POLLEN MORPHOLOGY, FERTILITY AND COMPATIBILITY STUDIES IN BANANA

By

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THESIS

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Dedicated to My Father

DECLARATION

I hereby declare that this thesis entitled "Pollen morphology, fertility and compatibility 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,
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CERTIFICATE

Certified that this thesis entitled "Pollen morphology, fertility and compatibility studies in banana" is a record of research work done independently by Mr. Jay Krishna Lal Karmacharya, 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.

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Introduction

INTRODUCTION

India occupies the second place in world banana production with about 2.7 lakh hectares producing annually about 46 lakh tonnes of fruits (Venkataraman, 1980). Kerala state ranks first in the acerage in banana cultivation in India (Anon, 1983). Surprisingly the productivity of banana in Kerala is very low. In spite of the best care and management the bunch weight often remains below standard. The low number of functional leaves, and leaf diseases appear to be some of the factors responsible for low bunch weight.

Exploring the possibilities of improving the clones through hybridisation seems to be a desirable line of approach for a breakthrough of the above situation.

The classic experiments in banana breeding started in Jamaica and Trinidad during 1920s were mainly directed towards tackling the panama disease problem (Simmonds, 1966).

In the early breeding programmes the two wild species, viz., Musa acuminata and Musa balbisiana

were used as male parents (Menendez and Shepherd, 1975).

The use of edible diploids as a male parent in banana breeding programme is comparatively of recent origin. The results of the hybridization conducted by Tamil Nadu Agricultural University is of considerable interest (Anon, 1982).

In these breeding programmes the main emphasis was on the use of cultivars as male and female parents which perhaps points out to a shift in strategy that is needed in further banana breeding experiments. The successful hybrids, viz., H.74, H.88, H.109 and H.110 produced out of crosses of 'Matti' with 'Pisang lilin', 'Namarai', and 'Tongat' (as male parents) shows that further works on those lines may yield interesting results.

In the state of Kerala practically no work has been carried out so far in banana breeding. Therefore it appeared, necessary to collect information in the various aspects of male and female fertility, pollen production etc., based on which further breeding experiments could be designed. An understanding of

of the inter-clonal compatibility was also considered necessary to plan future detailed hybridization works.

With these objectives in view the present studies were designed on the following lines.

1. To collect data on the female and male phases, nature of opening bracts and total duration of the clones.
2. To study the pollen morphology, pollen fertility and pollen germination.
3. To study the pollen storage behaviour under different conditions of storage.
4. To study the compatibility and seed set in a few selected clones.

Review of Literature

REVIEW OF LITERATURE

Literature pertaining to aspects of flowering, pollen morphology, pollen production, pollen fertility, pollen storage and compatibility in banana is reviewed below.

1. Physiology of flowering

The transformation from the vegetative phase to flowering in banana varies with variety, season and other factors, which ultimately influence the total duration of the crop.

Summerville (1944) working on the 'Dwarf cavendish' banana in Queensland found that at a time when the young inflorescence could be first recognised with a hand lens, about eleven mature leaves were present. According to him, this was which indicated approximately the time of transformation of the growing point into the inflorescence. He found that the time lag between flower bud initiation and shooting varied with the season (from six months in winter to three months in summer).

Shakthavatsalu et al. (1968) compared 'Klue Teparod',

a natural tetraploid with a synthetic tetraploid hybrid banana viz., Ney Vannan (AAB) x Musa balbisiana (BB). They reported that while 'Klue Teparod' took 355 days, the hybrid took only 328 days from planting to harvest. From shooting to harvest, the above clones took 164 days and 108 days, respectively.

Nair and Nair (1969) reported that the total plant life varied from 16 to 19 months in 'Anamalu', 14 to 17 months in 'Bodles Altafort', 15 to 16 months in 'Rajda Sirha', 16 to 18 months in 'Rajda', 13 to 16 months in 'Pisang embun', 16 to 17 months in 'Giant Governer' and 17 to 18 months in 'Kapok'. In the case of clones 'Manoranjitham' and 'Mas', they took 16 months and 20 months, respectively.

Purseglove (1975) reported that within about seven to nine months after planting, the growing point in a banana sucker was transformed into an inflorescence. The time lag from this stage to the emergence of the inflorescence was about a month and the duration from shooting to harvest was about 90 days.

Sequence of events of flower bud initiation and further development of inflorescence was studied by

Pillai and Shanmugavelu (1981) in the variety 'Poovan' at the Tamil Nadu Agricultural University, Coimbatore. They recognised three cardinal stages in the process of flower bud initiation and differentiation, viz; vegetative, transitional and flowering. The vegetative stage terminated at the 220th day after planting and the transitional stage between 230 to 290 days. The flowering stage commenced from the 280th day and was completed by 320 days.

Female fertility

Most of the cultivated bananas are seedless due to highly inherent female sterility genes, triploidy and chromosomal changes (Simmonds, 1962). According to Simmonds, 'Cavendish' group never set seeds in spite of several experimental pollinations.

Simmonds (1953) observed that the physiology of parthenocarpic fruit development in banana is mediated by an autonomous production of auxin. Shanmugavelu and Rangaswamy (1962) also emphasised the role of auxins in parthenocarpic development of banana fruits. Simmonds (1962) and De Langhe (1969) explained that parthenocarpy was due to three complementary dominant

genes derived from the wild Musa acuminata.

Alexander (1972) studied the female fertility of 42 clones and reported that out of these, 28 were female sterile. Rowe (1976) observed that AAB group were usually sterile and hence could be useful for hybridization.

Fertility studies in banana were conducted by several workers. Cousins (1927) reported that 'Gros Michel', when crossed with 'Robusta' produced seeds. 'Ramkela', 'Honey', 'Apple', 'Whitehouse' and 'Gros Michel' when crossed with 'Kewensis', a male, also were found to produce seeds. Cheeseman, (1949) reported various clones 'Mysore', 'Pome', 'Bluggoe', 'Red' and 'Orotava' to be female fertile. Female fertility was also reported by Dodds and Simmonds (1948) in the clones 'Selangor', 'Calcutta 4','Long Tavoy' and 'Selangor' x 'Calcutta'4.

Reviewing hybridization work at Bedles, Shepherd (1954) reported that even under the most favourable conditions the fertility of 'Gros Michel' hardly exceeded three seeds per bunch. Many bunches were seedless.

Nair (1953) from Aduthurai reported that

pollination was found to be most successful when done between 7.00 a.m. and 8.00 a.m. Shepherd (1960) observed that a number of clones were found to be more fertile when pollinated prior to flower opening. The fact that fertility in banana was related to the climate and soil fertility of a locality to a great extent, was revealed by Simmonds (1966). He also observed that, generally, the best time for pollination was the mid or late morning hours. The fertility was more in the case of clones that produced larger bunches, in the hands which were at the basal ends and in the fingers at the distal ends.

De Langhe (1969) found that pollination was highly successful if carried out early in the morning. Receptivity did not have much relationship with lifting of the bracts. He reported that banana flowers were receptive in the morning, while the bracts opened usually in the afternoons. Purseglove (1975) found that bracts rose one per day before the flowers became functional.

Male fertility

Scientists working on fertility of banana have

reported several cases of male sterility and fertility from 1920's onwards.

Cousins (1927b) found 'Kewensis' as male fertile. Dodds and Simmonds (1948) reported that the clones 'Selangor', 'Long Tavoy', 'Pisang lilin' and Selangor x Calcutta 4 produced pollen grains which were fertile, the fertility ranging from 40 per cent (Selangor x Calcutta 4) to 100 per cent (Selangor and Long Tavoy).

Out of the 38 clones studied by Alexander (1972), 28 were classified as male sterile and 10 as male fertile. The male sterile clones reported were 'Durathabli', 'Dwarf Cavendish', 'Ayiramkarasathali', 'Attrutapani', 'Krishna vazhai', 'Ladan', 'Nendra padathi', 'Nendran', 'Pacha nadan', 'Rasthali', 'Sirumalai', 'Walha', 'Adakka kunnan', 'Kadali', 'Ney poovan', 'Thatila kunnan', 'Alsi', 'China', 'Chinali', 'Govankar', 'Kallu monthan', 'Kaali', 'Monthan', 'Madurangabale', 'Peyan', and 'Rajavazhai'. The male fertile clones were 'Beetjava', 'Local I', 'Manikachampa', 'Malla chakarkali', 'Red Banana', 'Robusta', 'Thenkadali', 'Sugandhi', 'West Indies' and Musa balbisiana.

Sathiamoorthy and Roo (1980) reported from Coimbatore that clones having AB diploids did not produce pollen.

2. Pollen studies

2.1. Pollen morphology

Erdman (1952) who reviewed the pollen analysis done in several crop species, concluded that pollen morphology was a useful means in the classification of species. Wodehouse (1953) opined that the form of pollen grains helped in distinguishing between the tribes, the families and the genera of plants.

Swarup and Singh (1964) observed that the number, the size and the shape of apex brochis of pollen grains differed between the 18 varieties of Bougainvillea they studied. Fegle (1977) and Mass (1977) suggested that the ultrastructure of pollen was a reliable means to identify the tree fruit species and even the clones within the species.

2.2. Pollen production

Several methods have been employed to assess the pollen production of crop plants.

In apple, Knowlton (1935) took a single anther and allowed it to dehisce on a glass slide ruled in squares. A drop of lactic acid was placed on the dehisced anther. The pollen was then spread out uniformly

and covered with cover glass. Using a binocular microscope, the pollen in each square was counted. He found that this method was very slow. He later developed the Haemocytometer method, which is largely used at present to assess the pollen production. Oberle and Geortsen (1952) and Rao and Khader (1962) estimated the pollen production in fruit trees by using haemocytometer technique. These workers used 2.5 ml water containing 0.25 per cent calgon, instead of lactic acid as dispersing agent of pollen grains.

Brooks and Puri (1963) and Sharma and Singh (1970) reported that variation in atmospheric conditions influenced the pollen production of plants.

Sathiamoorthy and Rao (1980) observed that pollen grains per anther in banana increased to about 13000 at node 10 of the male part of the inflorescence, which remained steady till node 30 and then declined to 5500 at node 100. They also found that all AB diploids did not produce pollen grains while Musa acuminata (AA) and Musa balbisiana (BB) produced pollen grains. They further observed that AAA clones among the triploids produced more pollen than those belonging to AAB or ABB group. Among the tetraploids, the synthetic

tetraploid produced more pollen than the natural tetraploid.

2.3. Pollen viability

2.3.1. Pollen staining method

Staining the pollen with different chemicals and dyes has been adopted to assess the viability of the pollen grains.

Zirkle (1937) described a method of staining the pollen grains to assess their fertility using acetocarmine. He found that plumpy, well shaped and fertile pollen grains took the stain in contrast to sterile or non-viable ones. Acetocarmine staining technique has since been used to assess the fertility of pollen grains in several crops, such as guava by Balsubramaniam (1959), pomegranate by Nath and Randhawa (1959), Okra by Dubey et al. (1968) and Annona by Malawadi et al. (1977).

Alexander (1972), while studying the megagametophyte fertility of banana clones, determined the fertility of pollen by staining them with acetocarmine. Pollen grains that stained were taken as fertile and those unstained as sterile.

Stanley and Linskens (1974) reported that acetocarmine perfectly stained the chromosomes, while iodine stained starch and tetrazolium salts changed their colour in the presence of enzymes present in viable pollen. They suggested that the use of stains was not sufficiently accurate when compared to *in vitro* germination tests.

Deshmukh *et al*. (1978) stained the colchicine-induced tetraploid sponge gourd pollen with propiocarmine. Fully stained pollen grains were taken as fertile ones.

Singh *et al*. (1978) used methyl green, glycerin jelly, aldin oil, gelatin violet and acetocarmine as stains to assess the viability of pollen grains.

2.3.2. Pollen germination

Germination of pollen *in vitro* is considered to be a better means of assessing the pollen fertility. By supplying the required nutrients, especially sugars, in an artificial medium the pollen grains have been successfully germinated in a large number of plants.

Jost (1905), Martin (1913), Anthony and Harlan (1920), and Visser (1955) suggested that externally

supplied sugars had only an osmotic role and were not utilised by the growing tube for any nutritional purpose.

Adams (1916) used cane sugar in artificial media for pollen germination of apple, pear, strawberry, raspberry and black currants in different concentrations and found that satisfactory germination of pollen was possible at concentrations of 2.5 to 10.0 per cent in apple, 4.0 to 8.0 per cent in pear, 8.0 per cent in strawberry, 6.0 per cent in raspberry and 16.0 per cent in black currants.

On the other hand, Brink (1924), O'kelly (1955), and Vasil (1958) suggested that apart from having an osmotic role, the externally supplied sugars in the medium definitely served as a nutrient material for the growing tubes.

Ostopenko (1956) found sucrose as a suitable artificial medium for testing pollen germination in several plants. Sucrose alone or in combination with other chemicals have been reported to be suitable for the germination of pollen grains (Vasil 1960; Jacob et al. 1969 and Deshmukh et al. 1978).

Sinha (1973) revealed that pollen germination and pollen-tube growth were highest in 10 per cent aquous sucrose solution, followed by 10 per cent sucrose-agar, 10 ppm IAA, 20 ppm α napthaleneacetic acid and 20 ppm boric acid.

Randhawa and Nair (1960) recommended 20 per cent sugar and 1.5 per cent agar for pollen germination in plum, while Rao and Khader (1960) used 16 per cent sucrose and 0.7 per cent agar for obtaining best germination of sapota pollen grains. Singh (1961) reported 25 per cent sucrose and 0.5 per cent agar as the best medium for mango. Veras and Soria (1962) suggested that 10 per cent sucrose with 2.0 per cent agar was the best medium for the germination of cocoa pollen grains.

The stimulating effect of boron on pollen germination and tube growth was studied by Schumucker (1932). He found that 1 to 10 ppm boric acid stimulated pollen germination and tube growth. Thompson and Batjer (1950) also reported that boron and boric acid at 25 to 40 ppm concentration had stimulative effect, whereas at higher concentrations they inhibited the pollen germination and tube growth.

Gausch and Dugger (1953) explained that borate

ions reacted with sugar molecules to form an ionizable sucrose-borax complex which moved through the cell readily than non-borated and non-ionizable sucrose molecules.

Rao and Khader (1960) found that the germination of sapota pollen was enhanced by the addition of 100 ppm boric acid to sucrose-agar (16 and 0.7 per cent medium). Vasil (1960) also observed that the effect of boric acid was most outstanding in certain cucurbitaceous crops. John and Vasil (1961) found that the effect of boron was far better than the effect of any known hormones, vitamines or other chemical substances. Varas and Sonia (1962) reported that addition of 1 to 100 ppm boric acid to 10 per cent sucrose with 2.0 per cent agar stimulated germination of cocoa pollen from 22 per cent to 42 to 43 per cent.

Jose and Magoon (1972) studied the effect of different culture media on pollen germination and tube growth in Dioscorea bulbifera. In 5.0 per cent sucrose solution, the pollen germination was found to be 34.5 per cent. The length of the tubes averages to 42.8 μ. By addition of 200 ppm boric acid to 5.0 per cent

sucrose solution, the pollen germination was enhanced to 85.5 per cent. The pollen tube attained an average length of 271 microns. Addition of 100 ppm calcium nitrate increased the pollen tube growth further.

Chemicals other than boron have also been reported to provide nutrition for the pollen grains in an artificial medium. The earlier workers like Lindforss (1896) and Brink (1924) found calcium nitrate to be toxic, even in small quantities, to pollen. On the other hand, Brewbaker and Kwack (1963), Kwack (1965), Jose and Magnoon (1972) and Ravindran (1977) reported that calcium nitrate, in fact, stimulated germination and growth of pollen tube.

The effect of growth regulators in enhancing the pollen germination and pollen tube elongation have been well established. Tsung and Tsung (1944) reported that Indole-3-acetic acid at low concentration was more effective than manganese sulphate or colchicine in promoting pollen germination and pollen tube growth. Indole-3-acetic acid at higher concentration was found to be grown inhibitory.

Sinha (1973) studied the effect of boron along with IAA and NAA at different concentrations on pollen

germination and found that 10 ppm IAA and 20 ppm boric acid were superior to the rest of the combinations.

Malik et al. (1977) explained auxins to be mobile food materials which enhanced the activity of hydrolysing enzymes which ultimately induced cell elongation.

Chandler (1957) observed differential effect of GA on pollen germination and pollen tube growth. When GA was added to sugar-agar medium, the germination and growth of pollen tube were not stimulated. Gibberellic acid in fact inhibited tube growth, caused coiling of pollen tubes, enlarged the tips of pollen tubes and even resulted in the exudation of cytoplasm in certain species of plants. But in some cases, he found that gibberellic acid medium gave good germination of pollen grains, which in the absence of gibberellins would have been considered as non-viable in artificial media like sucrose agar.

The fact that gibberellin caused cell elongation, was reported by Stowe and Yamaki (1957); Bose (1959); and Rao and Khader (1962). That the gibberellic acid at higher concentration inhibited pollen grain germination, at the same time increasing the pollen tube growth was

observed by Bose (1959); and Singh *et al*. (1961) in their experiments.

Alexander (1970) developed a method of germinating pollen grains of banana without any growth medium. He found that the fertile male bud when enclosed overnight in a polythene bag containing moist cotton wool, the humidity induced the pollen to germinate.

3.1.4. Pollen storage

A proper combination of factors such as low temperature, relative humidity and light has great bearing on pollen storage. Pollen storage methods have been studied in several crops (Pfundt, 1910; Knowlton, 1922; Dorosenko, 1928; Nebel and Ruttle, 1937; Maheswari, 1944 and Visser, 1955). Pfundt, (1910) found that most species maintained their pollen viability best at low relative humidity. The optimum storage temperature for pollen grains of deciduous fruit trees was reported to be around 30°F by King and Hesse (1938).

Nebel (1939) could successfully store the pollen of apple, pear, plum, peach and apricot for

2 to 2½ years in a desiccator over sulphuric acid under 50 per cent RH at 28°C. Vijayasaradhi (1939) found that sugarcane pollen stored in test tubes placed in a vacuum flask containing sulphuric acid and water exhibited increase in the storage life. Gollmick (1942) reported that longivity of pollen grain in most species was best maintained at a relative humidity between 6 and 60 per cent. He could store grape pollen for one year at 1°C and 40 to 50 per cent relative humidity without loosing viability.

Sinha (1973) observed that jack pollen grains could be stored for seven to eight months at 0°C under relative humidity of 50 to 1 per cent. Child (1974) found that coconut pollen dried at 40°C and kept over 43.4 per cent sulphuric acid in vacuum in sealed ampules at subzero temperature remained viable for more than one year.

Frankel and Galum (1977) reported that pollen of several crops retained their viability at low humidity, except in the case of trinucleate pollen. At very low temperature, pollen of apple, grape, tomato, potato, petunia and pine could be stored without loss of viability for more than one year.

Mishra and Shivanna (1982) reported that pollen grains of Crotolaria retusa, Lathyrus sativus, Pisum sativum, Trigonella foenumgraecum and Vicia faba could be successfully stored at controlled temperatures of 50°C and humidity upto 40 per cent. Organic solvents were found less suitable for the species they tried.

Griggs et al. (1953) concluded that pollen of plum, peach, apple, pear, cherry and olive could be stored in home-freezer at 18°C for one to three years. Storage of dried pollen of date palm in air tight containers at -18°C could be done successfully with little loss of viability from one season to the next. Singh (1962a) reported that litchi pollen stored under deep freeze condition at -23°C retained viability for 31 months. Mango pollen was stored for 14 months under deep freeze condition by Singh (1962b). Child (1974) opined that coconut pollen could be freeze dried and stored for long periods in sealed ampules for pollen exchange between distant countries.

Various reports on storage of pollen of fruit crops by dehydration and drying are available (Tatarincev and Ostrowhoa, 1950; Soost and Cameron, 1954; and Singh, 1961).

Sedov (1955) reported that apple pollen dried in shade and stored in desiccator over calcium chloride kept in darkness remained viable for long. Sajman and Kleeva (1964) found that apple pollen stored in desiccator, although did not germinate in an artificial medium, germinated satisfactorily on the stigmatic surface of female flower.

4. Cross-compatibility studies.

Systematic work on hybridization in banana was started in the 1920's in Trinidad and Jamaica, as reported by Simmonds (1966), Shepherd (1968) and Menendez and Shepherd (1975).

In both the places (Trinidad and Jamaica), when 'Gros Michel' as female parent was crossed with the wild strain of Musa acuminata sub sp. malaccensis, similar results were achieved.

Later, 'High gate', the somatic mutant of 'Gros Michel' also was used as female parent in Jamaica (Larter, 1947 and Osborne, 1961). The cross High gate x Pisang lilin produced more number of hands per bunch and the resultant hybrid was shorter and sturdier than the hybrids derived from the cross 'Gros Michel' x Pisang lilin.

Compatibility among several other clones has also been reported. Osborne (1962) found that the hybrid produced from the combination Gros Michel x Pisang lilin contained better bunch shape and larger fruits than the parental plants.

Borges (1971) observed that 'Bluggoe' clones with genomes ABB, when pollinated with wild diploids (2n = 22) Musa acuminata and Musa balbisiana, set seeds.

Hybridization work was undertaken in Tamil Nadu using 15 clones of cultivated bananas (triploids) and four species of Musa balbisiana (Raman et al., 1971). They reported many compatible clones in the cultivated bananas. Among the 28 combinations, except the hybrid Ney Vannan (ABB) x Musa balbisiana clone 'Sawai', all others were unthrifty and inferior. Hybrid Ney Vannan (ABB) x Musa balbisiana was found to be medium tall in stature, sturdy in appearance and yielded a heavy bunch with good round fruits while the female parent possessed only angular fruits. The fruits were devoid of seeds and developed parthenocarpically.

Rowe (1976) revealed that triploid plantains (AAB) were usually sterile; but he identified a fertile clone of the 'Laknau' type (AAB). He also found that

when 'Laknau' plants were pollinated by diploid types (AA), they produced normal tetraploids. The resultant tetraploid progeny, when crossed with diploid Musa acuminata, produced triploid hybrids. Stover et al. (1976) also reported similar results.

Azhakiamanavalan and Rao (1980) attempted hybridization in banana to develop a clone in place of 'Virupakshi' (grown extensively in lower Palneys), which was affected by 'bunchy top' disease. For this purpose, 'Ladan' was multiple crossed with Musa balbisiana and 'Kadali' (AA). The resultant hybrid, H135, phenotypically resembled 'Virupakshi'.

In an attempt to produce nematode resistant hybrids in place of 'Matti'(AA) grown extensively in Kanyakumari, crosses involving nematode resistant clones 'Anai Komban' (AA) and 'Tongat'(AA) were made (Anon; 1982). Among the inter-diploid hybrids (AA genomes), Musa acuminata x Musa laterita, Matti x Tongat (H.109 and H.110), Matti x Pisang lilin (H.79), Matti x Namarai (H.88), Matti x Anaikomban, Matti x Musa acuminata (H.21) and Tonget x Ambalakadali, two hybrids Matti x Pisang lilin (H.74) and Matti x Tongat (H.109) were found to be nematode resistant and retained the character of 'Matti'.

Materials and Methods

MATERIALS AND METHODS

The studies reported in the thesis were conducted in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the years 1982 and 1983. The banana clones maintained in the germplasm block at the College of Horticulture and the Banana Research Station, Kannara were made use of for the study.

The main aspects of study consisted of morphology, production, and viability of pollen as well as compatibility studies in the banana clones belonging to different genomic groups.

Clones used for pollen studies.

AA group	AB group	BB group
Ambalakadali	Adukkan	Elavazhai
Chingan	Lady's finger	
Erachivazhai	Njali poovan	
Matti		
Namarai		
Pachachingan		
Pisang lilin		
Pisang mas		
Sanna chenkadali		
Sikuzani		
Tongat		

AAA group	AAB group	ABB group
Agniswar	Adkka Kunnan	Alukehel
Basrai	Chetti	Ashy batheesa
Burharia	Chinali	Bluggoe
Chinia	Dakshin sagar	Boodi
Dudhsagar	Kaali	Chirapunchi
Galanamalu	Kapur	Enna benian
Gros Michel	Krishna vazhai	Kallu monthan
Harichal	Kullan	Kapok
High gate	Malai monthan	Karim bontha
Malakali	Mannan	Karpooravally
Manoranjitham	Nendra Kunnan	Kostha bontha
Mauritius	Palayankodan	Nalla bontha
Padathi ponnani	Pisang seribu	Nanguneri peyan
Red Banana	Poomkalli	Pacha bontha bathees
Red Jasirna	Sirumalai	Peyan
Sapumal anamalu	Sungandhi	Sawai
Wather	Suwandal	Venneettu mannan
	Thiruvanthapuram	
	Vannan	
	Walha	

AAAA group	ABBB group
Bodles Altafort	Hybrid Sawai
	Neyvannan sawai

Compatibility studies

Twenty six clones as given below were used for compatibility studies.

Female parents

AA group	AAA group	AAB group
Pachachingan	Agniswar	Karim kadali
	Amrit sagar	Krishna vazhai
	Harichal	Mannan
	Lacatan	Motta poovan
	Malakali	Nendran
	Padali moongil	Nandra vannan
	Padathi ponnani	Pacha naadan
	Pedda pacha	Palayankodan
	Vamanakeli	Vannan
		Zanzibar

Male parents

AA group	AAB group	AAAA group
Pisang lilin	Pisang seribu	Bodles Altafort
Namarai		
Sikuzani		
Tongat		

1. Duration of female and male phases

As a basis for future hybridization programmes, data were collected on the female phase and male phase of the clones used as female parents in the compatibility studies.

The opening of the first bract of the inflorescence was considered as the beginning of the female phase. In some cases, the first bracts did not possess any female flowers. In such cases, only when the female flowers were seen it was considered as the beginning of the female phase.

Opening of bracts was observed daily on the same plant until the completion of the female phase. The data on the number of bracts opened every day and the number of flowers per bract were also recorded.

The female phase was taken as complete when male flower production commenced. The male flowers were distinguished by their under developed stigma and ovary (Plate 1).

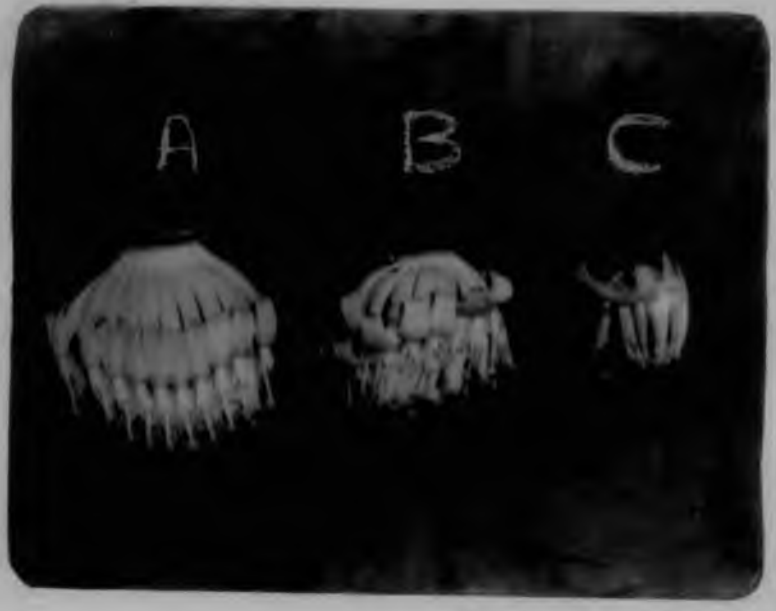
Plate 1

Types of flowers in banana

A. Female flowers

B. Female and male (Three male flowers on the right side of the hand)

C. Male flowers


A
B
C

Male phase

The date of opening of the first bract containing male flowers and the date of persistence of the last such bract were recorded. The time interval between these two was considered as the male phase.

Total duration.

The total duration of all the 84 clones used for different studies were recorded.

2. Pollen studies

The pollen studies consisted of pollen morphology, fertility, productivity and storage. These studies were conducted during the period from July, 1982 to September 1982.

2.1. Collection of pollen

Pollen grains were collected by scrapping the anthers, which were about to dehisce, using a blunt needle moving transversely along the lobe of the anther caring not to scrape the tissue.

2.2. Pollen morphology

Fresh pollen grains mounted on glass slides were

examined under high power of the microscope (10 x 40) for the colour and the nature of exine and intine.

The extracted pollen grains were mounted on glass slides and stained with 0.5 per cent acetocarmine. A few drops of glycerin were added and the pollen grains were covered with clean zero cover glass. The slides were kept as such for 30 minutes. Diameter of 45 well developed normal pollen grains was measured using a standardized occular micrometer under low power of the microscope (10 x 10). The mean diameter of pollen grain was expressed in microns.

For studying the shape of the pollen grains, the same slides were used. Observations were taken under high power magnification (10 x 40).

2.3. Pollen production

For estimating pollen production the methodology as adopted by Oberle and Geortzen (1952) 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 the pollen grains. The anthers were crushed with the edge of a glass rod in order to suspend

all the pollen grains properly. The contents were thoroughly shaken.

Pollen counts were made as per the procedure adopted by Rao and Khader (1962). Two drops of the suspension were pipetted and placed on each of the counting chambers of the Newbauer Improved Double Haemocytometer. The chambers consisted of nine equal squares each measuring 1 mm sq. The four corner squares (ie. the counting chamber) were ruled into 16 smaller divisions. The counting chamber was 0.1 mm in depth and could hold 0.1 mm^3. The number of pollen grains per anther was calculated as follows.

The contents of 10 anthers were suspended in 2.5 ml of solution. Therefore, 0.25 ml solution will have the contents of one anther.

For calculation, the following formula was adopted.

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

X = number of grains/anther,

Then, N : X = 0.1 : 250

Therefore, $0.1\ X = N \times 250$

and $X = 2500\ N$

For each clone, three such estimates were made and their mean value expressed as pollen production capacity of the clone.

2.4. Pollen viability

Viability of pollen grains was studied by mounting the pollen grains on glass slides in acetocarmine staining medium as well as by germinating the pollen grains in artificial media. Pollen viability was assessed only in 53 clones which were identified as pollen producers (in the studies on pollen production).

2.4.1. Acetocarmine staining technique

The collected pollen grains were spread over microscopic slides with a drop of acetocarmine glycerine medium, kept for 30 minutes for proper staining and examined under the low power of a microscope (10 x 10). 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 clone, three microscopic slides were prepared. Five fields from each slide were observed, and the values averaged. Viability of pollen grains was thus expressed as percentage.

2.4.2. Germination of pollen grains *in vitro* - Standardization of the media.

The following media were used for standardization.

1. Agar at 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 per cent concentrations.
2. Sucrose at 2, 4, 6, 8, 10, 12 and 14 per cent concentrations.

From among the pollen producing clones, the clone 'Elavazhai' which represented the prolific of pollen production group was selected for germination tests.

The pollen grains were spread over clean microscopic slides and a few drops of the prepared media were placed over them. The slides were kept on moist filter paper in petridishes, which were thus kept in a desiccator containing water to provide enough humidity for the pollen grains to germinate. The slides were examined (for pollen germination and pollen tube length simultaneously) every two hours until the pollen germination started.

In all the cases, five fields at random were examined on each slide to give about 100 pollen grains as an average.

Since maximum percentage of pollen germination was obtained from sucrose 12 per cent, it was used for detailed studies on pollen germination and tube growth. The slides were examined periodically for pollen germination and when the germination started they were examined at two hourly intervals till no further germination of pollen grains was obtained.

Effect of boric acid on pollen germination and pollen tube length

To study the effect of boric acid on pollen germination and tube growth boric acid at different concentrations (2, 4, 6, 8, 10, 12 and 14 ppm) was added to 12 per cent sucrose medium. Pollen grains were dusted on the medium on a slide. Based on the observations made while standardizing the medium, pollen germination and pollen tube length were recorded after 26 hours.

Fertility of pollen grains was expressed as the percentage of germinated pollen out of the total number. The pollen tube length was expressed in microns.

2.5. Pollen storage

The clones, 'Elavazhai', 'Wather', 'Bodles Altafort' and 'Hybrid Sawai' which showed higher percentage of pollen

viability were used for pollen storage studies.

The storage methods consisted of the following.

A. Open storage at room temperature (20.0°C to 33.2°C) at 92 per cent RH (Control).

B. In desiccator over calcium chloride at room temperature (30°C) and 6 per cent RH.

C. In refrigerator at 4°C and 40 per cent RH.

D. In desiccator over calcium chloride in refrigerator at (17°C to 7°C) temperature and 6 per cent RH.

The bracts along with flowers were collected just before anther dehiscence and kept under the different conditions of storage.

Pollen grains were collected from each treatment and were tested for their viability by acetocarmine staining test, every day. Three slides were prepared for each sample and in each slide, five fields at random were examined to assess the viability. The pollen viability was expressed in percentage.

3. Compatability studies

3.1. Technique of crossing

The inflorescences were bagged two to three days

before the anticipated opening of the first bract. Muslin cloth bags (0.5 x 1.0 m) were used for this purpose.

From the flowers of male parents opened on the day of crossing, anthers were collected just prior to dehiscence. Crosses were made between 7.00 am to 10.00 am. Since the 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 the inflorescences were examined to see whether or not the bracts containing female flowers were opened. The stigma of female flowers were tested for their receptivity, by finger touch. The stickiness of the stigma indicated receptivity. The pollen grains taken out with the help of camel hair brush were smeared over the receptive stigma of the female flowers. In some cases, in which receptivity was doubtful, the first day, hand pollination was repeated the next morning also. The stigma which had lost receptivity turned bluish brown. The inflorescences were rebagged after pollination in order to prevent any possible cross pollination by insects or wind. The details of crossings were tagged on to the female parents. The following crosses were made.

Sl. No.	Female parent	Male parent	No. of flowers pollinated
	Diploid x Diploid		
1.	Pachachingan (AA)	Pisang lilin (AA)	135
	Triploid x Diploid		
2.	Vamanakeli (AAA)	Namarai (AA)	84
3.	Vamanakeli (AAA)	Pisang lilin (AA)	82
4.	Agniswar (AAA)	Pisang lilin (AA)	230
5.	Padali moongil (AAA)	Pisang lilin (AA)	99
6.	Padathi ponnani (AAA)	Pisang lilin (AA)	230
7.	Pedda pacha (AAA)	Pisang lilin (AA)	323
8.	Harichal (AAA)	Pisang lilin (AA)	283
9.	Amrit sagar (AAA)	Pisang lilin (AA)	134
10.	Amrit sagar (AAA)	Namarai (AA)	66
11.	Malakali (AAA)	Pisang lilin (AA)	249
12.	Lacatan (AAA)	Pisang lilin (AA)	287
13.	Motta poovan (AAB)	Pisang lilin (AA)	181
14.	Palayankodan (AAB)	Pisang lilin (AA)	559
15.	Palayankodan (AAB)	Sikuzani (AA)	684
16.	Palayankodan (AAB)	Tongat (AA)	788
17.	Pacha naadan (AAB)	Pisang lilin (AA)	159
18.	Nendra vannan (AAB)	Pisang lilin (AA)	170
19.	Krishna vazhai (AAB)	Pisang lilin (AA)	148
20.	Karim Kadali (AAB)	Pisang lilin (AA)	109
21.	Zanzibar (AAB)	Pisang lilin (AA)	48
22.	Mannan (AAB)	Pisang lilin (AA)	176
23.	Nendran (AAB)	Sikuzani (AA)	116
24.	Vannan (AAB)	Pisang lilin (AA)	151
	Triploid x Triploid		
25.	Zanzibar (AAB)	Pisang seribu (AAB)	41
	Triploid x Tetraploid		
26.	Nendra vannan (AAB)	Bodles Altafort (AAAA)	100
27.	Harichal (AAA)	Bodles Altafort (AAAA)	138

4. Seed extraction

The fully mature bunches were harvested and ripened in the room. The ripe fingers were longitudinally cut with the help of a knife and were examined for seeds. The seeds when present were extracted carefully, washed in tap water and sown immediately in a mixture of sand and soil contained in earthen pot for germination.

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

5. Statistical analysis

Statistical analysis was done following the methods outlined by Snedecor and Cochran (1967).

Results

RESULTS

The observations made on the duration of female and male phases, the number of bracts opened per day, the total duration from planting to harvest, pollen studies and comptibility of banana clones are presented below.

Duration of female and male phases

Observations made on the female and male phases, number of bracts opened per day during the female phase of the twenty clones selected for the study as female parents are summarised in Table 1.

The following comparisons were made.

1. The diploids vs. the triploids.
2. The genomic groups in the diploids and in each genomic group, the different clones.
3. The genomic groups in the triploids and in each genomic group, the different clones.

Duration of female phase

When the diploids and the triploids were compared it was found that diploids took lesser time for the commencement of the female phase than the triploids

Table 1. Duration of female and male phases and the pattern of bract opening in banana clones

Sl. No.	Clones		Days taken from planting to commencement	Female phase duration (days)	Male phase duration (days)	No. of bracts opened per day
1	2		3	4	5	6
1.	Pachachingan	AA	292.0	5.5	97.5	1 - 2
2.	Agniswar	AAA	300.0	3.7	90.6	0 - 4
3.	Amrit sagar		304.7	3.3	63.0	1 - 2
4.	Harichal		323.0	4.3	77.7	0 - 4
5.	Lacatan		346.7	3.7	71.6	0 - 4
6.	Malakali		313.3	4.7	85.6	0 - 3
7.	Padali moongil		293.0	2.5	-	1 - 4
8.	Padathi ponnani		290.7	5.3	117.0	1 - 3
9.	Pedda pacha		307.7	5.3	71.0	1 - 3
10.	Vamanakeli		296.0	5.5	72.5	0 - 2
	Mean of AAA		308.3	4.3	81.3	

contd...

Table 1 contd...

1	2		3	4	5	6
11.	Karim kadali	AAB	332.0	5.0	57.0	0 - 3
12.	Krishna vazhai		311.0	3.5	106.0	0 - 3
13.	Mannan		321.8	6.5	96.0	0 - 2
14.	Motta poovan		340.5	7.0	80.0	1 - 2
15.	Nendran		235.0	2.0	86.0	1 - 3
16.	Nendra vannan		330.0	6.0	80.0	0 - 4
17.	Pacha naadan		311.5	6.5	99.0	0 - 2
18.	Palayankodan		320.1	7.7	79.5	0 - 3
19.	Vannan		291.2	4.5	112.5	1 - 2
20.	Zanzibar		322.7	1.8	79.5	1 - 3
	Mean of AAB		311.5	5.1	87.6	
	Mean of triploids		309.9	4.72	84.8	

(292.0 and 309.9 days respectively). The mean duration of the female phase was more in the diploids (5.50 days) than in triploids (4.72 days).

In the diploids the clone 'Pachachingan' belonging to the genomic group AA took 292 days to reach the female phase which extended to 5.5 days.

Among the triploids, the female phase commenced by 311.5 days after planting in AAB group while in AAA group the clone reached the female phase earlier (308.3 days after planting). Mean duration of the female phase was also more in AAB (5.1 days) than in AAA group (4.3 days).

Comparison of the clones within AAB group showed that 'Nendran' took the minimum time for the commencement of the female phase (235.0 days) while 'Motta poovan' recorded the maximum (340.5 days). Duration of the female phase was the least in 'Zanzibar' (1.8 days) and the maximum in 'Palayankodan' (7.7 days).

Among the clones in AAA group, the female phase started 290.7 days after planting in 'Padathi Ponnani' which was the minimum. In 'Lacatan', the female phase started by 346.7 days, which was the maximum. Duration of the female phase was the least in 'Padali moongil'

(2.5 days) among the clones in AAA group and the maximum in 'Vamanakeli' (5.5 days).

The number of bracts opened per day during the female phase was not constant and the pattern was irregular. In AA group, it ranged from one to two per day in 'Pachachingan', in AAB group 0 to 2 in 'Pacha naadan' and 'Mannan' to 0 to 4 in 'Nendra vannan' per day and in AAA group 0 to 2 in 'Vamanakeli' to 0 to 4 in 'Agniswar', 'Harichal' and 'Lacatan' per day.

Duration of male phase

The duration of the male phase was found to be more in diploids (97.5 days) than in triploids (84.8 days). In the diploids, the clone 'Pachachingan' belonging to AA group remained for 97.5 days in the male phase.

Within the triploids, the duration of the male phase in AAB group was found to be 87.6 days, which was higher than the duration of the male phase in AAA group (81.3 days).

Among the clones in AAB group 'Karim kadali'

recorded the shortest duration of the male phase (57.0 days), while 'Vannan' recorded the longest duration (112.5 days).

Among the clones in AAA group, the duration of the male phase ranged from 63.0 days in 'Amrit sagar' to 117.0 days in 'Padathi ponnani'.

Total duration

The total duration of the clones which were used for compatibility studies and pollen studies are given in Table 2a.

The tetraploids recorded the maximum duration (423 days) compared to the triploids (402.5 days) or the diploids (398.7 days).

Among the diploids, BB had the longest duration (435.0 days) than AB group (430.3 days) or AA group (388.7 days).

In the case of clones of AA group, the minimum duration was in 'Pisang mas' (323.0 days) and maximum in 'Namarai' (445.0 days). Within AB group the minimum duration was in the case of 'Njali poovan' (426.5 days) and maximum in the case of 'Adukkan' (433.5 days). In

Table 2(a). Total duration of banana clones arranged according to genomic group

Sl. No.	Clones		Genomic groups	Total no. of days from planting to harvest
1	2		3	4
1.	Ambalakadali	X		415.3
2.	Chingan	X		370.5
3.	Erachivazhai	X		377.0
4.	Matti	X		387.0
5.	Namarai	X		445.0
6.	Pachachingan	X		395.0
7.	Pisang lilin	X	AA	333.0
8.	Pisang mas	X		323.0
9.	Sanna chenkadali	X		434.0
10.	Sikuzani	X		430.5
11.	Tongat	X		364.0
	Mean of AA group			388.7
12.	Adukkan	X		433.5
13.	Lady's finger	X	AB	431.0
14.	Njali poovan	X		426.5
	Mean of AB group			430.3
15.	Elavazhai		BB	435.0
	Mean of diploids			398.7
16.	Agniswar	X		394.3
17.	Amrit sagar	X		371.0
18.	Basrai	X		427.0
19.	Burharia	X		435.0

Table 2(a) contd...

1	2	3	4
20.	Chinia		268.0
21.	Dudhsagar		445.0
22.	Galanamalu		354.0
23.	Gros Michel		437.2
24.	Harichal		405.0
25.	High gate		417.8
26.	Lacatan		422.0
27.	Malakali		403.6
28.	Manoranjitham	AAA	329.5
29.	Mauritius		362.4
30.	Padali moongil		429.5
31.	Padathi ponnani		413.0
32.	Pedda pacha		384.0
33.	Red Banana		473.0
34.	Red jasirna		408.0
35.	Sapumal anamalu		395.5
36.	Vamanakeli		374.0
37.	Wather		380.0
	Mean of AAA group		396.7
38.	Adakka Kunnan		346.5
39.	Chetti		423.3
40.	Chinali		433.0
41.	Dakshin sagar		446.0
42.	Kaali	AAB	412.2
43.	Kapur		326.0
44.	Karim kadali		394.0
45.	Krishna Vazhai		420.5

Table 2(a) contd...

1	2	3	4
46.	Kullan		421.4
47.	Malai monthan		408.5
48.	Mannan		424.3
49.	Motta poovan		427.5
50.	Nendra Kunnan		408.8
51.	Nendran		323.0
52.	Nendra vannan		416.0
53.	Pacha naadan		417.6
54.	Palayankodan	AAB	407.3
55.	Pisang seribu		391.0
56.	Poomkalli		332.5
57.	Sirumalai		424.0
58.	Sugandhi		434.0
59.	Suwandal		429.5
60.	Thiruvanthapuram		421.0
61.	Vannan		408.2
62.	Walha		332.0
63.	Zanzibar		404.0
	Mean of AAB group		401.2
64.	Alukehal		441.5
65.	Ashy batheesa		426.3
66.	Bluggoe		428.0
67.	Boodi	ABB	445.0
68.	Chirapunchi		347.5
69.	Enna benian		400.3
70.	Kallu monthan		443.0

Table 2(a) contd...

1	2		3	4
71.	Kapok	X		327.5
72.	Karim bontha	X		429.6
73.	Karpooravally	X		342.0
74.	Kostha bontha	X		420.0
75.	Nalla bontha	X	ABB	441.0
76.	Nanguneri payan	X		445.0
77.	Ney mannan	X		449.0
78.	Pacha bontha bathees	X		436.5
79.	Peyan	X		435.7
80.	Sawai	X		402.0
81.	Venneettu mannan	X		350.5
	Mean of ABB group			411.7
	Mean of triploids			402.5
82.	Bodles Altafort		AAAA	404.0
83.	Hybrid Sawai	X	ABBB	436.8
84.	Ney vannan sawai	X		428.3
	Mean of ABBB			432.6
	Mean of tetraploid			423.0

the case of BB group only one clone ('Elavazhai') was included in the study and this exhibited a duration of 435.0 days.

Among the triploids, clones of ABB group recorded the maximum total duration (411.7 days) followed by AAB group (401.2 days) and AAA group (396.7 days).

The total duration of the clones in AAA group ranged from 268.0 days (Chinia) to 473.0 days (Red Banana). In the case of AAB group, the total duration ranged from 323.0 days in 'Nendran' to 446.3 days in 'Dakshin sagar'. In the case of ABB group, it ranged from 327.5 days in 'Kapok' to 449.0 days in 'Walha'.

Among tetraploids, ABBB group had highest duration (432.6 days) than the AAAA group (404.0 days).

The total duration of clones arranged in ascending order are given in Table 2b. The total duration varied from 268 days in 'Chinia' to 473 days in 'Red Banana'.

2. Pollen studies

Seventy two clones were taken for pollen studies. Of these, 19 clones viz., 'Ambalakadali', 'Pacha chingan',

Table 2(b). Total duration of banana clones arranged in ascending order

Sl. No.	Clones		Total no. of days from planting to harvest
1	2		3
1.	Chinia	(AAA)	268.0
2.	Pisang mas	(AA)	323.0
3.	Nendran	(AAB)	323.0
4.	Kapur	(AAB)	326.0
5.	Kapok	(ABB)	327.5
6.	Manoranjitham	(AAA)	329.5
7.	Walha	(AAB)	332.0
8.	Poomkalli	(AAB)	332.5
9.	Pisang lilin	(AA)	333.0
10.	Karpooravally	(ABB)	342.0
11.	Adakka Kunnan	(AAB)	346.5
12.	Chirapunchi	(ABB)	347.5
13.	Venneettu mannan	(ABB)	350.5
14.	Galanamalu	(AAA)	354.0
15.	Mauritius	(AAA)	362.4
16.	Tongat	(AA)	364.0
17.	Chingan	(AA)	370.5
18.	Amrit sagar	(AAA)	371.0
19.	Vamanakeli	(AAA)	374.0
20.	Erachivazhai	(AA)	377.0
21.	Wather	(AAA)	380.0
22.	Pedda pacha	(AAA)	384.0
23.	Matti	(AA)	387.0
24.	Pisang seribu	(AAB)	391.0
25.	Karim kadali	(AAB)	394.0

Table 2(b) contd...

1	2		3
26.	Agniswar	(AAA)	394.3
27.	Pachachingan	(AA)	395.0
28.	Sapumal anamalu	(AAA)	395.5
29.	Enna benian	(ABB)	400.3
30.	Sawai	(ABB)	402.0
31.	Malakali	(AAA)	403.6
32.	Zanzibar	(AAB)	404.0
33.	Bodles Altafort	(AAAA)	404.0
34.	Harichal	(AAA)	405.0
35.	Palayankodan	(AAB)	407.3
36.	Red gasirna	(AAA)	408.0
37.	Vannan	(AAB)	408.2
38.	Malai monthan	(AAB)	408.5
39.	Nendra Kunnan	(AAB)	408.8
40.	Kaali	(AAB)	412.2
41.	Padathi ponnani	(AAA)	413.0
42.	Ambalakadali	(AA)	415.3
43.	Nendra Vannan	(AAB)	416.0
44.	High gate	(AAA)	417.3
45.	Pacha naadan	(AAB)	417.6
46.	Kostha bontha	(AAB)	420.0
47.	Krishna vazhai	(AAB)	420.5
48.	Thiruvanthapuram	(AAB)	421.0
49.	Kullan	(AAB)	421.4
50.	Lacatan	(AAA)	422.0
51.	Chetti	(AAB)	423.3
52.	Sirumalai	(AAB)	424.0
53.	Mannan	(AAB)	424.3
54.	Ashy batheesa	(ABB)	426.3

Table 2(b) contd...

1	2		3
55.	Njali poovan	(AB)	426.5
56.	Basrai	(AAA)	427.0
57.	Motta poovan	(AAB)	427.0
58.	Bluggoe	(ABB)	428.0
59.	Ney vannan sawai	(ABBB)	428.3
60.	Suwandal	(AAB)	429.5
61.	Padali moongil	(AAA)	429.5
62.	Karim bontha	(ABB)	429.6
63.	Sikuzani	(AA)	430.5
64.	Lady's finger	(AB)	431.0
65.	Chinali	(AAB)	433.0
66.	Adukkan	(AB)	433.5
67.	Sanna cherukadali	(AA)	434.0
68.	Sugandhi	(AAB)	434.0
69.	Elavazhai	(BB)	435.0
70.	Burharia	(AAA)	435.5
71.	Peyan	(ABB)	435.7
72.	Pacha bontha bathees	(ABB)	436.5
73.	Hybrid Sawai	(ABBB)	436.8
74.	Gros Michel	(AAA)	437.2
75.	Nalla bontha	(ABB)	441.0
76.	Alukehal	(ABB)	441.5
77.	Kallu monthan	(ABB)	443.0
78.	Namarai	(AA)	445.0
79.	Dudhsagar	(AAA)	445.0
80.	Boodi	(ABB)	445.0
81.	Nangumeri peyan	(ABB)	445.0
82.	Dakshin sagar	(AAB)	446.3
83.	Neymanan	(ABB)	449.0
84.	Red Banana	(AAA)	473.0

'Adukkan', 'Lady's finger', 'Njali poovan', 'Agniswar', 'Malakali', 'Padathi ponnani', 'Red jasirna', 'Adakka Kunnan', 'Kaali', 'Krishna vazhai', 'Kullan', 'Mannan', 'Nendra Kunnan', 'Poomkalli', 'Sirumalai', 'Vannan', and 'Enna benian' did not produce pollen. The remaining 53 clones were used for studies in pollen morphology, size, production and fertility. For pollen storage four clones 'Elavazhai', 'Wather', 'Bodles Altafort' and 'Hybrid Sawai' were used.

2.1. Pollen morphology

The pollen grains of all the banana clones studied appeared as creamy white powdery mass to the naked eye. In general the grains were spherical and some oval. However few pollen appeared ovoid. The exine and intine were clearly visible. The exine was smooth and uniform in thickness.

2.2. Pollen size

The observations on the size of the pollen grains of the 53 clones are given in Table 3.

Comparisons were made among the different ploidy groups. The genomic groups under each ploidy

Table 3. Variation in pollen size in different clones

Sl. No.	Clones		Size of the pollen (μ) Range	Means
1	2		3	4
1.	Chingan		88.88 - 144.43	118.10
2.	Erachivazhai		66.66 - 155.54	120.55
3.	Matti		99.99 - 155.54	120.32
4.	Namarai		111.10 - 166.65	138.65
5.	Pisang lilin	AA	111.10 - 155.54	120.87
6.	Pisang mas		77.77 - 133.32	111.99
7.	Sanna Chenkadali		88.88 - 123.43	105.32
8.	Sikuzani		88.88 - 133.32	110.43
9.	Tongat		99.99 - 133.32	120.87
	Mean of AA group			118.57
10.	Elavazhai	BB	88.88 - 111.10	100.88
	Mean of diploids			116.80
11.	Basrai		88.88 - 144.43	126.97
12.	Burharia		88.88 - 133.32	111.44
13.	Chinia		88.88 - 211.09	122.65
14.	Dudhsagar		77.77 - 144.43	118.21
15.	Galanamalu		88.88 - 211.09	137.21
16.	Gros Michel		111.10- 222.20	147.43
17.	Harichal	AAA	88.88 - 155.54	131.99
18.	High gate		99.99 - 166.65	139.54
19.	Manoranjitham		88.88 - 177.76	133.32
20.	Mauritius		111.10 - 177.76	148.65
21.	Red Banana		88.88 - 166.65	127.41
22.	Sapumal anamalu		88.88 - 144.43	118.76
23.	Wather		88.88 - 144.43	120.21
	Mean of AAA group			129.52

Table 3 contd...

1	2		3	4
24.	Chetti		88.88 - 144.43	111.65
25.	Chinali		99.99 - 144.43	120.88
26.	Dakshin sagar		77.77 - 133.32	113.88
27.	Kapur		77.77 - 133.32	109.32
28.	Malai monthan		77.77 - 133.32	109.32
29.	Palayankodan	AAB	99.99 - 166.65	120.41
30.	Pisang seribu		88.88 - 144.43	114.65
31.	Sugandhi		77.77 - 166.65	129.99
32.	Suwandal		122.21 - 188.87	149.32
33.	Thiruvanthapuram		88.88 - 155.54	117.88
34.	Walha		77.77 - 155.54	120.21
	Mean of AAB group			120.45
35.	Alukehel		77.77 - 133.32	105.54
36.	Ashy batheesa		77.77 - 166.65	115.32
37.	Bluggoe		88.88 - 177.76	119.77
38.	Boodi		66.66 - 144.43	108.99
39.	Chirapunchi		111.10 - 188.87	140.87
40.	Kallu monthan		88.88 - 166.65	111.29
41.	Kapok	ABB	77.77 - 144.43	111.97
42.	Karim bontha		88.88 - 177.76	122.21
43.	Karpooravally		111.10 - 199.98	156.87
44.	Kostha bontha		88.88 - 155.54	124.43
45.	Nalla bontha		77.77 - 144.43	103.99
46.	Nanguneri peyan		144.43 - 222.20	179.09
47.	Pacha bontha bathees		77.77 - 133.32	105.10
48.	Peyan		55.55 - 144.43	103.97
49.	Sawai		88.88 - 144.43	112.43
50.	Vennaettu mannan		66.66 - 144.43	99.21
	Mean of ABB group			120.06

Table 3 contd...

1	2	3		4
	Mean of triploids			123.24
51.	Bodless Altafort	AAAA	111.10 - 177.76	147.98
52.	Hybrid Sawai X Y	ABBB	111.10 - 155.54	133.31
53.	Ney vannan sawai X		88.88 - 155.54	127.53
	Mean of ABBB group			130.42
	Mean of tetraploids			136.27
	F' test			Sig.
	F' test Diploid and triploid			Sig.
	Diploid and tetraploid			Sig.
	Triploid and tetraploid			Sig.
	AAA and AAB			Sig.
	AAA and ABB			Sig.
	AAB and ABB			NS
	C.D. (0.05)			23.055
	C.D. (0.05) to compare diploid and triploid			5.764
	" diploid and tetraploid			10.731
	" triploid and tetraploid			9.759
	" AAA and AAB			6.679
	" AAA and ABB			6.087
	" AAB and ABB			4.915

Means of pollen size arranged in discending order

1. AA means

T_4	T_9	T_5	T_2	T_3	T_1	T_6	T_8	T_7
138.65	120.87	120.37	120.55	120.32	118.19	111.99	110.43	105.32

2. AAA means

T_{20}	T_{16}	T_{18}	T_{15}	T_{19}	T_{17}	T_{21}	T_{11}	T_{13}	T_{23}	T_{22}	T_{14}	T_{12}
148.65	147.43	139.54	137.21	133.32	131.99	127.41	126.97	122.65	120.21	118.76	118.21	114.44

3. AAB means

T_{32}	T_{31}	T_{25}	T_{29}	T_{34}	T_{33}	T_{28}	T_{30}	T_{26}	T_{24}	T_{27}
149.32	129.99	120.88	120.41	120.21	117.88	116.77	114.65	113.88	111.65	109.32

4. ABB means

T_{46}	T_{43}	T_{39}	T_{44}	T_{42}	T_{37}	T_{36}	T_{49}	T_{41}	T_{40}	T_{38}	T_{35}	T_{47}	T_{45}	T_{48}	T_{50}
179.09	156.87	140.37	124.43	122.21	119.77	115.32	112.43	111.97	111.29	108.99	105.54	105.10	103.99	103.97	99.21

levels were also compared among themselves in respect of the size of pollen grains (Plate 2 to 4).

The size of the pollen grains significantly varied among the different ploidy levels. Tetraploids produced the largest pollen grain (136.27 µ) followed by triploids (123.24 µ) and diploids (116.80µ).

Among the diploids pollen grains of AA group were bigger (118.57 µ) than those of BB group (100.88 µ).

The diameter of pollen grains of clones belonging to AA group ranged from 105.32 u in 'Sanna chenkadali' to 138.65 µ in 'Namarai', while in the case of 'Elavazhai' (BB group) the diameter was 100.88 µ.

Among the triploids, the diameter of the pollen grains of AAA group was significantly higher (129.52 µ) than that of AAB group (120.45 µ) or ABB group (120.06µ). Between AAB and ABB group the difference of pollen size was not significant.

Among clones in the AAA group size of the pollen grains ranged from 111.44 µ in 'Burharia' to 148.65 µ in 'Mauritius'. In the clones within AAB group the size of the pollen grains ranged from 109.32 µ in 'Kapur' to

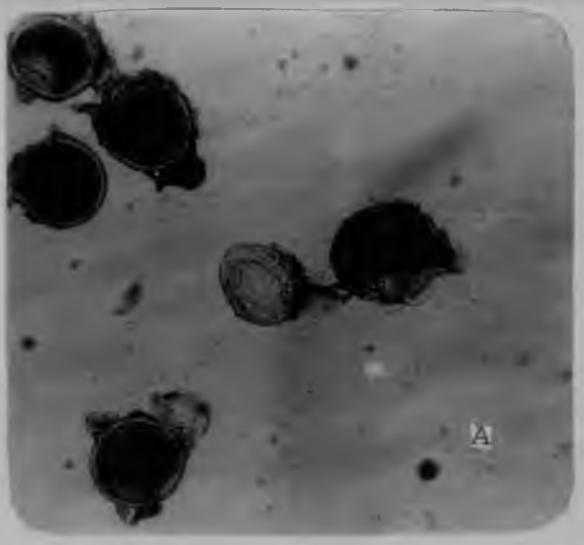
Plate 2 - 4

Pollen grains of the different clones belonging to different genomic groups (x 300)

Plate 2 Pollen grains of diploids

A. Chingan (AA)

B. Elavazhai (BB)


A

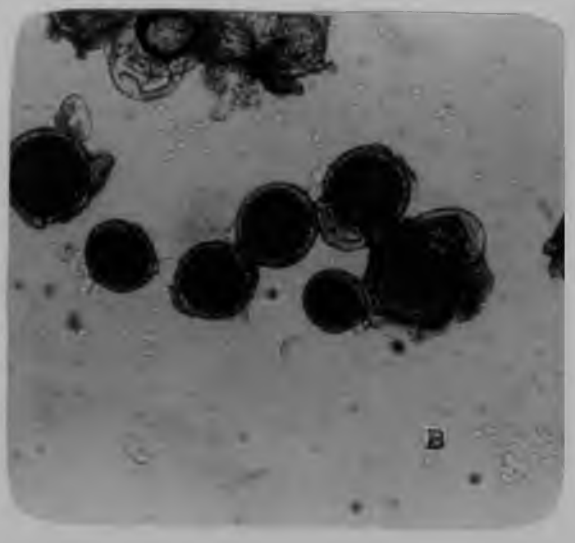
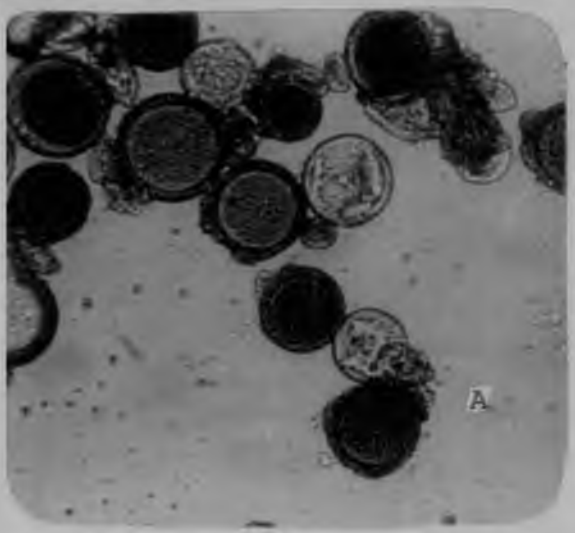

B

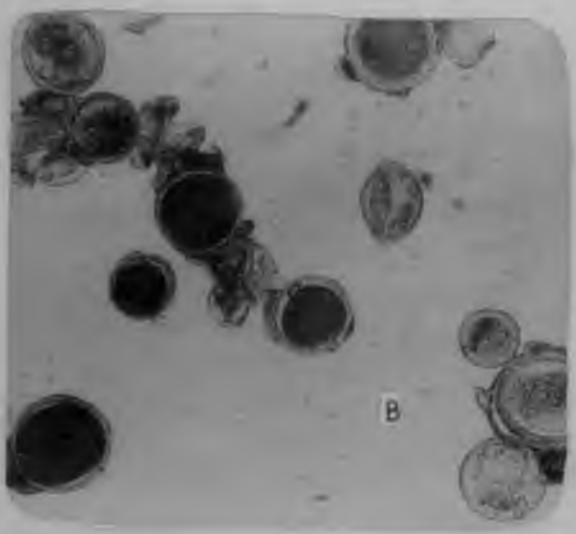
Plate 3 Pollen grains of triploids

A. Red Banana (AAA)

B. Walha (AAB)

C. Bluggoe (ABB)


A


B

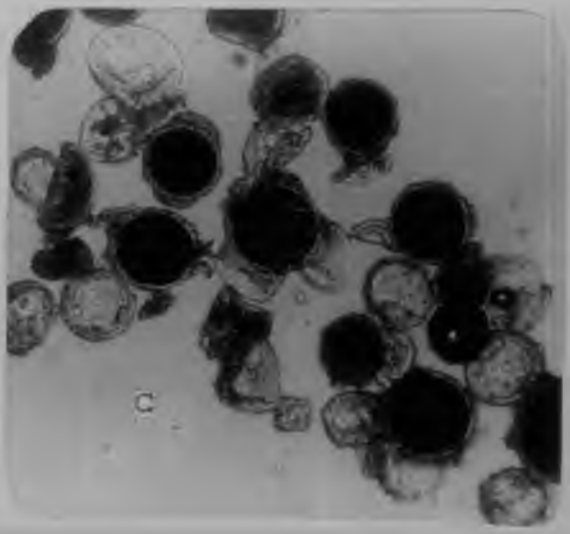
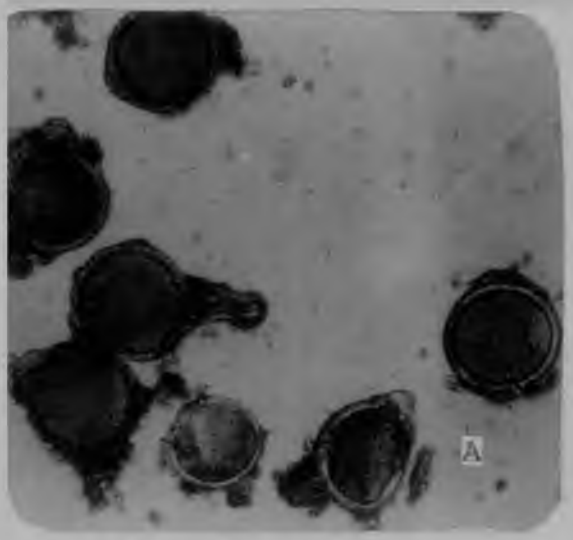
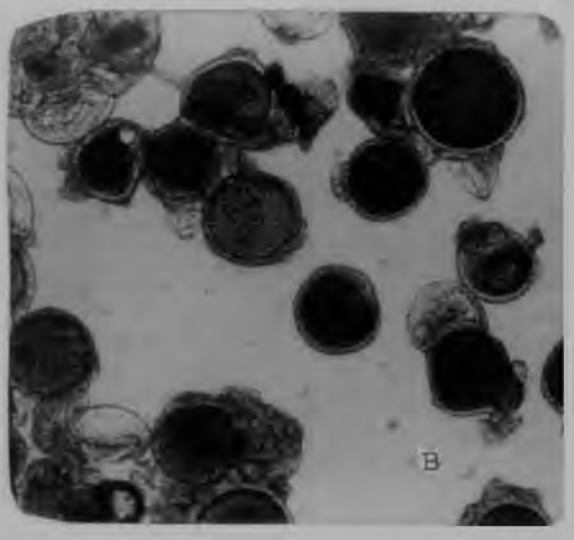

C

Plate 4 Pollen grains of tetraploids

A. **Bodles Altafort (AAAA)**

B. **Hybrid Sawai (ABBB)**


A


B

149.32 µ in 'Suwandal' and among the clones of ABB group it ranged from 99.21 µ in 'Venneettu mannan' to 179.09 µ in 'Nanguneri peyan'.

Between the two groups of tetraploids the size of pollen grains differed significantly. Clones of AAAA group had larger pollen grains (147.98 µ) than those of ABBB group (130.42 µ).

Pollen production

Data relating to the pollen production per anther in the different clones studied are given in Table 4.

Diploids, triploids and tetraploids were compared in respect of pollen production and in each ploidy level the genomic groups were also compared.

Among the three ploidy levels significant variation in pollen production was observed between the diploids and the triploids only. The means of pollen production per anther in diploids and triploids were 7,948.3 and 4,497.39 respectively.

In the case of diploids BB genomic group produced was significantly high number of pollen grains (16354.2) than AA group in which the mean number of pollen grain per anther was only 7014.32.

Table 4. Variation in pollen production in banana clones

Sl. No.	Clones	Pollen production	
		Range	Mean
1	2	3	4
1.	Ambalakadali	Nil	Nil
2.	Chingan	2,813 - 3,438	3,125 (3.493)
3.	Erachivazhai	10,000 - 10,625	10,316.7(4.013)
4.	Matti	1,563 - 1,875	1,666.7(3.220)
5.	Namarai	5,313 - 5,938	5,625 (3.749)
6.	Pachachingan	Nil	Nil
7.	Pisang lilin	8,750 - 9,375	9,062.5(3.957)
8.	Pisang mas	12,188 - 12,813	12,500 (4.097)
9.	Sanna chenkadali	1,563 - 1875	1,770.5(3.246)
10.	Sikuzani	9,375 - 10,000	9,687.5(3.986)
11.	Tongat	9,063 - 9,680	9,375 (3.972)
	Mean of AA group		7,014.32(3.748)
12.	Adukkan	Nil	Nil
13.	Lady's finger	Nil	Nil
14.	Njjali poovan	Nil	Nil
	Mean of AB group	Nil	Nil
15.	Elavazhai	15,625 - 17,188	16,354.2(4.213)
	Mean of diploids		7,948.3(3.794)
16.	Agniswar	Nil	Nil
17.	Basrai	2,188 - 2,813	2,500 (3.399)
18.	Burharia	7,500 - 7,813	7,604.2(3.881)
19.	Chinia	14,063 - 14,688	14,375 (4.158)
20.	Dudhsagar	4,375 - 5,000	4,687.5(3.670)
21.	Galanamalu	5,625 - 6,250	5,934.2(3.773)
22.	Gros Michel	938 - 1,250	1,041.3(3.018)

Table 4 contd...

1	2	3	4
23.	Harichal	6,250 - 6,563	6,458.3 (3.810)
24.	High gate	1,250 - 1,563	1,354.2 (3.129)
25.	Malakali	Nil	Nil
26.	Manoranjitham	4,688 - 5,313	5,000 (3.698)
27.	Mauritius	1,563 - 2,188	1,875 (3.269)
28.	Padathi ponnani	Nil	Nil
29.	Red Banana	5,313 - 5,625	5,416.7 (3.733)
30.	Red jasirna	Nil	Nil
31.	Sapumal anamalu	7,500 - 7,813	7,604.2 (3.881)
32.	Wather	5,938 - 6,250	6,041.7 (3.781)
	Mean of AAA group		5,376.6 (3.731)
33.	Adakka kunnan	Nil	Nil
34.	Chetti	6,563 - 7,188	6,875 (3.837)
35.	Chinali	3,125 - 3,750	3,437.5 (3.535)
36.	Dakshin sagar	2,813 - 3,438	3,125 (3.493)
37.	Kaali	Nil	Nil
38.	Kapur	3,438 - 3,750	3,541.3 (3.549)
39.	Krishna vazhai	Nil	Nil
40.	Kullan	Nil	Nil
41.	Malai monthan	1,875 - 2,500	2,187.5 (3.337)
42.	Mannan	Nil	Nil
43.	Nendra Kunnan	Nil	Nil
44.	Palayankodan	938 - 1,250	1,145.8 (3.055)
45.	Pisang seribu	2,188 - 2,813	2,500 (3.399)
46.	Poomkalli	Nil	Nil
47.	Sirumalai	Nil	Nil
48.	Sugandhi	2,813 - 3,438	3,125 (3.493)
49.	Suwandal	2,813 - 3,438	3,125 (3.493)
50.	Thiruvanthapuram	3,438 - 4,063	3,750 (3.573)

Table 4 contd...

1	2	3	4
51.	Vannan	Nil	Nil
52.	Walha	4,063 - 4,688	4,375 (3.640)
	Mean of AAB group		3,380.68 (3.529)
53.	Alukehel	3,750 - 4,688	4,166.7 (3.618)
54.	Ashy batheesa	4,688 - 5,313	5,000 (3.698)
55.	Bluggoe	3,750 - 4,375	4,062.5 (3.608)
56.	Boodi	7,500 - 8,125	7,812.5 (3.893)
57.	Chirapunchi	1,250 - 1,875	1,562.5 (3.188)
58.	Enna benian	Nil	Nil
59.	Kallu monthan	7,188 - 7,500	7,399.2 (3.869)
60.	Kapok	6,250 - 6,875	6,562.5 (3.817)
61.	Karim bontha	2,188 - 2,813	2,500 (3.399)
62.	Karpooravally	2,813 - 3,438	3,125 (3.493)
63.	Kostha bontha	1,563 - 2,188	1,875 (3.269)
64.	Nalla bontha	938 - 1,250	1,041.3 (3.014)
65.	Nanguneripeyan	2,813 - 3,438	3,125 (3.493)
66.	Pacha bontha bathees	2,500 - 3,750	3,125 (3.493)
67.	Peyan	4,375 - 5,000	4,687.5 (3.670)
68.	Sawai	11,875 - 13,125	12,500 (4.097)
69.	Venneettu mannan	4,063 - 4,375	4,270.8 (3.630)
	Mean of ABB group		4,550.78 (3.658)
	Mean of triploids		4,497.39 (3.653)

Table 4 contd...

1	2	3	4
70.	Boddles Altafort	11,250 - 11,563	11,354.2 (4.055)
71.	Hybrid Sawai	6,875 - 7,500	7,187.5 (3.856)
72.	Ney Vannan sawai	938 - 1,250	1,145.8 (3.055)
	Mean of ABBB group		4,166.65(3.620)
	Mean of tetraploids		6,562.5 (3.817)
	'F' test		Sig
	'F' test Diploid and Triploid		Sig
	Diploid and Tetraploid		NS
	Triploid and Tetraploid		NS
	CD (0.05)		0.415
	CD (0.05) to compare diploid and triploid		0.1022
	to compare diploid and tetraploid		0.1904
	to compare Triploid and tetraploid		0.1731

Values in the paranthesis denote the means of the transformed data

Means of pollen production arranged in descending order

1. AA means

T_8	T_3	T_{10}	T_{11}	T_7	T_5	T_2	T_9	T_4
4.097	4.013	3.980	3.972	3.957	3.749	3.493	3.246	3.220

2. AAA means

T_{19}	T_{18}	T_{31}	T_{23}	T_{32}	T_{21}	T_{29}	T_{26}	T_{20}	T_{17}	T_{27}	T_{24}	T_{22}
4.158	3.881	3.881	3.810	3.781	3.773	3.733	3.698	3.670	3.399	3.269	3.129	3.017

3. AAB means

T_{34}	T_{52}	T_{50}	T_{38}	T_{35}	T_{36}	T_{48}	T_{49}	T_{45}	T_{41}	T_{44}
3.837	3.640	3.573	3.549	3.535	3.493	3.493	3.493	3.399	3.337	3.055

4. ABB means

T_{68}	T_{56}	T_{59}	T_{60}	T_{54}	T_{67}	T_{69}	T_{53}	T_{55}	T_{62}	T_{65}	T_{66}	T_{61}	T_{63}	T_{57}	T_{64}
4.097	3.893	3.869	3.817	3.698	3.670	3.630	3.618	3.608	3.493	3.493	3.493	3.399	3.269	3.188	3.014

Among the clones in AA group the pollen production ranged from 1666.7 in 'Matti' to 12,500 in 'Pisang mas'. In the case of BB, 'Elavazhai' produced 16354.2 pollen grains per anther.

Within the triploids, the genomic groups did not differ significantly in respect of pollen production, having ranged from 3380.7 in AAB to 5376.6 in AAA.

Among the clones in AAA group the pollen production ranged from 1041.3 in 'Gros Michel' to 14,375 in 'Chinia' and in the clones of AAB group it ranged from 1145.8 in 'Palayankodan' to 6875 in 'Chetti'. In ABB group the pollen production ranged from 1041.3 in 'Nalla bontha' to 12,500 in 'Sawai'.

Within the tetraploids the genomic group AAAA was significantly superior to ABBB in pollen production (11,354.2 and 4166.65 respectively).

Pollen viability

Observations on the viability of pollen grains of the 53 clones are presented in Table 5.

The diploids, triploids and tetraploids were compared in respect of pollen viability. Within each

Table 5. Viability per cent of pollen grains of banana (Acetocarmine staining test)

Sl. No.	Clones	Staining per cent Mean	
1.	Chingan	34.55	(35.99)
2.	Erachivazhai	46.11	(42.79)
3.	Matti	37.30	(37.61)
4.	Namarai	71.33	(57.63)
5.	Pisang lilin	44.99	(42.19)
6.	Pisang mas	71.43	(57.71)
7.	Sanna chenkadali	52.78	(47.17)
8.	Sikuzani	24.96	(29.95)
9.	Tongat	82.02	(65.40)
	Mean of AA group	51.72	(46.27)
10.	Elavazhai	86.51	(59.88)
	Mean of diploids	55.20	(50.29)
11.	Basrai	44.56	(41.83)
12.	Burharia	60.55	(51.16)
13.	Chinia	57.46	(49.39)
14.	Dudhsagar	28.67	(32.25)
15.	Galanamalu	51.30	(45.73)
16.	Gros Michel	49.38	(44.62)
17.	Harichal	61.11	(51.45)
18.	High gate	55.26	(48.03)
19.	Manoranjitham	61.92	(51.95)
20.	Mauritius	50.93	(45.56)
21.	Red Banana	48.73	(44.22)
22.	Sapumal anamalu	59.10	(50.25)
23.	Wather	72.27	(58.34)
	Mean of AAA	53.94	(47.29)

Table 5 contd...

Sl. No.	Clones	Staining per cent Mean	
1	2	3	
24.	Chetti	57.72	(49.47)
25.	Chinali	41.53	(40.12)
26.	Dakshin sagar	41.31	(40.08)
27.	Kapur	44.39	(41.78)
28.	Malai monthan	52.43	(46.40)
29.	Palayankodan	41.53	(39.45)
30.	Pisang seribu	22.20	(28.12)
31.	Sugandhi	55.00	(47.87)
32.	Suwandal	17.40	(23.99)
33.	Thiruvanthapuram	45.16	(42.22)
34.	Walha	52.97	(36.78)
	Mean of AAB group	42.88	(39.66)
35.	Alukehel	55.27	(48.04)
36.	Ashy batheesa	45.13	(42.16)
37.	Bluggoe	52.02	(46.19)
38.	Boodi	55.14	(47.96)
39.	Chirapunchi	46.25	(42.66)
40.	Kallu monthan	60.40	(51.07)
41.	Kapok	70.67	(57.24)
42.	Karim bontha	49.86	(49.38)
43.	Karpooravally	53.28	(46.89)
44.	Kostha bontha	57.54	(49.38)
45.	Nalla bontha	37.79	(37.86)
46.	Nanguneri peyan	37.33	(37.65)
47.	Pacha bontha bathees	50.05	(45.04)

Table 5 contd...

1	2	3	
48.	Peyan	46.14	(42.73)
49.	Sawai	57.93	(49.61)
50.	Venneettu mannan	66.59	(54.72)
	Mean of ABB group	52.59	(46.79)
	Mean of triploids	50.36	(44.99)
51.	Bodles Altafort	82.84	(65.62)
52.	Hybrid Sawai	61.25	(51.49)
53.	Ney vannan sawai	55.08	(47.95)
	Mean of ABBB group	58.16	(49.72)
	Mean of tetraploids	66.39	(55.02)
	'F' test	Sig.	
	'F' test diploids and triploid	Sig.	
	'F' test diploid and tetraploid	NS	
	Triploid and tetraploid	Sig.	
	AAA and AAB	Sig.	
	AAA and ABB	Sig.	
	AAA and ABB	NS	
	AAB and ABB	Sig.	
	CD (0.05)	12.703	
	CD (0.05) to compare diploid and triploid	3.176	
	" Diploid and tetraploid	5.913	
	" Triploid and tetraploid	5.377	
	" AAA and AAB	3.679	
	" AAA and ABB	3.354	
	" AAB and ABB	3.518	

Values in the parenthesis denote the means of the transformed data.

Means of pollen viability percent arranged in discending order

1. AA means

T_9	T_6	T_4	T_7	T_2	T_5	T_3	T_1	T_8
65.40	57.71	57.63	47.17	42.79	42.19	37.61	35.99	29.95

2. AAA means

T_{23}	T_{19}	T_{17}	T_{12}	T_{22}	T_{13}	T_{18}	T_{15}	T_{20}	T_{16}	T_{21}	T_{11}	T_{14}
58.34	51.95	51.45	51.16	50.25	49.39	48.03	45.73	45.56	44.62	44.22	41.83	32.25

3. AAB means

T_{24}	T_{31}	T_{28}	T_{33}	T_{27}	T_{25}	T_{26}	T_{29}	T_{34}	T_{30}	T_{32}
49.47	47.87	46.40	42.22	41.78	40.12	40.08	39.45	36.78	28.12	23.99

4. ABB means

T_{41}	T_{50}	T_{40}	T_{49}	T_{42}	T_{44}	T_{35}	T_{38}	T_{43}	T_{37}	T_{47}	T_{48}	T_{39}	T_{36}	T_{45}	T_{46}
57.24	54.72	51.07	49.61	49.38	49.38	48.04	47.96	46.89	46.19	45.04	42.73	42.66	42.16	37.86	37.65

ploidy level, the genomic groups were also compared.

The pollen viability varied significantly among the diploids, triploids and tetraploids. The viability was highest in tetraploids (66.39 per cent), followed by diploids (55.2 per cent) and triploids (50.36 per cent).

Between the different genomic groups in the diploids, BB group recorded a higher pollen viability (86.51 per cent) than AA group in which the pollen viability was only 51.72 per cent. In AA group pollen viability ranged from 24.96 per cent in 'Sikuzani' to 82.02 per cent in 'Tongat'.

Within triploids, the viability of pollen grains differed between the genomic groups. The highest viability was noted in AAA group (53.94 per cent) followed by in ABB (52.59 per cent) and AAB groups (42.88 per cent).

In clones coming under the AAA group the pollen viability ranged from 28.67 per cent in Dudhsagar to 72.27 per cent in 'Wather'. In the ABB group, it ranged from 37.33 per cent in 'Nanguneri peyan' to 70.67 per cent in 'Kapok'. In AAB group the viability ranged from 17.40per cent in 'Suwandal' to 57.72 per cent in 'Chetti'.

The tetraploid groups AAAA and ABBB differed significantly in the percentage viability of pollen grains, the former recording higher viability (82.84 per cent) than the latter (58.16 per cent).

Standardization of media for pollen germination

The media tried consisted of agar at concentrations ranging from 0.5 per cent to 3.0 per cent and sucrose at concentration from 2.0 to 14.0 per cent.

Out of the above two media agar was not found suitable since in all the concentrations tried, there was no pollen germination. The pollen grains in agar media were seen burst.

The percentage of germination of the pollen and pollen tube growth in different concentrations of sucrose after 26 hours of incubation are presented in Table 6. Out of the eight concentrations of sucrose tried, no pollen germination was observed upto 4.0 per cent of sucrose. Maximum germination (23.77 per cent) was observed in 12.0 per cent sucrose followed by in 10.0 per cent, 8.0 per cent, 14.0 per cent and 6.0 per cent. There was no statistically significant difference between 12.0 and 10.0 per cent sucrose.

Table 6. Effect of sucrose on pollen germination of banana clone 'Elavazhai'

Treatment	Sucrose concentration	Mean	
		Percent germination	Tube length (μ)
S_1	0	0	0
S_2	2	0	0
S_3	4	0	0
S_4	6	3.73 (8.59)	64.81
S_5	8	10.46 (18.27)	149.99
S_6	10	14.75 (21.84)	304.79
S_7	12	23.77 (28.79)	164.22
S_8	14	6.41 (15.11)	126.65
	'F' test	Sig	Sig
	CD (0.05)	8.431	25.51

1. Means of pollen germination per cent in sucrose media arranged in descending order

S_7	S_6	S_5	S_8	S_4
28.79	21.84	18.27	15.11	3.59

2. Means of pollen tube length in sucrose media arranged in descending order

S_6	S_7	S_5	S_8	S_4
304.79	164.22	149.99	126.65	64.81

Maximum pollen tube length (304.79 u) was recorded in 10 per cent which was significantly higher than that observed in the rest of the concentrations. This was followed by 12.0, 8.0, 14.0 and 6.0 per cent.

Table 7 represents the data on pollen germination and tube growth in 12.0 per cent sucrose from 20 hours to 32 hours after incubation.

The percentage of germination of pollen grains reached its maximum in 26 hours. From 24 hours to 32 hours, the observed difference in the germination was not statistically significant which indicated that maximum germination was attained by 26 hours. Pollen tube growth recorded in 26 hours also was significantly higher than that in 24 hours, 22 hours or 20 hours, but the treatment was on par with each increase in tube length recorded in subsequently progressing time.

Effect of boric acid on germination and pollen tube length.

The effect of boric acid on pollen germination and tube growth in the sucrose media can be seen in the data presented in Table 8. Out of the seven concentrations tried (2, 4, 6, 8, 10, 12 and 14 ppm boric acid in 12 per cent sucrose), addition of 12 ppm boric acid to 12

Table 7. Pollen germination at hihourly intervals from the time of commencement to completion in 12 per cent sucrose

Treatment	Time (hrs)	Means	
		Percent germination	Tube length (u)
T_1	0 - 18	0	0
T_2	20	11.19 (19.45)	33.70
T_3	22	15.76 (23.23)	81.47
T_4	24	19.81 (26.38)	118.51
T_5	26	23.35 (29.07)	147.76
T_6	28	23.30 (28.79)	148.14
T_7	30	23.58 (28.91)	152.95
T_8	32	23.73 (28.99)	156.28
'F' test		Sig	Sig
CD (0.05)		4.6998	20.217

Values in the parenthesis denote the means of the transformed data

3. Means of pollen germination per cent in 12 per cent sucrose media arranged in descending order

T_5	T_8	T_7	T_6	T_4	T_2	T_1
29.07	28.97	28.91	28.79	26.38	23.23	19.45

4. Means of pollen tube length in 12 per cent sucrose media arranged in descending order

T_8	T_7	T_6	T_5	T_4	T_3	T_2
156.28	152.95	148.14	147.76	118.51	81.47	33.7

Table 8. Effect of sucrose 12 per cent with boric acid on pollen germination of banana clone Elavazhai

Sucrose (12%) + Boric acid (ppm)		Means	
		Percent germination (%)	Tube length (μ)
SB_1	2	26.61 (31.05)	222.11
SB_2	4	29.87 (32.94)	297.16
SB_3	6	30.17 (33.25)	348.32
SB_4	8	31.34 (33.96)	388.96
SB_5	10	33.61 (35.40)	529.26
SB_6	12	34.15 (35.69)	414.87
SB_7	14	27.63 (31.70)	363.54
'F' test		Sig	Sig
CD (0.05)		0.57	22.78

5. Means of pollen germination per cent in 12 per cent sucrose and boric acid media arranged in descending order

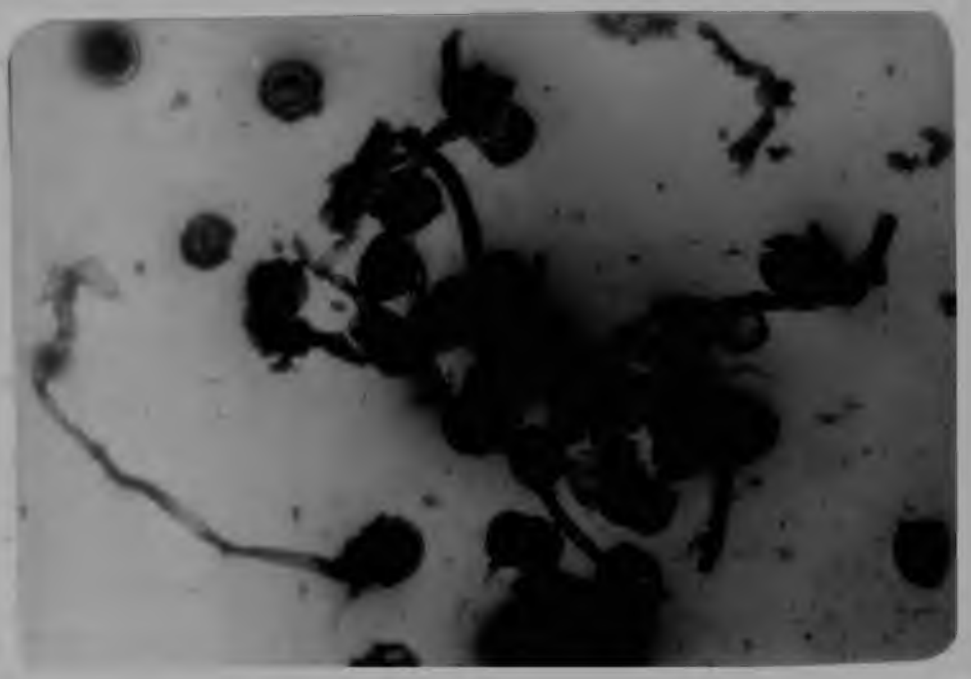
SB_6	SB_5	SB_4	SB_3	SB_2	SB_7	SB_1
35.69	35.40	33.96	33.25	32.94	31.70	31.05

6. Means of pollen tube length in 12 per cent sucrose and boric acid media arranged in descending order

SB_5	SB_6	SB_4	SB_7	SB_3	SB_2	SB_1
529.26	414.87	388.96	363.54	348.32	293.16	222.11

Plate 5

Pollen germination in sucrose 12 per cent + Boric acid 12 ppm clone 'Elavazhai' (BB) (x 300)



per cent sucrose was found to be the best for maximum pollen germination (Plate 5). Pollen tube growth was found to be maximum in 10 ppm boric acid. These two treatments which were at par were significantly superior than the other combinations used.

2.5. Pollen storage

Table 9 gives the data on the storage life of pollen grains of the four clones of banana under four conditions of storage. Among the four types of storage, it was found that pollen viability could be maintained for maximum period when bracts with flowers intact were stored in refrigerator. This method of storage was, however, on par with the method of storing bracts in desiccator at room temperature and bracts stored in desiccator in refrigerator. The storage period under open condition at room temperature was the lowest than that in the other three treatments. Under room temperature, the pollen could be stored only for 11 to 20 days, depending upon the clones.

The varietal response to storage conditions is also evident from the data presented in Table 9 and Fig. 1 and 2. Out of the four clones, the pollen grains of 'Bodles Altafort' exhibited the maximum

Table 9. Number of days taken for losing viability for different clones under different storage conditions

Clones	Storage condition				Total	Mean
	Bracts at room temperature	Bracts in refrigerator	Bracts in desiccator at room temperature	Bracts in desiccator in refrigerator		
Elavazhai	11	26	20	14	71	17.75
Bodles Altafort	20	38	32	28	118	29.50
Wather	13	30	26	22	91	22.75
Hybrid Sawai	12	24	19	16	71	17.75
Total	56	118	80	97		
Mean	14	29.50	20	24.25		

Values of chi-square

Chi-square for testing the interaction between the storage conditions and clones = 4.24 NS

Chi-square for comparing clones = 16.195**

Chi-square for Elavazhai vs Bodles Altafort = 5.84*

Chi-square for Elavazhai vs Wather = 1.235 NS

Chi-square for Bodles Altafort vs Wather = 1.74 NS

Chi-square for storage condition = 23.58**

Chi-square for Bracts at room temperature vs Bracts in refrigerator = 11.046**

Chi-square for Bracts at room temperature vs Bracts in desiccator at room temperature = 2.118 NS

Chi-square for Bracts at room temperature vs Bracts in desiccator in refrigerator = 5.493*

Chi-square for Bracts in refrigerator vs Bracts in room temperature = 3.646 NS

Chi-square for Bracts in refrigerator vs Bracts in desiccator in refrigerator = 1.026 NS

Chi-square for Bracts in desiccator at room temperature vs Bracts in desiccator in refrigerator = 0.816 NS

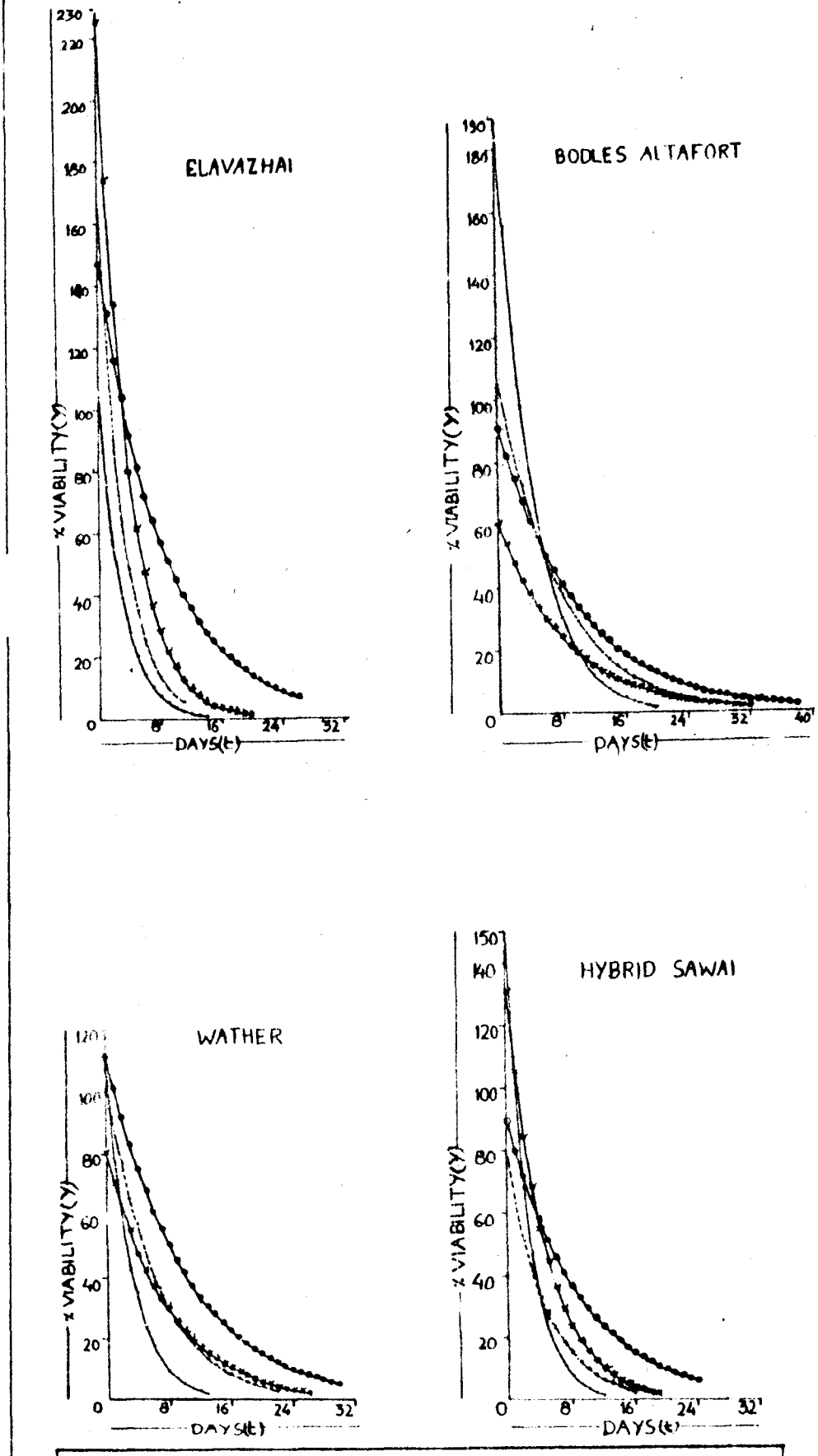


FIG.1 POLLEN VIABILITY UNDER DIFFERENT STORAGE CONDITIONS.
(EXPONENTIAL CURVES, $Y = ab^t$)

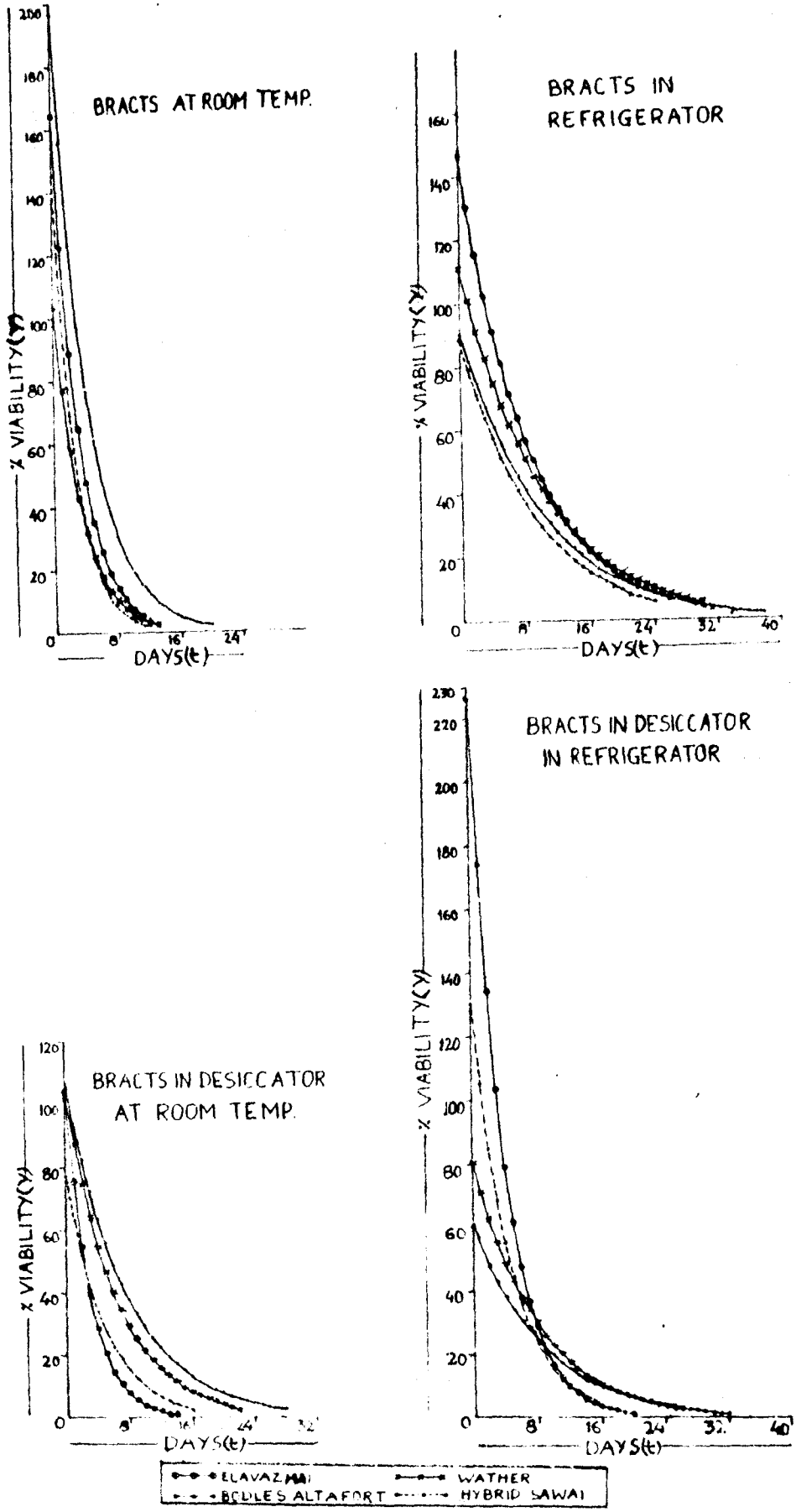


FIG.2 CLONAL VARIATION IN POLLEN VIABILITY UNDER DIFFERENT STORAGE CONDITIONS

(EXPONENTIAL CURVES, $Y = ab^t$)

storage life under all the methods of storage conditions. Under the open storage of bract in refrigerator, the pollen remained viable for 38 days. Storage life was the least in 'Hybrid Sawai' and 'Elavazhai' where in the open storage under refrigerator the viability was lost within 24 to 26 days.

In Table 10, the relative rate of reduction in viability of the four clones under the treatment conditions are presented. The rate of reduction in viability was found minimum in 'Bodies Altafort' and maximum in 'Hybrid Sawai'.

Cross-compatibility studies

Out of the 27 cross combinations tried (Fig.3), compatibility was obtained only in the case of eight crosses. The pattern of fertility and seed production are given in Table 11.

With respect to the female parents, maximum seed set was found in 'Agniswar' and the least in 'Nendra vannan' (Plate 6). Comparison of the seed formation with respect to the position of the hands showed that the female parent 'Agniswar' produced seeds upto the 6th hand from the basal. However, the maximum number of seeds was produced in the third hand

Table 10. Relative rate of reduction in viability of various clones under different storage conditions

Clones	Storage condition				Total	Mean
	Bracts at room temperature	Bracts in desiccator at room temperature	Bracts in desiccator in refrigerator	Bracts in refrigerator		
Elavazhai	29.85	28.09	23.16	12.28	93.38	23.35
Bodles Altafort	21.60	12.80	11.08	10.25	55.73	13.93
Wather	27.52	18.01	12.7	10.48	68.71	17.18
Hybrid Sawai	32.43	20.45	21.11	12.16	86.15	21.54

FIG.3 CROSS COMPATIBILITY AMONG CLONES IN BANANA.

♀ \ ♂	Pisang lilin (AA)	Sikuzani (AA)	Tongat (AA)	Namarai (AA)	Pisang seribu (AAB)	Bodles Altafort (AAAA)
Pachachingan	(N)	..	..	..	..	..
Agniswar	(C)	..	..	..	..	..
Amrit sagar	(N)	..	..	(N)	..	..
Harichal	(C)	..	..	..	..	(N)
Lacatan	(C)	..	..	..	..	..
Malakali	(N)	..	..	..	..	..
Padali moongil	(N)	..	..	..	..	..
Padathi ponnani	(N)	..	..	..	..	..
Pedda pacha	(N)	..	..	..	..	..
Vamanakeli	(N)	..	..	(N)	..	..
Karim kadali	(N)	..	..	..	..	..
Krishna vazhai	(N)	..	..	..	..	..
Mannan	(C)	..	..	..	..	..
Motta poovan	(N)	..	..	..	..	..
Nendran	..	(C)	..	..	..	..
Nendra vannan	(C)	..	..	..	..	(N)
Pacha naadan	(N)	..	..	..	..	..
Palayankodan	(C)	(C)	(N)	..	..	..
Vannan	(N)	..	..	..	..	..
Zanzibar	(N)	..	..	..	(N)	..

(C) Compatible
(N) Not compatible
.. Not tried

Table 11. Compatibility and pattern of fertility in banana clones with respect to position of hands

Sl. No.	Parental plants	Position of hand	No. of seeds in hands			Total seeds	Mean no.of seeds per bunch	Mean no.of seeds per bunch
			1st cross	2nd cross	3rd cross			
1	2	3	4	5	6	7	8	9
1.	Agniswar x Pisang lilin	1	-	3	5	8	2.67	25.33
		2	2	4	4	10	3.33	
		3	1	10	17	28	9.33	
		4	2	6	7	15	5.00	
		5	1	3	5	9	3.00	
		6	-	2	4	6	2.00	
		7 - 8	-	-	-	-	-	
	Total		6	28	42	76		
2.	Palayankodan x Pisang lilin	1	1	3	1	5	1.67	9.67
		2	-	-	2	2	0.67	
		3	3	2	3	8	2.67	
		4	-	1	2	3	1.00	
		5	2	2	-	4	1.33	
		6	1	1	-	2	0.67	
		7	-	3	-	3	1.00	
		8	1	1	-	2	0.67	
		9 - 15	-	-	-	-	-	
	Total		8	13	8	29		

Table 11 contd...

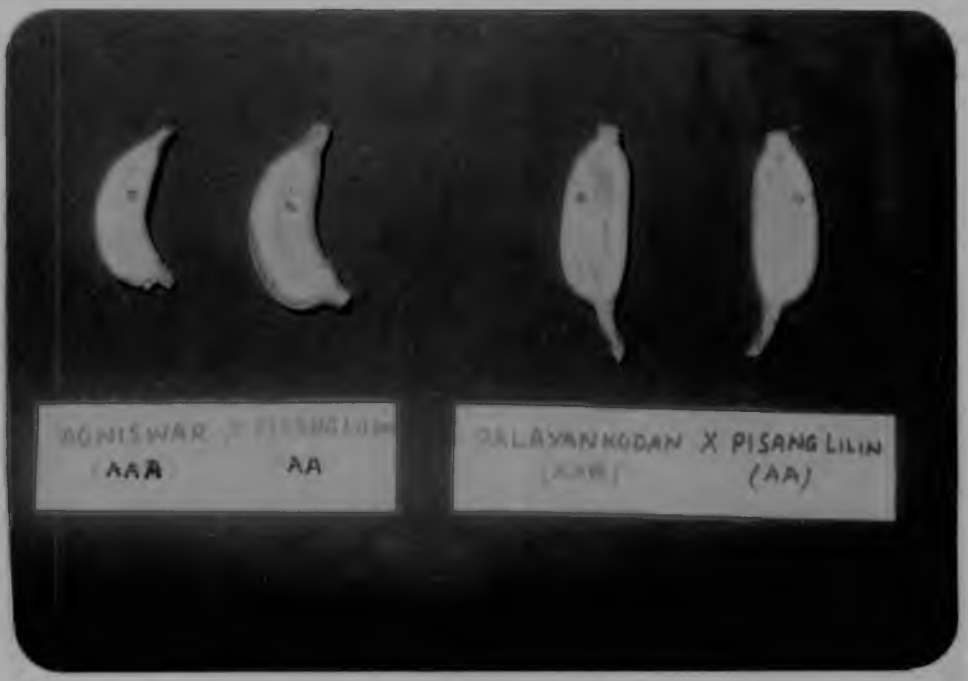
1	2	3	4	5	6	7	8	9
3.	Palayankodan x Sikuzani	1	-	-	-	-	-	5.00
		2	-	2	2	4	1.33	
		3	-	2	2	4	1.33	
		4	-	2	2	4	1.33	
		5	2	-	-	2	0.67	
		6 - 9	-	-	-	-	-	
		10	1	-	-	1	0.33	
		11 -15	-	-	-	-	-	
	Total		3	6	6	15		
4.	Harichal x Pisang lilin	1	-	1	-	1	0.33	0.67
		2	-	-	-	-	-	
		3	1	-	-	1	0.33	
		4 - 8	-	-	-	-	-	
	Total		1	1	-	2		
5.	Mannan x Pisang lilin	1 - 2	-	-	-	-	-	
		3	2	-	-	2	0.67	1.67
		4 - 5	-	-	-	-	-	
		6	2	1	-	3	1.00	
		7	-	-	-	-	-	
	Total		4	1	-	5		

Table 11 contd...

1	2	3	4	5	6	7	8	9
6.	Nendra vannan x Pisang lilin	1	-	-	-	-	-	0.33
		2	1	-	-	1	0.33	
		3 - 8	-	-	-	-	-	
	Total		1	-	-	1		
7.	Lacatan x Pisang lilin	1	-	-	-	-	-	
		2	-	-	-	1	0.33	1.33
		3 - 4	-	-	-	-	-	
		5	-	1	1	2	0.67	
		6	-	-	1	1	0.33	
		7	-	-	-	-		
	Total		1	1	2	4		
8.	Nendran x Sikuzani	1	-	-	-	-	-	
		2	2	-	-	2	0.67	3.67
		3 - 5	-	-	-	-	-	
	Total		2	-	-	2		

Plate 6

Seed set in inter-clonal crosses

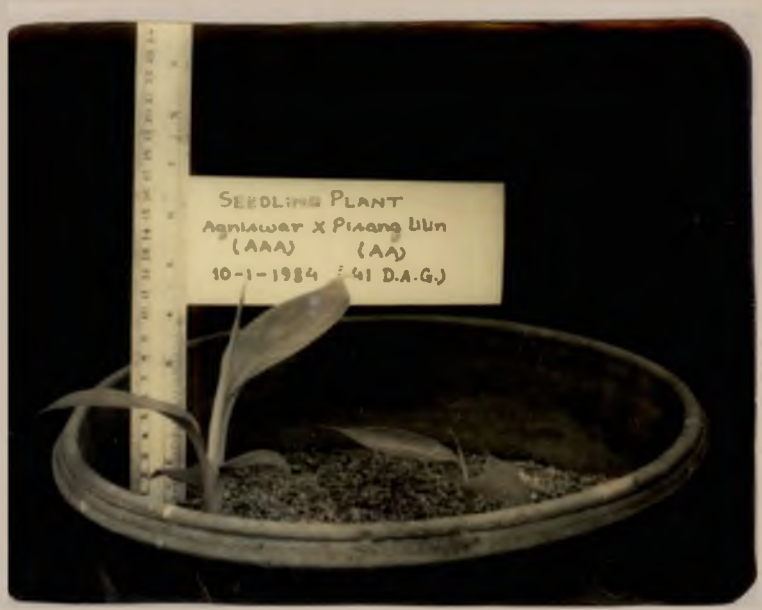

AGNISWAR
(AAA
AA
SALAYAN KODAN
X PISANG LILIN
(AA)

and the least in the sixth hand. 'Palayankodan' when crossed with 'Pisang lilin' produced seeds upto the 8th hand, producing maximum number of 2.67 seeds in the third hand and minimum of 0.67 seeds in the second, sixth and eighth hand. When crossed with 'Sikuzani', 'Palayankodan'(female) produced seeds in the second to the fifth and tenth hand. Maximum number of seeds (1.33) was in the second, third and fourth hand and the least (0.33), in the tenth hand. 'Harichal' produced equal number of seeds (one each) in the first and third hand. 'Mannan' produced seeds in the third and sixth hand, having more number of seeds (1.00) in the sixth hand. 'Nendra vannan' produced seeds only in the second hand, while 'Lacatan' produced seeds in the second, fifth and sixth hand, producing maximum (0.67) in the fifth hand. In the case of 'Nendran' seeds production was restricted to the second hand only.

On an overall analysis, it was found that 'Pisang lilin' was compatible with most of the female parents. Among the female parents tried, 'Agniswar' and 'Palayankodan' were most fertile. With respect to the position of hands, the basal hands were fertile than the distal ones.

Plate 7

A seedling in the early stage


SEEDLING PLANT
Agniawar x Pisang Lilin
(AAA) (AA)
10-1-1984 (41 D.A.G.)

Discussion

DISCUSSION

The present studies on morphology, production, viability of pollen grains and on compatibility were mainly undertaken with a view to generating certain basic data on the above aspects in some of the banana cultivars of Kerala. In recent years, there appears to be a rethinking in banana breeding. It is indicated that there exist possibilities of evolving new clones through interclonal hybridization. In this respect, pollen studies detailed analysis of male and female fertility, and assessment of compatibility between the different clones assume great importance. Some of the salient results obtained in the present studies are discussed below in this chapter.

The transition from vegetative to reproductive phase is critical in a crop like banana. Genetic as well as physiological factors govern this transition. Banana has distinct female and male phases, the former preceding the latter. The duration of these phases is of interest to a breeder in planning his/her breeding programmes in systematic lines.

The present study showed that the diploid

cultivars came to female phase earlier by 18 days than the triploids. In terms of duration of the female phase and the male phase, the diploids had a longer span compared to the triploids. The female phase was considerably short (1.8 to 7.7 days) as compared to male phase (57 to 117 days), although differences were seen between ploidy levels. In the triploid AAB the duration of the female and male phases were more than that in the triploid AAA. The clones under AAA group remained in reproductive phase for 85.6 days while in the case of AAB it was only 92.8 days (Table 1).

Thus genomic configuration and the ploidy levels seem to have definite influence on the duration of the different reproductive phases.

The influence of both the genome and the ploidy level is reflected in the total duration also. Comparative analysis of the 84 clones studied showed that the total duration increased with ploidy level. The diploids recorded the shortest total duration followed by the triploids and tetraploids. Within a ploidy level, the influence of 'B' genome was distinct. Musa balbisiana (BB) represented by the clone 'Elavazhai'

exhibited the maximum total duration among the diploids. Interestingly, the duration of the male and female phases was also more in the case of the clones of bispecific origin of triploids. In the triploids the clones coming under ABB recorded the maximum total duration, followed by those of AAB and AAA. Again within the tetraploids, ABBB took longer duration than AAAA. The contribution of 'B' genome towards extended female and male phases was also thus evident. It would thus be possible to conclude that the duration of the vegetative as well as the reproductive phase (total duration) is basically controlled to a great extent by the genomic make up and the ploidy level in banana. The role of the environmental factors on duration may be additive in nature and seems to influence the duration to greater or lesser degree (Summerville, 1944).

The opening of bracts, on the other hand does not appear to be influenced by the genomic nature or ploidy levels. The pattern of opening of bracts was found to be irregular. Even within a clone the number of bracts that opened per day varied (Table 1). Presumably, the factor(s) responsible for the lifting

of the bracts appear to revolve around climatic parameters rather than on the genetic make up of the clones. The present results substantiate the observation made earlier by De Langhe (1969) that lifting of the bracts occurred at a time when there was a sharp fall in the relative humidity, which resulted in the shrinking of the bract.

Pollen studies

The pollen grains of the 53 banana clones exhibited similar morphological characteristics. They were creamy white powdery mass. The pollen grains were generally spherical. In few cases, the pollen grains were ovoid.

Pollen size varied among the clones and also between the genomic groups. Pollen size increased with the increase in the ploidy level. In several other crops, increase in the size of pollen grains has been reported with the increase in ploidy level (Wilson, 1946).

The variations within the ploidy levels were also significant. Acuminata genome generally contributed

towards increased pollen size. The largest pollen grains were found in the clones belonging to AAAA group and the least in those of AA group, the AAA group occupying a middle position.

The influence of 'A' genome on the pollen size was also evident in the present study. Wherever the predominance of 'A' genome occurred, whether it be in diploids, triploids or tetraploids, significant increase in pollen size was observed. Thus within diploids, AA group possessed larger pollen grains than BB group. In the case of triploids AAA had larger sized pollen grains compared to AAB or ABB. The largest pollen grains were seen in the clone of AAAA group.

Variation in the size of pollen grains between clones have been reported in pineapple by Collins (1969), Bhowmik and Bhagat (1975), Nayar *et al.* (1981) and Nair (1982).

The genomic constitution and the level of ploidy seemed to exert a combined influence on the pollen size. The pollen size therefore appears to be a useful character in determining the ploidy level as well as the contribution of *acuminata* or *balbisiana* in the genomic constitution.

The studies on pollen producitivtty yielded useful results. Out of the 72 clones studies, 19 were male sterile. The non-polleniferous clones belonged to different genomic groups. Interestingly, none of the clones belonging to AB group ('Adukkan', 'Lady's finger' and 'Njali poovan') produced pollen grains.

The pollen production per anther varied among the genomic groups and also among the clones in a genomic group. Diploids produced more pollen per anther than the triploids or tetraploids. Simmonds (1962) and Sathiamoorthy and Rao (1980) explained that the low productivity of pollen in triploids was due to meiotic abnormality resulting in more of sterile pollen grains.

In general, it was found that clones of balbisiana or acuminata origin irrespective of their ploidy level, produced more number of pollen grains per anther than the clones of bispecific origin ie. AAB or ABB in the triploids and ABBB in the tetraploids. However, there were exceptions like some clones of AA group ('Ambalakadali', 'Pachachingan'), and some clones of AAA group ('Agniswar', 'Malakali', 'Padathi ponnani'

and 'Red jasirna') which were non-polleniferous. Some clones belonging to AAB group (Adukka Kunnan', 'Kaali', 'Krishna vazhai', 'Kullan', 'Mannan', 'Nendra Kunnan', 'Poomkalli', 'Sirumalai' and 'Vannan') and 'Enna benian' clone of ABB group also did not produce pollen.

Non-polliniferous character of some of the clones of AAB group like 'Adakka Kunnan', 'Kaali', 'Krishna vazhai' and 'Sirumalai' has been reported by Alexander (1972).

The highest pollen productivity of BB group, and the higher pollen producing pattern of the clones of AA group in the diploids among the triploids clones of AAA group having highest productivity and among the tetraploids the higher pollen producing capacity of AAAA group than ABBB are in agreement with the results achieved by Sathiamoorthy and Rao (1980).

Pollen viability was studied in 53 clones belonging to all the genomic groups and ploidy levels. The pollen viability as indicated by the acetocarmine staining test showed that viability of pollen was highest in the tetraploids followed by in diploids and triploids. Within each ploidy level the clones of

pure acuminata (AA, AAA and AAAA) and Musa balbisina showed higher pollen viability than the clones of bispecific origin (AAB, ABB or ABBB). It seemed that the bispecific origin of clones resulted in reduced pollen viability, as was observed in the case of pollen production. The reduced viability in the case of bispecific origin might be due to abnormalities in meiosis and the production of large number of ill formed pollen grains.

Standardisation of media

Acetocarmine test is reported to be less dependable for assessing the pollen viability in several crop plants (Stanley and Linskens, 1974). The pollen viability as determined by the acetocarmine test has been reported to be higher than those recorded in artificial medium. Stanley and Linskens (1974) explained that the use of stains was less acurate when compared to germination tests.

The more dependable method for testing viability is germinating the pollen in vitro. The absence of previous work on banana pollen germination in vitro necessitated standardization of the medium. Generally,

sucrose in combination with agar is used as a medium for pollen germination (Randhawa and Nair, 1960; Singh, 1961; and Rao and Khader, 1960). There are reports of the use of sucrose alone also as a medium for pollen germination (Adams, 1916; East and Park, 1918; Autchor, 1921; O'Kelley and Joseph, 1955; Nazeem, 1979 and Nair, 1982).

Sucrose apart from increasing osmotic pressure serves as a nutrient material for the growing tube, suggested by Brink (1924), O'Kelley (1955) and Vasil (1958).

The initial trials with agar and sucrose had indicated that agar did not serve as a suitable medium for pollen germination in banana. In the agar medium the pollen grains were seen burst. Sucrose was found to be the most satisfactory medium. Among the different concentrations tried (2, 4, 6, 8, 10, 12 and 14 per cent), a concentration of sucrose at 10 - 12 per cent was found to give the maximum germination and pollen tube growth.

The pollen started germinating after 20 hours of dusting on the medium. The incubation period for

pollen germination varies from crop to crop. For instance, in apple and black currant it took six hours (Adam,1916) and in nutmeg one hour (Nazeem, 1979).

In the present study, it was observed that although the germination started after 20 hours of dusting, maximum germination was recorded after 26 hours in 12 per cent sucrose medium.

The stimulatory effect of boric acid reported by several workers in other crops (Thompson and Batjer, 1950; O'Kelley and Joseph, 1955; Vasil, 1960; Shapiro and Budrick, 1961; Varas and Soria, 1962; Dutta et al. 1972; Jose and Magnoon, 1972; Sinha, 1973; Vijay et al. 1975 and Ravindran, 1977), was also observed in the present study. Boric acid at 12 ppm added to 12 per cent sucrose gave the maximum germination. Boric acid at 10 ppm in 12 per cent sucrose gave maximum pollen tube length. Higher concentration of boric acid had retarding effect, probably due to its toxic effect (Thompson and Batjer, 1950).

Gaush and Dugger (1953) explained that borate ions reacted with sugar molecule and formed ionizable

sucrose-borax complex, which moved faster than non-borated sucrose molecule through the cell.

It was not possible to locate literature on pollen germination studies in banana clones. Probably pollen germination studies in banana clones were not considered necessary, as it was believed that inter-clonal hybridization might not yield promising results. The experience gained by the banana breeders of the Tamil Nadu Agricultural University (Anon, 1982) perhaps pointed out the possibility of inter- or intra-clonal hybridization in banana. From this point, standardization of a suitable medium for pollen germination appears to be useful for future analysis of pollen viability in the clones of banana.

Pollen storage studies

Storage of pollen becomes necessary especially when male and female parents come to reproductive phase in different times. In a crop like banana although synchronisation of the reproductive phases of the parents appears to be possible by adjusting the planting time, studies on pollen storage reported in this thesis will be of importance.

Among the four conditions of storage tried (bracts in room temperature, bracts in desiccator at room temperature, bracts in refrigerator and bracts in desiccator in refrigerator) in all the four clones ('Elavazhai', 'Wather', 'Bodles Altafort' and 'Hybrid Sawai'), it was found that pollen could be stored longer (for 29.5 days) under refrigerated open storage condition (Table 9 and Figs. 1 and 2). The viability was lost within 14 days when the bracts were kept at room temperature.

The rate of decrease in viability was also maximum when bracts were kept in the open at room temperature and minimum in refrigerated conditions.

Storage of flowers in desiccator kept in a refrigerator was found to reduce the storage life by 10 days compared to open storage in a refrigerator. It was observed that inside the desiccator the temperature was higher (17°C) in the initial stages which came down to 7°C in two days. The temperature variation throughout the period of storage thus appears to have affected the storage life. Moreover the relative humidity in the desiccator was also low (6%).

Pollen grains could be stored in desiccator over

calcium chloride at room temperature longer than in the open conditions at room temperature, because of the low R.H. inside the desiccator. Similar findings of successful pollen storage in desiccator over calcium chloride for longer periods, were reported by Sedov (1955), and Sajman and Kleeve (1964).

It was interesting to note that even under room temperature the pollen remained viable for two weeks when the flowers were intact with bracts. This perhaps indicates that the bracts provide useful protection to the enclosed flowers.

It would thus appear that high relative humidity and low temperature are essential for the pollen storage in banana. Further detailed investigation with controlled temperature and humidity will be of interent.

With regard to pollen storage behaviour, the clones responded differently. Pollen of 'Bodles Altafort' could be stored for 29.5 days in comparison to that of Wather (23 days) or 'Elavazhai' (18 days). In a crop like banana, where genomic constitution and ploidy levels vary greatly, this difference could be

expected in contrast to horticultural varieties of other crops.

Compatability studies.

In the present study, compatibility between six male and 20 female parents was studied. Among these, eight crosses, (Agniswar x Pisang lilin, Palayankodan x Pisang lilin, Palayankodan x Sikuzani, Harichal x Pisang lilin, Mannan x Pisang lilin, Nendra vannan x Pisang lilin, Lacatan x Pisang lilin and Nendran x Sikuzani) were found to be compatible.

Raman et al. (1971) reported that the hybridization work done in the Tamil Nadu Agricultural University between four male and 27 female parents which revealed all the parents as compatible. Alexander (1970), working in Karnataka reported that 'Red Banana', 'Poovan', 'Sugandhi', 'Nattu poovan', 'Alshi', 'Chindi', 'Kallu monthan', 'Kaali', 'Chinia', 'Madurangable', 'Govakar', 'Monthan', 'Rajavazhai' and '*Musa balbisiana*' were female fertile and 'Beet Java', 'Burathkali','Dwarf cavendish', 'Local I', 'Robusta', 'Manikachampa', 'Nalla chakrakali', 'Thenkadali', 'Ayiramka rasathali', 'Amruthapani', 'Krishna vazhai', 'Ladan', 'Motta poovan', 'Nendra padaththi','Nendran',

'Pacha naadan', 'Rasthali', 'Sirumalai', 'Walha', 'West Indies', 'Adukka Kunnan', 'Eththa chingan', 'Kunnan', 'Kadali', 'Ney poovan','Pey Kunnan', 'Thattila Kunnan' and 'Venneetu Kunnan' as female sterile.

The female sterility in banana is reported to be due to genetic factors acquired from the ancestral Musa acuminata (Shepherd, 1960).

The present studies also point out that in banana there is incompatibility between certain clones. 'Pachachingan', 'Amrit sagar', 'Padali moongil', 'Padathi ponnani', 'Pedda pacha', 'Vamanakeli', 'Karim kadali', 'Krishna vazhai', 'Motta poovan', 'Pacha naadan', 'Vannan' and 'Zanzibar' were incompatible with 'Pisang lilin' (used as male parent), 'Palayankodan' was incompatible with 'Tongat', 'Amrit sagar' and 'Vamanakeli' were incompatible with 'Namaral', 'Zanzibar' was incompatible with 'Pisang seribu' and 'Harichal'. 'Nendra vannan' was incompatible with 'Bodles Altafort'.

Based on his studies involving several clones crossed with Nendran, Alexander (1970) reported that 'Nendran' was female sterile. In the present studies,

'Nendran' was found to produce seeds when crossed with 'Sikuzani' indicating the female fertility status of 'Nendran'. The present studies have further shown that Nendran is compatible with Sikuzani. Attempt of more crosses would yield strength to this evidence.

The present studies have clearly shown that compatibility exists between several clones. It was however found that only diploid males were compatible with triploid females.

The early breeding programmes in banana were conducted mainly by utilising wild Musa acuminata or Musa balbisiana (Menendez and Shephered, 1975; Simmonds, 1976 and Azhakiamanabalan and Rao 1980). The major defect in the use of wild species was that the progenies inherited undesirable qualities like horizontal bunches and seediness from the wild diploid parents. In order to avoid these undesirable characters either cultivated acuminata diploids or synthetic male parents were used subsequently.

The use of cultivated clones for breeding purposes is comparitively of recent origin. Alexander (1972) used 'West Indies' as the male parent, Azhakiamanavalan

and Rao (1980) used 'Kadali' as the second male parent to produce H 135 in Tamil Nadu Agricultural University. In Tamil Nadu Agricultural University itself 'Matti', was crossed with various cultivated clones.

Clones belonging to different ploidy levels and genomic groups thus appear to be promising materials for hybridization programme in banana. The present studies on compatibility of banana clones also show that interclonal hybridization is possible in banana and that the clones belonging to different genomic groups could be used as female and male parents, if they are compatible. Analysis of the resultant hybrids for characters like seediness, bunch size, quality etc. have to be done before any final word can be said on the possibilities of interclonal hybridization.

Seed production

Seed production was found maximum in the case of Agniswar x Pisang lilin, followed by in Palayankodan x Pisang lilin and Palayankodan x Sikuzani. In other successful combinations, seed production was found to be very low. Scanty seed production by 'Gros Michel'

was reported by Shepherd (1954).

The fertility pattern with reference to the hands in a bunch showed variation. In the clones 'Agniswar' and 'Palayankodan' the basal hands upto the middle of the bunch were more fertile. Fertility in basal hands was also found in the case of 'Harichal', 'Nendra vannan' and 'Nendran', while it was found distributed in the case of 'Mannan' and 'Lacatan' De Langhe (1969) reported that in seeded bananas all the hands were equally fertile, but in cultivated bananas certain hands were more fertile than the others, depending upon variety. In moderately parthenocarpic cultivated bananas, there was uniform but reduced fertility in all the hands. Extremely parthenocarpic bananas were totally infertile.

The pollen fertility status of the 72 clones were analysed and it was interesting to note that there were varieties which were non-polleniferous. A medium for pollen germination of banana could be standardized. The result of the compatibility studies indicated the possibilities of inter-clonal hybridization in bananas. However, the ultimate results depend upon the production of parthenocarpic hybrids with superior characteristics.

Summary

SUMMARY

The present studies were carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the years 1982 and 1983. The salient results obtained are summarised below.

1. The genomic configuration and the ploidy levels in banana influenced the duration of the male and female phases of the clones as well as their total duration.

2. The diploids generally attained reproductive stage earlier than the triploids.

3. The duration of the female and male phases was more in diploids than in triploids. In the triploids of AAB group, the duration of the female and male phases was more than that in AAA group.

4. Total duration increased with the increase in ploidy level. Within a ploidy level also the total duration was found to be more in the clones having 'B' genome.

5. The lifting of bracts appeared to be influenced

by environmental factors than genomic status or ploidy levels of the clones. The number of bracts opened per day ranged from zero to four.

6. The pollen grains in all the clones studied were creamy white in colour and spherical in shape. The pollen size increased with the increase in ploidy level. Acuminata genome generally contributed towards increased pollen size. The pollen diameter ranged from 99.21 μ to 179.09 μ in the clones studied.

7. Out of the 72 clones studied, only 53 produced pollen. None of the clones of diploid, belonging to AB group produced pollen grains. In the case of triploids and tetraploids, clones of pure acuminata group produced more number of pollen grains than in the clones of bispecific group. The pollen production per anther ranged from 1,041.3 to 16,354.2.

8. Pollen viability in the clones studied ranged from 17.40 to 86.51 per cent. It was more in clones of monospecific origin than in those of bispecific origin. Tetraploids possessed highest pollen viability values followed by diploids and triploids.

9. Pollen germination was studied in the clone 'Elavazhai' belonging to BB group. Medium for pollen

germination was standardized. A medium containing sucrose (12%) and boric acid (10 to 12 ppm) was found to be the best for pollen germination and tube growth.

10. The germination of pollen grains commenced after 20 hours of dusting in the medium in desiccator containing water and the rate of germination and tube elongation was maximum at the 26th hour.

11. Acetocarmine test was found to be inadequate in assessing the pollen viability as all the grains stained in acetocarmine technique did not germinate *in vitro*.

12. Pollen storage studies showed that when flowers along with the bract were stored in the open at room temperature, the pollen remained viable for 14 days. The storage life was increased to the maximum ie. to 29.5 days when flowers along with bracts were stored in a refrigerator (4°C and 40% RH). The flowers when kept in desiccator inside the refrigerator resulted in slight reduction in storage life (24 days).

13. Out of 27 cross combinations studied, only 8 combinations, Agniswar x Pisang lilin, Palayankodan x Pisang lilin, Harichal x Pisang lilin, Lacatan x Pisang lilin, Mannan x Pisang lilin, Nendra vannan x Pisang lilin, Palayankodan x Sikuzani and Nendran x Sikuzani were found

to be compatible. The female fertility and seed set in Nendran is reported for the first time.

14. Among the successful combinations 'Agniswar' and 'Palayankodan' were more female fertile.

15. Among the six male parents tried, 'Pisang lilin' and 'Sikuzani' were the only compatible ones with various female parents.

16. Seed production was found maximum in the case of Agniswar x Pisang lilin, followed by Palayankodan x Pisang lilin and Palayankodan x Sikuzani. In other successful combinations, seed production was found to be very low.

17. The fertility pattern with reference to the hands in a bunch showed variation. In the clones 'Agniswar' and 'Palayankodan', the basal hands upto the middle of the bunch were more fertile. Fertility in basal hands was also found in the case of 'Harichal', 'Nendra vannan' and 'Nendran', while it was found distributed in the case of 'Mannan' and 'Lacatan'.

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* Originals not seen

Appendices

Appendix-I. Analysis of variance for pollen size studies in bananas

Source	df	Mean squares
Between ploidy level	2	1,366.38**
Within diploids	1	844.79*
Within AA	8	421.81*
Within triploids	2	1,141.58**
Within AAA	12	396.13*
Within AAB	10	396.75*
Within ABB	15	1,408.81**
Within tetraploids	1	616.82 NS
Within ABBB	1	55.62 NS
Error	152	208.816

* Significant at 5% level

** Significant at 1% level

NS Non-significant

Appendix-II. Analysis of variance for estimation of pollen production in banana clones

Source	df	Mean squares
Between ploidy level	2	0.6045**
Within diploids	1	0.585**
Within AA	8	0.354**
Within triploids	2	0.174 NS
Within AAA	12	0.331**
Within AAB	10	0.165*
Within ABB	15	0.237**
Within tetraploids	1	0.718**
Within ABBB	1	0.971**
Error	152	0.0658

*Significant at 5% level

**Significant at 1% level

NS Non-significant

Appendix-III. **Analysis of variance for pollen viability per cent studies in banana**

Source	df	Mean square
Between ploidy level	2	449.93**
Within diploids	1	499.75**
Within AA	8	475.70**
Within triploids	2	479.72**
Within AAA	12	162.25**
Within AAB	10	237.08**
Within ABB	15	131.07*
Within tetraploids	1	505.20**
Within ABBB	1	52.36 NS
Error	152	63.393

* Significant at 5% level

** Significant at 1% level

NS Non-significant

Appendix IV. Analysis of variance for pollen germination and pollen tube growth studies in banana clone 'Elavazhai' (in sucrose media)

Source	df	Mean squares	
		Pollen germination (%)	Pollen tube growth (μ)
Treatment	4	283.64**	46017.15**
Error	20	40.84	373.73

Appendix V. Analysis of variance for pollen germination and pollen tube growth at bihourly interval in 12 per cent sucrose

Source	df	Mean squares	
		Pollen germination (%)	Pollen tube growth (μ)
Treatment	6	70.08**	10735.13**
Error	28	12.667	242.68

Appendix VI. Analysis of variance for pollen germination and pollen tube growth studies, in sucrose 12 per cent with boric acid, of banana clone 'Elavazhai'

Source	df	Mean squares	
		Pollen germination (%)	Pollen tube growth (μ)
Treatment	6	8.14**	46109.42**
Error	28	7.10	309.11

POLLEN MORPHOLOGY, FERTILITY AND COMPATIBILITY STUDIES IN BANANA

By

JAY KRISHNA LAL KARMACHARYA

ABSTRACT OF THE THESIS

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ABSTRACT

Studies on pollen morphology, fertility and compatibility of banana were carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the year 1982 and 1983.

The genomic configuration and the ploidy levels influenced the duration of the male and female phases of the clones as well as their total duration. The duration of male and female phases decreased with the increased ploidy level and increased with presence of 'B' genome. Total duration increased with the increase in ploidy levels and with presence of 'B' genomes. The lifting of bracts in banana was influenced by the environmental factors irrespective of the ploidy level or genomic configuration. It ranged from zero to four per day.

Pollen grains were creamy white in colour and spherical in shape. The pollen size increased with the increase in ploidy levels. Acuminata genome generally contributed towards increased pollen size. The pollen size in the clones studied ranged from 99.21 μ to 179.09 μ.

Out of the 72 clones studied, only 53 produ pollen. The AB group did not produce pollen. I case of triploids and tetraploids, clones of pu

produced more number of pollen grains than that in the clones of bispecific group. Pollen production per anther ranged from 1,041.3 to 16,354.2.

Pollen viability was more in the case of monospecific clones than in clones of bispecific origin. Tetraploids recorded the highest viability of pollen followed by in diploids and in triploids. Pollen germination and tube growth was found maximum in 12 per cent sucrose + 10 to 12 ppm boric acid. The germination was found maximum after 26 hours of dusting them on the medium.

Pollen storage studies showed that when flowers along with the bract were stored in the open at room temperature, the pollen remained viable for 14 days. The storage life was increased to the maximum ie. to 29.5 days when flowers along with bracts were stored in a refrigerator (4^{o}C and 40% RH). The flowers when kept in desiccator inside the refrigerator resulted in slight reduction in storage life (24 days).

Out of 27 cross combination studied, 8 combinations, Agniswar x Pisang lilin, Palayankodan x Pisang lilin, Harichal x Pisang lilin, Lacatan x Pisang lilin, Mannan x Pisang lilin, Nendra vannan x Pisang lilin, Palayankodan x Sikuzani and Nendran x Sikuzani were compatible. Among

them clones 'Agniswar' and 'Palayankodan' were found more female fertile and 'Pisang lilin' and 'Sikuzani' were the only compatible males with various female parents. The seed set noticed in Nendran by crossing with a compatible male parent is reported for the first time.

The fertility pattern with reference to the hands in a bunch showed variation. In the clones 'Agniswar' and 'Palayankodan', the basal hands upto the middle of the bunch were more fertile. Fertility in basal hands was also found in the case of 'Harichal', 'Nendra vannan' and 'Nendran', while the same was found distributed in the case of 'Mannan' and 'Lacatan'.