Banana and Plantain Breeding – A Review of Problems, Prospects and New Initiatives

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BANANA AND PLANTAINS

Â Tropical fruit crop – acclimatized - subtropical and to some extend in semi arid zones.

Â Raised status - backyard crop to high value crop.

Â Banana and Plantains are no more considered as single crop commodity but a complex crop with broader utilities.

Â Major world production is consumed as dessert (60 %) and 40% contributes to staple diet.
Improvement of Banana and Plantains is become more complex two major reasons

1. Plant based constraints – inherent complexities

2. System based constraints – external threats including biotic and abiotic stresses

Comprehensive reviews on the above aspects done by various earlier workers

(Simmonds, 1962, 1966; Rowe and Rosales, 1996; Stover and Buddenhagen, 1986; Persley and de Langhe, 1987; Ganry, 1993; Ortiz et al., 1995; Vuylsteke et al., 1997; Tenkouano, 2006;
How safe is the crop despite its growth?

Nature of crop existence – very very FRAGILE

Shift from low value to High value status of the crop
  through very high productivity
  through high inputs

• This is possible only through mono cropping systems

This has led to high pressure due to biotic and abiotic stresses
  Existing diseases and pests
    • emerging diseases (Panama disease TR4; Race 1 on Cavendish, BXW etc.)

• Climate changes (drought, salinity etc)

• High feeding nature of the crop + reduced access to inputs
Priorities of banana breeding

Ideotype of banana

- Good quality
- Fruit shattering
- Long green / Yellow life
- High nutrition values

Quality

Resistance

- Fusarium wilt
- Sigatoka
- Bacterial wilt

- Weevil
- Borers
- Nematodes

Tolerant to drought

Marginal conditions

High yield

Dwarfism

Short duration

Good ratoon
Banana production problems and priorities identified in the Bogor meeting, 2012

Compilation – J.Sardos and N.Roux)
### Country wise problem prioritization

<table>
<thead>
<tr>
<th>Priority</th>
<th>Australia</th>
<th>Brazil</th>
<th>China</th>
<th>East Africa</th>
<th>French West Indies</th>
<th>Hawaii</th>
<th>India</th>
<th>Indonesia</th>
<th>Malaysia</th>
<th>North Africa</th>
<th>Pacific (Fe/bananas)</th>
<th>Philippines</th>
<th>PNG</th>
<th>Thailand</th>
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</table>
Plant based constraints

- Narrow genetic base for resistance against pests and diseases
- Identification of potential sources of resistance
- Low female fertility – Identification of female/male parents
- Sterility male and/or female
- Limited knowledge on crop genetics
- Polyploid nature of the crop
- Compatibility and Poor seed set
- High level of structural, genic heterogygosity
- Too many factors affecting seed set
- Problems with hybrid regeneration
- Longer crop duration for quicker evaluations.
- Occurrence of BSV (integrated activable sequences)
Review of the status of the current genetic diversity

All commercial clones - are edible triploids (AAA, AAB, ABB):

- In nature - Sterile crop
  - sexual recombination events (narrow)
  - Dependency on only one genotype (Cavendish)

- Existing diversity - Simply phenotypic diversity

- Perpetuation - through vegetative propagation
Approaches
I. Overcoming plant based constraints

Broadening of the narrow genetic base

• Regular and systematic explorations in the areas of natural variability

• Identification of interesting gene sources among landraces and wild species.

• Utilization of these landraces – development of progenies (diploid and tetraploid) which are in various stages of evaluation.
Banana Improvement program

1. Search for new variability and exploitation as substitutes

Replacement of Fusarium tolerant landrace of Silk

Eg. Local Rasthali (AAB-Silk)  Bangladesh Malbhog
Replacement through introductions

Selection from ITC introductions, Dwarf Pisang Awak

<table>
<thead>
<tr>
<th></th>
<th>Traits of interest</th>
<th>P.Awak selection</th>
<th>Local K. Valli</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Height (mt.)</td>
<td>2.2</td>
<td>&gt; 4.0</td>
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<tr>
<td>2</td>
<td>Days to flowering (days)</td>
<td>273.0</td>
<td>&gt; 360</td>
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<tr>
<td>3</td>
<td>Days to maturity (days)</td>
<td>125.0</td>
<td>&gt; 130-140</td>
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<tr>
<td>4</td>
<td>Yield</td>
<td>15-16kg</td>
<td>20.0kg</td>
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</tbody>
</table>

Presently planted in 3 locations at NRCB, still remains short.
Advantage: May be good for high density planting OR 2 pl/hill
Since early flowering can adopt to annual cropping system
Replacement of local P, Awak with dwarf Klui Namwa
Other introductions performing fairly well in India are,

- **Saba**
  - Proven for drought tolerance and
  - Suited for water deficit environments
  - Tested under GCDT program

- **Burro Cemsa**
  - Same as above

- **FHIA-01**
- **FHIA-03**
- **FHIA-17**
- **FHIA-21**

Programs with international vision are lauded....
Identification of female/male parents

Development of Baseline information
- on compatibility and
- breeding behavior
- Ploidy of progenies among potential *Musa* germplasm

Details on
- seed set
- Seed properties and
- seedling establishment
- 206 successful combinations
Various breeding schemes—Advantages and necessities

Diploid breeding

Vital to banana improvement programmes and advantages like,

- Vast genetic background,
- Occurrence of high levels of male and female fertility
- Low levels of heterozygosity  
  (which reduces time to develop homozygous lines)
- Easy genetic manipulations and ease of their studies.
Problem with them are,

- Delicate in nature and perish in harsh weather conditions
- Need periodic restoration and maintenance of their vigour by selfing.
- Open field conditions of diploid germplasm may lead to extended variability.
- They exhibit differential performance in terms of reduced vigour after long storage under *in-vitro*
- Needs to be restored with selfing and field regeneration,
Utilization of diploids

Diploids could be of monospecific (AA/ BB) or bispecific (AB) in origin.

Bispecific origin with B genome imparts hardiness to the diploid and in many occasions they found to be much preferred cultivar of commerce.

Eg. Ney Poovan (AB) and Kunnan

Improved knowledge on fertility status of AB diploids has broadened the usage which was not there till recently.

Diploids of derived from triploid X diploid crosses could be of some benefits which haven’t been exploited for Niche banana growers.
<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Trait evaluated for</th>
<th>No. of accessions evaluated</th>
<th>Gene sources identified</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sigatoka leaf spot disease (<em>Mycosphaerella eumusae</em>)</td>
<td>360</td>
<td>13</td>
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<tr>
<td>2.</td>
<td>Fusarium wilt disease</td>
<td>360</td>
<td>Pisang Lilin - became susceptible</td>
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<td></td>
<td>Race 1&amp;2,</td>
<td></td>
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<tr>
<td></td>
<td>For VCG groups - 124 &amp; 125</td>
<td></td>
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<tr>
<td></td>
<td>(in sick plot)</td>
<td></td>
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<tr>
<td>3.</td>
<td>Tolerance to drought</td>
<td>104</td>
<td>7 – tolerant</td>
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<td>24 – moderately tolerant</td>
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<td>4.</td>
<td>Pseudostem weevil (<em>O.longicollis</em>)</td>
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<td>11</td>
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<td>5.</td>
<td>Nematodes</td>
<td>360</td>
<td>7 - <em>P. coffeae</em></td>
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<td></td>
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<td>9 – <em>M. incognita</em></td>
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### II. System based constraints

They include large number of biotic and abiotic stresses

<table>
<thead>
<tr>
<th>Constraint</th>
<th>Caused by</th>
<th>Susceptible groups and subgroups</th>
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<tbody>
<tr>
<td><strong>Fungal Diseases</strong></td>
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<td></td>
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<tr>
<td>Fusarium wilt Race-1-4</td>
<td><em>Fusarium oxysporum f.sp. cubense</em></td>
<td>&gt;95%</td>
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<tr>
<td></td>
<td></td>
<td>Silk, Pome, Pisang Awak, cooking bananas, Ney Poovan, cooking bananas, Cavendish</td>
</tr>
<tr>
<td>Black Sigatoka</td>
<td><em>Mycosphaerella fijiensis</em></td>
<td>&gt;95%</td>
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<td></td>
<td></td>
<td>Almost all groups</td>
</tr>
<tr>
<td>Yellow Sigatoka</td>
<td><em>M.muscola</em></td>
<td>&gt;65</td>
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<td>Almost all except few AAB subgroups</td>
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<td><em>M.eumusae</em></td>
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<td>No clear cut information</td>
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<tr>
<td>Bacterial wilt</td>
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<td>12-20%</td>
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<td><strong>Viral Diseases</strong></td>
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<td>BSV, BBrMV, BBTV, CMV</td>
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<td>Wild and cultivated types</td>
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<td><strong>Pests</strong></td>
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<tr>
<td>Corm weevil</td>
<td><em>Compolites sordidus</em></td>
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<tr>
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<td>Almost all groups</td>
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<tr>
<td>Stem weevil</td>
<td><em>Odoiporus longicollis</em></td>
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<td>All group and subgroups with differential preferences</td>
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<tr>
<td>Nematodes</td>
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<td>100%</td>
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<tr>
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<td>Almost all groups</td>
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Apart from introductions... Some of the wild acuminata diploid landraces being used in breeding programs
Some of the wild acuminata subspecies being used in breeding programs.
Major obstacles for using wider strata of breeding material

- Lack of diploid populations/ lines
- Lack of diversity and difficulty to access it (especially CWRs)
- Lack of knowledge (e.g. ecology of CWRs populations)
- Lack of knowledge on performance in the natural habitats
- Sufficient funding
Development of Improved diploids for use in improvement

- Parthenocarpy
- Drought tolerant
- R. similis tolerant
- Acceptable qualities
- Susceptible to Sigatoka (Mycospherella eumusa)

All parental qualities with Sigatoka resistance
Improved diploid

Parthenocarpy,
Drought tolerant
*P. offeae* tolerant
Tolerance to Sigatoka
(*Mycospherella eumusae*),
Acceptable fruit qualities

This is mostly used apart from a couple of other improved diploids.....
Triploid breeding in Musa

1. Pre Breeding Activity

Some of the priorities identified during the Bogor meeting 2012

- Diploid populations well characterized and evaluated (association studies)

- Populations of *Musa* wild relatives

- Broader allele base for specific traits

- Knowledge on the genetics of specific traits
1. Pre Breeding Activity

Development of improved diploids and tetraploids

- Aaw x AAcv
- Aacv X AAcv
- Aacv X BB

AAcv → AAAAcv (1)
ABcv → Chromosome doubling (colchicine) → AABBcv (2)

Synthetic diploids- Direct utility in breeding

CIRAD, NRCB, IITA, EMBRAPA
Triploid x diploid breeding scheme

Triploid (3x) \times Diploid (2x)

Euploids & aneuploids
2n = 22, 33, 44,…

Selection of primary tetraploids
Development of Hybrid triploids

AA × AAAAcv → AAAcv

BB × AAAAcv → AABcv

AA × AABBCv → AABcv

BB × ABBBcv → ABBcv
Knowledge on fertility in Kunnan led us to develop AB x AA derived progenies

Earlier we were trying to achieve this with *in-vitro* tetraploidization which was Cumbersome.
## Application of polyploidy in banana breeding

<table>
<thead>
<tr>
<th>Variety</th>
<th>Stomatal density per sq. mm</th>
<th>Ploidy status assessed using stomatal density</th>
<th>Ploidy status confirmed using Flow Cytometry</th>
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<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Treated</td>
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<tr>
<td>Matti (AA)</td>
<td>56.04</td>
<td>38.46</td>
<td>Diploid</td>
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<tr>
<td>Cultivar Rose (AA)</td>
<td>50.54</td>
<td>15.80</td>
<td>Tetraploid</td>
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<tr>
<td>Valiyakunnan (AB)</td>
<td>55.89</td>
<td>50.66</td>
<td>Stable diploid</td>
</tr>
<tr>
<td>Ney Poovan (AB)</td>
<td>53.85</td>
<td>39.56</td>
<td>Diploid</td>
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</table>
**Outcome of tetraploidization project**

- One out of 4 varieties resulted in stable tetraploid
- But it never came to flowering through successive 4 years
- Project was abandoned.
Breeding for AAA hybrids

CV Rose, 2x → CV Rose, 4x → M. acuminata malaccensis, AAw, 2x (seedy) → AAA hybrid family

- 99.5% of triploids: (32 to 34 chromosomes)
- Parthenocarpic and no parthenocarpic hybrids
- Mean value of the family tested over ± 30 individuals
- Selection over ± 300 individuals

Seedy banana

Courtesy - Fred Bakry \ Bor\gor meeting 2012
Breeding for AAB/ABB hybrids

'M. a. malaccensis, AAw

Synthetic AAB hybrid

'Synthetic ABB hybrid

'Kunnan 4X' AABBCv

M. balbisiana, BBw
Improvement of French Plantains

Progenies of various ploidy status

3x \times 2x \rightarrow \text{Sigatoka resistant, Short stature}

Progenies of various ploidy status

2x, 4x

4x \times 2x \rightarrow \text{Sigatoka resistance, short stature}

Higher yield (20kg)

3x \times 2x \rightarrow \text{Sigatoka resistance, Normal stature}

Sigatoka resistance, Normal stature
Yield is not the major criterion as there is sufficient diversity....... But yield stability over ratoons is an important factor.
View of progeny evaluation block of cooking bananas
Other problems needing attention are

- Improving regeneration efficiency of hybrid seeds
- Through embryo culture and embryo rescue
- Embryo culture has been successful is diploid crosses
- Embryo culture protocols is not universal to all crosses
- But not suitable for triploid crosses, so embryo rescue….
Morphological studies to understand the reasons for poor germination

T. S of embryo

L. S of embryo

778 µ
932 µ

948 µ
708 µ

1142 µ
1032 µ

988 µ
1262 µ
Embryo rescue

60 % Maturity

80 % Maturity

100 % Maturity
Multiple shoot induction per individual event

For important triploid crosses
Different types of callus

Callus proliferation (60% matured embryos)

Callus obtained from 80% & 100% matured embryos
Multiple shoot induction

Callus Proliferation
Some approaches for tackling the problem of banana breeding
Global Banana Breeding Centers

**FHIA** : Fundacion Hondurena de Investigacion Agricola, Honduras

**IITA** : International Institute of Tropical Agriculture, Nigeria / Uganda

**CARBAP** : Centre Africain de Recherches sur Bananiers et Plantains (CARBAP)

**EMBRAPA** : Empresa Brasiliera de Pesquisa de Mandioca e Fruticultura (Brazil)

**CIRAD** : Centre de Coopération Internationale en Recherche Agronomique pour le Développement

**India**

**NRCB** : National Research Centre for Banana, Tamil Nadu, India

**TNAU** : Tamil Nadu Agricultural University, Tamil Nadu, India

**KAU** : Kerala Agricultural University, Kerala, India
Genetic Resource Management

Genus *Musa* (+*Ensete*) has a great diversity spread across the Pacific to south, south East Asia up to sub Saharan Africa.

As per the data (2006),
- ITC has nearly 1200 collection
- only 30% is sought from various programs.

This accounts for efficient utilization of <30% of our valuable gene sources.

So emphasis should be on the need for efficient utilization of available genetic material.
Reasons for non utilization could be,

Å Incomplete knowledge on their potential benefits

Å Accessibility

Å Lack of facilities for complete evaluation of new materials leading to beneficial germplasm going unnoticed

Å Collecting more and better variability

Å Recent collecting missions in India, Pacific Islands, Indonesia, Congo and other countries have demonstrated the knowledge and access Musa diversity as far from complete.

Å Evaluation of wild collections, wild relatives, landraces for various biotic and abiotic stresses from all these countries is yet to be complete and results to be made available in public published domain.
Thus collection, introductions, evaluation, utilization form an important aspects in better management of genetic resources.

This process is aided by MGIS, molecular characterization and other applied molecular techniques.
Need for strong evaluation and characterization programs.....

Availability of information to enable the selection of right parents

Ability to select tolerant genotypes

Need to focus on trait specific phenotyping - strong phenomic programs

Collection of trait specific data across the genebanks involved in evaluation programs.
CONCLUSION

Search for diversity is a continuous process

At least effective use of the diversity for which we have access.

Extracting more information from locals –

Its about looking at possible replacements of susceptible ones with resistant clones

Use of molecular tools complementing the conventional breeding

Use of non conventional tools for speeding up hybrid regeneration

Most important is….
Strong support to breeding programs
Thank You