Herbicide Tolerance & Insect Resistance

Jay G.Varshney

Director

DIRECTORATE OF WEED SCIENCE RESEARCH

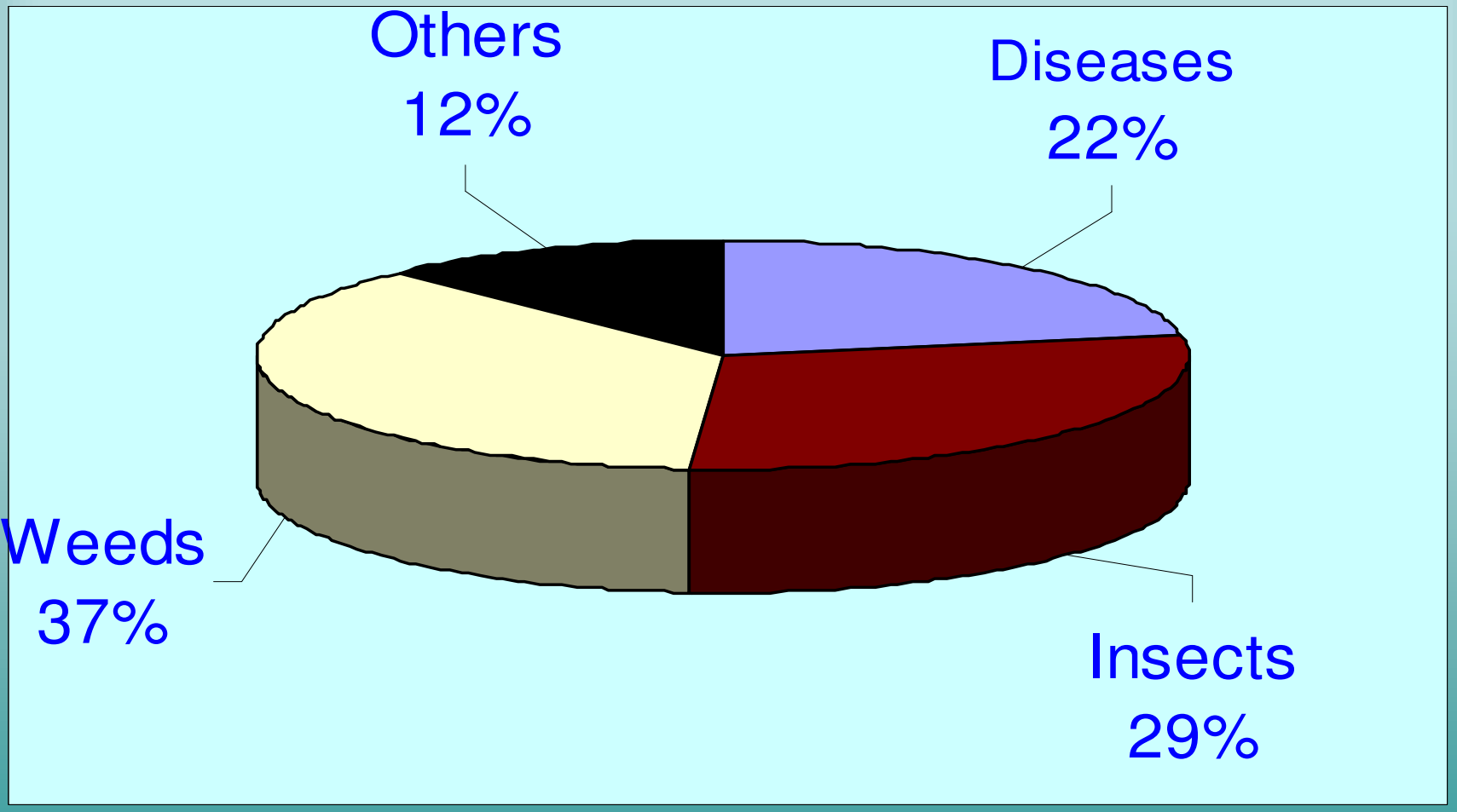
JABALPUR (M.P)

INDIAN AGRICULTURE - SOME BASIC FACTS

- In India, the population has already exceeded 1.1 billion and it is projected to be the most populous country in the world with about 1.5 billion by 2050.
- Despite the significant achievements in food grain production since independence, Indian agriculture continues to face serious challenges from ever increasing population.
- The arable land is diminishing every year as it is diverted for industrial, residential, recreational and other human needs.
- Other resources like water, fertilizer and labor are also becoming scarce and costly.

- Net sown area is almost constant at around 140 m ha.
- There is a likelihood of shortfall of 41 per cent in the food grain production in the country by 2020 (IFPRI, Washington).
- The shortfall can be met only by vertical increase in the production as horizontal increase i.e., bringing more area under cropping has little possibility.

TOTAL LOSSES CAUSED BY PESTS

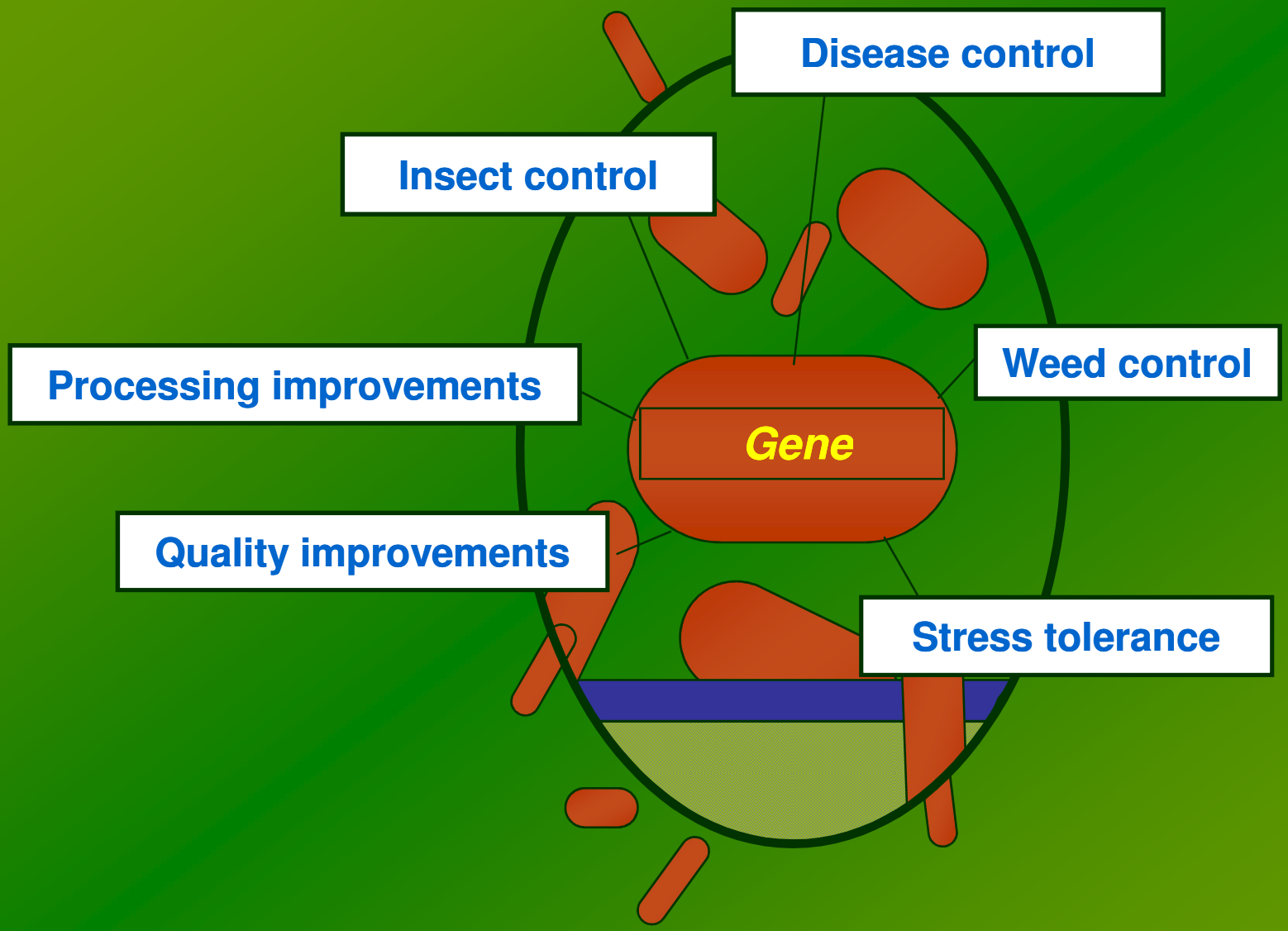


Out of the losses due to various pests, weeds account for nearly one-third

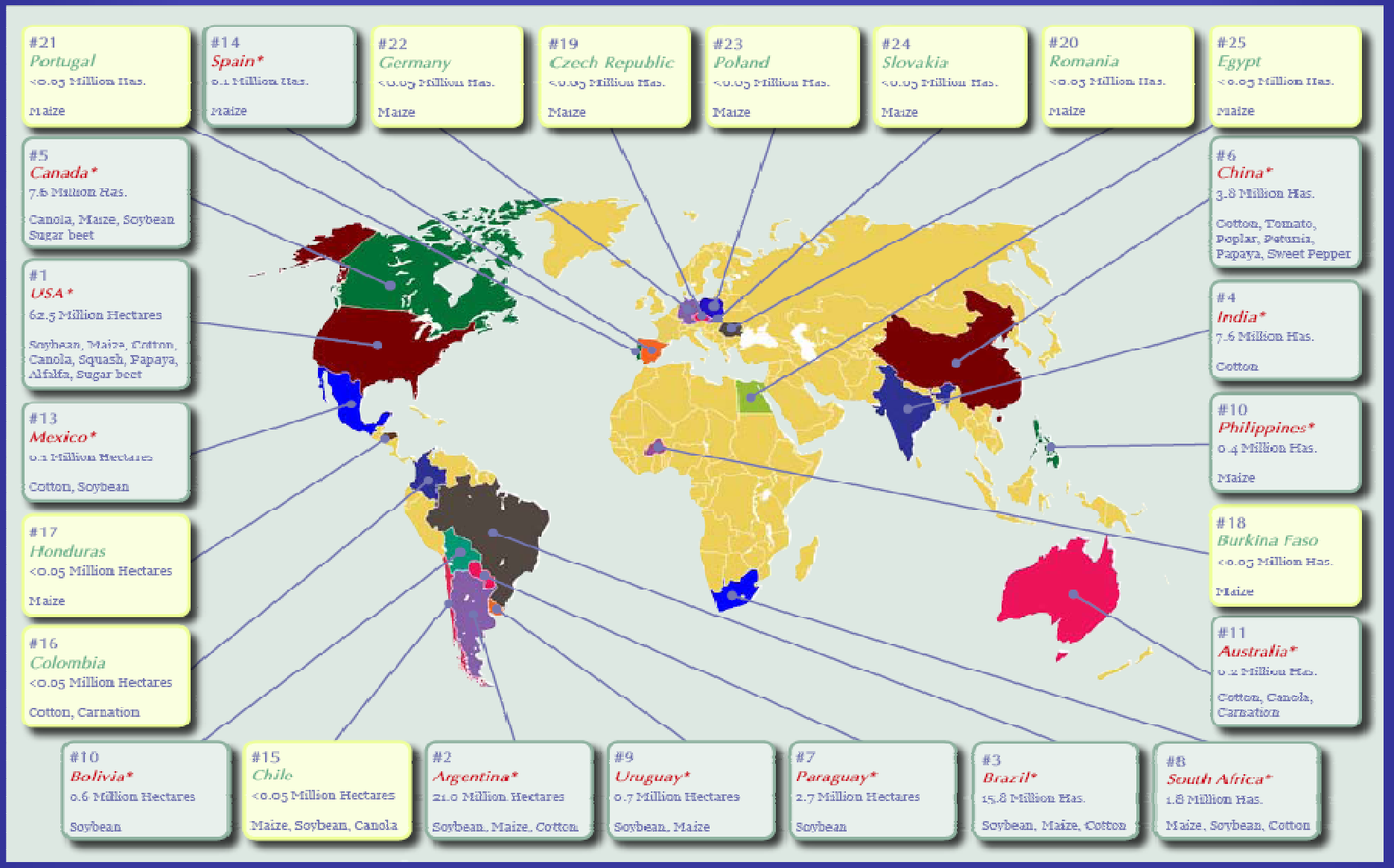
- More than 65% of our crop yield losses are due to weeds and insect pests
- Therefore, the challenge before the agricultural scientists today is to ‘produce more from less’
- We certainly need new technologies to accomplish these as the prevailing technologies alone do not seem to be adequate.
- Modern biotechnology, also known as gene technology, is being used in agriculture to develop new crop varieties with improved productivity and sustainability.

- World agriculture must continue to fulfill the food and fibre needs of the growing human population as well as rectify the existing widespread malnutrition.
- To achieve this aim, pest control will have to rely on integrated pest management practices which include crop rotation, biological control, transgenic technology and the sparing use of pesticides. Transgenic technology has shown itself to be a valuable contribution to knowledge based agriculture.

Transgenic Technology can contribute to ...

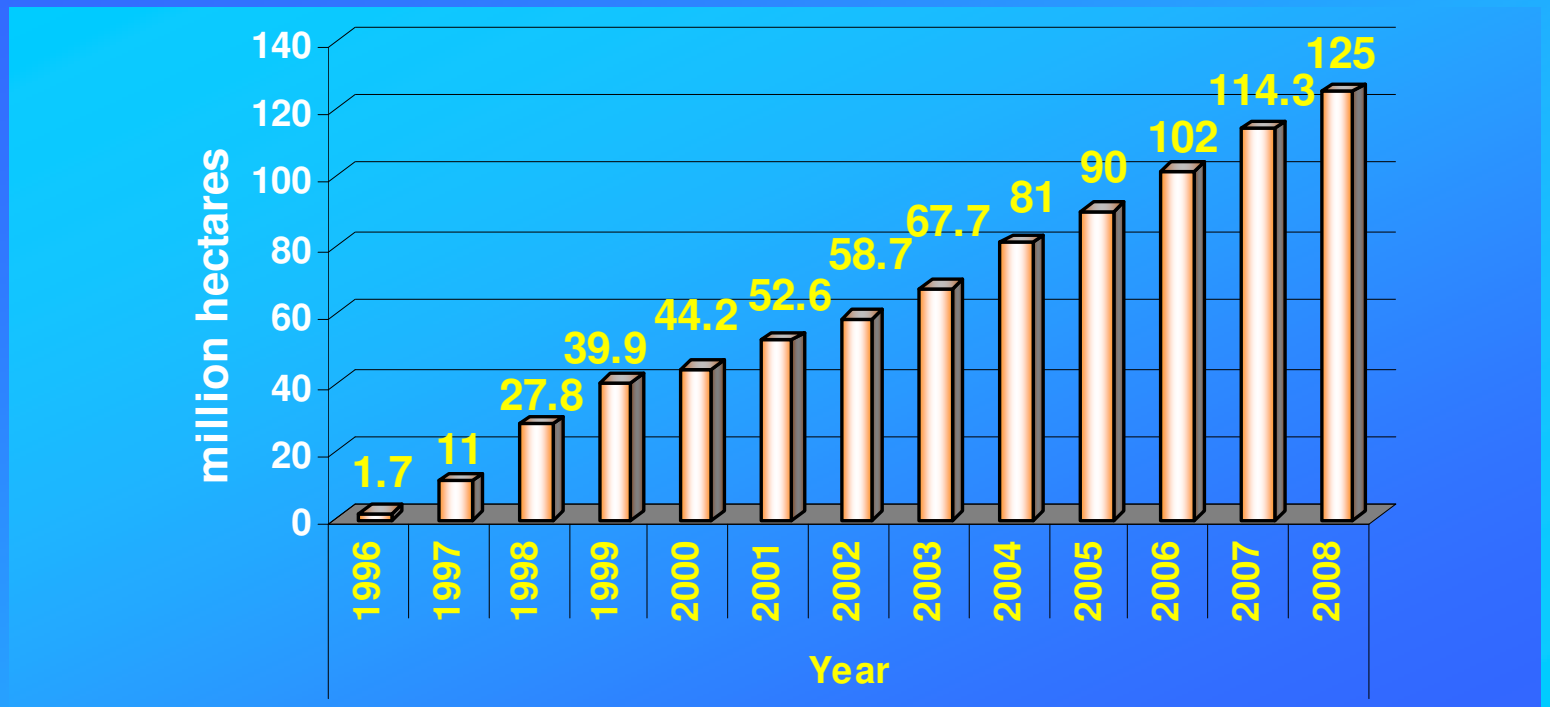


Global Scenario of Transgenic Crops: 2008



Directorate of Weed Science Research, Jabalpur

Global area of biotech crops, 1996-2008



Directorate of Weed Science Research, Jabalpur

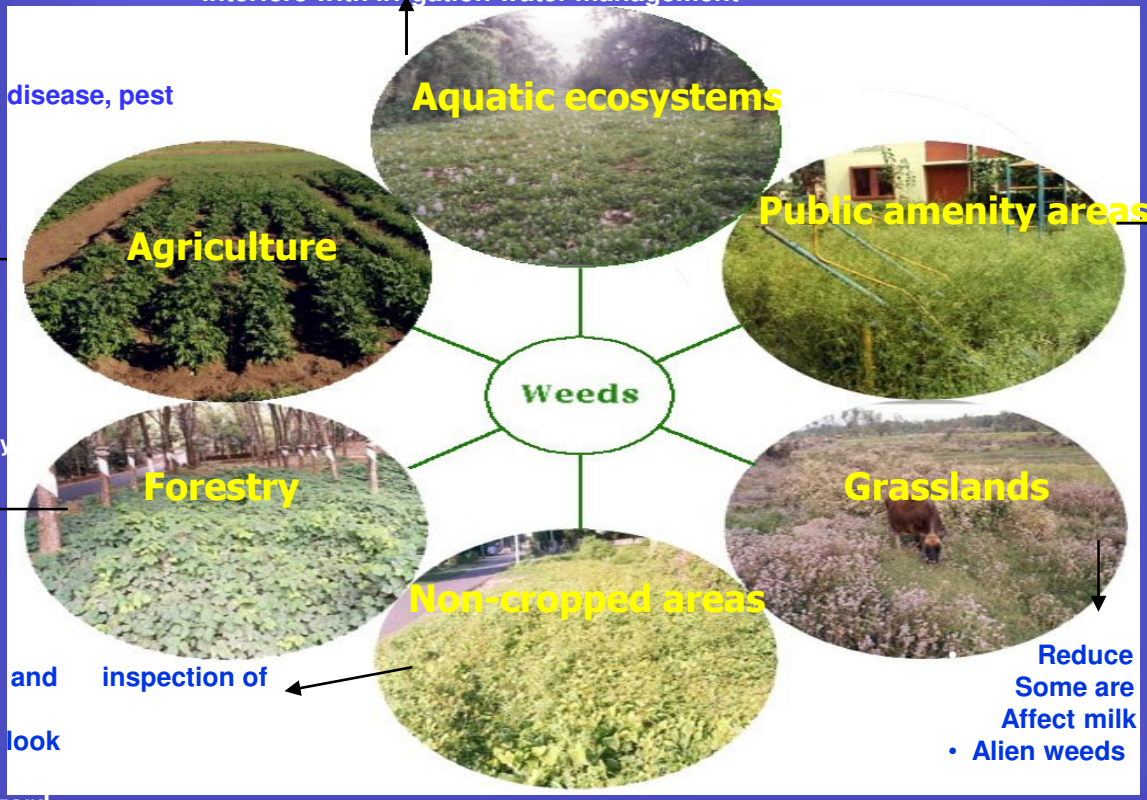
ABOUT WEEDS

Weed is a plant that is objectionable or interferes with the activities or welfare of man.

- Affect fisheries/aquaculture
- Interfere with navigation
- Reduce aesthetic and recreational value of water
- Result in excessive loss of water
- Interfere with irrigation water management

- Affect the aesthetic look
- Some cause allergy & health problems
- Invade open areas

- Reduce crop yields
- Impair crop quality
- Act as alternate hosts of disease, pest and nematodes



- Are a fire hazard
- Affect productivity
- Alien weeds endanger biodiversity

- Interfere with maintenance and inspection of installations
- They mar the aesthetic look

- They are a potential fire hazard

Reduce grazing area
Some are poisonous to livestock
Affect milk quality
- Alien weeds endanger biodiversity

However, many plants termed as 'weeds' are also beneficial to mankind. They find use in ayurvedic medicine, animal feed, compost making etc, and are a rich source of genes with resistance to biotic and abiotic stresses.

Directorate of Weed Science Research, Jabalpur

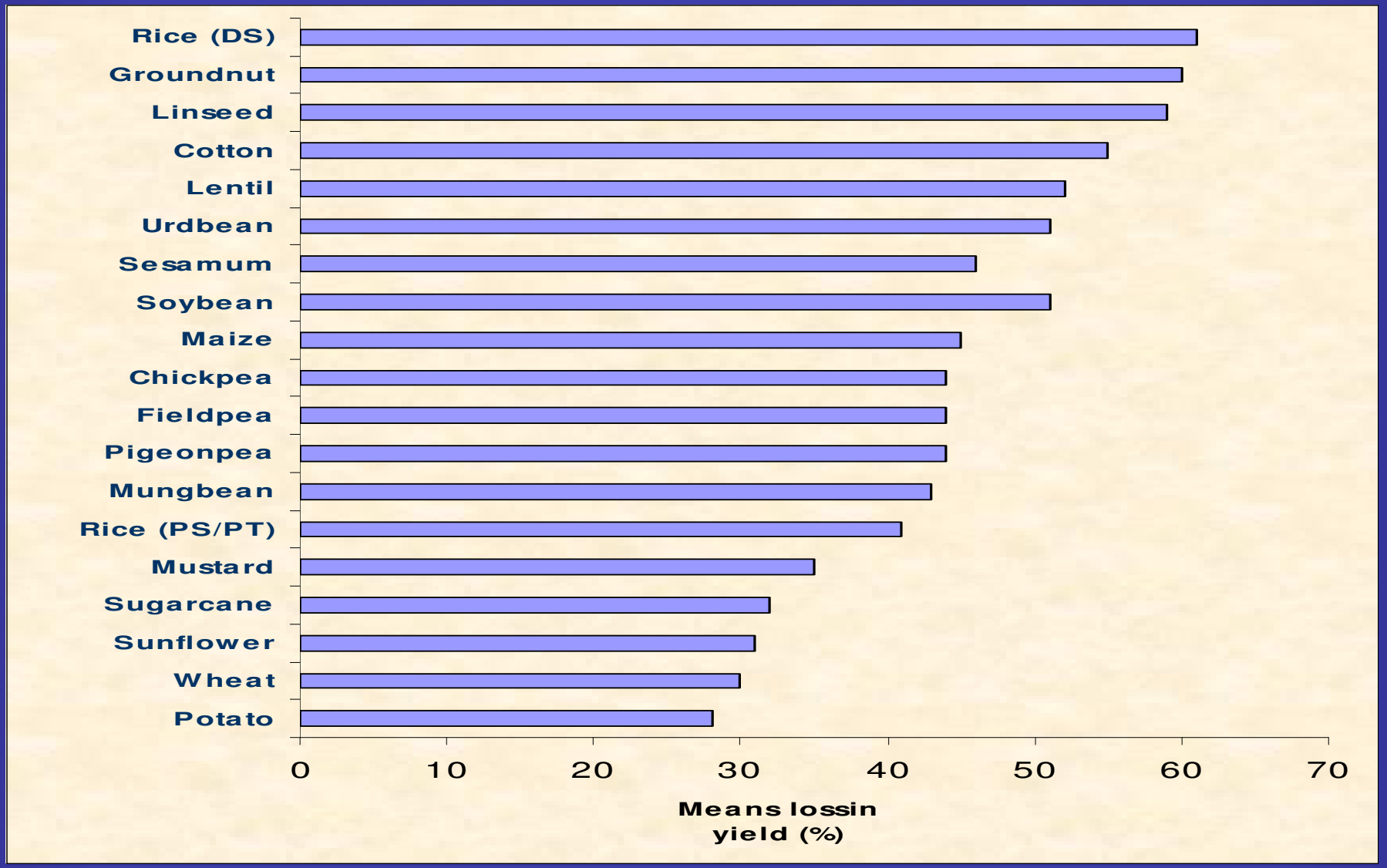
POTENTIAL YIELD LOSSES DUE TO WEEDS

(million tonnes)

Category	Losses per annum	Current production	Gap in demand by 2020
Food grains	103	230	48
Pulses	15	14	8
Oilseeds	10	25	10
Commercial crops*	52	262	-
Total	180	531	-
Rs. 1, 000 billion per annum			

Directorate of Weed Science Research, Jabalpur

Yield losses due to weeds in principal crops



Directorate of Weed Science Research, Jabalpur

Weed Management with the use of herbicides is widely accepted because…

- Save labour
- Permit early planting
- Control difficult weeds (perennial/parasitic)
- Efficient and economical control of weeds
- Reduce number of tillage operations
- Mechanical damage to crop is prevented
- Offers gender equality
- Enthuse youth to take up farming
- Aids in diversifying farming

Herbicides are important component in the Integrated Weed Management (IWM) system

"IWM involves the deliberate selection, integration and implementation of effective weed control measures with due consideration of economic, ecological and sociological consequences"

Directorate of Weed Science Research, Jabalpur

Why do we need HT crops ?

Difficulties in weed management

- Complexity of weed flora
- Inefficient traditional methods
- Complexity of application of different herbicides for different weeds in varying crops.
- Laborious and drudgery causing.
- Adverse environmental and soil conditions
- Smaller land holdings
- Lack of technical knowledge.

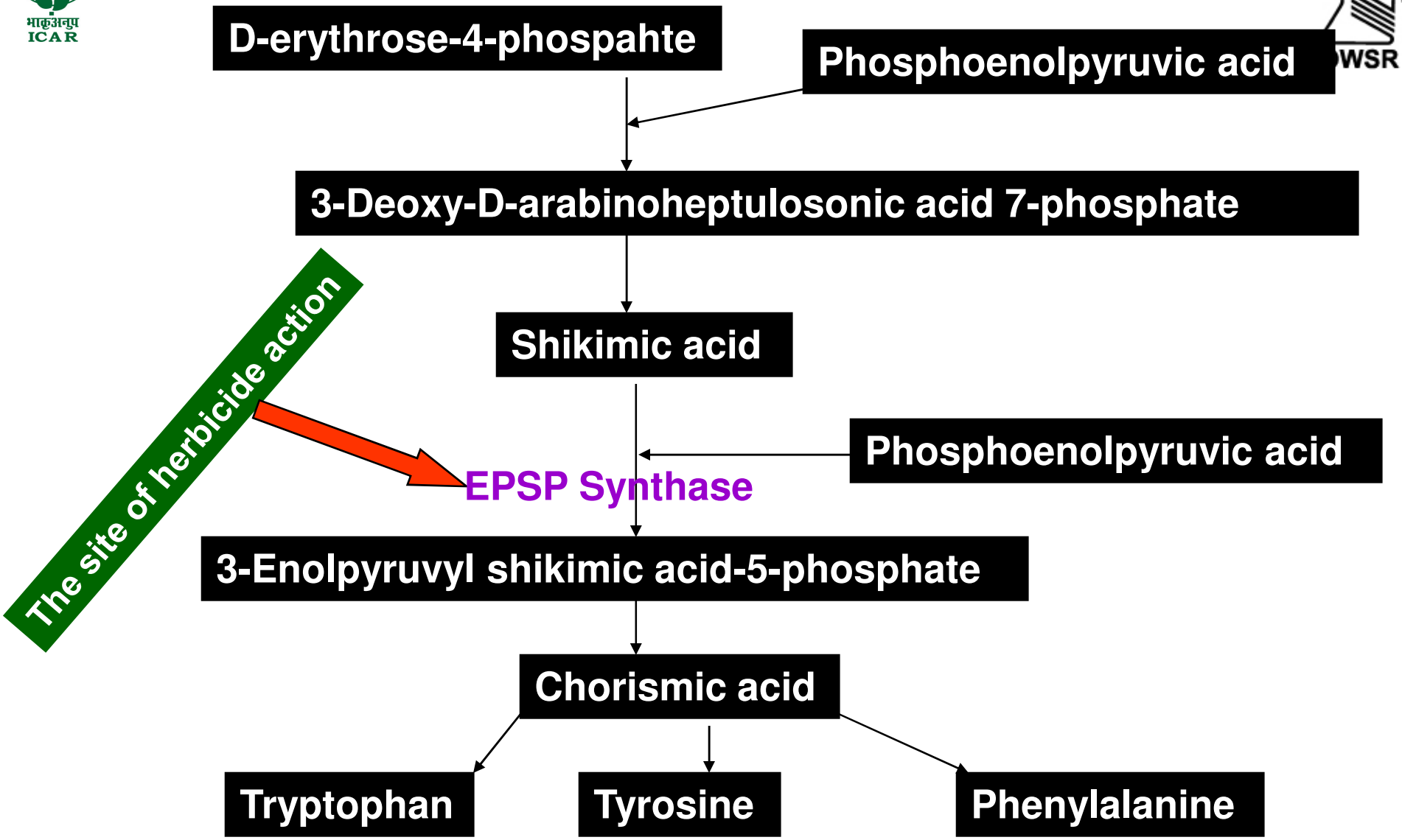
Herbicide tolerance

- The crops are genetically modified to withstand the application of powerful herbicides.
- Herbicide-tolerant crops contain a gene that makes them resistant to the herbicide that is sprayed to kill herbs and weeds.
- The herbicides to which the GM crops are tolerant are 'broad spectrum' weed killers, which means they can be sprayed over the entire field, killing all plants apart from the GM crop.

Techniques for producing herbicide resistant crops

- Herbicide resistance in crops can be achieved by Altering the target site so that the herbicide no longer binds.
- Over expressing a target enzyme so that the effect of the herbicides is overcome.
- Detoxifying the herbicide so that it is no longer lethal to the plant.

Inhibition of Shikimic acid pathway



Example: Glyphosate

Claims for GM herbicide tolerant crops

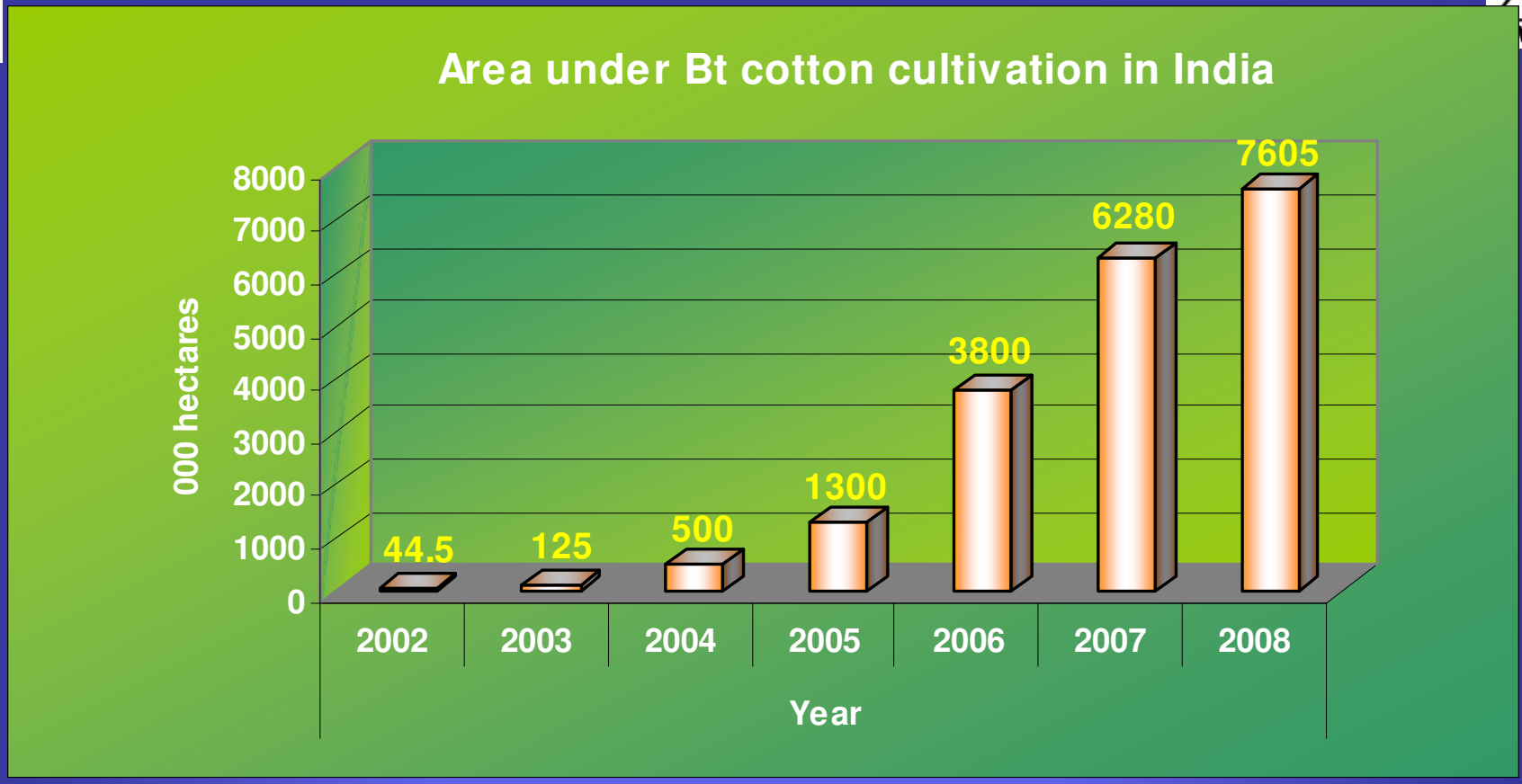
- GM herbicide tolerant (GMHT) crops will bring environmental benefits by reducing the use of chemicals in farming, particularly the older, more toxic herbicides. It claims farmers will need to spray their fields less often - perhaps only once - in the course of a rotation.
- By encouraging the practice of 'no-till', ie minimum ploughing prior to sowing, it is also claimed that GMHT crops can contribute to reduction in soil erosion. It is claimed that farmers will benefit from simplified weed management, thereby saving time and money.

Benefits of HTGM crops

- New strategies and increased flexibility to manage problem weeds.
- Multiple use of herbicides will be prevented.
- Less use of prophylactic soil-applied herbicides.
- Reduced total herbicide usage.
- Use of more environmentally benign herbicides.
- Greater adoption of conservation tillage.
- More practical use of economic thresholds in treatment decisions.
- Lack of herbicide carryover problems.
- An increased margin of safety with which herbicides can be used and subsequent reductions in crop loss due to herbicide injury.
- Reduced risk of crop damage from residual herbicides used in previous rotational crops.
- Better resistance to stress: If crops can be made more resistant to pest outbreaks, resistance to severe weather, such as water logging or drought, it would reduce the danger of crop failure.

Insect Resistance

- Insect resistant plants have the ability to withstand the effects of an insect by becoming resistant to its ill effects by means of Genetic manipulation. Several plants are being genetically engineered to make them toxic to insect pests.
- Another most widely used genetic modification is done by using Biotechnological techniques ; several crops derived through biotechnology produce a protein from the bacterium, *Bacillus thuringiensis* (Bt), to provide protection from certain damaging insect pests.
- In case of Brinjal the estimates suggest that the crop loss due to pest and disease infestation ranged between 54 and 70 per cent in India which the GM Brinjal is successfully expected to tackle.



The area under Bt-cotton in 2002, the first year of introduction in India, was about 44, 500 hectares it increased significantly to reach 7.6 million hectares in 2008, a remarkable growth rate in a short period of seven years.

Directorate of Weed Science Research, Jabalpur

Farmers' field studies on Bt cotton in 2002 and 2003 in the state of Maharashtra

- Bt cotton yield increased by 45% in 2002, and by 63% in 2003 compared to non-Bt cotton.
- Higher revenues were attained by Bt cotton farmers compared to those who planted conventional cotton.
- Average income difference for 2002 and 2003 were 43% and 63% respectively
- The average gross margin (difference of the revenue and variable costs which include seed and insecticide costs) is much higher for Bt cotton compared to growers of non-Bt varieties.
- Less insecticide input against cotton bollworms resulted in an average reduction in expenditure per hectare of 72% and 82% in 2002 and 2003, respectively.

Transgenic plants Expressing crystal-protein genes from *Bacillus thuringiensis* (Bt)

Crystal Proteins	Target insect	Transformed plants
Cry 1 Aa	Lepidoptera	Cranberry, poplar, rutabaga
Cry 1 Ab	Lepidoptera	Apple,cotton,maize,poplar,potato,rice,tobbaco tomato ,White clover ,white spruce
Cry 1 Ac	Lepidoptera	Apple, broccoli, cabbage ,cotton , grapevine , oilseed, rape ,peanut ,rice
Cry 1 Ba	Lepidoptera	White clover
Cry 1 H	Lepidoptera	Alfalfa, Arabidopsis, tobacco
Cry 2 Aa	Lepidoptera	Maize
Cry 1 3A	Lepidoptera	Cotton
Cry 1 6A	Coleoptera	Eggplant, potato, tobacco
Cry 1 9C	Coleoptera	Maize
Bt (unspecified)	Lepidoptera	Juneberry , hawthorn, pear ,sugar cane

Insect resistance

Over-expression of a weed (*Solanum americanum*) Proteinase Inhibitor in Transgenic Tobacco Results in Increased Glandular Trichome Density and Enhanced Resistance to *Helicoverpa armigera* and *Spodoptera litura*

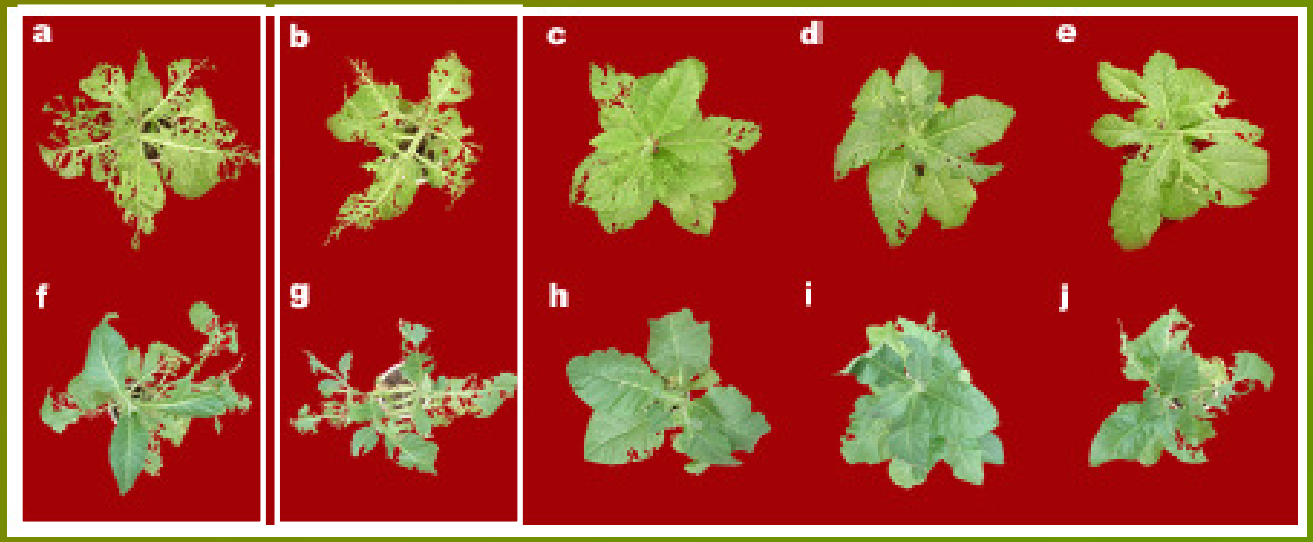
Tobacco plants → **Transformed with Proteinase Inhibitor (*SaPIN2a* gene) from *Solanum americanum* (a weed: known for biotic and abiotic stress tolerance)**

Hypothesis: under any biotic or abiotic stress , activity of proteinase (protein degrading enzymes) increases which degrade the proteins and damage plants

Luo et al., 2009, *Int. J. Mol. Sci.* 2009, *10*, 1896-1910

Insect resistant phenotype of *SaPIN2*-overexpressing transgenic tobacco plants

Wild type | Vector only | SnPIN2 overexpressing lines



Helicoverpa armigera

Spodoptera litura

Conclusion

Over-expression of *Solanum americanum* Proteinase Inhibitor (*SnPIN2a* gene) conferred resistance against *Helicoverpa armigera* and *Spodoptera litura*

Bt Eggplant-Large scale trials in India

- Approval-16th August 2007 by GEAC
- Location of trials-IIVR, Varanasi
- Entries-Mahyco's seven Bt eggplant hybrids: MHB-4, 9, 10, 11, 39, 80 and 99,

Summary of field trial results with Bt eggplant hybrids

	Reduction in insecticide use (%)	
	Against ESFB	Against all insect pests
2004-05	80	44
2005-06	79	40
Average	80	42

ESFB- Eggplant Shoot and Fruit borer

Source- Mahyco-Unpublished data

Directorate of Weed Science Research, Jabalpur, is taking up field studies on Bt/HT corn (stack hybrid) under the guidelines of Review Committee on Genetic Manipulation (RCGM).

Stack Hybrid : Product Concept

- Increased spectrum of activity against lepidopteran insect pests compared to MON 810.
- Provide flexibility for weed management
- Ideal product from IRM perspective
- Combination of MON 89034+ NK603 offers dual benefits of pest management (Weeds & Insects)

Herbicide Tolerant Trait in Corn : NK603

- Event provide tolerance to K salt of Glyphosate herbicide
- Glyphosate is a non selective systemic herbicide which kills all type of weeds
- Used for better weed management
- We need to test the economic importance of this trait for Indian farmers

Insect Protection Trait in Corn (MON 89034)

- The Next Generation Insect-protected Corn
- Produce two Bt proteins, Cry1A.105 and Cry2Ab2 *(Vector stacked)*
- Increased spectrum of activity
- Marker free event selected

Transgenic Corn Hybrids Containing Event 'MON89034' For Insect Pest Management and Event 'NK603' for effective Weeds Management

Insect Pest Management (MON 89034)

Effective Weeds Management (NK603)

Directorate of Weed Science Research, Jabalpur

Can environmental groups justify campaigning against a product that could save thousands of lives?

- A recent report from UK consultancy PG Economics charting the global impact of GM crops from 1996 to 2007 found that over that period, pesticide spraying dropped by 8.8 per cent. And because fields don't have to be tilled before planting GM crops, energy savings in 2007 alone amounted to the equivalent of removing 6.3 million cars from the road.

- These findings are disputed by environmental groups and need to be independently confirmed, but if they hold up it will be time for the technology's critics to reconsider.

Contribution of Bt/Ht technology to environmental safety

- The use of herbicide and insect resistant GM soybeans, maize, cotton and canola made a major impact on environment by reducing the usage of herbicides and insecticides (active ingredients) globally by about 6% through 1996-2004.
- Less frequent herbicide and insecticide applications and reduced tillage operations further lead to the savings in greenhouse gas emissions and fuel usage.
- In 2004, a reduction of about 1 billion kg carbon dioxide is estimated due to reduced fuel usage. This is equivalent to removing nearly 0.5 million cars from the roads.
- The adoption of GM herbicide tolerant crops reduces a number of tillage operations related to seedbed preparation and weeding. Not only that the tractor fuel use for tillage is reduced, soil quality is enhanced due to low tillage and soil erosion is prevented. In turn more carbon remains in the soil, leading to lower emission of greenhouse gases.
- An extra 3 billion kg of soil carbon (equivalent to 10 billion kg of CO_2, not released to atmosphere) may have been sequestered in 2004.
- These enormous gains to environment are in spite of the fact that as yet only a few agronomic traits have been engineered, that too in a small number of crops and in a few countries.

Increasing adaptation of the Bt/Ht crops by the farmers worldwide shows the success of these technologies

Global Scenario of Biotech Traits: 2008

Trait	Million Hectares (2008)	% of Global GM Crop Area
Herbicide Tolerance (HT)	79	63%
Insect Resistance (*Bt*)	19.1	15%
Bt / Herbicide Tolerance	26.9	22%
Virus Resistance / Other	<0.1	<1%
Total	125.0	100

Source: Clive James, 2008

Global Scenario of GM Crops: 2008

Trait/Crop	Million Hectares (2008)	% Transgenic
Herbicide Tolerant Soybean	65.8	53
Bt Maize	7.1	6
Bt / Herbicide Tolerant Maize	24.5	20
Herbicide Tolerant Maize	5.7	4
Herbicide Tolerant Canola	5.9	5
Bt Cotton	11.9	9
Bt / Herbicide Tolerant Cotton	2.6	2
Herbicide Tolerant Cotton	1	1
Herbicide tolerant Sugar beet	0.3	<1
Herbicide tolerant Alfalfa	0.1	<1
Total	125.0	100

Source: Clive James, 2008

PLANT BIOTECHNOLOGY RESEARCH IN INDIA

Biotech research is underway in many crops, both in the private and public sector \ laboratories (below)

PLANT BIOTECHNOLOGY RESEARCH IN INDIA			
S.No	CROP	NEED / TECHNOLOGY IN RESEARCH	INSTITUTION
1	Banana	Virus Resistant	NRCB and IARI
2	Brinjal	Insect Resistance	Mahyco
3	Cabbage	Insect Resistance	Nunhems India Pvt. Ltd.
4	Castor	Insect Resistance	Mahyco
5	Cauliflower	Insect Resistance	Sungro Seeds Research Ltd.
6	Corn	Insect Resistance & Herbicide Tolerant	Monsanto India Ltd.
7	Groundnut	Fungus Resistant	ICRISAT
8	Mustard	Yield Improvement	Delhi University
9	Okra	Insect Resistance	Mahyco
10	Onion	Disease Resistant	National Research Centre on Onion and Garlic
11	Papaya	Virus Resistant	Tamil Nadu Agriculture University (TNAU)
12	Potato	Disease Resistance (late blight)	Central Potato Research Institute (CPRI)
13	Rice	Insect Resistance	Bayer Bioscience Pvt. Ltd.
14	Tomato	Increased Lycopene Content	Avesthagen Ltd.

- Pest-resistant genetically modified crops can contribute to increased yields and agricultural growth in those situations, as the case of Bt cotton in India demonstrates.

Thank You

Directorate of Weed Science Research, Jabalpur