INTERCLONAL HYBRIDIZATION STUDIES IN BANANA

By

KRISHNAKUMAR. M. P.

THESIS

submitted in partial fulfilment of
the requirements for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Horticulture
(Pomology & Floriculture and Landscaping)
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1987

DECLARATION

I hereby declare that this thesis entitled "Interclonal hybridization studies in banana" 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,
11-5-1987.

KRISHNAKUMAR, M.P.

CERTIFICATE

Certified that thesis entitled "Interclonal hybridization studies in banana" is a record of research work done independently by Mr.Krishnakumar, M.P. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Dr.(Mrs) P.K.Valsalakumari,
Chairman,
Advisory Committee,
Assistant Professor,
Department of Pomology and
Floriculture.

Vellanikkara,
5 -1987.

CERTIFICATE

We, the undersigned, members of the Advisory Committee of Mr.Krishnakumar, M.P., a candidate for the degree of Master of Science in Horticulture with major in Horticulture, agree that the thesis entitled "Interclonal hybridization studies in banana" may be submitted by Mr.Krishnakumar, M.P., in partial fulfilment of the requirement for the degree.

Dr.(Mrs) P.K. Valsalakumari,
Advisor and Chairman.

Dr.T.V.Viswanathan
Member.

Dr.K. Gopikumar,
Member.

Sri.V.K.G. Unnithan,
Member.

External Examiner
Dr. J.V. Narayana Gowda.

ACKNOWLEDGEMENT

I have no words to express my heartfelt gratitude and obligation to Dr.(Mrs) P.K.Valsalakumari, Assistant Professor, Department of Pomology and Floriculture and Chairman of my Advisory Committee for suggesting the problem, her valuable guidance, fruitful discussions, friendly criticisms, everwilling help, constant encouragement and logic conclusions during entire course of my research work as well as in the preparation of the manuscript. The guidance she gave me and the supervision she did on my work were far beyond the call of duty, for which I am very much indebted to her.

I am fortunate in having Dr.M.Aravindakshan, Director of Research i/c. and Head of Department of Pomology and Floriculture as member of my Advisory Committee. His valuable and critical suggestions helped me a lot for preparation of this thesis.

My indebtedness is also due to Dr.K.Gopikumar, Assistant Professor, Centre for Advanced Studies, member of Advisory Committee for his sincere help and valuable suggestions in the conduct of research work and in the preparation of manuscript.

I express my sincere gratitude to Sri.V.K.G. Unnithan, Associate Professor, Department of Agricultural Statistics, for his keen interest in the study, whole hearted co-operation and immense help rendered for the statistical analysis of the data and the interpretation of the results. The help and co-operation offered by other members of staff of the department is also greatly acknowledged.

I am very much thankful to Dr.P.K.Gopalakrishnan, Associate Dean, College of Horticulture, for providing necessary facilities for conducting the research.

My profound sense of gratitude is also due to Mr.Balasubramaniam, M., Pathologist, Kerala Forest Research Institute, Peechi, for his immense help in the photomicrography.

My indebtedness is also due to all the staff members of the Department of Pomology and Floriculture and of AICFIP who were always with me and provided all the facilities and encouragement during the entire course of study.

I express my gratitude to the labourers of Kerala Agricultural University for their sincere co-operation rendered to me during the field and laboratory works.

My friends were of immense help to me especially, Mr.Joseph, T.F.; Mr.Vijayakumar, K.K.; Mr.Shaji Alexander; Mr.Jayan, K.; Mr.Pradeep G. Varma; Mr.Anilkumar, K.S.; Mr.Rajasekharan, P.; Mr.Sanjeev, K.V. and Mr.Sunil, P.L. and Junior students Mr.Usman, T. and Mr.Thampan, P.V. at various stages of this investigation by giving me their physical and moral support. My thanks are also due to them.

I remain deeply indebted to my brothers, Mr.Raghavan,M.P.; Mr.Muralidharan, M.P.; Mr.Chandrasekhar, M.P. and sisters Mrs.Sathy Unnikrishnan, M.P. and Mrs.Lathika Raghavan, K. and other relatives for their encouragement and help during the course of study.

I shall be failing in my duty, unless I record by heartfelt gratitude to my beloved parents whose love, affection and blessings had always been a neverending source of inspiration to me.

It is with deep sense of admiration and affection that I remember the name of Sri.Joy.K.A. who had shown extreme patience in the long process of typing the manuscript.

The award of research fellowship by Kerala Agricultural University for the Post Graduate course is greatly acknowledged.

Above all, I bow my head before God who blessed me with lots of health, confidence and for His grace to undertake this M.Sc.(Hort.) Programme successfully.

Vellanikkara,
Date : 11-5 -1987.

KRISHNAKUMAR, M.P.

TO MY PARENTS

CONTENTS

LIST OF TABLES

19. Mean values of finger characters of hybrids and parents.

20. Mean values of quality characters of hybrids and parents.

21. Pollen size, production, fertility and viability in hybrids and male parent.

22. Crosses between hybrids and male parent, 'Pisang Lilin' and seed set.

23. Pattern of fertility in hybrids and female parent 'Agniswar' with respect to position of hands.

24. Taxonomic scoring and chromosome number of hybrids.

LIST OF FIGURES

3. Number of functional leaves

4. Leaf area per plant

5. Petiole length

6. Phylacron

LIST OF PLATES

LIST OF APPENDICES

INTRODUCTION

INTRODUCTION

Banana is one of the earliest crops cultivated by man. It is one of the most important tropical fruit crops, and its delicious fruits are favoured throughout the tropics. The importance of the crop to tropical economics can hardly be exaggerated.

In India, banana is one of the most important fruit crops, next only to mango and the country is considered as one of the centres of origin of the crop. Inspite of the fact that India ranks second in banana production among the various banana producing countries of the world, with an acerage of 2.7 lakh hectares under this crop, her contribution to world market is rather negligible. The acerage under banana in Kerala is estimated to be 50,100 hectares with a production of 16,15,227 tonnes per year (FIB, 1985).

Vegetative selection has, until recently, been said to give minimal improvements of bananas. Naturally evolved seedless bananas are perhaps the most conscipicuously sterile of all cultivated fruits. This is one of very few crops in which cultivars developed by controlled breeding have not yet replaced those that were derived from natural

evolution. The approach towards improvements initated at Trinidad and Jamaica in 1920's was intended only for stepping up the desirable quality of the singular variety, 'Gros Michel', grown in monoculture. This commercial cultivar was seriously affected by the notorius disease, 'Banana wilt' or 'Panama disease' caused by the fungus Fusarium Oxysporum f. sp. cubense which rendered the continual cultivation of the cultivar unprofitable. The adaptation of 'Cavendish' clones provided an excellant substitute for 'Gros Michel', but they were highly susceptible to 'Leaf spot' and nematodes. The only satisfactory approach was to induce disease resistance in 'Gros Michel' through breeding so that more genetically diverse clones could be produced for protection against epidemic diseases.

The earlier attempts to cross 'Gros Michel' with wild seeded, disease resistant strains of Musa acuminata were not promising. Slight shortening of finger length, and presence of seeds disqualified the progeny. With the introduction of an edible diploid, 'Pisang Lilin' in 1933, dramatic changes took place in banana breeding and a tetraploid hybrid, 'Bodles Altafort' was released to the growers. But the tall nature of the new hybrid limited its use in high density planting. The use of synthetic parents

is well advanced, but none of their hybrids with 'Gros Michel' has not yet reached commercial level. Recently triploidy breeding has also gained much attention.

The classic banana breeding experiments initiated at the West Indies clearly indicated the possibilities of improving the clones through hybridization. Improvement of Indian bananas has to be considered from a different angle. In India, varieties representing the hybrid origin especially of AB, AAB and ABB genomic group are the largest group and varieties like 'Gros Michel' which has nearly all traits of Musa acuminata are rare.

High degree of variability has been reported in Indian bananas. The variation in quality and productivity has necessitated the use of a good number of cultivars in commercial cultivation. As with 'Gros Michel' in West Indies and Central America, India does not depend on a single banana cultivar for commercial cultivation. The area under each variety depends on local market as well as agroclimatic conditions. In Kerala, the 'Nendran'; in Lower Palanis, the 'Virupakshi'; in Madras, 'the Poovan'; and in Bombay, the 'Basarai' are the important commercial cultivars. The major problem is to restrict the cultivars so that with the use of a few high yielding ones with

desirable qualities, the production can be stepped up. In meeting these objectives new forms can be developed through hybridization with advantage which will have an assemblage of desirable attributes. With more variable varieties in India, the ultimate success of hybridization programme is bound to take a fairly long period.

From the morphological and physiological points of view, many of our commercial cultivars suffer from one defect or other. One of the choicest variety of South India, 'Rasthali' has weak pedicel, which causes the shedding of ripened fruits from bunch while other cultivar like 'Ney Poovan' has short fingers. The edible quality of 'Palayankodan' is relatively poor due to its acidity and soggy pulp. The commercial cultivar of Kerala, 'Nendran' has only a few hands (5-6 per bunch), posses relatively hard textured flesh as compared to 'Gros Michel' and the 'Cavendish' clones, and thick rind; susceptible to bunchy top disease and easily damaged by wind. To meet the demands of internal and export markets, breeding of new forms combining high yield and desirable quality of produce and attributes which reduce damage in storage and transit have to be developed.

As mentioned earlier, India being one of the centres of genetic diversity of bananas, varietal collection is

high and in cultivation, in addition to triploids, a large number of diploid forms also exist. The edible forms of the diploids, such as 'Sanna chenkadali', 'Namarai' and 'Anaikomban', though are seed sterile in mature, have varying degrees of pollen fertility, expression of parthenocarpy and desirable agrobotanic features which point to their high potentalities as male parents in hybridization programmes (Raman, 1976). The pollen production noticed in some of triploids may also be taken advantage for hybridization with other female triploids which produce seeds only on artificial crossing.

The triploids are superior in commercial cultivation. The development of new triploids would be of new preposition. In building up new triploids, it is necessary to keep in view the dwarf habit, upright leaves, lesser suckering and desirable features of bunch and fruit to meet the requirements for the internal market and export.

The hybridization investigations carried out at Tamil Nadu Agricultural University and Kerala Agricultural University are of significant importance with respect to banana breeding in India (Karmacharya, 1984; Tamil Nadu Agricultural University, 1982, 1985). Recently a new hybrid, 'Co.1' has been released from Tamil Nadu Agricultural

University, for cultivation (Azhakiamanavalan et. al., 1985). In Kerala, breeding is in its initial stage. The basic principles of banana breeding - cytotaxonomical studies, pollen fertility and compatibility studies were carried out at the Department of Pomology and Floriculture, College of Horticulture (Karmacharya, 1984; Valsalakumari, 1984). The results revealed that, interclonal hybridization in banana could be carried out between clones that are compatible.

Bearing these aspects in mind, and the significant improvements achieved so far in banana hybridization at the West Indies, United Fruit Company, Honduras, Tamil Nadu Agricultural University and at various other centres, the present studies have been initiated with the following objectives:

1. To study the compatibility among selected female and the male parents and examine the seed set.
2. To study the pollen production per anther, fertility and viability in different nodes of the clones selected as male parents.
3. To study the female fertility pattern in different hands of the selected female parents.
4. To study the effects of different seed treatments on germination of banana seeds and.
5. To evaluate the interclonal hybrids already available.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In crop improvement programme, hybridization offers far greater possibilities than other breeding methods and is the only effective means of combining the desirable characters of two or more varieties in a single plant. In an asexually propagated crop like banana, the significance of hybridization need not be over emphazised since, it helps to create genetic variability and there by production of new varieties. Banana hybridization had its origin over sixty years ago simultaneously and independently in Trinidad and Jamaica. Since then, though some breeding efforts are being made by a number of major banana exporting countries, the progress so far made is very meagre.

1. Hybridization in banana

A brief review of research done in the various aspects of banana hybridization at various centers are discussed here under.

The classic banana hybridization programmes were started in Jamaica and Trinidad in the 1920's (Dodds, 1950; Simmonds, 1966; Shepherd, 1968, 1974; Menendez and Shepherd, 1975), with the main aim of evolving a

cultivar having the desirable qualities of 'Gros Michel' and resistance to Panama disease, the most important threat to banana culture in Jamaica and in Central and South American countries. Switching over to Panama disease resistant 'Cavendish' clones; 'Lacatan' and 'Robusta' did not relieve the problem as they were highly susceptible to leaf spot and nematodes (Stover, 1962, 1972; Leach, 1964).

1.1. Earlier hybridization schemes

The earlier hybridization schemes can be divided into three stages based on the selection of male parents. In the first stage, the two wild seeded species Musa acuminata and Musa balbisiana; in the second stage, the edible diploids and in the third stage, synthetic diploids were used as the male parents.

1.1.1. Wild species as the male parents

Since the main aim of breeding was to induce Panama disease resistance in 'Gros Michel' it was crossed as female parent with wild seeded and disease resistant strains of Musa acuminata subspecies malaccensis as male parent in Trinidad and in Jamaica. The resultant tetraploid hybrids namely 'I.C.2' in Trinidad and 'S.19' in Jamaica resembled the female parent in majority of the

characters, but possessed inferior bunch characters of the male parent such as smaller fruits and occasional seed set, though they were resistant to Panama disease and leaf spot (Cheesman, 1934; Dodds, 1958; Osborne, 1958; Simmonds, 1966).

Dodds (1958) had reported that, undoubtedly, Musa acuminata is the most promising species as male parent. This is the closest relative of most of the dessert bananas, originated in Malaya-Indonesia region. It is a diploid species (2n = 22), immune to Panama disease and Leaf spot. It is highly fertile, giving a copious amount of viable pollen. It was used as a male parent in many other crosses. Crossing 'Mysore' with Musa acuminata, Cheesman (1934) obtained sufficient number of viable seeds. The dessert variety 'km 5' was successfully crossed with Musa acuminata and a number of viable seeds were obtained (National Institute of Agronomy, 1955). Devreux (1959) stated that, crossing of edible bananas with subspecies of Musa acuminata and Musa balbisiana had given rise to diploid and tetraploid hybrids. Borges (1971) observed that 'Bluggoe' clones with ABB genomic group, when pollinated with Musa acuminata and Musa balbisiana set seeds.

1.1.2. Edible diploids as the male parents

The occasional seed set in the tetraploid progenies from 'Gros Michel' x Musa acuminata subspecies malaccensis prevented their commercial adaptability. The main reason for the presence of seeds in the progeny was the transference of fertility genes through the pollen of the male parent to the progeny. The seedlessness in progeny could be achieved by using male parents which are female sterile (parthenocarpic) but at the same time male fertile (Dodds and Simmonds, 1948 a; Simmonds, 1953 a, 1962). The solution to banana breeding problems revealed to be nearer when the first pollen fertile diploid edible cultivar, 'Pisang Lilin' was introduced from Malaya into Trinidad in 1933 and in Jamaica in 1937 (Simmonds, 1966). It had larger fruits than wild types, was resistant to both diseases and as an added advantage, transmitted a high degree of female sterility to progenies which was a desired trait.

'Pisang Lilin' was crossed on to 'Gros Michel' on a large scale in Jamaica during the 1940's and produced several promising progeny. The standards of fruits were better than that of progenies from 'Gros Michel' x Musa acuminata and two of the clones underwent extensive field

trials. The first 'J-1877' was finally rejected and the second was released to growers in Jamaica in 1962 as 'Bodles Altafort' (Osborne, 1962; Simmonds, 1966).

Later on another three edible diploids, 'Paka' and 'Sikuzani' from Zanzibar and 'Tongat' from North Borneo were identified and were used as male parents (Simmonds, 1966).

1.1.3. Synthetic diploids as the male parents

Although, itself immune to Panama disease, 'Pisang Lilin' produced a rather high proportion of (about 60 per cent) disease susceptible plants among its progenies with 'Gros Michel' so that the rejection rate for this reason was high (Larter, 1947). The parthenocarpic tetraploids possessed poorly shaped bunches and often, rather small fruits. These were the defects of 'Pisang Lilin' itself which cannot therefore be regarded as a satisfactory male parent (Dodds, 1958). Similarily, all the known edible diploids suffer from one or other defects and the only generally feasible approach is to breed the male parents (Simmonds, 1966).

Dodds (1958) emphazised that the hope for banana breeding lay in first finding or breeding new male parents

and then seeking commercial bananas among the primary tetraploids produced by them from 'Gros Michel'. In these terms, everything depended on the male parent. He suggested the characters required for an ideal male parent. It must be highly resistant to both diseases, it must have a vertical and compact bunch, it must be parthenocarpic, and it must have sufficient viable pollen in the male flowers to permit its use as a male parent.

Baker and Simmonds (1949, 1951 a) and Simmonds (1956 a, 1956 b) made expeditions to East Africa, Far East and Pacific and collected superior and wild types and edible diploids. From the crosses made from edible diploids with wild Musa acuminata, the progenies were found to be diploids, segregating for parthenocarpy ranging from 10-50 per cent or less. This indicated that parthenocarpy is determined by a series of complementary genes for which the edible diploids are variously heterozygous (Dodds and Simmonds, 1948 a; Simmonds, 1953 a, 1962).

Simmonds (1966) has given a list of important wild Musa acuminata clones and edible diploid clones often used in male parent synthesis. The use of such synthetic male parents is now well advanced, but none of their hybrids, with 'Gros Michel' has yet reached the commercial level.

From United Fruit Company, Hondurars three superior synthetic diploid hybrids have been reported (Rowe and Richardson, 1975; Rowe, 1984). The first is 'SH-2095' which has an unprecedented combination of desirable agronomic features and was derived from crosses between ('Sinwobogi' x 'Tjau Lagadu') x (Musa acuminata x 'Gyod'). The pendulous parthenocarpic bunches of 'SH-2095' has upto 19 hands and weigh upto 30 kg. Another diploid hybrid, 'SH-3142' which was found to be resistant to burrowing nematode and race 4 of Fusarium oxysporum f. sp. cubense was obtained from the 'Pisang Jari Buaya (PJB)' group of diploid accessions. The third hybrid, 'SH-669' which was found to be Moko (bacterial wilt) resistant, was derived from a cross between a wild Musa acuminata Siamea and an edible diploid 'Manag'. These three hybrids are extensively used as male parents in banana breeding in United Fruit Company.

1.2. Recent developments in breeding

'Bodles Altafort', has not gained acceptance with growers since, the banana growers switched over to short statured 'Cavendish' clones, mainly 'Robusta', owing to the possibility of accomodating more number of plants per acre (Simmonds, 1966). Neither it nor any other 'Gros Michel'

is now likely to do so (Shepherd, 1968). They are too tall in stature and so subject to wind damage. Simmonds (1966) described 'Bodles Altafort' as the last of the 'banana dinosaurs'.

Solution to this problem was available in 'Highgate', a semitall somatic mutant of 'Gros Michel'. As large size fruited, disease resistant male parents are available, defects in 'Highgate' (Short fingers) could be overcome (Simmonds, 1966). Now 'Highgate' has replaced 'Gros Michel' completely in the hybridization programme (Shepherd, 1968). The cross, 'Highgate' x 'Pisang Lilin' produced more number of hands per bunch and the resultant tetraploid hybrids were shorter and sturdier than the hybrids derived from the cross 'Gros Michel' x 'Pisang Lilin'. Besides dwarfing allele is dominant and is thus transmitted to all tetraploid progenies (Richardson, 1961).

1.3. Triploid breeding

Secondary triploids bred from 'advanced' diploids, with several possible advantages over primary tetraploids are now being produced at Jamaica (Osborne, 1961-3, Simmonds, 1966). The two great attractions of breeding triploids are the relative ease of producing seedlings and

the avoidance of tetraploidy at the commercial level (Simmonds, 1966). Triploids retain their leaves longer without premature petiole breakage common in tetraploids. Moreover they have practically no pollen and natural female sterility is imparted by the uneven number of chromosome sets and so probability of occasional seed set in them is low (Rowe and Richardson, 1975).

But many secondary triploids (raised from back cross of primary tetraploids to seeded diploids) found unpromising also (Dodds, 1943 a; Simmonds, 1966). It was pointed out that while the primary tetraploids contained all three 'Gros Michel' genomes intact, the secondary triploids were the products of meiosis in which the 'Gros Michel' chromosome sets had participated. The highly selected and desirable 'Gros Michel' combination was therefore broken down and so the secondary triploids were unpromising.

The banana breeding to date could be summarised by a broad statement (Simmonds, 1966). Early cross of 'Gros Michel' by wild strains of Musa acuminata, though nearly successful, were all ultimately rejected for defects in bunch characters, later crosses of 'Gros Michel' with 'Pisang Lilin' yielded some extremely promising clones of

which one clone, 'Bodles Altafort' was released to the trade; the third phase of banana breeding, the use of 'Synthetic' male parents is now well developed and the most advanced clones are entering the later stages of testing.

1.4. Banana hybridization in India

Hybridization programme was started at the Central Banana Research Station, Aduthurai, in Tamil Nadu State during 1950's. Nair (1953) reported that the aim of breeding at the station was to evolve a wind resistant dwarf form of the variety 'Monthan'. The male parents employed were all wild seeded diploids, namely, Musa accuminata, Musa balbisiana, Musa chiliocarpa and Musa coccinea. Commercial triploids of bispecific origin, 'Poovan', 'Monthan', 'Rasthali', 'Peyen', 'Thote', 'Peykunnan', 'Rajavazhai' and 'Neyvannan' were used as female parents. The progenies included diploids, tetraploids, and aneuploids. In all the crosses, the fruit quality of hybrids was found to be far inferior to the female parents and fruits were seedy. The reduction in quality and seediness was due to the inferior qualities of the wild male parents. Of the several hybrids, the tetraploid hybrid, 'Hybrid Sawai' evolved from cross

between 'Neyvannan' x Musa balbisiana was found promising in respect of yield and quality (Raman et. al., 1971).

In an attempt to produce nematode resistant hybrids in place of 'Matti' (AA) grown extensively in Kanyakumari, crosses involving nematode resistant clones, 'Anaikomban' (AA), 'Pisang Lilin' (AA) and 'Nmarai' (AA) were carried out (Tamil Nadu Agricultural University, 1982). Hybrids such as 'H-109' ('Matti' x 'Tongat'), 'H-79' ('Matti' x 'Pisang Lilin'), 'H-88' ('Matti' x 'Namarai'), 'H-21' ('Matti' x 'Anaikomban'), 'H-74' ('Matti' x 'Pisang Lilin') and 'H-109' ('Matti' x 'Tongat') were produced, among which 'H-74' and 'H-109' were found to be nematode resistant and retained the characters of 'Matti'. Considering the important role of synthetic parents in the banana breeding programme, the following crosses were undertaken in 1983 (Tamil Nadu Agricultural University, 1985). 'Rasthali' x 'H-106' ('Matti' x 'Tongat'), 'Poovan' x 'H-67' ('Matti' x 'Pisang Lilin'), 'Poovan' x 'H-94' ('Matti' x 'Tongat'), 'Chinali' x 'H-84' ('Matti' x 'Namarai'), 'Karpooravally' x 'H-84' ('Matti' x 'Namarai'), 'Poovan' x 'H-94' ('Matti' x 'Namarai') and 'Poovan' x 'H-21' ('Matti' x Musa acuminata). Seeds were obtained from crosses of 'Rasthali' x 'H-106', 'Poovan' x 'H-67' and 'Poovan' x 'H-94', but none germinated.

Recently Tamil Nadu Agricultural University has released a hybrid, 'Co-1' for commercial cultivation (Azhakiamanavalan et. al., 1985). The hybrid was evolved as a result of multiple cross involving 'Laden' (AAB) as female parent and Musa balbisiana (BB) and Kadali (AA) as male parents. The triploid hybrid finally produced was found to be phenotypically resembling the hill banana 'Virupakshi'.

In the State of Kerala, even though banana is an important fruit crop, hybridization was started only in 1982 (Karmacharya, 1984). Studies were conducted on the pollen fertility, and compatibility in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara. The results revealed that clones belonging to the different genomic groups could be used as male and female parents if they are compatible (Karmacharya, 1984; Valsalakumari, 1984).

Out of the 27 cross combinations studied by Karmacharya (1984), 8 combinations, 'Agniswar' x 'Pisang Lilin'; 'Palayankodan' x 'Pisang Lilin'; 'Lacatan' x 'Pisang Lilin'; 'Mannan' x 'Pisang Lilin'; 'Nendravannan' x 'Pisang Lilin'; 'Palayankodan' x 'Sikuzani'; 'Nendran' x 'Sikuzani' were compatible. Among these, four hybrids, with 'Agniswar',

'Nendravannan', 'Mannan', and 'Harichal' as female parents and 'Pisang Lilin' as male parent produced bunches with promising features.

The work on the cytotaxonomical studies in banana cultivars by Valsalakumari (1984) indicated the possibility of improving the cultivars by selection to meet the location specific requirements. The results also indicated that several desirable cultivars such as 'Rasthali', 'Red Banana' and 'Palayankodan' had viable pollen which could be utilized for the hybridization programme. The classification based on genetic divergence suggested the groups from which the parents could be conveniently selected for exploiting the wide variability to improve the crop.

2. Fertility aspects in banana

The two wild diploid species, Musa acuminata and Musa balbisiana, which are considered as the ancestors of the present day cultivated edible bananas (Simmonds and Shepherd, 1955) are both female and male fertile. The cultivars are both female and male sterile and it is the most important difficulty encountered in banana hybridization programme. The edible cultivars do not produce seeds when grown in pure stands, some of them are entirely female sterile; others will produce an occasional seed when a source of viable

pollen is available (Purseglove, 1975).

Sterility in banana is due to a combination of gametic sterility resulting from structural hybridity of chromosomes, polyploidy and zygotic sterility resulting from genetic control of female sterility and parthenocarpy (Dodds, 1958). Most of the cultivated bananas are seedless due to highly inherent female sterile genes, triploidy and chromosomal changes (Simmonds, 1962). The improvement of bananas amounts to a constant fight against fertility, a property which, however, is the essential instrument of the improvement itself (De Langhe, 1969).

Sterility is mainly due to meiotic anomalities, although physiological and morphological factors also play a role. Meiosis does not occur readily in triploids, even in edible diploids absolute female sterility exists. During female gametogenesis multivalents and univalents are seen in metaphase and bridges are very often seen in anaphase, these pointing to structural heterozygosity for interchanges and inversions. Sometimes successful meiosis and subsequent fertilizations may occur, but the Zygotes so formed fail to develop (Dodds, 1943 b, 1945; De Langhe, 1969). It is suggested that these failures may be brought about by disturbances in timing relations of post fertilization development and may be correlated with incidence of

parthenocarpy.

In the matter of parthenocarpy, Dodds (1943 b) has clearily explained the existence of vegetative parthenocarpy in cultivated bananas, where fruit formation is not disturbed even if all pollen is excluded from inflorescence and compared this with the position of wild species where if pollen is excluded from flowers and ovaries do not develop and remain immature and eventually shrivel. Parthenocarpic development of banana fruit is accompanied by female sterility (absence of seed setting). These two characters, parthenocarpy and associated female sterility are under genic control and are transmitted through male parents (Dodds, 1943 b; Dodds and Simmonds, 1948 a; De Langhe, 1969).

Genetical determination of parthenocarpy primarily involves control of hormones. It has been shown that parthenocarpy is due to three complementary genes derived from the wild Musa acuminata (Dodds and Simmonds, 1948 a; Simmonds, 1953 a, 1962; De Langhe, 1969). Simmonds (1953 a) and Steward and Simmonds (1954) suggested that the physiology of parthenocarpic development of banana fruit is mediated by an autonomous production of auxins. Shanmughavelu and Rangaswamy (1962) also emphasized the role of auxins in parthenocarpic development of banana fruits.

In tracing the evolution of edible sterile bananas, Dodds (1958) concluded that parthenocarpy and sterility might have arisen as gene mutations in fertile diploids and subsequent types with edible fruits were taken into culture. Through human selection, fruits with fewest seeds were refused and parthenocarpy was completely established and vegetative propagation became obligatory. At the same time, as selective control of maintaining the balance of sexual process was removed, structural changes in chromosomes of somatic tissues were no longer eliminated and might even have been favoured since they would further reduce the amount of seed formed. Hence nearly complete male sterility was gradually added to existing female sterility.

2.1. Female fertility

Occasional seed set has been noticed in many cultivated banana on artificial pollination (Purseglove, (1975).

Female sterility in banana is not always complete as compared to male fertility (Dodds, 1943 b). A genetical abnormality makes banana breeding possible. Cytological studies (Cheesman, 1931, 1932 a, 1932 b, 1934; Cheesman and Larter, 1935; Larter, 1935; Wilson, 1946) have shown that 'Gros Michel' is triploid with thirty three chromosomes;

Musa acuminata is diploid with twenty two chromosomes and their progenies ('I.C.2' and 'S.19') are tetraploid (2n = 44). Evidently 'Gros Michel' does not undergo normal meiosis during sexual reproduction, but instead produces unreduced female gametes, thus explaining predominance of 'Gros Michel' characters in the tetraploid progeny. The diploid parents undergo normal meiosis and produce haploid gametes. The progenies between 'Gros Michel' and Musa acuminata are thus tetraploids. Cytological studies also showed that some heptaploids (2n = 77) result from the cross, presumably as a result of double restitution on the female side (3x + 3x + x = 7x); they are 'Thick Leaved Dwarf' (TLD) plants which grow slowly and never flower. It is upon this genetic abnormality of 'Gros Michel' in contributing unreduced egg cells during meiosis that whole programme of banana breeding is depended (Rowe and Richardson, 1975).

There are several reports of female fertility in cultivated banana. Cousins (1927) observed that, 'Gros Michel' when crossed with 'Robusta' produced seeds. 'Ramkela', 'Honey', 'Apple', 'White House' and 'Gros Michel' when crossed with 'Kewensis' as male also found to produce seeds. Cheesman (1949) reported various clones, 'Mysore', 'Pome', 'Bluggoe', 'Red' and 'Orotava' to be female fertile. The 'Cavendish' group is completely sterile, so sterile

that they have never been known to set seed (Cheesman, 1934; Simmonds, 1966).

Wilson (1946) studied the meiosis in five triploid clones namely: 'Canary', 'Lacatan', 'Gros Michel', 'White House' and 'Maiden'. He observed that the 'Canary' and 'Lacatan' bananas were completely sterile in cytological picture. Low trivalent - high univalent formation was seen. The cytological behaviour of 'Gros Michel' was completely in accordance with its normal breeding behaviour. Suppression of the first division of meiosis leads to triploid gametes which could combine with haploid gametes from wild male parent to get tetraploid progeny. The 'White House' and 'Maiden' plantains were similar cytologically but differ markedly in their breeding behaviour. The former was quite as sterile as 'Canary' banana, while latter set some seeds.

Sundaraj et. al., (1957) reported the clones, 'Poovan', 'Monthan', 'Peykunnan', 'Vennettumannan', 'Thote' and 'Rajavazhai' to be female fertile and 'Rasthali' to be female sterile. In the clones 'Mysore', 'Pisang Awak', and 'Bluggoe' mature embryosacs are rare which limits fertility (Simmonds, 1960 b). In 'Gros Michel' on the other hand, embryosacs frequently exceeds fertility.

Borges (1971) obtained seeds when clones 'Topoch Canizo' and 'Topochongro', both 'Bluggoe' clones (ABB) when pollinated with Musa acuminata and Musa balbisiana as male parents. Almost entirely empty seeds were produced by 'Cambur Morado' (AAA) pollinated with wild diploids.

Alexander (1976) in a detailed study grouped forty one banana clones into female fertile and sterile clones. The female fertile clones were 'Red Banana' (AAA); 'Nattupoovan'; 'Poovan' and 'Sugandhi' (AAB); 'Alshi', 'Chinia', 'Chinali', 'Govakar', 'Kali', 'Monthan' and 'Rajavazhai' (AAB) and Musa balbisiana (BB). The female sterile clones were, 'Beetjava', 'Burathkali', 'Dwarf Cavendish', 'Local 1', 'Manikachampa', 'Nallachakrakali', 'Robusta' and 'Thenkadali' (AAA); 'Attupani', 'Ayiram-karasthali', 'Krishnavazhai', 'Landan', 'Mottapoovan', 'Nendrapadthi', 'Nendran', 'Rasthali', 'Pachanaadan', 'Sirumali', 'West Indies' and 'Walha' (AAB); 'Adukkakunnan', 'Ethachingan', 'Kunnan', 'Kadali', 'Neypoovan', 'Peykunnan', 'Thatilakunnan' and 'Vennetu Kunnan' (AB) and 'Kallumonthan' and 'Madurangable' (ABB).

'Laknaw' clone of triploid plantain (AAB) when fertilized with pollen from diploid AA produced seeds (Rowe et. al., 1976). They concluded that such fertile

clones can be used for genetic improvement in plantains. Karmacharya (1984) obtained seeds from 'Hariohal', 'Lacatan' (AAA); 'Agniswar' (AB); 'Palayankodan' and 'Mannan' and 'Nendran' (AAB) when pollinated with the edible diploid 'Pisang Lilin' (AA) as male parent.

2.1.1. Factors affecting fertility and seed set

Research has been conducted by various investigators regarding the factors affecting fertility and seed set in bananas clones. Seed yields are found to vary with locality, and time, the size of inflorescence, and the time of the day at which pollination is done and degrees of parthenocarpic development of fruit. Seeds are non randomly distributed within the fruit bunch, proximal flower cluster being considerably more fertile than distal ends. Within the fertile fruits, the seeds are localized at stylar ends. The pollination was highly successful if carried out early in the morning (Nair, 1953; Shepherd, 1954, 1960 a, 1960 b; Simmonds, 1966; De Langhe, 1969; Sathiamoorthy, 1973; Karmacharya, 1984).

Shepherd (1960 a) noted that a number of clones were found to be more fertile when pollinated prior to flower opening. Receptivity of flowers do not have relationship with lifting of bracts (De Langhe, 1969). He reported

that banana flowers were receptive in morning, while bracts opened usually in afternoons. Purseglove (1975) observed that bracts rose one per day before the flowers became functional.

Shepherd (1954) recommended that heavy pruning of parental trees should be avoided as this apparently depresses seed yield for bunch although bunches are larger.

The fact that fertility in bananas was related to the climate and soil fertility of a locality to a great extent was revealed by Simmonds (1966). The fertility was more in case of clones that produced larger bunches.

2.2. Male fertility

As compared to female fertility, male fertility has been reported only in a very few banana clones.

Cousins (1927) found 'Kewensis' as male fertile. The short statured 'Cavendish' clone 'Robusta' was found to be male fertile (Cousins, 1927; Cheesman, 1934). Dodds and Simmonds (1948 a) reported that clones, 'Selangor', 'Long Tavey' and 'Selangor' x 'Calcutta 4' produced pollen grains which were fertile, the fertility ranging from 40 per cent ('Selanger' x 'Calcutta 4') to 100 per cent ('Selangor' and 'Long Tavoy'). Among the edible diploids (AA),

'Pisang Lilin'. 'Tongat', 'Paka' and 'Sikuzani' were found to be male fertile and 'Pisang Lilin' is extensively used as male parent in banana breeding programme and has contributed to the constitution of nearly all the male parents bred for use in banana breeding during recent years (Simmonds, 1966).

Out of the thirty eight clones studied by Alexander (1976) ten were found to be male fertile and twenty eight were male sterile. The male fertile clones were, 'Beetjava', 'Local 1', 'Manikachampa', 'Nallachakrakali', 'Red Banana', 'Robusta', and 'Thenkadali' (AAA); 'Sugandhi' and 'West Indies' (AAB) and Musa balbisiana (BB), 'Durathabali' and 'Dwarf cavendish' (AAA); 'Ayiramkarasthali', 'Attupani', 'Krishnavazhai', 'Ladan', 'Nendrapadathi', 'Nendran', 'Pachanaadan', 'Rasthali', 'Sirumali', and 'Walha' (AAB); 'Adukkakunnan', 'Ethachingan', 'Kunnan', 'Kadali', 'Neypoovan' and 'Thatilakunnan' (AB) and 'Alshi', 'Chinia', 'Chinali', 'Govakar', 'Kallumonthan', 'Kali', 'Monthan', 'Madurangable', 'Peyan' and 'Rajavazhai' (ABB) were found to be male sterile. Raman (1976) suggested that the edible diploids such as 'Namarai', 'Sanna chenkadali' and 'Anaikomban' could be used as male parents in hybridization programmes due to high female sterility, expression of parthenocarpy, availability of viable pollen and desirable agrobotanic features.

Sathiamoorthy and Rao (1980) revealed that clones belonging to AB genomic group did not produce pollen and so are completely male sterile. Valsalakumari (1984) studied the pollen production and fertility of sixty two cultivars of different genoale groups and observed that twenty two cultivars were non-polleniferous. All cultivars belonging to genomic group AB ('Agniswar', 'Krishnavazhai', 'Virupakshi', 'Sirumali', 'Vannan', 'Neypoovan', 'Adakkakunnan', 'Valiyakunnan', 'Thaenkunnan', 'Kostabontha', 'Vennettu Mannan' and 'Padalimoongil'); 'Pachachingan', 'Mannan', 'Malakali', 'Pachanaadan', 'Nendrapadathi' and 'Kullen' belong to genomic group AAB; 'Walha', 'Ashy batheesa' and 'Jurmony Kunthali' belonging to genomic group AAB did not produce pollen. All the other 40 cultivars belonging to the diploid, triploid and tetraploid groups produced pollen grain.

3. Seed germination studies

The germination of hybrid seeds play an important role in hybridization programmes. It is primarily the condition of seed that is important for germination rate. Seeds from ripe fruits which are immediately sown in light and well drained soil are those which will germinate with highest probability. If storage of seeds is necessary, they are washed very carefully and immediately sundried and may

be kept in laboratory for six months, but for longer periods seeds should be stored over dry calcium chloride (Simmonds, 1952 c, 1959; De Langhe, 1969; Sathiamoorthy, 1973; Purseglove, 1975; Karmacharya, 1984).

Since banana seeds possess a hard testa, several attempts have been done by various investigators to soften the testa and to get early germination.

An exhaustive study was conducted by Simmonds (1952 c) on germination of banana seeds. He noticed that presowing treatments such as chipping of the testa, soaking seeds in sulphuric acid, soaking in water and the application of temperature shocks are usually deleterious and often lethal. Dodds (1958) stated that failure of seed germination was usually due to a lack of viable embryo and this difficulty cannot be overcome by chemical means.

Methods for germinating seeds of Musa balbisiana under artificial conditions have been developed (Stotzky et. al., 1962). Scarification was required under these conditions and mechanical was superior to chemical scarification. Removing a chip from lateral portion of seed coat to expose the endosperm was the most effective method of scarification. Germination percentage averaged to 80 per cent and time required for germination in sterile culture was

shortened from 3-6 weeks required for intact seeds in soil to 6-10 days. Scarification did not shorten the time required for germination in soil and seeds treated with methods of mechanical scarification failed to germinate as a result of their decomposition by microbes.

Stotzky et. al., (1962) observed that alternating temperatures were needed for germination of Musa balbisiana seeds. The temperature differentials optimum for germination in soil were dependent upon both high and low temperature and ranged from 8-23°C. Germination was maximum when seeds were held at 6-12 hours at high (27-32°C) and 12-18 hours at the low (12-18°C) temperatures. They concluded that factors affecting delaying germination and mechanisms affected by alternating temperature reside not in embryo, but in other parts of seed.

The erratic and generally low germination levels of seeds from banana hybrids has rendered the use of embryo culture very valuable. Cox et. al., (1960) described a technique for sterile in vitro culture of young seedlings of Musa balbisiana seeds. The technique was employed to overcome self sterility of seeds. They suggested that a modified Knudson's medium or Randolph and Cox's medium (1943) containing 0.12 M sucrose (but without growth

regulators) solidified with agar (0.5-0.7 per cent) could be used to rear young plantlets from the tiny embryos excised from the seeds until they are large enough to be placed in soil. Shepherd (1968) stated that germination of hybrid banana seeds in Jamaica has been greatly influenced by extracting embryos and growing them on a nutrient agar medium based on Knudson's solution. Rowe and Richardson (1975) aspetically cultured embryos of hybrid banana seeds in modified Knudson's solution and claimed that embryo culture resulted in 50 per cent germination.

4. Studies on banana hybrids

Eversince the hybridization in banana was initiated, the breeders were eagerly looking at the hybrids, so as to know whether the hybrids were superior, inferior or intermediate to parents. The two earlier tetraploid hybrids from 'Gros Michel' x Musa acuminata, namely 'I.C.2' and 'S.19' (Cheesman, 1931, 1932 a, 1932 b, 1934; Cheesman and Larter, 1935; Larter, 1935), possessed the predominance of 'Gros Michel' characters and the inferior bunch characters of Musa acuminata.

Of the nine hybrids raised and studied from the cross, 'Mysore' x Musa malaccensis (Cheesman, 1932 b), six were

tetraploids (2n = 44) and resembled their female parent in vegetative habit, two were 'Thick Leaved Dwarfs (TLD)'. The cross between 'Gros Michel' and 'Robusta' produced fourteen tetraploid (2n = 44) and one triploid (2n = 33) hybrids, (Larter, 1935).

An interspecific Musa hybrid produced at the Central Banana Research Station, Aduthurai (Nair, 1953) from the cross between, a cooking variety 'Monthan' as female parent and the dwarf statured Musa coccinea (2n = 20) as male parent was found to be mostly intermediate in characters between male and female parents and has shown accumulation of desirable characters which were lacking in female parents. The hybrid was found to be diploid (2n = 24) and seeded.

The tetraploid progeny, 'Bodles Altafort' from the cross 'Gros Michel' x 'Pisang Lilin' (Osborne, 1962) was found to be resistant to Panama disease, Leaf spot and nematodes. It suckers freely, permitting rapid multiplication, the roots were more vigorous than 'Lacatan' and the fruits were about the same size as 'Lacatan'. Unfortunately it was too tall in stature and so subjected to wind damage (Simmonds, 1966).

Hybridization work at Central Banana Research Station, Aduthurai, involving fifteen edible bananas and four species

of Musa (Raman et. al., 1971) revealed that the hybrids were all various mixtures of diploids, tetraploids and parthenocarpic derivatives. It was observed that in most of the combinations, the hybrids obtained were tetraploids. The edible hybrid of 'Ladan' x Musa balbisiana was intermediate in respect to plant height, size of leaf, width of petiolar groove and number of hands per bunch. It resembled male parent only in girth of pseudostem. It had more number of fruits per hand than both parents. The size of fruits was however, less than the female parent and were less-seeded. The tetraploid hybrid (2n = 44), from the cross, 'Poovan' x Musa acuminata produced fruits of superior quality over the female parent. But the hybrid was lacking in commercial qualities of the fruit such as good bunch grade and fruit size. The derivatives either tetraploid or diploid were not superior from the commercial point of view, excepting the tetraploid hybrid, 'Hybrid Sawai', evolved from cross between, 'Ney Vannan' x Musa balbisiana, clone 'Sawai'. The tetraploid was found to be medium tall in stature, sturdy in appearance and yielded a heavy bunch with good round shaped fruits, while the female parent had only angular fruits. The fruits were devoid of seeds and developed parthenocarpically.

Bhaktavathsalu et. al., (1968) conducted a comparative study on 'Klue Teparod' a natural tetraploid (ABBB) and the synthetic tetraploid hybrid, 'Hybrid Sawai' (ABBB). Both were sturdy with 355 and 328 days of respectively between planting to shooting and 164 and 108 days between shooting to harvest. The fruits of the former were medium sized, while those of the latter were large and plump.

A comparative study of the hybrid 'Co.1' with the hill banana, 'Virupakshi' revealed that the former phenotypically resembled the latter (Azhakiamanavalan, et. al., 1985). The hybrid was found to be quite promising in the plains retaining the flavour and taste of 'Virupakshi'. It took 9 months for shooting and 5½ months for fruit maturity. The total duration was 14 to 14½ months, where as that of 'Virupakshi' it was 17 months. The average hybrid bunch had 7 hands, 80-85 fingers per bunch and recording a weight of 10.6 kg. with an average yield of 22 t/ha.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigations on "Interclonal hybridization studies in banana" were carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, during 1985-'86. The banana clones maintained in the germplasm block and the hybrids evolved at the College of Horticulture were used for the study.

The investigations consisted of the following main aspects:

1. Hybridization using six female parents and three male parents.
2. Estimation of pollen production, fertility and viability in different nodes of the male parents,
3. Studies on compatibility, fertility pattern and seed set in female parents,
4. Studies on the effect of different seed treatments to improve the germination of seeds, and
5. Evaluation of hybrids already available.

1. Selection of parents

Six female and three male parents were selected for the study. The female parents were selected based on their table quality and popularity and high fertility as reported by Karmacharya (1984). The male parents were selected based on their high pollen production and fertility (Karmacharya, 1984).

Female parents:

Musa (AAB group) 'Palayankodan'
Musa (AAB group) 'Rasthali'
Musa (AAB group) 'Nendravannan'
Musa (AB group) 'Ney Poovan'
Musa (ABB group) 'Karpooravally'
Musa (AAB group) 'Nendran'

Male parents:

Musa (AA group) 'Pisang Lilin'
Musa (AA group) 'Tongat'
Musa (AA group) 'Sanna chenkadali'

The biometrical observations of the nine parents were taken at monthly intervals from two months after planting, upto harvest. Three plants of each parent were taken for observations and the following procedures were

followed.

1.1. Plant height (cm)

The height of plant was measured from the ground level to the axil of the youngest leaf.

1.2. Plant girth (cm)

The girth of pseudostem was measured at 20 cm above the ground level.

1.3. Functional leaves per plant

Fully opened functional (more than 50 per cent green) leaves present at the time of observation were recorded.

1.4. Phylacron

Phylacron is the day interval between the production of two successive leaves. For this, the just unfurled leaf was marked on its petiole and after six weeks, the number of leaves emerged and unfurled were noted. From this phylacron was calculated.

1.5. Total leaf area per plant (m^2)

The leaf area was calculated by applying the formula, Leaf area = Length x Breadth x 0.8 (Murray, 1960). Length of lamina was measured from the base to the tip and breadth

was measured at the broadest point in the middle.

1.6. Petiole length (cm)

The length of the petiole was measured from the base to the point of emergence of lamina.

1.7. Duration (days)

1.7.1. Planting to flowering interval (days)

The number of days from planting to flowering was recorded.

1.7.2. Flowering to harvest interval (days)

The number of days taken from bunch emergence to harvest was computed noting the date of emergence and the date of harvest. The time of harvest was determined when the angularity of skin disappeared, that is, at the stage of 'round full' (Simmonds, 1960 a).

Total duration of plant was computed by adding (1.7.1) and (1.7.2).

1.8. Bunch characters

1.8.1. Bunch weight (kg.)

The bunch was weighed with 10 cm length of peduncle

above first hand and 5 cm length of the male axis below the last hand.

1.8.2. Hand weight (g)

The weight of second hand was taken as the average weight of a hand. (Gottreich et. al., 1964).

1.8.3. Number of hands

The number of hands in each bunch was recorded.

1.8.4. Number of fingers

The total number of fingers in each bunch was recorded.

1.8.5. Finger characters

The middle finger in the top row of the second hand was chosen as representative finger (Gottreich et. al., 1964) for recording the physical characters of the finger.

1.8.5.1. Pedicel length (cm)

Pedicel was split longitudinally and the distance from base of pedicel upto pulp region was measured.

1.8.5.2. Finger length (cm)

The length of finger was measured from base of

pedicel to apex along dorsal curve using a fine non-elastic thread and scale.

1.8.5.3. Finger girth (cm)

Circumference of finger was measured at middle using a non-elastic thread and scale.

1.8.5.4. Finger weight

It was recorded in gram.

1.8.5.5. Finger volume (cc)

The finger volume was recorded by the water displacement method.

1.8.5.6. Pulp/peel ratio

Weight of pulp and peel was recorded and pulp/peel ratio was calculated on weight basis.

2. Pollen Studies

The pollen studies consisted of the estimation of pollen production per anther, pollen fertility and viability in different nodes of male axis of the three male parents (Plate 1.)

2.1. Collection of pollen

Pollen grains were collected by scraping the anthers

Plate 1. Male axis showing node positions.

Plate 1

which were about to dehisce, using a blunt needle passing transversely along the lobe of the anther caring not to scrape the tissue (Karmacharya, 1984).

2.2. Pollen production

The Haemocytometer method was used for determining the pollen production per anther (Oberole and Goertzen, 1952; Pozzi, 1953; Gangolly et. al., 1961; Rao and Khader, 1962). The procedure standardised by Sathiamoorthy and Rao (1980) was followed.

Ten anthers from one bract were taken just before dehiscence in a vial containing 2.5 ml of distilled water. Two drops of teepol were added for proper suspension of pollen grains. The anthers were crushed with the edge of a glass rod in order to suspend all pollen grains properly. The contents were thoroughly shaken. Two drops of suspension was pipetted and placed in each of the counting chambers of Newbauer Improved Double Haemocytometer. The chambers consisted of nine equal squares each measuring 1 mm. sq. The four corner squares were ruled into sixteen smaller divisions. The counting chamber was 0.1 mm in depth and could hold 0.1 mm^3 solution. The number of pollen grains per anther was calculated as follows.

The contents of ten anthers were suspended in 2.5 ml of solution. So 0.25 ml solution will have the contents of one anther. The following formula was used for the calculation.

If N = average number of pollen grains calculated per corner square, and

X = number of grains per anther,

N : X = 0.1 : 250

so, 0.1 X = 250 N

$$X = 2500\ N$$

Pollen production was estimated, starting from the first node upto last node in all the three male parents.

2.3. Pollen fertility

Pollen fertility was estimated by mounting pollen grains on glass slides in acetocarmine stain.

The collected pollen grains were dusted in a drop of acetocarmine stain (Alexander, 1980) on a clean microscopic slide and kept for proper staining and examined under low power of a microscope (10x10). Pollen fertility was estimated by counting both fertile and sterile pollen. Pollen grains which were well stained, normal and plumpy were considered as fertile, while those which were unstained

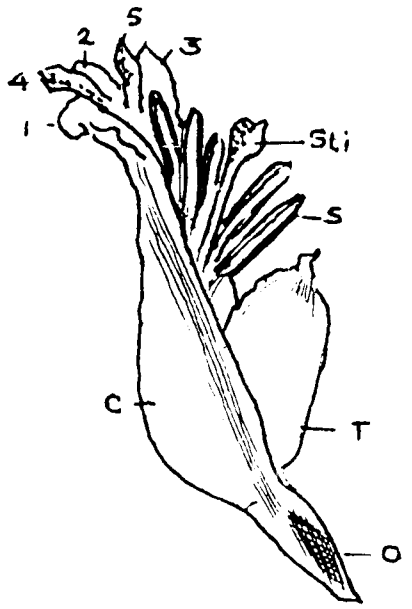
and shrivelled were taken as sterile. For each node three such microscopic slides were prepared and five fields from each slide were observed and values averaged. Fertility was expressed as per cent of total number observed.

2.4. Pollen viability

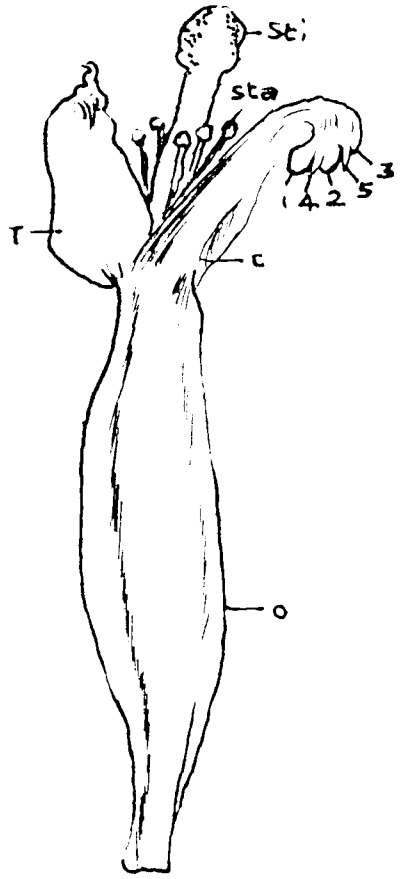
Pollen viability was determined by growing pollen grains in artificial media which consisted of simple sucrose solution in distilled water. The media for pollen germination was standardised following the method of Karmacharya (1984). The medium in which maximum germination as well as maximum tube length were observed, was taken as standard medium. The pollen grains were spread over clean microscopic slides and a few drops of prepared media were placed on them. The slides were kept on moist filter paper in petridishes which were thus kept in a descicator containing water to germinate. The slides were examined (for pollen germination and pollen tube length simultaneously) every two hours until the germination started. When germination started, they were examined at two hours intervals till no further germination of pollen grains was obtained.

FIG : 1 BANANA FLOWER

MALE FLOWER



FEMALE FLOWER



O -- ovary

C -- compound tepal with

1, 2, 3 - the major lobes

4, 5 - the minor lobes

T - free tepal

Sti - stigma

Sta - staminode

S - stamen

Five fields at random were examined on each slide to get 100 pollen grains in an average. For each node three such slides were prepared. The germinated and non germinated pollen grains were counted and pollen germination was expressed as per cent of total number observed. The pollen tube length was expressed in microns (μ).

3. Studies on compatibility, fertility pattern and seed set

3.1. Technique of crossing

The method suggested by Simmonds (1966) and followed by Sathiamoorthy (1973), and Karmacharya (1984) was adopted to transfer the pollen from male parents to stigma of female parents.

The inflorescence of female parents were bagged two or three days before opening of the first bract. Muslin cloth bags (0.5 x 1.0 M) were used for this. From the flowers (Fig.1) of male parents opened on the day of crossing, anthers were collected just prior to dehiscence. Crossing was made between 6 am to 8 am. Since anthers did not dehisce properly, they were twisted and forced to dehisce. Pollen grains were taken out using No.1 Camel hair brush. The cloth bags were opened and inflorescences

Plate 2. A bunch in female phase (cultivat 'Nendran')

Plate 2.

were examined to see whether the bract containing female flowers (Plate 2. , Fig. 1) were opened or not. The stigma of female flowers were tested for their receptivity by finger touch. The stickiness of stigma indicated receptivity. The pollen grains were taken out and with the help of Camel hair brush, they were smeared over stigma of female flowers. The inflorescences were bagged after pollination in order to prevent any possible cross pollinations by insects or wind. The details of crossing viz: male parent, female parent, date of crossing etc. were tagged on the female parents.

All the three male parents were used to cross the six female parents so as to form 18 cross combinations. Each cross was repeated thrice.

Platform type aluminium ladders were used for climbing and to do the pollination. Being light in weight, aluminium ladders were easy to carry.

Inorder to study the female fertility pattern in different hands, all the hands were equally pollinated in an inflorescence.

3.2. Seed extraction

The fully mature bunches were harvested and ripened

Plates 3 to 10. Parents used in hybridization.

Plate 3. Musa (AAB) 'Palayankodan'

Pate 4. Musa (AAB) 'Rasthali'

Plate 3

Plate 4

Plate 5. Musa (AAB) 'Nendravannan'

Plate 6. Musa (AB) 'Ney Poovan'

Plate 5

Plate 6

Plate 7. Musa (ABB) 'Karpoorvally'

Plate 8. Musa (AAB) 'Nendran'

Plate 7

Plate 8

Plate 9. Musa (AA) ' Pisang Lilin '

Plate 10. Musa (AA) ' Tongat '

Plate 9

Plate 10

in room. The ripe fingers were longitudinally cut with the help of a knife and were examined for seeds. The seeds when present were extracted, washed in tap water and were used for seed treatment studies.

The number of seeds produced in each hand in all the crosses were counted and average number of seeds produced were worked out as per position of hand. The average number of seeds from each particular cross was also recorded.

4. Seed treatment studies

The effects of the following treatments to improve the germination of seeds were studied.

1. Seed treatment with concentrated Sulphuric acid.
2. Quick dip of seeds in boiling water.
3. Seed treatment with Gibberellic acid (GA) at 250 and 550 ppm.
4. Chipping the testas of seeds.
5. Sowing the seeds without any treatment. (Control)

4.1. Collection of seeds

The seed extracted from well mature ripe fruits were used for the study (Simmonds, 1952 c, 1959, 1966; De Langhe, 1969; Sathiamoorthy, 1973; Purseglove, 1975; Karmacharya,

1984). The collected seeds were grouped into 'good' and 'bad' adopting floatation technique (Sathiamoorthy, 1973). The seeds were put in a beaker containing water. All the seeds floating on the surface of water were discarded and others at bottom of container were taken for seed treatments.

4.2. Seed treatment with conc. H_2So_4

Well cleaned, good seeds were placed in a glass beaker containing sufficient quantity of conc. H_2So_4 (Specific gravity 1.84) so as to cover the entire seed lot. After five minutes the seeds were washed in cool running water for 5-10 minutes to remove all the acid (Hartman and Kester, 1972; John, 1975).

The seeds were sown at once in a mixture of sand and soil contained in earthern pot for germination as suggested by Simmonds, (1952 c); De Langhe (1969); Purseglove (1975); Karmacharya (1984).

4.3. Hot water treatment

Water was heated upto boiling point (100°C) in a beaker using a gas burner. The seeds were placed in boiling water for two seconds, after which the seeds were taken out, and were sown in a mixture of sand and soil contained in earthern pot for germination.

4.4. Treatment with GA

The seeds were soaked in each of 250 ppm and 500 ppm GA solution for 12 hours. They were then taken out and were sown in the media in earthern pot as in the first two treatments.

4.5. Chipping the testas

A chip from the lateral portion of the seed coat was removed so as to expose the endosperm (Stotzky et. al., 1962) using a knife and the treated seeds were sown in media as in earlier cases.

4.6. Control

The seeds were sown in a mixture of sand and soil without giving any treatment.

5. Evaluation of hybrids

Three hybrids produced from the cross between 'Agniswar' x 'Pisang Lilin' (Karmacharya, 1984) were evaluated. Four plants under each hybrid were observed.

The suckers of the hybrids were planted in the College Orchard. The recommended package of practices were followed uniformly (Kerala Agricultural University, 1986). The study

consisted of evaluating the quantitative characters of hybrids viz: plant height, girth, number of functional leaves, total leaf area, petiole length, duration and bunch characters; quality characters, viz: TSS, acidity and total and reducing sugars; male and female fertility; taxonomic scoring and counting the number of somatic chromosomes.

5.1. Quantitative characters

The biometrical observations were taken from two months after planting upto harvest. The procedures adopted were similar as in the case of the nine parents (1.1. to 1.8.5.6.).

5.2. Quality characters

This consisted of quality analysis of fruits.

The fruits collected from well ripe bunches were used, for quality analysis. The middle fruit in the top row of second hand was selected as the representative sample (Gottreich et. al., 1964). Samples were taken from three positions, viz: top, middle and bottom and these samples were then pooled and macerated in warring blender. Triplicate samples from these were used for analysis of different constitutents as described below.

5.2.1. Total soluble solids (TSS per cent)

Total soluble solids were found out using an Erma pocket refractrometer and was expressed as per cent.

5.2.2. Sugars (Per cent)

Total reducing and non-reducing sugars in the sample were determined as per the method described by Association of Official Agricultural Chemists (1960).

5.2.3. Acidity (Per cent)

The macerated sample (10 g.) was mixed with distilled water and made upto a known volume. 10 ml. of the filtered solution was titrated against 0.1 N NaoH using phenolphthalein as indicator. The acidity was expressed as per cent of citric acid (Association of Official Agricultural Chemists, 1960).

5.2.4. Sugar/acid ratio

The sugar/acid ratio was determined by dividing the total sugars with titrable acidity.

5.3. Pollen studies

The pollen studies consisted of the estimation of pollen production per anther, pollen fertility and viability

in different nodes of male axis. The procedure followed was similar to that in the case of male parents. (2.1 to 2.4).

5.4. Female fertility

In order to findout whether the hybrids are female fertile or not, they were crossed with 'Pisang Lilin' as male parent.

5.5. Taxonomic scoring at flowering

The hybrids were scored based on the fifteen morphological characters, diagnostic of Musa acuminata and Musa balbisiana as suggested by Simmonds and Shepherd (1955). The fifteen morphological characters of the hybrids were examined and respective scores were given, finally scores were added and the ploidy level was determined.

5.6. Cytological study

Cytological study consisted of counting somatic chromosomes number of hybrids in root tips. Squash preparations were made following fulgen squash method (Hillary, 1939, 1940; Battaglia, 1957; Darlington and La Cour, 1976).

6. Statistical analysis

The data collected on the different aspects were tabulated and analysed statistically. Transformations were done wherever needed and the data were analysed following methods outlined by Snedecor and Cochran (1967).

RESULTS

RESULTS

Results of the interclonal hybridization studies in banana are presented below.

1. Details of parents

Observations made on the growth parameters, duration, bunch characters and finger characters of the female parents, viz: 'Palayankodan', 'Rasthali', 'Nendran', 'Nendravannan', 'Ney Poovan' and 'Karpooravally', and the male parents viz: 'Pisang Lilin', 'Tongat' and 'Sanna chenkadali' are presented in Tables 1 to 5. Photograps of all the parents are presented in Plates 3 to 10.

The mean values of the growth parameters viz: height, girth, number of functional leaves, leaf area per plant, petiole length and phylacron of the nine parents are given in Table 1. The growth models of the parents are shown in Table 2 and Fig. 2.1 to 2.6. Exponenetial growth curves were fitted for describing the variations in plant height and girth (Fig. 2.1 and 2.2). Quadratic curves were fitted for assessing the variations in the number of leaves, leaf area and petiole length (Fig.2.3 to 2.5). For phylacron, a linear model was found satisfactory (Fig.2.6).

Table-1.

Mean values of the growth parameters of the parents

Cultivar	Growth Parameters					
	Height (cm)	Girth (cm)	Functional leaves	Leafe area per plant (m^2)	Petiole length (cm)	Phylacron (days)
1	2	3	4	5	6	7
Female parents						
Palayankodan	300.15	69.16	8.66	6.5560	44.87	8.50
Rasthali	320.12	76.51	8.00	8.0062	50.69	7.00
Nendravannan	301.33	67.66	6.90	3.6687	49.68	7.00
Neypoovan	280.00	68.00	7.00	4.1087	46.07	7.00
Karpooravally	307.33	78.01	8.30	5.1065	41.08	10.00
Nendran	225.13	67.17	8.92	7.8832	31.66	7.16
Male parents						
Pisang Lilin	160.33	38.33	5.66	2.6315	39.66	8.03
Tongat	252.66	50.66	9.12	8.9271	29.66	7.00
Sanna chenkadali	177.86	50.66	9.66	4.6630	39.08	7.68

Table-2

Growth models of parents

Characters	Parents	Equation	Coefficient of determination(R^2)%
1	2	3	4
Height	Palayankodan	$Y = 169.257e^{0.037x}$	78.81
	Rasthali	$Y = 146.614e^{0.045x}$	73.31
	Nendravannan	$Y = 132.511e^{0.052x}$	83.68
	Ney Poovan	$Y = 127.211e^{0.047x}$	76.04
	Karpooravally	$Y = 105.542e^{0.053x}$	82.32
	Nendran	$Y = 67.330e^{0.072x}$	85.06
	Pisang Lilin	$Y = 52.656e^{0.078x}$	84.92
	Tongat	$Y = 93.741e^{0.054x}$	87.42
	Sanna chenkadali	$Y = 98.461e^{0.035x}$	89.81
Girth	Palayankodan	$Y = 49.689e^{0.021x}$	72.61
	Rasthali	$Y = 38.362e^{0.040x}$	78.94
	Nendravannan	$Y = 43.179e^{0.029x}$	72.14
	Ney Poovan	$Y = 23.412e^{0.012x}$	86.25
	Karpooravally	$Y = 31.560e^{0.044x}$	79.25
	Nendran	$Y = 23.968e^{0.044x}$	78.67
	Pisang Lilin	$Y = 18.389e^{0.052x}$	82.70
	Tongat	$Y = 34.278e^{0.037x}$	79.91
	Sanna chenkadali	$Y = 26.727e^{0.040x}$	74.51
Functional leaves	Palayankodan	$Y = 0.122+1.1792x-0.088x^2$	72.84
	Rasthali	$Y = 0.55+1.370x-0.059x^2$	71.91
	Nendravannan	$Y = 2.082+1.181x-0.061x^2$	70.02
	Ney Poovan	$Y = -0.16+1.534x-0.065x^2$	71.04
	Karpooravally	$Y = 0.676+1.296x-0.049x^2$	72.26
	Nendran	$Y = 0.448+1.435x-0.062x^2$	77.86
	Pisang Lilin	$Y = 1.235+1.087x-0.060x^2$	73.46
	Tongat	$Y = 1.142+1.429x-0.058x^2$	76.42
	Sanna chenkadali	$Y = 0.357+1.853x-0.082x^2$	77.46

Contd.

Table-2. Continued

1	2	3	4
Leaf area per plant	Palayankodan	$Y = -2.490+2.218x-0.107x^2$	74.81
	Rasthali	$Y = -1.314+1.662x-0.071x^2$	75.91
	Nendravannan	$Y = -0.755+1.384x-0.070x^2$	75.96
	Ney Poovan	$Y = -4.212+1.654x-0.065x^2$	71.24
	Karpooravally	$Y = -0.979+0.988x-0.035x^2$	73.45
	Nendran	$Y = -3.078+1.836x-0.079x^2$	72.24
	Pisang Lilin	$Y = -0.886+0.849x-0.045x^2$	73.23
	Tongat	$Y = -2.323+1.813x-0.070x^2$	75.23
	Sanna chenkadali	$Y = -2.124+1.536x-0.082x^2$	74.24
Petiole Length	Palayankodan	$Y = 9.496+5.790x-0.224x^2$	74.25
	Rasthali	$Y = 37.743+3.617x-0.154x^2$	76.43
	Nendravannan	$Y = 27.632+4.058x-0.177x^2$	80.24
	Ney Poovan	$Y = 37.030+1.785x-0.080x^2$	81.21
	Karpooravally	$Y = 17.535+4.001x-0.139x^2$	74.24
	Nendran	$Y = 6.390+3.211x-0.105x^2$	76.23
	Pisang Lilin	$Y = 12.58+4.25x-0.175x^2$	71.25
	Tongat	$Y = 12.054+3.245x-0.136x^2$	73.24
	Sanna chenkadali	$Y = 25.700+3.190x-0.156x^2$	72.24
Phylacron	Palayankodan	$Y = 6.634+0.144x$	90.03
	Rasthali	$Y = 7.073+0.067x$	89.12
	Nendravannan	$Y = 6.146+0.111x$	87.15
	Ney Poovan	$Y = 7.065+0.057x$	88.14
	Karpooravally	$Y = 7.125+0.112x$	82.14
	Nendran	$Y = 7.039+0.117x$	85.16
	Pisang Lilin	$Y = 9.103-0.161x$	85.18
	Tongat	$Y = 7.670+0.061x$	86.14
	Sanna chenkadali	$Y = 8.680-0.089x$	83.14

FIG 2. GROWTH MODELS OF PARENTS

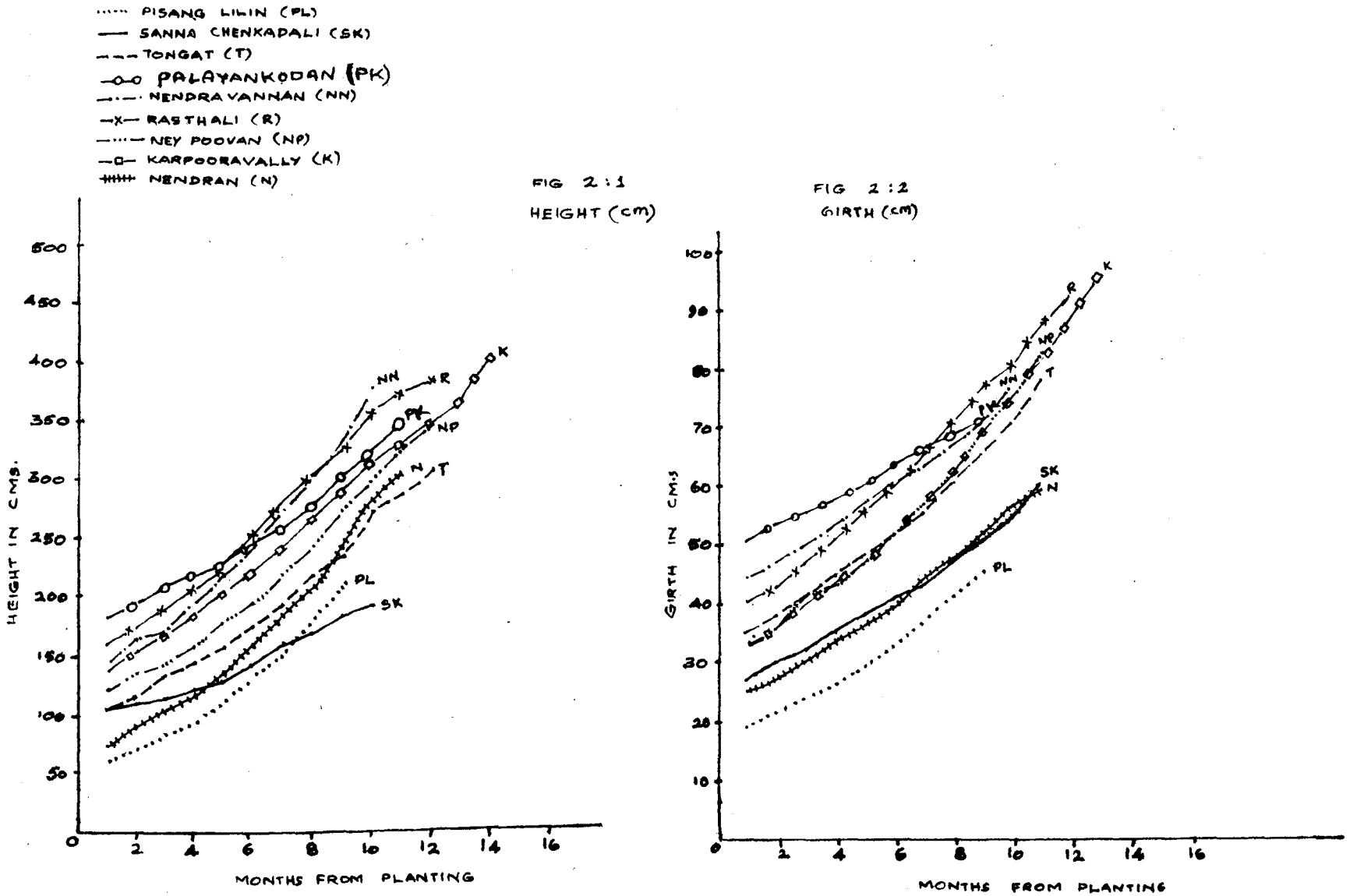


FIG 2:3 FUNCTIONAL LEAVES

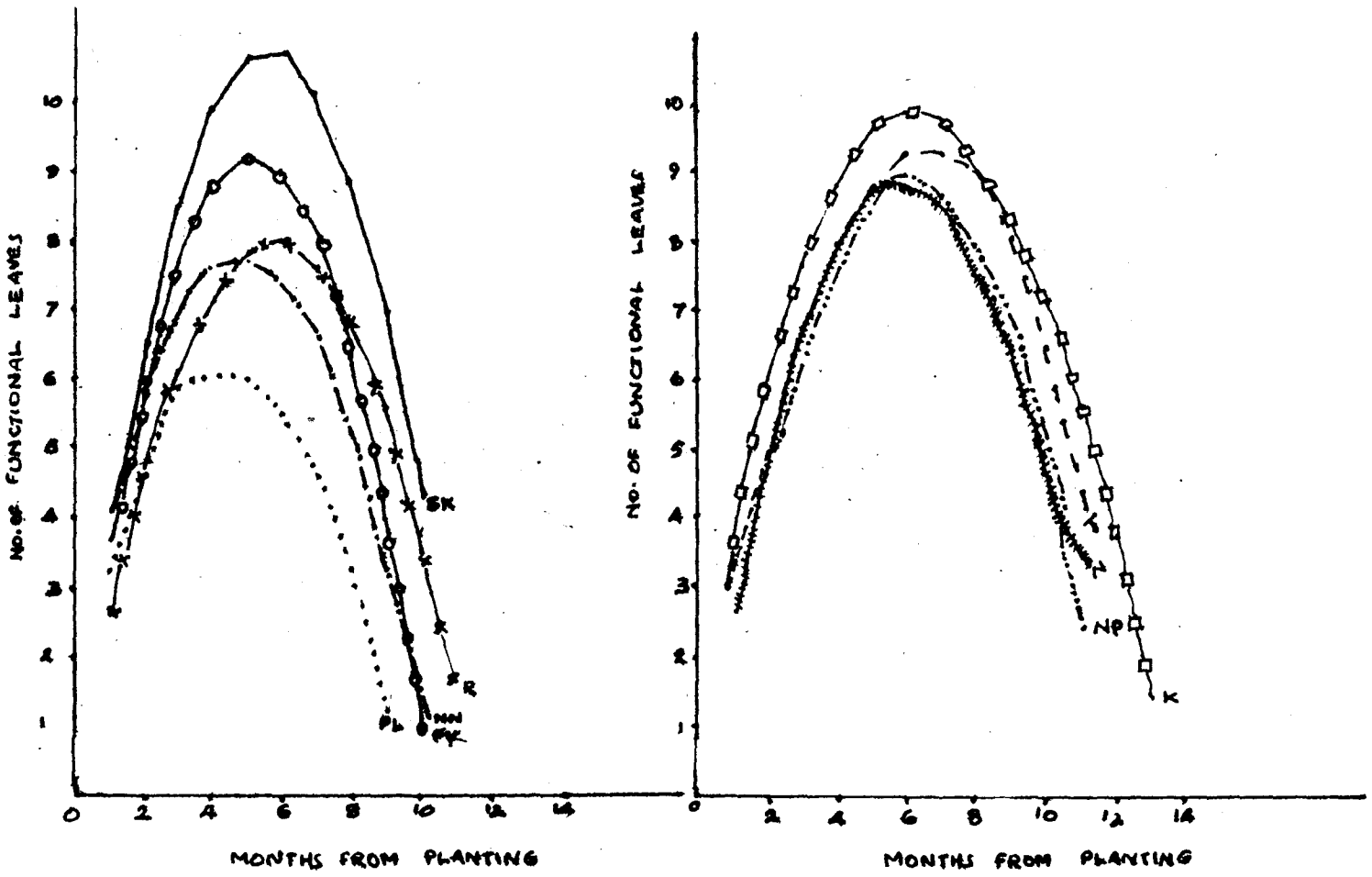


FIG 2:4 LEAF AREA PER PLANT (m^2)

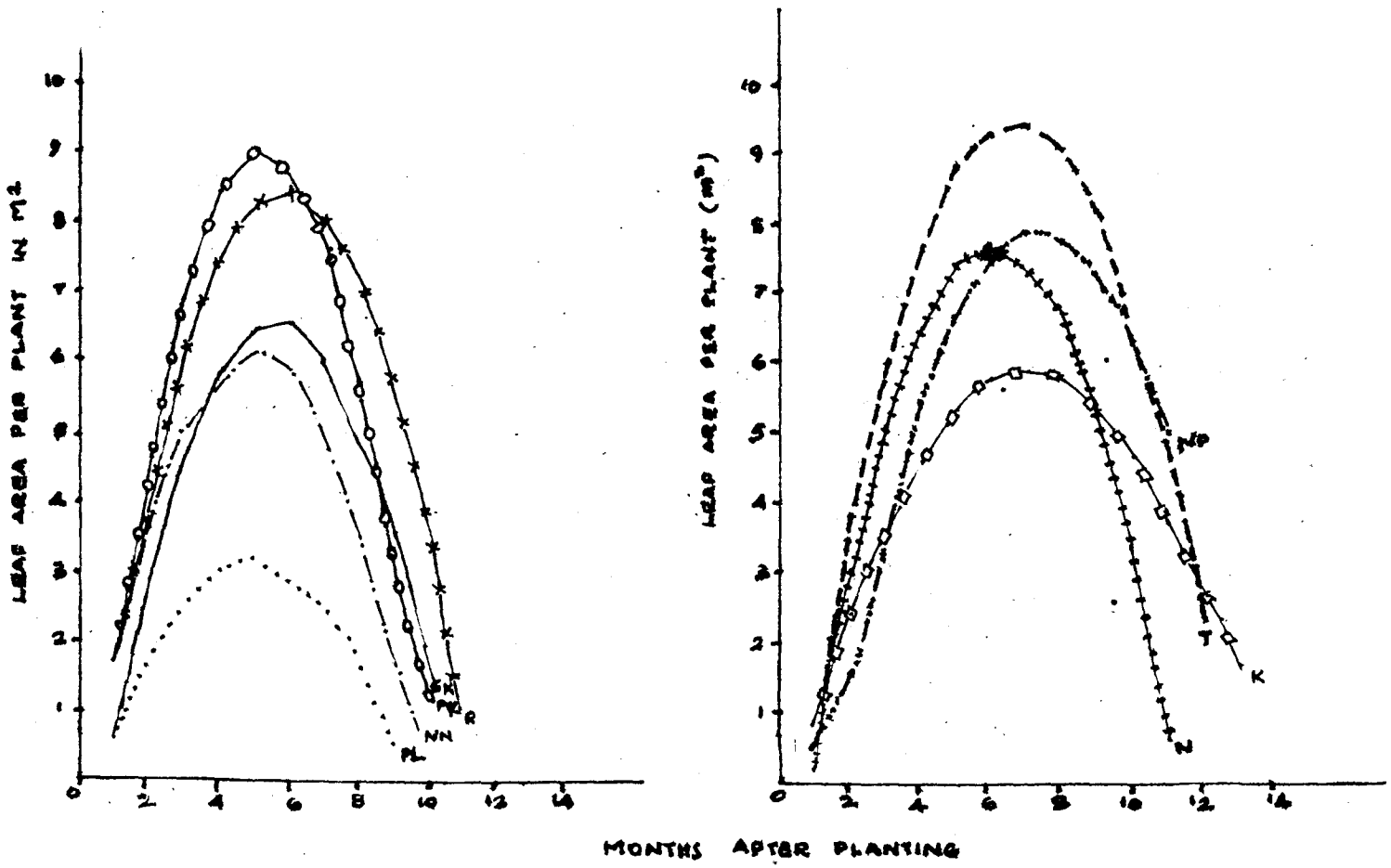


FIG. 2.9. PETIOLE LENGTH (cm)

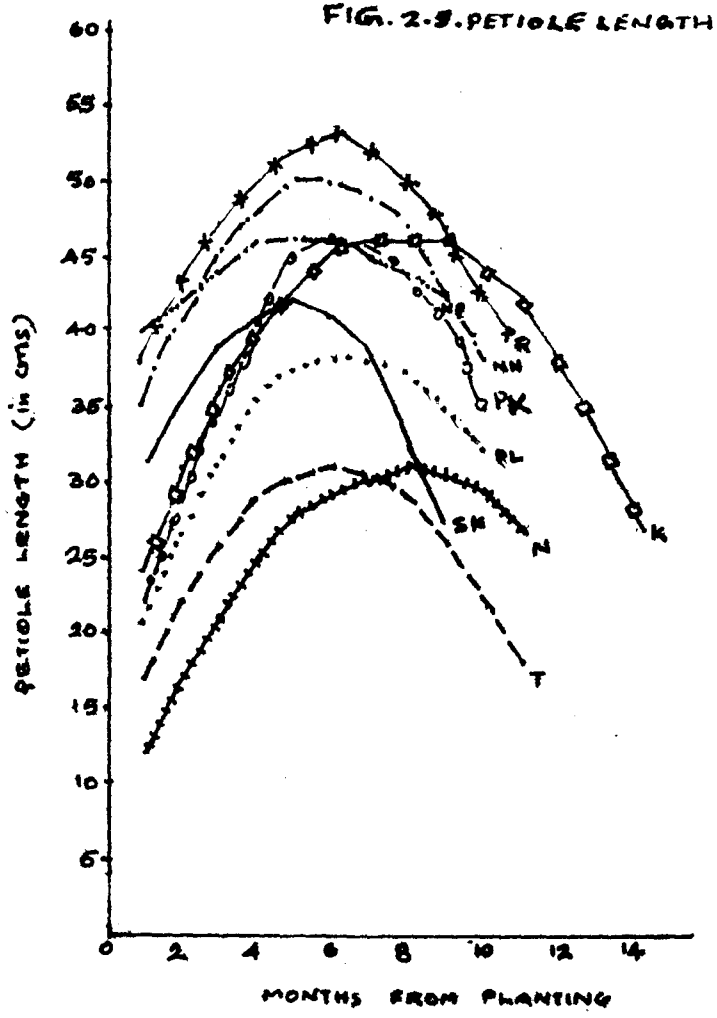


FIG 2:6 PHYLACRON (DAYS)

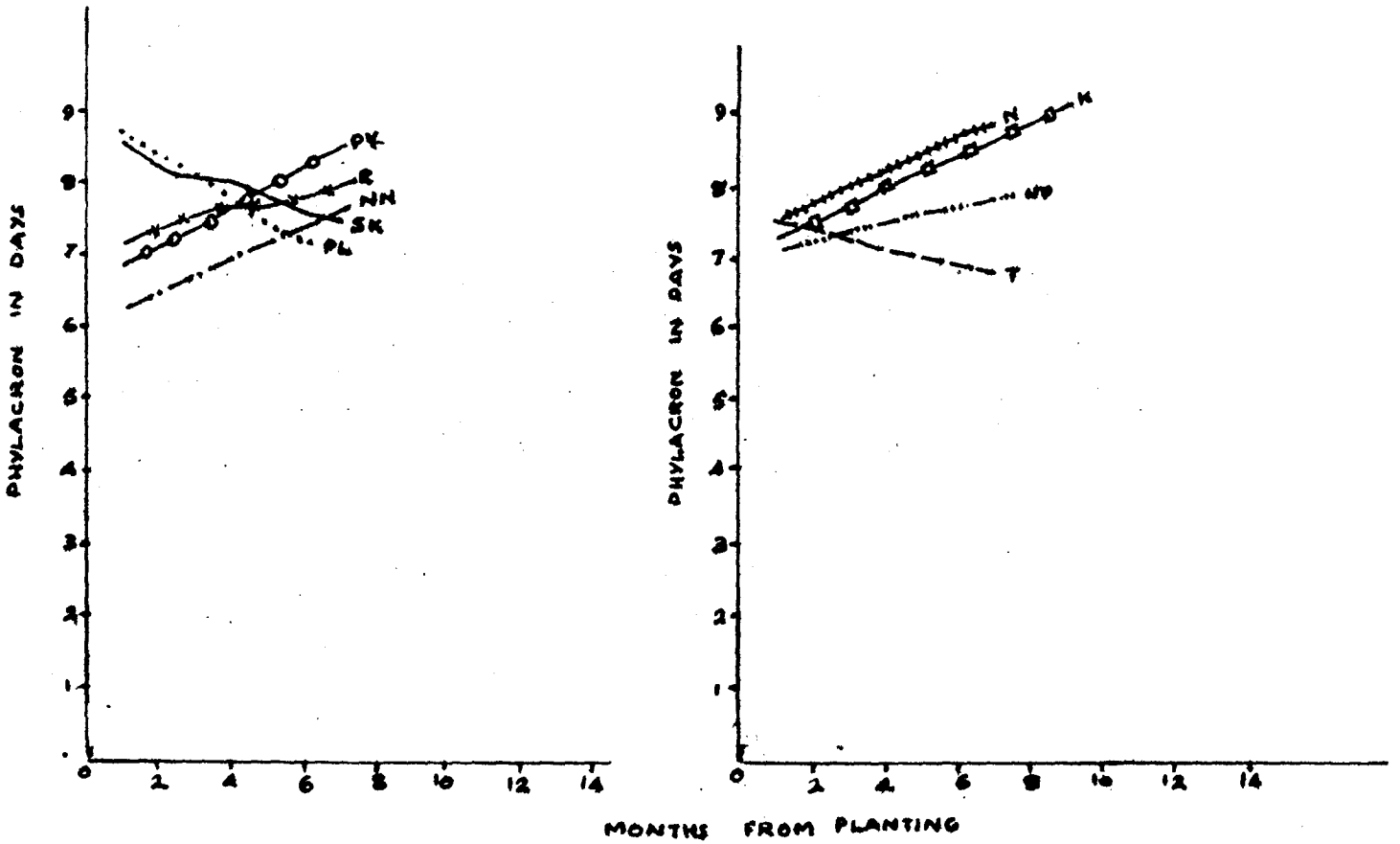


Table-3

Mean values of the duration of parents

Cultivar	Duration (days)				
	Planting to flowering interval	Flowering to harvest interval	Planting to harvest interval	Male phase	Female phase
1	2	3	4	5	6
Female parents					
Palayankodan	212.66	96.33	308.99	88.00	7.33
Rasthali	234.00	94.33	328.33	91.00	6.66
Nendravannan	214.00	111.33	325.33	101.00	6.66
Ney Poovan	286.66	105.33	391.99	91.33	9.66
Karpooravally	358.33	90.00	448.33	75.66	7.66
Nendran	246.33	91.33	337.66	91.33	2.33
Male parents					
Pisang Lilin	177.00	107.00	284.00	93.66	4.66
Tongat	268.00	116.00	384.00	111.00	4.00
Sanna chenkadali	241.00	95.66	336.66	76.00	5.33

Table-4

Mean values of the bunch characters of the parents

Cultivar	Bunch characters			
	Bunch weight (kg)	Hand weight (g)	Number of hands	Number of fingers
1	2	3	4	5
Female parents				
Palayankodan	10.00	1200.00	11.27	180.00
Rasthali	11.78	1300.00	9.78	109.44
Nendravannan	8.50	1275.00	8.00	93.00
Ney Poovan	11.00	985.00	12.75	188.66
Karpooravally	10.90	760.12	9.16	165.06
Nendran	9.62	1734.00	5.25	47.25
Male parents				
Pisang Lilin	2.40	600.00	4.30	50.44
Tongat	9.25	500.00	11.76	226.50
Sanna chenkedali	8.28	1300.00	12.90	112.00

Table-5

Mean values of the finger characters of the parents

Cultivar	Finger characters					
	Pedicel length (cm)	Finger length (cm)	Finger girth (cm)	Finger weight (g)	Finger volume (cc)	Pulp/peel ratio
1	2	3	4	5	6	7
Female parents						
Palayankodan	3.57	12.78	11.65	76.80	77.80	3.63
Rasthali	2.63	17.79	15.16	90.96	128.00	3.15
Nendravannan	1.70	10.84	9.80	84.77	80.66	1.25
Ney Poovan	3.68	10.58	7.66	60.56	68.75	1.93
Karpooravally	3.50	14.14	12.80	56.00	50.57	2.19
Nendran	2.81	24.25	11.75	180.00	175.82	3.12
Male parents						
Pisang Lilin	1.68	15.25	6.16	38.50	27.03	1.66
Tongat	2.50	8.58	8.23	40.26	32.50	1.81
Sanna chenkadali	2.25	12.25	8.57	73.00	55.27	2.95

The number of days to flower, flowering to harvest interval total duration and male and female phase of parents are presented in Table 3. The mean values of bunch characters viz: bunch weight, hand weight, number of hands and fingers are summarised in Table 4. Table 5 shows the mean values of finger characters viz: pedicel length; length, girth, weight and volume of fingers and pulp to peel ratio of the nine parents.

2. Pollen studies

Pollen studies included the estimation of pollen production per anther, fertility and viability in different nodes of the three male parents, namely; 'Pisang Lilin', 'Tongat' and 'Sanna chenkadali'. The results of the pollen studies are given in Tables 6 to 11 and Fig.3.1 to 3.4.

The three parents differed greatly in all these aspects. Within each parent, pollen production per anther, fertility, viability and tube length varied between different nodes. All these parameters were found to follow a quadratic trend. The values were low in first few nodes (upto 10th node), then increased steadily to a maximum at the 20th to 30th nodes which varied according to the clone and then decreased.

Table-6

Regression of pollen production, fertility and viability on node position of the three male parents.

Pollen characters	Parents	Equation	Coefficient of determination(R^2)%
1	2	3	4
Production	Pisang Lilin	$Y = 3482.22+401.33x-8.13x^2$	65.84
	Tongat	$Y = 2252.43+61.61x-1.59x^2$	61.83
	Sanna chenkadali	$Y = 2135.64+156.13x-2.90x^2$	63.15
Fertility	Pisang Lilin	$Y = 45.32+0.83x-0.02x^2$	64.94
	Tongat	$Y = 28.34+0.19x-0.005x^2$	72.66
	Sanna chenkadali	$Y = 34.46+0.79x-0.01x^2$	69.74
Germination	Pisang Lilin	$Y = 13.98+0.51x-0.01x^2$	62.91
	Tongat	$Y = 4.82+0.48x-0.008x^2$	75.87
	Sanna chenkadali	$Y = 7.75+0.27x-0.005x^2$	71.60
Tube growth	Pisang Lilin	$Y = 72.66+11.41x-0.23x^2$	66.33
	Tongat	$Y = 103.04+2.96x-0.087x^2$	66.22
	Sanna chenkadali	$Y = 96.52+3.28x-0.076x^2$	70.19

2.1. Pollen production

Table 7 gives an account of the estimation of pollen production per anther in different nodes of the three male parents. The trend in pollen production is represented in Fig.3.1.

In 'Pisang Lilin' pollen output varied between 3875.41 in the 1st node to 947.14 in the 55th node with a maximum output of 8431.12 in the 25th node after which it started decreasing sharply. In the 30th, 35th, 40th, 45th and 50th nodes pollen outputs were 8200.66, 7563.45, 6519.50, 5068.79 and 3211.34 respectively. The pollen output in 'Sanna ehenkadali' ranged between 2288.66 in the 1st node to 206.50 in the 65th node with a maximum of 4229.98 in the 27th node. The peak output continued upto 30th node after which it decreased to 4035.77 in the 35th, 3725.25 in the 40th, 3269.24 in the 45th, 2667.73 in the 50th, 1920.74 in the 55th and 1028.82 in the 60th nodes. In the case of 'Tongat' pollen production varied between 2315.45 in the first node to 241.35 in the 65th node with a peak production of 2908.24 in the 20th node after which values decreased. The pollen production in the 25th, 30th, 35th, 40th, 45th, 50th, 55th and 60th nodes were 2873.28, 2758.76, 2564.67, 2267.39, 1857.60, 1408.91, 880.64 and

Table-7

Pollen production per anther in different nodes of the three male parents

Node position	Pollen production per anther		
	Pisang Lilin	Tongat	Sanna chenkadali
	2	3	4
1	3875.41 (3.588)	2315.45 (3.364)	2288.86 (3.359)
2	4252.33 (3.628)	2375.29 (3.375)	2436.27 (3.386)
3	4612.94 (3.663)	2431.95 (3.385)	2577.85 (3.411)
4	4957.37 (3.695)	2485.43 (3.395)	2713.62 (3.433)
5	5285.49 (3.723)	2535.73 (3.464)	2843.56 (3.453)
6	5599.34 (3.748)	2582.84 (3.412)	2967.69 (3.472)
7	5892.91 (3.770)	2626.77 (3.419)	3068.99 (3.486)
8	6172.22 (3.790)	2667.52 (3.426)	3198.48 (3.504)
9	6435.25 (3.808)	2705.08 (3.432)	3305.15 (3.519)
10	6682.62 (3.824)	2739.46 (3.437)	3405.99 (3.532)
11	6912.52 (3.839)	2770.66 (3.442)	3501.02 (3.544)
12	7126.74 (3.852)	2798.68 (3.446)	3590.23 (3.555)
13	7324.70 (3.864)	2823.51 (3.452)	3673.62 (3.565)
14	7506.38 (3.875)	2845.16 (3.454)	3751.18 (3.574)
15	7671.80 (3.884)	2863.63 (3.456)	3822.93 (3.582)
16	7820.95 (3.893)	2878.92 (3.459)	3888.86 (3.589)
17	7953.82 (3.900)	2891.02 (3.461)	3948.97 (3.596)
18	8070.43 (3.906)	2899.94 (3.462)	4003.26 (3.602)
19	8170.77 (3.912)	2905.68 (3.463)	4051.73 (3.6076)
20	8254.85 (3.916)	2908.24 (3.463)	4094.38 (3.612)
21	8322.63 (3.920)	2907.61 (3.463)	4131.21 (3.616)
22	8374.16 (3.922)	2903.80 (3.462)	4162.22 (3.619)
23	8409.41 (3.924)	2896.81 (3.461)	4187.41 (3.621)
24	8428.40 (3.925)	2886.64 (3.460)	4206.78 (3.623)
25	8431.12 (3.925)	2873.28 (3.458)	4220.34 (3.625)
26	8417.57 (3.925)	2856.74 (3.455)	4228.07 (3.626)
27	8317.55 (3.923)	2837.02 (3.452)	4229.98 (3.626)
28	8311.65 (3.921)	2814.11 (3.449)	4226.07 (3.625)
29	8300.29 (3.917)	2788.03 (3.445)	4216.35 (3.624)
30	8200.66 (3.913)	2758.76 (3.440)	4200.80 (3.623)

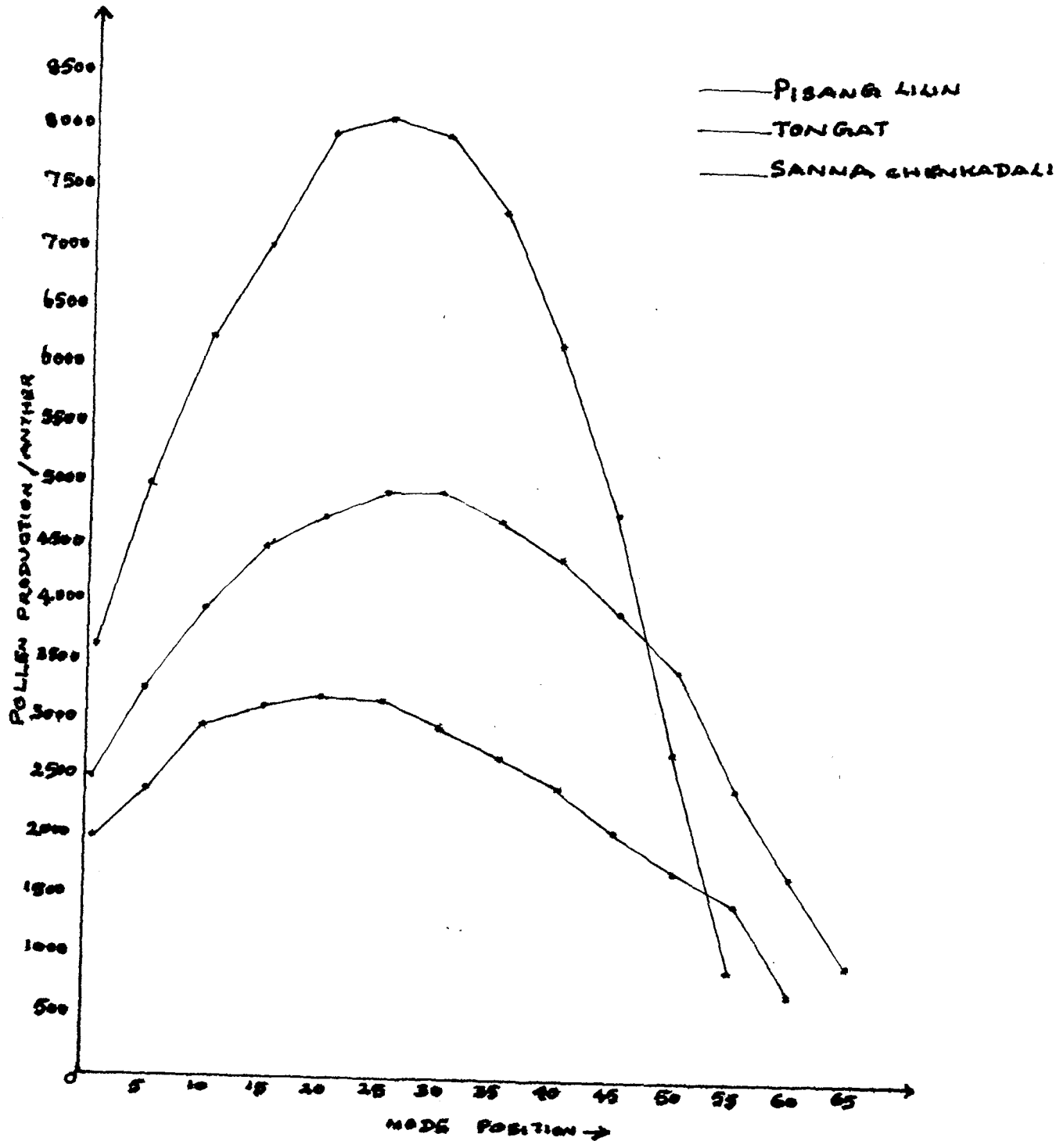
Contd.

Table-7. Continued

1	2	3	4
31	8105.76 (3.908)	2726.30 (3.435)	4179.43 (3.621)
32	7994.59 (3.902)	2690.67 (3.429)	4152.25 (3.618)
33	7867.14 (3.895)	2651.85 (3.423)	4119.24 (3.614)
34	7723.43 (3.887)	2609.85 (3.416)	4080.42 (3.610)
35	7563.45 (3.878)	2564.67 (3.409)	4035.77 (3.605)
36	7387.20 (3.868)	2516.30 (3.400)	3985.31 (3.600)
37	7194.68 (3.857)	2464.75 (3.391)	3929.02 (3.594)
38	6985.89 (3.844)	2410.07 (3.380)	3866.92 (3.587)
39	6760.83 (3.830)	2352.11 (3.371)	3798.99 (3.579)
40	6519.50 (3.814)	2267.39 (3.355)	3725.25 (3.571)
41	6261.89 (3.796)	2159.27 (3.334)	3645.69 (3.561)
42	5988.02 (3.777)	2088.63 (3.319)	3560.30 (3.551)
43	5697.88 (3.777)	2014.80 (3.304)	3469.10 (3.540)
44	5391.47 (3.731)	1937.79 (3.287)	3372.08 (3.527)
45	5068.79 (3.704)	1857.60 (3.268)	3269.24 (3.514)
46	4729.84 (3.674)	1774.23 (3.249)	3160.58 (3.499)
47	4374.62 (3.640)	1687.67 (3.227)	3046.09 (3.483)
48	4003.13 (3.602)	1597.93 (3.203)	2925.79 (3.466)
49	3615.37 (3.558)	1505.01 (3.177)	2799.67 (3.447)
50	3211.34 (3.506)	1408.91 (3.148)	2667.73 (3.426)
51	2791.04 (3.445)	1309.62 (3.117)	2529.97 (3.403)
52	2354.47 (3.371)	1207.15 (3.081)	2386.39 (3.377)
53	1901.63 (3.279)	1101.50 (3.041)	2236.99 (3.349)
54	1432.52 (3.156)	992.66 (2.996)	2081.77 (3.318)
55	947.14 (2.976)	880.64 (2.944)	1920.74 (3.283)
56		765.44 (2.883)	1753.88 (3.243)
57		647.06 (2.810)	1581.20 (3.198)
58		525.50 (2.720)	1402.70 (3.146)
59		400.75 (2.602)	1218.38 (3.085)
60		270.67 (2.432)	1028.82 (3.012)
61		266.61 (2.425)	832.29 (2.920)
62		254.55 (2.405)	630.61 (2.799)
63		250.66 (2.399)	422.92 (2.626)
64		243.44 (2.386)	209.50 (2.321)
65		241.35 (2.382)	206.50 (2.314)

(Values in parentheses denote the means of the transformed data)

FIG 3:1 POLLEN PRODUCTION PER ANTHER IN DIFFERENT NODES OF MALE PARENTS



270.67 respectively. The decreasing trend in 'Pisang Lilin' was sudden, whereas in 'Sanna chenkadali' and 'Tongat' it was gradual (Fig.3.1).

Among the three male parents, 'Pisang Lilin' produced the maximum number of pollen grains per anther (8431.12) which was followed by 'Sanna chenkadali' with a pollen output of 4229.98. 'Tongat' recorded the least pollen production per anther (2908.24).

2.2. Pollen fertility

The data presented in Table 8 gives the results of pollen fertility studies by acetocarmine staining technique in different nodes of the three male parents. Fig.3.2 represents the trend in pollen fertility in different nodes.

The fertility ranged between 46.14 per cent in the 1st node to 28.45 per cent in the 55th node with a peak of 53.74 per cent in the 20th node in 'Pisang Lilin'. The peak fertility continued upto 25th node. The fertility per cent in 30th, 35th, 40th, 45th, 50th and 55th were 51.71, 49.15, 45.53, 40.87, 35.18 and 28.45 respectively showing a decreasing trend. In case of 'Sanna chenkadali', the fertility was found to be vary between 35.24 per cent in the first node to 19.96 per cent in the 65th node, with a maximum fertility 44.85 per cent in the 28th node. The peak

Table-8

Pollen fertility in different nodes of the three male parents.

Node position	Pollen fertility (per cent)		
	Pisang Lilin	Tongat	Sanna chenkadali
1	2	3	4
1	46.14 (42.76)	28.53 (32.27)	35.24 (36.39)
2	46.91 (43.22)	28.71 (32.39)	35.99 (36.81)
3	47.65 (43.62)	28.88 (32.46)	36.71 (37.29)
4	48.35 (44.03)	29.04 (32.58)	37.40 (37.70)
5	48.99 (44.37)	29.19 (32.65)	38.05 (38.66)
6	49.59 (44.71)	29.32 (32.77)	38.68 (38.41)
7	50.16 (45.06)	29.45)(32.83)	39.27 (38.76)
8	50.69 (45.34)	29.56 (32.90)	39.83 (39.11)
9	51.17 (45.63)	29.66 (32.96)	40.36 (39.41)
10	51.16 (45.63)	29.75 (33.02)	40.86 (39.70)
11	52.01 (46.15)	29.83 (33.09)	41.33 (39.99)
12	52.27 (56.32)	29.90 (33.15)	41.77 (40.22)
13	52.69 (46.49)	29.95 (33.15)	42.17 (40.46)
14	52.96 (46.66)	30.00 (33.21)	42.55 (40.69)
15	53.20 (46.83)	30.03 (33.21)	42.89 (40.86)
16	53.39 (46.87)	30.07 (33.21)	43.20 (41.09)
17	53.54 (47.01)	30.07 (33.21)	43.48 (41.21)
18	53.65 (47.06)	30.06 (33.21)	43.74 (41.38)
19	53.72 (47.12)	30.06 (33.21)	43.94 (41.50)
20	53.74 (47.12)	30.03 (33.21)	44.13 (41.61)
21	53.73 (47.12)	30.00 (33.21)	44.28 (41.67)
22	53.67 (47.06)	29.96 (33.16)	44.40 (41.78)
23	53.57 (47.01)	29.83 (33.09)	44.50 (41.84)
24	53.43 (46.95)	29.75 (33.02)	44.56 (41.84)
25	53.25 (46.83)	29.66 (32.96)	44.58 (41.84)
26	53.02 (46.72)	29.56 (32.90)	44.58 (41.84)
27	52.76 (46.55)	29.45 (32.83)	44.55 (41.84)
28	52.45 (46.38)	29.32 (32.77)	44.85 (42.02)
29	52.10 (46.20)	29.19 (32.65)	44.38 (41.73)
30	51.71 (45.97)	29.19 (32.65)	44.25 (41.67)
31	50.81 (45.46)	29.04 (32.58)	44.09 (41.55)

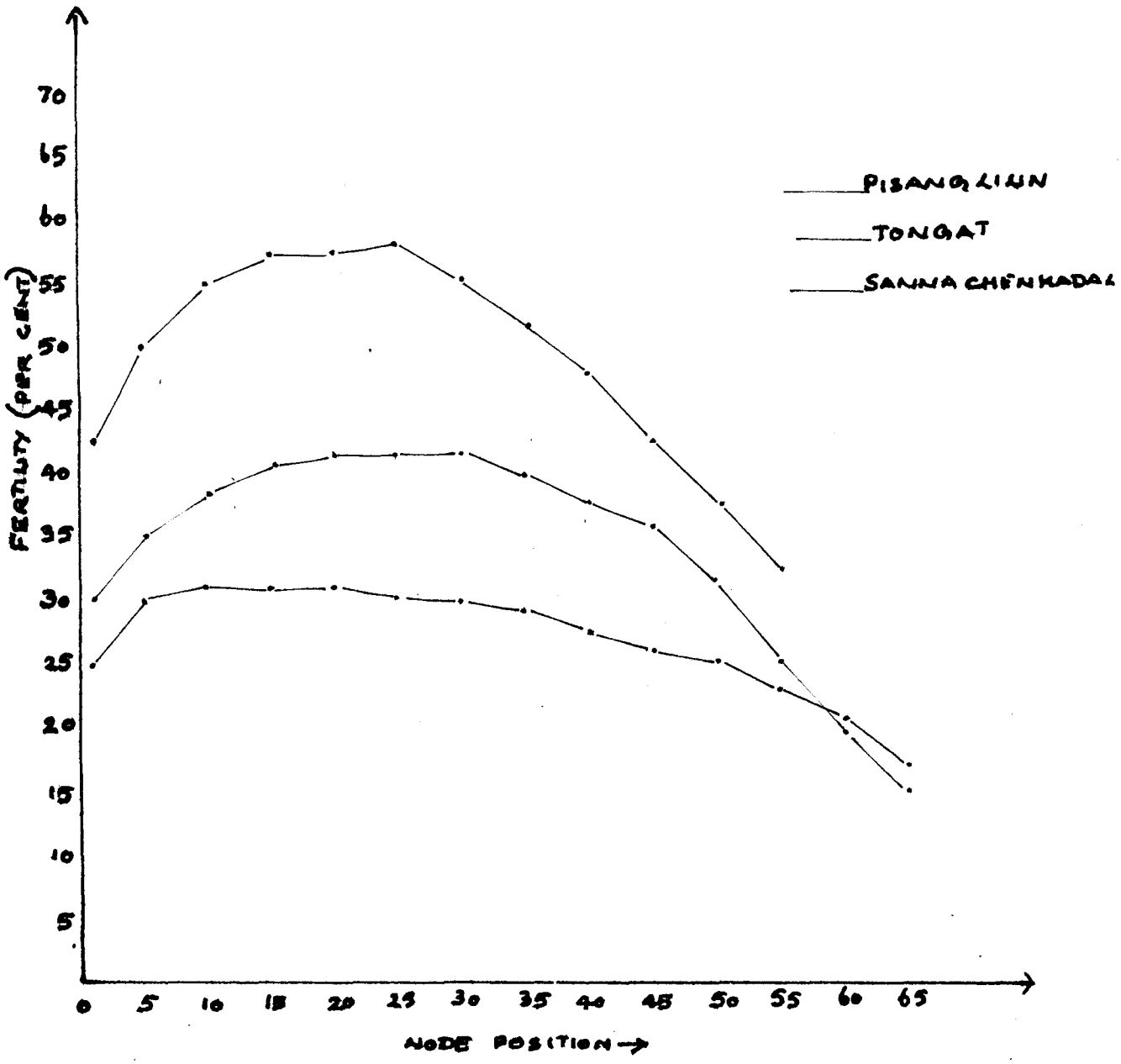
Contd.

Table-8. Continued

1	2	3	4
32	50.81 (45.46)	28.89 (32.46)	43.90 (41.50)
33	50.29 (45.11)	28.72 (32.39)	43.68 (41.32)
34	49.74 (44.85)	28.54 (32.27)	43.43 (41.21)
35	49.15 (44.48)	28.35 (32.14)	43.14 (41.03)
36	48.50 (44.14)	28.14 (32.01)	42.82 (40.86)
37	47.82 (43.74)	27.93 (31.88)	42.47 (40.68)
38	47.10 (43.34)	27.70 (31.76)	42.09 (40.40)
39	46.33 (42.88)	27.47 (31.56)	41.68 (40.16)
40	45.53 (42.42)	27.22 (31.76)	41.24 (39.93)
41	44.68 (41.90)	26.96 (31.24)	40.77 (39.64)
42	43.76 (41.38)	26.69 (30.05)	40.26 (39.35)
43	42.86 (40.86)	26.41 (30.92)	39.72 (39.06)
44	41.89 (40.28)	26.12 (30.72)	39.15 (38.70)
45	40.87 (39.70)	25.81 (30.45)	38.56 (38.35)
46	39.82 (39.11)	25.50 (30.33)	37.92 (38.00)
47	38.72 (38.47)	25.17 (30.07)	37.26 (37.58)
48	37.58 (37.76)	24.83 (29.83)	36.57 (37.17)
49	36.40 (37.11)	24.48 (29.60)	35.84 (36.75)
50	35.18 (36.33)	24.12 (29.40)	35.09 (36.27)
51	33.92 (35.61)	23.75 (29.06)	34.30 (35.70)
52	32.61 (34.82)	23.37 (28.86)	33.48 (35.30)
53	31.26 (33.96)	22.97 (28.59)	32.63 (34.82)
54	29.88 (33.09)	22.57 (22.32)	31.74 (34.27)
55	28.45 (32.14)	22.15 (28.04)	30.83 (33.71)
56		21.72 (27.76)	29.88 (33.15)
57		21.29 (27.42)	28.91 (32.52)
58		20.83 (27.16)	27.90 (31.88)
59		20.37 (26.78)	26.86 (31.88)
60		19.90 (26.49)	25.79 (30.45)
61		19.42 (26.13)	24.69 (29.73)
62		18.92 (25.77)	23.55 (29.00)
63		18.41 (25.40)	22.39 (28.18)
64		17.60 (24.80)	21.19 (27.35)
65		17.37 (24.58)	19.96 (26.49)

(Values in parentheses denote the means of the transformed data)

FIG. 3:2 POLLEN FERTILITY (PER CENT) IN DIFFERENT NODES OF MALE PARENTS



fertility continued upto 30th node. In the 35th, 40th, 45th, 50th, 55th and 60th nodes, the fertility per cent were 43.14, 41.24, 38.56, 35.09, 30.83 and 25.79 respectively. The fertility in 'Tongat' ranged between 28.33 per cent in the 1st node to 17.37 per cent in the 65th node with a peak of 30.07 per cent in the 16th node which continued upto 20th node. The fertility per cent in the 25th, 30th, 35th, 40th, 45th, 50th, 55th and 60th nodes were 29.66, 29.19, 28.35, 27.22, 25.81, 24.12, 22.15 and 19.90 respectively.

2.3. Pollen viability (germination)

2.3.1. Standardisation of the culture medium (sucrose solution).

Results of the studies on the standardisation of medium for In vitro culture of pollen grains are presented in Table 9 and Fig. 3.3.

The germination percentage varied depending upon the sucrose concentrations in the medium. Of the 9 sucrose concentrations tried, 35 per cent sucrose gave significantly the highest percentage of germination (31.15) followed by 30 per cent sucrose (24.41). The lowest per cent of germination (6.11) was recorded in the 50 per cent sucrose solution.

Table-9

Effect of sucrose on pollen germination of the male parent 'Pisang Lilin'

Treatments	Conc. of sucrose solution (%)	Mean germination (%)	Mean pollen tube growth (μ)
1	2	3	4
T_0	10	0	0
T_1	15	10.02 (18.44)	103.46
T_2	20	14.56 (22.38)	135.46
T_3	25	19.19 (26.49)	166.40
T_4	30	24.41 (29.60)	262.40
T_5	35	31.15 (33.89)	412.80
T_6	40	17.91 (24.03)	100.26
T_7	45	11.28 (19.55)	71.46
T_8	50	6.11 (14.30)	61.86
C.D. (0.05)		1.63	30.06

(Values in parentheses denote the means of the transformed data)

FIG 3 : 3 EFFECT OF SUCROSE ON POLLEN GERMINATION AND TUBE GROWTH

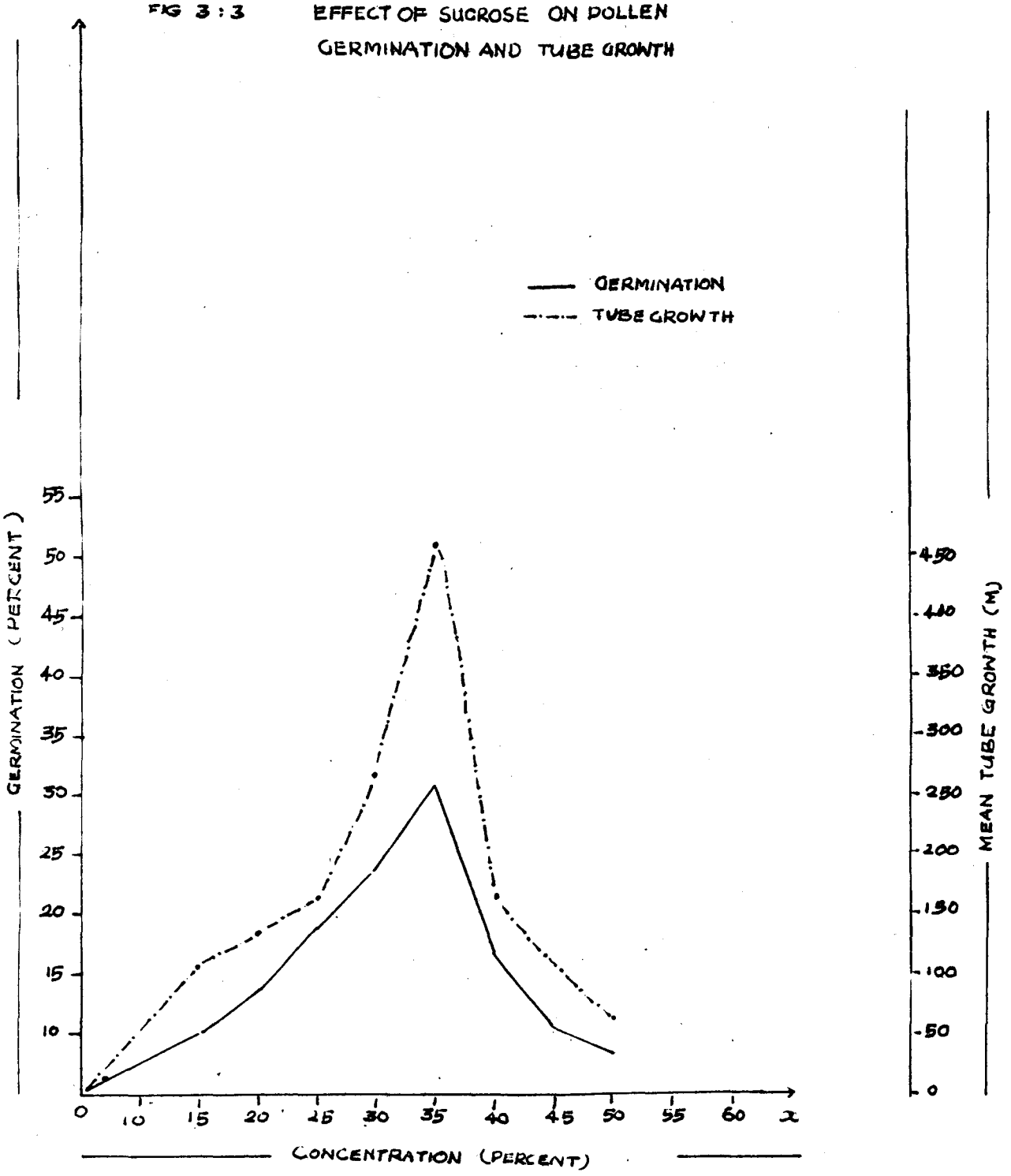


Table-10

Pollen germination at bihourly intervals from the time of commencement to completion in 35% sucrose.

Treatments	Time (hours)	Mean germination (%)	Mean pollen tube growth (μ)
1	2	3	4
T_1	0-18	0	0
T_2	20	20.44 (26.85)	208.00
T_3	22	25.92 (30.59)	267.33
T_4	24	31.03 (33.83)	336.00
T_5	26	31.03 (33.83)	336.00
T_6	28	31.39 (34.02)	337.06
T_7	30	31.74 (34.27)	339.20
T_8	32	31.74 (34.27)	339.20
C.D. (0.05)		1.59	34.39

(Values in parentheses denote the means of the transformed data)

Maximum tube growth was also observed in 35 per cent sucrose (412.80 μ) which was significantly higher than that observed in the rest of the concentrations. This was followed by 30 per cent sucrose which produced at tube growth of 262.4 μ. The minimum tube growth (61.86 μ) was produced in the 50 per cent sucrose solution.

The percentage of germination of pollen and tube growth in 35 per cent sucrose from 20 hours to 32 hours after incubation at bihourly intervals are presented in Table 10.

The germination percentage reached its maximum in 24 hours. From 24-32 hours, the observed difference in the germination was not statistically significant which indicated that maximum germination was attained by 24 hours. Pollen tube growth recorded in 24 hours also was significantly higher than that in 22 hours or 18 hours, but the treatment was on par with each increase in tube length recorded in subsequently progressing time.

2.3.2. Pollen viability of the three male parents

The results of the studies on pollen viability (germination per cent and tube growth) in different nodes of the male parents are given in Table 11. Fig. 3.3.1. and 3.3.2. represent the trend in pollen viability of the male parents in different nodes.

Table-11.

Pollen viability in different nodes of the three male parents

Node position	Pollen viability					
	Pisang Lilin		Tongat		Sanna chenkadali	
	Mean germination (%)	Mean tube length (μ)	Mean germination (%)	Mean tube length (μ)	Mean germination (%)	Mean tube length (μ)
1	2	3	4	5	6	7
1	19.63 (26.28)	210.12	0	0	9.81 (18.24)	102.79
2	19.83 (26.42)	215.93	0	0	9.92 (18.34)	102.79
3	21.86 (27.83)	220.19	0	0	9.96 (18.34)	130.66
4	21.97 (27.90)	240.18	0	0	9.98 (18.34)	135.78
5	23.72 (29.13)	245.16	0	0	10.11 (18.53)	150.17
6	23.76 (29.13)	275.18	7.00 (15.34)	90.12	10.25 (18.63)	152.18
7	26.84 (30.98)	285.12	7.38 (15.68)	90.15	10.39 (18.72)	173.18
8	27.68 (31.69)	285.16	9.75 (18.15)	93.66	10.45 (18.81)	185.66
9	27.92 (31.88)	290.00	8.06 (16.43)	112.77	10.56 (18.91)	186.77
10	18.16 (32.01)	290.18	8.42 (16.85)	119.86	10.62 (19.00)	200.16
11	30.10 (33.27)	290.96	8.72 (17.16)	123.44	10.31 (18.72)	205.18
12	30.11 (33.27)	330.18	9.03 (17.46)	125.66	15.12 (22.87)	208.16
13	31.13 (33.89)	338.64	9.30 (17.76)	127.54	15.13 (22.87)	208.88
14	31.14 (33.89)	345.61	9.56 (17.95)	127.44	15.15 (22.87)	215.16
15	31.15 (33.89)	350.00	9.80 (18.24)	128.33	15.66 (23.26)	220.18

Contd.

Table-11. Continued

1	2	3	4	5	6	7
16	31.14 (33.89)	350.16	10.00 (18.44)	126.41	16.17 (23.66)	220.19
17	31.14 (33.89)	350.18	10.23 (18.63)	125.02	16.19 (23.58)	220.63
18	31.14 (33.89)	360.92	10.41 (18.81)	121.67	17.21 (24.50)	224.75
19	31.13 (33.89)	360.81	10.58 (18.91)	120.19	17.28 (24.50)	228.68
20	31.11 (33.89)	396.16	10.74 (19.09)	118.44	18.09 (25.10)	231.65
21	31.10 (33.89)	390.93	10.87 (19.19)	117.61	18.09 (25.10)	230.16
22	31.08 (33.83)	396.16	10.98 (19.28)	115.64	18.09 (25.10)	230.15
23	31.00 (33.83)	396.82	11.08 (19.37)	113.16	18.08 (25.10)	228.16
24	31.00 (33.83)	400.12	11.16 (19.46)	112.19	18.08 (25.10)	228.10
25	31.00 (33.83)	410.81	11.23 (19.55)	110.66	18.06 (25.10)	225.64
26	30.06 (33.21)	410.83	11.27 (19.55)	110.57	18.06 (25.10)	225.63
27	30.04 (33.21)	410.63	11.30 (19.64)	110.11	18.04 (25.10)	224.15
28	28.04 (32.33)	410.15	11.30 (19.64)	108.66	18.04 (25.10)	224.66
29	27.51 (31.63)	400.16	11.30 (19.64)	108.54	18.00 (25.10)	224.10
30	27.12 (31.37)	400.13	11.12 (19.46)	107.66	16.19 (23.66)	223.16
31	26.17 (30.72)	386.85	11.00 (19.37)	105.64	15.14 (22.87)	222.88
32	26.16 (30.72)	386.80	11.00 (19.37)	104.33	13.12 (21.22)	221.77
33	25.94 (30.59)	386.60	11.00 (19.37)	102.11	12.10 (20.36)	221.66
34	25.18 (30.07)	386.77	10.89 (19.19)	101.16	11.99 (20.18)	220.99
35	22.92 (28.59)	386.77	10.81 (19.19)	100.88	10.18 (18.53)	220.19
36	22.18 (28.04)	380.66	10.40 (18.81)	100.51	10.17 (19.53)	220.01
37	22.12 (28.04)	350.77	10.27 (18.63)	98.77	10.17 (18.53)	218.16

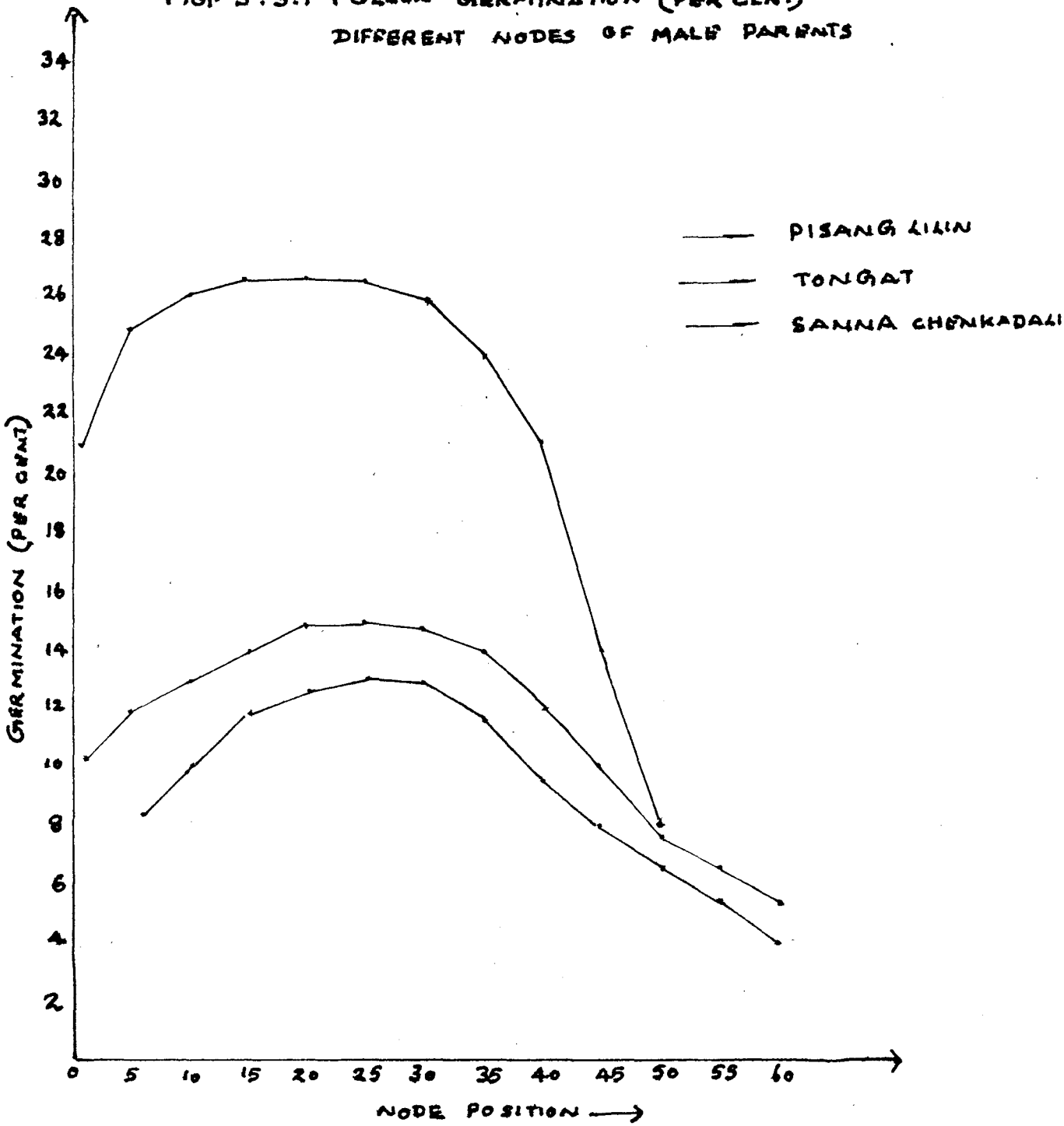
Contd.

Table-11. Continued

1	2	3	4	5	6	7
38	20.17 (26.64)	320.66	10.12 (18.53)	98.66	10.15 (18.53)	217.17
39	19.99 (26.49)	250.65	9.80 (18.24)	98.66	10.13 (18.53)	216.16
40	19.99 (26.49)	284.15	9.62 (18.05)	98.66	9.91 (18.34)	215.89
41	18.16 (25.18)	250.16	9.43 (17.85)	96.44	9.16 (17.56)	215.86
42	18.15 (25.18)	190.17	9.23 (17.66)	96.44	9.16 (17.56)	214.16
43	18.12 (25.18)	185.18	9.02 (17.46)	95.99	9.15 (17.56)	214.08
44	14.16 (21.97)	175.16	8.80 (17.26)	95.77	9.15 (17.56)	214.13
45	10.12 (18.53)	150.18	8.31 (16.74)	94.32	8.92 (17.36)	210.99
46	9.68 (18.05)	139.14	8.05 (16.43)	94.11	8.99 (17.36)	209.16
47	8.90 (17.36)	133.80	7.78 (16.11)	93.26	8.89 (17.26)	200.18
48	7.38 (15.68)	128.20	7.50 (15.89)	93.16	8.71 (17.16)	198.19
49	6.58 (14.77)	122.33	7.21 (15.56)	93.18	8.70 (17.16)	197.16
50	6.14 (14.30)	112.40	6.90 (15.23)	93.16	8.16 (16.54)	190.71
51			6.58 (14.77)	93.15	7.98 (16.32)	180.19
52			6.26 (14.42)	93.11	7.81 (16.22)	180.09
53			5.92 (14.06)	92.99	7.80 (16.22)	160.75
54			5.20 (13.18)	92.88	7.70 (16.11)	160.13
55			4.83 (12.66)	92.77	7.64 (16.00)	150.71
56			4.44 (12.11)	92.28	7.51 (15.89)	140.73
57			4.04 (11.54)	92.15	7.43 (15.79)	133.83
58			3.63 (10.94)	92.13	7.42 (15.79)	125.91
59			3.21 (10.47)	92.12	7.31 (15.68)	100.92
60			2.77 (9.46)	90.12	7.21 (15.56)	88.12

(Values in parentheses denote the means of the transformed data)

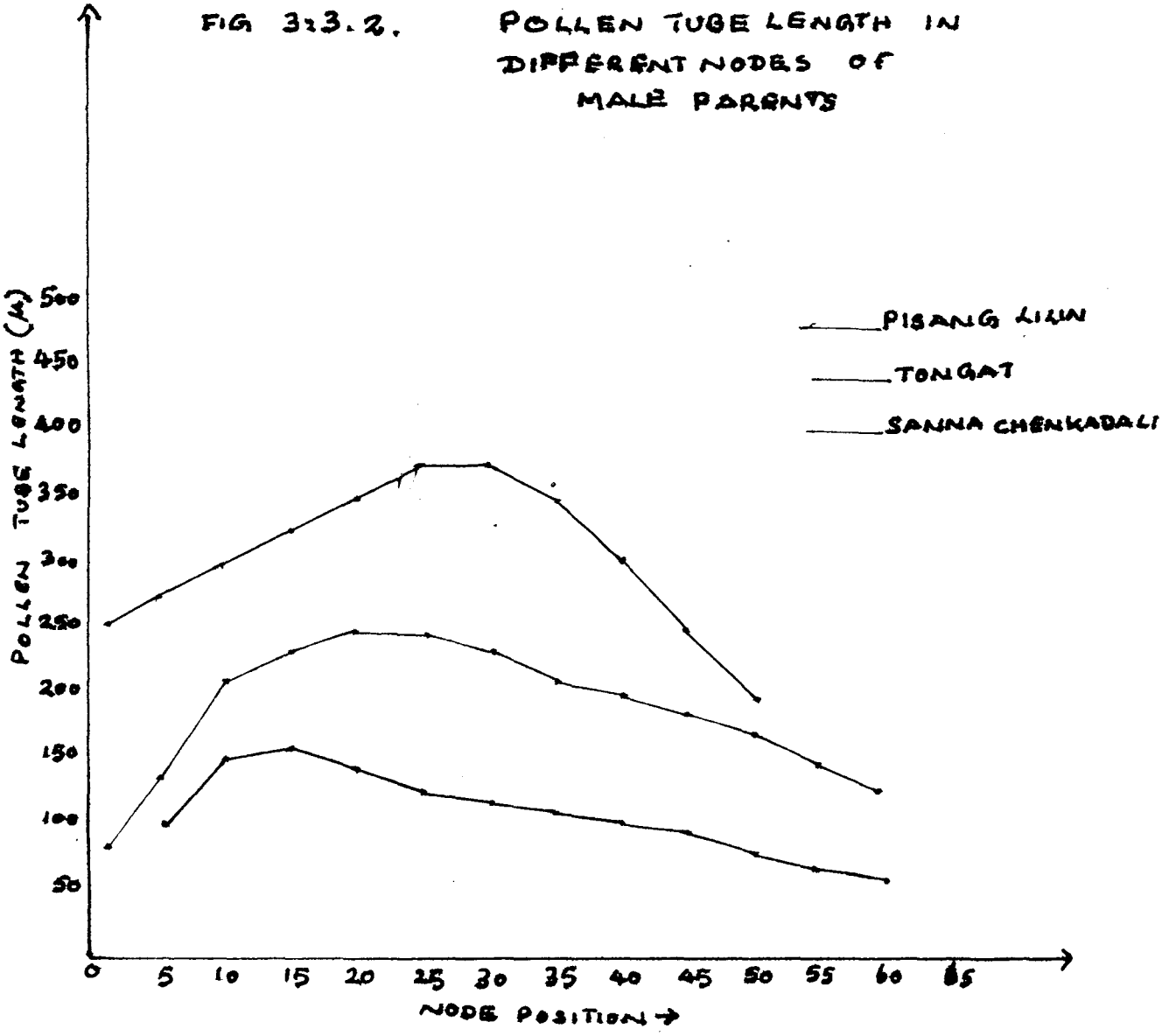
FIG. 3:3.1 POLLEN GERMINATION (PER CENT) IN DIFFERENT NODES OF MALE PARENTS



In 'Pisang Lilin', the germination percentage varied between 19.63 in the first node to 6.14 in the 50th node, with a maximum of 31.15 in the 15th node. The peak viability continued upto 25th node. In the 30th, 35th, 40th and 45th nodes, the pollen germination percentages were 27.12, 22.92, 19.99 and 10.12 respectively, showing a sharp decrease. The pollen viability ranged between 9.81 per cent in the 1st node to 7.21 per cent in the 60th node, with a peak of 18.09 per cent in the 20th node in 'Sanna chenkadali'. The peak continued upto 30th node. In the 35th, 40th, 45th, 50th and 55th nodes the viability percentages were 10.18, 9.91, 8.92, 8.16, and 7.64 respectively, showing a gradual decrease. In 'Tongat' viability was found to vary between 7.0 per cent in the sixth node to 2.77 per cent in the 60th node, with a peak of 11.30 per cent in the 27th node which continued upto 30th node. There was no pollen germination in the 1st, 2nd, 3rd, 4th and 5th nodes. The pollen germination percentages in the 35th, 40th, 45th, 50th and 55th nodes were 10.81, 9.62, 8.31, 6.90 and 4.83 respectively, showing a gradual decrease.

The pollen tube length in 'Pisang Lilin' varied between 210.12 μ in the first node to 112.40 μ in the 50th node, with a maximum tube length 410.83 μ in the 25th node.

FIG 3:3.2. POLLEN TUBE LENGTH IN DIFFERENT NODES OF MALE PARENTS



The tube length in 30th, 35th, 40th and 45th nodes were 400.13 µ , 386.77 µ , 284.15 µ and 150.18 µ respectively showing a gradual decrease. In 'Sanna chenkadali' tube length was found to vary between 102.79 µ in the 1st node to 88.12 µ in the 60th node with a peak tube length of 231.65 µ , in the 20th node. The tube length in the 25th, 30th, 35th, 40th, 45th, 50th and 55th nodes were 225.64 µ , 223.16 µ , 220.19 µ , 215.89 µ , 210.99 µ , 190.71 µ and 150.71 µ respectively. The tube length ranged between 90.12 µ in the 6th node to 90.22 µ in the 60th node, with a maximum of 128.33 µ in the 15th node in 'Tongat'. The tube growth started decreasing from the 20th node which was 118.44 µ , 110.66 µ in the 25th, 107.66 µ in the 30th, 100.88 µ in the 35th, 98.66 µ in the 40th, 94.32 µ in the 45th and 93.16 µ and 92.28 µ in the 55th nodes.

Both, germination percentage and tube length in 'Pisang Lilin' decreased sharply, whereas in 'Sanna chenkadali' and 'Tongat' the decreasing trend was gradual (Fig. 3.3 and 3.4).

Among the three male parents studied, 'Pisang Lilin' recorded the highest values both for pollen germination (31.15%) and tube length (410.83 µ) followed by 'Sanna chenkadali' (18.09%, 231.65 µ respectively).

Plate 11 & 12. Pollen grains of 'Pisang Lilin' germinated in 35% sucrose solution (x 30.)

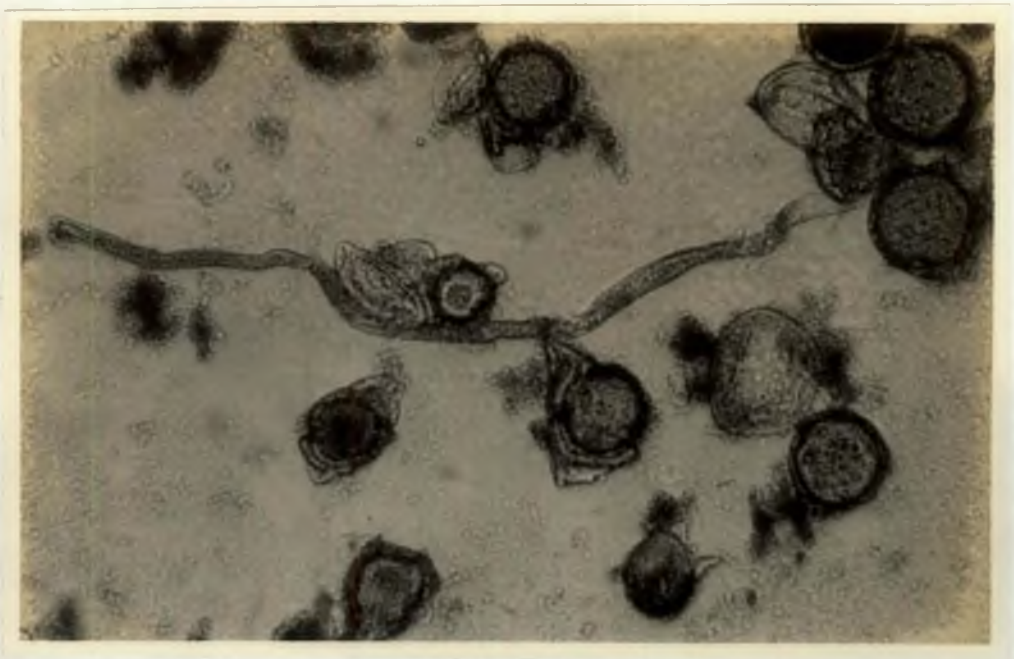


Plate 11

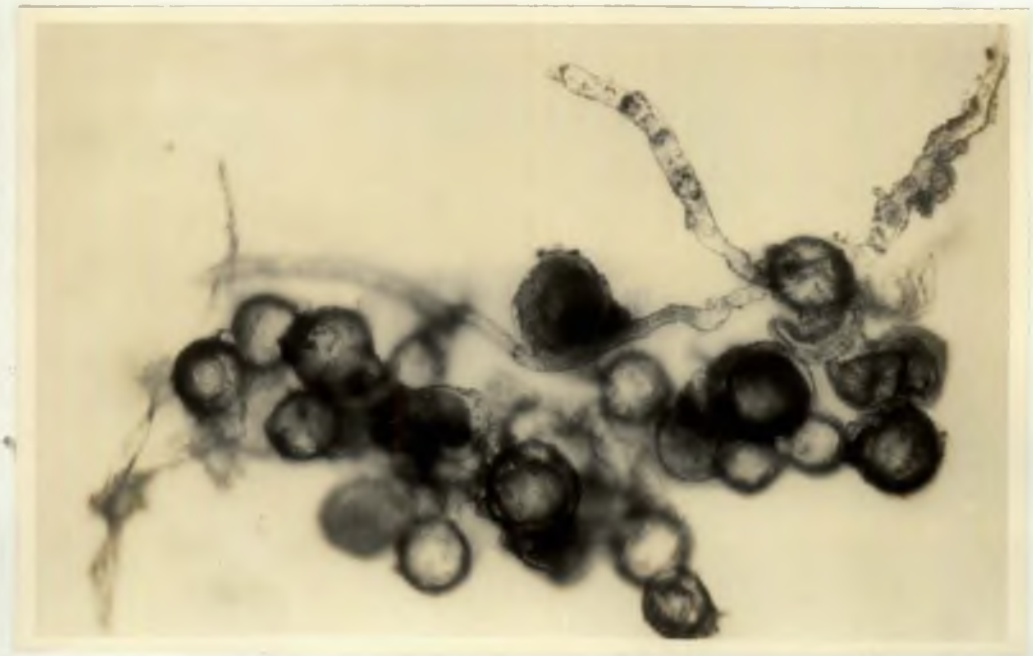


Plate 12

Plate 13. Pollen grains of 'Pisang Lilin stained in acetocarmine (x 300)

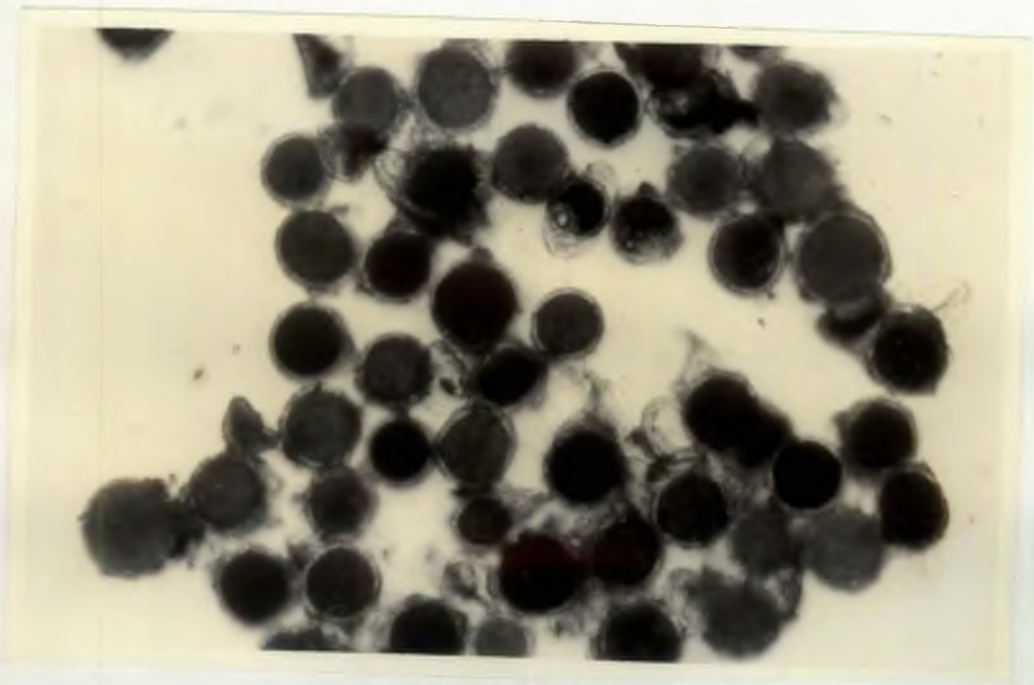


Plate 13

The lowest germination (11.30%) and tube length (128.23 μ) were recorded by 'Tongat'.

3. Cross compatibility, female fertility and seed set

Cross compatibility among six female and three male parents were studied. Table 12 gives an account of number of crosses attempted and seeds obtained in each cross. The pattern of fertility and seed production are given in Table 13.

The results of the crosses, (Fig.4.1) showed that, out of the 18 cross combinations tried, compatibility was obtained only in three crosses. The successful combinations were, 'Palayankodan' x 'Pisang Lilin', 'Rasthali' x 'Pisang Lilin' and 'Nendran' x 'Pisang Lilin'. Among the three male parents tried, only 'Pisang Lilin' was found to be compatible with the female parents. With respect to seed set, maximum was found in 'Palayankodan' (102.96 seeds per bunch) and the least in 'Rasthali' (10.98 seeds per bunch). 'Nendran' produced 13.65 seeds per bunch (Table 13).

Comparison of the seed formation with respect to position of hands (Fig. 4.2) showed that, basal hands were more fertile than the distal ones. 'Palayankodan' produced seeds upto tenth hand from the base. The maximum number of

Table-12

Number of crosses done and seed set

Sl. No.	Crosses	Number of flowers pollinated				Number of seed obtained			
		1st cross	2nd cross	3rd cross	Total	1st cross	2nd cross	3rd cross	Total
1	2	3	4	5	6	7	8	9	10
1	Palayankodan x Pisang Lilin	171	186	197	554	179	68	62	309
2	Rasthali x Pisang Lilin	95	103	110	308	10	17	6	33
3	Nendravannan x Pisang Lilin	100	85	84	269	Nil	Nil	Nil	Nil
4	Ney Poovan x Pisang Lilin	185	180	174	539	"	"	"	"
5	Karpooravally x Pisang Lilin	200	185	190	575	"	"	"	"
6	Nendran x Pisang Lilin	86	90	87	263	18	11	12	41
7	Palayankodan x Sanna chenkadali	180	190	195	565	Nil	Nil	Nil	Nil
8	Rasthali x Sanna chenkadali	111	100	112	323	"	"	"	"
9	Nendravannan x Sanna chenkadali	98	90	112	300	""	"	"	"
10	Ney Poovan x Sanna Chenkadali	209	180	175	586	"	"	"	"
11	Karpooravally x Sanna chenkadali	204	189	188	581	"	"	"	"
12	Nendran x Sanna chenkadali	85	95	89	269	"	"	"	"
13	Palayankodan x Tongat	192	195	200	587	"	"	"	"
14	Rasthali x Tongat	115	110	112	337	"	"	"	"
15	Nendravannan x Tongat	100	115	110	325	"	"	"	"
16	Ney Poovan x Tongat	178	185	188	551	"	"	"	"
17	Karpooravally x Tongat	200	178	180	558	"	"	"	"
18	Nendran x Tongat	87	89	90	266	"	"	"	"

Table-13. Compatibility and pattern of fertility in parents with respect to position of hands

Sl. No.	Parents	Position of hand	Number of seeds in hands				Mean number of seeds per hand	Mean number of seeds per bunch
			1st cross	2nd cross	3rd cross	Total seeds		
1	2	3	4	5	6	7	8	9
1	Palayankodan x Pisang Lilin	1	23	10	6	39	13.00	102.96
		2	38	15	14	67.00	22.33	
		3	56	8	18	82.00	27.33	
		4	23	8	5	36.00	12.00	
		5	18	7	7	32.00	10.66	
		6	13	6	4	23.00	7.66	
		7	4	9	4	17.00	5.66	
		8	4	3	3	10.00	3.33	
		9	0	1	1	2.00	0.66	
		10	0	1	0	1.00	0.33	
		11	0	0	0	0	0	
	Total		179	68	62	309		
2	Rasthali x Pisang Lilin	1	-	4	-	4.00	1.33	10.98
		2	3	3	2	8.00	2.66	
		3	4	2	2	8.00	2.66	
		4	2	3	1	6.00	2.00	
		5	1	4	1	5.00	2.00	
		6	-	1	-	1.00	0.33	
		7	-	-	-	-	-	
	Total		10	17	6	33		
3	Nendran x Pisang Lilin	1	5	3	-	8.00	2.66	13.65
		2	8	6	7	21.00	7.00	
		3	4	2	3	9.00	3.00	
		4	1	-	1	2.00	0.66	
		5	-	-	1	1.00	0.33	
	Total		18	11	12	41		

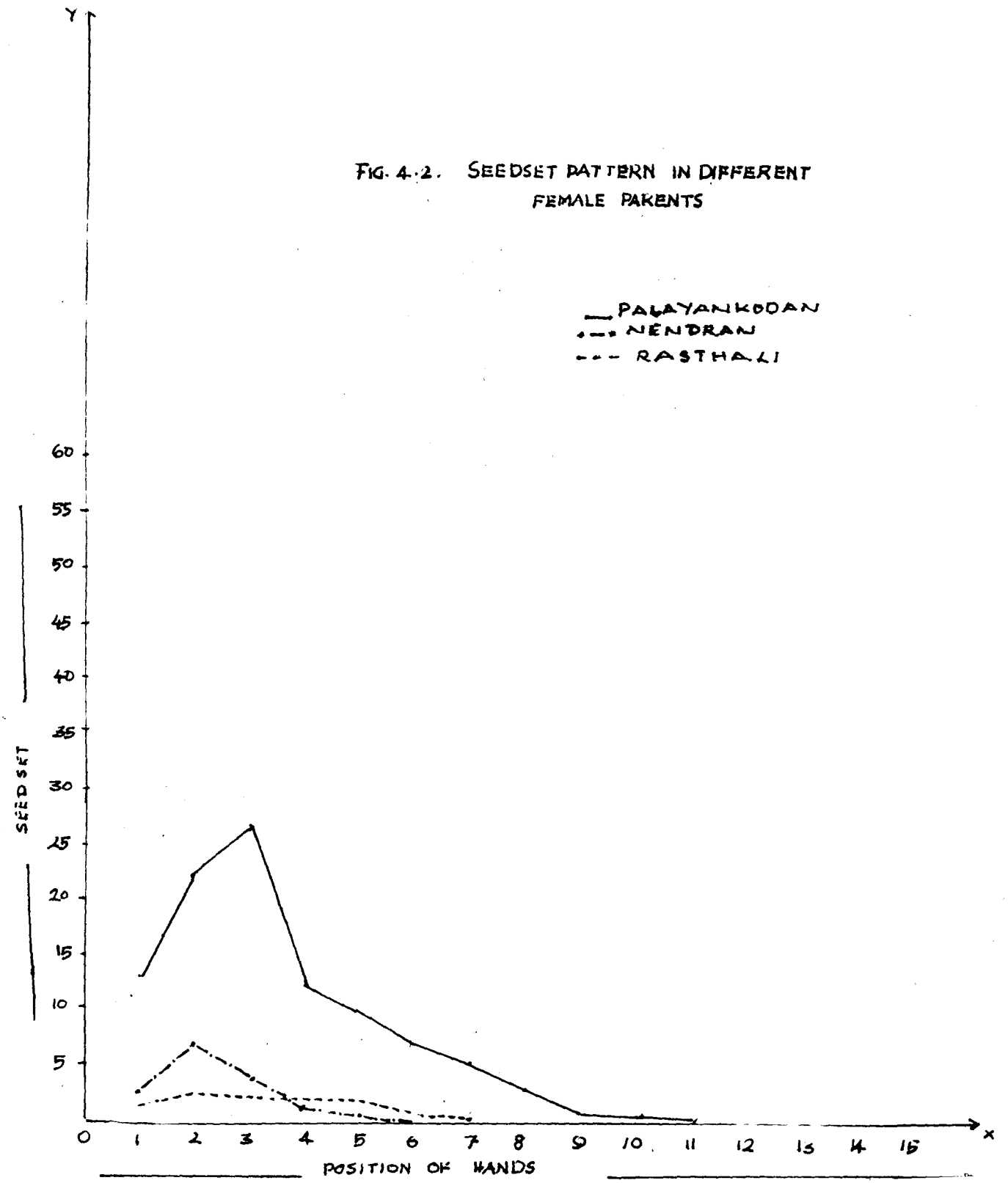
FIG: 4.1. CROSS COMPATIBILITY AMONG PARENTS

♀ \ ♂	Pisang Lilin (AA)	Tongat (AA)	Sanna Chenkadali (AA)
Palayankodan (AAB)	C	N	N
Rasthali (AAB)	C	N	N
Nendravannan (AAB)	N	N	N
Ney Poovan (AB)	N	N	N
Karpooravally (ABB)	N	N	N
Nendran (AAB)	C	N	N

C..... compatible

N..... Non-compatible.

FIG. 4.2. SEEDSET PATTERN IN DIFFERENT FEMALE PARENTS



Plates 14 to 16. Successful cross combinations.

Plate 14. 'Palayankodan' x 'Pisang Lilin'

Plate 15. 'Rasthali' x 'Pisang Lilin'

Plate 14

Plate 15

Plate 16. 'Nendran' x 'Pisang Lilin'

Plate 16

seeds was produced in the third hand (27.33) and the least in the tenth hand (0.33), 'Rasthali' produced seeds upto sixth hand, producing maximum seeds in second and third hands (2.66) and least in the sixth hand (0.33). 'Nendran' produced seeds upto fifth hand, producing maximum number of seeds (7.00) in the second and least in the fifth hands (0.33).

4. Seeds and seed treatment studies

The seeds from the three crosses, 'Palayankodan' x 'Pisang Lilin', 'Rasthali' x 'Pisang Lilin' and 'Nendran' x 'Pisang Lilin' were found to have more or less similar characters (Plates 17 to 19). They are about 3-4 mm in diameter, variously subglobose or angular in shape, very hard, endospermic with minute embryo at microphylar end. The seeds were black when fresh and turned to brownish black on drying.

Table 14 shows the results of seed treatment studies. Out of the five seed treatments (including control), only two seeds in the acid treatment from cross, 'Palayankodan' x 'Pisang Lilin' germinated. Of the two germinated seedlings, only one survived and it is in good condition in the field. (Plates 20 to 22).

Plates 17 to 19. Seed set in inter-clonal crosses.

Plate 17. 'Palayankodan' x 'Pisang Lilin'

Plate 17

Plate 18. 'Nendran' x 'Pisang Lilin'

Plate 19. 'Rasthali' x 'Pisang Lilin'

Plate 18

Plate 19

Table-14

Seed treatment studies

Sl. No.	Treatments	Cross					
		Palayankodan x Pisang Lilin		Rasthali x Pisang Lilin		Nendran x Pisang Lilin	
		Number of seeds treated	Germinated	Number of seeds treated	Germinated	Number of seeds treated	Germinated
1	2	3	4	5	6	7	8
1	Conc. H_2SO_4	50	2	6	Nil	8	Nil
2	Boiling Water	50	Nil	6	"	8	"
3	Chipping testas	50	"	6	"	8	"
4	GA treatment	50	"	6	"	8	"
5	Control	50	"	6	"	8	"

Plate 20 to 22. Seedling in various stages of growth.

Plate 20. Seedling 95 days after germination.

Plate 20

Plate 21. Seedling when transplanted in field.
(6 months after germination)

Plate 22. Seedling of 10 months old.

Plate 21

Plate 22

5. Studies on hybrids

Three hybrids from the cross 'Agniswar' x 'Pisang Lilin' (Karmacharya, 1984) were studied.

5.1. Morphological description

The three hybrids were morphologically described. The ploidy level of hybrids were determined using Taxonomic scoring and cytological studies. The photographs of the hybrids are shown in plates (23 to 26).

Hybrid No.I. AAB, 2n = 33

The plant is 271.00 cm tall at flowering with a circumstance of 68.33 cm at the base. It takes 168.33 days from flowering to harvest and the total duration is 303.99 days.

Pseudostem: is green with black blotches.

Leaves: Petiole 52.33 cm long, clasping the pseudostem loosely, margins of petiole erect, red coloured, with wings below, lamina 2.25 M long, 0.5 M broad, base of lamina equal, number of leaves 33.41.

Inflorescence: With basal female and distal male flowers, female axis semipendulous, male axis positively geotropic,

male flowers deciduous, pedunele medium long and glabrous.

Bract: deciduous, shoulder low (ratio 0.8), outside colour dark purple, inside dull purple, inside colour continues to base, broadly ovate, roll back after opening, apex obtuse, bract scars prominent.

Female flowers: arranged in two rows, united tepal 4.32 cm long, 2.3 cm broad, cream coloured, lobes 3 + 2, acute, free tepal 3.3 cm long, 3.7 cm broad, colour cream below tip corrugated, stamens not fertile, staminodes 5, filament length 1.63 cm, another lobe 0.73 cm long, cream coloured, pistil 4.58 cm length, stigma cream coloured, 2.54 cm in circumference, with 3 lobes, ovary 8.3 cm long, 7.54 cm in circumference, colour light green, ovules arranged in two regular rows in each loculus.

Male flowers: arranged in two rows, united tepal 4.5 cm long, 1.4 cm broad, below tip corrugated, stamens 5, all fertile, filament 1.7 cm long, colour white, anther lobe 2.00 cm long, cream coloured, pistillode, 3.6 cm long, stigma, colour orange yellow, 0.3 cm in circumference, ovary white with reddish tinge at the base, 1.5 cm long and 1.7 cm broad.

Bunch: position of mature bunch 45-50° to the horizontal,

bunch weight 6.40 kg, number of hands 5.0, number of fingers 85.0, fingers in a hand arranged loosely.

Finger: 15.0 cm long, and 12.66 cm in circumference, round in shape, tip also round, apex straight, finger weight 71.66 g.

Ripe fruit: Yellow, loosely attached to the hand, rind thin, pulp yellow coloured, fit for consumption, sweet taste, T.S.S. 18.63%, total sugars 13.24%, reducing sugars 11.73%, non reducing sugars 1.51%, sugar/acid ratio, 31.25, keeping quality good.

Hybrid No.II. AAB, 2n = 33

The plant is 249.33 cm tall at flowering with a circumference of 67.66 cm at the base. It takes 316.00 days from planting to flowering, 105.33 days from flowering to harvest and the total duration is 421.33 days.

Pseudostem: is light green with slight brown to black blotches.

Leaves: petiole 47.66 cm long, clasping pseudostem, margins of petiole erect and spreading, red coloured, lamina 175 cm long, 40 cm broad, base of lamina equal, number of leaves 25.41.

Plates 23 to 26. Hybrids and female parent 'Agniswar'.

Plate 23. Musa (AB) 'Agniswar' (♀)

Plate 24. Hybrid No.I

Plate 23

Plate 24

Inflorescence: with basal female and distal male flowers, female axis semipendulous, male axis positively geotropic, male flowers deciduous, peduncle medium long and glabrous.

Bract: deciduous, shoulder low (ratio 0.32), outside colour dark purple, inside bright crimson, inside colour fades throughout, narrowly ovate, roll back after opening, apex acute, bract scars prominent.

Female flowers: arranged in two rows, united tepal 3.5 cm long, 2.5 cm broad, lobes 3 + 2, obtuse, cream coloured, free tepal 2.9 cm long, 3.0 cm broad, cream coloured, below tip corrugated, stamens not fertile, staminodes 5, filament length 0.5 cm, anther lobe 0.4 cm long, pistil 3.5 cm long, stigma cream coloured, 2.3 cm in circumference, with 3 lobes, ovary 5.5 cm long, 5.0 cm in circumference, colour light green, ovules arranged in two regular rows in each loculus.

Male flowers: arranged in two rows, united tepal 6 cm long, 2 cm broad, creamy white coloured, lobes 3 + 2, acute, free tepal 2.5 cm long, 1.5 cm broad, below tip corrugated, stamen 5, all fertile, filament 2.8 cm long, colour white, anther lobe 2.5 cm long, cream coloured, pistilode 4 cm long, stigma colour orange yellow, ovary white with reddish tinge at the base, 1.5 cm long and 1.3 cm broad.

Bunch: position of mature bunch 35-40° to the horizontal, bunch weight 2.57 kg, number of hands 3.33, number of fingers 35.0, fingers in a hand arranged loosely.

Finger: 10.66 cm long, and 11.00 cm in circumference, round in shape, tip also round, finger weight 61.16 g.

Ripe fruit: Golden yellow, tightly attached to the hand, rind thin, flesh white coloured, fit for consumption, sweet taste, T.S.S. 22.17%, total sugars 15.17%, reducing sugars 13.72%, non reducing sugars 1.45%, sugar/acid ratio 71.86, keeping quality good.

Hybrid No.III. AAB, 2n = 33

The plant is 285.00 cm tall at flowering with a circumference of 64.00 cm at the base. It takes 281.66 days from planting to flowering, 119.66 days from flowering to harvest and the total duration is 401.32 days.

Pseudostem: is green with black blotches.

Leaves: petiole 46.0 cm long, clasping pseudostem loosely, margins of petiole erect and spreading, red coloured, lamina 250 cm long, 68 cm broad, base of lamina equal, apex truncate, number of leaves 35.41.

Plate 25. Hybrid No.II

Plate 26. Hybrid No.III

Plate 25

Plate 26

Inflorescence: with basal female and distal male flowers, female axis semipendulous, male axis positively geotropic, male flowers deciduous, peduncle medium long and glabrous.

Bract: deciduous, shoulder low (ratio 0.5), outside colour dull purple, inside colour dull pirple, insides colour fades throughout, broadly ovate, roll back after opening, apex obtuse, bract scars prominent.

Female flowers: arranged in two rows, united tepal 4.5 cm long, 2.5 cm broad, cream coloured, free tepal 2.9 cm long, 3.1 cm broad, cream coloured, below tip corrugated, stamens not fertile, staminodes, filament 1.2 cm long, anther lobe 0.7 cm long, cream coloured, pistil 4.5 cm long, stigma cream coloured, 2.7 cm in circumference with 3 lobes, ovary 8.0 cm long, 7.0 cm in circumference, colour light green, ovules arranged in two regular rows in each loculus.

Male flowers: arranged in two rows, united tepal 6.0 cm long, 2.5 cm broad, below tip corrugated, stamens 5, all fertile, filament 1.5 cm long, white coloured, anther lobe 3.5 cm long cream coloured, pistilode 3.6 cm long, stigma orange yellow, 0.41 cm in circumference, ovary white with reddish tinge at the base, 1.2 cm long and 1.2 cm broad.

Bunch: position of mature bunch 45-50° to the horizontal, bunch weight 9.10 kg, number of hands 7.0, fingers 95.0,

fingers in a hand arranged tightly.

Finger: 13.26 cm long, 14.50 cm circumference, round in shape, finger weight 83.33 g.

Ripe fruit: Yellow, tightly attached to the hand, rind thin, flesh yellow coloured, fit for consumption, sweet taste, T.S.S. 21.17%, total sugars 15.50%, reducing sugars 14.08%, non reducing sugars 1.42%, sugar/acid ratio 48.40, keeping quality excellent.

5.2. Evaluation of hybrids

The mean values of the 27 characters of the hybrids and parents are given in Tables 15 to 20. The analysis of variance of the characters are given in appendices III to VIII.

The following comparisons were made.

1. The hybrids were compared with the parents.
2. The hybrids were compared among themselves.

5.2.1. Growth parameters

The mean values of the growth parameters like the height, the number of functional leaves, the leaf area per plant, the petiole length and phylocron of the hybrids and

their parents are given in Table 15. Growth models are shown Table 16 and in Fig. 5.1 to 5.6. Significant variations were observed between hybrids and parents and also among hybrids. Among the hybrids 'Hybrid No.III' was found to be superior in height, girth, number of functional leaves, leaf area per plant, and petiole length. Though 'Hybrid No.II' was inferior in all parameters, it was dwarfest among the hybrids. 'Hybrid No.I' was medium in all parameters.

5.2.1.1. Height

When hybrids and parents were compared, the hybrids were significantly taller than the parents (Table 15). Among the hybrids 'Hybrid No.III' recorded the maximum height (285.00 cm) which was on par with the female parent 'Agniswar' (284.66). The least in height was recorded by 'Hybrid No.II' (249.33 cm). 'Hybrid No.I' was 271.0 cm in tall, and the male parent 'Pisang Lilin' was 160.33 cm in tall.

5.2.1.2. Girth

Hybrids 'No.II' and 'No.III' as compared to the female parent 'Agniswar', did not show significant difference in girth (Table 15). The mean values of girth for 'Hybrid No.II' and Hybrid No.III were 67.66 cm and 64.00 cm respectively

Table-15

Mean values of growth parameters of hbyrids and parents

Hybrids/parents	Growth parameters					
	Height (cm)	Girth (cm)	Functional leaves	Leaf area per plant (m^2)	Petiole length (cm)	Phylacron (days)
1	2	3	4	5	6	7
Hybrid No.I	271.00	68.33	7.33	8.14	52.33	7.50
Hybrid No.II	249.33	67.66	4.66	4.20	47.66	11.00
Hybrid No.III	285.00	64.00	8.33	9.30	46.00	8.00
Agniswar (♀)	284.66	64.33	9.33	8.06	42.33	7.66
Pisang Lilin (♂)	160.33	38.33	5.66	2.63	39.66	8.00
CD (0.05)	12.55	3.74	0.73	0.63	1.44	0.87

Table-16

Growth models of hybrids and parents

Characters	Hybrids/parents	Equation	Coefficient of determination (R^2)
Height	Hybrid No.I	$Y = 151.195e^{0.038x}$	80.06
	Hybrid No.II	$Y = 191.523e^{0.013x}$	70.76
	Hybrid No.III	$Y = 150.202e^{0.031x}$	86.27
	Agniswar	$Y = 164.503e^{0.038x}$	80.46
	Pisang Lilin	$Y = 52.656e^{0.078x}$	84.92
Girth	Hybrid No.I	$Y = 39.592e^{0.036x}$	81.71
	Hybrid No.II	$Y = 37.497e^{0.021x}$	90.66
	Hybrid No.III	$Y = 43.297e^{0.059x}$	95.14
	Agniswar	$Y = 51.325e^{0.017x}$	70.82
	Pisang Lilin	$Y = 18.389e^{0.052x}$	82.70
Functional leaves	Hybrid No.I	$Y = 0.041+1.646x-0.083x^2$	72.14
	Hybrid No.II	$Y = 1.305+0.565x-0.023x^2$	73.16
	Hybrid No.III	$Y = 0.968+1.187x-0.044x^2$	71.82
	Agniswar	$Y = 0.829+1.623x-0.088x^2$	74.81
	Pisang Lilin	$Y = 1.235+1.087x-0.060x^2$	73.46
Leaf area per plant	Hybrid No.I	$Y = -1.763+1.816x-0.087x^2$	72.48
	Hybrid No.II	$Y = 0.290+0.664x-0.026x^2$	73.94
	Hybrid No.III	$Y = -0.031+1.512x-0.056x^2$	74.15
	Agniswar	$Y = -2.272+1.831x-0.093x^2$	73.82
	Pisang Lilin	$Y = -0.886+0.849x-0.045x^2$	73.23
Petiole length	Hybrid No.I	$Y = 34.616+2.810x-0.113x^2$	71.24
	Hybrid No.II	$Y = 29.828+2.048x-0.066x^2$	72.38
	Hybrid No.III	$Y = 10.030+4.341x-0.125x^2$	74.28
	Agniswar	$Y = 37.029+1.569x-0.115x^2$	72.31
	Pisang Lilin	$Y = 12.528+4.253x-0.175x^2$	71.25
Phylacron	Hybrid No.I	$Y = 6.740+0.025x$	82.16
	Hybrid No.II	$Y = 8.305+0.234x$	85.12
	Hybrid No.III	$Y = 7.775+0.002x$	80.16
	Agniswar	$Y = 7.800+0.095x$	88.17
	Pisang Lilin	$Y = 0.103-0.161x$	85.18

FIG 5 GROWTH MODELS OF PARENTS AND HYBRIDS

FIG 5:1

HEIGHT IN CM

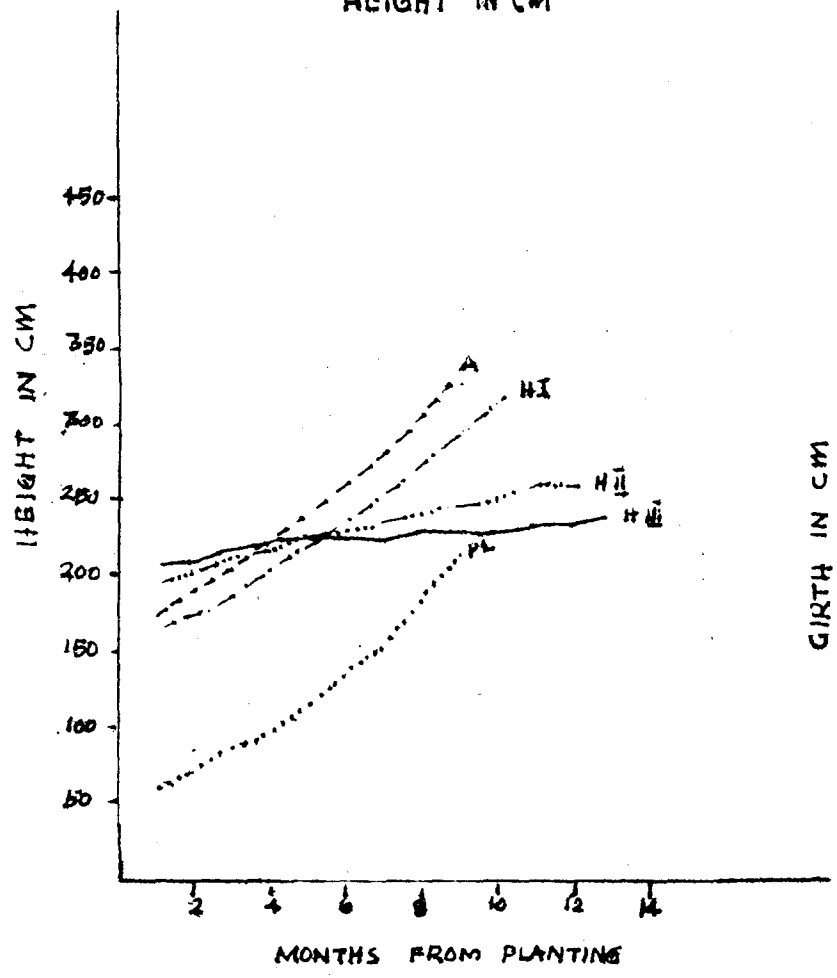
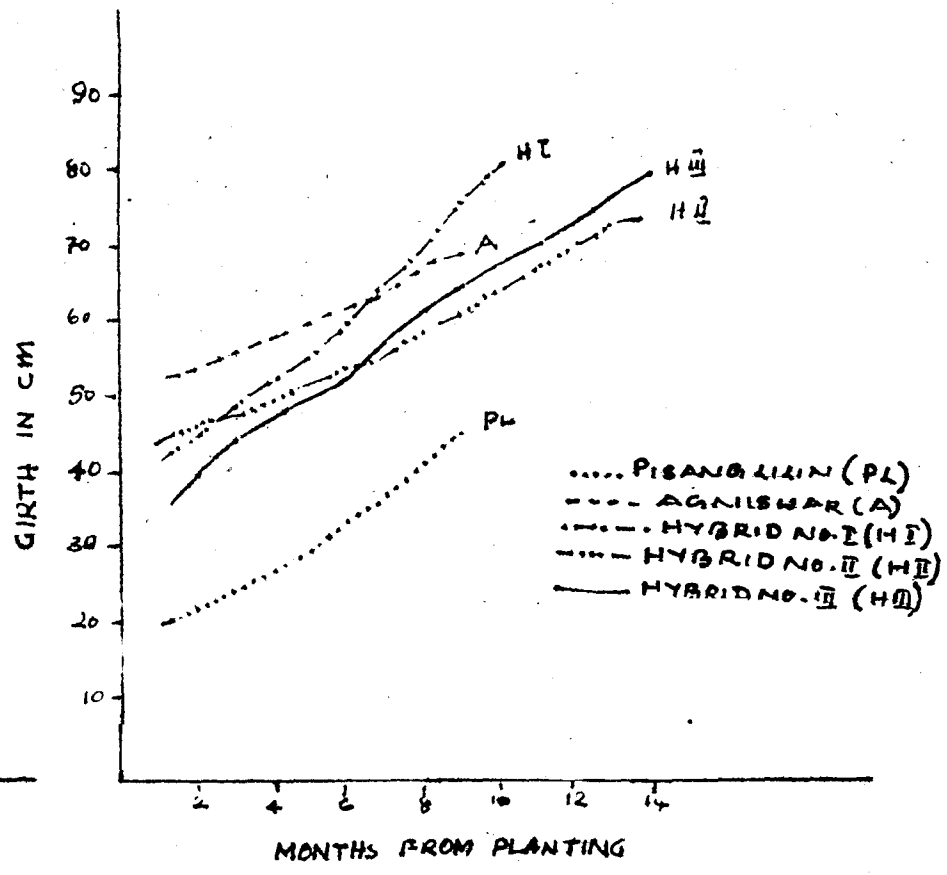


FIG 5:2

GIRTH (CM)



which were on par with 'Agniswar' (64.33 cm). 'Hybrid No.I' was superior in girth (68.33 cm) which was on par with 'Hybrid No.II'. The hybrids significantly differed from the male parent, 'Pisang Lilin' (38.33 cm).

5.2.1.3. Number of functional leaves

The hybrids were significantly superior to the male parent, 'Pisang Lilin' (5.66), with respect to number of functional leaves, but were inferior to the female parent 'Agniswar' (9.33) (Table 15). Among hybrids, 'Hybrid No.III' had more number of functional leaves (8.33) which was significantly superior to 'Hybrid No.I' (7.33) and 'Hybrid No.II' (4.66).

5.2.1.4. Leaf area per plant

'Hybrid No.III' recorded the highest leaf area (9.3 m^2) which was significantly superior to 'Hybrid No.I' (8.14 m^2) and 'Hybrid No.II' (4.20 m^2) (Table 15). 'Hybrid No.II' and 'Agniswar' (8.06 m^2) did not differ significantly with respect to leaf area. 'Pisang Lilin' recorded a leaf area of 2.63 m^2. The hybrids were significantly superior to the male parent.

5.2.1.5. Petiole length

The hybrids were significantly superior to both the

FIG 5 : 3

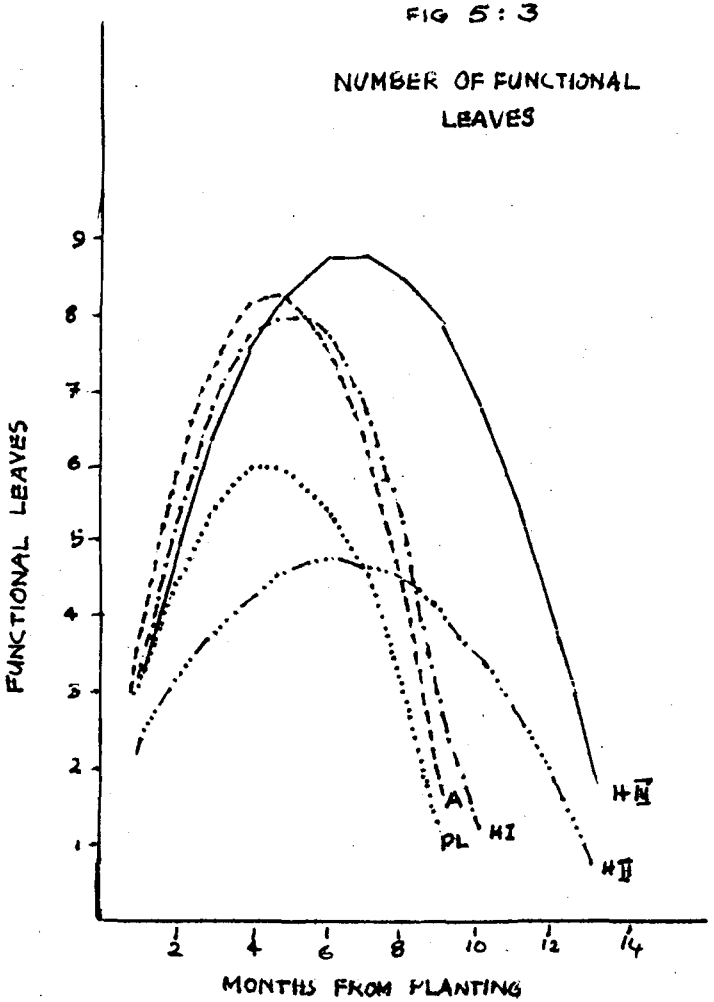
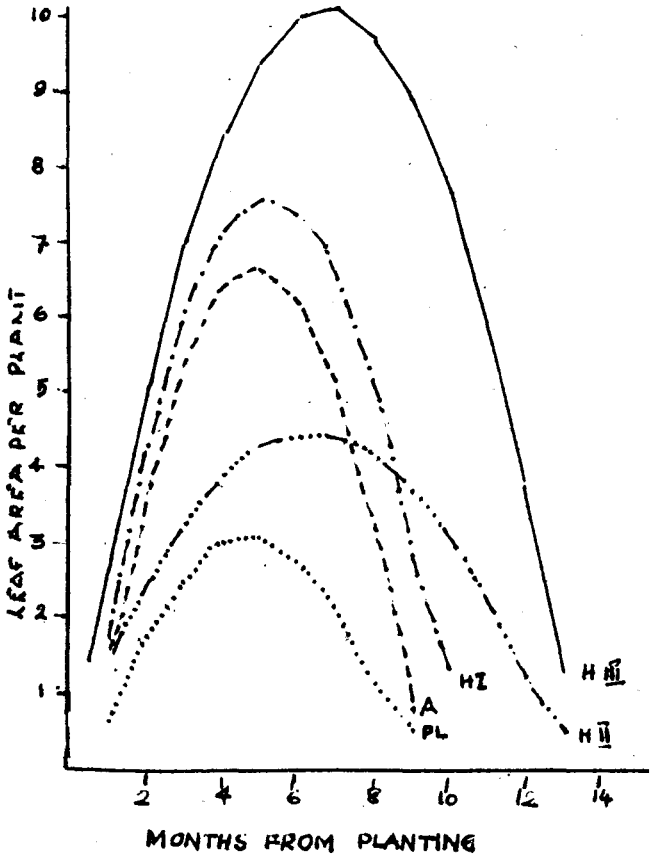

NUMBER OF FUNCTIONAL LEAVES
FUNCTIONAL LEAVES
9
8
7
6
5
4
3
2
1
A
PL
HI
H IV
H II
2
4
6
8
10
12
14
MONTHS FROM PLANTING

FIG 5 : 4

LEAF AREA PER PLANT (M^2.



parents in petiole length (Table 15). Among hybrids, 'Hybrid No.I' had longer petiole (52.33 cm) than other two hybrids. 'Hybrid No.II' and 'Hybrid No.III' had petiole length 47.66 cm and 46.00 cm respectively which were on par. The parents 'Agniswar' and 'Pisang Lilin' had petiole length 42.33 cm and 39.66 cm respectively.

5.2.1.6. Phylacron

Hybrids differed significantly on phylacron (Table 15). The maximum was for 'Hybrid No.II' (11.0 days). 'Hybrid No.I' and 'No.III' recorded phylacron of 7.5 and 8.0 days respectively which were on par with 'Agniswar' (7.6) and 'Pisang Lilin' (8.0 days).

5.2.2. Duration

The duration aspects such as planting to flowering interval, flowering to harvest interval, planting to harvest interval and male and female phases of hybrids and parents are summarised in Table 17. There was significant variation between hybrids and parents and also within the hybrids. Among the hybrids, 'Hybrid No.II' had more duration than other two hybrids.

5.2.2.1. Planting to flowering interval

Generally hybrids took longer duration from planting

FIG · 5 : 5

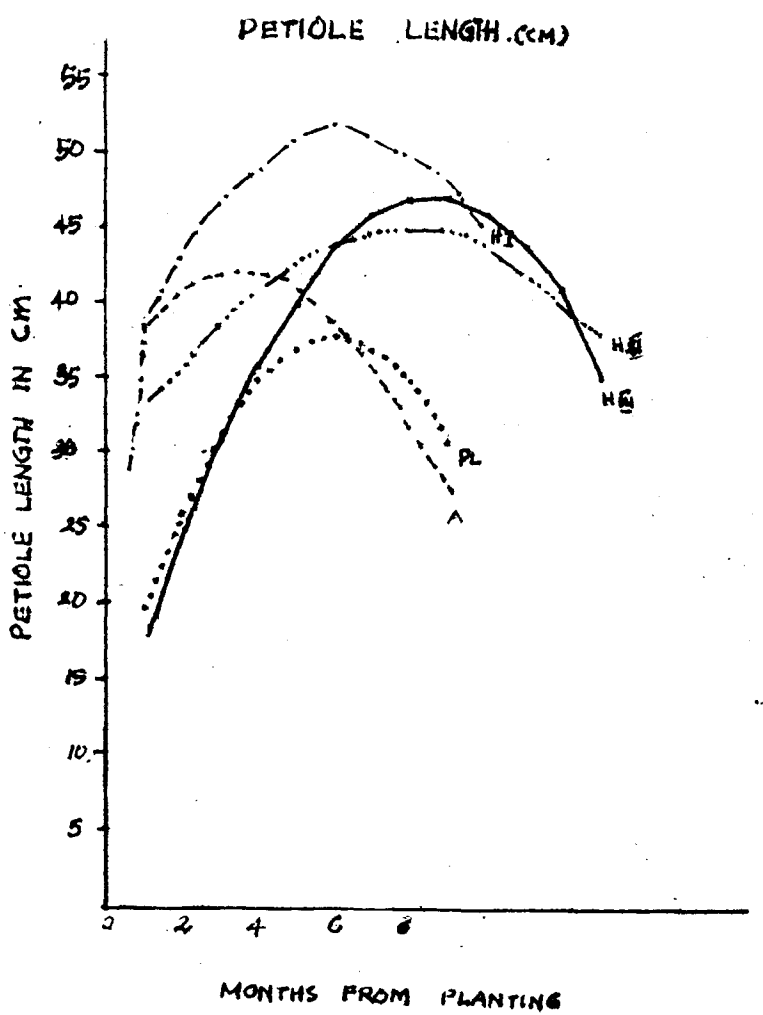

PETIOLE LENGTH (CM)
PETIOLE LENGTH IN CM
55
50
45
40
35
30
25
20
15
10
5
0
2
4
6
8
HI
HII
HIII
PL
A
MONTHS FROM PLANTING

FIG 5 : 6

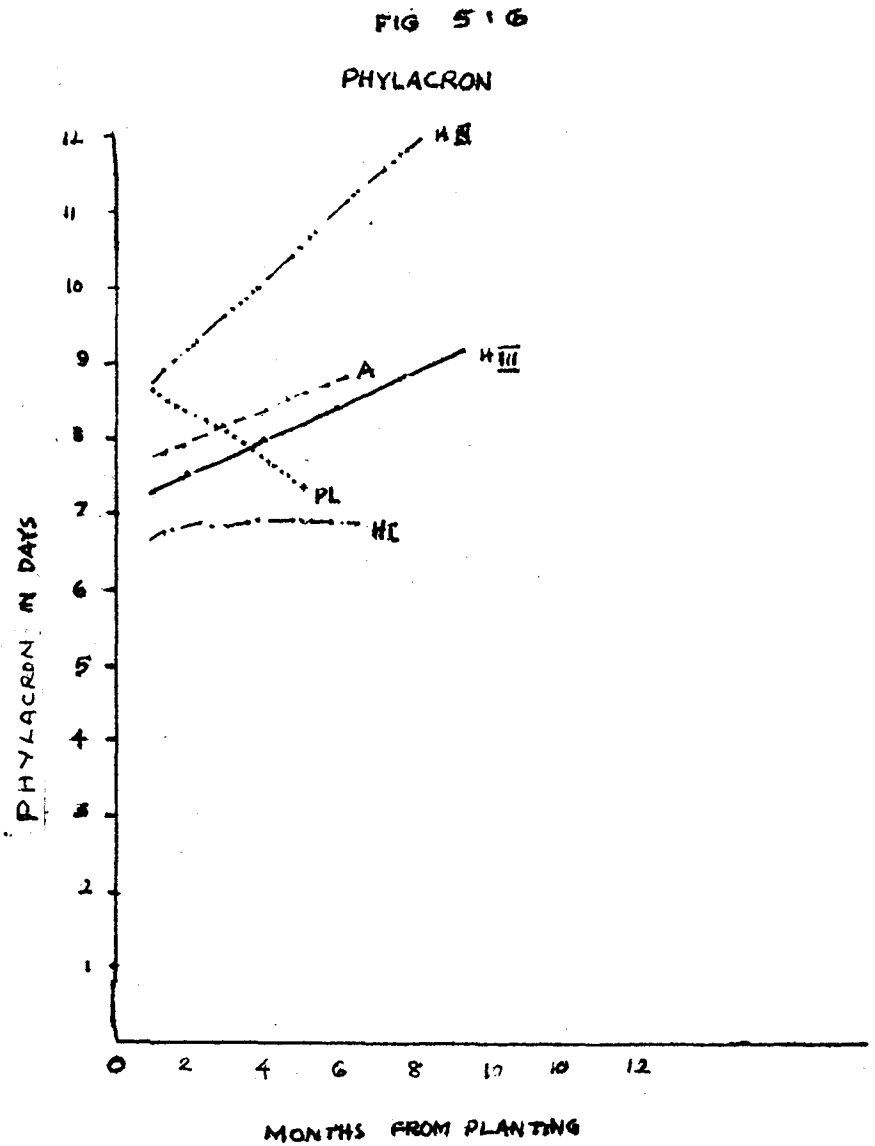

PHYLACRON
PHYLACRON IN DAYS
12
11
10
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
HII
A
HIII
PL
HI
MONTHS FROM PLANTING

Table-17

Mean values of duration of hybrids and parents

Hybrids/parents	Duration (days)				
	Planting to flowering interval	Flowering to harvest interval	Total duration	Male phase	Female phase
1	2	3	4	5	6
Nybrid No.I	168.33	135.66	303.99	123.33	4.33
Hybrid No.II	316.00	105.33	421.33	149.33	3.33
Hybrid No.III	281.66	119.66	401.32	127.00	4.33
Agniswar	171.33	139.00	310.33	132.33	5.33
Pisang Lilin	177.66	107.00	284.66	93.66	4.66
CD (0.05)	17.25	10.66	11.79	8.67	0.93

to flowering, however 'Hybrid No.I' was an exception (Table 17). Within the hybrids, 'Hybrid No.I' took the least number of days from planting to flowering (168.33) which was on par with the parents, 'Agniswar' (171.33) and 'Pisang Lilin' (177.66). Hybrids 'No.II' and 'No.III' took 281.66 and 316.0 days for flowering, which were on par.

5.2.2.2. Flowering to harvest interval

Hybrids differed significantly in time taken for flowering to harvest (Table 17). Among the hybrids, 'Hybrid No.II' took least number of days (105.33) from flowering to harvest which was on par with 'Pisang Lilin' (107.00 days). 'Hybrid No.I' took maximum number of days from flowering to harvest (136.66) which was on par with 'Agniswar' (139.0 days). 'Hybrid No.III' took 119.66 days for harvest.

5.2.2.3. Total duration

'Hybrid No.II' took the maximum number of days from planting to harvest (421.33 days) followed by 'Hybrid No.III' (401.32 days) and 'Hybrid No.I' (303.99days) (Table 17). 'Hybrid No.II' 'Nc.III' were on par. 'Hybrid No.I' and 'Agniswar' (310.33 days) did not differ significantly. 'Pisang Lilin' took 284.66 days from planting to harvest.

5.2.2.4. Male phase

The male phase was maximum for 'Hybrid No.II' (149.33 days) which was significantly more than that of 'Hybrid No.I' (123.33 days) and 'Hybrid No.III' (127.00 days) (Table 17). 'Hybrid No.I' and 'Hybrid No.III' were on par. The parents 'Agniswar' and 'Pisang Lilin' had male phase 132.33 days and 93.66 days respectively.

5.2.2.5. Female phase

There was significant difference between hybrids and parents in female phase (Table 17). Among hybrids, 'Hybrid No.I' and 'No.III' took 4.33 days for completion of female phase, whereas that of 'Hybrid No.II' it was 3.33 days. The parents, 'Agniswar' and 'Pisang Lilin' took 5.33 and 4.66 days respectively, for the completion of female phase.

5.2.3. Bunch characters

The mean values of bunch characters like bunch weight, number of hands and fingers, and weight of hand are summarised in Table 18. With respect to the bunch characters, 'Hybrid No.III' was found to be significantly superior than other two hybrids.

Table-18

Mean values of bunch characters of hybrids and parents

Hybrids/parents	Bunch characters			
	Weight of bunch (Kg)	Weight of hand (Kg)	Number of hands	Number of fingers
1	2	3	4	5
Hybrid No.I	6.40	1.23	5.00	85.0
Hybrid No.II	2.57	0.54	3.33	35.0
Hybrid No.III	9.10	1.26	7.00	95.0
Agniswar	5.28	0.79	5.66	75.0
Pisang Lilin	2.30	0.65	4.00	50.0
CD (0.05)	0.31	0.22	0.46	6.43

5.2.3.1. Bunch weight

Significant variation was observed between hybrids and parents and also within hybrids (Table 18). 'Hybrid No.III' had heavier bunches (9.10 kg) followed by 'Hybrid No.I' (6.4 kg) and 'Hybrid No.II' (2.57 kg). The parents, 'Agniswar' and 'Pisang Lilin' recorded bunch weight 5.28 kg and 2.3 kg respectively. 'Hybrid No.II' and 'Pisang Lilin' were on par.

5.2.3.2. Number of hands

The hybrids were significantly superior to parents with respect to number of hands per bunch (Table 18). Among hybrids, 'Hybrid No.III' (7.00) produced maximum number of hands per bunch, followed by 'Hybrid No.I' (5.00) and 'Hybrid No.II' (3.33). The parents 'Agniswar' produced 5.66 hands where as 'Pisang Lilin' 4.00 hands per bunch.

5.2.3.3. Hand weight

The 'Hybrid No.III' had the heaviest hand (1.26 kg), followed by 'Hybrid No.I' (1.23 kg) and 'Hybrid No.II' (0.54 kg) (Table 18). 'Hybrid No.I' and 'No.III' were on par. The parent 'Agniswar' with an average hand weight of 0.79 kg was on par with 'Pisang Lilin' (0.65 kg). 'Pisang Lilin' and 'Hybrid No.II' were on par.

5.2.3.4. Number of fingers

When the hybrids and parents were compared for the mean number of fingers per bunch, the bunches of 'Hybrid No.I' and 'No.III' had significantly more fingers than the parents, whereas 'Hybrid No.II' and lesser fingers than both the parents and other two hybrids (Table 18). Within the hybrids, 'Hybrid No.III' had maximum number of fingers per bunch (95.00) which was significantly superior to 'Hybrid No.I' (85.0) and 'Hybrid No.II' (35.0). The average number of fingers for parents, 'Agniswar' and 'Pisang Lilin' were 75.0 and 50.0 respectively.

5.2.4. Finger characters

Table 19 represents the mean values of finger characters such as pedicel length; length, girth, weight, volume of finger and pulp/peel ratio. On an overall view, 'Hybrid No.III' recorded significantly higher values.

5.2.4.1. Pedicel length

Hybrids and parents significantly differed in pedicel length (Table 19). Within the hybrids, maximum pedicel length was found in 'Hybrid No.III' (2.36 cm), followed by 'Hybrid No.II' (2.13 cm) and least for 'Hybrid No.I' (1.23 cm). The parents, 'Agniswar' with an average pedicel length of

Plates 27 to 31. Hands of Hybrids and parents.

Plate 27. Musa (AB) 'Agniswar' (♀)

Plate 28. Musa (AA) 'Pisang Lilin' (♂)

Plate 27

Plate 28

Plate 29. Hybrid No.I

Plate 30. Hybrid No.II

Plate 29

Plate 30

Plate 31. Hybrid No.III

Plate 31

Table-19

Mean values of finger characters of hybrids and parents

Hybrids/parents	Finger characters					
	Pedicel length (cm)	Finger length (cm)	Finger girth (cm)	Finger weight (g)	Finger volume (cc)	Pulp/peel ratio
1	2	3	4	5	6	7
Hybrid No.I	2.13	15.00	12.66	71.66	80.00	2.85
Hybrid No.II	1.23	10.66	11.00	61.16	65.00	2.55
Hybrid No.III	2.36	13.26	14.50	83.33	83.33	2.91
Agniswar	2.10	12.00	7.50	45.00	51.80	2.72
Pisang Lilin	1.68	15.25	6.16	38.50	27.03	1.66
CD (0.05)	0.14	1.18	0.84	3.96	7.00	0.09

2.1 cm was significantly superior to 'Pisang Lilin' with an average pedicel length of 1.68 cm. 'Hybrid No.I' and 'Agniswar' did not differ significantly.

5.2.4.2. Finger length

The hybrids when compared to female parent, 'Agniswar', former had significantly longer fingers than the latter, but when compared to the male parent, 'Pisang Lilin', hybrids had shorter fingers (Table 19). Within the hybrids, 'Hybrid No.I' produced longer fingers (15.0 cm) followed by 'Hybrid No.III' (13.26 cm) and 'Hybrid No.II' (10.66 cm). The male parent, 'Pisang Lilin' with an average finger length of 15.25 cm was significantly superior to female parent 'Agniswar' with an average finger length of 12.0 cm . 'Pisang Lilin' and 'Hybrid No.I' were on par.

5.2.4.3. Finger girth

Hybrids were found to be superior to both parents with respect to finger girth (Table 19). Within the hybrids also variation in finger girth was significant. 'Hybrid No.III' had the maximum finger girth (14.5 cm) followed by 'Hybrid No.I' (12.66 cm) and 'Hybrid No.II' (11.0 cm). The parents 'Agniswar' and 'Pisang Lilin' had finger girth 7.5 cm, 6.16 cm respectively.

5.2.4.4. Finger volume

Hybrid fingers possessed significantly more volume than both parents (Table 19). Among hybrids, maximum finger volume was noticed with 'Hybrid No.III' (83.33 cc), followed by 'Hybrid No.I' (80.0cc) and 'Hybrid No.II' (65.0 cc). The hybrids 'No.III' and 'II' were on par. 'Agniswar' and 'Pisang Lilin' had fingers volume 51.8 cc and 27.03 cc respectively.

5.2.4.5. Finger weight

With respect to finger weight, hybrid fingers were significantly superior to both parents (Table 19). Within the hybrids also, variation noticed was significant. 'Hybrid No.III' recorded the highest finger weight (83.33 g) followed by 'Hybrid No.I' (71.66 g) and 'Hybrid No.II' (61.66 g). The parents 'Agniswar' and 'Pisang Lilin' recorded finger weight 45.0 g and 38.5 g respectively.

5.2.4.6. Pulp/peel ratio

Pulp/peel ratio differed significantly between hybrids and parents (Table 19). The highest ratio was observed in 'Hybrid No.III' (2.91), followed by 'Hybrid No.I' (2.85) and 'Hybrid No.II' (2.55). The parents 'Agniswar' and 'Pisang Lilin' had pulp/peel ratio 2.72 and 1.66 respectively.

5.2.5. Quality characters

The data pertaining to the quality characters viz. Total soluble solids (TSS), acidity, reducing sugars, non reducing sugars, total sugars and sugar/acid ratio of the parents and hybrids are given in Table 20. Significant variations were observed between hybrids and parents and also within the hybrids in various quality aspects. Among the hybrids, 'Hybrid No.III' recorded significantly higher values for reducing and total sugars. 'Hybrid No.I' recorded the maximum value for acidity, whereas 'Hybrid No.II' recorded the maximum value for sugar/acid ratio. Within the parents, 'Agniswar' recorded significantly higher values than 'Pisang Lilin' in all the quality characters except for sugar/acid ratio.

5.2.5.1. Total soluble solids (TSS)

Within the hybrids, TSS was maximum in 'Hybrid No.II' (22.17 per cent) followed by 'Hybrid No.III'(21.17 per cent) and 'Hybrid No.I' (18.63 per cent) (Table 20). 'Hybrid No.III', 'Hybrid No.II' and the female parent 'Agniswar' (21.33 per cent) were on par, whereas 'Hybrid No.I' was on par with the male parent, 'Pisang Lilin'.

Table-20

Mean values of quality characters of hybrids and parents

Hybrids/parents	Quality characters					
	T.S.S. (%)	Acidity (%)	Reducing sugars (%)	Non-reducing sugars(%)	Total sugars (%)	Sugar/acid ratio
1	2	3	4	5	6	7
Hybrid No.I	18.63	0.41	11.73	1.51	13.24	31.25
Hybrid No.II	22.17	0.28	13.72	1.45	15.17	71.86
Hybrid No.III	21.17	0.32	14.08	1.42	15.50	48.40
Agniswar	21.33	0.44	11.70	1.39	13.09	30.28
Pisang Lilin	19.03	0.24	7.38	0.97	8.35	34.32
CD (0.05)	1.40	0.047	1.01	0.08	0.99	5.90

5.2.5.2. Acidity

Acidity was maximum in 'Hybrid No.I' (0.41 per cent), followed by 'Hybrid No.III' (0.32 per cent) and 'Hybrid No.II' (0.28 per cent) Table 20. The parents 'Agniswar' and 'Pisang Lilin' had acidity 0.44 per cent and 0.24 per cent respectively. 'Hybrid No.I' and 'Agniswar' were on par, whereas 'Hybrid No.II' and 'Pisang Lilin' were on par.

5.2.5.3. Reducing sugars

The reducing sugar content varied significantly between hybrids and parents and also within the hybrids (Table 20). Among hybrids, the highest content was recorded hy 'Hybrid No.III' (14.08 per cent), followed by 'Hybrid No.II' (13.72 per cent) and 'Hybrid No.I' (11.73 per cent). The parents 'Agniswar' recorded a content of 11.70 per cent which was significantly superior to 'Pisang Lilin' (7.38 per cent). 'Hybrid No.III' and 'Hybrid No.II' were on par, 'Hybrid No.I' and 'Agniswar' were on par.

5.2.5.4. Non reducing sugars

The hybrids as compared to the male parent 'Pisang Lilin' were significantly superior in nonreducing sugar content (Table 20). The content was highest in 'Hybrid No.I'

(1.51 per cent) followed by 'Hybrid No.II' (1.45 per cent) and 'Hybrid No.III' (1.42 per cent). 'Agniswar' recorded reducing sugar content 1.39 per cent and 'Pisang Lilin' 0.97 per cent. Hybrids 'No.I' and 'No.II' were on par, similarily Hybrid 'No.II', 'No.III' and 'Agniswar' were on par.

5.2.5.5. Total sugars

Hybrid fruits had significantly more total sugars than both the parents (Table 20). Among hybrids, 'Hybrid No.III' recorded the highest non reducing sugar content 15.5 per cent followed by 'Hybrid No.II' 15.17 per cent and 'Hybrid No.I' (13.24 per cent). 'Hybrid No.III' and 'Hybrid No.II' were on par. The parents 'Agniswar' and 'Pisang Lilin' recorded non reducing sugar content 13.09 and 8.35 per cent respectively. 'Hybrid No.I' and 'Agniswar' were on par.

5.2.5.6. Sugar/acid ratio

The hybrids as compared to the parents significantly differed in sugar/acid ratio (Table 20). Within theh hybrids also variation in ratio was significant. 'Hybrid No.II' recorded the highest ratio (71.86) followed by 'Hybrid No.III' (48.40) and 'Hybrid No.I' (31.25). In the

parents 'Agniswar' and 'Pisang Lilin' ratios were 30.28 and 54.32 respectively. 'Hybrid No.I' and 'Agniswar' were on par.

5.2.6. Male fertility - pollen studies

All the three hybrids were found to produce abundant pollen in their male flowers in the nodes of male axis. The pollen of the hybrids were compared with the pollen of male parent 'Pisang Lilin'. Female parent, 'Agniswar' was found to be non polleniferous, the anther lobes of which were black and dry (Valsalakumari, 1984). In 'Hybrid No.I', the first few nodes (upto 4) had male flowers with black and dried antherlobes.

Table 21 gives an account of results of pollen studies viz. pollen size, pollen production per anther, fertility and viability of hybrids and the male parent.

5.2.6.1. Pollen morphology

The pollen grains of the hybrids and the male parent, 'Pisang Lilin' were found to have more or less similar morphological features. The grains appeared as creemy white powdery mass to naked eye. The grains are spherical to avoid in shape. The intine and exine were clearly visible. The exine was smooth and uniform in thickness. (Plates 32 to 34).

Table-21

Pollen size, production, fertility and viability in hybrids and male parent

Hybrids/parents	Pollen size (diameter in μ)	Pollen production per anther	Pollen fertility (%)	Pollen viability	
				Germination (%)	Tube length (μ)
1	2	3	4	5	6
Hybrid No.I	132.65	4087.91 (3.611)	49.85 (44.90)	17.00 (24.35)	360.68
Hybrid No.II	134.68	5256.60 (3.720)	53.69 (45.93)	24.52 (29.67)	194.68
Hybrid No.III	134.24	5051.49 (3.703)	62.67 (52.25)	21.81 (27.83)	246.93
Pisang Lilin	123.40	8359.63 (3.922)	52.00 (46.13)	29.61 (32.94)	418.40
CD (0.05)	3.12	0.026	1.83	1.29	25.90

(Values in parentheses denote the means of the transformed data)

Plates 32 to 34. Pollen grains of hybrids stained in Acetocarmine. (x 300)

Plate 32. Hybrid No.I

Plate 33. Hybrid No.II

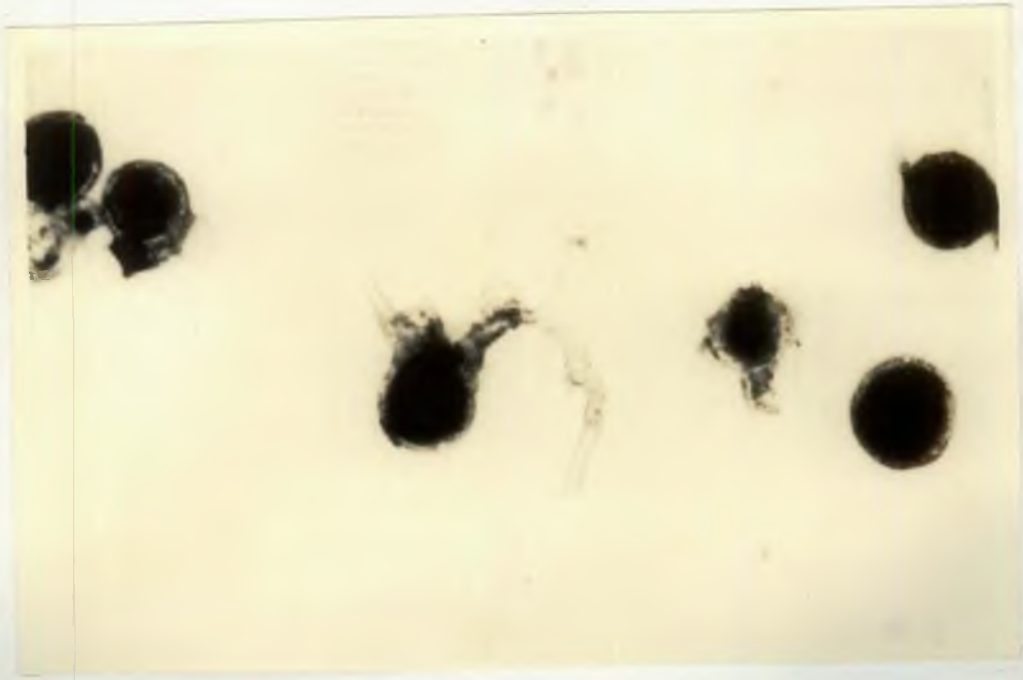


Plate 32

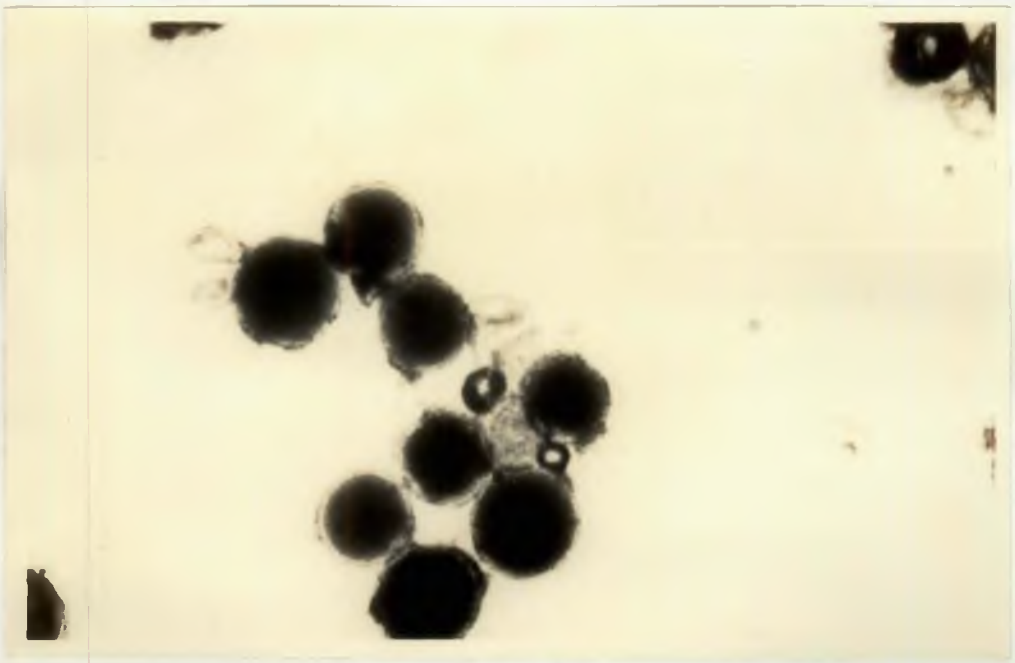


Plate 33

Plate 34. Hybrid No.III

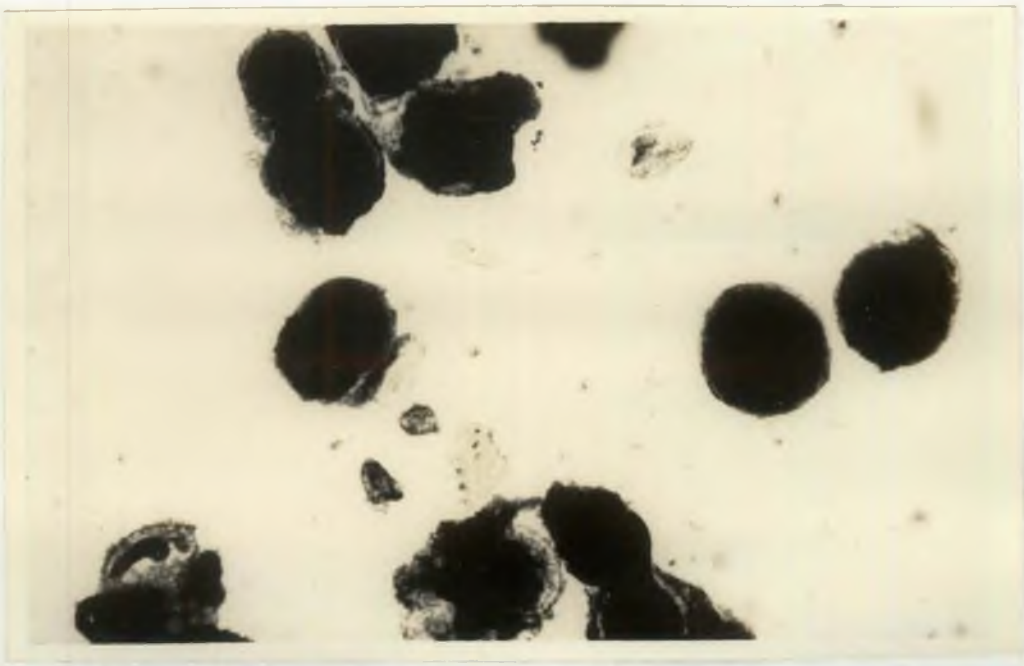


Plate 34

5.2.6.2. Pollen size

The pollen grains of all the three hybrids were significantly bigger than that of the male parent (Table 21). Within the hybrids the size did not vary significantly. The mean values of the hybrids were 132.65 μ , 134.68 μ and 134.24 μ , for 'Hybrid No.I', 'No.II' and 'No.III' respectively. The pollen grains of 'Pisang Lilin' were 123.40 μ in diameter.

5.2.6.3. Pollen production

The pollen production per anther in the three hybrids and the male parent are presented in Table 21. Significant variations were noticed between hybrids and parent, also within the hybrids. Generally all the three hybrids were significantly inferior to the male parent in number of pollen grains produced. The male parent 'Pisang Lilin' produced pollen grains upto 8359.13 per anther. Within the hybrids, 'Hybrid No.II' produced maximum number of pollen grains (5256.60), which was on par with 'Hybrid No.III' (5051.49) and 'Hybrid No.I' (4087.91).

5.2.6.4. Pollen fertility

The results of the pollen fertility by acetocarmine staining technique of the hybrids and the male parent are

summarised in Table 21. Within the hybrids, 'Hybrid No.III' recorded the highest fertility (62.67 per cent), followed by 'Hybrid No.II' (53.69 per cent) and 'Hybrid No.I' (49.85 per cent). The male parent recorded fertility of 52.00 per cent. 'Hybrid No.III' was significantly superior to the male parent and other two hybrids, whereas 'Hybrid No.I' and 'No.II' were on par with male parent.

5.2.6.5. Pollen viability

The data pertaining to the pollen germination percentage and tube growth (μ) of hybrids and male parent are presented in Table 21. The male parent was significantly superior to all the three hybrids in pollen viability. Within the hybrids also, significant variations were observed. The male parent had a mean germination 29.61 per cent, with a tube growth 418.40 μ. Within the hybrids, maximum germination was seen in 'Hybrid No.II' (24.52 per cent), which was significantly superior to 'Hybrid No.III' (21.81 per cent) and 'Hybrid No.I' (17.00 per cent), 'Hybrid No.III' was superior to 'Hybrid No.I'.

With respect to pollen tube length, highest value was recorded by 'Hybrid No.I' (360.68 μ), followed by 'Hybrid No.III' (246.93 μ) and 'Hybrid No.II' (194.68 μ).

5.2.7. Female fertility

In order to asses the fertility status of the hybrids, they were crossed with 'Pisang Lilin' as male parent. The details of crosses and seed set obtained are furnished in Table 22. Female fertility of hybrids was compared with their female parent, 'Agniswar'. Table 23 shows the pattern of fertility of hybrids and the female parent, when crossed with 'Pisang Lilin'.

The results of the crosses showed that, of the three hybrids, only two were fertile and compatible with 'Pisang Lilin'. Hybrids No.I and No.III were fertile, where as 'Hybrid No.II' was not fertile.

With respect to seed yield per bunch, female parent 'Agniswar' recorded a seed set of 20.50 per bunch, where as the two fertile hybrids, 'Hybrid No.I' and 'Hybrid No.III' produced 5.00 and 11.00 seeds per bunch respectively. 'Agniswar' produced seeds upto sixth hand, with maximum number of seeds in the third and fourth hands (4.50). 'Hybrid No.I' produced seeds only in second and third hands, in equal numbers (2.50), whereas 'Hybrid No.III' produced seeds upto fourth hand, producing maximum number of seeds in second hand (4.0) and least in fourth hand (1.00).

Table-22

Crosses between hybrids and male parent Pisang Lilin and seed set

Sl. No.	Crosses	Number of flowers pollinated			Total seeds obtained
		Ist cross	2nd cross	Total flowers pollinated	
1	2	3	4	5	6
1	Hybrid No. I x Pisang Lilin	62	63	125	10
2	Hybrid No. II x Pisang Lilin	46	50	96	Nil
3	Hybrid No. III x Pisang Lilin	93	96	189	22.00

Table-23. Pattern of fertility in hybrids and Female parent 'Agniswar' with respect to position hands

Sl. No.	Parents	Position of hand	Number of seeds in hands			Mean number of seeds per hand	Mean number of seeds per bunch
			1st cross	2nd cross	Total seeds		
1	2	3	4	5	6	7	8
1	H - I x Pisang Lilin	1	-	-	-	-	-
		2	2	3	5	2.5	5.0
		3	2	3	5	2.5	
		4	-	-	-	-	
		5	-	-	-	-	
	Total		4	6	10		
2	H - III x Pisang Lilin	1	3	2	5.0	2.50	11.00
		2	4	4	8.0	4.00	
		3	5	2	7.0	3.50	
		4	1	1	2.0	1.00	
		5	-	-	-	-	
		6	-	-	-	-	
		7	-	-	-	-	
	Total		13	9	22		
3	Agniswar x Pisang Lilin	1	3	4	7.0	3.50	20.50
		2	3	4	7.0	3.50	
		3	4	5	9.0	4.50	
		4	4	5	9.0	4.50	
		5	3	3	6.0	2.00	
		6	2	1	3.0	1.50	
		7	-	-	-		
	Total		19	22	41.0		

5.2.8. Chromosome number

On cytological examination all the three hybrids were found to be triploids with 2n = 33 (Table 24). The taxonomic scoring at flowering also revealed that, they were triploids of AAB genomic group.

Table-24

Taxonomic scoring and chromosome number of hybrids

Cultivars	Scores obtained for fifteen Morphological characters																Chromosome number (2n)	Genomic group
	Pseudostem colour	Petiolar canal	Peduncle	Pedicel	Ovule	Bract shoulder	Bract curling	Bract shape	Bract apex	Bract colour	Bract colour fading	Bract scars	Face tepal of male flower	Male flower colour	Stigma colour	Total scores		
Hybrid No.I	4	1	1	3	1	4	1	4	4	4	4	1	4	1	4	41	33	AAB
Hybrid No.II	4	3	3	2	1	4	3	2	4	4	2	2	4	1	4	43	33	AAB
Hybrid No.III	2	3	1	1	1	4	2	2	3	3	3	1	1	2	1	30	33	AAB

DISCUSSION

DISCUSSION

Hybridization plays a key role in improvement of crops especially in an asexually propagated crop like banana, in which all the commercial cultivars are propagated vegetatively. Gene recombinations occur only as a result of sexual reproduction. In asexually propagated plants, sexual reporduction is used to create genetic variability. Hybridization between clones followed by clonal selection within the hybrid population can be followed in bananas.

In the present investigations on interclonal hybridization in banana, six female parents, viz: 'Palayankodan', 'Rasthali', 'Ney Poovan', 'Nendravannan', 'Karpooravally' and 'Nendran' and three male parents viz: 'Pisang Lilin', 'Sanna chenkadali' and 'Tongat' were selected with a view to make a detailed study on pollen production, fertility and viability in different nodes of the three selected male parents and female fertility pattern in different hands of the selected six female parents, compatibility and seed set pattern in 18 cross combinations involving six female and three male parents, effect of different seed treatments on germination of banana seeds and evaluation of existing interclonal hybrids already available.

For an efficient hybridization programme of breeding, parent varieties need to be carefully selected for the traits that they possess so that the desired characteristics may be combined in the progeny of the cross. In the present studies, the six female parents, 'Palayankodan', 'Nendravannan', 'Nendran', 'Rasthali', 'Ney Poovan' and 'Karpooravally' were selected based on their table quality, popularity and female fertility (Karmacharya, 1984). The three male parents namely, 'Pisang Lilin', 'Tongat' and 'Sanna chenkadali' were selected based on their high pollen production and fertility (Karmacharya, 1984).

Pollen studies:

The pollen studies included the estimation of pollen production per anther, fertility and viability in different nodes of the three male parents. The quantitative estimation of pollen produced by flowers of different clones is a very important factor to be considered in choosing a variety as male parent. In order to standardise the stage at which samples should be taken for assessment and to study the variation of various pollen characters as influenced by age of male bud, the characters were estimated from first node to last node in all the three male parents. The values were low in first few nodes (upto 10th node), then increased steadily to maximum at the 20th to 30th nodes

which varied according to the clone and then decreased. Such a variation in the pollen production, fertility and viability in different nodes of the banana clones has been reported by Sathiamoorthy (1973). He observed that the pollen production in the diploid clone 'Erachivazhai', increased to about 13000 per anther at node of 10 of male part of inflorescence, stayed until upto 30 and then declined to 5300 at node 100, ie. as the bud becomes older, the production capacity decreases.

The results of the studies on pollen production per anther in different nodes the three selected male parents are furnished in Table 7. In 'Pisang Lilin', pollen output varied between 3875.41 in the 1st node to 947.14 in the 55th node with a maximum output of 8431.12 in the 25th node after which it started decreasing sharply. In the 30th, 35th, 40th, 45th and 50th nodes pollen outputs were 8200.66, 7563.45, 6519.50, 5068.79 and 3211.34 respectively. The pollen output in 'Sanna chenkadali' sanged between 2288.66 in the 1st node to 206.50 in the 65th node with a maximum of 4229.98 in the 27th node. The peak output continued upto 30th node after which it decreased to 4035.77 in the 35th, 3725.25 in the 40th, 3269.24 in the 45th, 2667.73 in the 50th, 1920.74 in the 55th and 1028.82 in the 60th nodes. In the case of 'Tongat' Pollen production varied

between 2315.45 in the first node to 241.35 in the 65th node with a peak production of 2908.24 in the 20th node. After the peak the values decreased. The pollen production in the 25th, 30th, 35th, 40th, 45th, 50th, 55th and 60th nodes were 2873.28, 2758.76, 2564.67, 2267.39, 1857.60, 1408.91, 880.64, 270.67 respectively. The decreasing trend in 'Pisang Lilin' was sudden, whereas in 'Sanna chenkadali' and 'Tongat' it was gradual (Fig. 3.1). The results of the present study are also in general agreement with Sathiamoorthy's (1973) findings.

With respect to pollen production per anther in the three male parents studied, 'Pisang Lilin' recorded the maximum value (8431.12), followed by 'Sanna chenkadali' (4229.98) whereas 'Tongat' recorded the least output (2908.24). (Table 5). Such a variation in pollen production has been reported in banana clones by Sathiamoorthy (1973), Karmacharya (1984) and Valsalakumari (1984).

Similarily, the pollen fertility as measured by stainability in acetocarmine stain and viability as measured by germinability in artificial medium indicated a steady increase in fertility and viability from first node to 30th node and then a gradual decline. But this reduction was not so well marked so as to affect its utility in breeding programmes.

The data presented in Table 8 gives the results of pollan fertility studies by aceto carmine staining technique in different nodes of the three male parents. The fertility ranged between 46.14 per cent in the 1st node to 28.45 per cent in the 55th node with a peak of 53.74 per cent in the 20th node in 'Pisang Lilin'. The peak fertility continued upto 25th node. The fertility per cent in 30th, 35th, 40th, 45th, 50th and 55th were 51.71, 49.15, 45,53, 40.87, 35.18 and 28.45 respectively showing a decreasing trend. In case of 'Sanna chenkadali', the fertility was found to be vary between 35.24 per cent in the 1st node to 19.96 per cent in the 65th node, with a maximum fertility 44.85 per cent in the 28th node. The peak fertility continued upto 30th node. In the 35th, 40th, 45th, 50th, 55th and 60th nodes, the fertility per cent were 43.14, 41.24, 38.56, 35.09, 30.83 and 25.79 respectively. The fertility in 'Tongat' ranged between 28.33 per cent in the 1st node to 17.37 per cent in the 65th node with a peak of 30.07 per cent in the 16th node which continued upto 20th node. The fertility per cent in the 25th, 30th, 35th, 40th, 45th, 50th, 55th and 60th nodes ware 29.66, 29.19, 28.35, 27.22, 25.81, 24.12, 22.15 and 19.90 respectively. These results are in general agreement with that of Sathyamoorthy's (1973) findings.

Among the three male parents, 'Pisang Lilin' recorded the highest number of fertile pollen (53.74 per cent) followed by 'Sanna chenkadali' (44.85 per cent) and least by Tongat (30.07 per cent) (Table 8). Sathiamoorthy (1973), Karmacharya (1984) and Valsalakumari (1984) also reported similar variation in pollen fertility of banana clones.

Pollen germination was studied in different sucrose media, viz: 10 per cent, 15 per cent, 20 per cent, 25 per cent, 30 per cent, 35 per cent, 40 per cent, 45 per cent and 50 per cent. From the studies it was found that maximum germination of pollen was attained in 35 per cent sucrose solution. (Table 9, Fig. 3.3). Pollen germination and tube growth improved with the increasing concentration upto 35 per cent, there after recording a downward trend.

The study on *in vitro* germination of pollen grains is limited in banana. Dodds (1943 b) failed in his attempts to germinate diploid banana pollen in artificial media. Shepherd (1954, 1960 b) reported *in vivo* germination of haploid pollen on different styles and Alexander (1970) obtained viviparous germination of banana pollen. Sathiamoorthy (1973) found 10 per cent sucrose solution + 2 ppm boric acid for best pollen germination of clone, 'Anaikomban' (AA) and Karmacharya (1984) observed 12 per cent sucrose solution for satisfactory pollen germination of clone

'Elavazhai' (Musa balbisiana, BB).

Thm pollen germination studias utilizing the medium as reported by Karmacharya (1984) did not give satisfactory gerainationof pollen which necessitated standardisation of proper medium for the best pollen germination and tube growth. Pollen germination studies showed that sucrose content in the growth media had profound influence on germination and tube growth of banana clones. There was no germination in distilled water. The inability of the pollen grains to grow in distilled water might be due to lack of food reserves in the pollen grains (Echlers, 1951). Sucrose apart from increasing osmotic pressure serves as a nutrient material for the growing tube (Visser, 1955; Johri and Vasil, 1961).

The pollen grains commenced germination within 20 hours of dusting in the best medium, 35 per cent sucrose. After 24 hours, the germination and tube length reached their maximum. Thus the optimum incubation period for pollen germination and tube growth was found to be 20 - 24 hours after pollen planting (Table 10). This is in general agreement with the reports of Karmacharya (1984), who found that pollen grains of clone 'Elavazhai' (Musa balbisiana) started germinating after 20 hours of dusting and maximum germination was recorded after 26 hours in 12 per cent sucrose medium.

The results of the studies on pollen viability (germination per cent and tube growth) in different nodes of the male parents are given in Table 9. Fig.3.3.1 and 3.3.2 represent the trend in pollen viability of the male parents in different nodes.

In 'Pisang Lilin', the germination percentage varied between 19.63 in the 1st node to 6.14 in the 50th node, with a maximum of 31.15 in the 15th node. The peak viability continued upto 25th node. In the 30th, 35th, 40th and 45th nodes, the pollen germination percentages were 27.12, 22.92, 19.99 and 10.12 respectively, showing a sharp decrease. The pollen viability ranged between 9.81 per cent in the 1st node to 7.21 per cent in the 60th node, with a peak of 18.09 per cent in the 20th node in 'Sanna chenkadali'. The peak continued upto 30th node. In the 35th, 40th, 45th, 50th and 55th nodes the viability percentages were 10.18, 9.91, 8.92, 8.16 and 7.64 respectively, showing a gradual decrease. In 'Tongat' viability was found to vary between 7.0 per cent in the sixth node to 2.77 per cent in the 60th node, with a peak of 11.30 per cent in the 25th node which continued upto 30th node. There was no pollen germination in the 1st, 2nd, 3rd, 4th and 5th nodes. The pollen germination percentages in the 35th, 40th, 45th, 50th and 55th nodes were 10.81, 9.62, 8.31, 6.90 and 4.83 respectively,

showing a gradual decrease.

The pollen tube length in 'Pisang Lilin' varied between 210.12 µ in the 1st node to 112.40 µ in the 50th node with e maximum tube length 410.83 µ in the 25th node. The tube length in 30th, 35th, 40th and 45th nodes were 400.13 µ , 386.77 µ , 284.15 µ and 150.18 µ respectively showing a gradual decrease. In 'Sanna chenkadali' tube length was found to vary between 102.79 µ in the 1st node to 88.12 µ in the 60th node with a peak tube length of 231.65 µ , in the 20th node. The tube length in the 25th, 30th, 35th, 40th, 45th, 50th and 55th nodes were 225.64 µ , 223.16 µ , 220.99 µ , 215.89 µ , 210.99 µ , 190.71 µ and 150.71 µ respectively. The tube length ranged between 90.12 µ in the 6th node to 90.12 µ in the 60th node, with e maximum of 128.33 µ in the 15th node in 'Tongat'. The tube growth started decreasing from the 20th node which was 118.44 µ , 110.66 µ in the 25th, 107.66 µ in the 30th, 100.88 µ in the 35th, 98.66 µ in the 40th, 94.32 µ in the 45th, 93.16 µ in the 50th and 92.77 µ in the 55th nodes.

Similar results were reported by Sathiamoorthy (1973). He obtained a steady increase in pollen germination and tube length from first node to 30th node and then a gradual decline.

The results of pollen germination and tube length studies in three male parents showed that there was variation among the three in germination per cent and tube length (Table 9). Maximum germination per cent (31.15) and tube length (410.83 μ) was recorded by 'Pisang Lilin' followed by 'Sanna chenkadali' with a germination per cent of 18.09 and tube length 231.65 μ . 'Tongat' recorded the least germination per cent (11.31) and tube length (110.66 μ). Similar variation in pollen germination and tube growth in banana clones has been reported by Sathiamoorthy (1973).

Karmacharya (1984) and Valsalakumari (1984) obtained high fertility in acetocarmine test for 'Sanna chenkadali' and 'Tongat'. But the pollen grains of these two clones had poor germination in vitro in the present studies. The necessity of in vitro culture of pollen grains to assess the viability is thus emphasised. Stanley and Linskens (1974) opined that the use of stain was less accurate as compared to germination tests, because the immature and aborted pollen grains also contained levels of constitutent chemicals enough to yield positive results in stain tests.

Female fertility - compatibility studies

In the present study, compatibility among six female parents namely, 'Palayankodan', 'Rasthali', 'Nendravannan',

'Ney Poovan', 'Karpooravally' and 'Nendran' and three male parents viz: 'Pisang Lilin', 'Sanna Chenkadali' and 'Tongat' were studied. Among the 18 cross combinations tried, only three were successful. (Table 12, Fig.4.1). The successful crosses were, 'Palayankodan' x 'Pisang Lilin', 'Rasthali' x 'Pisang Lilin' and 'Nendran' x 'Pisang Lilin'. Only 'Pisang Lilin' was found to be the satisfactory male parent among the three studied.

'Palayankodan' has been found to be female fertile in many crosses (Cheesman, 1934; 1949; Sundaraj et. al., 1957; Nair; 1953; Alexander, 1976; Raman, 1976; Karmacharya, 1984). The female fertility status of 'Nendran' was first reported by Karmacharya (1984). He obtained seeds when 'Nendran' was crossed with 'Sikuzani'.

The results also indicated that 'Rasthali' although repeated by several workers (Sundaraj et. al., 1957); (Alexander, 1976) to be female sterile, is female fertile. In the present studies, 'Rasthali' was found to produce seeds when crossed with 'Pisang Lilin' indicating the fertility status of 'Rasthali'. Attempts of more crosses would yield strength to this evidence.

The other three female parents, 'Nendravannan', 'Karpooravally' and 'Ney Poovan' were found to be female

sterile. However, Alexander (1976) and 'Karmacharya' (1984) reported that 'Nendravannan' and 'Karpooravally' were female fertile. In the present studies, in spite of the several pollinations of these two clones with 'Pisang Lilin', not even a single seed was obtained. This may be attributed to the difference in location, climate and fertility of the area. It has been reported that fertility in banana clones to a certain extent is controlled by location, climate and fertility of the area (Shepherd, 1954; 1960 a; 1960 b; Simmonds, 1966).

'Ney Poovan' was reported to be female sterile by Alexander (1976). The present studies also agree with his report. He revealed that all the members of the genomic group AB (Kunnan group) which are of South Indian Origin are both female and male sterile. Sathiamoorthy (1973) and Valsalakumari (1984) found that the members coming under AB genomic group are male sterile. De Langhe (1969) revealed that sterility in AB species hybrids occur due to abnormalities in meiosis.

The two wild diploid species - Musa acuminata and Musa balbisiana which are considered as the ancestors of the present cultivated bananas (Simmonds and Shepherd, 1955) are both female and male fertile, producing seeds in their

fruits on pollination and copious amount of viable pollen in their male flowers. Edible triploids do not produce seeds when grown in pure stands, some of them are entirely female sterile, other will produce an occasional seed when a source of viable pollen is available. The seed set in cultivated bananas, on artificial pollination has been reported by many workers (Cousins, 1927; Cheesman, 1934; 1949; Nair, 1953; Sundaraj et. al., 1957; Borges, 1971; Alexander, 1976; Raman, 1976; Karmacharya, 1984).

Female sterility of banana cultivars is a combination of genetic sterility resulting from structural hybridity of chromosomes and polyploidy and zygotic sterility resulting from genetic control of female sterility and parthenocarpy (Dodds, 1958). Simmonds (1962) reported that cultivated bananas are seedless due to highly inherent female sterility genes, triploidy and chromosomal changes. De Langhe (1969) revealed that, sterility was mainly due to meiotic anomalities, although physiological and morphological factors also play a role.

In earlier hybridization programmes, the wild diploid species, Musa accuminata and Musa balbisiana were used as parents (Cheesman, 1934; Dodds, 1950; Nair, 1953; Simmonds, 1966; Raman et. al., 1971; Sathiamoorthy, 1973; Menendez

and Shepherd, 1975; Azhakiamanavalan, et. al., 1985). The use of edible diploids as male parents for breeding is of comparatively recent origin (Simmonds, 1966; Alexander, 1976; Raman, 1976; Azhakiamanavalan, et. al., 1985).

Among the three male parents used in hybridization programmes, only 'Pisang Lilin' was found to be the compatible parent. The other two parents 'Sanna chenkadali' and 'Tongat' were not found to be compatible even with a single female parent. Among the various edible diploids employed in banana hybridization at the various banana breeding centres of the world, 'Pisang Lilin' is the important one. According to Simmonds (1966) it was the first edible diploid to be intensively studied cytologically and the first also to be used in banana breeding and has contributed to the constitution of nearly all the male parents bred for use in banana breeding. Karmacharya (1984) reported that 'Pisang Lilin' had high pollen output and fertility. In the present studies also, the pollen studies of the clone revealed its high male fertility status to be used as a pottential male parent in hybridization programme.

With respect to other two parents, 'Sanna chenkadali' and 'Tongat', the pollen studies indicated their low male fertility status which limit their use as male parents in hybridization. Simmonds (1966) reported that 'Tongat' was

highly male sterile. He suggested the use of 'Tongat' as a female parent (as it was slightly female fertile) and commended that the intererosses of edible diploids, 'Tongat' x 'Pisang Lilin' and 'Tongat' x 'Paka' were very valuable and much promising.

Among the three successful cross combinations obtained, seed production was found to be maximum in 'Palayankodan' x 'Pisang Lilin' (102.96), followed by 'Nendran' x 'Pisang Lilin' (13.65). The cross 'Rasthali' x 'Pisang Lilin' recorded the least seed yield (10.98). Karmacharya (1984) obtained 9.67 seeds per bunch when 'Palayankodan' was crossed with 'Pisang Lilin' and 3.67 seeds per bunch from the cross 'Nendran' x 'Sikuzani'.

The fertility pattern with respect to the position of hands in a bunch showed much variation. Generally in all the three parents, basal hands were more fertile than the distal hands. In the clone 'Palayankodan', the third hand (27.33), in 'Rasthali' the second and third hands (2.66) and in 'Nendran' second hand (7.00) produced more number of seeds. De Langhe (1969) reported that in seeded bananas all the hands were equally fertile, whereas in cultivated bananas, basal hands were more fertile than the other depending upon the variety which is in general agreement with results of present study.

The cultivated bananas even though are slightly female fertile, on pollination yield only few number of seeds as compared to their wild ancestors. Reviewing hybridization work at Bodles, Shepherd (1954, 1960 a, 1960 b) reported that even under the most favourable conditions the fertility of 'Gros Michel' hardly exceeded three seeds per bunch. Many bunches were seedless.

Seeds and seed treatment studies

The seeds from the three crosses, 'Poovan' x 'Pisang Lilin'; 'Rashhali' x 'Pisang Lilin' and 'Nendran' x 'Pisang Lilin' were found to have more or less similar shape. Plates (17 to 19). Dodds (1950); Simmonds (1966); De Langhe (1969) and Purseglove (1975) reported that banana seeds were about 5 mm diameter, black in colour, subglobose or angular, very hard, endospermic with minute embryo at micropylar end.

The studies on various seed treatments tried (Table 14) on banana seeds so as to get better and quicker germination showed that, there was no effect for any of the treatments tried. However two seeds from the cross 'Palayankodan' x 'Pisang Lilin' germinated. Dodds (1943 b) stated that failure of seed germination was often due to lack of viable embryo and this difficulty could not be overcome by chemical

means. Simmonds (1952 c, 1959) noticed that presowing treatments such as chipping of the testa, soaking in sulphuric acid, soaking in water and the application of temperature shocks were deleterious and often lethal. Present studies also agree with his results.

Germination of hybrid seeds play an important role in breeding programmes. Seeds borne by edible bananas show poor viability. Simmonds (1959 b) observed 21.0 per cent viability for 'Gros Michel' seeds, while Shepherd (1960 b) reported 5 to 25 per cent for triploid clones. The germination of banana seeds is low and erratic (Simmonds, 1962). Sathiamoorthy (1973) noticed germination per cent ranging from 0.003 - 0.60 in banana seeds.

The stimulatory effect of sulphuric acid in seed germination of various crops, the seeds of which posses a hard seed coat has been reported by various investigators. Jadhave (1960) obtained 72 per cent germination in hard, black seeds of canna, when subjected to chemical scarification with sulphuric acid for three hours. Hett (1971) found that in pelargonium seeds, which possess a hard seed coat, the germination could be improved by treating seeds with conc. Sulphuric acid for 5 to 8 minutes at 24 to 30°C. The acid treatment often helps to soften the hard seed coat, exposing the lumens of the macrosclereid

cells, and there by permitting imbibition of water (Liu and Khatamian, 1981).

The hot water treatment has been found to be effective in enhancing germination of many crops. Leucanea leneocephala seeds when treated with hot water at 80°C for 60 sec. a high per cent germination of 90 to 100 was obtained (Eduardo and West, 1980). Araujo et. al., (1983) reported 92 to 98 per cent germination in Cassia multijuga, when subjected to hot water treatment (60°C) for 20 minutes. However, in the present studies, there was no effect of hot water treatment on germination of banana seeds. Inhibitory effects of hot water treatment on seed germination has been established by several workers. Hartman and Kester (1972) suggested that exposure of seeds to high temperature is hazardous since it is likely to injure seeds. Sinha et. al., (1973) revealed that the scarification methods like treatment with boiling water for 5 minutes had an adverse effect on germination of guava (Psidium gujava) seeds.

The mechanically scarified (removal of a chip from lateral portion of seed coat to expose the endosperm) banana seeds, when sown in soil, failed to germinate, as a result of their docomposition by microbes (Stotzky et al., 1962). They suggested that such seeds have to be germinated under artificial conditions.

Banana seeds do possess hard seed coat and as the various seed treatments have failed in enhancing the seed germination per cent, new methods like embryo culture have to be tried. Advances in embryo culture methods have served to open the way effectively to obtain plants from seeds which are traditionally condemned and discarded due to their inability to germinate under normal conditions. The studies on embryo culture technique in banana seeds (Cox et. al., 1960) revealed that excised embryos does not exhibit any dormancy, and so embryo culture could be applied to increase the germination rate. Stotzky et. al., (1962) and Stotzky et. al. (1962) reported that factors affecting delaying germination reside not in embryo, but in other part of seed. Embryo culture techniques have been effectively used in raising embryos from hybrid banana seeds in West Indies (Shepherd, 1968) and in United Fruit Company, Honduras (Rowe and Richardson, 1975).

Detailed investigation on embryo culture method in banana seeds has to be carried out so that it may yield fruitful results.

Studies on hybrids

Three hybrids from the cross 'Agniswar' x 'Pisang Lilin' (Karmacharya, 1984) were studied. The various

characters like quantitative characters (growth parameters, bunch and finger characters), duration aspects, quality aspects, fertility aspects and ploidy level of the hybrids were studied in detail and were compared with the parents.

All of the three hybrids were found to be triploid (2n = 33) with AAB genomic group on cytological studies and taxonomic scoring at flowering (Simmonds and Shepherd, 1955). Cytological studies have shown that the female parent, 'Agniswar' is diploid (2n = 22) of AB type (Valsalakumari 1984) and the male parent, 'Pisang Lilin' is diploid (2n = 22) of AA type (Dodds and Simmonds, 1948; Wilson, 1946). Since the hybrids are triploids, it is clear that the maternal parent does not undergo normal meiosis, instead produces unreduced diploid gametes. The paternal parent undergoes normal meiosis and produce haploid gametes. The progenies between 'Agniswar' and 'Pisang Lilin' are thus triploids. The earlier breeding investigators also obtained similar results in cytological study (Cheesman, 1931, 1932 a, 1932 b, 1934; Cheesman and Larter, 1935; Larter, 1935; Wilson, 1946).

Morphological description of the three hybrids clearily showed that with respect to vegetative characters, the two hybrids, 'Hybrid No.I' and 'Hybrid No.III' were more or less

similar in characters to the maternal parent. 'Hybrid No.II' was inferior in all the vegetative characters, resembled the paternal parent and it was the shortest among the hybrids. All the hybrids had more or less similar floral characters. The morphological description of banana hybrids has been given by Cheesman (1932 a, 1932 b, 1934, 1949); Larter (1935); Nair (1953) and Raman (1976). Valsalakumari (1984) morphologically described 62 banana cultivars.

With respect to various growth parameters, duration aspects, bunch characters and quality aspects (Table 15 to 20) the hybrids were found differ significantly. Such a variation among hybrids of same parentage may be attributed to the expression of heterozygousness in the parents (Poehlman, 1977). Similar variations were also observed in other fruit crop hybrids of same parentage by Rao et. al., (1963); Singh (1963); Khader et. al., (1977) in mangoes; Sharma and Uppal (1977) in grapes and Veerannah et. al., (1982-83) in papayas.

The hybrids have shown marked variation in growth parameters like, height, girth, number of functional leaves, leaf area, petiole length and phylacron (Table 15). Among the three hybrids, 'Hybrid No.III' recorded the higher values for height (285.0 cm), number of functional leaves

(8.33) and leaf area (9.3 M^2), whereas 'Hybrid No.I' recorded the highest value for girth (68.33 cm) and petiole length (52.33 cm). These two hybrids were found to be similar to the maternal parent. The similarity of these two hybrids with the female parent may be due to the fact that they have acquired both the genomes from the maternal parent. Such a type of similarity of hybrids with female parent has been reported by Cheesman (1932, 1934); Larter (1935); Wilson (1946) and Dodds (1950) in bananas.

'Hybrid No.II' was found to be intermediate to both parents in height (249.33 cm) and inferior to parents and other two hybrids in number of functional leaves (4.66) and in leaf area (4.20 M^2). It had the maximum value for Phylacron (11.0 days). Generally the hybrid was found to be inferior in various growth parameters. The expression of intermediary characters in banana hybrids has been noticed by Nair (1953) and Raman (1976).

The hybrids differed significantly in average bunch yield, fruit characters and quality aspects (Table 18 to 27). Among the hybrids, 'Hybrid No.III' recorded the highest value for average bunch weight (9.10 kg), number of hands (7.0) and fingers (95.0) per bunch followed by 'Hybrid No.I'. 'Hybrid No.II' recorded the least values for various bunch

characters. Considering the quality aspects, 'Hybrid No.III' produced superior quality fruits in terms of reducing sugars (14.08 per cent), acidity (0.32 per cent), sugar/acid ratio (48.40) and TSS (21.77 per cent). This was followed by 'Hybrid No.I' which recorded reducing sugar content 11.73 per cent, acidity 0.41 per cent, sugar/acid ratio 31.25 and TSS 18.63 per cent. 'Hybrid No.II' though had higher sugar/acid ratio (71.86), reducing sugar (13.72 per cent) and TSS (22.17 per cent) was inferior in acidity (0.21 per cent). It was interesting to note that all the three hybrids produced bigger fruits with an attractive yellow colour than both the parents.

In an overall view, 'Hybrid No.III' was found to be superior in various bunch and fruit characters and quality aspects to both parents and other two hybrids. This indicates the expression of heterosis in banana hybrids. Heterosis with respect to bunch yield and quality has been reported Raman (1976) in banana hybrids. The superiority of hybrids over parents has been revealed by Rao et. al., (1963), Singh (1963) and Khader et. al., (1977) in mangoes, Sharma and Uppal (1977) in grapes, Chelliappen et. al., (1982) in jack, Veerannah et. al., (1982-83) in papayas and Gopimony and Balakrishnan (1984) in pineapple.

With respect to fertility status, except 'Hybrid No.II' the other two hybrids were found to be both male fertile on pollen studies and female fertile on artificial pollination. Hybrid No.II was only male fertile. The male fertility of hybrids was compared with the paternal parent only as the maternal parent was non pollaniferous (Valsalakumari, 1984) and female fertility was compared with maternal parent, as the paternal parent was female sterile (Simmonds, 1966).

There was significant variation between hybrids and paternal parent and also among hybrids in various pollen characters (Table 21). The hybrids had significantly larger sized pollen grains that of parent. Within the hybrids variation in pollen size in terms of diameter (μ) was not significant. In pollen production and fertility aspects hybrids were inferior than that of the parent. Among the hybrids, 'Hybrid No.II' produced more number of pollen/ anther (5256.60) with high viability (24.52 per cent) followed by 'Hybrid No.III'. 'Hybrid No.I' recorded the least values for pollen output and viability.

The presence of viable pollen in the male flowers of banana hybrids such as I.C.1 and I.C.2 has been reported by Cheesman (1932 a, 1932 b, 1934).

The female fertility on artificial pollination with pollen from 'Pisang Lilin' was observed only in 'Hybrid No.III' and 'Hybrid No.I'. The seed yield per bunch was lower than that of maternal parent (Table 23). 'Hybrid No.III' recorded the maximum seed yield per bunch (11.00) while 'Hybrid No.I' produced only 5.0 seeds per bunch.

The banana hybrids should be seed sterile. It is the absence of the seeds and development of a high proportion of edible pulp that make bananas an acceptable fruit for consumption (Dodds, 1950). Any improvement for the cooking or dessert bananas, the main aim is to produce edible fruits and so the final result of banana hybridization would be seed sterile (De Lenghe, 1969). The presence of seeds in banana hybrids I.C.1 and I.C.2, on artificial pollination has been reported by Cheesman (1932 a, 1932 b, 1934).

SUMMARY

SUMMARY

The present investigations on Interclonal hybridization in banana were carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the year 1985-86. The salient results obtained are summarised below.

1. The growth parameters, duration, aspects, bunch characters and finger characters of the selected female parents viz: 'Palayankodan', 'Rasthali', 'Nendravannan', 'Ney Poovan', 'Karpooravally' and 'Nendran' and the male parents, 'Pisang Lilin', 'Tongat' and 'Sanna chenkadali' were studied.

2. Pollen production, fertility and viability of the three edible diploids (AA), namely 'Pisang Lilin', 'Tongat' and 'Sanna chenkadali' were estimated in the different nodes. The mean values of these characters were found to be low in first few nodes (upto 10th node), then increased to maximum (in the 30th node) after which decreased.

2.1. In 'Pisang Lilin' pollen output varied between 3875.41 in the 1st node to 947.14 in the 55th node with a maximum output of 8431.12 in the 25th node

after which it decreased sharply. The pollen output in 'Sanna chenkadali' ranged between 2288.66 in the Ist node to 206.50 in the 65th node with a maximum of 4229.98 in the 27th node. In the case of 'Tongat', pollen production varied between 2315.45 in the first node to 241.35 in the 65th node with a peak production of 2908.24 in the 20th node. Among the three clones studied, 'Pisang Lilin' produced maximum number of pollen grains per anther (8431.12) which was followed by 'Sanna chenkadali' with a pollen output of 4229.98. 'Tongat' recorded the least pollen production per anther (2908.24).

2.2. The pollen fertility as estimated by acetocarmine staining technique varied greatly in all the three clones, with respect to position of node. The fertility ranged between 46.14 per cent in the 1st node to 28.54 per cent in the 55th node with a peak of 53.74 per cent in the 20th node in 'Pisang Lilin'. In the case of 'Sanna chenkadali' the fertility was found to be vary between 32.24 per cent in the first node to 19.96 per cent in the 65th node with a peak of 44.85 per cent in 28th node. The fertility in 'Tongat' ranged between 28.33 per cent in the 1st node to 17.37 per cent in the 65th node

with a peak of 30.07 per cent in the 16th node. Among the three clones studied, 'Pisang Lilin' (53.74 per cent) recorded the highest pollen fertility, followed by 'Sanna chenkadali' (44.58 per cent) and least fertility was shown by 'Tongat' (30.07 per cent)

2.3. Medium for pollen germination was standardised. A medium containing 35 per cent sucros was found to be the best for pollen germination as well as for better pollen tube length. The pollen grains commenced germination after 20 hours of dusting in the medium in a dessicator containing water and rate of germination and tube growth was maximum at the 24th hour.

2.4. The pollen germination and tube length estimated in the three clones revealed that there was marked variation between the three clones with respect to position of node. In 'Pisang Lilin', the germination percentage varied between 19.63 in the first node to 6.14 in the 50th node, with a maximum of 31.15 in the 15th node. The pollen viability ranged between 9.81 per cent in the 1st node to 7.21 per cent in the 60th node, with a peak of 18.09 per cent in the 20th node in 'Sanna chenkadali'. In 'Tongat'

viability was found to vary between 7.0 per cent in the sixth node to 2.77 per cent in the 60th node, with a peak of 11.30 per cent in the 27th node. The pollen tube length in 'Pisang Lilin' varied between 210.12 μ in the first node to 112.40 μ in the 50th node, with a maximum tube length 410.83 μ in the 25th node. In 'Sanna chenkadali' tube length was found to vary between 102.79 μ in the 1st node to 88.12 μ in the 60th node with a peak tube length of 231.65 μ, in the 20th node. The tube length ranged between 90.12 μ in the 6th node to 90.12 μ in the 60th node, with a maximum of 122.33 μ in the 15th node in 'Tongat'. Among the three clones studied, 'Pisang Lilin' recorded the highest values both for pollen germination (31.15%) and tube length (410.83 μ), followed by 'Sanna chenkadali' (18.09%, 231.65 μ respectively). The lowest germination (11.30%) and the length (128.23 μ) were recorded by 'Tongat'.

3. Out of 18 cross combinations studied only 3 combinations were found to be compatible. The successful combinations were 'Palayankodan' x 'Pisang Lilin', 'Rasthali' x 'Pisang Lilin' and 'Nendran' x 'Pisang Lilin'. Among the three male parents used for hybridization, only

'Pisang Lilin' was found to be compatible with the fertile female parents.

4. Seed production was found to be maximum in 'Palayankodan' (102.96 seeds per bunch) followed by 'Nendran' (13.65 seeds per bunch) 'Rasthali' produced the least number of seeds per bunch (10.98).

5. The fertility pattern with reference to position of hands in a bunch showed variation. In 'Palayankodan', fertility was maximum in the third hand (27.33), while in 'Nendran' second hand was more fertile (7.00). 'Rasthali' produced maximum number of seeds in second and third hands (2.66).

6. The various seed treatments studied were not effective either in enhancing seed germination or getting early germination. However two seeds in acid treatment from the cross 'Palayankodan' x 'Pisang Lilin' germinated.

7. The three hybrids from the cross 'Agniswar' x 'Pisang Lilin' were found to be triploid (2n = 33) with AAB genomic group. Morphological description of the hybrids showed that 'Hybrid No.I' and 'Hybrid No.III' were similar and resembled the female parent.

8. With respect to various growth parameters, duration aspects, bunch characters, finger characters and

quality aspects, the three hybrids differed significantly between parents and also among themselves. Among the three hybrids, 'Hybrid No.III' was superior in characters such as height (285.00 cm), number of functional leaves (8.33), leaf area (9.3 M^2), petiole length (47.66 cm), bunch yield (9.10 kg), number of hands (7.00), number fingers (95.00) and quality aspects viz. Total solube solids (21.17 per cent), and total sugars (15.5 per cent), to both the parents and other to hybrids. 'Hybrid No.I' was intermediate in characters and 'Hybrid No.I' was the dwarfest among the hybrids and was inferior in all aspects.

9. Excepting the hybrid, 'Hybrid No.II', all were female fertile on artificial pollination and male fertile on pollen studies. 'Hybrid No.II' was only male fertile. The pollen production was maximum in 'Hybrid No.II' (5256.60), followed by 'Hybrid No.III' (5051.49). 'Hybrid No.I' recorded the least pollen output (4087.91). In pollen fertility, 'Hybrid No.III' recorded the highest value (62.67 per cent), followed by 'Hybrid No.II' (52.59 per cent) and 'Hybrid No.I' (49.85 per cent). With respect to pollen viability, 'Hybrid No.II' had highest pollen germination (24.52 per cent), followed by 'Hybrid No.III' (21.81 per cent) and 'Hybrid No.I'

(17.00 per cent), while pollen tube length was maximum in 'Hybrid No.I' (360.68 u), followed by 'Hybrid No.III' (246.93 u) and 'Hybrid No.II' (194.68 u).

10. 'Hybrid No.I' and 'No.III' were female fertile. On crossing with 'Pisang Lilin', 'Hybrid No.I' produced 5.00 seeds per bunch and 'Hybrid No.III' produced 11.00 seeds per bunch. However the seed yield in both hybrids was low when compared to maternal parent.

REFERENCES

REFERENCES

Alexander, M.P. 1970. A simple method for testing viability of banana pollen. Indian J. Hort., 27 (3/4) : 128-129.

Alexander, M.P. 1976. Mega and microgametophyte fertility of some banana varieties. (In.) Chadha, K.L. (Ed). Third International Symp. trop. subtrop. Hort. Proc. Today and Tomorrow printers and publishers, New Delhi. pp : 27-28.

Alexander, M.P. 1980. A versatile stain for pollen fungi, yeast and bacteria. Stain. Tech. 55(1) : 15-18.

*Araujo, M.A.S., Santos, D.M.M. and Dos, L.G. 1983. Germination of Cassia multijuga seed. Garlia deorta, Botanica, Brazil. 6(½) : 13-16.

Association of Official Agricultural Chemists. 1968. Official method of analysis. Washington, DC : 225-226.

Azhakiamanavalan, R.S., Sathiamoorthy, S. and Bhakthavathsalu, C.M. 1985. Co.1, Hybrid banana for plains, Indian Hort. 30 (1) : 3-4.

*Baker, R.E.D. and Simmonds, N.W. 1949. Report on a visit to British East Africa to study the wild and cultivated bananas. I.C.T.A., Trin., mimeographed.

*Baker, R.E.D. and Simmonds, N.W. 1951a. Bananas in East Africa I. Emp. J. Exp. Agric. 19 : 283-290.

*Battaglia, E. 1957. A simplified Fuelgen method using cold hydrolysis. Caryologica. 9 : 372-373.

Bhakthavathsalu, C.M., Manichavagam, P. and Sathiamoorthy, S. 1968. Comparative studies on Klue Teparod, a natural tetraploid banana and a synthetic tetraploid hybrid. South Ind. Hort. 16 : 158-162.

*Borges, F.O.L. 1971. Study of female fertility in clones of plantain and cultivated bananas. Agronomia Tropical. 21 (2) : 135-137.

*Cheesman, E.E. 1931. Banana breeding at the Imperial College of Tropical Agriculture. Emp. Mktg. Bd. Rep. 47 : 35.

Cheesman, E.E. 1932 a. Genetic and cytological studies of Musa I. Certain hybrids of Gros Michel banana. J. Genet. 26 : 291-312.

Cheesman, E.E. 1932 b. Genetic and cytological studies of Musa II. Hybrids of the Mysore banana. J. Genet. 26 : 313-316.

Cheesman, E.E. 1934. Principles of banana breeding. Trop. Agric. Trin. 11 (8) : 132-137, 176-181, 203-207.

Cheesman, E.E. 1949. Banana research at I.C.T.A. Trop. Agric. Trin. 26 : 78-84.

Cheesman, E.E. and Larter, L.N.H. 1935. Genetical and cytological studies of Musa III. Chromosome numbers in the Musaceae. J. Genet. 30 : 31-52.

Chellappan, K. and Ignatius, J. 1982. A hybrid Jack. South Ind. Hort. 30 (3) : 76-81.

Cousins, H.H. 1927. New varieties of banana. Trop. Agric. Trin. 31 : 336-338.

Cox, E.A., Stotsky, G. and Goos, R.D. 1960. Invitro culture of Musa balbisiana colla embryos. Nature. 185 : 403-404.

Darlington, C.D. and La Cour, L.E. 1976. The Handling of chromosomes. Ed.6. George Allen and Unwin Ltd., London. pp. 36-39.

De Langhe, E. 1969. Banana (Musa spp.). (In) Ferweda, F.P. and Wit, F.H. (Ed). Outline of perennial crop breeding in the topics. Verman and Zonen, N.V. Wageningen. pp : 63-65.

*Devreux, M. 1969. Phylogeny of edible bananas. Proceeding of the IX International Botanical Congress, Montreal, August, 1929. 12 : 1444.

*Dodds, K.S. 1943a. The genetic system of banana varieties in relation to banana breeding. Emp. J. Agric. 11 : 89-98.

Dodds, K.S. 1943 b. Genetical and cytological studies of Musa V. Certain edible diploids. J. Genetics. 45 (2) : 113-138.

Dodds, K.S. 1945. Genetical and cytological studies of Musa VI. The development of female cells of certain edible diploids. J. Genet. 46 : 161-179.

Dodds, K.S. 1950. The breeding of disease resistant banana. World Crops. 2 : 56-59.

Dodds, K.S. 1958. Problems and techniques in breeding new varieties of bananas. Indian J. Hort. 15 : 210-214.

Dodds, K.S. and Simmonds, N.W. 1948 a. Sterility and Parthenocaspy in diploid hybrids of Musa. Heredity. 2 : 101-117.

*Echlers, H. 1951. Untresuchungen Zur Ernahrungsphysiologie der Pollenschlan-che. Biol. Zbl. 70 : 432-451.

*Eduardo, O. and West, S.H. 1980. Leucanea seed Scarification. News letter. 1 : 52.

F.I.B. 1985. Farm guide. Farm Information Bureau, Government of Kerala. India : pp.9.

Gangolly, S.R., Kamalakaran, A.K. and Balakrishnan, T.K. and Pandalai, K.M. 1961. Studies on the pollen in the coconut. I. Its importance, output in different varieties and composition in the still air. Indian Coconut J. 14 (2) : 49-66.

Gopimany, R. and Balakrishnan, S. 1984. Features of Inter-varietal hybrids of pineapple. South Ind. Hort. 32 (2) : 65-68.

*Gottreich, M., Bradu, D. and Halevy, 1984. A simple method for determing average banana fruit weight. Ktavim. 14 : 161-162.

Hartman, H.T. and Keister, D.E. 1972. Plant Propagation, Principles and Practices. Ed.2. Prentice Hall of India, Private Ltd., New Delhi. pp : 159-164.

*Hett, C.F. 1971. Germination studies with geranium seed. Proceedings of the Association of Official Seed Analyst. New York Agrl. Expt. Station, Geneva, USA : 105-111.

Hillary, B.B. 1939. Improvements in the permanent root tip squash technique. Stain Tech. 14 : 97-99.

Hillary, B.B. 1940. Use of the feulgen reaction in cytology. II. Bot. Gaz. 102 : 225-235.

Jadhave, A.S. 1960. Canna seeds can be germinated. Poona Agric. Coll. Mag. 51 : 28-29.

John, P.M. and Earnest, S.H. 1975. Plant Propagation. John Willey and Sons. INC. London. pp : 114-115.

Johri, B.M. and Vasil, I.K. 1961. Physiology of pollen. Bot. Rev. 27 : 325-381.

Karmacharya, J.L. 1984. Pollen morphology, fertility and compatibility studies in banana. Thesis submitted to Kerala Agricultural University in part fulfilment of the requirements for the degree of M.Sc. in Horticulture.

Kerala Agricultural University. 1986. Package of Practices Recommendations. Directorate of Extension, Kerala Agricultural University, Vellanikkara, Trichur, India. pp : 157-162.

Khader, J.B.M., Gowder, R.B., Irulappan, I. 1977. A promising mango hybrid for Tamil Nadu. South Ind. Hort. 25 (2) : 48-55.

Larter, L.N.H. 1935. Hybridism in Musa I. Somatic cytology of certain Jamaican seedlings. J. Genet. 31 : 297-316.

*Larter, L.N.H. 1947. Report on banana breeding. Dep. Agric. Jamaica Bull. 34 : 24.

Leach, R. 1964. Black leaf streak, a new form of banana leaf spot in Fiji. World Crops. 16 (4) : 60-65.

Liu, N.Y. and Khatamian, H. 1981. Seed coat structure of three woody legumes species, after chemical and physical treatments to increase seed germination. Journal of American Society for Horticultural Science. U.S.A. 106 (5): 691-694.

Menendez, T. and Shepherd, K. 1975. Breeding new bananas. World Crops. 27 : 104-112.

Murray, D.B. 1960. The effect of defencies of the major elements on the growth and leaf analysis of banana. Trop. Agric. Trin. 37 (2) : 97-106.

Nair, T.G. 1953. An interspecific Musa hybrid produced at the Central Banana Research Station, Aduthurai. Madras Agric. J. 40 : 420-425.

*National Institute of Agronomy. 1955. Annual report for the financial year, 1954. Congo. pp : 492.

Oberole, G.D. and Geortzen, K.L. 1952. A method for evaluating pollen production of fruit varieties. Am. Soc. Hort. Sci. Proc. 59 : 263-265.

*Osborne, R.E. 1958. Breeding the immune banana. Ban. Bd. Res. Dep. Jamaica. Occ. Bull 2 : 8.

*Osborne, R.E. 1961-3. Report of the plant breeder. Ann. Rep. Res. Dep. Ban. Bd. Jamaica. 1960: 29-31; 1961 : 22-23; 1962 : 22-23.

*Osborne, R.E. 1962. Bodles Altafort, a new banana for Jamaica. Ban. Bd. Res. Dep. Jamaica Occ. Bull. 3 : 7.

Poehlman, J.M. 1977. Breeding field crops. The Avi Publishing Company, INC. Westport, Connectieut. pp: 415.

*Pozzi, A. 1953. A rapid method of determining the amount of pollen produced for fruit tree varieties. (In) Rao, V.N.M. and Khader, J.B.M. Md.A. 1962. Estimation of pollen production in fruit crops. Madras Agric. J. 49(5) : 152-156.

Purseglove, J.W. 1975. Tropical crops. Monocotyledons Vol.2. Ed.2. The English Language Book, Society and Longman. London. pp : 356-377.

Raman, V.S. 1976. Problems and prospects in breeding Indian bananas. (In) Chadha, K.L. (Ed) Third International Symp. Trop. Subtrop. Hort. Proc. Today and Tomorrow Printers and Publishers, New Delhi. pp : 15-26.

Raman, V.S., Alikhan, W.M., Manimekhalai, G. and Bhakthavathsalu, C.M. 1971. A study of the cytomorphology of some banana hybrids. Madras Agric. J. 58 (2) : 55-63.

Randolph, L.F. and Cox, L.G. 1943. Factors influencing the germination of iris seed and the relation of inhibitory substances to embryo dormancy. Proc. Sm. Soc. Hort. Sci. 43 : 284-300.

Rao, B.C. and Swamy, G.S., Nagabhushanam, M. and Rama Rao, B.V. 1963. Performance of some promising Andhra Mango Hybrids. Punjab Hort. J. 3 (2/4) : 124-136.

Rao, V.N.M. and Khader, J.B.M.Md.A. 1962. Estimation of pollen production in fruit crops. Madras Agric. J. 49 (5) : 152-156.

Richardson, D.L. 1961. A note on the reversion of the dwarf banana "Cocos to Gros Michel". Trop. Agric. Trin. 38 : 35-37.

*Rowe, P.R. 1976. Potential for genetic improvement in Plantation yield. Fruits, Div. Trop. Res. United. Brands, Co. Lima. Honduras. 3 (9) : 531-536.

Rowe, P.R. and Richardson, D.L. 1975. Breeding banana for disease resistance fruit quality and yield. Tropical Agriculture Research Series. (SIASTSA). Lalima, Honduras, USA.

Rowe, P. 1984. Breeding Bananas and Plantains (In) Jules Jamik (Ed). Plant Breeding Reviews. Vol.2. Avi Publishing Co. INC. West Post. pp : 135-155.

Sathiamoorthy, S. 1973. Preliminary investigations on breeding potential of some banana clones. Thesis submitted to the Tamil Nadu Agricultural University in part fulfilment of the requirements for degree of M.Sc. in Horticulture.

Sathiamoorthy, S. and Rao, V.N.M. 1980. Pollen production in relation to genome and ploidy in Banana clones. National Seminar on Banana Production Technology. Tamil Nadu Agricultural University, Coimbatore. pp : 46-49.

Shanmugavelu, K.S. and Rangaswamy, G. 1962. Tryptophan and indole compounds in banana ovaries. Nature 194 : 715-716.

Sharma, S.D. and Uppal, D.K. 1977. Performance of seedless hybrids in Intervarietal crosses of Grapes. (Vitis vinifera L.). Punjab Hort. J. 27 (1 & 2) : 41-46.

Shepherd, K. 1954. Seed fertility of the Gros Michel banana in Jamaica. J. Hort. Sci. 29 : 1-11.

Shepherd, K. 1960 a. Seed fertility of Gros Michel bananas. Trop. Agric. Trin. 37 : 211-221.

Shepherd, K. 1960 b. Seed fertility of edible bananas. J. Hort. Sci. 35 : 6-30.

*Shepherd, K. 1968. Banana breeding in West Indies. Pest. Arts. News Summ. 14 : 370-379.

Shepherd, K. 1974. Banana research at ICTA. Trop. Agric. Trin. 51 : 482-490.

Simmonds, N.W. 1952 c. The germination of banana seeds. Trop. Agric. Trin. 29 (3) : 2-16.

Simmonds, N.W. 1953 a. Segregations in some diploid bananas. J. Genet. 51 : 458-469.

Simmonds, N.W. 1956 a. A banana collecting expedition to South-East Asia and the Pacific. Trop. Agric. Trin. 33 : 251-271.

*Simmonds, N.W. 1956 b. Botanical results of the banana collecting expedition. 1954-5. Kew Bull. 1956 : 463-489.

Simmonds, N.W. 1959. Experiments on germination of banana seeds. Trop. Agric. Trin. 36 : 259-273.

Simmonds, N.W. 1960 a. Experiments on banana fruit development. Ann. Bot. 24 : 212-222.

Simmonds, N.W. 1960 b. Megasporogenesis and female fertility in three edible triploid bananas. J. Genet. 60 (2) : 269-278.

*Simmonds, N.W. 1962. The evolution of bananas. Longman.

Simmonds, N.W. 1966. Bananas. Ed.6. Longman. London. pp:512.

*Simmonds, N.W. and Shepherd, K. 1955. The taxonomy and origin of the cultivated bananas. J. Linn. Soc. Lond. 55 : 302-312.

Singh, S.V. 1963. Mango hybridization in U.P. Punjab Hort. J. 3 (2/4) : 121-123.

Sinha, M.M., Verma, J.P. and Koranga, 1973. Studies on the seedgermination of guava. I. Effect of scarifications and plant growth regulator treatments. Progve. Hort. 5 (2) : 37.

Snedecor, G.M. and Cochran, W.G. 1967. Statistical Methods. Ed.6. Oxford and IBH. Publishing Co. New Delhi. pp : 418.

Stanley, R.G. and Linskens, H.F. 1974. Pollen Biology, Biochemistry and Management. Ed.1. Springerverlang Berlin Heidelberg. New York. pp : 39-85.

Steward, F.C. and Simmonds, N.W. 1954. Growth Promoting substances in the ovary and immature fruit of the banana. Nature. 173 : 1083-1084.

Stotzky, G., Cox, E.A. and Goos, R.D. 1962. Seed germination studies in Musa I. Scarification and aseptic germination of Musa balbisiana. Am. J. Bot. 49 (5) : 515-520.

Stotzky, G., Cox, E.A. and Goos, R.D. 1962. Seed germination in Musa II. Alternating temperature requirement for the germination of Musa balbisiana. Am. J. Bot. 49 (7) : 763-770.

Stover, R.H. 1962. Furarial wilt (Panama disease) of banana and the Musa species, Phtopath pap. Common W. mycol. Inst. 4 : 177.

*Stover, R.H. 1972. Banana, plantain and abaca disease. Commonwealth Mycological Institute. Kew : 315.

Sundaraj, T.S., Padmanabhan Nambisian, K.M. and Appaiyan, M.C. 1957. Hybridization and its scope for improvement in bananas. Madras Agric. J. 44 : 663-672.

Tamil Nadu Agricultural University, 1982. Breeding investigation. Research report on citrus, banana, pineapple and papaya. All India Co-ordinated Fruit Improvement Project (Cell.I), IIHR. pp : 33-34.

Tamil Nadu Agricultural University, 1985. Breeding investigations, Hybridization studies in banana. All India Co-ordinated Fruit Improvement Project (Cell.I), National Fruit Research Workshop conducted at Trichur. pp : 1-7.

Valsalakumari, P.K. 1984. Cytotaxonomical studies on banana cultivars. Thesis submitted to Kerala Agricultural University in part fulfilment of the requirements for the degree of Ph.D. in Horticulture.

Veerannah, L., Kulasekharan, M. and Muthuswamy, S. 1982-83. New hybrid papayas. South Ind. Hort. 30-31 : 261-263.

*Visser, J.K. 1955. Germination and storage of pollen, Meded. Land. Hogersch. Wagningen. 55 (1) : 1-68.

Wilson, G.B. 1946. Cytological studies in Musa I. Meiosis in some triploid clones. Genetics. 37 : 241-258.

---

* Original not seen

APPENDICES

APPENDIX - I

Analysis of variance for standardisation of sucrose medium for pollen germination and tube growth

Source	Degree of freedom	Mean sum of squares	
		Pollen germination (%)	Tube length (μ)
Treatment	7	121.38**	42481.37**
Error	16	0.890	301.65
Total	23		

** Significant at 1% level

APPENDIX - II

Analysis of variance for pollen germination and tube growth at bihourly intervals in 35% sucrose solution

Source	Degree of freedom	Mean sum of squares	
		Pollen germination (%)	Tube length (μ)
Treatment	6	23.42**	7995.08**
Error	14	0.186	554.24
Total	20		

** Significant at 1% level

APPENDIX - III

Analysis of variance for growth parameters of hybrids and parents

Source	Degrees of freedom	Mean sum of squares					
		Height (cm)	Girth (cm)	Functional leaves	Leaf area (M^2)	Petiole length (cm)	Phylacron (days)
Treatment	4	8181.23**	473.26**	10.90**	24.36**	71.73**	6.31**
Error	15	63.46	5.64	0.22	0.16	0.84	0.31
Total	19						

** Significant at 1% level

APPENDIX - IV

Analysis of variance for duration of hybrids and parents

Source	Degree of freedom	Mean sum of squares				
		Planting to flowering interval (days)	Flowering to harvest interval	Total duration	Male phase	Female phase
Treatment	4	13517.82**	758.43**	10488.78**	1225.76**	1.56*
Error	15	119.91	45.86	56.04	30.31	0.35
Total	19					

** Significant at 1% level

* Significant at 5% level

APPENDIX - V

Analysis of variance for bunch characters of hybrids and parents

Source	Degrees of Freedom	Mean sum of squares			
		Bunch weight (kg)	Hand weight (kg)	Number of hands	Number of fingers
Treatment	4	23.99**	0.335**	6.16**	1860.00**
Error	15	0.048	0.024	0.086	16.66
Total	19				

** Significant at 1% level

APPENDIX - VI

Analysis of variance for finger characters of hybrids and parents

Source	Degree of freedom	Mean sum of squares					
		Pedicel length (cm)	Finger length (cm)	Finger girth (cm)	Finger weight (kg)	Finger volume (cc)	Pulp/peel ratio
Treatment	4	0.602	11.47**	36.47**	1026.85**	1584.91**	0.775**
Error	15	0.008	0.56	0.28	6.33	19.75	0.003
Total	19						

** Significant at 1% level

APPENDIX - VII

Analysis of variance for quality characters of hybrids and parents

Source	Degree of freedom	Mean sum of squares					
		T.S.S. (%)	Reducing sugars (%)	Non reducing sugars(%)	Total sugars (%)	Acidity (%)	Sugar/acid ratio
Treatment	4	8.02**	21.26**	0.139**	24.14**	0.032**	921.85**
Error	15	0.79	0.41	0.003	0.401	0.0009	14.07
Total	19						

** Significant at 1% level

APPENDIX - VIII

Analysis of variance for pollen characters of hybrids and male parents

Source	Degree of freedom	Mean sum of squares				
		Pollen diameter (μ)	Pollen production	Pollen fertility (%)	Pollen germination (%)	Pollen tube growth (μ)
Treatment	3	112.33**	0.073**	44.70**	52.33**	4002.35**
Error	12	4.15	0.004	1.43	0.708	284.97
Total	15					

** Significant at 1% level

INTERCLONAL HYBRIDIZATION STUDIES IN BANANA

By

KRISHNAKUMAR. M. P.

ABSTRACT OF A THESIS

submitted in partial fulfilment of
the requirements for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Horticulture
(Pomology & Floriculture and Landscaping)
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1987

ABSTRACT

Investigations were carried out on the interclonal hybridization in banana, involving six female parents, viz: 'Palayankodan', 'Rasthali', 'Nendravannan', 'Ney Poovan', 'Karpooravally' and 'Nendran' and three male parents, viz: 'Pisang Lilin', 'Tongat' and 'Sanna chenkadali', with a view to make a detailed study on pollen production, fertility and viability in different nodes of the male parents and female fertility pattern in different hands of the six female parents, compatibility and seed set in 18 cross combinations involving six female parents and three male parents, effect of different seed treatment on germination of banana seeds and evaluation of existing interclonal hybrids already available, in the Department of Pomology and Floriculture, College of Horticulture during the year 1985-86.

Pollen production, fertility and viability studied in the three male parents, viz: 'Pisang Lilin', 'Tongat' and 'Sanna chenkadali' revealed that there was marked variation among the parents in all these pollen characters. Within each parent, all these characters varied greatly with the age of bud. 'Pisang Lilin' recorded the maximum pollen production per anther (8431.12) and highest pollen fertility

(53.74 per cent). The pollen production varied from 3875.41 in the 1st node to 947.14 in the 55th node and fertility from 46.14 per cent in the 1st node to 28.45 per cent in the 55th node, with the maximum pollen production and fertility in the 25th and 20th nodes. In 'Sanna chenkadali', the maximum pollen production and fertility were obtained in the 27th and 28th nodes and in 'Tongat' in the 20th and 16th nodes respectively.

Standardisation of media for pollen germination and tube growth indicated that a medium consisting of 35 per cent sucrose was the best. The germination of pollen grains was found to be maximum after 24 hours of dusting on the medium. The pollen viability in terms of germination per cent and tube growth was also found to be maximum in 'Pisang Lilin' which varied between 19.65 in the 1st node to 6.14 in the 50th node, with a maximum of 31.15 in the 15th node. The pollen tube length varied between 210.12 μ in the 1st node to 112.40 μ in the 50th node, with a maximum tube length of 410.83 μ in the 25th node.

Out of the 18 cross combinations studied, only 3 combinations, involving, 'Palayankodan', 'Rasthali' and 'Nendran' as female parents and 'Pisang Lilin' as male

parent were compatible. Among the three male parents used for hybridization, only 'Pisang Lilin' was found to be compatible with the fertile female parents. Seed production was found to be maximum in 'Palayankodan' (102.96 seeds per bunch) followed by 'Nendran' (13.65 seeds per bunch). 'Rasthali' produced the least number of seeds per bunch (10.98). The fertility pattern with respect to position of hands in a bunch showed variation. In 'Palayankodan', fertility was maximum in the third hand (27.33), while in 'Nendran', second hand was more fertile (7.00). 'Rasthali' produced maximum number of seeds in second and third hands (2.66).

Among the various seed treatments tried, only two seeds subjected to acid treatment, from the cross 'Palayankodan' x 'Pisang Lilin' germinated. However, the treatments were not found to be effective.

The three hybrids from cross, 'Agniswar' x 'Pisang Lilin', were found to be triploids (2n = 33) with AAB genomic group. With respect to various growth parameters, duration aspects, bunch characters, finger characters and quality aspects, the three hybrids differed significantly between parents and also among themselves. Among the hybrids, 'Hybrid No.III' was superior in characters such as height (285.00 cm), number of functional leaves (8.33), leaf

area (9.3 M^2), petiole length (47.66 cm), bunch yield (9.10 kg), number of hands (7.00), number of fingers (95.00) and quality aspects, viz: total soluble solids (21.17 per cent) and total sugars (15.5 per cent), to both the parents and other two hybrids. The hybrids were found to be male fertile on pollen studies and female fertile on artificial pollination, excepting 'Hybrid No.II' which was only male fertile. However, hybrids were inferior in pollen production, fertility and viability as compared to the paternal parent and poor in seed yield as compared to the maternal parent.