The mission of the **International Network for the Improvement of Banana and Plantain** is to increase the productivity and stability of banana and plantain grown on smallholdings for domestic consumption and for local and export markets.
INIBAP has four specific objectives:
- to organize and coordinate a global research effort on banana and plantain, aimed at the development, evaluation and dissemination of improved cultivars and at the conservation and use of *Musa* diversity;
- to promote and strengthen regional efforts to address region-specific problems and to assist national programmes within the regions to contribute towards, and benefit from, the global research effort;
- to strengthen the ability of NARS to conduct research on bananas and plantains;
- to coordinate, facilitate and support the production, collection and exchange of information and documentation related to banana and plantain.

In May 1994, INIBAP was brought under the governance and administration of the International Plant Genetic Resources Institute (IPGRI) to enhance opportunities for serving the interest of small-scale banana and plantain producers.

The International Plant Genetic Resources Institute is an autonomous international scientific organization operating under the aegis of the Consultative Group on International Agricultural Research (CGIAR). The international status of IPGRI is conferred under an Establishment Agreement which, by December 1995, had been signed by the Governments of Australia, Belgium, Benin, Bolivia, Burkina Faso, Cameroon, China, Chile, Congo, Costa Rica, Côte d'Ivoire, Cyprus, Czech Republic, Denmark, Ecuador, Egypt, Greece, Guinea, Hungary, India, Iran, Israel, Italy, Jordan, Kenya, Mauritania, Morocco, Pakistan, Panama, Peru, Poland, Portugal, Romania, Russia, Senegal, Slovak Republic, Sudan, Switzerland, Syria, Tunisia, Turkey, Ukraine and Uganda. IPGRI's mandate is to advance the conservation and use of plant genetic resources for the benefit of present and future generations. IPGRI works in partnership with other organizations, undertaking research, training and the provision of scientific and technical advice and information, and has a particularly strong programme link with the Food and Agriculture Organization of the United Nations. Financial support for the agreed research agenda of IPGRI is provided by the Governments of Australia, Austria, Belgium, Canada, China, Denmark, France, Germany, India, Italy, Japan, the Republic of Korea, Mexico, the Netherlands, Norway, Spain, Sweden, Switzerland, the UK and the USA, and by the Asian Development Bank, IDRC, UNDP and the World Bank.

Citation:
Frison, Emile A., Horry, Jean-Pierre and Dirk De Waele, editors. 1996. Proceedings of the workshop on New Frontiers in Resistance Breeding for Nematode, Fusarium and Sigatoka, 2-5 October 1995, Kuala Lumpur, Malaysia. International Network for the Improvement of Banana and Plantain, Montpellier, France.

INIBAP ISBN 2-910810-07-0

IPGRI Headquarters
Via delle Sette Chiese 142
00145 Rome, Italy

INIBAP Headquarters
Parc Scientifique Agropolis
34397 Montpellier Cedex 5, France

New Frontiers in Resistance Breeding for Nematode, Fusarium and Sigatoka

Proceedings of the workshop
held in Kuala Lumpur, Malaysia
2-5 October 1995

Edited by
E.A. Frison,
J-P. Horry
and D. De Waele

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Current Approaches and Future Opportunities for Improvement of Major *Musa* Types Present in Asia and the Pacific: Silk / Pome (AAB Dessert Types)

H.P. Singh and S. Uma

Banana and plantain constitute the fourth most important staple food commodity of the world, exceeded only by rice, wheat and dairy products in terms of gross production value (Valmayor 1994). In Asian and Pacific regions, banana is a premier fruit having great socioeconomic significance. The region is the major centre of diversity and most of the edible bananas within the *Eumusa* section are believed to have originated in the region through complex hybridization events from two species, *Musa acuminata* and *Musa balbisiana*. Banana cultivars with *acuminata* characteristics (AA, AAA) originated primarily in Malaysia and Indonesia while India is a centre of origin for the clones (AB, AAB, ABB) with both *acuminata* and *balbisiana* characters (Singh and Chadha 1993). High diversity in the region has contributed significantly to all the commercial banana cultivars in the world (Valmayor *et al.* 1990).

Owing to long periods of domestication in the region, banana is threatened by many insect pests and diseases:

- Insect pests: Banana weevil *(Cosmopolites sordidus)*, pseudostem borer *(Odoiporus longicolis)*, thrips *(Thrips* sp.) and aphids *(Pentalonia nigronervosa)*;
- Nematodes: burrowing nematode *(Radopholus similis)*, spiral nematode *(Helicotylenchus multicinctus)*, lesion nematode *(Pratylenchus coffeae)*, Cyst nematode *(Heterodera orizicola)* and root–knot nematodes *(Meloidogyne incognita* and *M. javanica)*;
- Diseases: Sigatoka diseases *(Mycosphaerella musicola* and *M. fijiensis)*, *Fusarium oxysporum* f.sp. *cubense* (*Foc*), banana bunchy top virus (BBTV), infectious chlorosis (CMV), banana bract mosaic virus (BBMV).

NRCB, Trichy, India

All these pests and diseases are widespread in the region and are reported to be causing considerable losses (Valmayor *et al.* 1990; Singh 1990, 1992; Razak 1994; Stanton 1994; Maolin 1994; Pone 1994; Davide 1994; Hadisoeganda 1994, Prachasiaso Radej *et al.* 1994). Chemical control of these pests and diseases is not only ineffective and costly but also causes environmental pollution. Therefore, the cultivars should have resistance to these insect pests and diseases with required agronomic characters. Current approaches and opportunities for the development of dessert banana of the AAB group are discussed in this paper.

Current status of research

General introduction

Banana production in this region largely depends upon the selections made from the germplasm. A breeding programme in India has yielded a few hybrids but they have limited adoption potential. The failure of breeding programmes in other countries to replace the commercial cultivars, mainly because of the complexity of banana breeding, has not encouraged National Research Systems to develop systematic improvement programmes, although a few attempts have resulted in the development of hybrids (Sathiamoorthy 1994; Sathiamoorthy and Balmohan 1993). However, with advancement in knowledge and better understanding of the species, along with biotechnology as a tool, there is a growing appreciation of the problem and enhanced interest in improvement.

Except for collecting, conservation, evaluation and characterization of genetic resources of banana, not much has been done on conventional breeding in the region other than in India. When Fusarium wilt (race 4) became common on resistant Cavendish clones in Taiwan, research was stimulated. Large-scale multiplication of plants through meristem tissue culture provided the possibility for detecting somaclonal variants from large populations. A screening programme of tissue culture plantlets in diseased fields, highly infested with the pathogen, resulted in the selection of 10 resistant clones. Subsequent selection among their progenies produced by tissue culture resulted in selection of GCTCV–215–1 (Hwang 1991) which showed a moderate level of disease resistance with good agronomic characters. In subsequent attempts, a semi-dwarf mutant (TCI–229), derived from GCTCV–215–1 was selected which maintained a high level of resistance (Tang and Hwang 1994). Success of the programme in Taiwan has provided insight for selection of beneficial mutants from somaclonal variants through the accumulation of beneficial genes step by step, which is made possible by recurrent selection among the tissue culture progenies. However, for the success of the programme, it is essential to raise a large sample size because of the low frequency of mutation. Therefore, selection of beneficial mutants from

somaclonal variants appears to be an efficient breeding method in banana (Tang and Hwang 1994).

In Australia and Malaysia, a major improvement programme is through mutation breeding which has the advantage of changing one or more characters of an outstanding cultivar without altering the remaining genotype. GN–60A (AAA Cavendish), induced by gamma irradiation of micropropagated Grande Naine at IAEA, Austria, has been found to be early flowering at QDPI, Australia. The mutant was also found to be early flowering and have high yield capacity at MARDI, Kuala Lumpur (Roux *et al.* 1994). Jamaluddin (1994) exposed the shoot-tips, comprised of meristem surrounded by one or two leaf primodia, with fast neutron and gamma irradiation. Optimum dose of gamma irradiation was 30 Gy for Pisang Rastali (AAB Silk), known as Rasthali in India, 25 Gy for Pisang Berangan (AA) and 60 Gy for Grande Naine. The variants generated from *in vitro* mutation induction techniques had early flowering, reduced plant stature and increased yield for both Grande Naine and Rasthali. However, for the success of *in vitro* mutation breeding, especially for disease resistance, it is essential to develop reliable screening techniques to screen a large number of plants.

Improvement of banana in India

India is credited with being the largest producer of banana in the world with total production of 10.4 million tonnes of fruit annually. It contributes 31.7% to total fruit production and ranks as the number one fruit crop in the country for the production volume. Diverse growing conditions ranging from humid tropics to semi-arid subtropics and humid subtropics, from sea level up to 2000 m a.s.l. have resulted in adoption of a large number of cultivars depending upon growing conditions and production system (Table 1). Thus, productivity varies from region to region depending upon cultivars and production system. However, Dwarf Cavendish clones are the basis of commercial cultivation, contributing to 58% of total production (Fig. 1). Other dessert bananas, e.g. Poovan (AAB Mysore), Rasthali (AAB Silk), Virupakshi (AAB Pome), Elakki Bale (AB Ney Poovan), are grown commercially in southern and eastern regions of the country. In South India, there is growing preference for these clones which sell at premium prices, while Cavendish is most preferred in North India. These clones are grown largely by marginal farmers under both medium inputs and subsistence cultivation. Although these cultivars are moderately resistant to yellow Sigatoka *(Mycosphaerella musicola)*, they suffer heavy losses due to *Foc*. Severity of these diseases depends upon cultivars. The Silk subgroup of banana is so susceptible that it is difficult to grow even with the best management system. Constraints of production are well reviewed (Singh 1990, 1992; Singh and Uma 1994) which has attracted concerted efforts for the improvement of banana. ICAR has established a National Research Center on Banana (NCRB) to work exclusively on banana improvement.

Table 1. Banana cultivars grown in different regions in India

S. No.	State	Cultivar
1	Andhra Pradesh	Dwarf Cavendish (AAA), Robusta (AAA), Amritapani (Rasthali, AAB), Thella Chakkarakeli (AAA), Karpoora Chakkarakeli (Poovan, AAB)
2	Assam	Jahaji (AAA), Dwarf Cavendish, Borjahaji (AAA, Robusta), Malbhog (AAB), Chinia (AAB), Manohar (ABB), Kanchkol (AAB), Chini Champa (AB), Bhimkol (BB)
3	Bihar	Dwarf Cavendish (AAA), Alpon (AAB), Chini Champa (AB), Malbhog (AAB), Muthia (ABB), Kothia (ABB), Monthan (ABB)
4	Gujarat	Dwarf Cavendish (AAA), Lacatan (AAA), Harichal (Lokhandi, AAA)
5	Karnataka	Dwarf Cavendish (AAA), Robusta (AAA), Poovan (AAB), Rasabale (AAB, Rasthali) Hill Banana (AAB), Monthan (ABB), Elakkibale (AB)
6	Kerala	Nendran (AAB Plantain), Palayankodan (Poovan, AAB), Rasthali (AAB), Dwarf Cavendish (AAA), Robusta (AAA), Monthan (ABB), Red Banana (AAA)
7	Maharashtra	Basrai (Dwarf Cavendish), Robusta (AAA), Lalvelchi (AAB), Safed Velchi(AB), Rajeli (AAB,Nendran), Clones of Basrai
8	Tamil Nadu	Virupakshi (AAB), Co–1 (AAB), Robusta (AAA), Dwarf Cavendish (AAA), Red Banana (AAA), Poovan (AAB), Rasthali (AAB), Nendran (AAB), Monthan (ABB)
9	West Bengal & Orissa	Champa (AAB), Morthaban (AAB, Rasthali, Amrit Sagar (AAB), Giant Grover (AAA), Lacatan (AAA), Monthan (ABB)

Production of banana in India has risen from 1.5 million tonnes in 1955 to 10.4 million tonnes in 1992–93, owing to adoption of improved production technologies, as agronomy, physiology and crop protection received priority attention for banana research. Breeding programmes have not yet yielded valuable hybrids which could replace the existing cultivars, although many of them are susceptible to insect pests, nematodes and diseases.

Hybridization and recombination

The breeding programme dates back to 1949, when many crosses were made using Poovan (AAB), Rasthali (AAB), Peyan (ABB), Thote (ABB), Peykunnan (ABB) and Ney Vannan (ABB) as female parents and *Musa balbisiana* as male parents at Central Banana Research Station, Aduthurai.

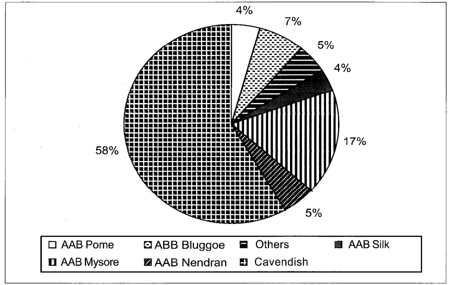

Figure 1. % share of different cultivars in banana production

Progenies from these crosses, Ney Vannan x *M. balbisiana* clone Sawai, had promise as cooking bananas but were susceptible to *Foc*. The breeding programme, including germplasm, was shifted to Tamil Nadu Agricultural University (TNAU), Coimbatore and breeding work was continued under AICRP. In an attempt to improve Kallar Ladan (AAB, Pome), *M. acuminata* and *M. balbisiana* accessions were used in a two-step sequential process. Kallar Ladan (AAB) was crossed to produce AB which was crossed to a diploid cultivar Kadali (AA) to develop a triploid hybrid which was released later as Co.1 (Azhakiamanavalan *et al.* 1985). The hybrid is akin to Virupakshi (AAB Pome) but develops distinct flavour even when grown in the plains, unlike the former. The hybrid was evaluated in multilocational trials at three centres but has not found acceptance owing to its poor yield (Anon. 1991).

At Banana Research Station (BRS), Kannara, a large number of crosses using Agniswar (AAB Pome), Palayankodan (AAB Mysore), Harichal (AAA), Lacatan (AAA), Mannan (AAB) and Nendran (AAB) as female parents and Pisang lilin (AA) as male parent were made. In other cross combinations, Palayankodan, Rasthali and Nendran as female parents and Pisang lilin as male parent were most compatible. Female fertility was found to be influenced by location and season of crossing. The progenies of crosses were diploid and triploid. Four hybrid progenies from these crosses were selected and tested in the field which indicated the superiority of two hybrids (Puskaran *et al.* 1989). H–1 is a short-duration hybrid with bunch weight ranging from 14 to 16 kg. It has high resistance to BLS/BS, *Foc* and burrowing nematode. H–2 has small fingers with acidic flavour. Characteristics of these hybrids along with their parents are presented in Table 2.

Under multilocational testing, H–1 has been found highly promising in the region where Sigatoka leaf spot is a serious problem. Interestingly, this hybrid has a very short crop cycle compared with all the commercial cultivars, and has a highly resistant reaction to BLS/BS. Incidence of *Foc* and burrowing nematode was also not observed. Thus, this hybrid holds promise for subsistence cultivation.

At TNAU, extensive crosses were made to develop new diploids having resistance to nematodes, BLS/BS disease and *Foc* (Sathiamoorthy and Balmohan 1993). Progenies of crosses from Matti x *M. acuminata* ssp. *burmannica*, Matti x Anaikomban, Matti x Tongat are diploids with AA genomic constitution. Triploid progeny (AAA) from these crosses of Matti x Anaikomban, Matti x Pisang lilin and Matti x Tongat were also obtained. Hybrid–109 (Matti x Tongat), H–65 (Matti x Anaikomban), H–59 (Matti x Anaikomban) are resistant to yellow Sigatoka and burrowing nematode and have both male and female fertility. Crosses with triploid (AAB, AAA) are continued both at TNAU and at BRS. But poor seed germination is a hindrance in raising large numbers of progenies. Extensive crosses using Monthan, Poovan, Red Banana, Kali, Peyan and Nattupoovan were also made at the Indian Institute of Horticultural Research (IIHR), Bangalore. Three hybrids from the cross of Bhoodi Bale x Manik Champa and five hybrids from the cross of Karpooravalli x West Indies and five hybrids from Karpooravalli x *M. balbisiana* were obtained and planted in the field for evaluation (Rekha, pers. comm.).

Table 2: Bunch characters and quality of hybrids and their parents

Hybrids	Days to harvest			Bunch weight			No. of fingers			TSS Brix	Acidity %
	IC	IR	IIR	IC	IR	IIR	IC	IR	IIR		
H1	322	193	187	12.4	14.8	14.7	113	111	116	27.4	0.29
H2	329	286	252	14.4	15.0	15.5	179	182	198	25.6	0.25
Agniswar	368	220	212	6.9	6.2	6.8	105	87	90	26.7	0.28
Ney Vannan	356	225	220	7.6	7.8	6.7	108	85	86	25.1	0.28
Pisang lilin	242	157	146	4.7	4.9	4.0	60	65	52	27.6	0.24

IC: Plant Crop; IR: First ratoon; IIR: Second ratoon
H1: (Agniswar x Pisang lilin), H2 :(Ney Vannan x Pisang lilin)

Mutation breeding

Mutation breeding was attempted at BRS, Kannara and BRS Jalgaon by treating 30–70 g suckers with gamma rays. The programme was continued for 10 years. Initial variability in population was observed but subsequently useful variants could not be located (Anon. 1991). This programme of mutation breeding was phased out with a note to try *in vitro* mutation. Failure of the programme was attributed to the fact that induced mutations are of a recessive nature and specific mutation is a unicellular event; chimera formation usually occurs after mutagenic treatment of multicellular apex. Therefore, mutation breeding using suckers having a multicellular apex has its limitations and *in vitro* mutation breeding using shoot apex has potential as demonstrated by Roux *et al.* (1994) and Jamaluddin (1994).

Clonal selection

Natural crossing and mutation have contributed to diversity. Occurrence of a mutant is a common phenomenon in cultivated clones (Singh and Chadha 1993) which have been identified in many cultivars. Exploration and selection have given rise to many cultivars in the past and thus these phenomena were exploited. Two high-yielding superior clones in Nendran were selected which performed well at two locations (Anon. 1991). In Dwarf Cavendish, four promising clones were selected for earliness and higher bunch weight (Anon. 1991). Gandevi selection known as Hanuman or Padarse is becoming popular due to heavy bunch weight (55-60 kg) although it takes longer to harvest. This selection was tested at four locations and has been found promising (Singh 1993). Clonal selection is continuing in Poovan (Mysore AAB), Karibale (Bluggoe ABB) and Rasthali (AAB Silk) at different locations.

Need for improvement

In Asian and Pacific regions, 50-55% of banana production comes from dessert (Pome and Silk subgroups) and cooking bananas. Many of these Asian countries have identified commercial banana by different names (Valmayor 1986; Valmayor *et al.* 1990). Therefore, improvement strategies for Pome, Silk and cooking banana in this region shall have identical approaches. By and large, the problems are also similar except for the few which have regional significance (Table 3).

Foc is a major constraint of production throughout the region on both Silk and Pome and is thought to have evolved with edible banana and their edible diploid progenitor in Asia (Pegg *et al.* 1993). It is widespread and affects preferred and commercially important cultivars. However, Papua New Guinea, southeastern Indonesia and Bismark Archipelago have remained free of *Foc* (Ploetz 1994).

Table 3. Constraints of production of dessert banana (Silk and Pome) in Asia and Pacific

	India	Malaysia	Philippines	Indonesia	Australia	Others
1 Banana weevil (*Cosmopolites sordidus*)	++	++	++	++	+	+
2 Nematodes						
.a *Radopholus similis*	++	++	++	++	++	++
.b *Helicotylenchus multicinctus*	+	+	+	++	+	+
.c *Meloidogyne* sp.	+	+	+	+	+	+
.d *Pratylenchus coffeae*	+	–	–	–	–	–
3 Fungal and bacterial diseases						
.a Fusarium (*Fusarium oxysporum* f.sp. *cubense)*	+++	+++	+++	+++	+++	++
.b Yellow Sigatoka (*Mycosphaerella musicola*)	+	+	+	+	+	+
.c Black Sigatoka (*M. fijiensis*)	–	+	+	+	+	+
.d Moko disease	–	++	+++	–	–	–
4 Viral diseases						
.a BBTV	++	++	++	++	++	++
.b CMV	+	–	+	+	+	–
.c BBMV	++	–	+	–	–	–
.d BSV	+	–	–	–	–	–

+++ Widely spread and serious.
++ Widely spread and serious on few cultivars.
+ Present but not alarming.
BBTV: Banana bunchy top virus; CMV: Cucumber mosaic virus;
BBMV: Banana bract mosaic virus; BSV: Banana streak virus.

Sigatoka leaf spot is present in the region (Valmayor *et al.* 1990) but is serious on Cavendish subgroup. Silk and Pome subgroups have moderate tolerance to the disease. Banana bunchy top and cucumber mosaic virus are also causing considerable loss to these dessert bananas. In India, Virupakshi (AAB Pome) is seriously affected by this disease, which has devastated a large number of plantations in Tamil Nadu (Singh 1990). However, sanitation and use of disease-free suckers have been practised to contain the disease. Banana bract mosaic and banana streak virus were also identified, which may become serious if not contained.

Banana weevil *(Cosmopolites sordidus)* and pseudostem borer *(Odoiporus longicolis)* are serious on these dessert banana in India, China, Philippines, Indonesia, Thailand and Australia (Singh 1993; Stanton 1994). However, Saba from the Philippines and Bhimkol (BB) from India are highly resistant cultivars (Anon. 1991).

Among the nematodes, *Radopholus similis* is widespread and causes considerable losses to banana plantations (Charles and Venkitesan 1993; Davide 1994; Hadisoeganda 1994, Maolin 1994; Pone 1994; Razak 1994; Reddy 1994). In China, however, *Pratylenchus reniformis* is widespread and has high population densities (Stanton 1994). In Malaysia, *Helicotylenchus* spp. (*H. dihystera* and *H. multicinctus*) are the most prevalent nematodes followed by *Meloidogyne* sp. (Razak 1994). In India, *R. similis* is more prevalent in south India while *H. dihystera* is an important nematode in the northeastern region (Singh 1993).

Long duration of cropping, tall plant and smaller bunches are some of the abiotic constraints and require improvement. If Pome and Silk have to be a better proposition for commercial production, there is a need for improvement in agronomic characters to obtain yields comparable to Cavendish within a short duration. Therefore, an ideotype of Pome/Silk dessert banana is presented in Table 4. Ideotype plants of dessert banana AAB should express disease/pest resistance, early flowering, early maturity, dwarfism and regular suckering behaviour. They should produce large and pendulous bunches and the postharvest characters should be equivalent to traditional cultivars. Poovan (AAB Mysore) and Ney Poovan (AB) are also popular cultivars in India and would require improvement for plant characteristics and yield. Resistance to *Foc* will be required in Ney Poovan. Therefore, there is an urgent need for improvement in dessert banana (Pome/Silk) for resistance to *Foc*, agronomic characters and postharvest qualities.

Table 4. Ideotype requirements of AAB (Silk and Pome) banana

Requirements
1. Resistance to *Foc*
2. Nematodes
3. BBTV, BBMV

Agronomic characters
1. Yield comparable to Cavendish cultivars
2. Reduced plant height
3. Short crop cycle and early maturity
4. Responsive to application of nutrients and water

Quality requirements
1. Increased finger size with minimum curvature
2. Flavour acceptable, true to type
3. Reduction in acidity and improved keeping quality

Opportunities

After 70 years of banana breeding, the programme has been unable to produce hybrids to meet the quality demands of the export trade. This is due to the complexity of problems in breeding, and so opportunities have not been fully exploited in Asia and Pacific. High genetic diversity coupled with an appreciation of problems provides opportunity for improvement. Successes in FHIA (Rowe and Rosales 1994) and IITA (Ortiz and Vuylsteke 1994) programmes shall be a catalyst for the utilization of opportunities in improvement of dessert banana. Recent advances in biotechnology as tools for improvement also provide greater opportunities.

Genetic diversity

The genetic diversity present in Southeast Asia (Valmayor *et al.* 1990), India (Singh and Chadha 1993) and Pacific is documented. Many of the accessions are found to be resistant to major diseases and nematodes (Singh 1993) which can be utilized in breeding programmes for the transfer of desirable traits. Germplasm is largely conserved in field genebanks and attempts at *in vitro* conservation are also successful. In addition to morphotaxonomical evaluation, diversity has also been studied using isozyme systems (Bhatt *et al.* 1992). Lebot *et al.* (1993) studied 563 accessions for the genetic relationship among cultivated bananas from the Asian and Pacific regions. The isozyme data suggested that the genes contributed by the *M. acuminata* genome to AAB Popoulou/Maia Maoli are similar to those of *M. acuminata* ssp. *banksii* complex of PNG. Isozyme evidence also suggested that cv. Saba is a *M. acuminata* x *M. balbisiana* triploid and distinct from other members of the Saba subgroup. Thus, there is better understanding of genetic diversity in Asia and Pacific and this may require further research to remove many of the synonyms. India has a unique situation where banana is grown in diverse agroecological conditions which may favour the analysis of genotype x environmental interaction.

Cytological behaviour of banana studied on different genomic groups (Sathiamoorthy 1994; Aggarwal 1983, 1987, 1988) has favoured the better understanding of triploids, diploid from AA or BB and their hybrids. Double restitution (4*x* gamete) in embryos giving pentaploids after diploid x diploid crosses is attributed to fertilization of double restituted (4*x*) egg cell by *x* gamete (Agarwal 1988), a rare phenomenon. In female fertile AAB banana there is higher frequency of functional haploid gametes which results in more diploid than tetraploid when AAB x AA crosses are made. However, functional female gametes with reduced chromosomes are low in AAA banana. Therefore, it is possible to have enhancement of germplasm at diploid level through the crosses of AAB dessert banana with diploid.

Aggarwal (1987) conducted meiotic studies in eight male sterile triploid banana cultivars and observed the pollen mother cell degeneration at various stages of development. Through the cytological studies and genetic evaluation of progenies from different crosses, it has been possible to have insight on inheritance of many desirable traits which shall be a guiding force for effective planning of breeding strategies.

Quantity of pollen produced is reported for 34 accessions by Sathiamoorthy (1994). Robusta (AAA), Nendran (AAB) and Pisang Seribu have already been used as pollen parents successfully. At IIHR, Bangalore, BRS, Kannara and NRCB, Trichy, a large number of accessions have been identified as having pollen fertility (Singh and Uma, in press). Most dessert bananas–either diploid AA, BB or triploid AAA, AAB, ABB–produce pollen under south India conditions. However, fertility of pollen is determined by growing conditions and season, which is largely influenced by temperature and humidity. Female fertility has been studied in a large number of accessions at these locations. Agniswar (AAB Pome), Ney Vannan (AAB Pome), Karpooravalli (ABB), Poovan, Red Banana, Virupakshi and many other accessions have been found to be female fertile but seed production is influenced by season, location of hand on bunches and growing conditions. Evidence available from IITA's programme also suggests the influence of season on female fertility.

Experience from the FHIA and IITA programmes suggests that breeders are more likely to succeed in breeding plantain and cooking banana than export banana. An elite diploid population developed at FHIA, which has shown the feasibility of population improvement at diploid level, has potential for use in breeding dessert banana. International cooperation through donation of improved diploid material may enhance the breeding process for improvement of dessert banana in the region. At Coimbatore also, more than 10 elite diploids with male and female fertility have been identified which have resistance to yellow Sigatoka and nematode.

Micropropagation has been standardized for all the banana clones, which may be used for rapid development of male and female parents for establishing crossing blocks and multiplication of promising new hybrids for evaluation trials. Application of embryo culture has also been found to enhance the production of viable plants in a hybridization programme. The embryo rescue has increased the seed germination rate by a factor 3 to 10. Stereomicroscopically, a 0.7-1 mm diameter embryo is removed from the hardened seed coat and raised in half concentration of MS media with a range of hormones (Vuylsteke *et al.* 1990) and maintained at room temperature. Biotechnological approaches–mutation breeding (Roux *et al.* 1994) and somaclonal variation (Hwang 1991)–also provide opportunities for the improvement of dessert banana.

In recent decades, there has been a phenomenal change in appreciation of the need for banana improvement. As a result, strong NARS programmes have emerged with continuing efforts to improve their capabilities. Australia and Taiwan have strong programmes on biotechnology in banana and also for the investigations of diseases. In India, the NRCB has started functioning and is committed to the improvement of banana through conventional and non-conventional methods of breeding.

Approaches

Conventional breeding

One of the approaches in conventional breeding of dessert banana (Silk, Pome, Poovan) would be to involve crosses between AAB or ABB cultivars as female parents and best synthetic diploid or disease-resistant wild type (*acuminata* or *balbisiana*) as male parents. The primary tetraploids can be crossed to improve diploid banana to produce secondary triploids. Secondary triploid can also be crossed with *M. acuminata* to get tertiary tetraploid or other tetraploid hybrids having disease resistance and acceptable agronomic traits. Developing tetraploid from diploid through colchicine treatment and crossing it to diploid to get triploid is also an approach.

Since triploids are superior to tetraploids with respect to leaf retention, bunch with strong peduncles, strength of fruit neck, seedlessness, etc., breeding has to be aimed at production of secondary triploids. This approach would also provide for the recovery of diploid hybrids for enhancing the genetic resources for further utilization. In a breeding programme, in addition to resistance and agronomic characters, post-harvest quality should focus on consumer acceptability, fruit palatability (flavour, texture), shelf-life, ripening, damage susceptibility and storage properties.

The first stage in breeding will be selection of seed parents with desirable agronomic traits identified through study on seed-set through hand-pollination using male fertile wild types. Seasonal variability for seed-set will also require study for greater success in a breeding programme. Synchronized flowering of male and female parents would be essential for effective crosses; this can be achieved through manipulation at time of planting. A large number of female and male parents should be raised through tissue culture in a breeding block and allowed for open-pollination, as open-pollination produces more seeds than hand-pollination. *In vitro* seed germination shall be practised to get more viable plants. The progenies should be evaluated and backcrosses should be attempted to get secondary triploids.

In addition to gene transfer through hybridization and recombination, survey and selection of superior type in dessert banana should be a priority approach; it has been successful for improving banana cultivars in many countries. In India, this approach of selection from natural populations has resulted in many superior types.

Biotechnological breeding approach

Promising results have been obtained in research conducted at the TBRI (Hwang 1991) for selection of somaclones resistant to *Foc*. Intensive studies

on somaclonal variation and identification of variants with desirable traits hold promise for improvement of dessert banana. Mutation breeding using physical or chemical mutagens has failed to produce variants but *in vitro* mutation breeding has promise (Roux *et al.* 1994; Jamaluddin 1994). To ensure success, large populations should be raised.

Conclusion

Dessert banana (AAB, Silk and Pome subgroups) currently faces extremely serious threats from *Foc* and nematode. These bananas have a long crop cycle and lower yield per unit area than Cavendish banana. Chemical control methods are either ineffective, unusable or too expensive. NARS in the Asian and Pacific regions have excellent collections of genetic resources which have potential for use in improvement programmes. Conventional breeding, other than in India, has received little attention. In India, three promising hybrids have been developed. The encouraging results from the breeding programme at FHIA and IITA, plus the better understanding of cytogenetics, inheritance and improvement in breeding methods through the use of *in vitro* methods, offer great promise for the improvement of dessert banana in Asia and the Pacific. The capability of NARS in the region has improved along with a growing appreciation by policy-makers. Novel approaches have the potential to enhance opportunities for improvement of dessert banana. Selection of improved genotypes, hybridization of female fertile AAB dessert banana with improved diploid and development of secondary triploid, selection from somaclonal variation, and *in vitro* breeding shall be the approaches for improvement of dessert banana in Asia and Pacific with effective collaboration among countries in the region.

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