The application of plant biotechnology in seed industry in the developing countries

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The message

Overview of plant biotechnology

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What the seed industry in developing countries actually needs

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The quick and easy way to make a difference: prioritization

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Gaps in the development of seed industry in developing countries

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How to address the gaps

Contents

- Seed industry structure for biotech application
- Importance of localized small and medium scale seed industry in developing countries
- Plant biotech overview: Sections
- Technologies proven in seed industry
- Future biotech in seed industry
- Maximizing gains
- Conclusions
- References

Seed industry structure & biotech

The indigenous seed industry

Small and medium scale seed industry
Low-investment potential
Low technological power

Large trans-national seed companies

Well established sales and marketing network
Satellite biotech support laboratories
High investment potential
High technological power

Importance of local seed industry

- Captures a consumer niche not addressed to by the large trans-national seed companies
- Biodiversity conservation
- Variety in food, better catering to local tastes and requirements
- Self reliance, national economy
- Check monopolization in seed industry

Plant biotech overview: Sections

Seed industry (Vegetable crops, Cereals, field crops, some fruit crops and ornamentals)

Technologies: Molecular breeding, plant genetic transformation, molecular diagnostics, doubled haploids, embryo rescue

Oil palm/Trees

Technologies: Everything above, special focus micropropagation and somatic embryogenesis

Floriculture

Technologies: Special focus on Somatic embryogenesis, micropropagation, mutation breeding

Public genebanks

Technologies: Special focus on cryopreservation, tissue banking, artificial seeds

Universities and public sector research institutes

Technologies: All the above

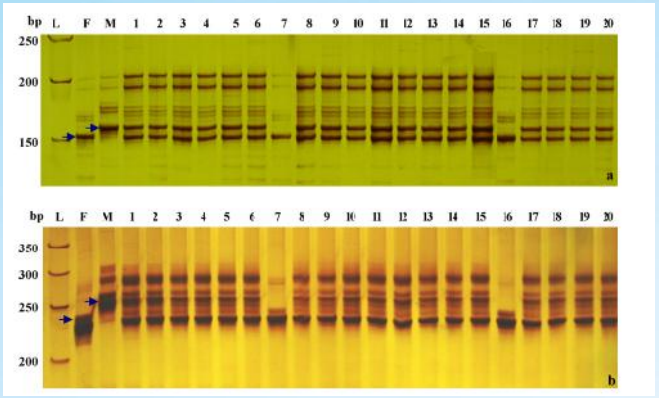
Pharmaceuticals

Technologies: Molecular farming

Biotechnology in seed industry

- Molecular breeding
- Doubled Haploids
- Plant genetic transformation
- Molecular diagnostics

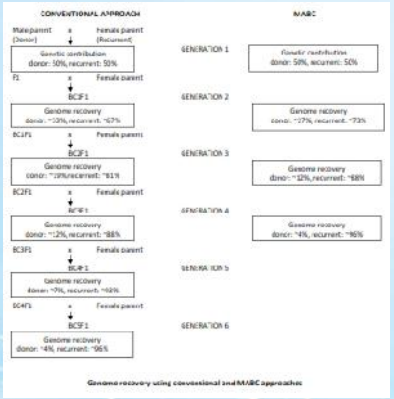
Biotech seed industry: molecular breeding



Hybrid seed purity testing



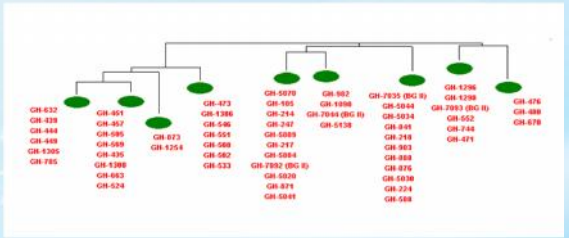
DNA fingerprinting



Marker-assisted-backcross

Marker assisted selection





Heterotic grouping

Biotech in seed industry: DH



Doubled Haploids - Uniformity

Biotech in seed industry: transgenics



Comparison of unsprayed Bt-cotton and non-Bt cotton

Biotech in seed industry: molecular diagnostics

Activities

Hybrid seed purity testing
Zygosity testing
Pathogen detection

Techniques

PCR-ELISA
Immuno assays / strip-tests
FISH
Microscopy
Microbiological cultures
DNA markers/probes
DNA barcdoing

NGS and Marker technologies

- Sequencing/genotyping infrastructure not a constraint anymore
- Analytics the challenge now – molecular breeding to information science
- Major marker technologies now: GBS, SNPs and SSRs

Future trends

- Big data handling – information science – molecular breeding
- Cheap sequencers – Oxford Nanopore, Illumina MiniSeq
- Use of a wider germplasm base – increased confidence in breaking harmful linkage drag using a dense molecular-markers coverage
- Deciphering the molecular basis of heterosis – over a hundred year old riddle – clear role genetics and epigenetics – tools developing – once the mechanism discovered, dramatic improvement in hybrid crop varieties may be expected
- Epigenetics – increased application - how
- Climate-change-ready crops
- Genome editing
- DH increased use – inducer lines maize, rice

Maximizing gains – how?

- Time-tested and proven technologies
- Quick delivery: short timelines
- Readily available technologies
- Minimal risk in investment:
  Minimal public and environmental concerns
- Minimal financial resources

Maximizing gains – low input industry

Molecular breeding in small & medium seed industry

- Marker assisted selection/gene-stacking (MAS)
- Marker assisted backcross (MABC)
- Heterotic grouping
- DNA fingerprinting of inbred lines
- DNA fingerprinting of hybrids
- Germplasm management
  - Germplasm characterization
  - Diversity analysis
  - Screening for biotic & abiotic stress resistances
  - Removal of duplicates
  - Purification of germplasm accessions
- Line stabilization
- Hybrid seed purity testing

Maximizing gains – high input industry

Molecular breeding in large companies and academia

- Breeding by design (BBD)
- Genomics assisted breeding (GAB)
- Fine-level QTL mapping
- Association mapping
- Genome Wide Association Studies (GWAS)
- Nested association mapping (NAM)
- Multiparent Advanced Generation inter-Cross (MAGIC)
- Mutation breeding (TILLING/Eco-TILLING)
- Genomic selection
- Genome editing

Maximizing gains: low input v/s high input

Small & medium seed industry
Focus: proven useful technology

- Marker assisted selection (MAS)
- Heterotic grouping
- DNA fingerprinting of inbred lines
- DNA fingerprinting of hybrids
- Germplasm management
  - Germplasm characterization
  - Diversity analysis
  - Screening for biotic &
  - abiotic stress resistances
  - Removal of duplicates
  - Purification of germplasm accessions
- Line stabilization
- Hybrid seed purity testing

Academia & large seed industry
Focus: Stay updated with technologies, market leader

- Breeding by design (BBD)
- Genomics assisted breeding (GAB)
- Fine-level QTL mapping
- Association mapping
- Genome Wide Association Studies (GWAS)
- Nested association mapping (NAM)
- Multiparent Advanced Generation Inter-Cross (MAGIC)
- TILLING/Eco-TILLING
- Genomic selection (GS)
- Genome editing

Maximizing gains: low input v/s high input

Comparison

- Cheap infrastructure: MiniSeq $49,500, Oxford Nanopore MinIon $1,000 base unit
- Less number of markers ~300 v/s ~10,000 markers
- Analytical demands relatively low
- Returns on investment more assured

Maximizing gains – case of transgenic crops

Transgenic technology (e.g. Bt genes)

- Identify, isolate and characterize protein/s of interest — Protein chemistry
- Make a gene construct …… — Molecular biology
- Develop transformation and regeneration protocols .. — Cell & microbiology
- Transform crop of interest, expression analysis, ……. copy number analysis, insert size & sequence, elite event selection etc.: — Cell biology and molecular biology
- Extensive environmental and biosafety testing …… — Field testing, clinical trials with animals
- Regulatory approval by multiple governmental …… departments — Ministry of Environment/ Health/ Agriculture
- Introgression of gene of interest into . ……. elite breeding lines — Plant breeding
- Develop hybrid varieties for commercialization …… — Plant breeding

Maximizing gains: Transgenics v/s mol breeding

Transgenic crops

Timelines:
~13 years
Commercializing the crop variety

Budget:
Major CapEx – Small companies
Can not afford, medium companies pay massive royalties
USD 2m-10m (?, personal comm)

Public acceptance:
Difficult

Molecular breeding

Timelines:
Quality control – No time loss
Crop variety development – 3-5 years

Budget:
CapEx affordable for both small and medium biotech/seed business enterprises
Variable but a fraction of the cost incurred for GMOs

Public acceptance:
Guaranteed/ No ethical, biosafety/environmental concern

Maximizing gains: Public-private linkages

Employability
New markets

Seed industry

Commercial relevance
Customer benefits



Academia

Technological innovations
Technical work force

Government

Financial support
Regulatory policies

The growth engine for seed industry

Conclusions

- The local seed industry in developing country has an important role in society to compliment the large seed companies.

- The low-investment-based local seed industry has its own set of biotech requirements different from those of large scale seed industry and academia.

- Local seed industry in developing countries requires ear-marked support and not broad-based policy support in the name of plant biotechnology.

- There is a need to synchronize government policy making, academia and seed industry.

References

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Thank you