of self compatibility occurs in Pampakuda local.

5.3. Hybridization and Production of Hybrids

5.3.1. Hybridization

For crossing the selected six genotypes in all possible combinations, bagging of the inflorescence was done prior to the beginning of flower opening. The general suggestion was that bagging was not necessary in pineapple due to the absence of

natural cross pollination (Collins, 1960). But Chan (1986) pointed out the danger of mixed cropping of highly compatible varieties that may produce seedy fruits. Bagging was done in the present study because in the natural situation, it was not rare to find a few seeds in fruits especially in Kew and Mauritius in the flowers at the basal part of the fruit, in Vazhakulam area. It was assumed that these seeds were produced by cross pollination probably by bees or by ants. The bees approach the flowers at the base of the inflorescence usually over the opened petals first for honey as the leaves just below it forms a circle around the inflorescence and cover it in the base at the initial stage of the development of the inflorescence. In this situation there is a chance that the bees may rest on the petals and probe through the corolla tube for honey paving the way for bringing foreign pollen into contact with the stigma. Cross pollination may also occur through ants, as the ants visit the inflorescence at the time of flower opening and they may bring pollen from one plant to another. They come from the base and reach the basal flower first. It was also observed that ants and snails eat the flower and destroy petals, anthers, stigmas etc. Hence protection against ants and snails was given by applying insecticides at frequent intervals. Wee and Rao (1974) reported that honey bees and pineapple beetles occasionally effect cross pollination between different compatible cultivars if they are grown near each other.

Among the thirty cross combinations attempted, four crosses, viz., K x S-1, S-1 x K, M x RQ and RQ x M were incompatible and for another four crosses, where Ripley Queen was used as female parent, sufficient seeds could not be obtained due to crop failure. Hybrid seeds were obtained only in the remaining 22 crosses for further studies.

5.3.2. Seed set and seed production

In the 22 successful cross combinations, all the four crosses where Mauritius was used as female parent and the cross PKDA x M were found to have high values for percentage of flowers with seed set, number of seeds per pollinated flower, number of seeds per successful cross and percentage of bold seeds out of total seeds and low value for percentage of shriveled seeds out of total seeds. The values were low for the cross

KKR x PKDA and comparatively low for its reciprocal. This showed that some amount of incompatibility occurs between Kakkoor local and Pampakuda local. Even though the values for M x K was high, its reciprocal K x M recorded comparatively low values for percentage of flowers with seed set, number of seeds per pollinated flower, number of seeds per successful cross and percentage of bold seeds out of the total seeds, indicating differential seed set depending on the pollen source.

It was observed that Mauritius was the most compatible pistillate parent for hybridization with Kew, PKDA local, KKR local and S-1. The high value for M x PKDA and its reciprocal indicated that Mauritius and Pampakuda local are the most compatible parents among the six genotypes used in the study.

In a study involving four genotypes, Chan (1986a) reported that differential seed set by female and male sources and their interactions were observed. One way compatibility was also reported. He also pointed out the danger of mixed cropping of highly compatible varieties that may produce seedy fruits. Differential seed set and bold seed production, due to variation in cross compatibility depending on the pollen and pistillate parents, was earlier reported by Bhowmik and Bhagabati (1975), Gopimony *et al.* (1976), Chan (1993) and Radha *et al.* (1994).

5.3.3. Germination of hybrid seeds

The seed coat of pineapple seed was very hardy and hence seed treatments like scarification, acid treatment or incubation was recommended, for uniform and quick germination, by earlier workers like Collins (1960), Gopimony *et al.* (1976a) and Chan (1986). However, seed treatment was not adopted in the present study so as to get information on any differential seed germination pattern between cross combinations.

The results of the germination of seeds showed that the bold seeds germinate uniformly irrespective of the cross combinations. As the major part of the seeds produced were bold seeds, this trend of uniform germination irrespective of cross combination was reflected in the same pattern in the germination of the total seeds.

There was significant difference between the cross combinations with regard to the percentage of germination of shriveled seeds. Shriveled seeds consisted of unfilled and partially filled seeds. The partially filled seeds are at different levels of filling. The difference between the cross combinations with regard to the percentage of germination of shriveled seeds indicated that there was difference between cross combinations with regard to the development of seed from the stage of its formation to maturity, probably due to the difference in the cross compatibility and post fertilization physiology.

With regard to the duration for completion of germination of seeds, all the crosses where Mauritius was used as pistillate parent took maximum time. This might probably be due to the reason that maximum number of seeds germinated in these crosses and as the genotypes are highly heterozygous, each seed is unique and behaved independently.

The germination of seeds started in the second week after sowing in six crosses, during the third week in fifteen crosses and in one cross during fourth week. Maximum germination occurred in the fourth week in all the crosses and thereafter it decreased and continued up to seventeenth week in the cross M x S-1.

5.3.4. Percentage of albino seedlings

When the seeds germinated, albino seedlings were observed in many crosses. In the hybrid progenies of pineapple albino seedlings was reported by Chan (1986) also. Production of albino seedlings can be taken as a measure of incompatibility. Maximum number of albino seedlings was observed in the cross PKDA x KKR and its reciprocal indicating a higher level of incompatibility between PKDA and KKR. There was no albino seedling in all the crosses where Kew was used as pistillate parent. Very low number of albino seedlings was observed in crosses where S-1 was used as pistillate parent. These results indicated that Kew followed by S-1 were the most compatible pistillate parents, with regard to this character, among the six genotypes studied.

5.3.5. Self incompatibility and cross compatibility studies

Selection-1 and Ripley Queen were self-incompatible as there were no flowers with seed set under self-pollinated conditions. Very low seed set under self-pollinated condition was observed in Mauritius (2.9 %) and Kew (0.7%), indicating that self-incompatibility existed in these two genotypes also. Seed set was observed in 25.8% flowers in PKDA and 11.9 % flowers in KKR under self-pollination indicating some amount of self-compatibility in these two genotypes (Table 10). Majumder *et al.* (1964) found that Smooth cayenne and three other varieties were highly self-incompatible while results with one variety were variable. Bhowmik (1982) reported that self-pollination within four clones (Kew, Queen, hybrid Kew x Queen and hybrid Queen x Kew) did not produce any seeds. Collins (1960), Marr (1964) and Purseglove (1975) reported that all varieties of *Ananas comosus* produced functional germ cells, but could not be self fertilized. Self incompatibility in pineapple was reported by Simmonds (1976), Brewbaker and Gorrez (1967) and Coppens *et al.* (1993).

Cross incompatibility was observed in four crosses involving four genotypes. The crosses K x S-1 and M x RQ and their respective reciprocal crosses were incompatible. The cross RQ x M was totally incompatible whereas its reciprocal M x RQ was having 3.5 percent flowers with seed set (Table 19). The cross S-1 x K with 4.1 percent and its reciprocal K x S-1 with 1.45 percent flowers with seed set was observed. Among the incompatible crosses, bold seeds was obtained only from the cross K x S-1 and its reciprocal. Out of the three incompatible crosses from which few seeds obtained, only the bold seeds of S-1 x K germinated. Chan (1986) observed differential seed set influenced by female and male sources and their interaction. He also observed one way compatibility for two sets of crosses. Bhowmik (1982) reported that reciprocal crosses between hybrids as well as back crosses in four clones (Kew, Queen, hybrid Kew x Queen and hybrid Queen x Kew) did not produce any seeds. Collins (1960), Marr (1964) and Purseglove (1975) reported that all varieties of *Ananas comosus* produced functional germ cells, but could not be self fertilized but most of them were cross compatible and sets seeds when cross pollinated. In the genotypes used for the present study, Kew was spineless whereas S-1 was spiny. With regard to

Mauritius and Ripley Queen, Ripley Queen was having a short stature and smaller fruit than Mauritius, showing that all the four have distinct characters. However, the cross incompatibility of K x S-1 and M x RQ and their respective reciprocal crosses confirmed that Kew and Selection-1 as well as Mauritius and Ripley Queen were genetically not much diverse even though they exhibited some variation in morphological and quantitative characters.

In the present study, the genotype Mauritius expressed maximum compatibility as a pistillate parent with all the other five genotype as pollen parent by showing more than 90 percent flowers with seed set (Table 13). M x PKDA and its reciprocal was the most compatible cross among all the thirty crosses tried, as it showed high percentage of flowers with seed set, with 97 percent and 88.65 percent respectively. The genotype KKR as pistillate parent with PKDA as pollen parent was less compatible as it showed only 39.75 percent flowers with seed set. None of the seedlings in PKDA x KKR survived up to 18 months (Table 20) and highest percentage of albino seedlings (28.74%) was also observed in this cross (Table 18). This might be probably due to incompatibility expressed in seedling stage. The cross S-1 x M was considered less compatible as it produced lowest percentage of bold seeds (40.2%) and highest shriveled seeds (59.8%). Cross-compatibility studies by Bhowmik and Bhagabati (1975) revealed that 39.09 % of bold seeds were formed when Kew was the female parent and 73.88 % when Queen was the female parent. In a cross compatibility study involving four genotypes, Gopimony *et al.* (1976) also reported variable compatibility depending on the crosses.

5.4. Evaluation of Hybrids

Percentage of seedlings survived at the stage of planting out and at intervals of 6, 12, 18 and 24 months after planting out

The data on the percentage of seedlings survived at different intervals showed that in all the crosses large number of seedlings died during the early stages of establishment, ie., from the stage of planting in the secondary nursery through the tertiary nursery till 18 months growth stage (Table 20). None of the seedlings of the

crosses where Ripley Queen was used as pollen parent survived up to 6 months except in the cross KKR x RQ and PKDA x RQ wherein only less than 2 % of the seedlings survived. These seedlings also did not survive up to 12 months. None of the seedlings of the cross PKDA x KKR survived up to 18 months and only a few seedlings of its reciprocal survived up to 18 months. After 18 months, death of seedlings was not observed in any of the cross combinations.

Maximum survival (76.05 %) was obtained in the cross PKDA x S-1 followed by KKR x S-1 (62.45 %). Apart from the complete death of seedlings in the five crosses, only less than 10 % of the seedlings survived in M x PKDA and PKDA x K. Radha *et al.* (1994) reported that only 2.5 % of the seedlings survived after six months in K x RQ. The high rate of mortality in seedlings from crosses involving Ripley Queen might be due to incompatibility expressed at the seedling stage. This suggests that Ripley Queen was not an ideal genotype for hybridization.

Further evaluation was carried out on each individual plant in each cross combinations and it was exceedingly tedious considering the large F_1 population grown for the purpose. All cross combinations were compared for the thirty five characters studied, using mean, range, percentage of variation, mode, mean deviation from mode and coefficient of dispersion, to find out the cross having maximum number of desirable characters for further selection of better hybrids.

5.4.1. Genetic variability between and within cross combinations

All the cross combinations were evaluated for their performance in various characters.

1. *Cross KKR x S-1*

The cross combination KKR x S-1 showed highest value of mean for *p*H of fruit juice; range for fruit weight without crown, girth of fruit at middle, brix/acid ratio and acidity of the juice; percentage of variation for fruit weight without crown, total sugars, non reducing sugars, girth of fruit at middle, brix/acid ratio and acidity of the juice;

mean deviation from mode for fruit girth, sugar/acid ratio and brix/acid ratio and coefficient of dispersion for total sugars, fruit girth, sugar/acid ratio and brix/acid ratio. The result indicated that selection for higher fruit weight might be possible in this cross. Chan (1989) observed higher values for range of fruit weight in the F_1.

2. *Cross KKR x M*

The cross combination KKR x M showed maximum value of mean for *p*H of the juice and number of suckers; range for length of peduncle; mode for fruit weight without crown, *p*H of the juice, brix/acid ratio and taper ratio; mean deviation from mode for fruit weight without crown and canning ratio and coefficient of dispersion for peel/pulp ratio.

3. *Cross KKR x K*

The cross combination KKR x K expressed maximum value of mean for juice weight percentage; range for duration from planting to beginning of inflorescence development and juice weight percentage; percentage of variation for fruit weight with crown, duration from planting to beginning of inflorescence development and duration of the crop; mode for duration from beginning to full development of inflorescence; mean deviation from mode and coefficient of dispersion for peel weight percentage, fruit development period and duration of the crop. Scope for selection of a short duration crop is high in this cross as the range for this character was high.

4. *Cross S-1 x KKR*

The cross combination S-1 x KKR expressed highest value of mean for height of the plant, number of slips per plant (Plate 21), length of fruit, girth of fruit at middle, fruit development period, L/B ratio, period from opening of first flower to last flower and period from opening of last flower to harvest; mode for height of the plant, length of peduncle, fruit development period, L/B ratio, period from opening of last flower to harvest; mean deviation from mode for length of peduncle and coefficient of dispersion for number of leaves. In the cross S-1 x KKR, slips were observed on the fruit eyelets also. Chan (1989) was of the opinion that the increased tendency for the production of

Plate 21. Production of slips among hybrids in S-1 x KKR

vegetative propagules in pineapple hybrids may be a natural reaction for dissemination of the species.

5. *Cross S- 1 x M*

The cross combination S-1 x M was having maximum value of mean for core weight percentage, period from full development of inflorescence to first flower opening, peel weight percentage and peel/pulp ratio; mode for core weight percentage, duration from beginning to full development of inflorescence, duration from full development of inflorescence to first flower opening and peel weight percentage; mean deviation from mode for fruit weight with crown, total sugar and L/B ratio and coefficient of dispersion for L/B ratio. Higher values of mean and mode for core weight % and peel weight % showed limited scope for selection for quality of fruit in this cross.

6. *Cross S-1 x PKDA*

The cross S-1 x PKDA was having progenies with highest values of mean for fruit weight with crown, fruit weight without crown and fruit breadth; mode for duration from full development of inflorescence to first flower opening, number of leaves, pulp percentage and crown weight percentage; mean deviation from mode for core weight percentage, pulp weight percentage and taper ratio and coefficient of dispersion for core weight percentage and pulp weight percentage. Higher mean value for fruit weight and fruit breadth indicated the scope for selection of hybrids with higher fruit yield.

7. *Cross M x S-1*

The progenies of the cross M x S-1 showed maximum value of range for pulp weight percentage and length of fruit; percentage of variation for length of peduncle and pulp weight percentage; mode for brix/acid ratio and acidity of juice and coefficient of dispersion for fruit weight without crown and duration from beginning to full development of inflorescence.

8. *Cross M x KKR*

The progenies of the cross M x KKR showed maximum value of mean for total sugar and fruit length; range for ascorbic acid, duration from beginning to full development of inflorescence, duration from full development of inflorescence to first flower opening, TSS, crown weight percentage (Plate 22), fruit development period and opening of last flower to harvest; percentage of variation for duration from beginning to full development of inflorescence, duration from full development of inflorescence to first flower opening, length of fruit, sugar/acid ratio, TSS, crown weight percentage, fruit development period, duration from opening of first flower to last flower and duration from opening of last flower to harvest; mode for canning ratio; mean deviation from mode for period from planting to beginning of inflorescence development and ascorbic acid and coefficient of dispersion for length of peduncle. Selection for higher TSS, total sugar and ascorbic acid content is possible in this cross as it expressed a wide range of values for TSS and ascorbic acid and high mean value for total sugar.

9. *Cross M x K*

The cross M x K was having highest values of mean for reducing sugar, non reducing sugar, sugar/acid ratio, brix/acid ratio, TSS and acidity of juice; range for duration from beginning to full development of inflorescence, total sugar, reducing sugar, non reducing sugar, sugar/acid ratio, peel weight percentage, peel/pulp ratio, breadth of fruit, L/B ratio, taper ratio (Plate 23) and duration of crop; percentage of variation for ascorbic acid, reducing sugar, juice weight percentage, peel weight percentage, peel/pulp ratio, breadth of fruit, L/B ratio and taper ratio; mode for total sugar and duration from beginning to full development of inflorescence; mean deviation from mode and coefficient of dispersion for reducing sugar. This cross M x K provided excellent scope for selection for most of the fruit quality parameters as it showed high mean values for those characters.

10. *Cross M x PKDA*

The cross combination M x PKDA was having maximum values of range and percentage of variation for *p*H of the juice and number of leaves; mode for ascorbic acid and brix/acid ratio; mean deviation from mode and coefficient of dispersion for

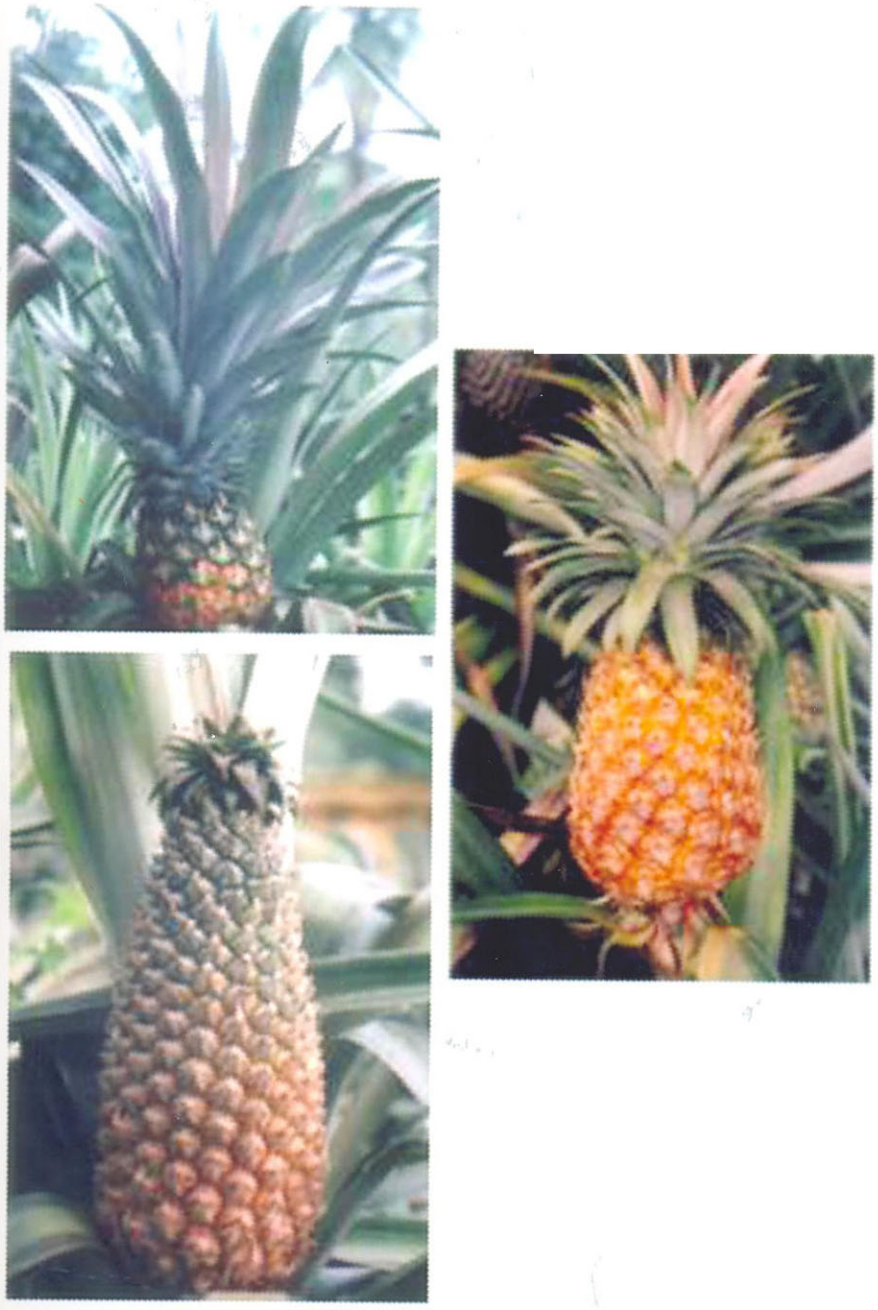


Plate 22. Variability in the size of crown among hybrids in M x KKR

Plate 23. Variability in size and shape of fruit and its eyes

length of fruit. Valsamma *et al.* (1979) reported that in a study involving 19 genotypes, the number of leaves per plant was influenced by environmental effect.

11. *Cross PKDA x S-1*

The cross combination PKDA x S-1 showed maximum values of range and percentage of variation for height of the plant (Plate 24) and number of suckers per plant; mode for girth of fruit at middle and juice weight percentage; mean deviation from mode for *p*H of juice, juice weight percentage, acidity of juice and crown weight percentage and coefficient of dispersion for *p*H of juice, crown weight percentage and taper ratio. Possibility for getting a plant with short stature is high in this cross as it showed wide range for height of the plant.

12. *Cross PKDA x K*

The cross PKDA x K showed highest value of mean for duration from beginning to full development of inflorescence and pulp weight percentage; mode for duration from beginning to full development of inflorescence, length of fruit, canning ratio, duration from opening of first flower to last flower and duration of crop; mean deviation from mode for duration from beginning to full development of inflorescence, TSS, peel/pulp ratio and duration from opening of last flower to harvest and coefficient of dispersion for TSS and duration from opening of last flower to harvest. Selection for the commercially important character pulp weight % is possible in this cross as it showed high mean value.

13. *Cross PKDA x M*

The cross PKDA x M showed maximum value of mean for ascorbic acid; range for fruit weight with crown and core weight percentage; percentage of variation for core weight percentage; mode for duration from beginning to full development of inflorescence and sugar/acid ratio and mean deviation from mode for canning ratio. The mean value for ascorbic acid content was high in this cross indicating the possibility for selecting plants with high ascorbic acid content. Marie *et al.* (2000) obtained hybrids with high ascorbic acid content in a hybridization programme.

Plate 24. Variability in height among hybrids

14. *Cross K x KKR*

The cross K x KKR showed highest value of mean for length of peduncle, core weight percentage and taper ratio; mean deviation from mode for canning ratio and coefficient of dispersion for ascorbic acid, non reducing sugar and canning ratio.

15. *Cross K x M*

The cross K x M showed highest value for duration from planting to beginning of inflorescence development, number of leaves and duration of crop; range for duration from full development of inflorescence to first flower opening, canning ratio and opening of first flower to last flower; percentage of variation for number of slips and canning ratio; mode for duration from planting to beginning of inflorescence development, duration from beginning to full development of inflorescence, reducing sugar, non reducing sugar and TSS; mean deviation from mode for duration from full development of inflorescence to first flower opening, height of the plant, number of leaves, non reducing sugar, breadth of fruit and duration from opening of first flower to last flower and coefficient of dispersion for fruit weight with crown, duration from full development of inflorescence to first flower opening, height of the plant, breadth of fruit and duration from opening of first flower to last flower. The possibility for getting hybrids with high TSS content is high in this cross as it showed high mode value.

16. *Cross K x PKDA*

The cross K x PKDA showed maximum value of mean for peel/pulp ratio; mode for fruit weight with crown, peel/pulp ratio and breadth of fruit and coefficient of dispersion for juice weight percentage and acidity of juice.

Evaluation of the hybrids based on the variability parameters, viz., mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion indicated that the F_1's vary widely in all the crosses and between cross combinations. The range of characters in all cross combinations showed that all the characters express transgressive segregation. The result further showed that it might be difficult to select out any of the cross combinations as the best for all the characters, based on all or any one of the variability parameters. Hence it may not be

possible to get any hybrid, from any one of the hybrid combinations, having all the desirable characters. These hybrids of pineapple in a genetic sense can as well be considered as recombinants. Collins (1960) and Chan (1989) suggested that the breeder should establish minimum selection standards for the important plant and fruit characters so as to select hybrids with an acceptable balance of desirable characters. In pineapple, five characters, viz., fruit weight without crown, TSS, total sugar, pulp weight percentage and juice weight percentage, can be considered as the most important ones when the interests of the processing industry, fresh fruit market and the farmer who produce it were taken into account.

All the sixteen cross combinations were further explored for maximum values of mean, range, percentage of variation, mode, mean deviation from mode and coefficient of dispersion for the selected five characters, viz., fruit weight without crown, TSS, total sugar, pulp weight percentage and juice weight percentage. The comparison showed (Table 66) that none of the cross combinations expressed maximum value for all the five selected characters in any of the variability parameters. Similarly, none of the characters showed maximum values in all the variability parameters studied in the same cross combination.

The result suggested that selection of pineapple hybrids based on several characters simultaneously by applying the variability parameters, viz., mean, range, percentage of variation, mode, mean deviation from mode and coefficient of dispersion, in any of the cross combinations was not that effective. However, the result further indicated that selection of hybrids best for any particular character was possible from a particular cross combination when screened for that particular character only. But this selection might not result in getting a best pineapple hybrid, as the selected plant might be good in one character but may be poor in other characters making it unattractive in all respects. Coppens and Duval (1995) observed that hybridization produce a much wider genetic variability because of the high heterozygosity of parents and the high recombination rate. They also observed that most varieties bring more negative traits than positive traits and the hybrids exhibiting good combinations are extremely rare.

Table 66. Cross combinations showing highest values for five selected characters

Characters	Crosses showing higher values of					
	Mean	Range	Percentage of variation	Mode	Mean deviation from mode	Coefficient of dispersion
Fruit weight without crown	S-1 x PKDA	KKR x S-1	KKR x S-1	KKR x M	KKR x M	M x S-1
TSS	M x K	M x KKR	M x KKR	K x M	PKDA x K	PKDA x K
Total sugar	M x KKR	M x K	KKR x S-1	M x K	S –1 x M	KKR x S-1
Pulp weight percentage	PKDA x K	M x S-1	M x S-1	S-1 x PKDA	S-1 x PKDA	S-1 x PKDA
Juice weight percentage	KKR x K	KKR x K	M x K	PKDA x S-1	PKDA x S-1	K x PKDA

Moreover, it is indicated that in the F_1 population of pineapple, each individual plant is unique due to the independent segregation of each character, probably due to the absence of linkage of genes controlling those characters. This was also due to the highly heterozygous nature of pineapple. This heterozygous makeup and absence of linkage of genes permits the genotypes to express transgressive segregation in the F_1 generation itself. This heterozygous nature was maintained in the crop due to the vegetative propagation of the plant.

5.4.2. Multivariate analysis

Collins (1960) opined that seedling population in pineapple are genotypically different and such populations should not be expected to exhibit the uniformity of growth rate, plant size, maturity date etc. and in making original selections from large hybrid population, the breeder should establish minimum selection standards for the important plant and fruit characters. Chan (1986 and 1989) observed that hybridization presents an extremely valuable method in generating widely variable genotypes through gene recombination and this variation may be exploited in selection and development of new varieties. It is unlikely that all desirable characters would be found in any one individual in the F_1 population, and hence some form of selection index and weighing must be imposed for picking progenies with an acceptable balance of desirable characters.

With a view to study the variability among the hybrids and to explore the possibility to identify hybrids having the most desirable combination of characters, the following studies were attempted.

5.4.2.1. *Determinant of the covariance matrix*

Based on the five selected characters, viz., fruit weight without crown, TSS, total sugar, pulp weight percentage and juice weight percentage, variance and covariance and determinant of the variance and covariance matrix were estimated for

the sixteen cross combinations to get an index of variability for each of the cross combinations.

The result of the variance estimation showed highly variable values for fruit weight without crown, but for all other characters, relatively low values were observed. The covariance of the five characters showed a negative relationship between fruit weight without crown vs. TSS and total sugar and positive relation between fruit weight without crown vs. pulp weight percentage and juice weight percentage. Highest determinant value was observed in S-1 x M indicating maximum variability in that cross. The lowest determinant value was observed in M x KKR indicating minimum variability in that cross, among the sixteen cross combinations.

5.4.2.2. *Principal Component Analysis*

Principal Component Analysis was done using the selected five characters, viz., fruit weight without crown, TSS, total sugar, pulp weight percentage and juice weight percentage for all the sixteen cross combinations to estimate the variability among hybrids within a cross and select out an F_1 with favourable value for all the five characters or a group of F_1's with desirable characters. All the cross combinations showed more than 50 percent cumulative variance indicating high variability among hybrids in all cross combinations. The scatter diagram (Fig 1) for all the sixteen cross combination showed variability among hybrids and no definite grouping pattern was observed. Duval and Coppens (1993) observed three distinct groupings within *Ananas comosus* in a study involving 89 clones, by Principal Component Analysis.

5.4.2.3. *Euclidean distance*

The Euclidean distances among all the hybrids were also estimated for the sixteen cross combinations using the selected five characters, viz., fruit weight without crown, TSS, total sugar, pulp weight percentage and juice weight percentage and the average of distances showed very high variability between the hybrids in all the cross combinations. A comparison of the maximum of the average Euclidean distances of all

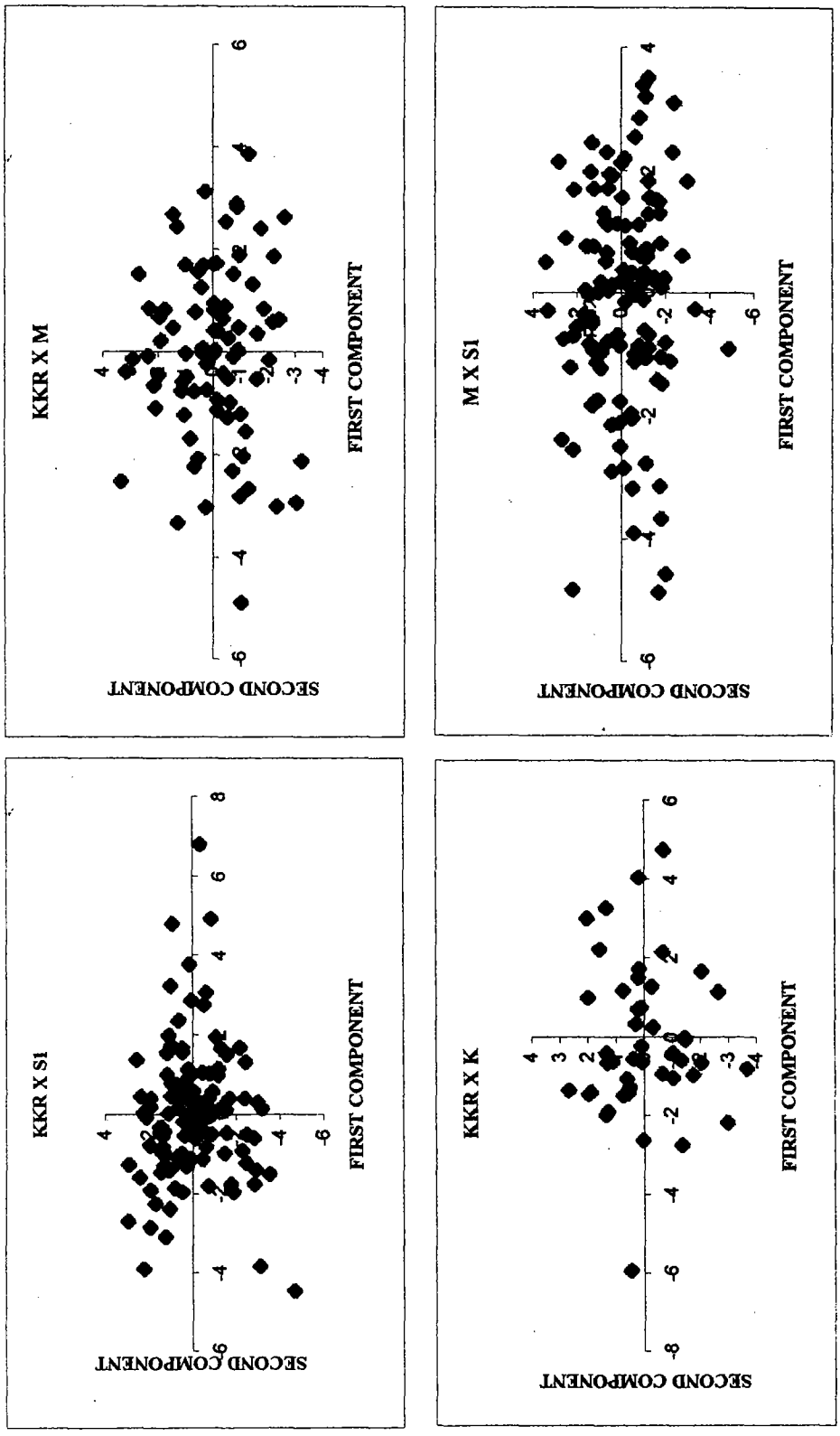
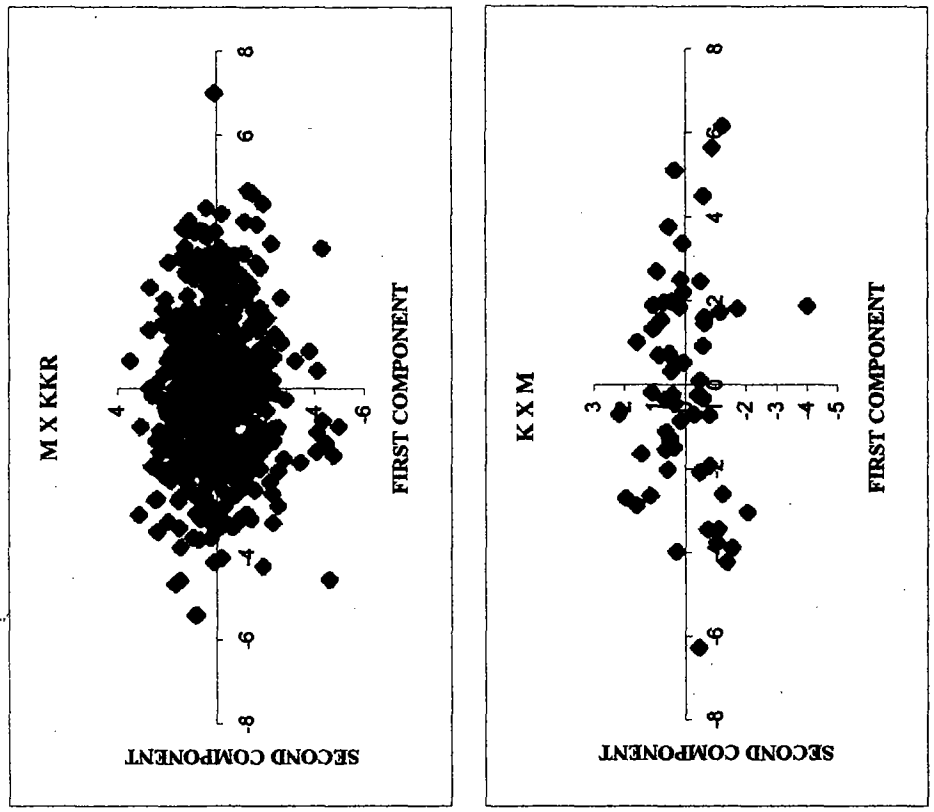
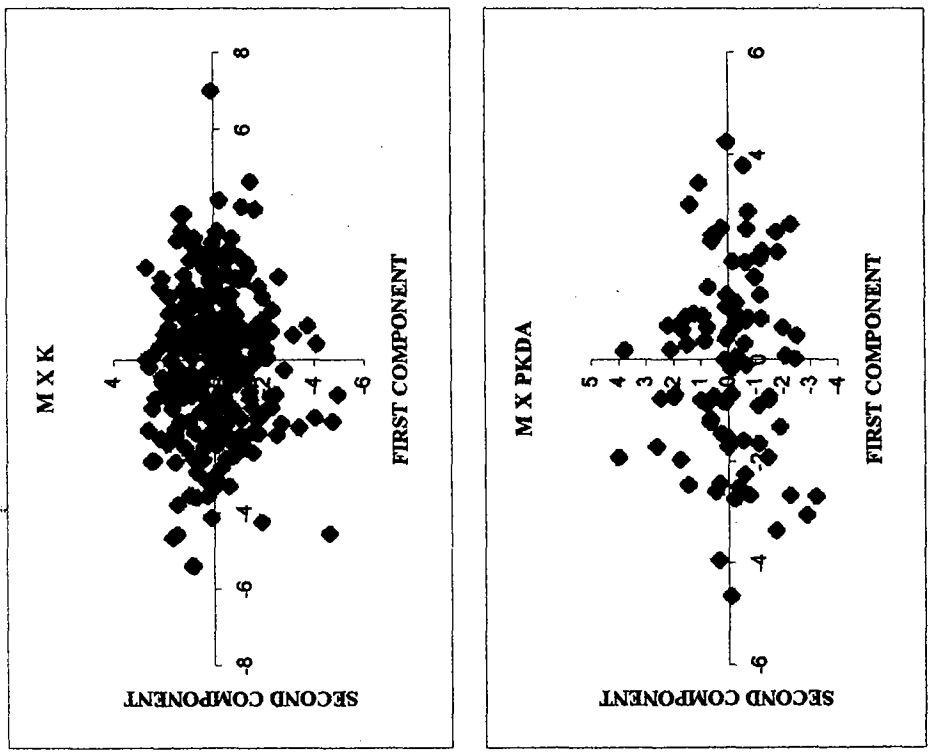


Figure 1. Scatter diagram showing the variability among hybrids in 16 cross combinations (Fig. 1 contd.)



(Fig. 1 contd.)



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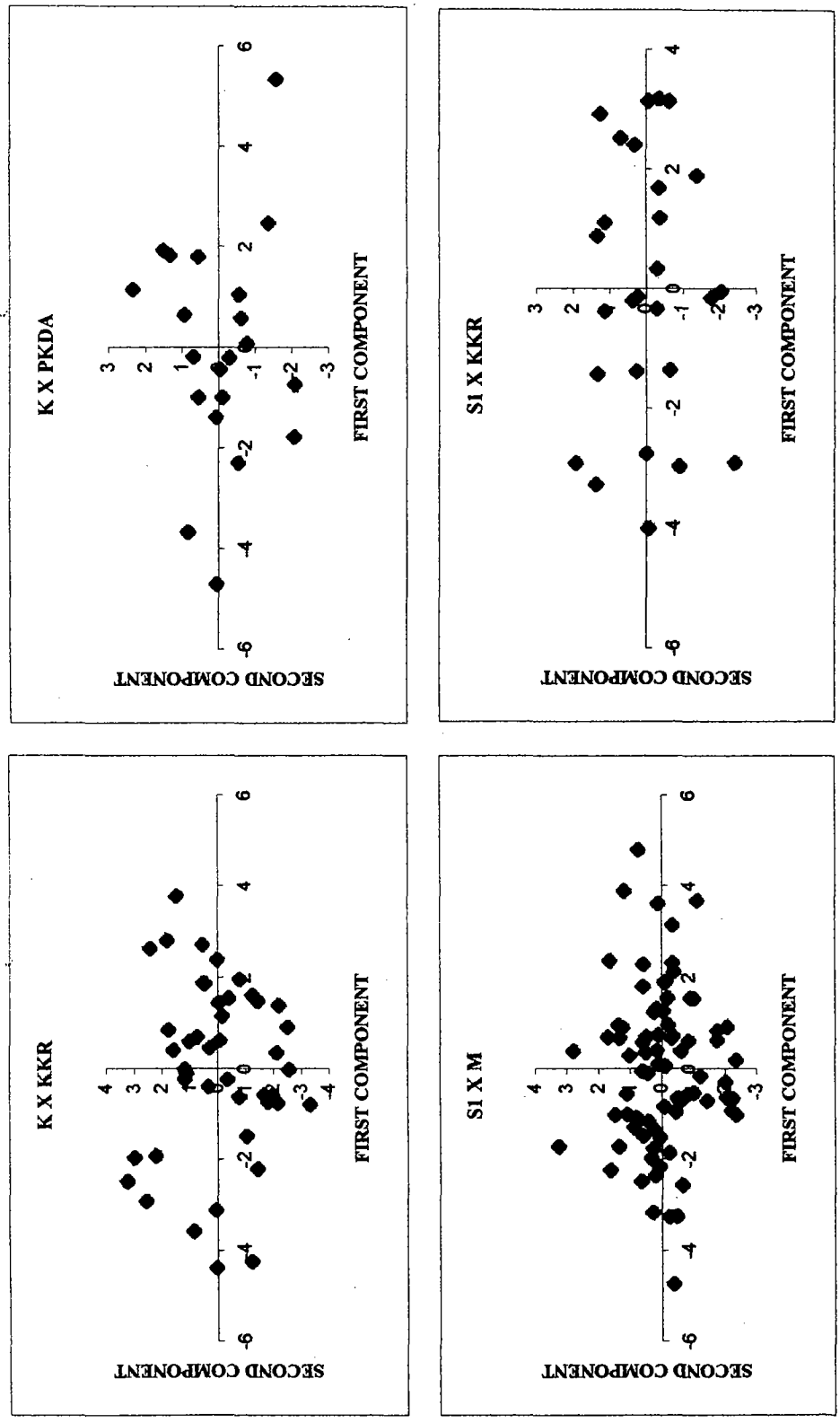

(Fig. 1 contd.)

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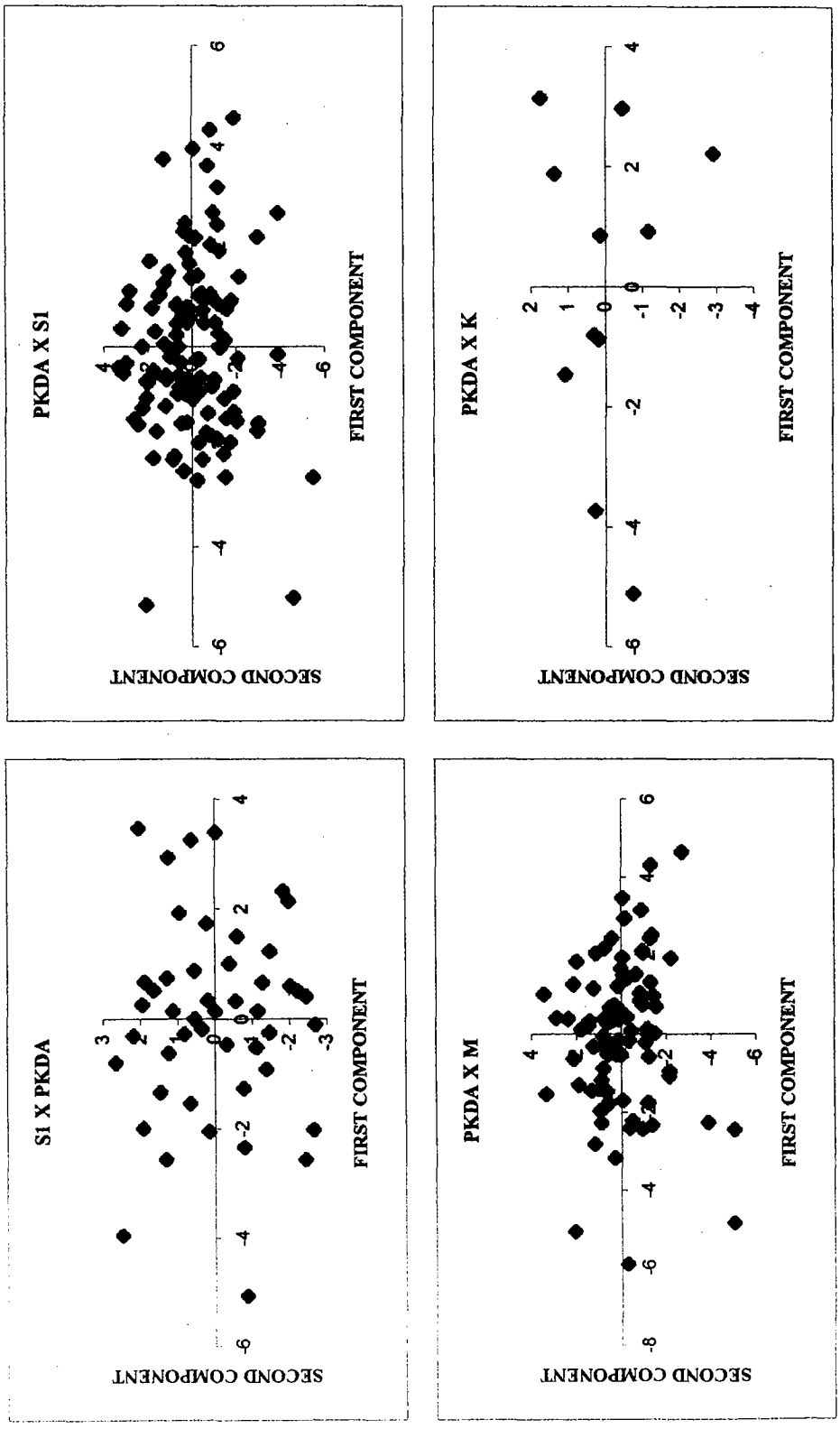
PKDA X S1
FIRST COMPONENT
SECOND COMPONENT
PKDA X K
FIRST COMPONENT
SECOND COMPONENT
S1 X PKDA
FIRST COMPONENT
SECOND COMPONENT
PKDA X M
FIRST COMPONENT
SECOND COMPONENT

(Fig. 1. Concld.)

the hybrids in each cross combination showed very high variability between cross combinations (Fig 2).

The evaluation of the cross combinations to find out the best cross combination suitable for selecting a pineapple with all or with selected characters using variability parameters like mean, range, percentage of variation, mode, mean deviation from mode and coefficient of dispersion indicated that the highest values of the selected characters were distributed in different cross combinations. An index of variability estimated by the determinant of the covariance matrix showed wide variability between cross combinations. Further, variability within cross combinations estimated by Principal Component Analysis showed no particular groupings in any of the cross combinations, based on the five selected characters. The Euclidean distances also showed high variability within a cross. All these methods clearly established the extent of variability within and between cross combinations. This also gave a definite picture about the possibility and scope for creation of genetic variability in pineapple for each character by adopting hybridization. All the characters expressed transgressive segregation and each character segregated independent of the other character. This phenomena made it difficult to pinpoint any particular hybrid having all the desirable characters together, based on the variability parameters applied.

5.4.3. Selection of desirable hybrids

Collins (1960) suggested selection of hybrids even from the nursery stage itself by removing the small, weak and slow growing seedlings at three stages before planting to main field. Chan (1986) suggested selection in nursery by removing seedlings showing poor vigour, albinism and spiny leaves. However, in the present study, no selection was exercised in the nursery stage based on vigour or any other criteria. This approach was taken in the present study on the assumption that seedling vigour or any such criteria need not be associated with the desirable characters for which selection is to be exercised at a later stage, because all the characters were found to express transgressive segregation independently. Hence all efforts were done to bring up

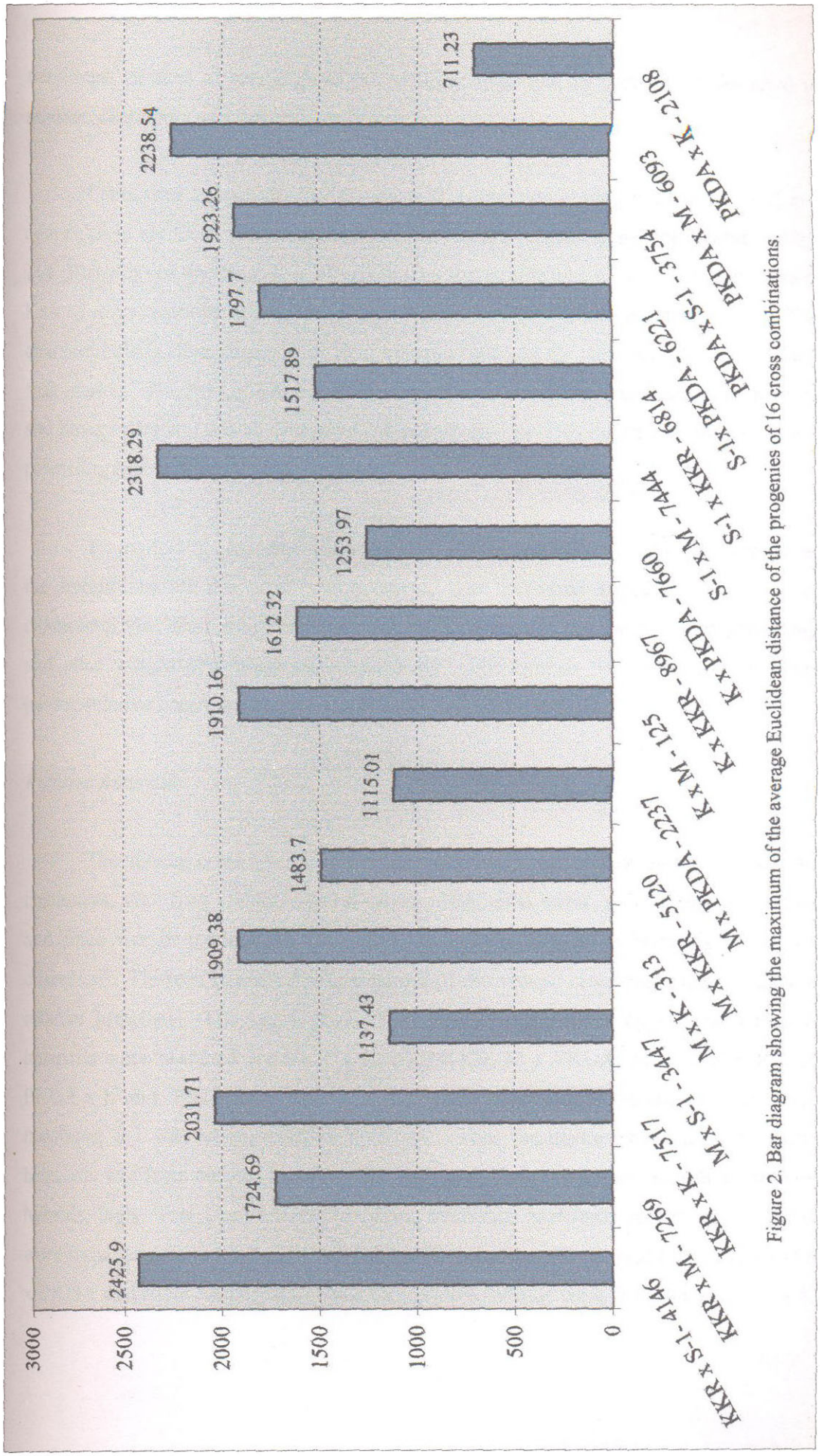

Figure 2. Bar diagram showing the maximum of the average Euclidean distance of the progenies of 16 cross combinations.

maximum number of seedlings to the yielding stage and to exert selection based on selected characters and general performance.

Cabot and Lacoeuilhe (1990) adopted a selection among hybrids to develop a new cultivar for fresh and processed market. In the present study, the hybrid number 214 (Plate 25) of the cross K x M was having the appearance of the plant characters of Kew (leaves without spines) and fruit characters of Mauritius (deep eye). This characteristic is advantageous for field management and for varieties intended for fresh fruit market. The fruit of this hybrid is very attractive catching the attention of anybody and have a pleasant aroma, but have comparatively low TSS limiting its direct use as a promising one.

To exploit the extreme variability created by the hybridization programme, all the hybrids in all the cross combinations were screened based on five selected characters, viz., fruit weight without crown, TSS, total sugar, pulp weight percentage and juice weight percentage, simultaneously. The hybrids were screened for plants having relative heterosis, heterobeltiosis and standard heterosis.

Relative heterosis

The sixteen cross combinations were evaluated simultaneously for five selected characters, viz., fruit weight without crown, TSS, total sugar, pulp weight percentage and juice weight percentage, to identify hybrids with relative heterosis for all the characters. Thirteen hybrids from seven out of the sixteen cross combinations showed relative heterosis. The seven cross combinations from which hybrids with relative heterosis were obtained are KKR x K, M x KKR, M x PKDA, M x K, K x PKDA, PKDA x K and PKDA x M. None of the hybrids from any of the cross combinations involving S-1 was having relative heterosis. Thus the thirteen hybrids with relative heterosis was from crosses involving the remaining four genotypes. Out of the thirteen hybrids, eight were from crosses involving Mauritius as female parent. Five hybrids were from the cross M x K alone and one each were from the crosses M x PKDA and K x PKDA and their reciprocals. Even though five hybrids were from the cross M x K,

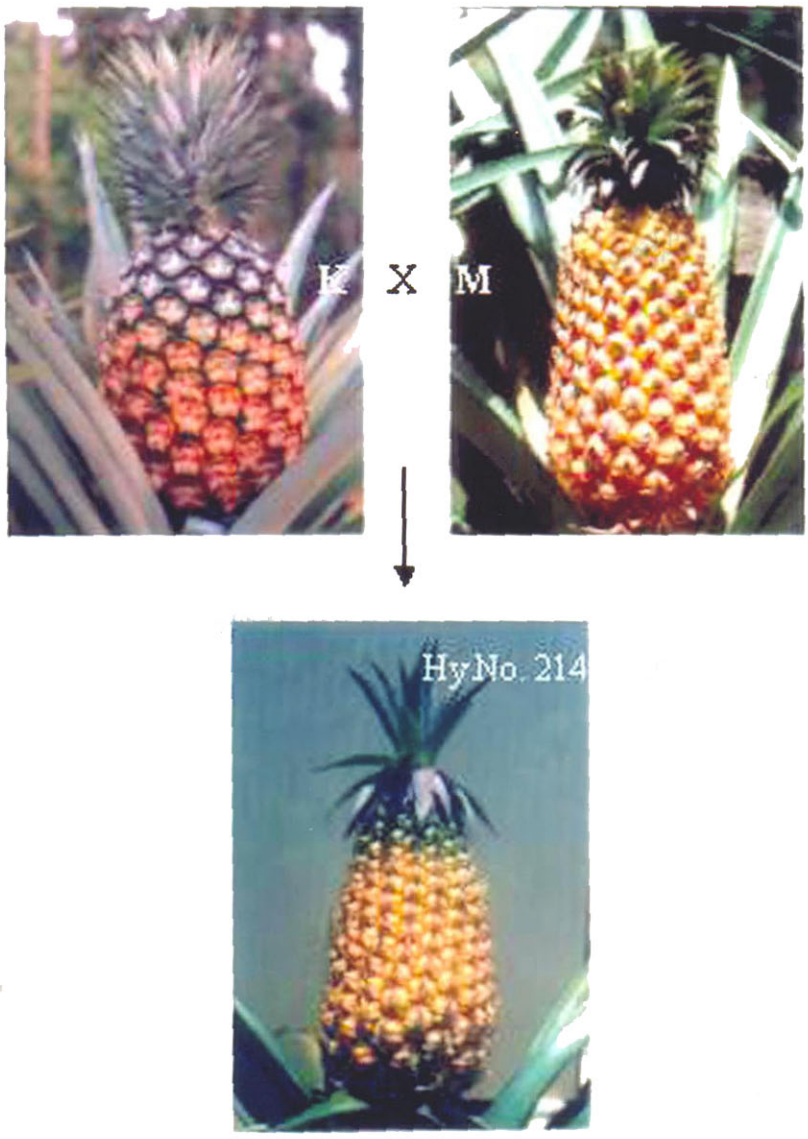

Plate 25. Hybrid with dual features

none were from its reciprocal. The result indicated that Mauritius was the best female parent for production of promising hybrids showing relative heterosis and when crossed against Kew as pollen parent, chances to get good recombinants were more.

Heterobeltiosis

When all the sixteen cross combinations were screened simultaneously for five characters, viz., fruit weight without crown, TSS, total sugar, pulp weight percentage and juice weight percentage, to identify hybrids with heterobeltiosis, none of the hybrids were found to have heterobeltiosis for all the characters.

Standard heterosis

All the sixteen cross combinations were screened simultaneously for five characters, viz., fruit weight without crown, TSS, total sugar, pulp weight percentage and juice weight percentage, to identify hybrids with standard heterosis for all the characters. Seven hybrids from three out of the sixteen cross combinations expressed standard heterosis over Mauritius. The hybrids with standard heterosis was observed in the crosses KKR x S-1, M x S-1 and M x K. Hybrids with standard heterosis were not observed in any of the crosses involving PKDA as a parent. Out of the seven hybrids with standard heterosis, five were from the cross M x K alone and one each from M x S-1 and KKR x S-1. Thus out of the seven hybrids with standard heterosis, six were from the crosses involving Mauritius as pistillate parent, indicating that Mauritius was the best pistillate parent for getting promising hybrids when crossed with the other four genotypes, viz., Kew, S-1, PKDA and KKR. The cross M x K was the best cross combination showing maximum number of good recombinants.

Thus from the sixteen cross combinations, thirteen hybrids with relative heterosis and seven hybrids with standard heterosis were selected. Out of this twenty selected hybrids that showed either relative heterosis or standard heterosis, only the hybrid No. 656 of the cross M x K showed both relative heterosis and standard heterosis. However, its TSS content was low when compared with the other selected

hybrids. As TSS content is an important character to be considered for selection of pineapple genotype suitable for both processing industry and fresh fruit market, the hybrid No. 656 has to be further evaluated to assess its acceptability.

Out of the twenty selected hybrids (Table 62), none of the hybrids was having highest values for all the five selected characters, viz., fruit weight without crown, TSS, total sugar, pulp weight percentage and juice weight percentage, expressed in their respective cross combinations. However, the hybrid No. 7637 of the cross K x PKDA was having the highest values for TSS, total sugar and pulp weight percentage expressed in that cross combination. This hybrid was having relative heterosis for all the five selected characters taken together. However, its TSS was low in comparison to other selected hybrids in other cross combinations.

The total sugar content of the hybrid No. 3523 of the cross M x S-1 was the highest recorded in that cross combination. Similarly, the total sugar content of the hybrid No. 6030 of the cross PKDA x M was the maximum recorded in that cross combination.

When all the twenty selected hybrids were compared, the hybrid No. 257 of the cross M x K was having the maximum standard heterosis in four out of the five characters on which it was selected. It was having highest TSS and total sugar content among all the twenty selected hybrids. It was also having higher fruit weight without crown, TSS and total sugar than all the five parental genotypes, viz., Mauritius, Kew, S-1, PKDA and KKR. Its pulp weight percentage and juice weight percentage are comparable with that of the parental genotypes, Kew and S-1, that showed maximum values for those characters. Considering all the above merits, hybrid No. 257 of the cross M x K (Plate 26) was considered as the best hybrid among all the hybrids evaluated in the sixteen cross combinations.

5.4.4. Spine character of the hybrids

Progenies with spiny, sparsely spiny and spineless leaves were observed in all

Plate 26. Fruit of hybrid number 257

the crosses where the parent Kew, having spineless leaves, was used as one of the parent. However, their segregation did not follow any particular ratio. Kinjo (1993) reported 1:1 segregation of spiny and smooth leaved parents suggesting expression of a single pair of alleles.

5.4.5. Hybrids with distinct or abnormal characters

Hybridization in pineapple has resulted in the production of plants with extreme segregations and gene recombination, with distinct or abnormal characters, that were not expressed in the parent populations.

5.4.5.1. *Hybrids with leaf colour variation*

All cross combinations expressed variability in the leaf colour exhibiting colours like pale green, green, deep green, green with reddish tinge and green with violet tinge (Plate 27).

5.4.5.2. *Hybrid with low chlorophyll content*

The progeny in several crosses produced albino seedlings and it continued to grow up to three to four leaf stage only, under shaded conditions. Certain seedlings with very low chlorophyll content continued to grow under shaded conditions. The chlorophyll content of such seedlings was so low that it was difficult to differentiate these seedlings from the albino seedlings during the early stages. However, one seedling continued to survive under partially shaded condition and is now about four years old and continues to grow without flowering. This hybrid, number 6170 of the cross PKDA x M, was having leaves with yellowish in colour with slight greenish tinge due to low chlorophyll content (Plate 13).

Plate 27. Variability in colour of among hybrids

5.4.5.3. *Hybrids with piping character*

Plants with piping character have leaves without spines even at the leaf tip and the leaf margins are soft and smooth. This character was commercially useful, as it will facilitate the management of the plants more friendly. However, it should be associated with plants having higher yield and quality of fruits. Plants with piping character of leaves was observed in four crosses, viz., PKDA x K, PKDA x M, PKDA x S-1 and KKR x PKDA. Maximum percentage of plants with piping character was produced in KKR x PKDA followed by PKDA x K. However, maximum number of plants with piping character out of the total seedlings survived was in PKDA x K followed by KKR x PKDA. Plants with piping character is continuing its growth even after four years, without flowering (Plate 14).

Among the five genotypes whose cross combinations were evaluated, the genotype PKDA was involved as one of the parent in all the crosses, whose progeny expressed the piping character. This indicated that piping character was associated with PKDA that will be expressed when crossed with all the other four genotypes. Collins and Kerns (1946) reported the inheritance of three leaf types, viz., spiny tips characteristic of Cayenne cultivar; spiny character in which the entire leaf margin bears spines and the piping character which is a completely spineless leaf form. The piping was controlled by the gene P (piping) which is epistatic to S and s (spiny). The homozygous PP genotype produces a more pronounced piping than does the Pp genotype. The homozygous recessive pp has no obvious phenotype in the presence of S or s genes, hence such genotypes, if they exist, cannot be distinguished phenotypically from spiny tip or spiny plants.

5.4.5.4. *Colour of heart at the beginning of inflorescence development*

The parental genotypes expressed different intensities of colour in the heart of the plant at the time of inflorescence development. It was deep red in KKR, creamy white in PKDA and has different intensities of red in Kew, S-1, RQ and Mauritius. In the progenies of all cross combinations, the colour development expressed

transgressive segregation, ranging from deep red to creamy white colour. The progenies of the cross KKR x K expressed a range of deep red to reddish white colour (Plate 28). The progenies of the crosses PKDA x K and S-1 x M (Plate 29) expressed a range of red to creamy white colour. The hybrid number 8565 of S-1 x M and the hybrid number 2070 of the cross PKDA x K was having a creamy white heart.

5.4.5.5. *Hybrid with white flower*

The colour of the petals of pineapple flower was normally purplish blue. But in the hybrid numbers 2095 and 2106 of the cross PKDA x K was having white coloured petals (Plate 15). Collins and Kerns (1946) had earlier reported white flower mutants in Cayenne variety and hence these hybrids with white flower may be recessive recombinants.

5.4.5.6. *Hybrids with extra long and cylindrical fruit*

The fruit of the hybrid No. 3005 of the cross M x S-1 was found to have 31.5 cm length and was perfectly cylindrical in shape (Plate 16). This shape was very much appreciated in processing industry.

5.4.5.7. *Fruit that ripened uniformly*

Ripening of pineapple fruit normally starts from the base of the fruit with yellowing of lower most eyes first and continued upwards following the sequence of its formation. However in the hybrid No. 1048 of the cross K x M, this process was not observed but instead, all the eyes in the fruit were found to turn yellow uniformly (Plate 30). But the intensity of yellowing, when fully ripe, was found to be more in the lower eyes. This plant was having plant characters of Kew (leaves without spines) and fruit characters of Mauritius (deep eyes). This character of uniform ripening is commercially important for processing industry as they require fully ripe fruits, without over ripening and damage. It is also advantages to fresh fruit market as it enhances storage life. The plant is advantageous to the grower also as it lack spines on the leaf.

Plate 28. Segregation of colour of heart at the time of inflorescence development in KKR x K

Plate 29. Segregation of colour of heart at the time of inflorescence development in S-1 x M

Plate 30. Hybrid number 1048 with uniform ripening of fruit (K x M)

5.5. *In vitro* Mutagenesis

In vitro mutagenesis is being used as a tool for induction of variation in large number of plants in a short time. This is more relevant in a vegetatively propagated crop like pineapple where regeneration of young plants for propagation is slow and limited.

In the present study, young suckers of healthy Mauritius genotype were used as source to develop *in vitro* culture. Earlier works reported the use of buds situated on pineapple stem fragments by Aghion and Beauchesne (1960); leaf buds by Scow and Wee (1970); shoot apices by Mapes (1973), Teo (1974) and Lakshmi *et al.* (1974); terminal buds by Pannetier and Lanaud (1976); lateral buds by Mathews *et al.* (1976), Zepeda and Sagawa (1981), Rangan (1984) and De Wald *et al.* (1988); syncarp, slip, crown, lateral bud and axillary bud by Wakasa (1979); axillary buds by Mathews and Rangan (1979); hybrid embryos by Rao *et al.* (1981); developed buds in the crown apical dome by Fitchet (1985, 1990, 1993); nodule culture by Teng (1997) and *in vitro* leaf culture by Dolgov *et al.* (1998). Production of one lakh plants from one shoot in less than 12 months was reported by Drew (1980).

After inoculation, greening of the explants started within 4-7 days. When sufficient masses of globular structures were formed (Plate 31), it was irradiated with gamma rays at the dose of 10, 15, 20, 25, 30, 35 and 40 Gy. to induce variability in Mauritius genotype. Much variability was observed between the different doses during all the stages of growth.

The plantlets, without roots when planted out, developed roots *ex situ*. Chlorophyll mutants were observed which did not have any chlorophyll and hence did not survive (Plate 18). Chimera in leaf was also observed (Plate 32). Singh *et al.* (1976) reported the occurrence of chimera and gene mutations in leaf characters of pineapple. Vesco *et al.* (2000) observed a frequency of 0.12 % somaclonal variants in micropropagated pineapple plants. Observations on height and number of leaves at plant out stage and at 30 days interval showed that radiation of *in vitro* culture at 30 Gy

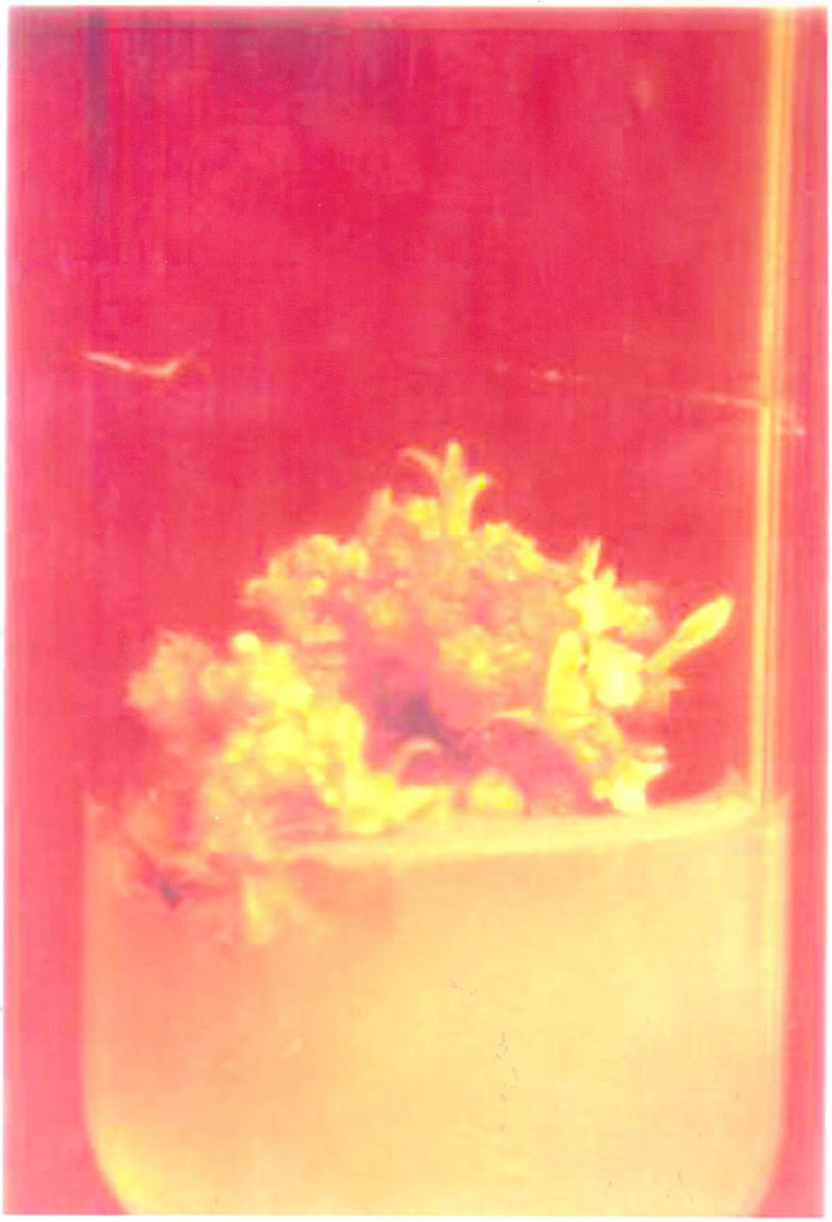

Plate 31. Irradiated globular structures in growth

gave enhanced vigour in growth of plantlets. The enhanced vigour on growth at 30 Gy was maintained at the grown up stage of the plantlet, that are ready to plant in the field, also (Plate 33). Nayar *et al.* (1978) reported a stimulant action of radiation at 4 Kr for flowering in pineapple. The various effects observed on *in vitro* plantlets like chlorophyll mutants, leaf chimera and variability in height and number of leaves indicated that *in vitro* mutagenesis could be used as a tool for creating genetic variability in pineapple.

Plate 32. Plant with chimera among irradiated *in vitro* plants

Plate 33. Variability in height of *in vitro* irradiated plants

Summary

SUMMARY

The present study entitled " Heterosis breeding and *in vitro* mutagenesis in pineapple (*Ananas comosus* [L] Merr.) was taken up under the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during 1998-2003. The field studies were carried out at Pineapple Research Station, Vazhakulam which is located amidst the commercially important pineapple growing area in the state.

This investigation was taken up to create genetic variability in pineapple so as to enable for selection of an ideal pineapple genotype having most of the desirable characters like medium fruit weight without crown, high TSS, total sugar, pulp weight % and juice weight %. A variety best suited for the dual purpose of meeting the requirements of fresh fruit market and processing industry is the most acceptable.

Evaluation of the six parental genotypes used for hybridization, their floral biology, hybridization of all the six genotypes in all possible combinations, production of hybrids, evaluation of the hybrids, *in vitro* mutagenesis and evaluation of mutants for their growth characters were taken up.

The salient results of the study can be summarized as follows:

The six selected pineapple genotypes differ in 11 growth characters and 23 yield and quality characters. They also differ in the colour of leaf, fruit and pulp. All the genotypes are having a few, not all, desirable characters.

The study of the floral biology indicated that the number of flowers opened per day was a varietal character and it did not vary much depending on the environmental factors. The number of days for completion of flower opening in pineapple was independent of the varieties, environment and the total number of flowers in an inflorescence.

Self incompatibility and cross compatibility studies showed that Selection-1 and Ripley Queen are totally self incompatible. Some amount of self compatibility occurs in Pampakuda local. Mauritius is a better female parent for hybridization work in pineapple, showing high compatibility with all other genotypes. The high rate of mortality of seedlings in all the crosses where Ripley Queen was involved suggests that Ripley Queen is not an ideal genotype for hybridization.

The study of the duration of receptivity of the stigma indicated that fertilization and seed set is possible in the six genotypes from 3 am to 6 pm. Germination of seeds was uniform in all the cross combinations and maximum germination was observed during the fourth week after sowing.

Evaluation of the F_1 progeny had brought out the wide variability among hybrids and showed that the range of all the characters studied express transgressive and independent segregation. In the F_1 population of pineapple, each individual plant is unique due to this independent and transgressive segregation for each character. The F_1 progeny also express characters that are not present in the parental population like plants with low chlorophyll content, piping character, creamy white heart during inflorescence development, white flower and fruits that ripen in toto uniformly. The result showed that lot of genetic variability could be created in pineapple through hybridization.

There is immense scope for selection of hybrids for any particular character in the F_1 population due to the transgressive and independent segregation of all characters. It is also possible to get better pineapple hybrids with relative heterosis and standard heterosis when several characters are taken together. However, the chance to get hybrids with heterobeltiosis is remote when several characters are taken together.

A number of promising hybrids could be identified through the evaluation of all the hybrid combinations. Among the cross combinations tried, M x K is the most effective cross. Hybrid No. 257 of the cross M x K is found to be the best hybrid among all the tested progenies.

In vitro mutagenesis was done using the variety Mauritius by irradiating *in vitro* culture at seven doses. Observations on height and number of leaves at one month interval indicated enhanced vigour in growth at 30 Gy dose. Albino plants and chimera in leaf due to induced mutation was also observed.

It is proposed as future line of work to evaluate further the twenty hybrids which are found to have either relative heterosis or standard heterosis when five characters are taken simultaneously, so as to select the best hybrid that meets the demand of the fresh fruit market and processing industry. The clonal progenies of all the promising hybrids have to be evaluated critically under the normal system of cultivation for making practical recommendations.

The hybrid with extra long and cylindrical fruit may be used for further breeding works. The hybrid that showed uniform ripening of fruit is to be critically evaluated for its utility in processing and fresh fruit market.

The spectrum of variability in the available and the newly created genotypes has given a fresh insight into the ideal genotype of pineapple for our requirements.

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Appendices

APPENDIX I

ANOVA for growth characters of six pineapple genotypes selected for hybridization

Source of variation	Df	Mean sum of squares											
		Height of the plant (cm)	Number of leaves per plant	Number of suckers per plant	Number of slips per plant	Length of peduncle (cm)	Duration from planting to beginning of inflorescence development (days)	Duration from beginning to full development of inflorescence (days)	Duration from full development of inflorescence to first flower opening (days)	Duration from opening of first flower to last flower (days)	Duration from opening of last flower to harvest (days)	Fruit development period (days)	Total duration of the crop (days)
Replication	3	65.77	20.36	19.30	5.25	5.26	1429.99	0.69	0.03	17.01	19.68	0.18	1407.72
Treatment	5	490.37	50.57	51.01	902.71	15.39	5292.91	8.77	10.72	12.44	459.06	484.51	8829.52
Error	15	22.45	18.31	4.81	32.23	3.17	80.17	2.11	1.06	2.44	12.86	0.70	66.32
'F' value		21.84	2.72	10.59	28.01	4.85	9.12	4.17	10.15	5.09	35.69	5.27	15.59

APPENDIX II

ANOVA for fruit characters of six pineapple genotypes selected for hybridization

Source of variation	Df	Mean sum of squares											
		Fruit weight with crown (g)	Fruit weight without crown (g)	Length of fruit (cm)	Breadth of fruit (cm)	Girth at middle (cm)	Canning ratio	L/B ratio	Taper ratio	Crown weight (%)	Peel weight (%)	Pulp weight (%)	Peel/ pulp ratio
Replication	3	33194.05	21555.92	3.45	0.05	1.47	0.02	0.02	0.01	10.45	1.04	9.18	0.01
Treatment	5	512766.23	382550.40	9.35	1.01	21.59	0.08	0.08	0.02	22.55	50.92	69.49	0.01
Error	15	37355.60	27553.61	0.94	0.34	2.45	0.01	0.01	0.01	3.76	4.74	8.75	0.01
'F' value		13.73	13.88	9.99	2.98	8.83	9.27	8.99	3.23	6.01	10.74	7.94	7.70

Appendix II (contd.)

Appendix II (concl.)

Source of variation	Df	Mean sum of squares										
		Core weight (%)	Juice weight (%)	T.S.S (^{0}brix)	Acidity (%)	Ascorbic acid (mg/100g)	Total sugar (%)	Non-reducing sugar (%)	Reducing sugar (%)	p^H of juice	Sugar /acid ratio	Brix/ acid ratio
Replication	3	4.34	6.49	0.46	0.01	283.73	0.35	0.06	0.14	0.02	18.87	15.94
Treatment	5	8.44	104.04	21.33	0.05	1213.74	17.69	17.4	2.44	0.16	31.14	30.97
Error	15	2.09	7.91	0.59	0.01	62.48	0.998	0.81	0.09	0.02	5.60	4.21
'F' value		4.02	13.16	35.74	10.57	19.43	17.89	21.93	26.71	10.49	5.56	7.35

APPENDIX III

Principal Component Analysis of sixteen cross combinations

1. Cross KKR x S-1

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
4043	-477.40	949.43	4101	-305.10	644.93	5834	-454.33	871.69
4044	-362.66	747.16	4102	-661.77	1245.36	5835	-214.26	475.84
4045	-553.17	1078.27	4103	-434.37	874.48	5837	-427.37	855.40
4048	-798.97	1482.64	4104	-678.59	1278.34	5838	-517.59	1005.64
4049 A	-552.16	1065.16	4105	-776.23	1452.75	5841	-195.92	452.71
4050	-645.93	1242.32	4106	-742.89	1398.34	5845	-421.10	855.57
4053	-313.63	625.32	4109	-714.01	1348.73	5846	-624.98	1171.78
4054	-630.64	1201.76	4110	-627.53	1192.05	5852	-394.56	794.45
4055	-1387.24	2462.65	4111	-504.40	994.26	5857	-363.02	733.60
4056	-530.65	1032.71	4112	-787.53	1466.47	5860	-547.21	1054.79
4057	-1013.75	1842.30	4113	-543.76	1052.83	5861	-819.93	1526.17
4058	-933.71	1706.07	4114	-437.73	870.84	5862	-533.45	1040.71
4059	-505.96	993.59	4115	-687.75	1296.48	5865	-798.17	1476.39
4060	-358.65	732.18	4116	-449.97	902.97	5868	-429.57	873.03
4061	-440.48	886.39	4117	-388.99	791.04	5869	-490.66	967.75
4062	-741.90	1379.84	4119	-389.77	806.04	5870	-507.61	992.94
4067	-1015.68	1856.92	4120	-369.42	761.12	5871	-410.15	826.76
4068	-482.44	947.31	4124	-742.01	1392.66	5872	-641.59	1222.40
4069	-112.89	319.30	4130	-315.33	654.67	5873	-1168.00	2097.84
4070	-334.16	694.87	4130A	-575.08	1103.37	5878	-301.34	646.94
4071	-517.57	1005.83	4134	-534.24	1029.86	5879	-772.21	1423.97
4073	-729.52	1364.33	4135	-643.03	1230.75	5880	-473.87	930.96
4074	-808.45	1492.92	4136	-512.80	996.94	5882	-383.16	776.40
4075	-785.13	1459.46	4145	-332.98	709.62	5885	-442.80	880.74
4076	-413.37	845.61	4146	-1574.71	2784.06	5887	-652.39	1236.76
4079	-868.25	1608.31	4150	-601.89	1143.28	5890	-417.16	841.51
4080	-254.39	550.01	4154	-460.65	921.66	5891	-447.52	890.51
4081	-838.48	1546.71	4155	-571.20	1099.63	5894	-300.37	642.83
4082	-501.39	987.97	4160	-865.22	1577.79	5895	-787.33	1465.61
4084	-896.12	1650.09	4165	-745.84	1406.73	5904	-341.64	713.37
4085	-368.08	749.92	4171	-788.78	1462.06	5905	-319.84	668.38
4086	-1098.35	1984.25	4172	-389.21	799.92	5910	-215.18	486.78
4087	-853.05	1574.58	4173	-527.53	1020.08	5913	-553.39	1081.34
4089	-819.22	1509.48	4176	-446.29	867.95	8619	-508.01	993.51
4090	-922.75	1698.54	5812	-351.79	714.20	8620	-712.59	1339.10
4091	-394.24	803.04	5813	-259.06	553.58	8621	-809.68	1504.40
4092	-482.93	944.39	5815	-145.58	406.98	8622	-485.76	976.53
4095	-531.35	1036.66	5818	-334.61	700.45	8623	-304.16	664.76
4096	-570.15	1096.12	5819	-524.68	1025.16	8624	-290.18	624.04
4097	-504.90	984.71	5829	-506.92	987.61			
4099	-363.89	755.95	5830	-512.65	981.77			

2. Cross S –1 x KKR

Hybrid Number	1st Component	2nd Component
6741	664.87	217.76
6755	1434.05	422.07
6757	1033.37	312.80
6758	1382.90	409.15
6762	1256.03	374.78
6767	933.68	292.46
6772	2260.36	633.43
6802	2029.33	574.20
6804	885.44	271.42
6805	2178.75	612.74
6806	1087.41	334.74
6807	629.63	216.06
6808	1011.05	315.31
6809	1583.89	458.94
6810	801.22	255.73
6811	1235.94	374.87
6813	1468.85	426.34
6814	2505.38	699.10
6815	982.71	309.21
6816	1540.62	452.42
6817	1346.12	402.80
6818	2024.13	578.03
6819	2033.37	578.26
6820	859.72	273.46
6822	1360.87	402.25
6827	708.09	230.55
6829	1695.56	487.54

3. Cross K x PKDA

Hybrid Number	1st Component	2nd Component
2193	694.75	871.88
2194	643.51	799.88
2195	1286.40	1741.39
7592	806.84	1051.43
7593	754.30	968.87
7595	894.84	1177.71
7596	292.54	318.72
7597	996.19	1330.65
7624	632.31	796.68
7625	1057.65	1412.48
7627	533.26	658.70
7631	844.47	1121.32
7632	751.51	970.69
7633	1165.30	1566.23
7637	790.36	991.33
7639	471.25	562.90
7640	1169.77	1569.04
7641	781.88	993.44
7644	1062.53	1415.90
7658	841.17	1096.88
7660	1474.06	2022.01
7664	1062.53	1415.90

4. Cross M x S-1

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
2855	75.05	1365.72	2988	69.29	1049.14	3106	76.27	1102.66
2860	66.74	1190.20	2989	74.03	871.26	3107	66.78	998.45
2863	71.19	804.19	2990	71.37	566.20	3108	74.57	664.85
2865	81.90	757.51	2993	73.94	933.40	3111	74.15	1434.24
2868	82.11	829.03	2994	72.90	1062.20	3116	69.55	1436.04
2872	78.08	548.26	2995	72.72	823.80	3119	72.63	904.83
2882	74.82	894.20	2997	75.42	641.35	3123	70.47	1538.30
2883	70.12	1421.18	2999	76.34	1329.60	3126	72.65	914.85
2886	68.73	636.48	3001	62.15	1019.37	3127	78.33	1191.01
2887	79.84	1178.57	3005	78.07	960.81	3133	78.27	1189.82
2890	83.91	557.67	3007	72.31	778.60	3134	82.47	987.31
2899	80.91	943.76	3008	74.49	915.28	3365	62.45	1637.36
2900	73.23	700.28	3014	74.55	605.85	3389	73.98	915.75
2902	70.04	770.13	3017	74.38	714.16	3399	74.01	1373.23
2904	74.64	1431.38	3022	76.07	1087.64	3416	74.49	577.52
2906	76.83	1080.75	3023	78.40	1297.54	3417	78.94	1454.17
2912	77.77	1301.11	3025	75.68	555.73	3420	81.33	1739.64
2913	71.67	967.02	3028	80.94	1023.50	3422	75.66	992.88
2914	70.26	1039.11	3029	61.65	616.60	3423	81.37	995.41
2916	74.78	1469.43	3030	68.14	654.19	3425	77.04	1197.22
2922	72.56	1415.26	3039	68.43	869.75	3430	77.37	1665.45
2923	72.73	1278.77	3044	77.25	966.75	3435	75.87	1264.97
2933	79.12	1025.49	3052	67.24	1627.68	3436	71.38	1038.03
2941	76.26	1271.70	3053	67.61	787.58	3439	65.28	318.79
2942	74.51	1652.77	3055	73.31	1045.05	3441	78.69	1256.82
2943	57.59	899.88	3063	67.89	824.56	3442	75.65	1541.57
2943A	56.98	1072.67	3064	69.07	1116.69	3447	79.01	1957.50
2944	71.86	1086.46	3067	61.77	1110.01	3448	77.76	923.22
2958	80.76	943.54	3074	75.75	748.05	3450	69.81	1497.61
2959	69.48	622.32	3075	75.73	852.01	3452	78.72	1055.90
2962	73.06	1492.09	3076	80.27	1429.65	3455	76.43	793.99
2968	76.06	500.69	3079	76.31	977.24	3456	77.26	562.61
2971	73.84	1031.88	3087	72.87	871.61	3457	82.21	1001.95
2972	70.12	323.05	3088	74.79	1064.13	3459	77.82	577.73
2973	73.08	1122.07	3091	73.28	740.96	3461	72.78	1167.66
2974	74.69	1229.51	3093	76.66	794.24	3462	64.11	1040.87
2975	79.68	854.17	3097	69.67	550.90	3464	83.40	1734.42
2976	64.08	999.13	3101	71.22	826.11	3466	65.73	1063.31
2985	70.29	375.95	3102	80.97	878.02	3471	74.17	1060.17
2986	81.84	1391.62	3104	73.13	1241.66	3473	71.06	851.15
3474	81.11	1449.61	3489	80.80	1752.19	3513	72.24	798.99
3477	72.17	946.32	3491	81.46	1257.32	3516	66.03	884.14
3478	64.53	1043.06	3499	66.44	829.68	3517	75.29	1239.77
3479	75.88	1768.27	3500	71.50	1255.32	3519	76.12	915.12
3481	81.03	1353.16	3502	76.52	1423.27	3521	79.95	1668.44
3482	82.26	1064.78	3504	73.91	1017.61	3522	76.48	1590.13
3483	75.52	1003.25	3505	74.21	778.28	3523	84.08	906.50
3484	68.33	711.23	3509	80.17	1491.77	3534	79.09	1027.34
3486	78.63	754.15	3510	74.13	876.83	3539	73.15	1198.12
3488	74.24	1368.46	3512	78.98	1454.73	3540	79.72	1445.27

5. Cross S – 1 x M

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
3286	1000.02	500.63	3339	1156.44	569.52	7463	907.69	462.57
3288	1938.07	925.71	3340	743.00	378.49	7475	1314.35	645.30
3290	947.32	472.30	3344	1695.01	825.91	7494	2499.22	1188.41
3292	513.95	267.90	3350	1138.21	556.48	7497	1539.12	743.21
3294	1656.27	796.89	3352	999.81	490.47	7498	1590.75	763.77
3307	2105.70	997.66	3353	1246.11	622.94	7499	1669.78	790.29
3308	1666.37	800.75	3364	1710.37	816.56	7500	1612.96	786.48
3309	869.14	426.30	7431	586.56	302.71	7501	1257.87	608.90
3310	774.34	391.81	7432	1353.48	658.06	7502	834.05	414.14
3311	864.42	440.30	7435	984.83	487.40	7504	1315.23	646.60
3312	1192.10	578.82	7437	1979.63	942.32	7510	815.42	404.83
3313	959.40	478.64	7438	588.21	311.90	8563	1074.39	529.56
3314	997.86	497.84	7439	2457.65	1168.30	8564	814.62	403.61
3315	585.54	296.91	7442	600.41	302.16	8565	518.84	263.39
3316	765.13	397.53	7443	523.94	283.69	8566	937.00	466.67
3317	577.08	301.57	7444	2653.94	1255.09	8567	1191.47	590.58
3319	740.12	365.89	7445	560.44	288.56	8568	458.09	248.72
3320	1023.77	510.97	7447	973.64	489.49	8570	564.85	297.65
3321	1002.15	501.12	7448	601.55	311.55	8571	807.78	424.59
3323	1201.63	592.11	7449	891.45	443.35	8572	640.09	333.12
3325	1171.27	577.03	7451	516.39	263.81	8573	956.80	486.23
3326	672.24	347.65	7453	696.12	362.42	8574	971.88	483.63
3330	1014.23	506.30	7456	776.07	398.41	8575	916.41	455.96
3333	888.06	442.61	7460	987.70	485.58	8577	1256.65	615.62
3334	1290.98	637.31	7461	1009.13	493.23	8578	693.66	360.59
3337	1264.23	615.02	7462	693.47	351.15	8579	633.32	317.60

6. Cross S-1 x PKDA

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
6216	1245.12	527.46	6237	1028.48	455.11	6271	1386.92	580.96
6217	2647.66	1039.98	6239	1556.93	644.64	6275	1785.26	728.85
6219	1927.33	778.10	6240	1502.81	620.85	6277	947.68	423.43
6221	2656.86	1037.12	6241	762.60	357.32	6278	857.86	386.13
6222	1137.53	501.73	6242	664.88	328.56	6281	832.04	376.75
6223	1484.18	619.82	6244	1728.10	705.73	6282	937.84	420.66
6224	1052.44	467.26	6250	1909.93	772.86	6283	1211.99	516.85
6225	1633.51	676.02	6252	1703.30	695.91	7781	965.52	430.08
6226	1131.70	487.32	6253	1933.32	781.96	7782	1238.39	535.92
6228	1351.07	568.18	6254	1328.68	562.60	7783	1334.36	560.38
6229	1082.42	480.28	6259	836.14	381.67	7784	980.87	442.06
6230	1222.00	526.70	6260	822.13	373.93	7785	1619.31	669.82
6232	1422.85	589.60	6261	1286.19	540.41	7786	2337.48	917.49
6233	1245.68	538.65	6263	943.25	426.37	7788	892.21	397.91
6234	698.21	344.36	6266	2289.89	911.90	7789	1257.51	535.75
6235	1808.45	735.50	6270	876.88	393.17			

7. Cross PKDA x S-1

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
3689	-433.49	1381.05	3761	-424.86	1347.83	3880	-320.33	1069.40
3692	-195.79	731.90	3762	-562.08	1734.23	3885	-294.94	1017.41
3693	-175.78	723.23	3764	-478.74	1496.66	3896	-539.09	1628.04
3696	-446.75	1428.29	3765	-337.42	1140.73	3897	-458.19	1471.10
3698	-602.60	1831.04	3766	-231.63	864.97	3900	-416.66	1344.50
3699	-157.92	671.43	3768	-225.54	848.72	3901	-171.94	684.91
3700	-399.11	1313.08	3769	-404.74	1293.87	3902	-291.21	1019.01
3701	-491.05	1534.84	3770	-611.58	1842.31	3904	-402.88	1294.78
3703	-417.53	1353.74	3772	-417.99	1367.93	3912	-444.24	1446.14
3707	-326.42	1093.61	3773	-348.98	1150.44	3914	-246.47	884.13
3708	-405.54	1286.38	3774	-230.76	846.03	3915	-447.11	1430.92
3709	-338.70	1151.65	3775	-388.90	1279.04	3918	-295.75	997.42
3714	-203.60	803.74	3781	-323.74	1096.31	3942	-325.22	1130.41
3717	-262.25	942.24	3788	-105.30	434.18	3944	-73.75	404.28
3719"	-558.22	1746.26	3795	-386.13	1252.34	3946	-439.61	1427.86
3720	-550.37	1696.29	3806	-236.56	875.82	3947	-236.10	848.84
3725	-330.33	1130.84	3814	-353.60	1156.44	3950	-224.75	858.77
3727	-310.98	1067.90	3815	-373.76	1244.41	3973	-334.23	1133.17
3728	-590.30	1813.48	3823	-196.02	740.40	3974	-509.55	1600.48
3730	-636.61	1942.29	3833	-641.68	1967.09	3980	-115.31	490.98
3732	-314.36	1079.91	3834	-296.13	1020.00	3985	-531.76	1669.92
3733	-480.49	1543.70	3835	-361.07	1200.42	3998	-246.81	913.96
3734	-419.06	1350.76	3836	-238.86	885.31	4000	-296.48	1023.64
3739	-417.90	1368.33	3837	-313.91	1068.86	4005	-478.81	1498.01
3740	-256.63	913.77	3839	-506.00	1597.62	4006	-550.31	1704.36
3742	-177.36	703.47	3840	-513.56	1609.44	4009	-441.09	1417.68
3746	-519.29	1602.88	3841	-342.56	1156.76	4011	-461.60	1472.78
3748	-337.68	1140.52	3842	-203.26	764.84	4012	-418.07	1338.43
3748A	-303.44	1066.59	3845	-235.23	850.22	4015	-156.26	658.72
3749	-292.70	1015.76	3857	-312.20	1058.91	4016	-358.62	1203.60
3750	-282.45	989.92	3860	-391.51	1295.56	4017	-441.72	1399.62
3751	-421.97	1342.96	3866	-321.40	1104.91	4018	-227.35	850.88
3752	-117.19	569.51	3871	-182.41	704.15	4024	-300.49	1016.74
3753	-590.41	1808.86	3874	-373.47	1211.60	4032	-570.28	1757.48
3754	-933.42	2678.64	3875	-476.77	1497.71	4033	-349.67	1163.39
3757	-181.71	746.06	3876	-466.16	1488.66	4040	-119.29	525.57
3759	-586.18	1791.94	3878	-193.43	753.62	4041	-598.94	1846.41
3760	-370.07	1224.74	3879	-92.89	418.72			

8. Cross KKR x M

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
7262	752.09	-509.91	7327	603.83	-392.91
7263	655.63	-432.22	7328	584.85	-379.92
7264	751.50	-506.11	7329	509.66	-329.64
7265	745.24	-498.48	7330	599.46	-398.13
7266	642.84	-423.42	7331	412.80	-242.18
7267	1096.01	-775.77	7332	704.89	-468.76
7268	839.35	-582.33	7336	466.13	-280.28
7269	1852.27	-1379.02	7337	1275.95	-925.35
7270	494.70	-301.22	7338	885.73	-606.87
7271	705.53	-469.93	7341	463.23	-285.54
7272	558.73	-360.61	7341A	834.97	-581.13
7273	862.16	-596.34	7343	806.13	-555.07
7274	540.89	-342.81	7345	654.78	-431.53
7285	499.77	-309.88	7346	716.16	-480.93
7286	787.20	-533.17	7347	979.74	-691.49
7287	740.39	-499.27	7349	1343.58	-982.31
7290	387.23	-218.47	7350	384.82	-228.40
7291	773.46	-526.60	7352	686.05	-456.59
7295	509.08	-315.22	7353	539.85	-359.56
7297	982.20	-686.83	7354	487.74	-307.88
7298	854.92	-592.64	7356	818.14	-556.54
7299	920.64	-642.36	7357	1155.33	-819.63
7300	1358.82	-984.41	7358	980.93	-684.60
7301	391.51	-228.41	7359	591.66	-377.18
7302	1348.94	-982.13	7362	616.04	-401.41
7303	959.99	-664.49	7363	900.32	-623.01
7304	753.83	-506.09	7364	769.72	-522.28
7305	1067.59	-771.39	7366	683.35	-460.89
7306	618.97	-406.08	7367	903.45	-628.96
7308	603.64	-391.44	7368	1177.97	-843.70
7309	838.22	-579.77	7370	1414.26	-1030.78
7310	688.38	-462.25	7371	368.82	-213.95
7313	1169.08	-833.32	7373	594.34	-379.14
7314	655.45	-434.08	7374	928.96	-651.89
7315	1103.24	-795.83	7381	1689.86	-1244.65
7317	727.40	-481.44	7741	1225.01	-890.08
7318	730.99	-494.07	7747	445.20	-275.59
7319	1163.03	-837.09	7748	865.88	-597.40
7320	1028.93	-725.66	7749	426.51	-243.55
7321	647.05	-431.18	7752	1333.25	-969.20
7323	747.51	-503.10	8618	484.44	-310.96
7326	685.70	-459.05			

9. Cross M x KKR

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
2125	-502.81	666.86	4224	-554.09	737.17	4298	-546.17	718.64
2126	-456.86	630.88	4226	-635.98	834.15	4298A	-448.69	613.08
2127	-842.16	1073.52	4227	-627.13	824.27	4299	-765.93	987.98
2139	-1003.05	1263.95	4228	-603.84	786.21	4301	-956.35	1200.06
2140	-515.34	695.86	4231	-925.99	1158.03	4304	-576.91	772.38
2143	-418.05	590.64	4237	-471.10	647.64	4305	-894.32	1133.03
2143A	-514.87	690.51	4240	-529.24	708.82	4306	-691.14	894.57
2145	-631.76	838.68	4241	-607.74	798.69	4307	-646.96	847.56
2152	-573.91	758.97	4243	-482.49	654.66	4309	-921.48	1166.23
2155	-691.09	900.01	4244	-347.29	494.84	4314	-617.08	813.31
2156	-622.50	827.02	4245	-464.29	630.26	4315	-563.80	752.95
2165	-622.44	817.28	4246	-618.99	820.96	4316	-448.87	622.05
2173	-545.48	733.08	4247	-642.76	844.29	4317	-597.72	783.74
2348	-651.25	860.21	4249	-384.40	553.74	4318	-1130.67	1409.26
2351	-529.43	715.67	4251	-423.07	580.12	4319	-788.60	1025.97
2371	-377.81	539.24	4252	-774.96	970.83	4322	-846.98	1078.94
2374	-426.05	594.52	4253	-344.15	499.58	4324	-647.47	848.02
4179	-321.38	470.08	4254	-854.86	1093.77	4325	-612.44	811.59
4185	-386.73	542.76	4256	-590.63	786.24	4326	-235.32	361.38
4186	-582.70	772.70	4259	-676.18	881.19	4327	-590.05	782.84
4190	-593.79	782.78	4260	-829.92	1060.75	4328	-452.45	625.58
4191	-505.93	684.22	4261	-442.29	617.52	4329	-410.52	573.06
4194	-666.03	869.82	4264	-635.59	841.65	4331	-701.14	914.79
4195	-306.60	457.22	4265	-359.89	515.54	4332	-643.95	836.30
4196	-338.25	489.19	4266	-543.15	726.78	4334	-431.14	589.91
4198	-328.44	478.45	4267	-286.77	432.29	4335	-377.84	535.07
4199A	-654.13	845.97	4275A	-96.50	202.36	4337	-398.13	562.34
4200	-225.54	360.05	4275	-153.06	274.96	4338	-734.52	950.06
4201	-828.62	1057.53	4278	-480.27	650.62	4339	-448.49	618.13
4203	-819.21	1052.98	4280	-279.51	419.14	4340	-800.18	1024.80
4204	-738.53	959.95	4283	-452.00	621.95	4341	-704.41	912.04
4205	-399.44	563.37	4284	-596.91	797.22	4342	-408.74	569.36
4207	-342.26	496.97	4285	-693.88	903.53	4343	-592.79	783.33
4210	-546.50	735.79	4286	-351.47	503.39	4345	-866.20	1104.90
4211	-520.74	706.40	4287	-717.40	932.39	4346	-486.66	665.25
4212	-430.53	586.80	4289	-295.82	431.06	4348	-588.20	775.92
4213	-485.19	667.47	4290	-554.18	734.49	4349	-536.87	714.72
4215	-637.50	835.00	4292	-243.63	369.87	4350	-151.07	284.54
4216	-1050.03	1308.57	4292A	-488.08	666.42	4351	-714.23	925.49
4217	-341.74	489.18	4295	-511.72	691.68	4352	-332.84	489.94
4357	-203.65	329.31	5014	-680.22	882.69	5081	-489.89	669.47
4358	-377.22	535.69	5017	-374.95	538.70	5082	-582.36	774.04
4359	-404.96	573.77	5019	-334.17	481.56	5083	-173.99	299.61
4360	-345.51	500.56	5021	-625.95	820.34	5083A	-240.75	378.42
4361	-503.97	686.60	5022	-285.33	425.75	5086	-200.66	317.09
4362	-540.82	735.66	5023	-305.61	455.47	5087	-148.30	273.64
4364	-393.11	550.90	5027	-568.76	751.04	5088	-520.91	694.63
4365	-552.70	745.42	5029	-556.45	741.50	5090	-682.39	880.99
4368	-1103.67	1381.37	5031	-355.57	500.59	5091	-617.71	820.67

4372	-210.94	338.05	5032	-404.60	572.06	5094	-303.34	456.28
4374	-449.24	618.43	5033	-299.26	443.53	5096	-258.15	394.11
4376	-848.34	1075.78	5035	-425.15	573.52	5097	-507.81	679.68
4377	-971.81	1226.29	5036	-388.48	545.15	5098	-689.23	899.92
4377A	-477.89	648.70	5038	-662.16	854.37	5101	-356.36	516.39
4378	-394.42	559.27	5039	-300.42	443.12	5102	-398.27	555.24
4379	-780.02	1001.76	5040	-461.59	623.64	5105	-518.16	705.25
4380	-665.10	865.19	5041	-507.63	693.88	5107	-525.30	708.58
4381	-629.21	836.39	5042	-299.38	450.80	5110	-332.94	486.53
4383	-511.30	697.76	5043	-206.85	330.58	5111	-641.54	843.14
4385	-674.04	883.66	5044	-363.53	525.06	5116	-456.94	631.16
4976	-358.77	502.42	5045	-363.62	518.03	5120	-1160.92	1441.89
4980	-484.63	653.17	5046	-527.34	701.84	5124	-573.94	756.95
4981	-504.98	678.28	5047	-292.29	424.29	5126	-807.49	1014.08
4982A	-606.86	799.28	5052	-484.40	653.11	5132	-776.90	985.44
4985	-383.87	546.50	5053	-215.06	355.58	5258	-138.35	244.67
4986	-199.75	311.48	5056	-531.29	715.36	5267	-458.77	611.46
4989	-744.59	970.38	5057	-319.62	463.96	5279	-152.80	266.72
4990	-230.91	356.35	5058	-323.15	471.49	5286	-254.67	392.29
4991	-287.35	433.48	5059	-475.68	650.68	5288	-303.43	436.59
4993	-361.78	519.56	5061	-528.38	712.21	5443	-670.11	868.12
4995	-306.14	444.62	5062	-475.70	652.89	5450	-373.27	523.78
4996	-391.83	556.40	5063	-294.69	431.99	5455	-427.48	591.73
4997	-698.04	900.35	5065	-317.81	464.05	5475	-212.74	336.60
4998	-373.22	531.38	5068	-545.22	734.98	5500	-312.04	458.96
5002	-433.41	597.84	5069	-364.29	527.19	5502	-531.42	705.00
5004	-537.42	733.67	5071	-508.88	689.50	5512	-433.42	596.35
5005	-359.96	513.45	5072	-121.99	228.21	5528	-474.28	639.37
5008	-527.47	710.67	5074	-373.95	539.91	5537	-390.79	549.62
5012	-309.72	448.74	5076	-421.00	577.64			
5013	-231.21	364.15	5079	-460.14	625.59			

10. Cross KKR x K

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
1962	107.94	1230.26	5920	108.52	1227.81	5942	98.15	1008.00
1966	104.20	1016.12	5922	89.29	1153.50	5943	111.79	1284.03
1967	107.28	1425.28	5923	104.30	1290.56	7517	123.62	2534.79
1968	98.11	1369.30	5927	93.09	790.97	7577	80.03	619.91
1970	121.07	1512.85	5928	94.91	1029.77	7580	94.25	814.44
1975	130.44	2151.85	5929	83.51	485.51	7581	74.17	718.23
1977	94.15	1048.08	5931	96.08	622.26	7583	98.72	1094.96
1978A	97.91	1201.07	5932	100.85	1342.18	7585	118.99	1721.45
1978	97.06	970.94	5933	115.57	355.07	7587	102.69	1317.40
1980	107.95	1786.89	5934	94.10	882.49	7588	94.83	1033.58
1982	105.20	600.39	5936	101.42	1275.43	7873	94.76	935.28
1984	119.84	1562.06	5937	81.80	573.11	7916	89.05	868.30
5916	117.83	937.79	5938	88.67	685.08	7918	79.20	418.75
5917	96.99	1037.32	5939	83.08	834.61	7919	102.29	1324.17

11. Cross K x KKR

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
1987	965.07	436.55	2034	933.07	423.61	8785	1261.22	547.79
1992	1366.97	590.80	2035	902.72	417.91	8794	1340.51	580.21
1996	890.70	417.18	2039	799.99	379.79	8796	947.01	428.19
1998	784.59	364.81	2040	1254.63	545.05	8799	635.72	297.63
1999	1433.95	618.22	2041	319.52	182.41	8827	1305.33	559.31
2000	678.36	325.02	8717	840.59	375.46	8839	793.44	359.82
2001	1258.05	547.72	8725	906.50	404.70	8948	692.71	321.67
2002	597.21	287.15	8726	840.53	387.19	8966	741.28	341.85
2003	1899.76	804.83	8730	620.90	295.84	8967	2308.63	963.50
2004	1056.11	471.72	8734	864.50	385.31	8970	1691.55	716.31
2008	1326.03	579.00	8746	967.60	428.75	8976	1232.65	543.23
2011	732.99	353.26	8759	1601.63	685.40	8989	1336.90	579.57
2022	497.21	256.01	8764	683.22	320.99			
2028	1200.72	525.82	8765	1547.06	658.05			
2029	1093.12	488.79	8773	909.68	404.66			

12. Cross K x M

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
95	-1427.30	-240.55	193	-858.39	-97.90
99	-1459.81	-223.62	193A	-503.98	-13.58
100	-1169.52	-163.45	194	-750.95	-69.98
101	-867.49	-91.14	202	-715.62	-63.53
105	-1230.75	-181.30	203	-376.55	-0.08
107	-1072.56	-140.53	210	-795.61	-87.45
108	-585.44	-41.72	211	-2076.06	-358.91
109	-728.32	-73.03	214	-772.31	-73.74
110	-958.02	-125.82	236	-1273.45	-188.17
113	-962.00	-115.90	237	-741.19	-74.75
114	-653.39	-64.98	239	-1407.65	-218.29
118	-634.63	-49.12	248	-2039.68	-359.30
119	-1491.67	-230.91	1025	-1590.14	-246.90
121	-1598.14	-261.27	1027	-1211.95	-165.09
125	-2642.55	-484.45	1028	-922.13	-98.25
126	-1465.66	-233.22	1028A	-873.69	-103.34
128	-879.09	-99.10	1035	-1855.65	-312.81
132	-1748.85	-288.12	1041	-983.72	-125.07
133	-731.79	-67.56	1044	-1136.17	-152.30
134	-1952.87	-335.10	1049	-839.49	-93.87
135	-969.57	-112.92	1052	-834.26	-93.14
145	-575.67	-34.22	1054	-1694.55	-283.04
154	-901.93	-106.29	1058	-903.63	-102.62
159	-1430.12	-218.70	1059	-2592.98	-480.23
161	-1345.61	-199.98	1060	-1889.68	-311.30
162	-763.97	-78.13	8680	-817.82	-97.99
166	-613.82	-42.42	8682	-1144.56	-160.24
176	-1514.86	-245.74	8683	-1561.32	-250.34
177	-1092.45	-149.69	8684	-1415.03	-220.97
178	-744.31	-68.84	8689	-558.50	-37.26
179	-962.60	-123.40			

13. Cross PKDA x K

Hybrid Number	1st Component	2nd Component
2076	1011.24	501.26
2077	1220.77	624.06
2090	854.96	441.65
2092	1227.51	617.94
2095	575.56	303.28
2106	658.46	345.62
2108	1582.09	804.45
2124	922.93	470.89
7606	1084.89	555.22
7613	1403.88	715.03
7620	1016.04	509.95

14. Cross M x K

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
255	-756.71	931.76	364	-641.37	806.14	481	-917.86	1109.45
256	-651.31	805.78	365	-978.35	1166.68	483	-698.00	868.02
257	-892.39	1096.14	366	-686.51	854.38	486	-450.96	595.87
262	-521.04	665.75	369	-573.18	728.95	488	-1294.16	1522.29
265	-822.98	1013.15	370	-833.84	1019.80	489	-429.49	570.56
266	-550.09	705.30	373	-427.41	558.81	490	-479.82	625.93
274	-581.95	737.26	381	-422.49	550.09	490A	-442.17	572.99
276	-428.40	572.25	392	-190.07	300.80	491	-550.65	698.62
277	-966.46	1161.42	393	-493.57	629.35	493	-446.78	579.34
278	-517.72	671.64	396	-688.89	859.06	500	-403.03	535.44
293	-389.46	521.70	397	-654.26	821.64	502	-570.91	732.38
295	-614.14	772.60	401	-383.42	509.94	502A	-369.50	505.00
297	-717.18	884.11	408	-1102.51	1318.98	511	-434.97	566.92
298	-624.65	783.32	409	-487.90	633.02	512	-498.77	638.03
302	-620.95	784.37	414	-1144.21	1363.04	512A	-418.50	550.75
305	-1392.39	1632.10	417	-722.60	889.42	522	-1040.10	1242.03
306	-385.96	519.47	420	-814.84	998.63	523	-1295.40	1534.88
308	-763.58	945.07	420A	-549.67	696.77	525	-730.59	903.54
311	-761.43	940.32	423	-697.01	867.51	538	-775.65	954.13
313	-1609.66	1885.62	424	-555.99	702.21	542	-974.47	1172.47
313A	-633.29	786.97	426	-504.57	645.22	548	-608.45	772.02
314	-599.52	759.80	432	-853.53	1043.62	549	-362.71	494.81
317	-725.88	894.15	438	-606.44	756.74	561	-567.71	721.12
319	-888.43	1083.55	439	-628.04	787.77	563	-515.21	666.38
324	-581.46	732.01	442	-456.46	591.41	568	-540.56	691.59
324A	-611.06	765.24	446	-786.34	960.29	571	-462.19	596.57
325	-1013.01	1225.07	447	-472.19	615.02	574	-759.09	924.83
328	-1252.14	1479.46	451	-415.30	549.45	575	-939.89	1143.39
330	-729.04	900.76	453	-1210.47	1434.63	577	-1014.16	1222.80
336	-414.60	554.67	456	-700.11	869.25	579	-1091.53	1308.29
339	-379.96	508.65	457	-539.77	699.79	580	-462.00	603.44
340	-688.66	851.48	459	-552.09	703.54	581	-828.45	1001.51
341	-903.36	1102.19	461	-435.58	576.57	585	-646.25	803.37
343	-760.43	940.29	462	-548.71	692.10	591	-918.57	1105.31
344	-1138.84	1362.27	464	-670.22	842.27	592	-705.65	874.82
346	-516.57	663.76	465	-222.06	324.35	594	-659.50	822.99
347	-446.80	588.99	467	-712.51	881.00	595	-989.54	1194.53
348	-334.07	440.16	471	-402.87	545.18	597	-543.00	692.11
357	-392.89	519.70	476	-733.57	908.97	598	-746.54	920.75
361	-676.60	840.27	481A	-449.39	591.96	598A	-551.20	694.96
600	-754.48	928.58	723	-571.84	722.24	816	-460.61	595.46
601	-879.40	1064.29	725	-1302.47	1545.22	818	-396.11	528.94
603	-690.04	864.61	727	-430.81	571.12	821	-904.44	1100.90
603A	-614.69	771.24	728	-641.36	813.39	822	-359.43	484.62
609	-1004.98	1209.75	732	-804.39	988.04	824	-502.09	647.93
611	-417.19	553.43	733	-750.58	925.93	829	-535.88	687.78
611A	-371.84	491.64	736	-365.68	479.58	833	-621.51	788.14
614	-707.02	881.55	737	-463.50	599.93	834	-918.52	1117.00
617	-455.65	596.22	738	-354.12	496.00	836	-592.09	749.43
619	-518.50	666.74	740	-631.37	797.62	836A	-281.45	400.63

625	-620.92	783.40	741	-795.06	976.59	837	-712.68	875.77
629	-898.98	1085.95	743	-713.52	894.27	839	-585.77	746.18
633	-663.11	823.46	744	-657.86	827.76	841	-1025.97	1237.27
642	-782.13	968.26	745	-761.19	940.57	842	-586.81	738.65
643	-802.77	980.14	746	-666.55	835.42	844	-534.01	682.88
645	-342.26	474.75	750	-1057.91	1268.38	845	-953.71	1147.90
647	-414.84	546.67	751	-629.70	797.09	846	-650.58	812.17
651	-1434.59	1683.40	752	-449.36	591.78	846A	-552.76	702.97
653	-584.30	718.76	756	-624.31	782.05	849	-577.30	736.80
655	-1060.47	1269.59	757	-712.76	873.46	850	-800.88	965.50
656	-809.07	996.99	765	-386.20	506.51	854	-1019.52	1220.99
658	-652.09	819.00	767	-419.25	561.48	855	-379.27	506.84
660	-652.14	818.28	768	-762.53	939.46	861	-833.16	1012.37
661	-674.31	839.45	775	-827.13	1012.71	864	-563.07	721.10
664	-1022.73	1231.12	780	-912.60	1106.05	867	-411.15	533.30
670	-548.56	699.11	781	-438.05	581.25	868	-491.48	630.01
671	-982.40	1193.73	783	-1095.09	1310.90	869	-920.48	1113.74
673	-692.34	855.20	785	-486.86	632.07	870	-828.39	1004.10
674	-690.78	858.88	786	-720.71	883.29	871	-580.18	735.50
674A	-556.90	709.14	787	-507.34	654.45	872	-321.27	440.37
676	-873.34	1064.74	791	-558.97	715.49	875	-370.18	496.06
684	-1120.83	1333.51	794	-460.27	599.73	881	-432.04	566.86
687	-633.52	795.62	794A	-582.19	728.08	882	-745.81	918.29
691	-642.83	808.52	795	-221.37	316.80	885	-860.55	1043.74
692	-734.97	912.28	800	-843.10	1034.97	888	-458.60	610.31
714	-492.84	612.76	800A	-709.65	877.61	891	-713.26	893.08
715	-808.30	987.92	802	-309.03	432.56	893	-402.75	528.89
717	-587.03	736.00	805	-529.90	677.46	894	-782.35	965.14
718	-495.05	648.22	806	-660.33	826.95	896	-1003.16	1199.24
719	-176.12	281.06	810	-791.71	965.09	897	-379.62	514.15
720	-333.05	456.38	812	-861.74	1041.53	898	-1156.97	1382.26
721	-316.78	448.11	815	-615.47	777.18	900	-338.60	462.75
902	-169.40	266.58	952	-323.92	434.95			
905	-781.93	955.87	953	-164.54	268.07			
908	-500.00	635.69	954	-577.17	728.41			
911	-890.20	1073.45	955	-555.74	711.29			
919	-501.30	643.53	956	-438.52	580.82			
921	-638.59	793.93	961	-868.06	1063.59			
922	-585.90	733.74	963	-580.20	724.37			
925	-547.69	696.76	968	-585.34	729.97			
926	-724.00	898.38	975	-267.32	385.40			
928	-522.85	661.39	982	-660.45	820.52			
929	-634.22	792.72	984	-538.34	675.03			
931	-441.03	576.12	989	-497.69	645.41			
932	-449.70	596.29	990	-330.34	457.04			
933	-172.48	268.96	992	-1096.80	1302.30			
936	-1078.18	1290.86	994	-1073.78	1282.11			
943	-779.38	961.56	995	-468.89	606.31			
947	-741.75	919.22	1004	-307.08	433.52			
948	-1068.01	1271.74	1009	-909.78	1095.70			
949	-584.58	745.95	1011	-828.39	1003.65			
950	-428.34	565.42	1012	-996.65	1201.58			
951	-604.04	758.39	1016	-1355.81	1593.96			

15. Cross M x PKDA

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
2200	1216.55	-168.98	2250	666.03	-75.70	2287A	751.09	-89.39
2200A	890.97	-113.48	2251	771.95	-89.18	2289	445.19	-33.37
2201	1199.05	-164.28	2251A	761.34	-87.33	2290	540.90	-53.13
2202	749.44	-81.06	2252	1605.97	-233.25	2294	1091.17	-152.19
2203	1182.18	-162.48	2254	782.76	-95.47	2296	1068.83	-145.09
2208	820.40	-101.99	2255	1128.65	-155.70	2297	748.38	-84.41
2209	732.28	-77.62	2256	788.75	-99.31	2297A	328.96	-17.46
2213A	1353.60	-197.43	2257	1184.36	-166.76	2298	980.32	-128.05
2213	811.30	-94.86	2259	830.95	-99.69	2300	897.16	-114.85
2215	1080.38	-146.40	2261	864.56	-108.83	2327	780.82	-93.26
2215A	1208.34	-172.75	2262	1129.87	-156.27	2328	1418.83	-197.33
2216	461.50	-43.18	2264	565.15	-56.84	8500	972.26	-123.98
2222	1726.58	-255.88	2265	745.92	-91.37	8502	616.73	-73.22
2227	987.79	-128.20	2267	937.09	-120.26	8503	994.34	-129.71
2228	861.86	-103.11	2268	1613.08	-234.70	8505	808.15	-101.94
2229	767.49	-96.03	2269	1539.27	-223.81	8506	968.32	-125.62
2230	1235.80	-169.34	2271	1152.09	-155.80	8507	1063.76	-141.09
2232	856.25	-106.90	2273	931.33	-120.88	8509	1158.75	-164.12
2233	1346.70	-192.05	2274	1530.26	-227.48	8510	1447.48	-209.48
2234	1091.49	-152.31	2276	1053.46	-143.84	8512	849.08	-105.95
2235	881.10	-111.82	2276A	742.87	-91.10	8513	456.59	-45.55
2237	1766.02	-267.19	2277	665.97	-72.79	8514	906.93	-123.47
2239	1701.35	-251.55	2278	738.00	-83.79	9500	441.97	-37.38
2240	1073.97	-142.36	2279	856.74	-105.69	9501	411.01	-38.09
2241	547.53	-53.08	2280	793.94	-99.86	9502	670.74	-77.68
2242	1340.67	-192.41	2281	1090.89	-148.38	9509	915.29	-122.27
2243	1641.22	-241.63	2282	965.02	-125.93	9510	786.57	-96.49
2246	1650.38	-245.85	2283	1177.69	-162.17	9513	1178.46	-164.40
2247	1171.50	-162.13	2284	538.64	-47.99	9517	1528.59	-224.44
2248	1344.18	-194.01	2285	1409.91	-208.84	9624	449.37	-39.79
2249	617.26	-64.40	2287	383.49	-25.94			

16. Cross PKDA x M

Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component	Hybrid Number	1st Component	2nd Component
5946	1250.33	-167.45	6025	815.19	-91.67	6091	1338.97	-183.21
5948	1463.18	-214.11	6028	1084.52	-139.15	6093	3069.35	-523.64
5949	1015.94	-132.20	6029	721.37	-85.64	6095	790.11	-93.49
5950	655.62	-63.37	6030	1301.61	-174.29	6097	1395.84	-200.07
5954	705.52	-64.22	6031	1362.98	-197.47	6098	907.40	-100.58
5955	655.33	-64.46	6033	1354.08	-195.83	6099	1341.05	-188.27
5956	978.35	-122.14	6037	1017.10	-127.79	6100	1098.36	-149.00
5957	1761.88	-269.92	6038	1529.17	-226.15	6102	1468.61	-214.35
5958	1114.37	-149.48	6042	1655.72	-250.66	6103	2089.37	-335.61
5967	1299.28	-182.81	6043	984.00	-122.35	6106	1614.77	-242.63
5969	1027.57	-132.55	6044	1433.96	-210.64	6122	1196.62	-168.84
5973	566.40	-59.49	6046	773.73	-81.43	6123	2341.73	-383.80
5974	461.13	-28.42	6048	1033.75	-131.55	6130	1024.34	-127.73
5975	2247.70	-366.13	6049	1286.14	-180.13	6131	1715.69	-258.94
5977	883.55	-104.58	6050	581.99	-59.47	6133	1642.50	-244.17
5978A	768.46	-74.61	6053	1707.81	-261.67	6134	505.10	-35.94
5978	963.78	-121.42	6056	789.06	-85.12	6143	851.82	-104.79
5979	556.39	-45.60	6061	1460.27	-215.20	6145	1634.96	-241.89
5993	2209.77	-355.90	6062	1604.26	-239.83	6148	1458.06	-214.46
5994	1828.16	-287.31	6066	1967.03	-315.19	6192	733.92	-81.60
5995	2072.08	-334.51	6067	320.60	-17.56	6193	971.56	-123.36
5997	1354.64	-189.27	6069	946.70	-119.00	6194	1484.24	-221.41
5998	834.45	-91.40	6073	1080.31	-142.53	6195	596.10	-52.99
6001	1044.82	-132.42	6075	2167.52	-346.70	6197	771.38	-88.62
6002	720.80	-72.67	6080	937.30	-112.43	6202	806.81	-90.49
6003	1463.76	-213.16	6083	1164.33	-153.88	6213	1095.66	-145.25
6005	926.85	-106.83	6084	1388.05	-202.75	6215	810.34	-90.75
6006	885.21	-102.75	6086	1117.48	-147.16			
6022	1099.68	-137.72	6087	1793.55	-273.68			

APPENDIX IV

Euclidean distance of the progenies in sixteen cross combinations

1. KKR x S-1

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
4043	431.68	4086	1317.30	4134	426.38	5860	432.16
4044	541.29	4087	791.90	4135	499.28	5861	730.97
4045	435.64	4089	718.17	4136	423.94	5862	427.11
4048	688.95	4090	932.61	4145	583.61	5865	686.52
4049A	434.55	4091	500.54	4146	2425.90	5868	459.88
4050	505.00	4092	432.27	4150	464.33	5869	427.15
4053	654.13	4095	425.68	4154	440.72	5870	423.66
4054	488.27	4096	444.54	4155	444.82	5871	486.09
4055	1975.69	4097	423.80	4160	812.85	5872	496.92
4056	425.99	4099	541.97	4165	626.15	5873	1468.73
4057	1129.24	4101	648.73	4171	673.49	5878	646.67
4058	953.50	4102	516.96	4172	501.63	5879	645.33
4059	423.52	4103	458.51	4173	425.03	5880	435.46
4060	556.45	4104	531.44	4176	455.18	5882	517.68
4061	454.02	4105	658.36	5812	573.48	5885	453.40
4062	603.31	4106	611.12	5813	752.85	5887	501.68
4067	1143.12	4109	578.44	5815	966.23	5890	477.40
4068	431.49	4110	483.50	5818	593.82	5891	450.05
4069	1080.15	4111	424.77	5819	424.70	5894	653.45
4070	586.69	4112	672.88	5829	424.28	5895	672.18
4071	423.40	4113	429.74	5830	424.73	5904	577.42
4073	589.33	4114	458.86	5834	452.69	5905	614.71
4074	700.21	4115	541.94	5835	852.75	5910	839.59
4075	675.73	4116	449.26	5837	467.75	5913	437.10
4076	477.05	4117	510.74	5838	423.60	8619	423.41
4079	826.92	4119	495.06	5841	885.77	8620	574.23
4080	760.06	4120	538.37	5845	471.55	8621	711.30
4081	769.64	4124	604.87	5846	481.09	8622	426.34
4082	423.66	4130	631.37	5852	501.96	8623	632.27
4084	877.48	4130A	446.31	5857	549.98	8624	672.49
4085	538.81						

2. KKR x K

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
1962	499.29	5916	480.33	5933	1067.27	7577	711.49
1966	457.83	5917	455.32	5934	502.41	7580	535.28
1967	640.87	5918	465.69	5936	522.20	7581	620.45
1968	592.93	5919	550.36	5937	764.44	7583	461.50
1970	724.17	5920	499.31	5938	655.00	7585	955.29
1975	1509.12	5922	475.42	5939	520.05	7587	547.04
1977	455.51	5923	530.49	5940	532.17	7588	455.34
1978A	490.16	5927	561.89	5941	897.00	7873	478.90
1978	466.23	5928	455.30	5942	457.43	7916	510.13
1980	1039.67	5929	875.41	5943	526.21	7918	950.66
1982	742.68	5931	710.68	7517	2031.71	7919	553.45
1984	776.27	5932	566.21				

3. KKR x M

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
7262	371.67	7298	401.34	7326	379.44	7356	384.34
7263	393.30	7299	443.25	7327	424.66	7357	671.06
7264	369.73	7300	938.17	7328	438.49	7358	491.55
7265	369.51	7301	675.87	7329	506.71	7359	437.73
7266	402.45	7302	933.54	7330	417.06	7362	415.35
7267	602.05	7303	466.99	7331	645.11	7363	427.69
7268	397.54	7304	369.85	7332	373.41	7364	372.13
7269	1724.69	7305	590.75	7336	570.17	7366	337.00
7270	531.33	7306	405.93	7337	832.57	7367	432.37
7271	375.01	7308	420.79	7338	415.72	7368	700.03
7272	458.71	7309	394.37	7341	565.96	7370	1026.29
7273	405.92	7310	378.51	7341A	395.97	7371	703.71
7274	481.38	7313	683.38	7343	383.74	7373	440.17
7285	535.21	7314	390.13	7345	392.36	7374	451.40
7286	376.35	7315	632.28	7346	371.62	7381	1453.07
7287	369.65	7317	370.91	7347	491.11	7741	773.00
7290	682.09	7318	370.43	7349	933.62	7747	586.89
7291	374.63	7319	687.05	7350	676.34	7748	406.95
7295	518.78	7320	537.43	7352	379.86	7749	632.87
7297	492.12	7321	394.57	7353	465.69	7752	906.63
		7323	369.59	7354	527.70	8618	537.71

4. M x PKDA

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
2200	494.19	2240	412.33	2269	817.42	2298	390.70
2200A	389.93	2241	637.72	2271	453.82	2300	388.84
2201	483.80	2242	606.93	2273	387.53	2327	422.99
2202	446.96	2243	943.74	2274	805.99	2328	697.67
2203	463.73	2246	962.21	2276	406.85	8500	390.19
2208	402.67	2247	473.28	2276A	449.16	8502	559.91
2209	452.46	2248	616.41	2277	527.51	8503	396.13
2213A	624.14	2249	572.04	2278	453.31	8505	406.39
2213	410.28	2250	521.82	2279	393.08	8506	392.81
2215	415.27	2251	432.47	2280	416.10	8507	411.95
2215A	498.33	2251A	434.84	2281	422.30	8509	467.95
2216	724.54	2252	895.27	2282	389.42	8510	724.43
2222	1046.88	2254	419.56	2283	468.54	8512	398.35
2227	393.14	2255	438.42	2284	650.88	8513	735.64
2228	394.47	2256	418.77	2285	693.19	8514	387.93
2229	427.34	2257	472.21	2287	843.46	9500	762.67
2230	521.63	2259	404.64	2287A	441.82	9501	798.56
2232	394.20	2261	394.54	2289	751.94	9502	507.37
2233	608.36	2262	437.44	2290	648.42	9509	387.73
2234	422.95	2264	621.17	2294	423.58	9510	418.76
2235	390.51	2265	439.21	2296	413.32	9513	472.18
2237	1115.01	2267	387.67	2297	440.43	9517	819.55
2239	1025.52	2268	900.58	2297A	914.17	9624	741.87

5. M x S-1

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
2855	482.04	2985	865.60	3097	650.43	3461	363.44
2860	376.06	2986	497.53	3101	390.26	3462	326.48
2863	406.95	2988	327.14	3102	362.39	3464	857.68
2865	448.00	2989	364.32	3104	398.02	3466	329.60
2868	391.46	2990	639.33	3106	337.40	3471	328.25
2872	655.09	2993	338.94	3107	326.06	3473	375.67
2882	352.93	2994	327.56	3108	530.43	3474	549.11
2883	527.90	2995	390.33	3111	537.05	3477	335.36
2886	561.82	2997	549.86	3116	536.81	3478	325.74
2887	368.64	2999	451.49	3119	347.63	3479	905.99
2890	650.50	3001	325.76	3123	638.26	3481	472.22
2899	337.81	3005	332.79	3126	346.20	3482	327.98
2900	495.64	3007	421.07	3127	374.30	3483	325.55
2902	432.79	3008	343.66	3133	371.42	3484	482.30
2904	534.63	3014	594.20	3134	327.25	3486	455.75
2906	331.39	3017	485.54	3365	752.58	3488	481.46
2912	437.14	3022	332.83	3389	344.99	3489	885.43
2913	329.85	3023	431.19	3399	484.19	3491	405.69
2914	325.54	3025	650.30	3416	625.99	3499	389.24
2916	577.65	3028	324.98	3417	560.48	3500	407.44
2922	522.70	3029	575.13	3420	871.92	3502	527.82
2923	422.26	3030	539.42	3422	327.04	3504	324.86
2933	324.95	3039	365.88	3423	329.01	3505	425.25.
2941	416.65	3044	331.16	3425	380.33	3509	588.73
2942	768.19	3052	748.61	3430	774.21	3510	360.67
2943	348.17	3053	414.87	3435	412.16	3512	552.16
2943A	337.14	3055	326.16	3436	325.03	3513	417.30
2944	335.47	3063	389.95	3439	919.83	3516	354.61
2958	338.05	3064	345.57	3441	406.92	3517	397.15
2959	579.91	3067	344.87	3442	644.98	3519	345.35
2962	594.30	3074	452.49	3447	1137.43	3521	779.72
2968	350.82	3075	377.65	3448	344.07	3522	697.38
2971	325.02	3076	531.91	3450	600.83	3523	349.74
2972	925.54	3079	328.58	3452	326.63	3534	324.88
2973	349.39	3087	368.24	3455	413.36	3539	377.43
2974	393.37	3088	328.85	3456	641.12	3540	548.37
2975	371.64	3091	458.30	3457	326.43		
2976	325.88	3093	415.24	3459	625.13		

6. M x KKR

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
2125	353.69	4246	427.67	4331	539.89	4998	411.98
2126	355.09	4247	462.52	4332	447.79	5002	364.40
2127	793.09	4249	396.71	4334	367.33	5004	361.63
2139	1138.23	4251	372.29	4335	404.59	5005	423.79
2140	352.35	4252	676.94	4337	382.76	5008	355.20
2143	368.98	4253	435.97	4338	600.76	5012	493.01
2143A	352.70	4254	820.86	4339	359.10	5013	624.33
2145	444.34	4256	399.57	4340	714.90	5014	508.45
2152	381.73	4259	508.89	4341	543.44	5017	400.48
2155	527.55	4260	779.00	4342	377.03	5019	451.93
2156	429.83	4261	357.54	4343	400.37	5021	432.14
2165	424.97	4264	452.51	4345	851.76	5022	529.02
2173	365.05	4265	418.00	4346	349.73	5023	502.81
2348	473.98	4266	363.33	4348	393.71	5027	377.47
2351	357.32	4267	515.29	4349	358.57	5029	368.02
2371	399.19	4275A	923.42	4350	789.26	5031	427.40
2374	367.58	4275	779.70	4351	560.01	5032	381.43
4179	474.49	4278	350.02	4352	450.82	5033	507.57
4185	397.57	4280	542.64	4355	359.96	5035	372.28
4186	390.73	4283	355.35	4357	684.11	5036	395.23
4190	400.35	4284	401.61	4358	404.15	5038	482.38
4191	350.39	4285	534.01	4359	378.19	5039	506.04
4194	487.09	4286	430.44	4360	439.41	5040	353.45
4195	490.05	4287	567.63	4361	350.53	5041	351.56
4196	441.92	4289	524.75	4362	365.19	5042	498.22
4198	464.32	4290	368.35	4364	389.57	5043	682.29
4199A	467.32	4292	604.55	4365	370.70	5044	412.69
4200	647.65	4292A	349.74	4368	1353.78	5045	420.49
4201	772.03	4295	351.40	4372	668.79	5046	355.55
4203	752.32	4297	544.27	4374	355.76	5047	527.49
4204	613.31	4298	367.55	4376	815.41	5052	350.10
4205	383.05	4298A	355.91	4377	1070.86	5053	651.99
4207	450.35	4299	649.92	4377A	350.50	5056	358.26
4210	367.07	4301	1033.18	4378	388.37	5057	476.47
4211	354.07	4304	388.13	4379	675.79	5058	473.29
4212	366.28	4305	897.83	4380	483.90	5059	350.08
4213	349.92	4306	518.39	4381	441.59	5061	355.38
4215	449.65	4307	456.53	4383	352.07	5062	350.67
4216	1237.24	4309	962.91	4385	499.50	5063	517.73
4217	444.08	4314	420.15	4976	423.48	5065	486.32
4223	437.68	4315	377.44	4980	349.86	5068	365.33
4224	370.04	4316	357.36	4981	350.37	5069	410.88
4226	443.21	4317	403.32	4982A	412.35	5071	350.98
4227	434.66	4318	1413.02	4985	395.96	5072	870.76
4228	406.81	4319	698.42	4986	699.95	5074	406.70
4231	976.63	4322	806.39	4989	613.48	5076	369.04
4237	351.88	4324	458.81	4990	632.91	5079	353.79
4240	356.74	4325	421.97	4991	519.67	5081	349.95
4241	412.80	4326	630.62	4993	416.26	5082	391.20
4243	349.84	4327	394.25	4995	503.18	5083	755.03
4244	429.53	4328	355.92	4996	392.04	5083A	623.60
4245	352.54	4329	375.31	4997	533.99	5086	701.63

5087	801.81	5101	421.48	5124	383.12	5443	491.31
5088	353.13	5102	388.00	5126	731.70	5450	413.47
5090	511.10	5105	353.10	5132	668.50	5455	366.92
5091	427.72	5107	356.48	5258	812.96	5475	677.33
5094	499.01	5110	458.71	5267	356.82	5500	485.85
5096	576.79	5111	453.00	5279	803.67	5502	355.65
5097	350.40	5116	353.81	5286	586.63	5512	364.32
5098	516.50	5120	1483.70	5288	509.13	5528	351.09
						5537	391.02

7. M x K

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
255	439.19	365	712.84	486	469.53	603A	377.59
256	379.61	366	395.62	488	1259.30	609	754.33
257	596.29	369	384.37	489	506.79	611	522.91
262	415.46	370	515.42	490	445.61	611A	603.12
265	500.57	373	514.84	490A	486.51	614	403.21
266	392.75	381	520.75	491	394.90	617	474.74
274	381.37	392	910.23	493	482.57	619	416.14
276	493.18	393	441.18	500	539.09	625	377.42
277	693.66	396	393.73	502	383.64	629	586.22
278	414.72	397	381.59	502A	585.47	633	382.14
293	553.57	401	566.85	511	498.07	642	462.18
295	377.61	408	924.56	512	437.27	643	476.77
297	407.67	409	446.17	512A	531.40	645	630.77
298	377.42	414	987.88	522	817.61	647	529.61
302	377.96	417	407.81	523	1276.58	651	1535.67
305	1450.57	420	482.95	525	421.60	653	384.90
306	565.19	420A	392.48	538	457.27	655	842.93
308	447.73	423	397.65	542	705.06	656	486.77
311	439.65	424	396.91	548	378.54	658	380.88
313	1909.38	426	424.42	549	598.82	660	381.18
313A	377.57	432	537.92	561	387.20	661	386.96
314	379.00	438	378.43	563	414.31	664	782.02
317	411.90	439	377.89	568	402.68	670	395.52
319	586.77	442	476.26	571	464.75	671	729.82
324	385.35	446	465.07	574	439.81	673	395.45
324A	378.33	447	456.51	575	653.35	674	391.78
325	775.40	451	525.97	577	775.41	674A	390.87
328	1182.92	453	1115.13	579	901.02	676	562.57
330	416.71	456	395.13	580	461.54	684	944.64
336	518.91	457	397.08	581	512.32	687	378.92
339	567.16	459	392.33	585	379.80	691	379.70
340	393.59	461	483.13	591	616.46	692	422.52
341	606.54	462	395.28	592	401.49	714	442.85
343	440.07	464	386.01	594	383.51	715	479.52
344	987.87	465	868.59	595	726.76	717	380.95
346	414.97	467	406.78	597	399.13	718	427.95
347	474.53	471	556.05	598	427.07	719	956.04
348	658.52	476	417.88	598A	395.92	720	659.94
357	550.60	481A	479.71	600	434.15	721	679.13
361	387.00	481	618.60	601	571.00	723	386.62
364	378.90	483	398.73	603	396.03	725	1294.02

727	493.73	795	875.40	861	510.66	931	492.94
728	380.41	800	528.71	864	386.56	932	478.02
732	487.06	800A	401.54	867	534.15	933	970.84
733	434.22	802	691.22	868	439.36	936	873.51
736	607.46	805	405.37	869	626.62	943	462.06
737	460.76	806	384.78	870	502.59	947	428.20
738	591.78	810	470.11	871	381.66	948	848.95
740	377.88	812	540.41	872	668.21	949	381.25
741	475.15	815	377.80	875	600.60	950	507.28
743	412.07	816	466.25	881	500.00	951	378.53
744	383.43	818	551.12	882	428.19	952	669.28
745	448.91	821	603.09	885	540.41	953	978.79
746	385.28	822	609.09	888	462.13	954	383.84
750	836.09	824	424.37	891	407.22	955	395.47
751	377.88	829	402.84	893	548.12	956	485.56
752	480.22	833	377.53	894	458.77	961	563.31
756	377.62	834	618.11	896	746.36	963	383.87
757	401.64	836	380.02	897	569.35	968	382.30
765	560.32	836A	744.21	898	1012.21	975	771.21
767	512.03	837	402.66	900	649.21	982	383.25
768	440.86	839	380.80	902	962.54	984	403.88
775	513.13	841	787.90	905	454.93	989	429.69
780	610.78	842	381.25	908	436.78	990	653.67
781	494.40	844	403.92	911	582.16	992	897.46
783	894.11	845	674.84	919	428.00	994	856.00
785	447.62	846	379.85	921	377.94	995	462.03
786	407.06	846A	394.20	922	382.28	1004	687.48
787	422.39	849	381.93	925	395.08	1009	603.80
791	388.17	850	471.22	926	411.31	1011	500.35
794	467.50	854	774.58	928	417.36	1012	741.57
794A	384.19	855	577.25	929	378.06	1016	1388.38

8. K x M

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
95	624.97	128	511.88	193	519.18	1028A	516.29
99	636.27	132	885.67	193A	858.12	1035	996.92
100	520.21	133	595.07	194	583.18	1041	497.94
101	518.47	134	1098.66	202	610.69	1044	511.84
105	538.54	135	498.00	203	984.53	1049	532.61
107	502.97	145	757.33	210	551.61	1052	529.33
108	726.87	154	507.11	211	1228.68	1054	831.68
109	596.15	159	619.67	214	571.81	1058	506.26
110	497.87	161	580.54	236	552.34	1059	1858.02
113	498.17	162	569.68	237	589.32	1060	1023.10
114	652.67	166	712.43	239	609.39	8680	537.66
118	681.79	176	672.78	248	1187.90	8682	512.67
119	659.50	177	505.33	1025	734.12	8683	708.65
121	742.26	178	585.66	1027	528.25	8684	612.11
125	1910.16	179	497.62	1028	505.58	8689	763.79
126	640.77						

9. K x KKR

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
1987	382.66	2011	477.17	8725	389.19	8794	506.08
1992	525.49	2022	715.52	8726	406.04	8796	382.57
1996	388.97	2028	435.90	8730	582.62	8799	569.27
1998	442.08	2029	403.82	8734	402.70	8827	486.33
1999	581.60	2033	533.77	8746	383.02	8839	437.12
2000	512.10	2034	383.58	8754	386.80	8948	512.01
2001	455.38	2035	386.36	8759	769.73	8966	471.57
2002	602.11	2039	426.98	8764	521.88	8967	1612.32
2003	1103.49	2040	456.05	8765	706.94	8970	862.07
2004	395.50	2041	924.79	8773	385.97	8976	447.49
2008	501.53	8717	408.59	8785	458.88	8989	510.24

10. K x PKDA

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
2193	519.52	7595	457.17	7627	719.15	7640	696.48
2194	575.36	7596	1146.34	7631	443.12	7641	447.51
2195	894.95	7597	516.44	7632	456.81	7644	559.93
7592	439.97	7624	574.76	7633	695.73	7658	439.94
7593	457.32	7625	560.96	7637	448.74	7660	1253.97
				7639	825.81	7664	559.93

11. S-1 x M

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
3286	506.24	3323	591.20	7439	2051.18	7500	959.91
3288	1349.42	3325	579.85	7442	720.26	7501	623.01
3290	506.03	3326	642.01	7443	808.48	7502	541.95
3292	826.66	3330	510.56	7444	2318.29	7504	672.79
3294	1005.26	3333	518.66	7445	756.47	7510	550.61
3307	1557.56	3334	660.56	7447	504.63	8563	530.15
3308	1007.91	3337	628.49	7448	716.22	8564	549.75
3309	527.18	3339	566.24	7449	519.41	8565	825.79
3310	572.70	3340	587.11	7451	822.02	8566	508.31
3311	526.70	3344	1058.34	7453	616.57	8567	584.88
3312	582.71	3350	556.31	7456	565.68	8568	896.62
3313	504.56	3352	505.82	7460	504.96	8570	760.41
3314	506.37	3353	620.78	7461	508.16	8571	549.80
3315	734.44	3364	1056.62	7462	630.67	8572	674.75
3316	573.24	7431	737.58	7463	514.19	8573	504.76
3317	743.12	7432	706.06	7475	667.85	8574	504.19
3319	594.66	7435	504.30	7494	2101.63	8575	511.43
3320	515.03	7437	1399.34	7497	881.68	8577	626.45
3321	507.26	7438	722.96	7498	929.66	8578	625.34
				7499	1004.87	8579	685.89

12. S-1 x KKR

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
6741	944.23	6772	1209.77	6809	646.39	6817	560.84
6755	579.37	6802	961.07	6810	792.90	6818	955.46
6757	623.00	6804	709.15	6811	566.87	6819	965.65
6758	565.48	6805	1118.19	6813	588.51	6820	732.48
6762	565.23	6806	605.72	6814	1517.89	6822	561.49
6767	676.72	6807	993.33	6815	649.77	6827	884.60
		6808	630.29	6816	620.00	6829	720.14

13. S-1 x PKDA

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
6216	513.06	6230	515.31	6252	719.49	6278	703.98
6217	1782.06	6232	551.19	6253	923.83	6281	732.19
6219	917.37	6233	512.77	6254	520.69	6282	644.92
6221	1797.70	6234	893.93	6259	732.40	6283	517.26
6222	537.67	6235	808.16	6260	753.06	7781	610.60
6223	581.24	6237	580.84	6261	515.09	7782	513.50
6224	570.88	6239	619.95	6263	633.62	7783	522.99
6225	666.24	6240	590.05	6266	1342.57	7784	609.68
6226	538.68	6241	815.37	6270	693.02	7785	656.48
6228	527.14	6242	943.76	6271	537.74	7786	1397.85
6229	559.64	6244	739.73	6275	787.95	7788	677.50
		6250	902.89	6277	630.59	7789	512.78

14. PKDA x M

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
5946	476.83	5997	502.47	6049	485.12	6099	499.72
5948	551.55	5998	550.49	6050	746.27	6100	460.75
5949	469.39	6001	465.59	6053	730.24	6102	557.25
5950	692.54	6002	633.12	6056	576.74	6103	1102.51
5954	647.93	6003	551.77	6061	553.22	6106	655.79
5955	690.89	6005	502.45	6062	646.63	6122	471.66
5956	479.07	6006	521.01	6066	981.35	6123	1386.80
5957	778.88	6022	461.07	6067	1049.59	6130	468.97
5958	461.90	6025	558.11	6069	488.45	6131	731.77
5967	490.86	6028	461.03	6073	461.23	6133	671.91
5969	467.36	6029	627.45	6075	1174.93	6134	847.29
5973	778.09	6030	487.60	6080	498.46	6143	536.33
5974	905.11	6031	507.49	6083	465.79	6145	662.26
5975	1275.93	6033	503.18	6084	517.28	6148	549.94
5977	520.70	6037	469.51	6086	461.38	6192	616.30
5978A	601.78	6038	594.42	6087	806.75	6193	478.66
5978	486.13	6042	689.48	6091	496.41	6194	570.97
5979	780.42	6043	478.18	6093	2238.54	6195	752.08
5993	1227.98	6044	541.22	6095	571.44	6197	590.73
5994	845.82	6046	592.12	6097	521.14	6202	562.52
5995	1092.97	6048	466.27	6098	512.34	6213	460.67
						6215	560.02

15. PKDA x S-1

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
3689	444.66	3749	436.80	3834	435.09	3918	442.97
3692	641.20	3750	451.03	3835	400.11	3942	401.99
3693	654.47	3751	429.84	3836	517.93	3944	1024.53
3696	471.77	3752	834.74	3837	416.15	3946	463.92
3698	837.58	3753	811.48	3839	593.58	3947	536.56
3699	715.12	3754	1923.26	3840	605.84	3950	539.98
3700	419.29	3757	636.45	3841	399.41	3973	401.33
3701	549.96	3759	792.35	3842	613.58	3974	597.24
3703	432.47	3760	402.06	3845	538.92	3980	901.35
3707	407.29	3761	432.63	3857	416.73	3985	663.39
3708	415.17	3762	726.08	3860	412.82	3998	500.48
3709	399.80	3764	518.07	3866	406.65	4000	433.71
3714	588.23	3765	400.94	3871	675.67	4005	522.24
3717	479.72	3766	530.22	3874	401.95	4006	703.02
3719	732.77	3768	545.75	3875	519.56	4009	460.99
3720	692.90	3769	414.71	3876	507.93	4011	496.51
3725	401.58	3770	859.06	3878	626.69	4012	427.91
3727	416.42	3772	436.77	3879	994.05	4015	730.17
3728	810.66	3773	400.04	3880	414.31	4016	400.45
3730	965.96	3774	542.98	3885	438.25	4017	457.39
3732	412.66	3775	410.29	3896	643.36	4018	539.16
3733	551.95	3781	408.87	3897	496.50	4024	434.69
3734	431.17	3788	908.24	3900	429.29	4032	751.22
3739	436.12	3795	406.99	3901	684.65	4033	399.04
3740	494.55	3806	521.50	3902	436.17	4040	872.45
3742	676.43	3814	399.25	3904	415.35	4041	845.96
3746	608.73	3815	404.22	3912	475.41		
3748	400.30	3823	635.58	3914	510.75		
3748A	416.94	3833	995.68	3915	471.26		

16. PKDA x K

Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances	Hybrid Number	Euclidean Distances
2076	306.21	2092	362.37	2108	711.23	7613	516.39
2077	368.85	2095	619.22	2124	337.04	7620	305.71
2090	376.21	2106	535.37	7606	314.91		

HETEROSIS BREEDING AND *IN VITRO* MUTAGENESIS IN PINEAPPLE (*Ananas comosus* [L] Merr.)

By

KURIAKOSE, K. P.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Breeding and Genetics
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680656
KERALA, INDIA

2004

ABSTRACT

A study entitled " Heterosis breeding and *in vitro* mutagenesis in pineapple (*Ananas comosus* [L] Merr.) was undertaken in the Department of Plant Breeding & Genetics, College of Horticulture, Vellanikkara during 1998-2003. The main objective of the study was to create wide genetic variability for selecting ideal pineapple genotypes. The field studies were taken up at Pineapple Research Station, Vazhakulam.

The six parental genotypes, used for hybridization, differ significantly in thirty four out of the thirty five growth, yield and quality characters studied. The genotypes also differ in qualitative characters like colour of leaf and fruit, depth of eyes and spine character. All the genotypes are having a few, not all, desirable characters.

The genotypes differ significantly in number of flowers opened per day and number of flowers per inflorescence. The flowers of Mauritius, Kew, Selection-1 and Ripley Queen open during 4 am to 5 am and that of Pampakuda local and Kakkoor local open during 5 am to 6 am. Flower opening and anther dehiscence coincides in all the genotypes. In all the genotypes, stigma remained receptive from 3 am to 6 pm.

All the six genotypes were crossed in all possible combinations. The crosses K x S-1 and M x RQ and their reciprocals were incompatible. The other crosses differ in the extend of cross compatibility. The genotype Mauritius expressed highest compatibility as a pistillate parent with all other genotypes. Among all cross combinations, Mauritius and PKDA are the most compatible parents. Out of the thirty cross combinations, only sixteen cross combinations reached the final stage of evaluation of the progenies. The highest survival of the seedlings was observed in PKDA x S-1.

The hybrids in the sixteen cross combinations were evaluated individually for thirty five growth and yield characters using the parameters mean, range, percentage of variation of range over mean, mode, mean deviation from mode and coefficient of dispersion. Further, multivariate analysis using five characters, viz., fruit weight

without crown, TSS, total sugar, juice weight % and pulp weight % was done by estimating the determinant of the covariance matrix, Principal Component Analysis and Euclidean distance. All the characters expressed transgressive and independent segregation. Thus each individual plant is unique due to the independent segregation of each character.

Evaluation of all the hybrids in all the cross combinations based on five selected characters, viz., fruit weight without crown, TSS, total sugar, pulp weight % and juice weight % simultaneously for relative heterosis, heterobeltiosis and standard heterosis resulted in identifying 13 hybrids with relative heterosis and 7 hybrids with standard heterosis. When all the twenty hybrids were compared, the hybrid number 257 of the cross M x K was having the highest heterosis in four out of the five characters.

Among the progenies, hybrids with several distinct or abnormal features were observed. Albino seedlings were observed in 16 cross combinations. Hybrids with dual feature, low chlorophyll content, piping character, segregation of colour of heart at the time of initiation of inflorescence, creamy white heart, white flower, extra long and cylindrical fruit and fruits that ripen uniformly were obtained from among various crosses.

For *in vitro* mutagenesis, shoot tips of Mauritius variety were cultured in MS medium supplemented with BAP and uniform masses of globular structures were irradiated with gamma rays at seven doses and compared with control. Chlorophyll mutants and chimera were observed among the *in vitro* plants. Observations on height and number of leaves at 30 days interval of growth up to 120 days from plant out stage showed that radiation of *in vitro* culture at 30 Gy gave enhanced vigour in growth of plantlets. The production of chlorophyll mutants, leaf chimera and variability in height and number of leaves indicated that *in vitro* mutagenesis could be used as a tool for creating genetic variability in pineapple.