Workshop and Training Program on Sampling and Detection Methods Applied to Transgenic,
National Institute of Nutrition, Hyderabad, Nov. 17-18, 2011

Genetically Engineered Crops
Product Development & Commercialization

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This presentation

- **Biotechnology for crop improvement**
- **Status of transgenic crops**
- **Status of transgenic crops @ ICRISAT**
- **Issues linked to the development & deployment of GE crops**
- **Overcoming the challenges**
- **Platform for translational Research**
- **Conclusions**

Challenges in agriculture

- Need for increased and efficient agricultural production to provide sufficient food for the growing population, estimated to increase by 3 Bn in next 50 years.
- Find solutions for important constraints to crop productivity.
- Develop new technologies that raise the yield in low potential areas.
- Create opportunities for diversification in agricultural value-chains & Develop sustainable models.

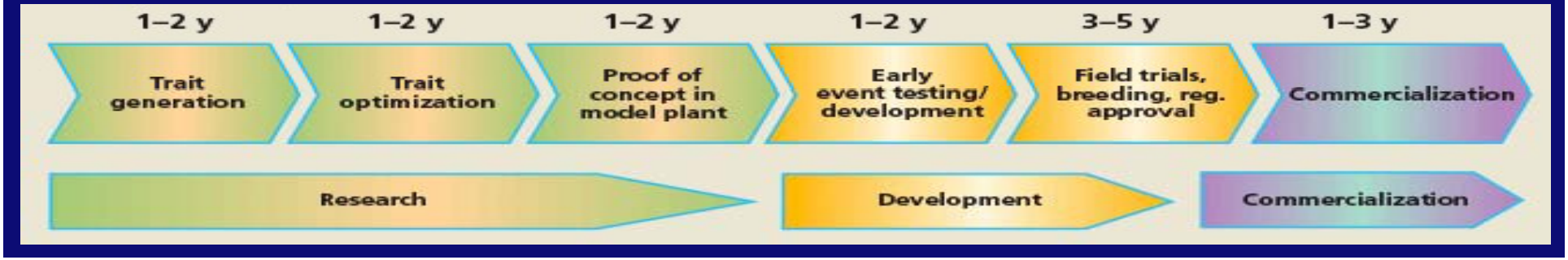
Modern Biotechnology, particularly the genetic engineering technology has the potential to provide new ideas and techniques to complement agricultural research

GE Crops: Major Focus

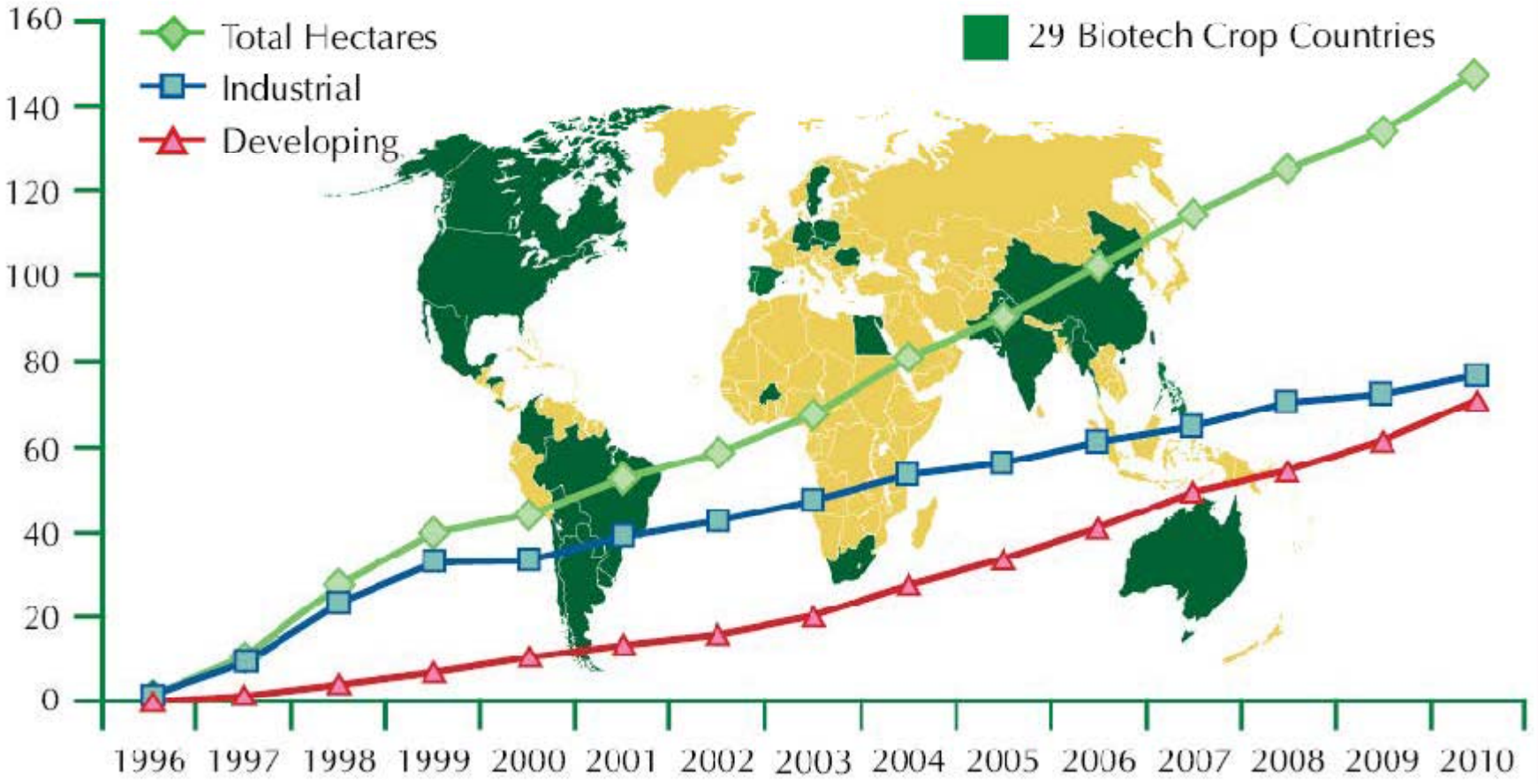
- Integrated pest management
- Herbicide tolerance
- Nutritional enhancements
- Product quality improvement
- Increase in yield
- Stress tolerance
- Plant based pharmaceuticals

Producing Transgenic Plants

- Efficient tissue culture system for regenerating shoots
- Introduction of gene into plant cells
- Selection of transformed cells or tissues
- Regeneration of putatively transformed whole plants
- Transfer to greenhouse and advancement of generations
- Molecular and genetic characterization
- Selection of events under greenhouse conditions
- Contained field testing under natural conditions
- Open field testing for agronomic performance
- Food and Environmental safety
- Release, introgression into new varieties, & Commercialization



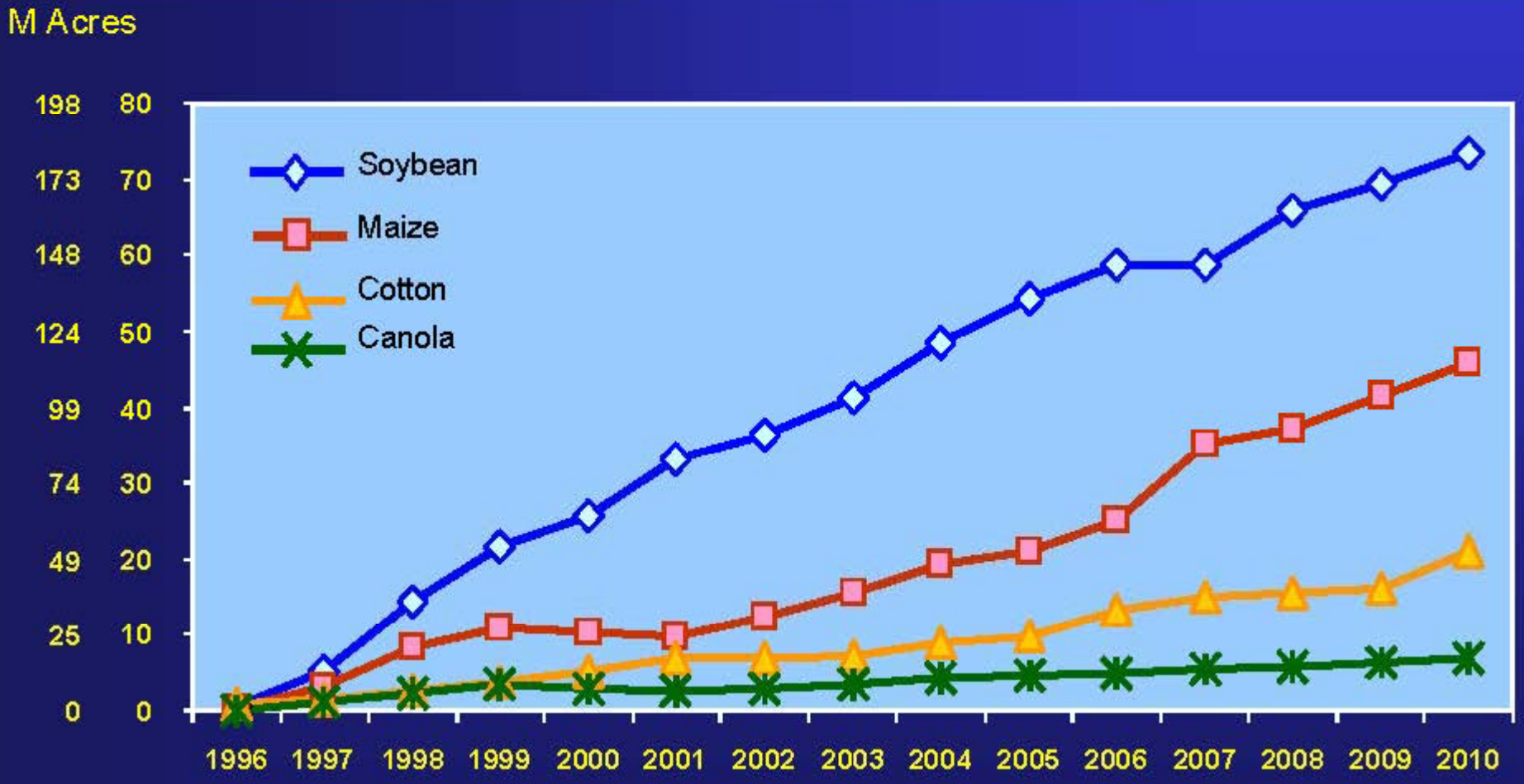
GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996-2010)



A record 15.4 million farmers, in 29 countries, planted 148 million hectares (365 million acres) in 2010, a sustained increase of 10% or 14 million hectares (35 million acres) over 2009.

Source: Clive James, 2010.

Global Area of Biotech Crops, 1996 to 2010: By Crop (Million Hectares, Million Acres)



Source: Clive James, 2010

Indian Research Scenario

Crops	Pub.	Pvt.	Total
FIELD CROPS			
Wheat	1	0	1
Rice	30	5	35
Ragi	2	0	2
Sorghum	10	2	12
Mustard	5	1	6
Maize	2	0	2
Subtotal	**50**	**8**	**58**
VEGETABLES			
Brinjal	4	5	9
Black Pepper	3	0	3
Bell Pepper	1	0	1
Okra	0	6	6
Cabbage	2	2	4
Carrot	1	0	1
Cauliflower	2	3	5
Chillies	4	0	4
Tomato	20	7	27
Potato	8	0	8
Subtotal	**45**	**23**	**68**

Crops	Pub.	Pvt.	Total
FRUITS			
Banana	3	0	3
Citrus	1	0	1
Muskmelon	1	0	1
Pomegranate	1	0	1
Watermelon	2	0	2
Subtotal	**8**	**0**	**8**
OTHER CROPS			
Chickpea	5	2	7
Pigeonpea	13	1	14
Groundnut	9	0	9
Cassava	2	0	2
Soybean	2	1	3
Sunflower	1	1	2
Mulberry	0	0	0
Cotton	11	50	61
Coffee	1	0	1
Cardamom	1	0	1
Sutotal	**45**	**55**	**99**
Total	**148**	**86**	**234**

The figures include basic research

Source: IGMORIS and public domain

Transgenic Crops Research in India

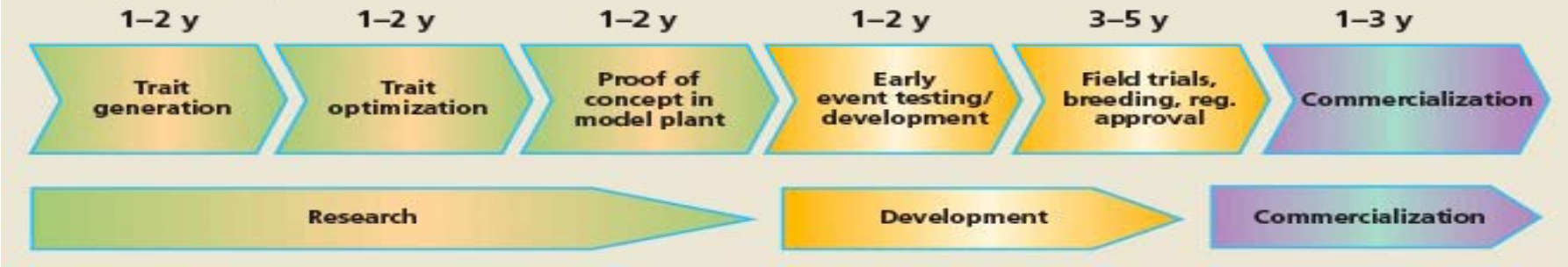
Crop	Public Sector Research	Private Sector Research	Total
Field Crops	50	8	58
Fruits	8	0	8
Vegetables	45	23	68
Other Crops	45	55	99
Total	148	86	234

- 6 technologies (cotton) already approved (5 private & 1 public)
- 4 technologies waiting for commercial approval (all private)
- 29 technologies approved for field testing in 2010 (4 in BRL stages and all belong to private)

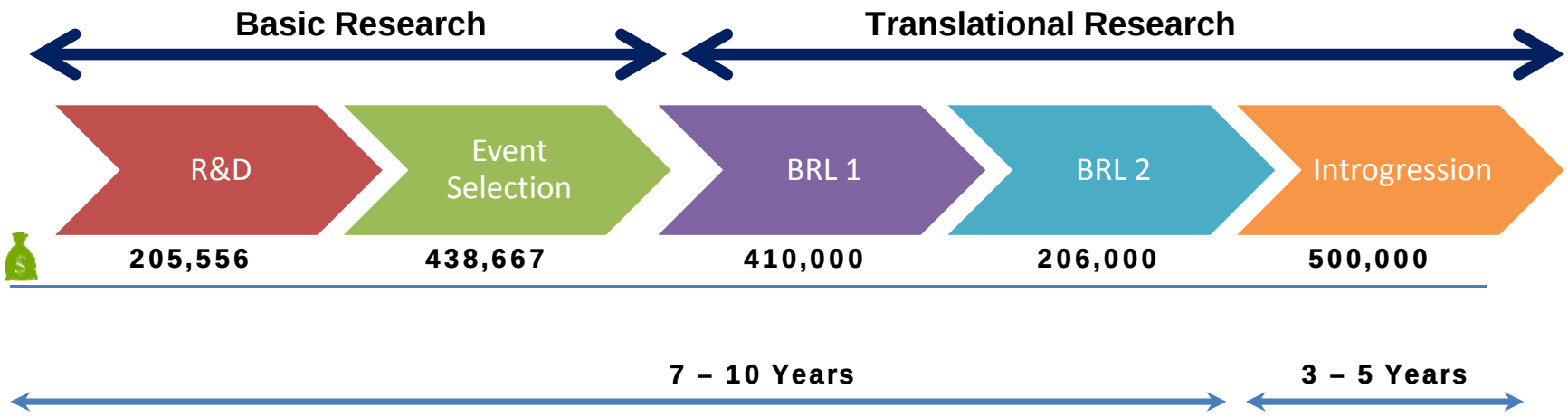
The figures include basic research

Source: IGMORIS and public domain

Timeline & Costs



Indian Context



BRL 1 – Biosafety Research Level 1

BRL 2 – Biosafety Research Level 2

Developing new Biotechnology is not cheap!

Most current research is being done by private sector companies in the developed world

Distribution of Total R&D Expenditure in Science and Technology

	Percentage	
	Public	Private
India	95	05
Mexico	88	12
Indonesia	96	04
Zimbabwe	86	14
USA	30	70
Switzerland	26	74

- *In most of the developing countries, public sector invests in research and development.*
- *Private sector investment is beginning to increase due to globalization and reforms in some of them.*

Source: S.R. Rao-DBT

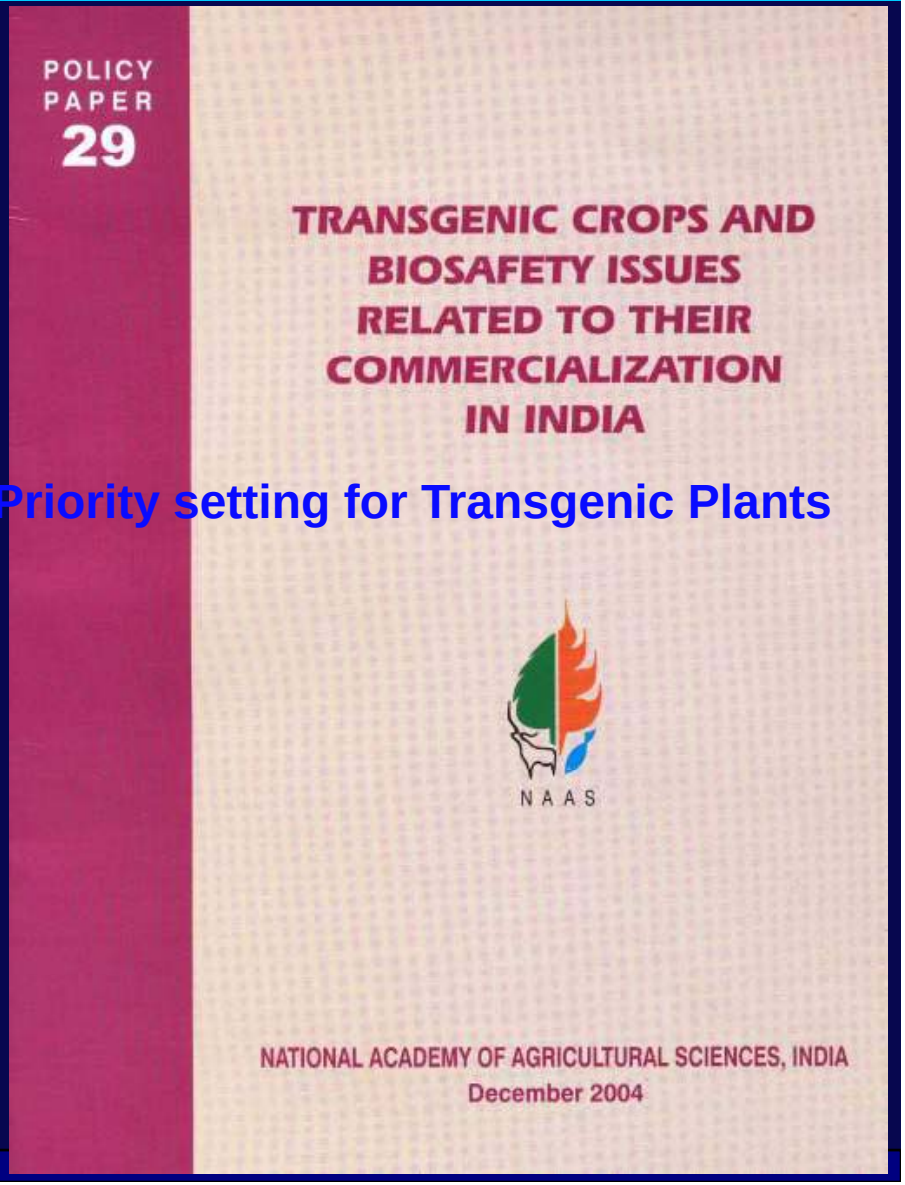
Bottlenecks

- Failure to test the concepts on a large scale
- Failure to translate concepts into commercial products
- Barriers of IP/Trade/interest of private sector
- Biosafety regulations/Food safety
- Risk assessment and risk management
- Training & Capacity building
- Partnerships for product development & deployment
- Commercialization limitations, a serious barrier

Problems in commercialization

Lack of proper understanding of issues related to:

- **Intellectual property rights**
- **Regulatory aspects**
- **Roadmap for lab to farmers' field**
- **Market demands**
- **Public-private partnerships in R&D**



Bottleneck in Technology Commercialization

- **Lack of awareness on commercialization process**
- **Market orientation of technology**
- **Valuation of technology**
- **Lack of tech transfer / facilitating agencies**
- **Monitoring and tracking (Stewardship)**

© From Excelence Through Stewardship (ETS)

Constraints

Technology Developer level

➢ Pre-commercialization

- Lack of commercialization knowledge and skills
- Funding need for refining / final packaging
- Cumbersome / costly patenting & protection process
- Fear of copy cats / patent infringement
- Ownership issues for jointly developed technologies
- Lack of technology valuation process
- Dependence on external commercial agency
- Institutional constraints

➢ Post commercialization

- Market testing and trials
- Monitoring and Tracking payments
- Market Feedback and corrections / Stewardship

Constraints

Technology Seeker level

- **Technology validation in conjunction with industry**
  - **What is available?**
  - **In which form industry requires?**
- **Industry oriented application**
- **Technology market assessment**
  - **Feasibility / market studies**
- **Valuation of technology matching**
  - **Market potential**
  - **Cost of development**
- **Working out terms of transfer**
  - **Exclusivity for competitive advantage**
  - **Licensing fee / royalty**
- **Cumbersome institutional process & procedures**
- **Post commercialization support**
  - **Technology refinement / modifications**

Overcoming Barriers
to market Biotech Crops

1. **Carefully assess the efficiency of genes in the field by employing the full toolbox for agronomy.**
2. **Focus on product concepts that address critical issues and/or needs.**
3. **Ensure FTO by licensing, and/or developing work-around methods for, all applicable methods and genetic elements.**
4. **Implement robust IP systems that comply with governmental agencies.**
5. **Obtain early buy-in from growers, processors, and retailers.**
6. **Ensure that the gene-of-interest does not code for potential toxicity and allergenicity, and maintain frequent and forthright communication with the regulatory agencies involved.**
7. **Obtain end-user support by addressing perception issues and providing clear consumer benefits.**

Rommens (2010), Plant Biotech. J., 8: 101-111

Technology Transfer

- **Develop strong relationships between:**

  Basic Research → Technology Development →

  Technology Transfer → Technology Diffusion

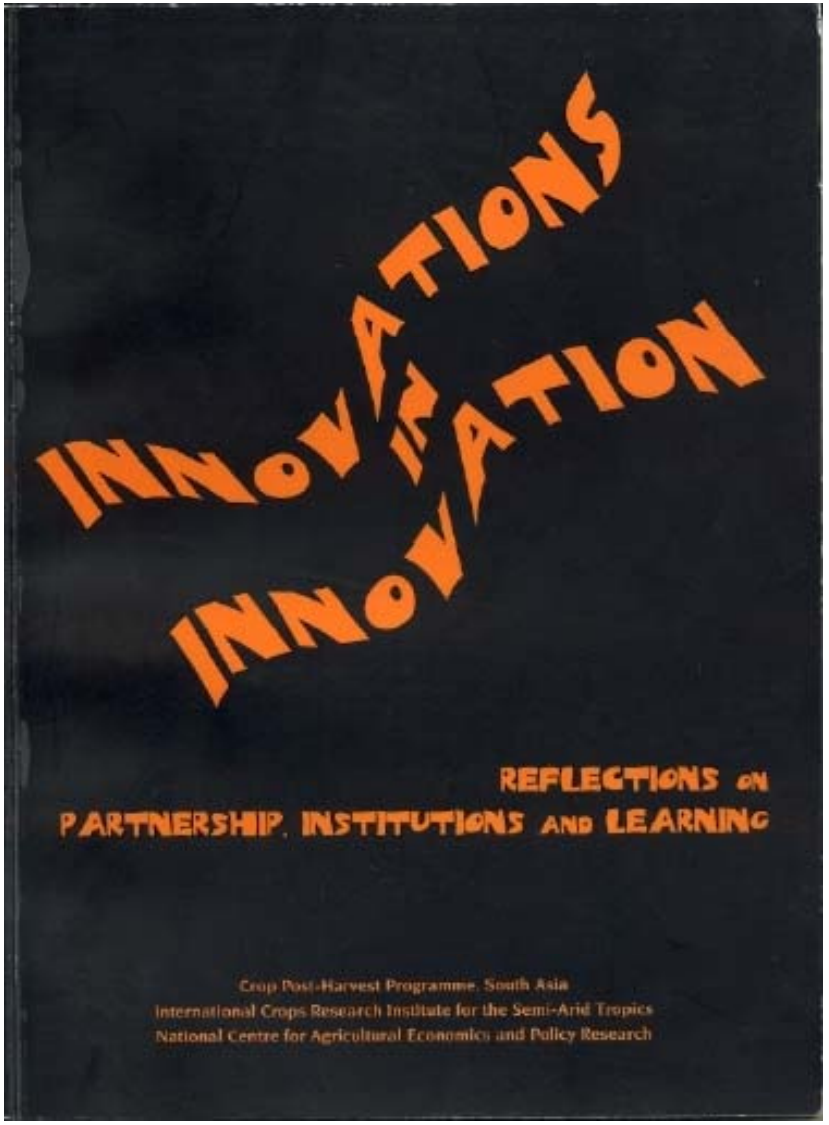
- **Focus on human resource development.**

- **Create congenial environment for encouraging R & D through the development of infrastructure and incentives.**

- **Interface public and private sectors for enhanced synergies in technology development and deployment.**

Public-Private-Partnerships
Challenges!!

- How to initiate and evolve relationships with the NARS, ARIs and private sector?
- How to ensure public access to proprietary (privately owned) technologies and processes?
- How to maximize the public good nature of innovations jointly owned with the private sector?
- How to negotiate new partnerships that ensure that all stakeholders including the poor stand to gain?



Solutions
Deployment of transgenics

- Overcome delays in moving GM crops to farmers.
- Food safety & Research issues linked to risk assessment and risk management.
- Public awareness (media workshops; training of policy makers, trainers, NGOs etc....).
- Socioeconomics & potential impact.

This will need:

- Effective multidisciplinary teams in R&D that interact closely, communicate openly, with relevant government agencies, patent attorneys, Industry Representatives and Consumer Groups.

  i. Public sector partners (groundnut, chickpea & other OPVs)
  ii. Transgenic Research Consortia (hybrid pigeonpea; other hybrid crops)
  iii. Facilitate technology development & commercialization (AIP@ICRISAT)
  iv. Facilities for translation of transgenic products (PTTC)

An ICRISAT-DBT Initiative
PTTC

Mission

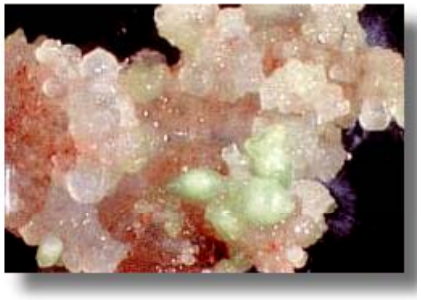
To "translate transgenic technology and harness its products to meet the needs of agricultural growth"

Principles

1. **Create and charter an entity with express purpose of "translating" genetic engineering research into a practical, value adding technology**
2. **The entity would embody the requisite scientific and business skills that are appropriately balanced**

Translational Research?

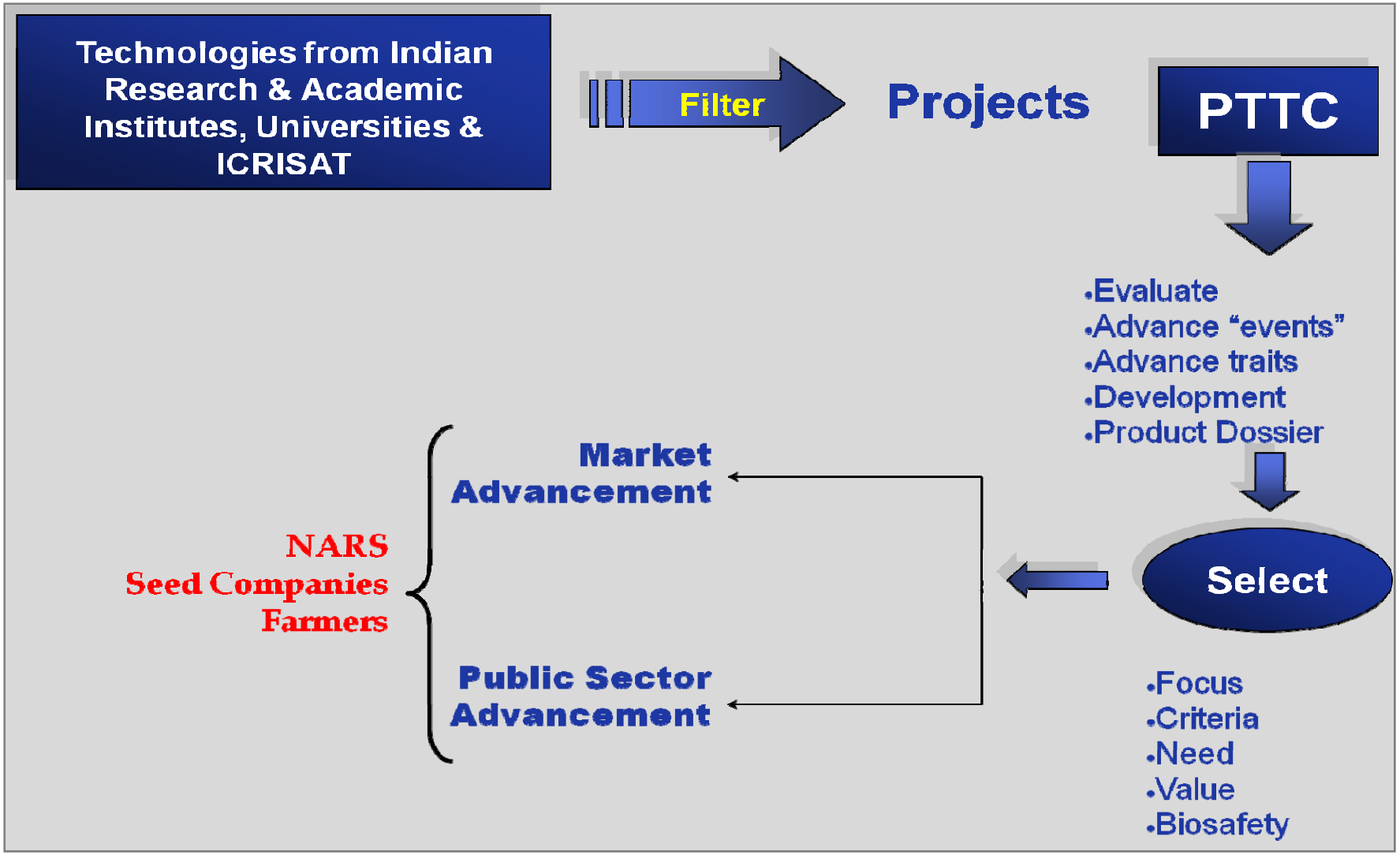
To promote an existing transgenic technology into a value added product of commercial use



Embryogenic callus of cotton

Transgenic cotton plants in the greenhouse

Concept


Technologies from Indian Research & Academic Institutes, Universities & ICRISAT
Filter
Projects
PTTC
•Evaluate
•Advance "events"
•Advance traits
•Development
•Product Dossier
Select
•Focus
•Criteria
•Need
•Value
•Biosafety
Market Advancement
Public Sector Advancement
NARS
Seed Companies
Farmers

Assessing Technologies

- WHAT is the current stage of the research technology?
- IS the technology innovative and scientifically credible?

  -the technology must have achieved proof of concept stage
- IS the technology commercially attractive?

  -there must be a clear path for its commercialization
- IS the technology accessible?
- WHAT is the technology development strategy?
- HAS the event identification and selection being done?
- IS it socially and environmentally beneficial?

  -technology/product must demonstrate specific social and/or environmental benefit

Objectives

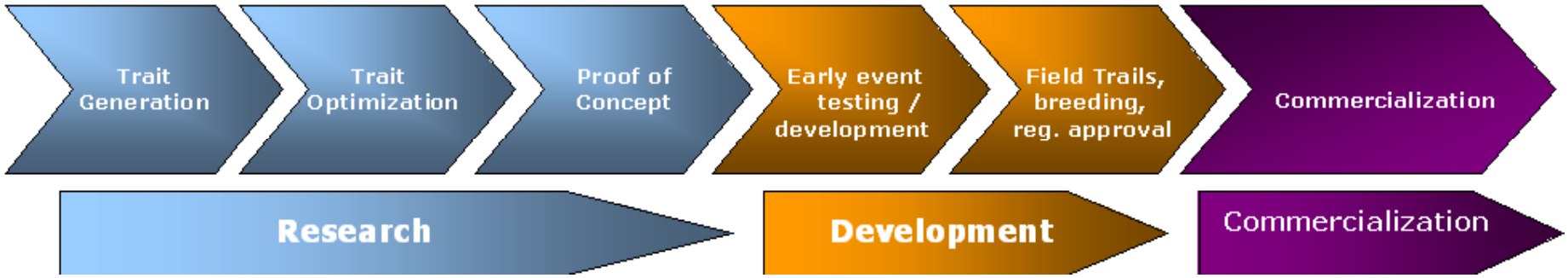
- To develop and deploy **state-of-the-art infrastructure** for conduct of transgenic research.
- To act as a **clearinghouse for technology inputs**, transgenic research leads/ prototypes with proof of concept derived from Indian research institutes, universities, and other likely sources.
- To evaluate specific concepts, ideas and technologies, and **advance the promising transgenic** events through a development cycle with adequate safety assessments.
- To "evolve" the technology to a point where a practical application can be demonstrated, and transfer this "evolved" technology for **product development and distribution** to appropriate agencies

Approach

- **Provide expertise and facilities for the production, assessment and commercialization of products through collaborative projects.**
- **Networking for product testing, biosafety assessment and IPR (institutions, industry, and the government)**
- **Strengthen national, regional and international collaborations for R&D.**
- **Provide & support training, consultations, extension services, and technology commercialization.**
- **Exchange of materials and information.**

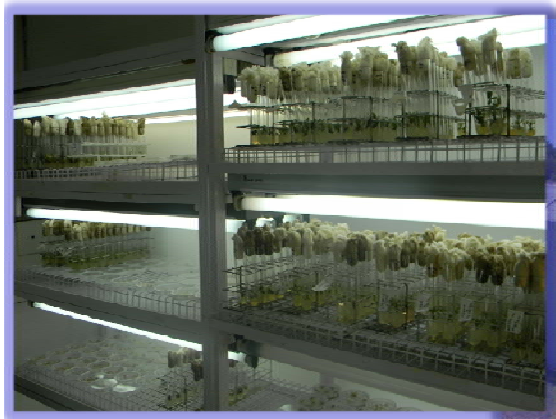
Activities

- Independent evaluation of trait-specific transgenic events
- Examine IPR issues in transgenic product development
- Develop product dossiers for commercialization
- Create specific projects with defined milestones and end-points
- Coordinate and conduct the evaluation of transgenic events for biosafety studies
- Introgression of the desirable transgenic events
- Identify partnerships for sharing mechanisms for marketing of the final “product”



Infrastructure & Facilities

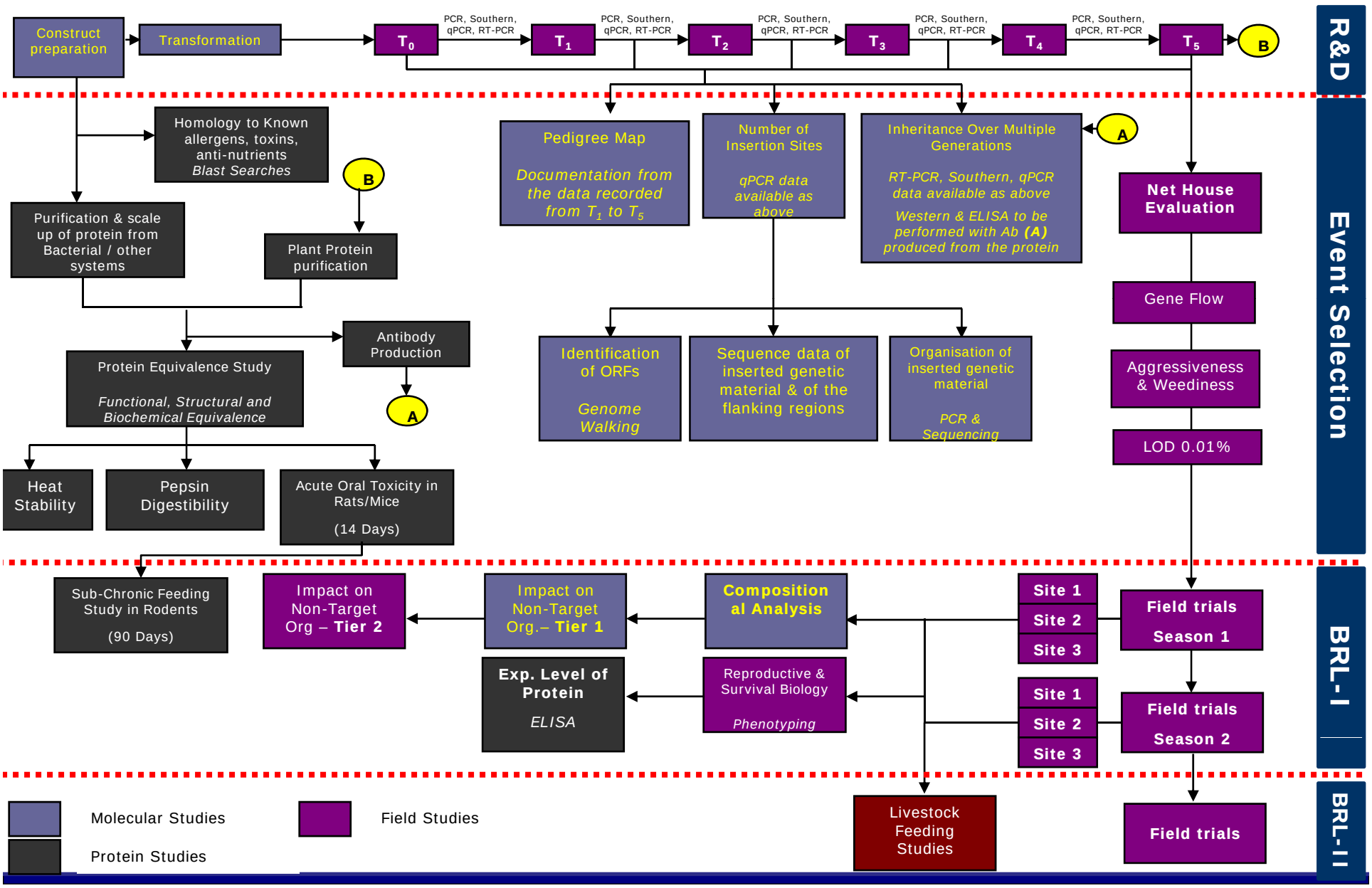
- State-of-the-art infrastructure for transgenic crop development on an area of **50,000 sq. ft.**
- High-throughput transformation facility
- Well equipped molecular biology laboratory
- Analytical laboratory & Instrumentation facility
- Plant pathology & virology laboratory
- Insect rearing facility
- P2 level contained and regular greenhouses
- Contained Fields



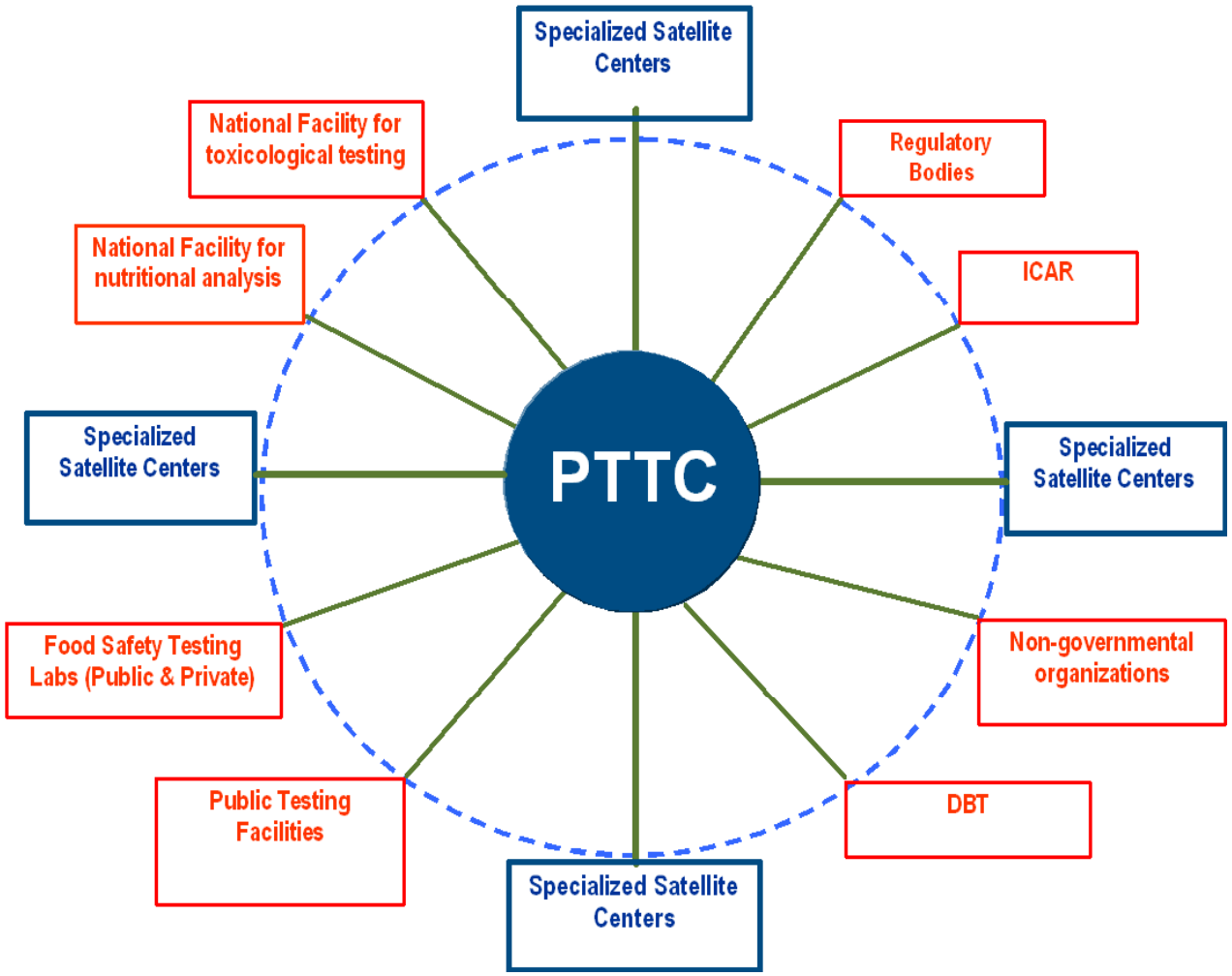
Research Capacities

- **Genetic transformation**
- **Genotyping:** PCR, Southern analysis, qPCR with liquid handling systems, proteomics, etc.
- **Phenotyping:** Screening for resistance to aflatoxin, virus, foliar diseases; tolerance to drought & salinity; etc.
- **Food & Feed Safety Assessment:** heat stability, pepsin digestibility, homology search, etc.
- **Environmental Safety Assessment:** Gene flow studies, aggressiveness & weediness Potential, effect on non target organisms (tier 2), etc
- **Field Trials:** Confined Field Trials (BRL I & BRL II)
- **IP Management:** FTO Analysis,
- **Product Dossier Preparation:** Crop biology document, Technology dossier, Biosafety dossier

Product Development Pipeline



PTTC Network



- **Project Partners** – ICRISAT & DBT
- **Activity Partners** - MoA with NARS like NIN, ITRI, SAUs, etc. and private sector organisations on need basis
- Preliminary discussion with some institutions already completed
- MoU with **Associates / Consultants**

PTTC Services

Research Services

- Genetic Transformation
- Genotyping & Phenotyping
- Recombinant Protein Studies

Field and Biosafety Assessments

- Net house Evaluation
- BRL I & BRL II trials
- Environmental Safety Studies
- Food and Feed Safety Studies

Consultancy Services

- GMO Consultancy
- Regulatory Compliance Management
- Intellectual Property Advisory

Research Service Packages

Genomics

- Stable integration over multiple generations
- copy Number and number of insertion sites
- Organization of Inserts
- Flanking regions study
- Bioinformatics analysis of novel ORFs putative chimeric proteins
- T-DNA sequencing
- Absence of plasmid backbone

Proteomics

- Protein Characterization & Scale-up
- Homology Studies
- Heat Stability
- Pepsin Digestibility

Livestock Feeding Studies

Representative Animals – Goat, Chicken, Cow / Buffalo, Fish, etc.

Toxicity and Allergenicity

- Acute oral toxicity test in rodents
- Sub chronic feeding test in rodents
- Primary skin irritation test in rabbits
- Mucous membrane irritation study in female rabbits

Environmental Assessment Studies

- Plant pest potential
- Out crossing
- Gene Flow Studies
- Aggressiveness and weediness
- Impact on NTOs (Tier-1 & Tier 2)
- LOD 0.01%

Compositional Analysis

Ash, Total fat, moisture, Protein, Crude fibre, Acid detergent fibre, amino acid profile, Total lipids, Fatty acid profile, Vitamin profile, Mineral profile

Risk Assessment

Common Safety Studies carried out for product testing	Food & Feed Safety Assessment		Environmental Risk Assessment	
	Field studies	Non-field studies	Field studies	Non-field studies
Acute oral safety limit study				
Pepsin digestibility assay				
Protein thermal stability				
Sub-chronic feeding study in rodents (if required)				
Livestock feeding study (if required)				
Molecular characterization				
Inheritance of introduced trait				
Stability of introduced trait				
Expression of introduced protein(s)				
Compositional analysis				
Reproductive and survival biology				
Impact on non-target organisms: Tier I testing				
Impact on non-target organisms: Tier 2 testing				

Referral Documents

Forms

- Expression of Interest – Public & Private Sector
- Evaluation of Technology Roadmapping

Agreements

- Memorandum of Understanding
- Memorandum of Agreement
  - ✓ Service Agreement
  - ✓ Partnership Agreement
- Non-Disclosure Agreement
- Material Transfer Agreement

Outreach

- **Flyers, FAQs, Posters, Website, etc.**
- **Stakeholder meetings, Media Workshops, Biosafety workshops etc.**
- **Crop biology documents/Biosafety Policies (e.g., Regulation of RNAi technology & Access to Biological Diversity)**

Way Forward

- Emphasis on public sector product development
- Strengthening capacities for monitoring & evaluation
- Advanced testing & detection mechanisms
- Increased communication & awareness
- Partnerships (Public-Public & Public-Private)
- Resource Pooling & Consortium Approach

Benefits to Public Sector Tech Transfer

- **Public sector technology developers find an outlet for their technologies.**
- **Small & Medium scale seed companies have access to products of biotechnologies.**
- **Technologies available to the stakeholders (resource-poor farmers) at an affordable cost.**
- **Products developed in the PTTC can be easily transferred to the participating countries and need only to be evaluated for their local agronomic performance.**

Looking ahead

- ***PTTC has the potential to evolve into a "leading edge" technology translational facility***

- ***It could serve as a global model for the utilization of transgenic technologies and their products*** ***(North-South & South-South)***

ICRISAT
Science with a human face

Thank you