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BALANCING BASIC, GENETIC ENHANCEMENT AND CULTIVAR DEVELOPMENT RESEARCH IN AN EVOLVING US PLANT GERMPLASM SYSTEM

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The structure of the United States (U.S.) public-private plant genetic research system is being transformed by the emergence of practical biotechnology protocols for creating transgenic plants; and by strengthened intellectual property protection in plants. This paper draws on some simple principles of incentives and appropriability to discuss the sharing of research responsibilities between the public and private sectors.

Key words: research policy; crop improvement

Two major forces are transforming the system for supplying improved plant varieties to U.S. farmers. The first is the emergence of practical biotechnology protocols for creating transgenic plants. The second is the strengthened and evolving environment for protecting intellectual property in plant innovations. These two forces have created a powerful incentive for private sector research investment, fundamentally altering the U.S. public/private plant genetic research system itself. Private investment tripled between 1980 and 1992 (Fuglie *et al.,* 1996) but much less is known about the effect of stronger intellectual property rights (IPRs) on the focus of planned research (Knudson & Pray, 1991). One concern is that the current balance between pre-technology and cultivar development research may be shifting in a direction that prejudices long-term productivity growth. The potential exists for public as well as private institutions to be lured away from upstream research that has public goods characteristics to focus on immediately appropriable efforts (Stallman, 1992; Duvick, 1984). In this paper, issues related to the public/private balance and sharing of research roles are discussed, with a focus on the balance among basic plant breeding science, genetic enhancement, and applied cultivar development research.

Public And Private Sector Research Roles

The U.S. crop improvement research effort is shared by three sets of institutions: the Agricultural Research Service/U.S. Department of Agriculture (ARS/USDA), state agricultural experiment stations (SAES), and private companies. No formal mechanism exists for coordinating research activities among federal, state and private institutions, but in the past the public sector has shown itself willing and able, if not always swift, to adjust its research focus to compliment the activities of the private sector. The U.S. corn seed sector provides a historical example of an evolving public

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sector research role induced by a growth in private sector capacity. When the hybrid seed industry was in its infancy, the public sector was important across the breadth of research activities, from basic genetics to germplasm collection, creation of breeding pools, pre-breeding, on through to the production of finished hybrid varieties. Over time public institutions have moved their corn research programs upstream – public varieties disappeared in the 1940s, as did public inbred lines in the 1970s. By 1994, less that 10% of U.S. corn breeders were employed in the public sector. Today, the public sector no longer provides new germplasm for commercial corn varieties, but remains a crucial part of the sector by concentrating its resources on the key functions of maintaining the national germplasm collection and by providing some basic research. The seed corn market has evolved further than other major field crops because of the IPR protection offered by hybrid seed and the large market size.

The recent biotechnology-driven explosion in private investment in U.S. plant improvement suggests that the time may be ripe to review public sector investment strategy. Through acquisitions and investment, "lifescience" firms have now come to dominate the financing and conduct of plant breeding research for most crops. Data on the types, or even the amount of research being done by these new giants are scarce, but the potential for duplication and overlap between public and private research portfolios may be increasing.

We are all familiar with a few axioms for guiding public research investments. Conventional wisdom has it that that basic research must be primarily a public sector activity due to long lead times, uncertain outcomes, and limited appropriability. Private investment in pure line crops is similarly proscribed by appropriability limitations. A recent study by Frey (1996) provides data on the number of plant breeders employed by private institutions by research focus (table 1). The data confirm that indeed most private sector scientists focus on applied cultivar development, regardless of the crop. It also confirms the far higher intensity of private investment in hybrid crops. It is possible, however, to stretch these axioms too far and conclude that the private sector is not interested in research with limited appropriability.

Table 1. Research Focus Of Private Sector Plant Breeders, 1994
(percentage of total private sector scientists)

		Cereals		
	Soybeans	**Hybrid**[a]	**Pure-line**[b]	**All Crops**
Cultivar Development	81%	82%	82%	79%
Genetic Enhancement	11%	7%	13%	11%
Basic Plant Breeding	8%	11%	5%	10%
Total Number Of Breeders	101	579	124	1,499
Breeders / Million Acres	1.4	6.4	1.4	N/A

[a] Dent corn, sweet corn, millet, sorghum. [b] Wheat, oats, barley, rice, wild rice, popcorn, triticale, rye. From "National plant breeding study - I: Human and financial resources devoted to plant breeding research and development in the United States in 1994" (Special Rep. No. 98) by K. Frey, 1996. Iowa: Iowa Agricultural and Home Economics Experiment Station.

Modern economic growth theory (Romer, 1990) posits that two fundamental attributes characterize any economic good - rivalry and excludability (or appropriability). The degree of rivalry is a purely technological attribute. A *purely rival* good has the property that its use by one firm or person precludes its use by another, while the use of a *purely nonrival* good by one firm or person in no way limits its use by another. Excludability is a function of both the technology and the legal system. A good is excludable if the owner can prevent others from sharing in the benefits from its use. Within this framework, genetic improvement research is a nonrival good whose excludability varies according to the type of innovation being considered (e.g., basic science versus a new variety), the crop (whether it is a pure-line or hybrid) and institutional conditions. In Romer's framework, one of the key engines of productivity growth in an economy is knowledge spillovers from incomplete excludability. That is, firms will invest in research and development to produce innovations even though they are providing benefits for other members of society, as long as they enjoy sufficient excludability to earn normal profits. In other words, industry has an incentive to invest in research even if it is not perfectly excludable.

At the time of Frey's (1996) survey the private sector employed more than two-thirds of all plant breeders, with the USDA and SAES combined employing one-third. Although industry emphasis is on cultivar development research, where it employs 83% of all plant breeders, industry had large numbers of breeders in all three research areas. Overall, approximately 40% of genetic enhancement and basic researchers are employed in the private sector, with much higher shares for hybrid crops (table 2). Nearly half of all pureline cereal breeders are in the private sector as well. The data may seriously underestimate industry basic research activity because only traditional seed companies were surveyed, so activity by Monsanto, DuPont and other biotechnology/lifescience firms was not captured in the data. The lifescience firms are relatively new players in the seed industry but possess the scientific and financial resources to fundamentally alter crop improvement research.

Table 2. Private Sector Breeders As A Percentage Of Total Plant Breeders By Research Area, 1994.

		Cereals		
	Soybeans	**Hybrid**[a]	**Pure-line**[b]	**All Crops**
Cultivar Development	79%	98%	67%	83%
Genetic Enhancement	41%	62%	31%	41%
Basic Plant Breeding	34%	74%	11%	38%
All Research Areas	65%	91%	48%	68%

[a] Dent corn, sweet corn, millet, sorghum. [b] Wheat, oats, barley, rice, wild rice, popcorn, triticale, rye. From "National plant breeding study - I: Human and financial resources devoted to plant breeding research and development in the United States in 1994" (Special Rep. No. 98) by K. Frey, 1996. Iowa: Iowa Agricultural and Home Economics Experiment Station.

It seems clear that there is more plant research going on today than at any time in history. United States farmers have an amazing diversity of quality germplasm to select from. It also seems fairly certain, despite financial problems in the public sector, that there is more "basic" research (if defined as upstream research using basic scientific principles) being conducted today than ever before; and that the bulk of that research is now in the private sector. Companies may only be interested in appropriable research, but one of the more interesting aspects of the evolution of the biotechnology industry is the amount of upstream research that is now being done in the private sector, apparently for strategic reasons. The lifescience giants are investing huge sums in biotechnology research that we would have considered exotic basic science in 1990. They apparently now view biotechnology activities, such as genomic mapping, to be applied strategic research that they can protect long enough to gain strategic advantage over their competitors. Mansfield, Schwartz and Wagner (1981) determined that a patent might provide a headstart of as little as 2 to 3 years before competitors invented around the patent. Could this explain private investment in basic biotechnology research? A two-year jump in developing biotechnology applications could be worth a lot in today's seed industry climate. Furthermore, the equity markets do not seem to be penalizing companies with large investments in sophisticated research.

How should the public sector react to the new research climate? It is difficult to say without more data on the "who", "what", and "how much" of private sector investment. But it seems that ideas about where the public goods research lies, and which public programs have the potential to achieve the necessary minimum size to be effective, need to be re-examined. In the future, the ARS and SAES may be important role players, but will no longer be the driving force behind technological change in crop improvement. The public sector should look to play a vital role in a few key areas, but must be cautious about attempting to cover too many bases with limited financial resources. The National Plant Germplasm System (NPGS) is one crucial area that appears to be dangerously underfunded (GAO, 1997). The NPGS maintains 440,000 germplasm samples for 85 crops in 22 U.S. sites on a budget of just $23.3 million. The ARS is already the key guardian of this vital genetic resource. With just 177 total plant breeding scientists, ARS might consider reassigning personnel from basic research to the effort of assuring that collections are adequately attended. It will be more difficult for SAES to elaborate a clear strategy. Political as well as agroclimatic factors are diverse and powerful determinants of state research agendas. Institutional mechanisms to coordinate regional research across states, and with private sector participation, need to be established to enable comprehensive crop improvement programs to function.

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