NORMAL BORLAUG, GENETICIST

GENETICS AND THE GREEN REVOLUTION

Daruma
(Japanese semi-dwarf)

X

Fultz
(U.S. winter wheat, high yield)

↓

Fultz-Daruma
(semi-dwarf, high yield)

X

Turkey Red
(U.S. winter, high yield)

↓

Norin 10
(semi-dwarf, winter, high yield)

Locals
(adapted to
U.S. Northwest)

X

↓

Gaines
(semi-dwarf, winter,
U.S. adapted)

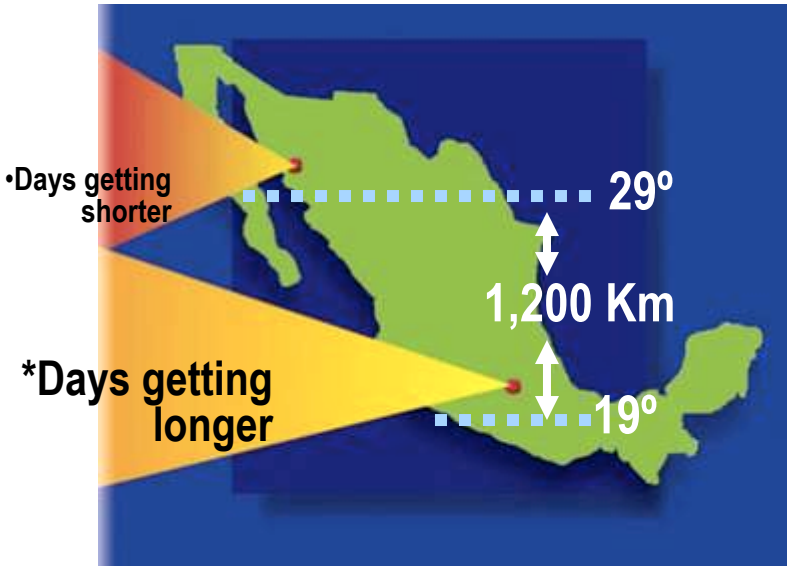
X

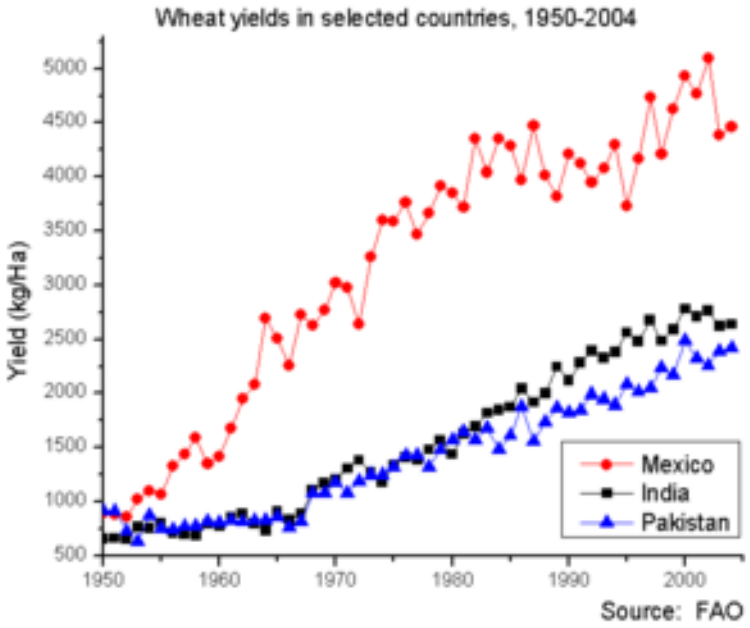
Local Strains

↓

New Wheats
(semi-dwarf, high yield, adaptable,
disease-resistant, fast-growing)

BREEDING IN TWO LOCATIONS RESULTED IN BROADLY ADAPTABLE WHEAT





GENETICS AND FOOD

A. ***Food and population***

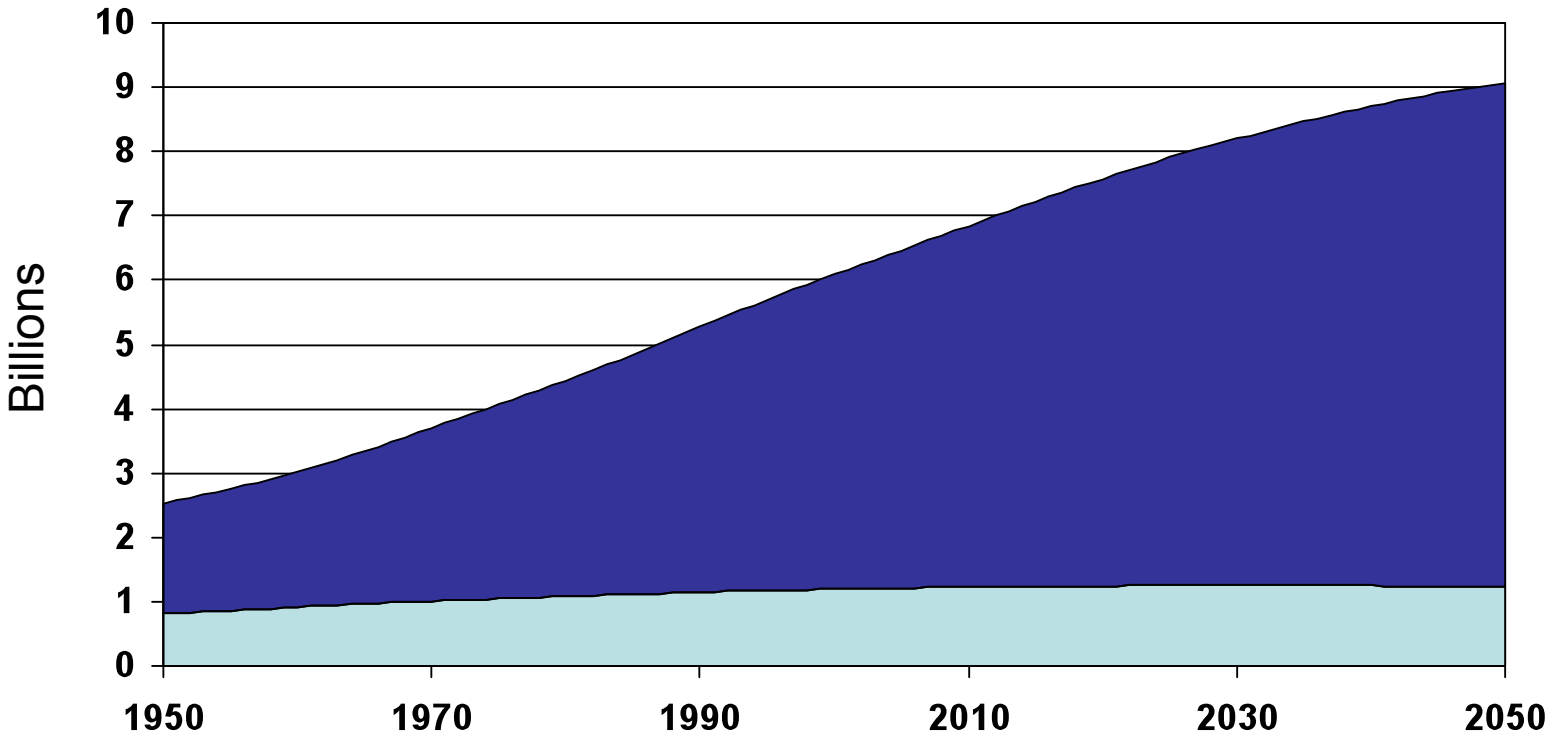
B. Land use in agriculture

C. Crop yields

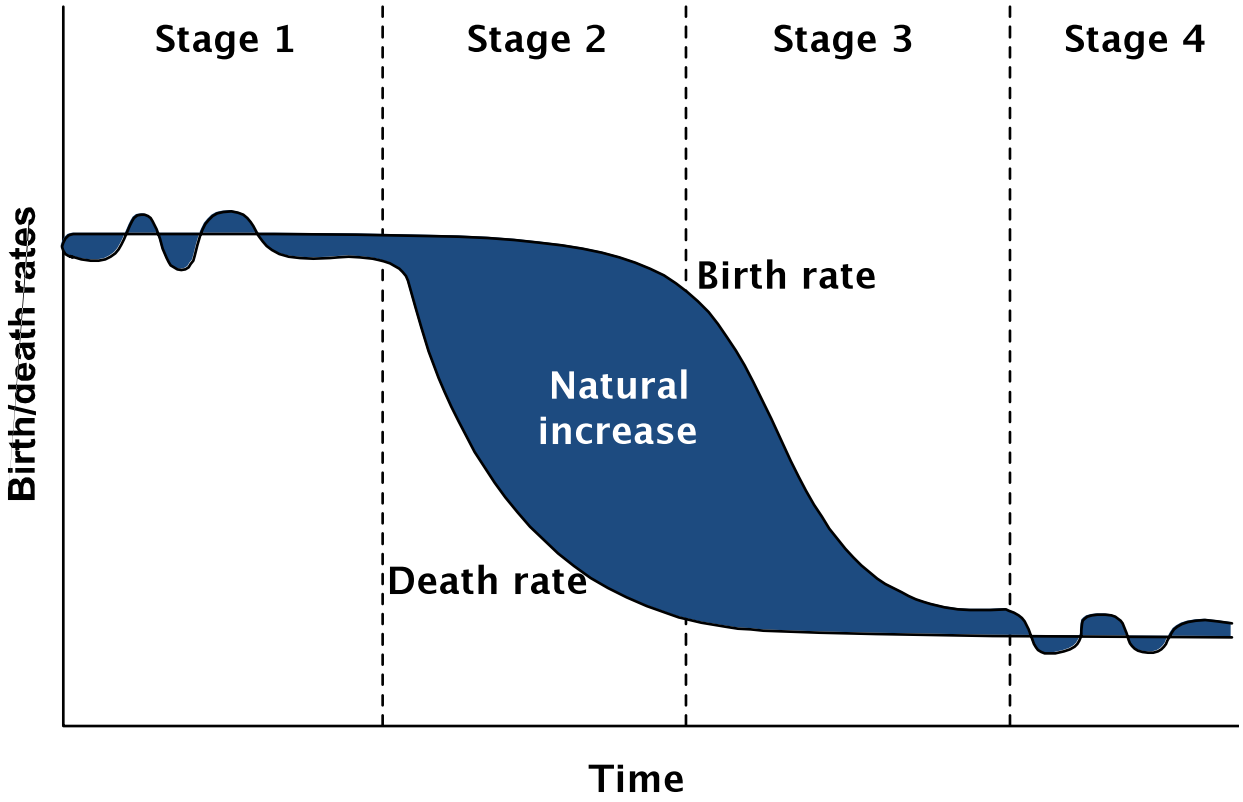
D. Conventional plant breeding

E. Plant breeding by genome modification

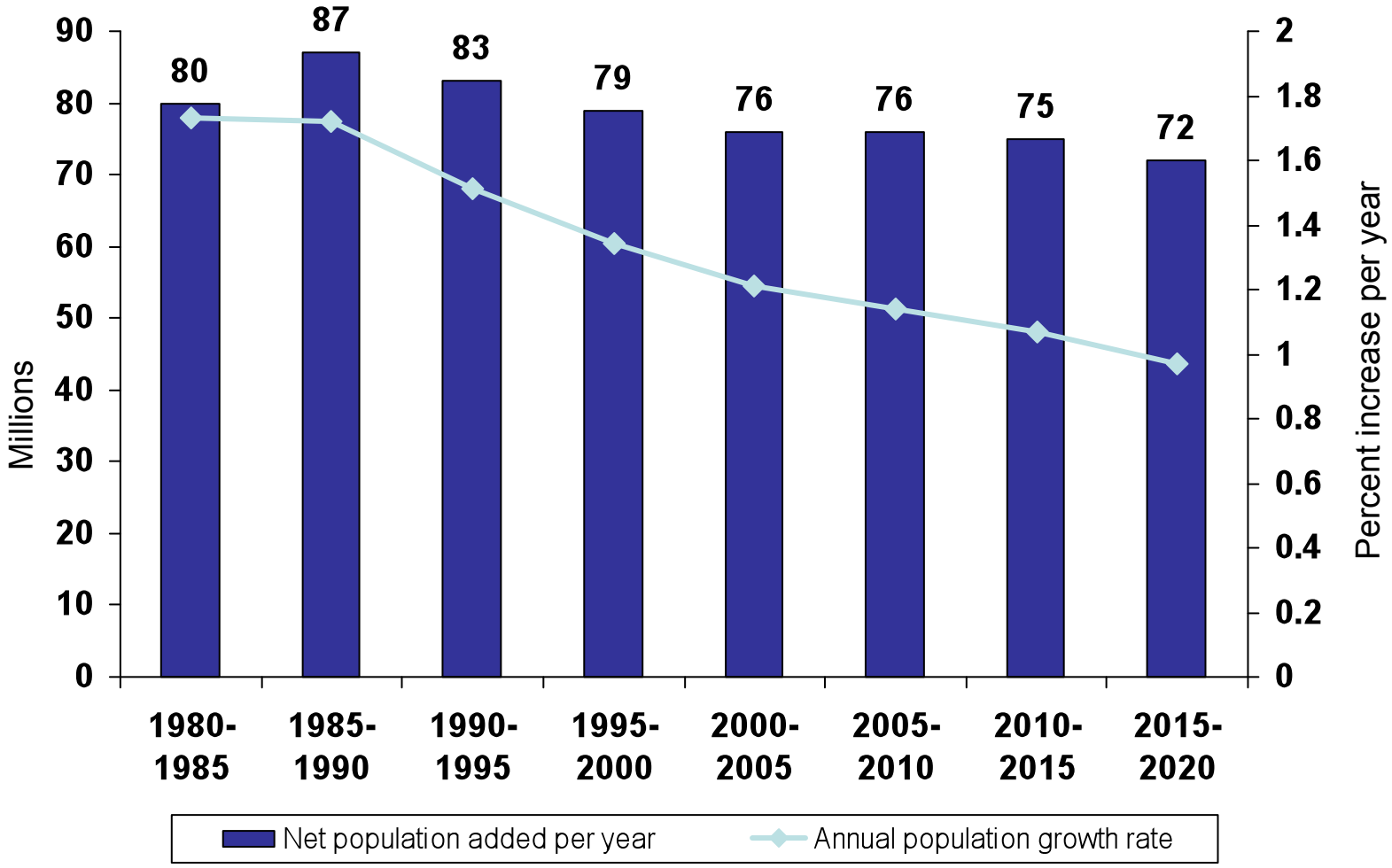
POPULATION GROWTH



DEMOGRAPHIC TRANSITION

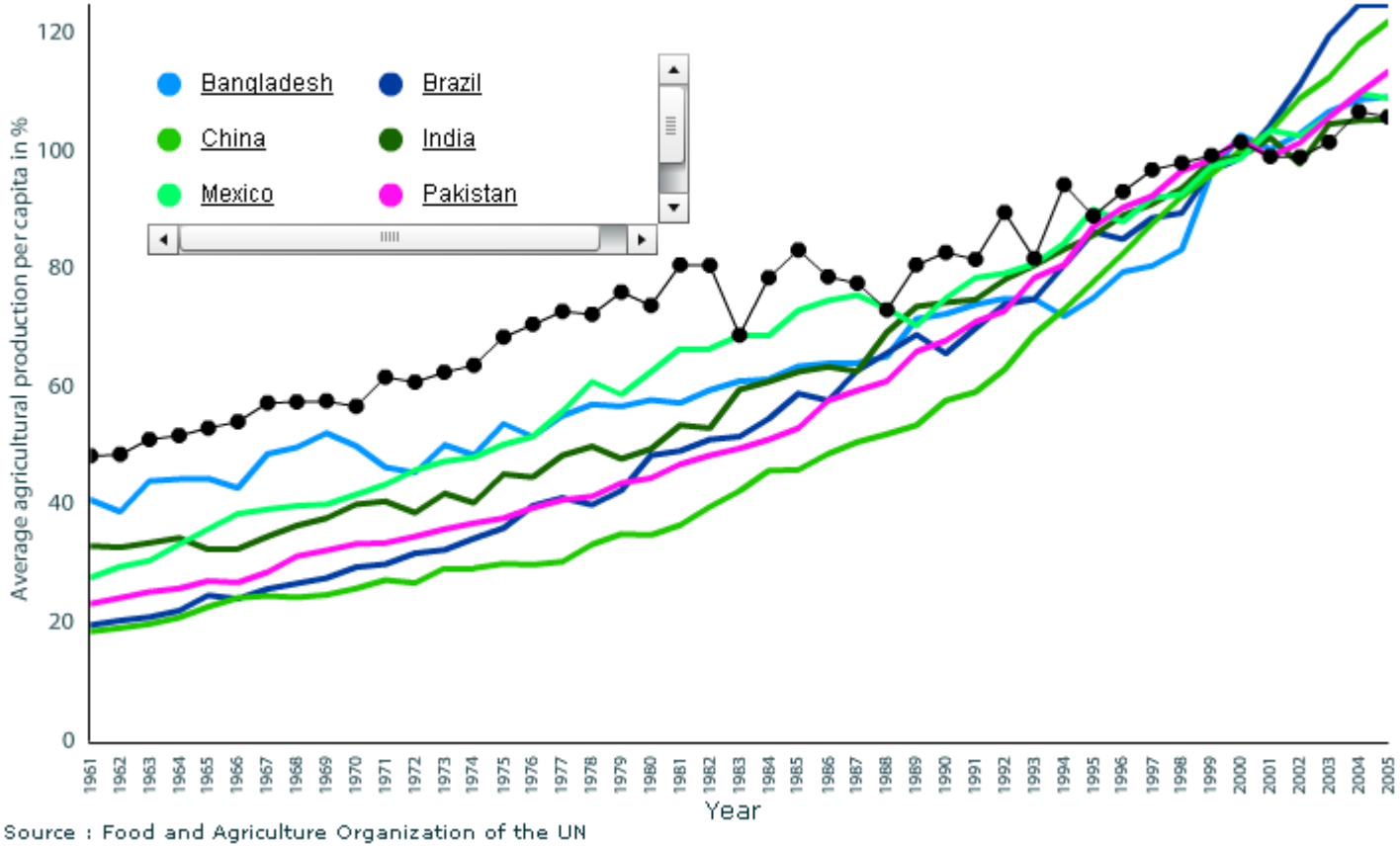


POPULATION GROWTH: A CHALLENGE FOR PLANT GENETICS



Source: United Nations, *World Population Prospects: The 2004 Revision* (medium scenario), 2005.

FOOD PRODUCTION PER PERSON

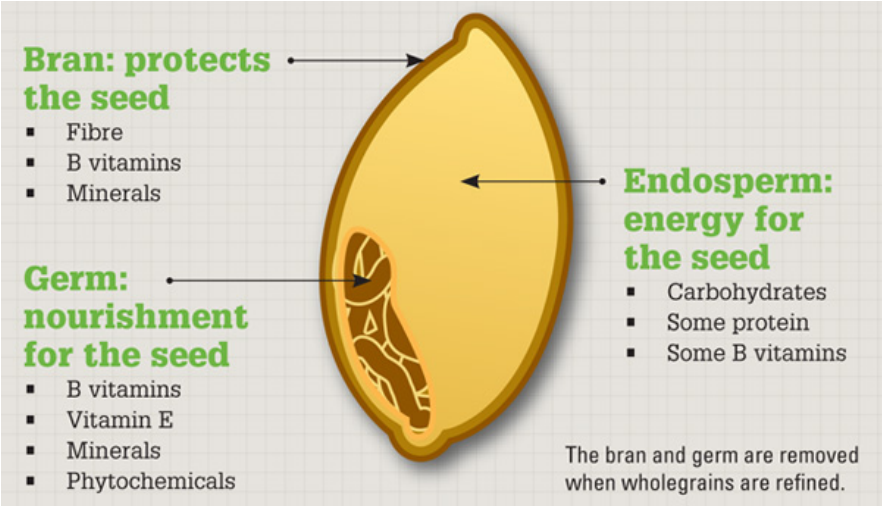


Source : Food and Agriculture Organization of the UN

DIETS IN INDIA VS. USA

Food	% cal. India	% cal. USA	% protein India	% protein USA
Cereals	61	23	59	21
Sugars	6	12		
Beans, lentils	11	4	16	4
Fruits, veg.	2	6	1	4
Fats	4	17		
Dairy	6	14	12	24
Meat, poultry, fish	10	24	12	47

CEREAL GRAINS



Rice

Ric

Wheat

Maize

GENETICS AND FOOD

A. Food and population

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E. Plant breeding by genome modification

FARMING SYSTEMS

Operation	*Forest fallow*	*Short fallow*	*Annual crop*	*Multiple cropping*
Land clearing	Fire	None	None	None
Land prep.	None	Plow	Plow, tractor	Plow, tractor
Fertilization	Ash	Manure, compost	Manure, compost, chemicals	Manure, chemicals
Weeding	Low	Intensive	Intensive	Intensive
Animals, machines	None	Plowing, transport	Plow, transp., irrigation	Plow, irrigation
Percent world cropland	2	28	45	25
Grain yield (kg/ha)	250	800	2000	5000

INPUTS PER HECTARE OF MAIZE, USA

Input	*Hand-produced*	*1910*	*2000*
Labor (h)	1200	120	12
Machinery (kg)	1	15	55
Animal use (h)	0	120	0
Fuel (L)	0	0	125
Manure (kg)	0	4000	1000
Fertilizer (kg)	0	0	316
Lime (kg)	0	10	426
Seeds (kg)	11	11	21
Insecticides (kg)	0	0	2
Herbicides (kg)	0	0	2
Irrigation (%)	0	0	17
Drying (kg)	0	0	3200
Electricity (1000 kcal)	0	0	100
Transport (kg)	0	25	326
Yield (kg)	1880	1880	6500

AGRICULTURAL TECHNOLOGIES

Soil

Water

Pests

GENETICS AND FOOD

A. Food and population

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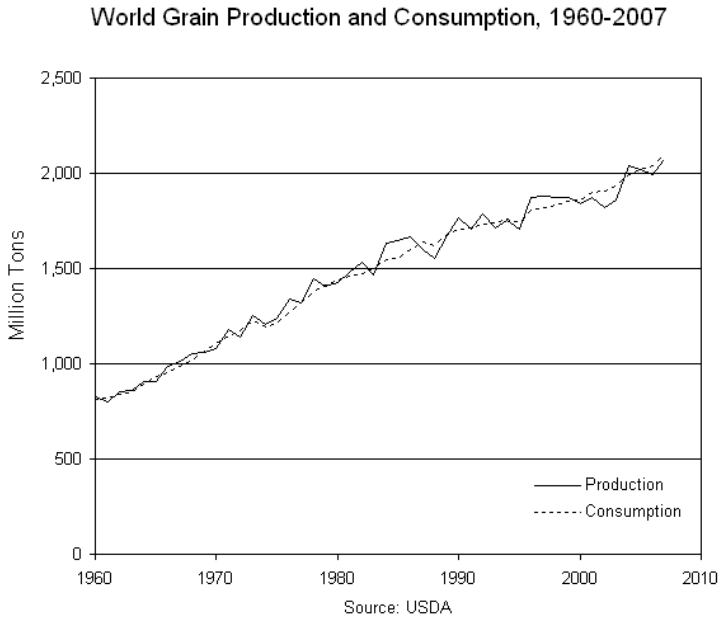
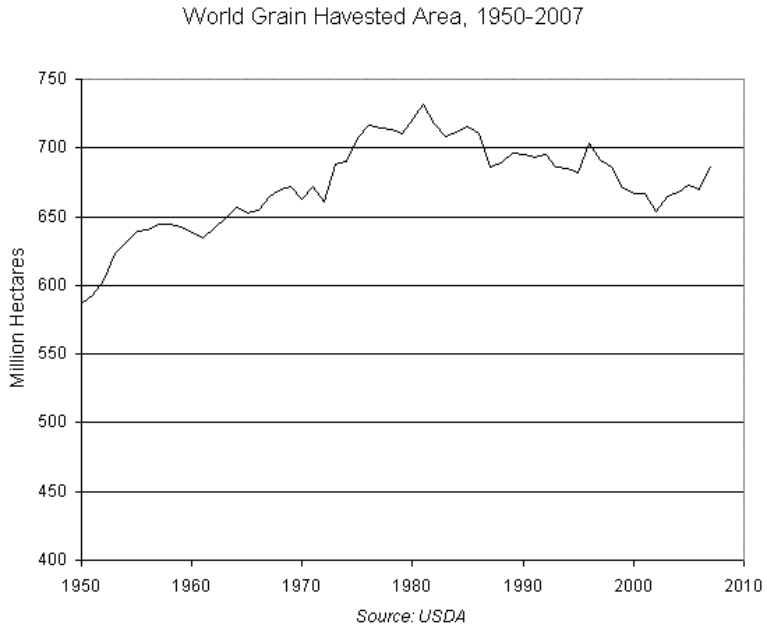
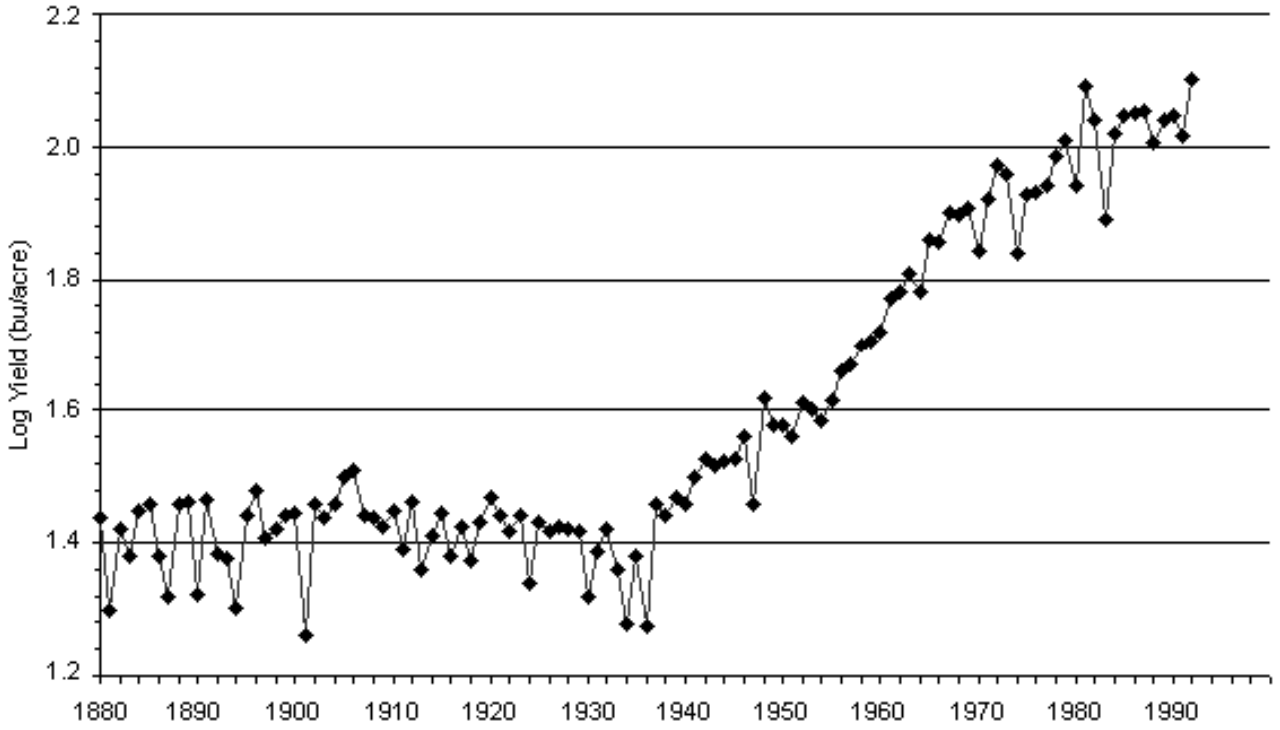
WORLD CEREAL PRODUCTION





YIELD TRANSITION MAIZE USA



GENETICS AND FOOD

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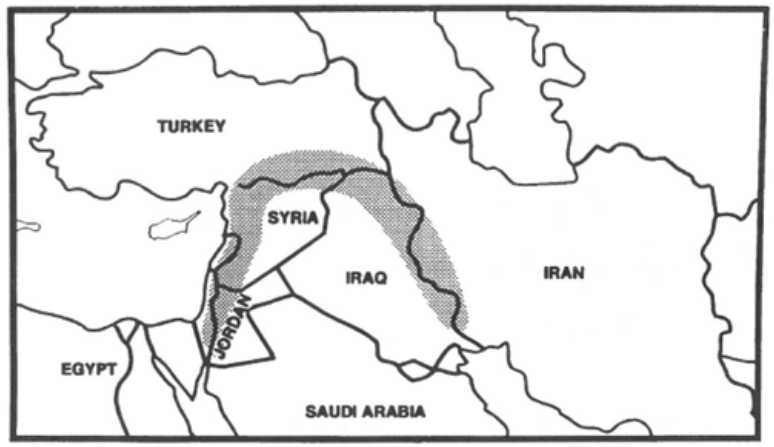
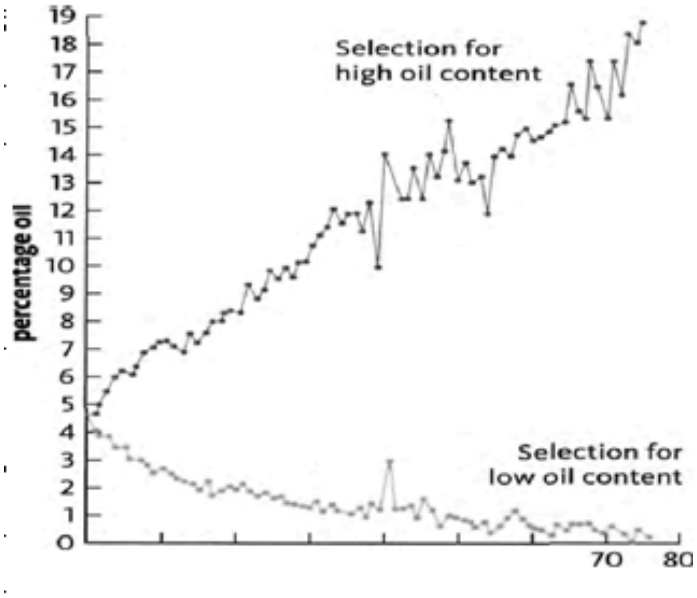
PURE-LINE SELECTION



Fertile Crescent: Origin of agriculture



Maize generations of selection

CHARACTERISTICS CHANGED BY SELECTION

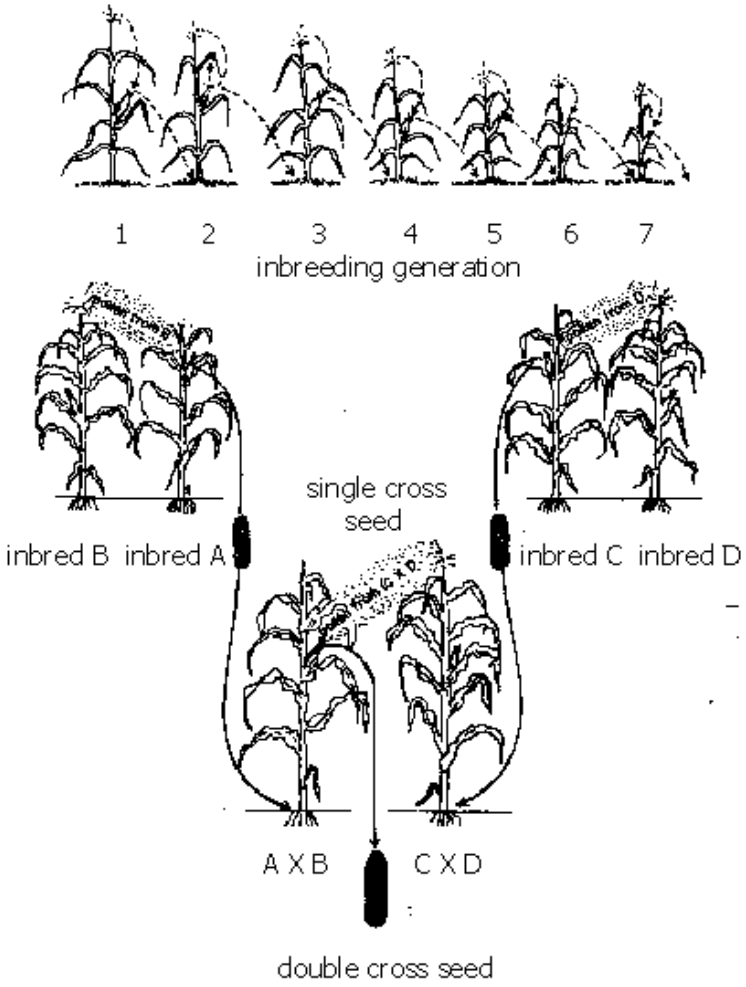
- Seeds that remain attached to the stem when harvested

- Seeds that do not have dormancy

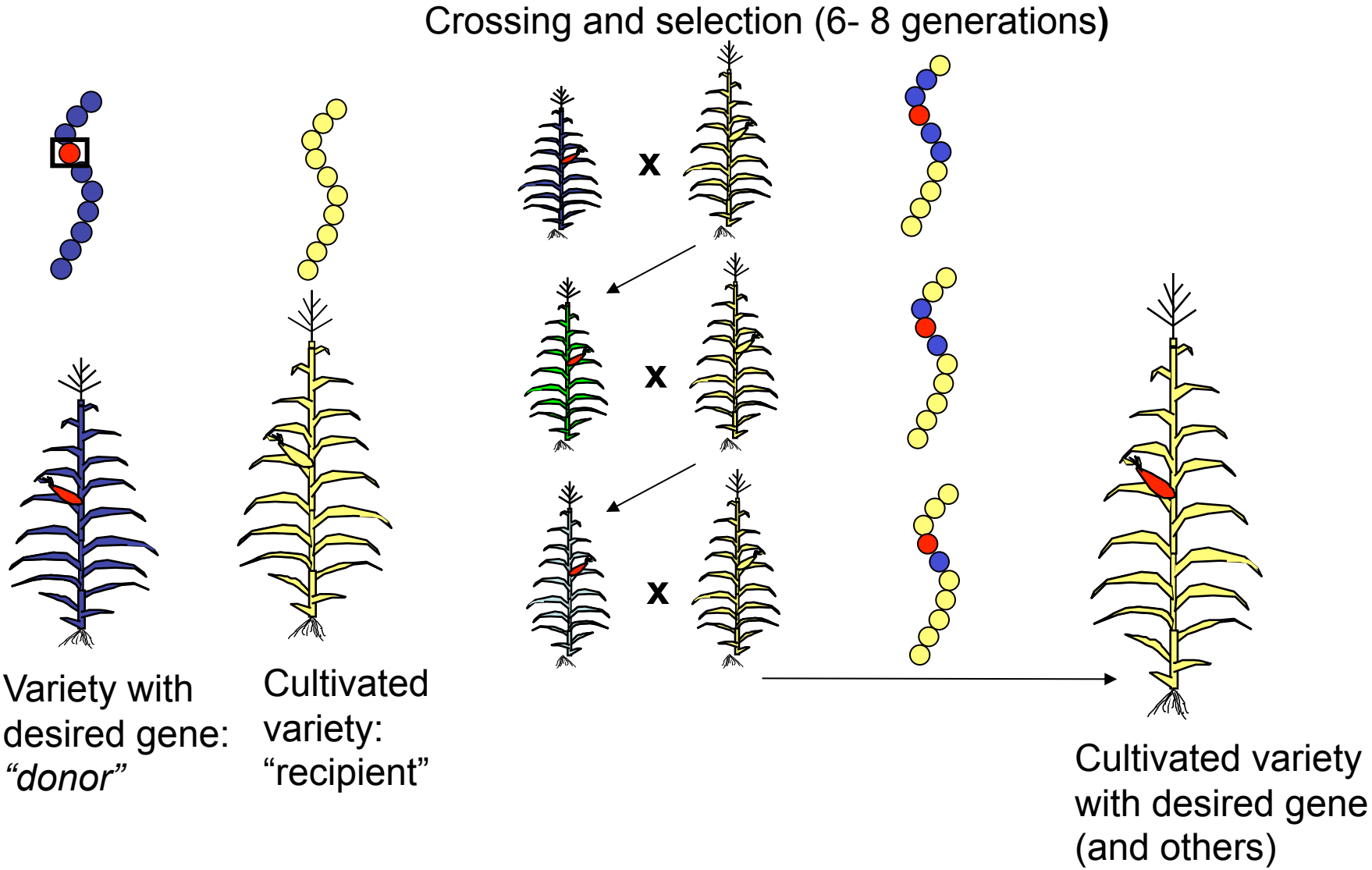
- Increased production of food parts

- Improvements in food characteristics: cooking, taste, etc.

HYBRID CORN


1 2 3 4 5 6 7
inbreeding generation
single cross seed
inbred B
inbred A
inbred C
inbred D
A X B
C X D
double cross seed

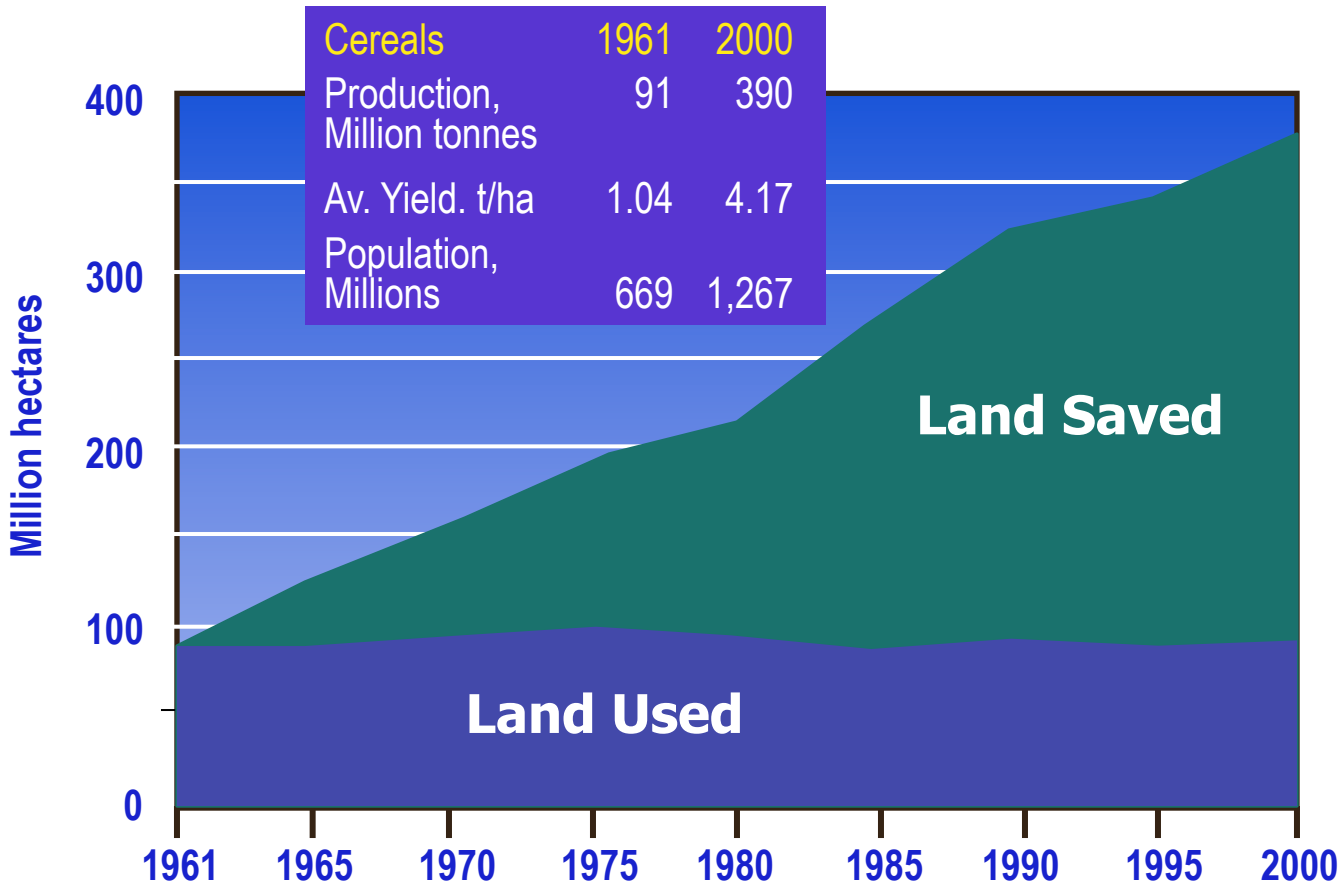
PLANT BREEDING



PLANT BREEDING COMBINED WITH TECHNOLOGIES

Adoption of Modern varieties		Fertilizer Nutrient	Cereal		
Wheat	Rice	Irrigation	Use Tractors	Production	
M ha / % area		million ha	million t	millions	million t
19610 / 0%	0 / 0%		8720.2309		
197014 / 20%	15 / 20%		106100.5463		
198039 / 49%	55 / 43%		129292.0618		
199060 / 70%	85 / 65%		158543.4858		
200070 / 84%	100 / 74%		175704.8962		

INCREASED YIELD REDUCED NEED FOR LAND EXPANSION: CHINA



LIMITATIONS TO TRADITIONAL PLANT BREEDING

- Hidden genes introduced
- Genes limited to the species being bred
- Slow
- Adapting environment to the plant

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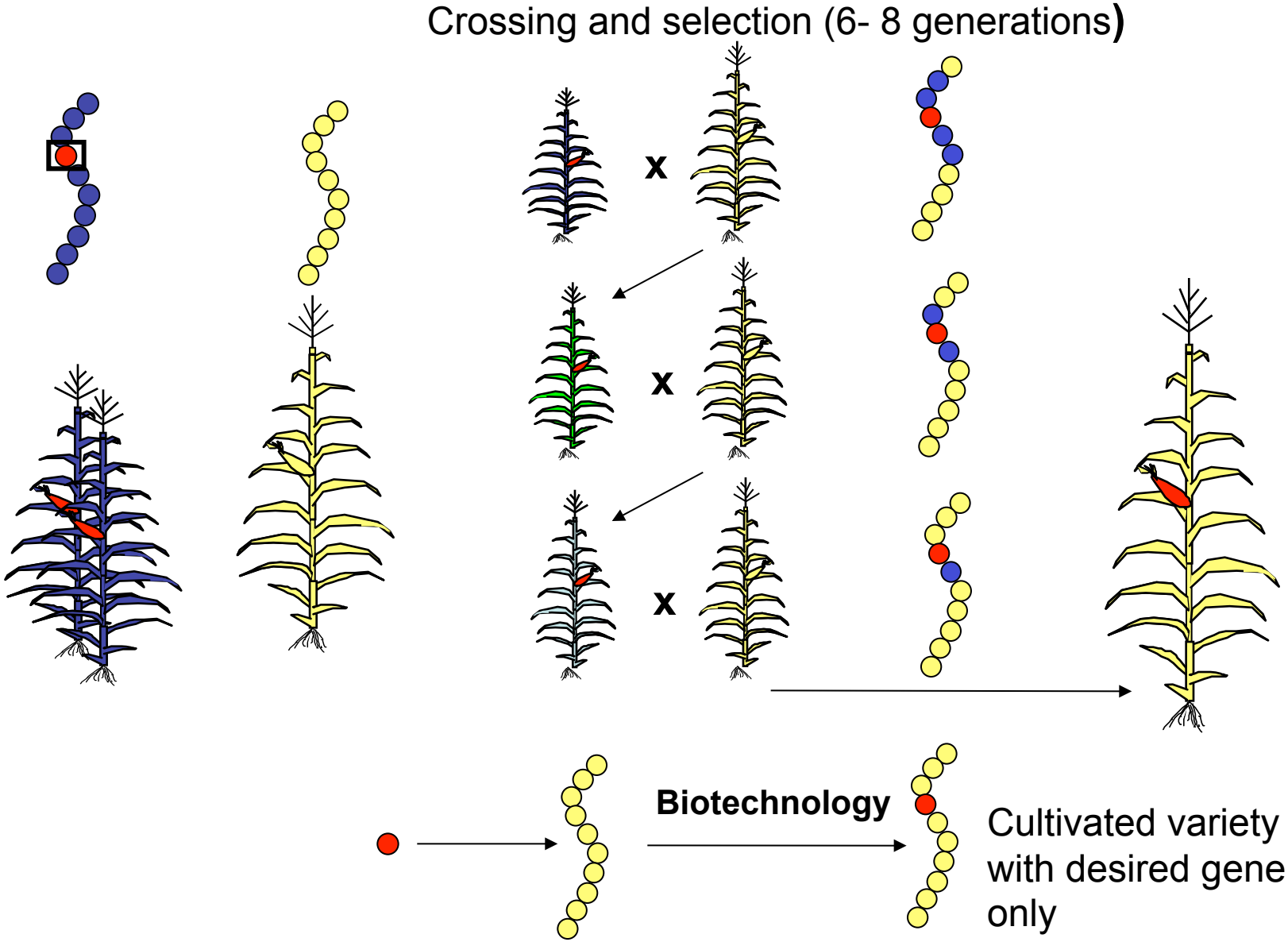
BREEDING BY BIOTECHNOLOGY



BIOTECHNOLOGY AND THE LIMITATIONS TO TRADITIONAL PLANT BREEDING

- Hidden genes introduced
- *Biotech.: Single gene introduced*

- Genes limited to the species being bred
- *Biotech.: Any gene from any species*

- Slow
- *Biotech.: Fast*

- Adapting environment to the plant
- *Biotech.: Can adapt plant to environment*

GOALS FOR PLANT GENETICS

1. Insect and Disease Resistance

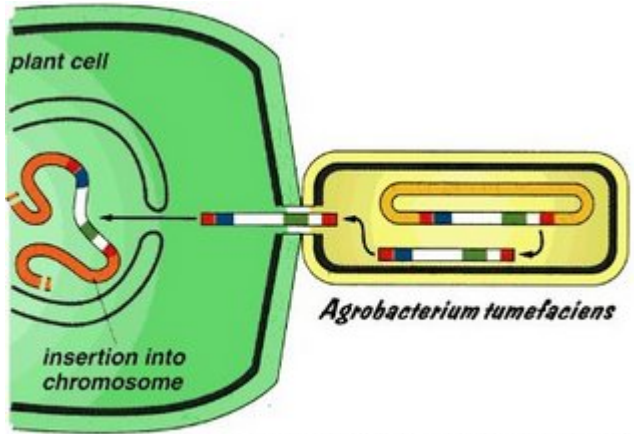
2. Herbicide Resistance

3. Nutritional Quality

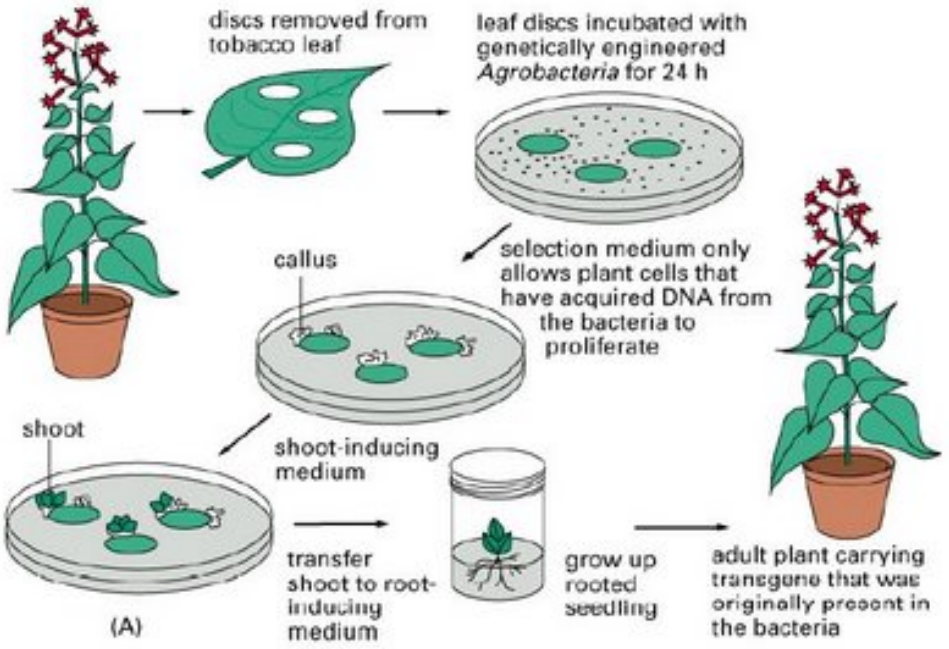
4. Environmental Stresses

Higher Yield

GENETIC MODIFICATION BY DNA



This DNA gets naturally inserted into plants



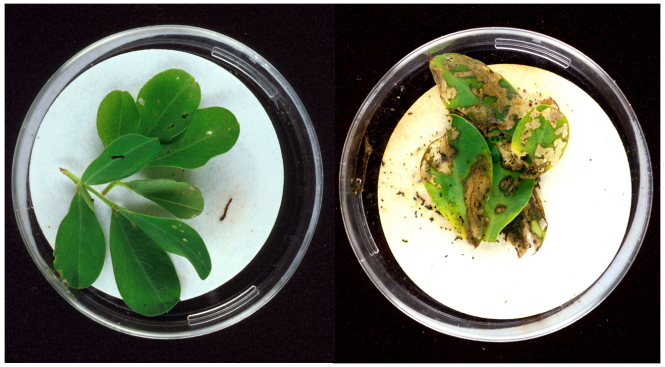
1. INSECT RESISTANCE: Bt PLANTS

Bacillus thuringiensis

Bacterium has a toxin that kills grubs of some insect pests

Bt plant with toxin DNA

Normal plant



INSECT RESISTANCE Bt PLANTS

Corn earworm

Normal plant

Plant with
Bt DNA

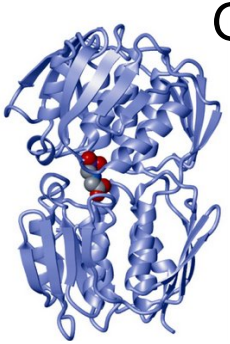
INSECT RESISTANCE

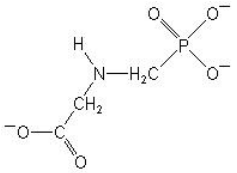
5 million acres of cotton

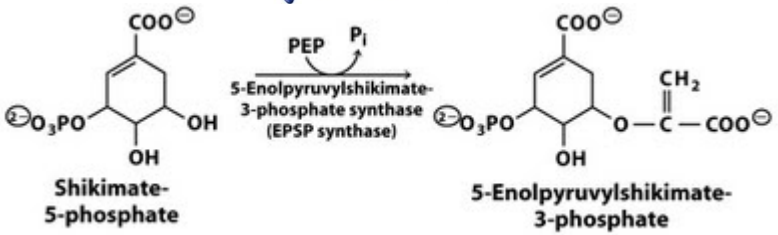
- Applies 1.04 million fewer pounds of insecticide in 2.5 fewer applications per acre
- Saves 41,250 10-hour farm work days
- Conserves 2.41 million gallons of fuel and 93.7 million gallons of water
- $168 million increased net profit
- 20% increased cotton produced
- Fiber equivalent to non-GM cotton

2. HERBICIDE TOLERANCE

Glyphosate bound to enzyme







This reaction occurs in plants but not in animals

Pathway

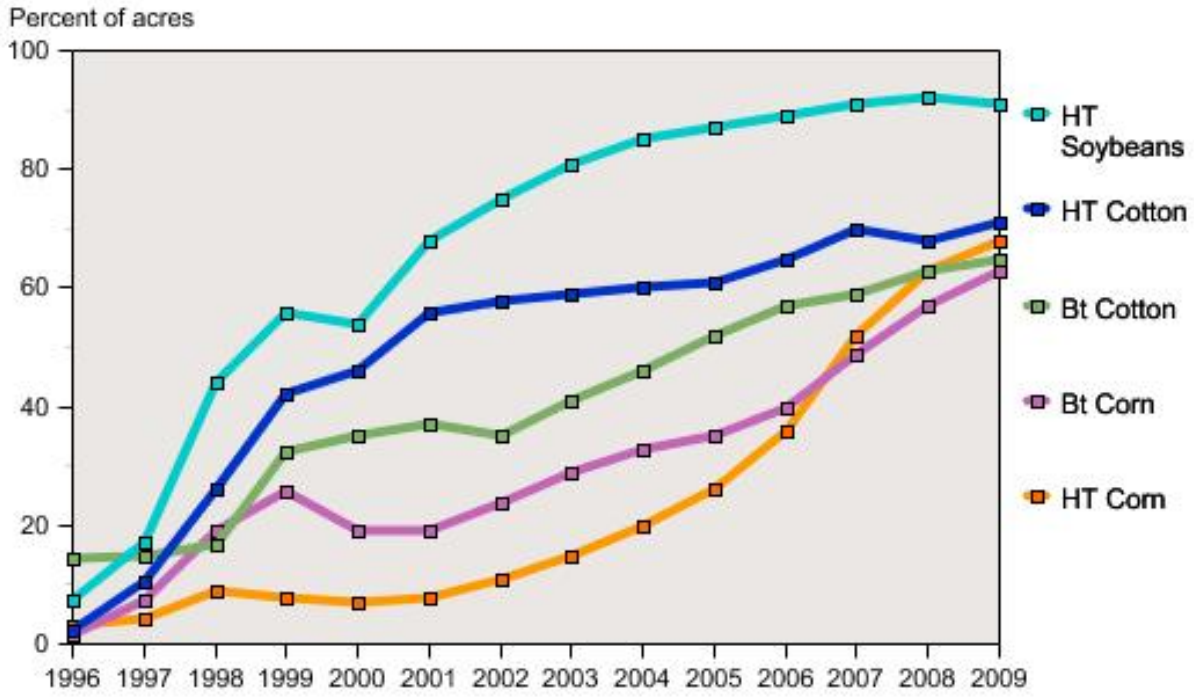
Herbicide glyphosate must be applied at least 4 times

HERBICIDE TOLERANCE

Per acre soybeans

- Applies 60% less herbicides: one application
- Saves 41,250 10-hour farm work days
- Conserves 20% of fuel
- 15% increased net profit
- 10% increased soybeans produced
- Soybeans equivalent to non-GM soybeans

GENETICALLY MODIFIED CROPS, USA

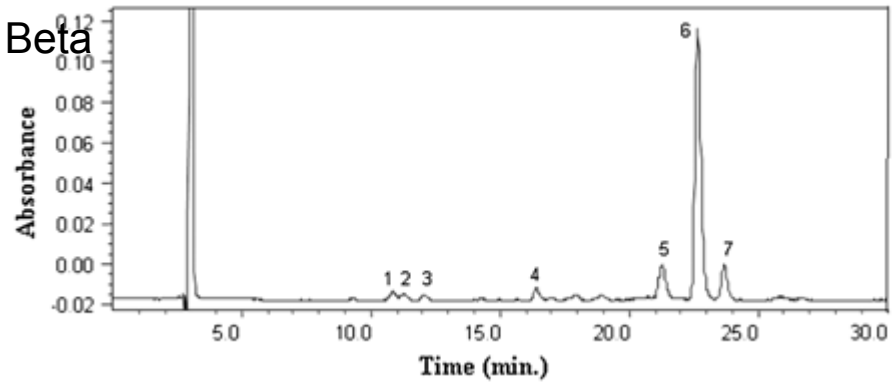


3. NUTRITION: GOLDEN RICE

Wild type | Golden rice 1 | Golden rice 2

NUTRITION: GOLDEN RICE

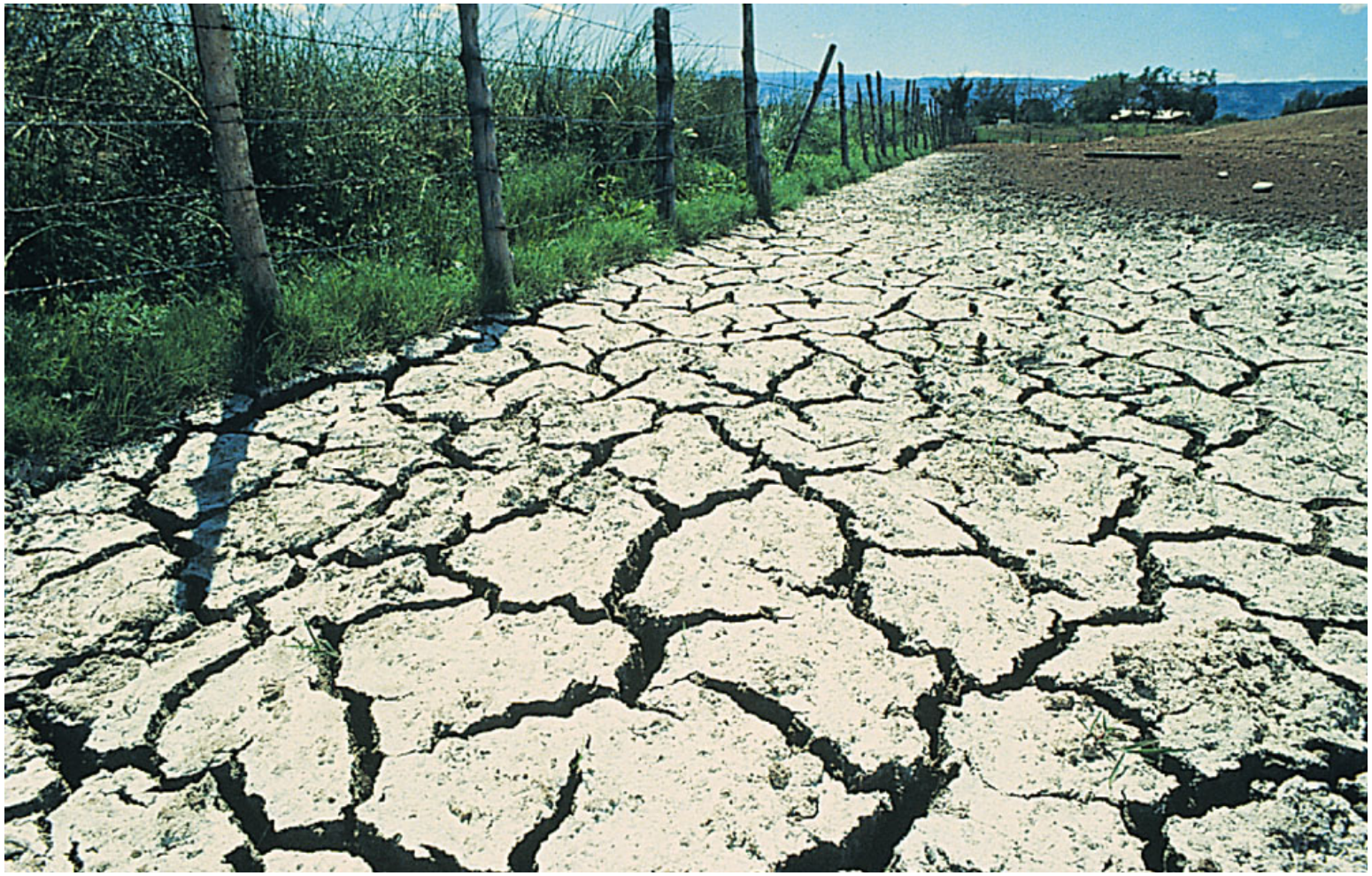
Golden Rice is an effective source of vitamin A
Am J Clin Nutr 2009 89: 1776-1783.



Beta carotene in golden rice

Objective: The objective was to determine the vitamin A value of dietary Golden Rice in humans.
Conclusion: *β*-Carotene derived from Golden Rice is effectively converted to vitamin A in humans.

4. ENVIRONMENT: SALINIZATION



ENVIRONMENT: SALT-TOLERANT TOMATOES

(A)

Genetically transformed: in very salty soil

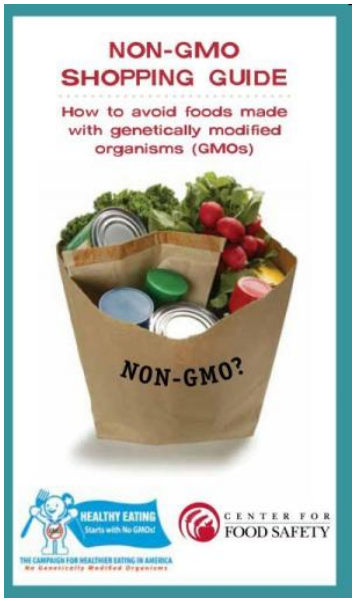
Genetically modified salt-tolerant tomato plants accumulate salt in foliage but not in fruit

(B)

Normal: in very salty soil

CONCERNS ABOUT GM PLANTS

- Intrusion into nature
- Possible allergens in foods
- Spread of genetic modification to non-target organisms



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