Union of Concerned Scientists

FACT SHEET

Seeds of the Future

How Investment in Classical Breeding Can Support Sustainable Agriculture

HIGHLIGHTS

The sustainable agriculture system of the future starts with seeds. Classical breeding can affordably develop the seeds needed for sustainable farming systems to thrive—seeds with key traits of drought tolerance, pest resistance, productivity, efficient nutrient use, and adaptation to local conditions and sustainable production methods. But publicly funded classical breeding programs with a mission to serve public interests are now severely underfunded. This leaves seed development largely in the hands of a few commercial seed companies, which are largely focused on short-term profits rather than long-term agricultural health. Increased public investment in classical breeding programs is urgently needed to ensure a sustainable food future for all.

Classical breeding—the practice of improving crop varieties by selectively breeding the best-performing plants—can help farmers increase their yields and profits, battle pests and weeds, resist drought, adapt to changing climate conditions, and enhance sustainability and global food security. These benefits are available for a relatively modest public investment in our nation's farms, universities, and agricultural research centers.

Decades of research and experience show that the technology of classical plant breeding is effective and efficient, outpacing genetic engineering in achieving the above goals at a fraction of the cost. But the few remaining publicly funded classical breeding programs are starved for resources. As these programs decline, the development of new crop varieties (or "cultivars") is increasingly determined by corporations that are driven by achieving large market shares and profit margins, and often opt for costly, proprietary genetic engineering techniques. As a result, big commercial seed companies are not currently addressing the needs of many of today's farmers, who require the diverse and regionally adapted seed varieties that are produced most affordably by classical breeding.

This situation must change. Because classical breeding for a more productive, adaptable, and sustainable farming future is essential, new public investments are needed now.

Farmers join researchers from the University of Wisconsin–Madison, Washington State University, and Organic Seed Alliance to evaluate carrots from classical breeding trials near Royal City, WA. These trials aim to support the development of both orange and novel-colored carrots with traits such as improved disease and pest resistance, nutritional value, flavor, and adaptation to regional climates.

Classical Breeding: A Proven Technology

Classical breeding is responsible for the majority of existing cultivars around the world. Breeding material may be selected on the basis of desirable physical traits (phenotypes), often in conjunction with analysis of genetic makeup (genotypes)—as permitted, for example, by the use of molecular marking to identify the genes that control those traits. Through repeated controlled crossing and selection, supported by statistical analysis, a novel combination of optimal traits is isolated in an improved cultivar after only a few generations of breeding. These relatively low-cost methods deliver traits that meet the needs of today's farmers. Some examples are:

- **Tolerance to adverse climatic conditions.** Drought-resistant corn, sunflower, soy, and sorghum have been developed using classical breeding methods. Rice, maize, and wheat show increased potential (Gurian-Sherman 2012). Recent breeding has led to dozens of new maize varieties that have improved yield by up to 30 percent under drought conditions in several countries (Gilbert 2014).
- **Resistance to disease and pests.** Disease resistance has long been a primary goal of crop improvement, and it is one of classical breeding's major successes across all major crops (Ellis 2014). Disease- and pest-resistant crops developed through classical breeding, combined with cropping system diversity, can reduce the amounts of pesticides and other inputs required for crop protection while also increasing yields.
- **Productivity.** Classical breeding has improved crop yields in several crops, such as corn, by approximately 1 percent per year (Fehr 1984), typically enabling greater crop production with fewer overall inputs. Similarly, soybean and wheat yields increased by 16 percent and 13 percent, respectively, from the early 1990s to the mid-2000s due to classical breeding (Gurian-Sherman 2009).
- **Nutrient-use efficiency.** The production and use of nitrogen fertilizers generate global warming emissions, while runoff of excess fertilizer is a waste of capital and a major source of water pollution. Classical breeding has improved nitrogen-use efficiency in U.S. corn by up to 40 percent in a few decades. Similar improvements have occurred in rice in Japan, cereal grains in the United Kingdom, and wheat in France and Mexico (Gurian-Sherman and Gurwick 2009). New cultivars of corn, classically bred by publicly funded programs, have attained significantly greater yields in nitrogen-poor soils than commercially available varieties, while comparable biotech cultivars are taking longer to develop (Gilbert 2014).

Diversified farms, like Arctic Organics in Palmer, AK (shown here), incorporate a variety of crops on their land to manage pests, support ecological diversity, increase yields, and more. To achieve the most benefits from these systems, farmers require locally adapted, affordable seeds.

- **Local adaptation.** Selective breeding is particularly effective for development of cultivars that thrive under specific conditions. For example, from the 1930s to 1960s, breeders developed short-season corn hybrids specifically for farmers in northern Wisconsin (Crabb 1992). Recently, breeders from Cornell University have developed potato and butternut squash cultivars that are particularly suited to the northeastern United States (Griffiths 2012).
- **Profitability.** Improvement of a single trait, or of multiple traits, can result in fewer inputs, increased yield, and reduced marginal production costs, while desirable flavor, appearance, or nutrition can bring higher prices. Classical techniques are suitable for single-trait improvement—for example, classical breeders were responsible for developing supersweet varieties of corn, based on a single gene modification (Tracy 1997). But classical techniques are especially efficient for multiple-trait selection and improvement, as in the cases of nitrogen-use efficiency and drought tolerance.
- **Adaptation to organic and other regenerative systems.** Farmers need crops whose genetics are specifically adapted to their cropping systems. Research has demonstrated that seeds bred for organic systems, for example, perform better under organic conditions (Murphy et al. 2007), yet the majority of organic and other smaller producers can choose only from seeds bred for conventional chemical-intensive systems.

The Current Crisis In Plant Breeding

Despite the proven benefits of classical plant breeding (Brummer et al. 2011), publicly funded programs that could produce the seeds of the future have been in decline for decades.

A 2013 survey of horticulture departments at public universities showed that classical cultivar development programs have decreased by more than 30 percent during the past 20 years, from 210 to 141 (Carter et al. 2014). This finding is consistent with other estimates that the number of public breeders decreased 34 percent, from 217 to 144, between 1994 and 2001 (Traxler et al. 2005; Frey 1996). Even widely grown crops have few remaining public breeders. Corn is the world's leading grain crop, yet only five publicly funded corn breeders are working in the United States today (RAFI 2014), down from 25 in the 1960s (Goodman, Holland, and Sanchez-Gonzalez 2014).

Overall, public investment in our nation's land grant universities is declining relative to private investment, thereby shifting research priorities from the broad public good toward the relatively narrow interests of agribusiness. Between 1953 and 2009, public contributions to agricultural research and development dropped from 56 percent to just 43 percent of total funding (Pardey, Alston, and Chan-Kang 2013).

The decline of public breeding programs has resulted in an overreliance on a few genetic lines for some major crops, which threatens our nation's food security. Low genetic diversity in farmers' fields makes crops increasingly susceptible to disease-causing agents, which could spread more quickly and widely than among a more genetically diverse crop. This happened in 1970, when an epidemic of Southern corn leaf blight destroyed 15 percent of the Corn Belt's crop, at an estimated cost of $1 billion (Agrios 2005).

Improving Sustainability with Classical Breeding

The need for publicly funded breeding programs is particularly acute when it comes to the development of sustainable farming systems. Agroecology—the application of ecological principles to farming—is the science most relevant to some of agriculture's biggest challenges, including the need to reduce its adverse environmental impacts. However, agroecological approaches can have maximal effect only when appropriate cultivars are available.

Agroecological approaches aim to manage whole systems by simultaneously sustaining crop and livestock productivity, efficiently recycling inputs, and building natural capital—such as soil fertility—while reducing harmful impacts on soil, air, water, wildlife, and human health. Some practices that enable these outcomes are cover cropping, complex crop rotations, integration of crops and livestock, and selection of crop varieties and practices in accordance with local conditions.

Classical breeding is much better suited than genetic engineering techniques to developing the cultivars needed for agroecological systems. Classically bred cultivars generally cost less to develop (see the table), and can be tailored to the specific needs of diversified and sustainable farming systems.

Classical Breeding and Crop Diversity Is Cost-Effective

	Cost Estimate
Classical Breeding Program	$5 million per cultivar
Biotech Breeding Program	$136 million per cultivar
Damage Caused by the 1970 Southern Corn Leaf Blight	$1 billion

Classical breeding techniques can develop desirable traits at a fraction of the cost of genetic engineering. They can also help promote and preserve genetic diversity, which is critical to reducing crops' vulnerability to pests and disease that can incur costly crop losses..

SOURCES: GOODMAN 2014; BELANGER 2013; MCDOUGALL 2011; AGRIOS 2005.

Recommendations

- Public research funding for classical breeding, especially for agroecological systems, should be sustained and increased. The appropriate lead agency, with the mission and capacity to support this effort, is the National Institute for Food and Agriculture of the U.S. Department of Agriculture (USDA).
- Development of publicly available cultivars suited to agroecological systems should be a distinct and high-priority category in USDA competitive research grant programs.
- Because field breeding programs tend to run on a 15-year cycle—the typical amount of time needed to produce new cultivars, regardless of the technologies used (Goodman 2014; Goodman, Holland, and Sanchez-Gonzalez 2014)—funding needs to reflect the scale and duration of commitment required. Therefore in order to produce new crop varieties that meet the needs of our nation's farmers and the broad diversity of production systems they manage, policy makers should focus on sustained long-term investments.

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