Plant Genetics and Breeding Lab

Objectives of the Lab:
1) To understand the interactions between plant life cycle and plant breeding techniques.
2) Learn basic principles of genetics including recessive genes, inbreeding depression and hybrid vigor
3) Learn basic understanding of molecular genetics including promoters, exons and introns
4) Understand how GMO's are constructed and with what intent. Also some known and potential impacts of GMO's on farmers and ecosystems.
5) Get introduced into some of the amazing changes wrought through artificial selection.

Plant life cycle:

Pollen - haploid, contains the sperm

Ovule - a combination of diploid (maternal) and haploid structures, contains the haploid egg cell

Seed - a diploid structure containing the embryo and embryo reserves. The seed coat is a tissue of maternal origin.

Reproducing plants:

Plants can be reproduced by seed (sexual), from cuttings (asexual), from a single cell grown in tissue culture (asexual and chemical), or by grafting onto the stem of another individual (confusing). What are the benefits and drawbacks of each of these methods?

Selecting plants:
Yield: the ratio of seeds harvested to seeds planted **or** the amount harvested per acre planted
Characteristics to select for:

-yield directly
-yield indirectly
-ease of harvesting
-"improvement"

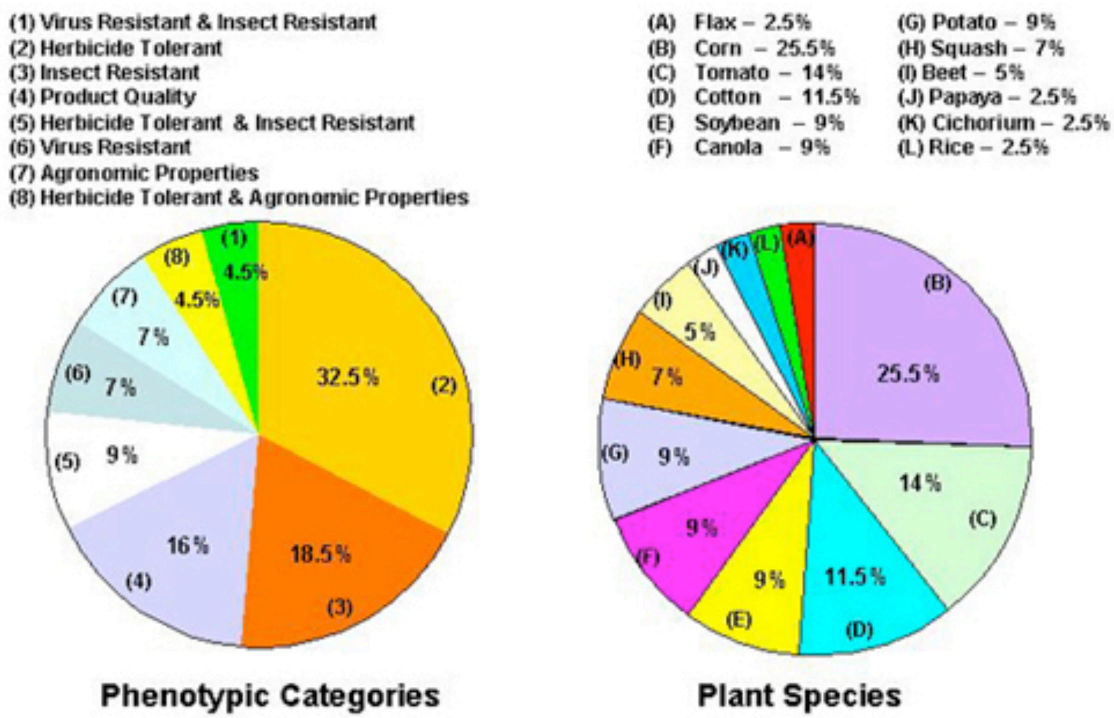
Hybrid Corn:
Inbred lines are crossed to produce heterozygous offspring. What are the advantages and disadvantages of single vs. double crosses? What are the theoretical/genetic reasons why hybrid corn works so well? What are the advantages and disadvantages to farmers of hybrid corn? Examine examples of corn varieties and crosses from the collections.

Some Poaceous Terms:
Popcorn: hard starch imbedded in elastic material surrounding small amount of soft starch; steam builds up on exposure to heat and causes the fruit to explode and turn inside out.
Dent corn: so-called because the soft starch shrinks as it dries and the kernels acquire a dented appearance; most widely grown corn in the North American Corn Belt; used for animal feed, corn starch and corn meal.
Sweet corn: more sugar than starch in endosperm cells (due to a single gene mutation relative to dent corn); primarily a U.S. corn, popular for human tables.

Flint corn: hard, smooth kernels containing little soft starch; early, vigorous grower; widely grown outside of U.S., especially in Europe
Husk: specialized bracts around the ears.
Tassel: male inflorescences
Ear: female inflorescences
Silk: stigma and style
Bran: the fused seed coat and fruit wall
Germ: the embryo
Groat: grain from which the fruit wall has been removed (aids in long-term storage for food)

Genetically Modified Organisms (GMO's)
Why? How are they made? How do they work? Who benefits?

Breakdown of GMO crop plants currently on the market



The tale of BT toxin
One toxin vs. many
Natural strain bt kurstaki HD-1 has Cry1Aa, Cry1Ab, Cry1Ac, Cry2A, Cry2B
All original GM plants had a single toxin
Resistance showed up in insect populations within first year of planting single toxin bt GMO's
Some new GM varieties carry two toxin genes
Persistent vs. transient

Use of BT by organic farmers was *transient* sprayings (toxins degrade in sunlight), but plants express toxins constitutively internally…different, stronger selection for resistance in local insects

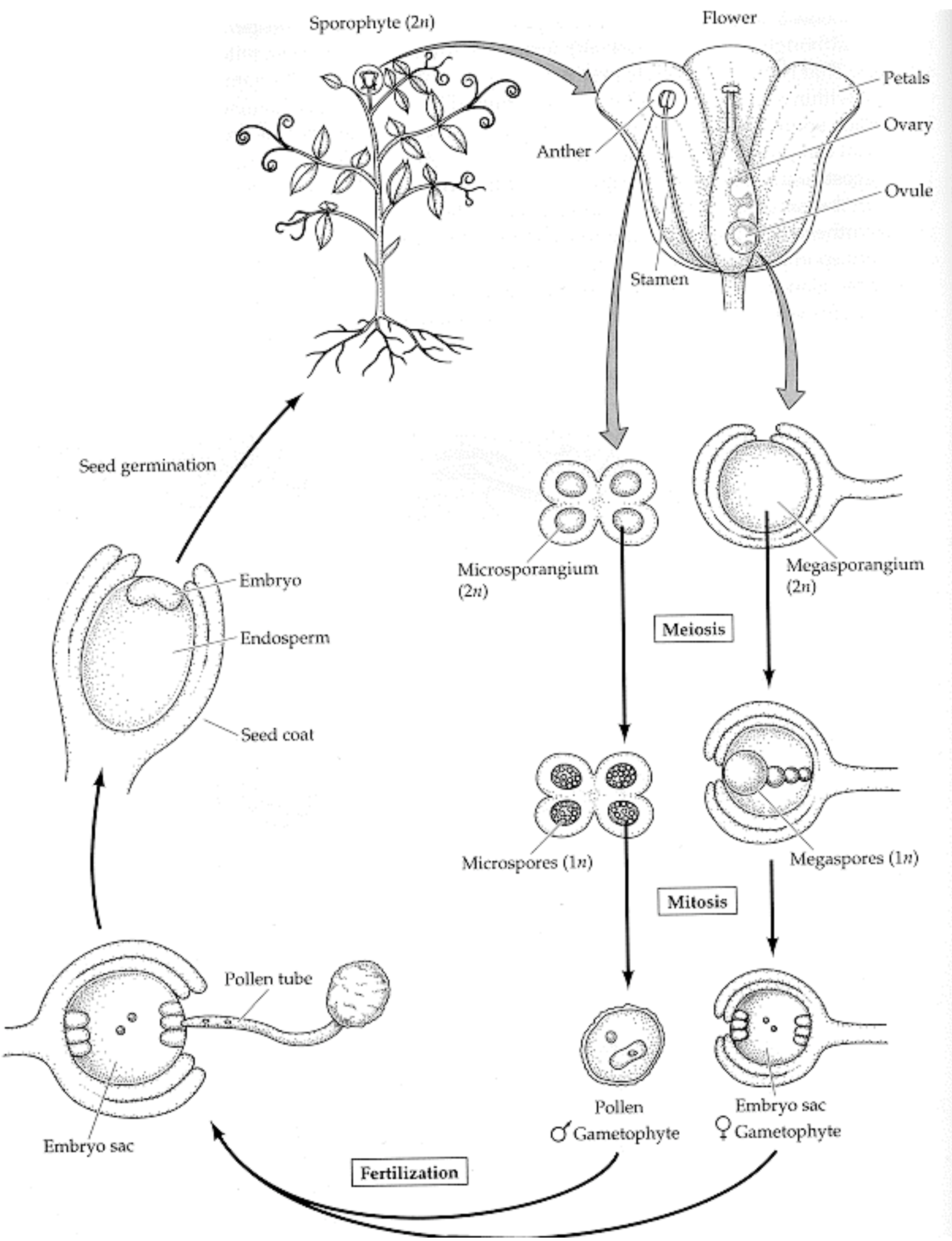
Refuge planting: sacrifice non-GMO's and breed insects in high numbers that are unlikely to be resistant in the hope that they will "dilute" out the resistant insects. What is the incentive for the farmer to comply?

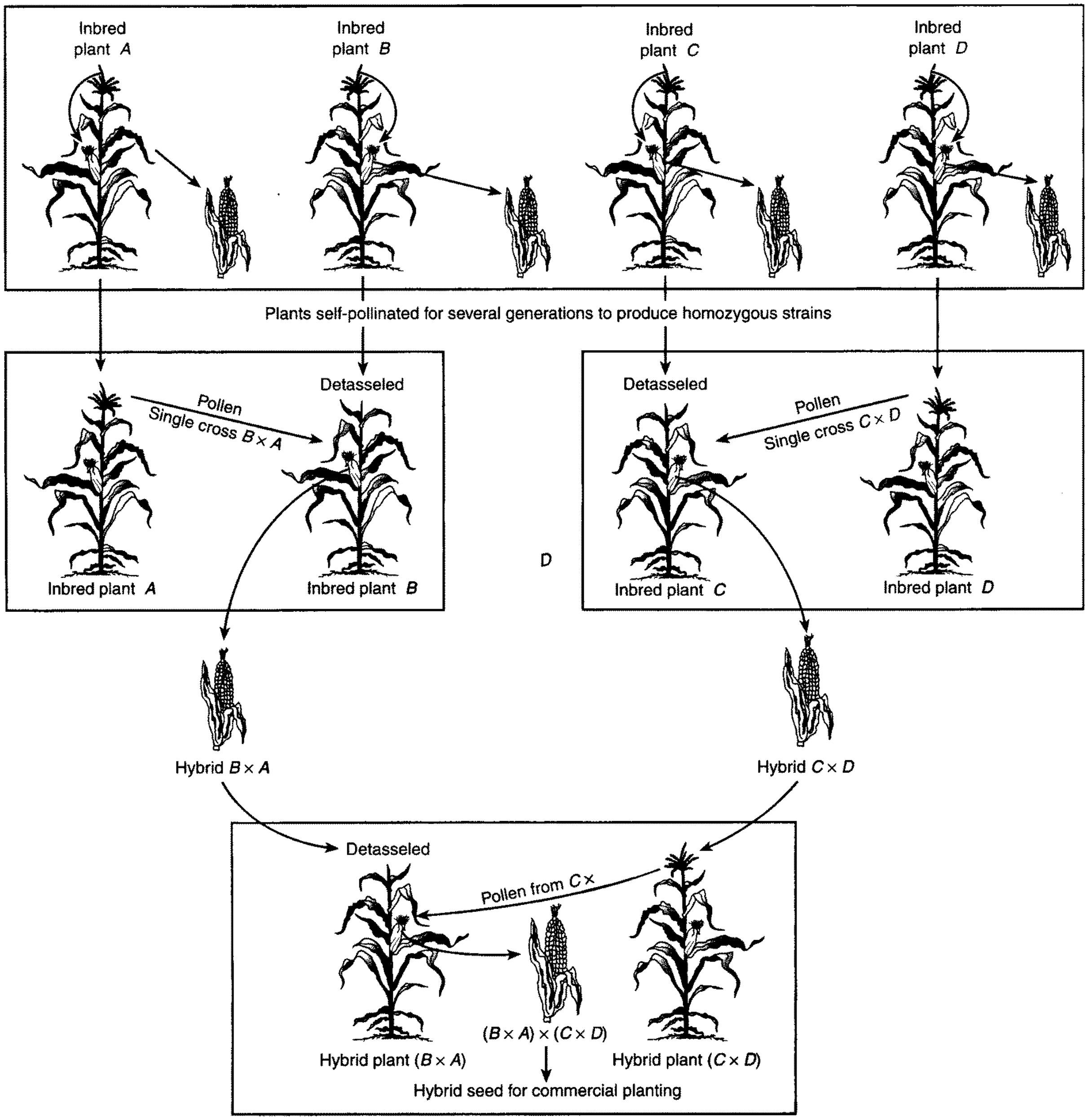
Plant Breeding	Plant Mutagenesis	Genetically Modified
Trait of interest identified among naturally occurring variants	Trait of interest identified among observed variants	Trait of interest is identified a priori and is known *not* to be a naturally occurring possibility
Danger that particular strain/individual with trait of interest will also harbor other mutations that make it less desirable -- these may get "pulled" along and included in selected lines	Danger that particular strain/individual with trait of interest will also harbor other mutations that make it less desirable (more likely when mutation rate is higher)	Danger that insertion of gene will cause disruption of one or more plant genes and/or biochemical pathways (more of a danger for edible plants that have close relatives with nasty secondary compounds)
Typically a slower process of gradual improvement of quantitative traits, frequently involving many individuals in each generation (i.e. the top 10% for a given trait)	Can be either quantitative or qualitative mutants chosen, selection often based on few individuals in early generations	A "yes-or-no" character, often limited to very few individuals in the early generations

Just what is possible? All the varieties of Brassica oleracea

Kale: Large leaves (green or red) with curled margins
Collard Greens: large uncurled ovoid leaves
Cabbage: Non-expanding terminal meristem makes for many leaves on a highly compressed stem.
Brussels sprouts: sprouts are side buds with compressed stalks, axillary "minicabbages"
Kohlrabi: An expanded hypocotyl region for consumption; stem-like structure eaten
Broccoli: highly branched inflorescence, we eat the fertile, unopened floral buds
Cauliflower: floral stem tips proliferate into "curds," kept white by breeding

Written by Amity Wilczek, 2003.


Sporophyte (2n)
Flower
Petals
Ovary
Anther
Ovule
Stamen
Seed germination
Microsporangium
(2n)
Megasporangium
(2n)
Embryo
Endosperm
Meiosis
Seed coat
Microspores (1n)
Megaspores (1n)
Mitosis
Pollen tube
Embryo sac
Pollen
♂ Gametophyte
Embryo sac
♀ Gametophyte
Fertilization


Inbred plant A
Inbred plant B
Inbred plant C
Inbred plant D
Plants self-pollinated for several generations to produce homozygous strains
Pollen
Single cross B × A
Detasseled
Inbred plant A
Inbred plant B
D
Detasseled
Pollen
Single cross C × D
Inbred plant C
Inbred plant D
Hybrid B × A
Hybrid C × D
Detasseled
Pollen from C ×
(B × A) × (C × D)
Hybrid plant (B × A)
Hybrid plant (C × D)
Hybrid seed for commercial planting

Genetically engineered crops allowed in the US food supply as of the year 2000

Product	Institution(s)	Engineered Trait(s)	Sources of New Genes	Name
Canola	Bayer	Resist glufosinate herbicide to control weeds	Bacteria, virus	LibertyLink 2000
Canola	Monsanto	Resist glyphosate herbicide to control weeds	Arabidopsis, bacteria, virus	Roundup Ready 1999
Canola	Monsanto	Altered oil (high lauric acid) for soap and food products	Calif bay, turnip rape, bacteria, virus	Laurical 1995
Canola	Bayer	Male sterile to facilitate hybridization; resist glufosinate herbicide to control weeds	Bacteria	SeedLink 2000
Chicory (radicchio)	Bejo Zaden	Male sterile to facilitate hybridization	Bacteria	SeedLink 1997
Corn	Bayer	Resist glufosinate herbicide to control weeds/male sterile to facilitate hybridization	Bacteria, virus	SeedLink Date unknown
Corn	Bayer	Resist glufosinate herbicide to control weeds	Bacteria, virus	LibertyLink Date unknown
Corn	Bayer	Resist glufosinate herbicide to control weeds/Bt toxin to control insect pests (European corn borer)	Bacteria, virus	StarLink 1998 (approved only for animal feed)
Corn	Dow/Mycogen	Bt toxin to control insect pests (European corn borer)	Corn, bacteria, virus	NatureGard 1995
Corn	Dow/Mycogen DuPont/Pioneer	Resist glufosinate herbicide to control weeds/Bt toxin to control insect pests (Lepidopteran)	Corn, bacteria, virus	Herculex I 2001
Corn	DuPont/Pioneer	Male sterile to facilitate hybridization	Potato, corn, bacteria, virus	Name unknown 1998
Corn	Monsanto/ DeKalb	Bt toxin to control insect pests (European corn borer)	Bacteria	Bt-Xtra 1997
Corn	Monsanto/ DeKalb	Resist glufosinate herbicide to control weeds	Bacteria, virus	Name, date unknown
Corn	Monsanto	Bt toxin to control insect pests (European corn borer)	Bacteria	YieldGard 1996
Corn	Monsanto	Resist glyphosate herbicide to control weeds/Bt toxin to control insect pests (European corn borer)	Arabidopsis, bacteria, virus	Name unknown 1998
Corn	Monsanto	Resist glyphosate herbicide to control weeds	Arabidopsis, bacteria, virus	Roundup Ready 1998
Corn	Syngenta	Bt toxin to control insect pests (European corn borer)	Bacteria	Bt11 1996
Corn	Syngenta	Bt toxin to control insect pests (European corn borer)	Corn, bacteria, virus	Knock Out 1995

Corn (pop)	Syngenta	Bt toxin to control insect pests (European corn borer)	Corn, bacteria, virus	Knock Out 1998
Corn (sweet)	Syngenta	Bt toxin to control insect pests (European corn borer)	Bacteria	Bt11 1998
Cotton	Monsanto/ Bayer	Resist bromoxynil herbicide to control weeds/Bt toxin to control insect pests (cotton bollworms and tobacco budworm)	Bacteria	Name unknown 1998
Cotton	Monsanto/ Bayer	Resist bromoxynil herbicide to control weeds	Bacteria, virus	BXN Cotton 1995
Cotton	Monsanto	Bt toxin to control insect pests (cotton bollworms and tobacco budworm)	Bacteria	Bollgard 1995
Cotton	Monsanto	Resist glyphosate herbicide to control weeds	Arabidopsis, bacteria, virus	Roundup Ready 1996
Flax	Univ Saskatchewan	Resist sulfonylurea herbicide to grow in soils with herbicide residues	Arabidopsis, bacteria	CDC Triffid 1999
Papaya	Cornell Univ/ Univ Hawaii	Resist papaya ringspot virus	Bacteria, virus	Sunup, Rainbow 1997
Potato	Monsanto	Bt toxin to control insect pests (Colorado potato beetle)	Bacteria	NewLeaf 1995
Potato	Monsanto	Bt toxin to control insect pests (Colorado potato beetle)/resist potato virus Y	Bacteria, virus	NewLeaf Y 1999
Potato	Monsanto	Bt toxin to control insect pests (Colorado potato beetle)/resist potato leafroll virus	Bacteria, virus	NewLeaf Plus 1998
Soybean	Bayer	Resist glufosinate herbicide to control weeds	Bacteria, virus	Name unknown 1998
Soybean	DuPont	Altered oil (high oleic acid) to increase stability, reduce polyunsaturated fatty acids	Soybean, bean, bacteria, virus	Name unknown 1997
Soybean	Monsanto	Resist glyphosate herbicide to control weeds	Petunia, soybean, bacteria, virus	Roundup Ready 1995
Squash	Seminis Vegetable Seed	Resist watermelon mosaic 2 and zucchini yellow mosaic viruses	Bacteria, virus	Freedom II 1995
Squash	Seminis Vegetable Seed	Resist watermelon mosaic 2, zucchini yellow mosaic, cucumber mosaic viruses	Bacteria, virus	Name unknown 1997
Sugarbeet	Bayer	Resist glufosinate herbicide to control weeds	Bacteria, virus	Name unknown 2000
Sugarbeet	Monsanto/ Syngenta	Resist glyphosate herbicide to control weeds	Bacteria, virus	Name unknown 1999
Tomato (cherry)	Agritope	Altered ripening to enhance fresh market value	Bacteria	Name unknown 1996
Tomato	DNA Plant Technology	Altered ripening to enhance fresh market value	Tomato, bacteria, virus	Endless Summer 1995

Tomato	Monsanto/ Calgene	Altered ripening to enhance fresh market value	Tomato, bacteria, virus	FlavrSavr 1994
Tomato	Monsanto	Altered ripening to enhance fresh market value	Bacteria	Name unknown 1995
Tomato	Zeneca/ PetoSeed	Thicker skin and altered pectin to enhance processing value	Tomato, bacteria, virus	Name unknown 1995

Table from Union of Concerned Scientists (http://www.ucsusa.org/food_and_environment/biotechnology/page.cfm?pageID=337)
Further information at:
http://www.cfsan.fda.gov/~lrd/biocon.html#list (more current FDA list of approved GMO's)
http://www.aphis.usda.gov/brs/not_reg.html (list of GMO's no longer regulated by the government because they are considered safe)
http://www.aphis.usda.gov/brs/de_reg.htm (deatiled documentation about the evaluation of deregulated GMO's)
http://usda.mannlib.cornell.edu/reports/nassr/field/pcp-bba/acrg0603.txt (acreage devoted to different crop species, including GMO's, in the US)

Artificially Induced Mutations in Crop Varieties

Crop	**Cultivar Name**	**Method Used to Induce Mutation**
rice	Calrose 76	gamma rays
wheat	Above	sodium azide
	Lewis	thermal neutrons
oats	Alamo-X	X-rays
grapefruit	Rio Red	thermal neutrons
	Star Ruby	thermal neutrons
lettuce	Ice Cube	ethyl methanesulphonate
	Mini-Green	ethyl methanesulphonate
common bean	Seafarer	X-rays
	Seaway	X-rays

Table from Colorado State University (http://www.colostate.edu/programs/lifesciences/TransgenicCrops/history.html)
More information about agricultural use of man-made mutants at the International Atomic Energy Agency's site...no kidding. (http://www-infocris.iaea.org/MVD/)