Sustaining Plant Breeding–National Workshop

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ABSTRACT

Sustaining plant breeding was the central theme of a national workshop held in Raleigh, NC, February 8–9, 2007. The workshop was spearheaded by Ann Marie Thro, National Program Staff of USDA-CSREES, and was co-hosted by the Departments of Crop Science and Horticultural Science of North Carolina State University. The major catalyst for the meeting was the growing imbalance between the importance of plant breeding to the nation's future versus the steady decline in the national plant breeding investment over the past 20 years. This has led to a significant reduction in the number of public plant breeders in the U.S. and an associated substantial weakening of university education programs in this area (Frey, 1996; Guner and Wehner, 2003; Morris et al., 2006; Price, 1999). Several previous efforts have drawn attention to our nation's declining plant breeding capacity (National Plant Breeding Study, 1994). More recently, a plant breeding workshop held in 2005 at Michigan State University also focused on the decline in numbers of plant breeders in the public arena (Hancock, 2006). However, the message from these efforts was not nationally audible or sustained through the establishment of a dedicated group interested in maintaining plant breeding as a science and profession.

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This workshop focused on how plant breeding fits into six national goals, (i) Excellence in Science and Technology, (ii) A Globally-Competitive Agricultural System, (iii) Competitiveness, Sustainability and Quality of Life in Rural America, (iv) A Safe and Secure Food and Fiber System, (v) A Healthy, Well-nourished Population, and (vi) Harmony between Agriculture and the Environment. Enthusiasm for the workshop was generated on the first day of the workshop by six presentations, each focusing on one of the goals. Action plans developed from small group discussions following these presentations focused on these goals. These plans outlined actions needed both for the next five years as well as plans for the next two years. The purpose of this paper is to discuss and reflect on the highlights of the six presentations. The action plans are presented and discussed in Hancock and Stuber (2008).

Goal #1: Excellence in Science and Technology

In the presentation on this goal, Stephen Baenziger and Fred Bliss first stressed that plant breeding is the ultimate impact science, with impact being defined by its outcomes, namely knowledge and products (cultivars). Plant breeders need to be able to effectively transmit this impact to the general public, and this action requires a better definition. They need to emphasize the "science" rather than the "art" in the definition of plant

Published in Crop Sci. 48:25–29 (2008).
doi: 10.2135/cropsci2007.07.0406spp

breeding. Defining plant breeding as an impact science necessitates having readily understood examples.

Some examples included, (i) *Opaque-2* maize (*Zea mays* L.) with the impact being better nutrition, (ii) Low phytate crops, reducing pollution, and (iii) Green Revolution crops, feeding the starving. Common threads in these examples are plant breeding meeting a great need, having excellent science and outcomes, and pulling in and expanding related sciences as well as the science of breeding. Other examples of plant breeding impacts include plant domestication, heterosis, disease and insect resistance, wide environmental adaptability, and increased productivity. Projected impacts for the future include competitive agriculture in a global economy; competitive, sustainable, high quality rural American life; a safe and secure food system; a healthy, well-nourished populace, and harmony between agriculture and the environment.

Strategic positioning for future impact from plant breeding will require a reliable supply of well-educated and capable scientists and technologists in plant breeding and related disciplines. Excellence in science and technology demands that we have excellence in education and infrastructure. This effort will require expanded investment in facilities and resources, both for teaching, research, and outreach. Excellence in science must be highly inclusive and involve all those working in plant breeding and in related sciences that support plant breeders. Support for these outcomes needs to be shared among individuals, private business, public agencies, and institutions.

Baenziger and Bliss summarized their presentation by stating that plant breeding has, (i) vibrancy based on knowledge creation and impact, (ii) optimism based on past and future successes, (iii) openness and sharing, and (iv) strength and need to face the future.

Goal #2: Plant Breeding for a Competitive Agriculture in the Global Economy

In this discussion, Ronnie Coffman, Robert Herdt, and William Niebur illustrated the global importance of plant breeding in a manner that appeals to those outside the field. They emphasized that it is essential to ensure competitiveness of U.S. agriculture through total factor productivity (TFP). They explained that TFP reflects the *total economic* cost of production per unit of output, and that plant breeding can contribute by manipulating the elements (plants) that collect radiant energy from the sun that ultimately support human civilization. They also emphasized that increasing the capture efficiency of those elements, through plant breeding, is fundamental to the improvement of human productivity and the maintenance of global competitiveness. They stressed that food production globally must double, in a sustainable manner without any additional land, by 2050 to feed the projected population increase.

Key aspects of the dynamics of globalization include: Trade (product flows), Production (technology flows), Finance (capital flows), Web (information flows), People (labor flows), Cultural (sounds and images flow), and Health (diseases flow). Globalization of agriculture provides some major challenges to U.S. plant breeding which is influenced by the privatization of major crops, multinational seed companies, international trade, and international flow of labor. The presentation stressed the need for international partnerships because plant breeders need access to germplasm worldwide, plant disease and insect pests are not restricted by international borders, plant breeders need access to worldwide testing networks, and, ultimately, the U.S. derives long term economic benefits from such partnerships.

The bifurcation of plant genetic research into applied breeding and molecular biology was highlighted as a major challenge to the future of U.S. plant breeding. Resolution of this situation will require greater emphasis on research and funding of applied plant breeding at public universities. Additional challenges to plant breeders include better communication of the fundamental societal need for improved and adapted genotypes developed by plant breeding through the power of a genomics and a systems biology approach.

In summary, Coffman, Herdt, and Niebur reiterated, (i) public plant breeding is essential to ensure the competitiveness of U.S. agriculture through total factor productivity, (ii) improving international competitiveness through plant breeding will provide increased exports, thus improving the U.S. economy and strengthening employment opportunities, (iii) the threat to the future of U.S. plant breeding because of bifurcation of plant genetic research into applied breeding and molecular biology needs to be remedied by redirected investments at public universities, (iv) plant breeders need to do a better job of communicating the fundamental societal need for improved and adapted genotypes, (v) international partnerships are essential for long term economic benefits for U.S. agriculture, and (vi) plant breeding is fundamental to capturing and improving the elements (plants) of the solar collection arrays that support human civilization.

Goal #3: Public Plant Breeding and Quality of Life in Rural America

William Tracy, John Navazio, and Marcelo Carena focused on the opportunities for plant breeding to improve and enhance rural life in the U.S. They noted that the benefits for the non-rural population resulting from 20th century yield increases based on the technological achievements of plant breeders included: more people fed, cheap food, and cheap industrial feedstock. Rural populations, however, have been subjected to damaged environments, declining populations, and often lower incomes than non-rural populations. They stressed that there is an urgent need for a renewed mandate in the public sector to serve farmers and the public interest.

In their discussion, they posed the question, "why should the public support plant breeders?" The answer was that well-adapted crop and horticultural varieties can create the basis for value-added economies in rural areas.

Their recommendations for enhancing rural life in the U.S. included the following: (i) public plant breeders need to work with local agricultural communities to develop value-added enterprises, (ii) public plant breeders need to develop cultivars that fit the needs of value-added enterprises in rural communities, that benefit the environment, and that provide better nutrition and focus on niche markets, (iii) public plant breeders need to focus on the needs for a diverse agricultural system (both crop and livestock) that will result in sustainable agricultural systems over the long term, and (iv) public plant breeders need to communicate their contributions to community leaders and decision makers. Getting there will require dynamic partnerships between (and among) public, private, non-governmental, farmer, and consumer groups.

Goal #4: Breeding for a Safe and Secure Food and Biomaterials System

James Holland and Thomas Isleib began their presentation by citing that plant breeding has been the most important contributor to the phenomenal yield increases and the development of sustainable disease resistance and abiotic stress resistance in many crop and horticultural plants. In rice (*Oryza sativa* L.), high-yielding Green Revolution varieties are estimated to have saved millions from famine and have provided a platform for Asia's subsequent economic growth, lifting more people out of poverty than at any other time in recorded history. They cited a number of success stories in which plant breeding has resulted in improved resistance to both biotic (insect and disease pests) and abiotic (such as drought, various soil toxicities, temperature variations, etc.) stresses.

Current and future challenges for providing a safe and secure supply of food and biomaterials will require a wide diversity of plant breeding efforts. These challenges include, (i) maintaining and enhancing the genetic diversity of the plant materials available for breeders, (ii) monitoring emerging disease and insect pests with continued breeding efforts in the global war against these pests, while reducing pesticide use, (iii) reducing allergens and mycotoxin contamination, (iv) enhancing nutritive value of crop and horticultural cultivars, and (v) safeguarding energy supplies through the creation of alternative energy sources (biofuels). Other challenges include the training of the next generation of plant breeders.

Holland and Isleib concluded by stressing the need for public and private sector cooperation to ensure a safe and secure supply of food and biomaterials. For some crops [such as peanut (*Arachis hypogaea* L.), oat (*Avena sativa* L.), and other "minor" crops] there is limited private investment, so the public arena will be the major contributor. For crops such as maize, soybean [*Glycine max* (L.) Merr.], cotton (*Gossypium hirsutum* L.), and canola (*Brassica napus* L.) there is a heavy private investment, with a much smaller role for the public sector. In general, the private sector is often best for the development and distribution of cultivars. The public sector will continue to be the major contributor for breeding of "minor" crops, for education and development of breeding technology, and for long-term investments in germplasm development and maintenance of germplasm diversity. Obviously, ensuring an enduring safe and secure supply of food and biomaterials will involve substantial inputs of both monetary and human resources from private and public institutions.

Goal #5: A Healthy Well-Nourished Population

Improving the nation's nutrition and health was the focus of the presentation by Linda Pollak and Philipp Simon. They began by asking the question, "Why should plant breeders care about this strategic goal?" We already have a stable and diverse food supply in the U.S., and our primary problem is over-consumption. Although it is often stated that it is only in underdeveloped countries where people are undernourished, many American diets are deficient in essential nutrients, too much food energy is derived from fat and not enough from carbohydrates, and there is an inadequate intake of fiber. All of these problems can be corrected from appropriate plant sources in our diets. They stated that in the U.S., consumers can always take supplements. "Is it the plant breeder's job to affect how people eat?" was another question posed by the presenters.

Although, historically, the focus of agriculture has been on growers and industry, they suggested that the primary focus needs to shift to the consumer and that a team approach to plant breeding research needs to include other food and health professionals. Foods and populations should be targeted in such a way that diversity is promoted in the diet rather than just in the diversity of the crops.

Pollak and Simon suggested that analytical services should be established that can provide efficient screening methods for major dietary nutrients that breeders can then use in making selections. Nutrient baselines could be published for major cultivars. Commitments from breeders to use these services and data would need to be promoted. They pointed out that there is a wide range of variation for dietary nutrients in adapted as well as in foreign cultivars, landraces and wild relatives, and that a broad team approach is needed that includes breeders, crop germplasm curators, seed companies, and biotechnologists.

They cited a number of examples in which breeding has produced cultivars and varieties with enhanced nutrient qualities including, (i) apples (*Malus domestica* L.) with better crispness and firmness, higher Brix, and with much higher levels of vitamin C, (ii) carrots (*Daucus carota* L.) with improved flavor and with much higher levels of vitamin A, (iii) soybean cultivars with much lower linolenic acid that provide healthier oil, and (iv) specialty maize lines with qualities needed for whole-grain Hispanic foods that are nutritionally enhanced, focusing on increasing amounts of slow sugar-released starch, that may help to reduce the incidence of diseases such as diabetes.

Pollak and Simon concluded that providing for a healthy well-nourished population not only would require more resources in terms of money and time, it would also necessitate that we convince policymakers that plant breeders can help solve major health problems in partnership with other food and health professionals. It also will require that consumers are convinced that continued access to a stable supply of healthy and diverse food depends on maintaining strong public breeding programs.

Goal #6: Breeding for Harmony between Agriculture and the Environment

Charles Brummer and Stephen Jones began their presentation by stating that an idealized agricultural system, (i) produces safe and secure food, feed, fiber, and fuel, (ii) is profitable for farmers, (iii) provides ecosystem services, (iv) contributes aesthetic values, and (v) stimulates vibrant rural economies.

They focused on six types of crops that public plant breeding programs could provide to reach this ideal system: (i) crops for specific environmental issues that can clean up toxic spills and excess nutrients, and crops for bioenergy uses, (ii) crops with local adaptation that are tailored to individual landscapes and systems, and that complement broad adaptation breeding programs, (iii) crops with in-field diversity that can reduce risks from global climate change leading to more variable growing environments. This could include multilines, mixtures, and open-pollinated cultivars, (iv) crops for alternative systems that could focus on value-added markets demanding different systems, e.g. organic, sustainable, grass-fed, etc. This would lead to more complex rotations and breeding targeted for specific systems, (v) crops for new agricultural paradigms such as perennial polycultures and perennial grains, and (vi) crops providing ecosystem services that could include perennials, cover crops and row crops integrated into thoughtfully designed rotations. Such system-oriented breeding would focus on all relevant crops, not only on commodities.

Focusing public resources on these goals will complement breeding done by the private sector, which will continue to have a clear focus on major commodity crops that maximize corporate profit. Public efforts on crops and cropping systems described above should help breeders garner support from non-traditional sources, e.g. environmentalists, conservationists, and wildlife groups. For many crops, public-private partnerships will be needed for marketing seeds developed from public breeding programs and will need to be actively encouraged to ensure that publicly developed cultivars get used on-farm.

Brummer and Jones concluded by focusing on three factors that are needed: (i) public funding for alternative crops and systems and systems-oriented approaches to crop breeding, (ii) federal agricultural subsidies for conservation, rather than production, and (iii) education of the public so that it is widely known that public plant breeding can positively affect environmental concerns.

Concluding Remarks

These six presentations made at the national workshop on plant breeding emphasized the fact that plant breeders play a critical role in using science and technology to develop, test, and deliver new plant cultivars to the world's farmers and producers of all plant-based products, and ultimately to the consumers who are sustained by plant agriculture. Concomitant with the rapid advances in molecular genetics and manipulation of plants at the molecular level through genetic transformation, classical breeding programs and professional breeders are needed more than ever to ensure full integration of these emerging technologies and the translation of their science into the effective development and distribution of new products both nationally and globally. Simply stated, the commercial outcome for much of biotechnology is improved plants, and this will continue to occur only with a dedicated cadre of practicing plant breeders.

The workshop provided an excellent opportunity for invigorating the plant breeding community and also provided the stimulus for developing the mechanism to communicate its science and impact to other scientists and to the public on a continuing basis. This mechanism, and the most tangible outcome of the workshop, was the Plant Breeding Coordinating Committee that was formed and will give leadership for at least the next five years, and hopefully longer, to the plant breeding community. The Plant Breeding Coordinating Committee is approved by the state agricultural experiment station directors' Committee on Operations and Policy (ESCOP) as multi-state committee SCC-080. This administrative structure establishes credibility and visibility for the committee at the state and federal level, it allows national participation across crops and sectors, and it spreads the workload through standard governance with elected officers. The multi-state committee structure also creates a measure of planning and accountability—important factors in the success of any such effort. For more information on the long-term goals and importance of this committee to plant breeding, please see the companion article (Hancock and Stuber, 2008)

In addition, please go to the plant breeding website: http://cuke.hort.ncsu.edu/gpb/pr/pbccmain.html (verified 15 Oct. 2007).

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