Overview of Plant Breeding, Seed Industry, and Biodiversity

Plant Breeding

Plant breeding is not a new technology. Since man first domesticated plants, plant growers have **selectively** used seed from crops with desirable qualities, choosing seed from the sturdiest plant, the largest or tastiest fruit. Following the work of Gregor Mendel, in the mid-19th century, plant breeders learned how to **crossbreed** compatible types of plants, creating hybrids that combined the best features of both parent plants.

As plant breeding techniques became more sophisticated, researchers discovered ways to overcome fertility barriers between similar species. A hybrid cereal, triticale, was created in 1875 by crossing wheat and rye. Since then, **cross-species hybridization** has yielded fruit like tangelos (tangerine and grapefruit) or the peachcot (peach and apricot), which have been well received by the public. Over the past 100 years, plant breeders have developed more breeding tools for improving crops for a variety of purposes including drought resistance, disease resistance, chemical resistance, better flavor, longer storage, increased nutrition and increased yield. Many of these tools require generations of plant growth before a marketable seed is produced.

Chemically or radioactively induced mutations, first introduced in the late 1920s, expanded after World War II. Seeds from plants are treated with either chemicals or irradiation and then selected for desired traits. These types of mutations have yielded over 2500 new varieties of plants, including most varieties of modern wheat, barley, rice, potatoes, soybeans, and onions.[1]

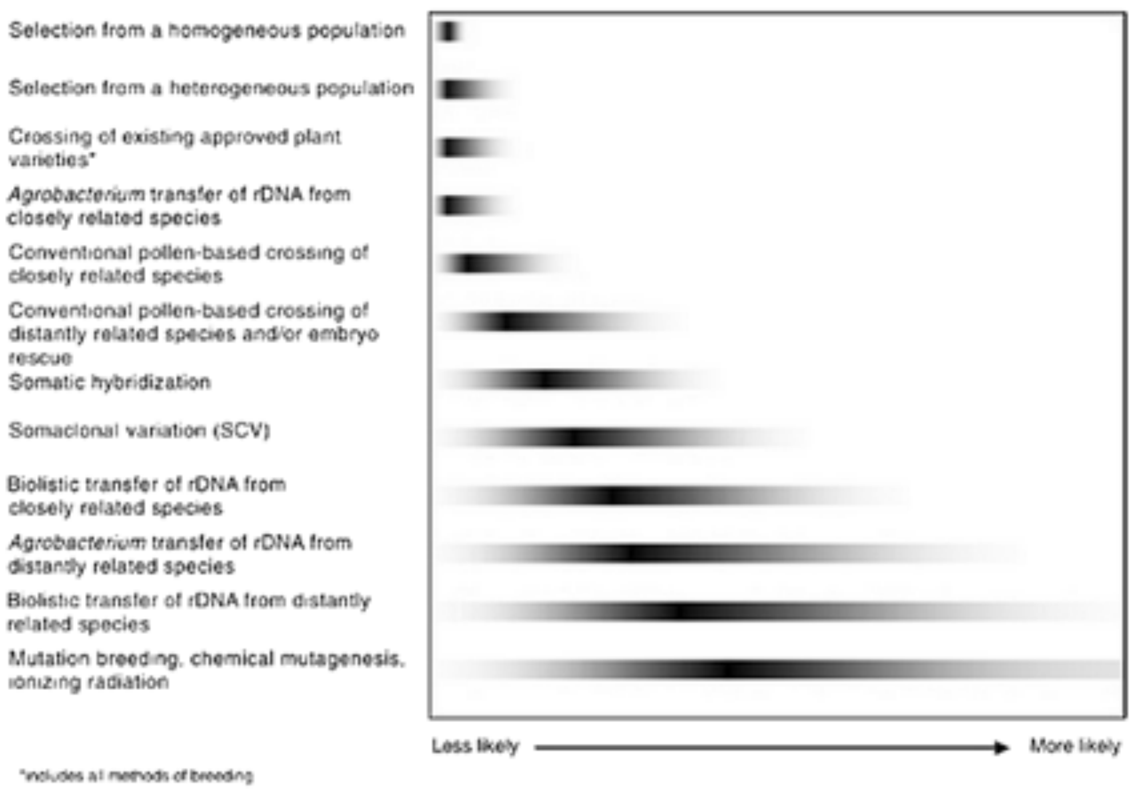
Over the last 50 years, plant breeding has moved to the laboratory. Cross breeding in a petri dish has become more common. For example a new broccoli that is less heat sensitive was developed by petri dish mating of broccoli with other species such as radishes.[2]

As knowledge of genes and plant processes continues to expand, plant breeders find new ways both to combine genetic material, as well as to speed the subsequent selection process. “Controlled mating” is one way to describe much conventional breeding: choosing superior parents, and then interbreeding them.[3] Of interest in this is a recent attempt to introduce wild plant sources to diversify the genetic base. By collecting and raising wild plants, selectively saving seed from those having the desired characteristics and cross breeding them and repeating the process, over time, new, desirable plants may be identified for cultivation.[4]

Plant breeding based on monitored recombination is the base for most genetic engineering (see Genetic Engineering paper of the Agriculture Update). Genetic material of the target organism is altered though insertion of specific genes from a different organism with known function into the DNA strands of the host organism to produce what are known as transgenic animals or plants, or genetically modified organisms (GMOs).[5]

A new factor in any of these processes is the ability to evaluate the genetic composition of a new variety without growing it to maturity, as was previously the case. Seeds can be tested for traits before being planted, speeding the selection process. "The rate of genetic gain per unit of time can be increased by speeding up the selection − recombination cycles, by intensifying the selection pressure, by improving the evaluation precision (thus increasing the heritability), or by any combination of those."[6]

Every form of plant breeding may yield unintended consequences. In 2004, a committee of scientists published a lengthy discussion regarding forms of genetic manipulation, possible risks, methods of assessment, as well as suspected range of unintended consequences. The following chart shows "Relative likelihood of unintended genetic effects associated with various methods of plant genetic modification. The gray tails indicate the committee's conclusions about the relative degree of the range of potential unintended changes; the dark bars indicate the relative degree of genetic disruption for each method."[7]



A more recent study has demonstrated significant unexpected mutations in versions of genetic manipulation the committee considered relatively unlikely to create unintended effects.[8] The review of this and similar studies concluded: "Even with the limited information currently available it is clear that plant transformation is rarely, if ever, precise and that this lack of precision may cause many of the frequent unexpected phenotypes that characterise plant transformation and that pose a significant biosafety risk."[9]

No matter the method:

> *Plant breeding is often said to be a process not of selection, but of elimination. Any off-types, unstable lines, or lines showing characteristics such as significant differences in nutrient content, responses to environmental stresses, diseases, or the presence of other undesirable traits are discarded as soon as they are noticed. This winnowing takes place over several years, so the remaining lines identified for prospective commercial release are unlikely, but not guaranteed, to have any significant compositional changes other than those related to the desired trait. For this reason, regulatory scrutiny focuses most often on the new trait and its metabolic perturbations. Nevertheless, the appearance of subtle or obscure phenotypic changes can go unnoticed by breeders or regulators and may subsequently have to be recalled from the market....*[10]

Seed Industry

Through the end of the 19th century, farmers saved their own seed, and shared seed from exceptional plants with fellow farmers. Between 1915 and 1930, seed certification programs at land grant institutions helped improve the quality of seed, which gave rise to the birth of private seed companies eager to help with distribution. Research and development was done by public institutions; seed companies planted, collected, cleaned, and distributed seed, and farmers enjoyed the benefits of increased yield and a reliable, field-tested seed supply.[11]

The introduction of high-yield hybrid corn in the 1930s fueled a rapid expansion of the US seed industry. The 1970 Plant Variety Protection Act (PVPA; see the Patent and Trademark Office paper of the Agriculture Update) gave further encouragement to the seed industry, and the balance began to shift from public research in open-pollinated seed, held in the public domain, toward private research in patented seed. In the years following the PVPA pharmaceutical, petrochemical, and food companies recognized the potential profits of patented seed and began buying out small, independent seed companies. The landmark patent case, *Diamond v. Chakrabarty*, 1980, (see the Patent and Trademark Office paper) along with developments in biotechnology in the 1980s, gave further incentive for large, multinational companies to invest in seed R&D. The high costs of biotechnology research prompted "extensive mergers, acquisitions, and joint ventures as companies sought to achieve economies of scale to offset the high costs of biotechnology R&D."[12]

As of 2012, five companies, Monsanto, DuPont, Pioneer, Dow AgroSciences, and Syngenta, together provided 80% of the US corn seed, and 70% of US soy seed.[13] These four firms, along with BASF and BayerCropScience, are the top six global agrochemical providers.[14]

An Economic Research Service (ERS) discussion of the seed industry notes potential benefits: "the entry of large multinational firms in the industry ... expands markets, from domestic or regional to global, increasing sales volume and profits supporting R&D."[15]

At the same time, the ERS suggests reasons for concern: the relatively small size of the commercial seed market "… means that seed divisions in large firms are less likely to exert influence on corporate decisions than those divisions involved in larger markets, such as pharmaceuticals and chemicals."[16] Observers wonder if this dynamic fuels research toward seed compatible with increased use of chemical inputs.[17]

In addition, the time-consuming nature of seed R&D requires a long-term perspective on R&D investments, which may not appeal to a firm's shareholders.[18] ERS research suggests private research focuses almost exclusively on commodity crops, a sector which promises a high volume of seed sales.[19] As private investment in R&D has increased, public investment stagnated through the 1990s, then has fallen dramatically. A 2012 letter to the USDA from the National Association of Plant Breeders (NAPB) expressed concern at low levels of US investment in plant breeding, asserting that "[f]unding for and support of public sector plant breeding, both the discipline and the science, has been eroding over the past 30 years."[20] The letter makes clear the opinion of NAPB that while private funding for certain select crops is thriving, public research expenditure is essential for improving yields and performance of less profitable crops, as well as for "[t]he integrated approaches and production practices that must be developed to reduce agriculture's negative impact on the environment while maintaining sufficient production.[21]Of specific interest to farmers: "[t]he presence of large firms in the industry raises concerns about increasing market concentration and oligopolistic competition among and between firms."[22] While seed prices have risen sharply since the mid-seventies, seed corporations explain that the increases are justified by the multiple biotech traits (see the Agriculture Update Genetic Engineering paper), providing increased efficiency for farmers.[23] A Department of Justice investigation of Monsanto's seed pricing practices begun in 2008 was quietly dropped in 2012 without explanation.[24]

CROP SEED COST ($/planted acre)	1975	1995	2011	1975-1995 (% increase)	1995-2011 (% increase)
SOYBEANS	$8.32	$13.32	$56.58	60%	325%
CORN	$9.30	$23.98	$86.16	158%	259%
COTTON	$5.88	$15.67	$96.48	166%	516%

Figures from USDA Economic Research Service: Commodity Costs and Returns: U.S. and Regional Cost and Return Data. Datasets accessible at: http://www.ers.usda.gov/Data/CostsAndReturns/testpick.htm. [25]

A concurrent concern is the loss of biodiversity when only certain kinds of seeds are available from major seed companies, while smaller, more diversified seed companies have been bought out or gone out of business. Attention has focused on the maintenance of seed banks, but for farmers wanting to avoid genetically engineered seeds, or looking for less expensive seed supplies, few options are available.[26]

Seed banks are one way to preserve biodiversity. In the United States, the National Center for Genetic Research Preservation locates and preserves heritage seeds.[27] While seed banks offer an avenue for preservation of seed stocks, the greater concern is the lack of readily available seed supply with enough genetic diversity to withstand crop failure in one particular strain. Critics point to the Irish potato famine as warning against dependence on a tightly controlled monocrop, and suggest that a far wiser course would be the kind of local, open breeding activity that yielded over 2000 Peruvian potato breeds.[28]

Some growers have expressed new interest in heirloom seeds: seeds developed over time, and passed on in local communities. Seed exchanges and local seed libraries provide opportunity for sharing seed on a small scale. International groups like Seed Savers Exchange are working to make farmer-saved seed available on a larger scale, with a widening diversity of varieties.[29] According to the national organization, Saving Our Seeds:

> *The genetic reservoir and uniqueness of our vegetable seed heritage resides principally in three places: (1) the USDA seed bank, (2) small specialized seed companies, and (3) small family farms, especially those in ethnic communities. Unfortunately, these are all at risk. Federally sponsored government institutions such as the USDA seed bank are subject to periodic funding crises. Small, specialized seed companies (which offer many unique varieties) have low market penetration, are labor intensive, and are subject to market pressures, which put them at risk. Small family farms are at risk from urbanization, rural outmigration, and economic change.*[30]

Recommended Reading

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[5] Breseghello, op cit., p. 8280

[6] Breseghello, op. cit., p. 8281

[7] Committee on Identifying and Assessing Unintended Effects of Genetically Engineered Foods on Human Health, "Safety of Genetically Engineered Food: Approaches to Assessing Unintended Health Effects," National Academies Press, 2004, page 64, http://www.nap.edu/openbook.php?record_id=10977&page=64, accessed 11/1/13.

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[10] Committee on Identifying and Assessing Unintended Effects of Genetically Engineered Foods on Human Health, p. 64.

[11] Jorge Fernandez-Cornejo, "The Seed Industry in U.S. Agriculture," Agriculture Information Bulletin No. (AIB-786) 81 pp, February 2004, pp. 25, http://www.ers.usda.gov/media/260671/aib786g_1_.pdf, accessed 11/1/13.

[12] Ibid. pp. 20-21.

[13] Sara Schafer, "Inside the Seed Industry," AgWeb, July 25, 2013 http://www.agweb.com/article/inside_the_seed_industry/, accessed 11/1/13.

[14] "Top Ten AgChem Firms Obtained Solid Sales Growth in 2012," Agropages, July 26, 2013, http://news.agropages.com/News/NewsDetail---10138.htm, accessed 11/1/13, **server not found 12/19/13.**

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[16] Fernandez-Cornejo, op. cit., pg. 27.

[17] See, for example, Philip H. Howard, "Visualizing Consolidation in the Global Seed Industry, 1996-2008," pp 1270-1271, *Sustainability* 2009, *1*, 1266-1287; doi:10.3390/su1041266, http://www.mdpi.com/2071-1050/1/4/1266, accessed 11/1/13.

[18] Fernandez-Cornejo, op. cit., pp. 27.

[19] Fernandez-Cornejo, op. cit., pp. 41-50.

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[28] Twilight Greenaway, “GMO Potatoes: Is the Biodiversity Shortcut Worth It?” Grist, August 1, 2012, http://grist.org/food/gmo-potatoes-is-the-biodiversity-shortcut-worth-it/, accessed 11/1/13.

[29] “Preserving Seed Diversity”, Food Security, http://foodsecurity.uchicago.edu/research/preserving-seed-diversity/, accessed 11/1/13.

[30] “Our Mission,” Saving Our Seeds, http://www.savingourseeds.org/, accessed 11/1/13.