
The Impact of Patents on Plant Breeding Using Biotechnology

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My first job after graduation was breeding tomato plants for resistance to a fungus disease. It was a simple program that involved the introduction of dominant genes for resistance, from other cultivars and from wild relatives, in a backcrossing program that employed several widely grown cultivars as recurrent parents. The first lines from this program appeared to be so promising that I sent them to some greenhouse tomato growers for small trials. The growers agreed that they were resistant to disease but said they were also resistant to yield. This taught me the important lesson — that no matter what new gene a crop cultivar may contain, unless its genetic background supports good agronomic performance it will be of no practical interest to growers and farmers. For this reason, a major part of the application of biotechnology to plant breeding has been the field trials to prove the agronomic qualities of newly engineered forms.

Field Trial — A Guide to What is Happening

Goy and Duesing (1995) reported a survey of field trials over the period 1986-1993. During this time, they examined records of some 1,025 field trials in 32 countries. Table 1 (on page 80), adapted from their paper, shows the range of characters introduced into the five most widely tested crops. The tobacco field trials for the most part reflect its use as an easily transformed crop plant model. Although the first field trials were carried out largely by the private sector, the first in the UK was a trial of a potato transformant carrying the gus marker gene. That trial was carried out in 1986 at the Plant Breeding Institute (PBI) in Cambridge. By 1993, the private sector was responsible for 71 percent of all trials, although by then a total of 61 public institutions and 88 companies had submitted applications or notifications to the various regulatory organizations controlling field tests of genetically manipulated plants (Goy and Duesing 1995).

Table 1. Number of Field Trials and Traits Tested

TRAIT	<i>Potato</i>	<i>Canola</i>	<i>Tobacco</i>	<i>Corn</i>	<i>Tomato</i>
Herbicide resistance	16 (5)	94 (7)	29 (6)	54 (3)	21 (5)
Quality	31 (9)	57 (5)	13 (4)	15 (2)	39 (3)
Virus resistance	60 (12)	2 (2)	24 (7)	10 (4)	20 (9)
Insect resistance	34 (4)	3 (3)	19 (3)	24 (2)	16 (1)
Marker gene	23 (7)	17 (5)	28 (9)	8 (4)	4 (3)
Fungal resistance	9 (7)	5 (4)	9 (4)	2 (1)	
Multiple traits	8 (7)	2 (1)	4 (3)	0	
Bacterial resistance	9 (3)	1 (1)	0	0	
Not specified	3	1	5	5	3
Total	193	181	128	120	105

Data are from 1986 to 1993

Adapted from Goy & Duesing 1995

71 percent of trials are by the private sector

Private and Public Plant Breeding

Throughout the last 50 years some major changes have affected the way varieties are released and how breeders are compensated for their work. Plant variety rights legislation is now common in many countries and protects the originators of new cultivars against theft and illegal sales of seeds and planting stocks by unauthorized propagators. In Europe, the introduction of these schemes spawned the development of the plant breeding industry by making investment in the technology profitable through the return of royalties on seed sales. As the private sector grew in strength and capability, there was a steady trend away from reliance on public sector plant breeders to produce new cultivars of the major agronomic crops. In the UK this culminated in the privatization of the Plant Breeding Institute in 1987, leaving only remnants of the public sector breeding that had largely supported British agriculture over the period from 1910 to the seventies. Although traumatic for those who lived through the transition, it re-emphasized the important role of the public sector in basic research. However, the demise of the PBI did destroy a unique and very successful organization that directly coupled basic and applied science for crop plant improvement.

In the U.S. there was a similar, if less dramatic, trend towards a reduced reliance on land-grant university and federal breeding programs. Some exceptions include crops, such as oats and alfalfa, which the private sector regarded as too small, in terms of seed sales, to be profitable. For corn, exclusive ownership of the inbred lines needed to make up F₁ hybrids provided an alternative to plant variety rights.

Patents

Although plant variety rights provided reasonable protection for conventionally bred varieties, the scheme could not protect the hard won fruits of biotechnology. The capital and personnel investments in molecular biology were considerable. These costs, and the precedents from earlier decisions for patenting living organisms, made it clear that utility patents were the answer. As a result, there has been a tremendous increase in the filing of patents to protect discoveries such as cloned genes, methods of effecting transformation, and the development of systems for using molecular mapping as an aid to selection. At Rutgers, this is reflected in the appointment of additional staff to the University Office of Corporate Liaison and Technology Transfer, which has six people who assist faculty and graduate students in patent filing. The total number of faculty at Rutgers is about 1,100. However, in one U.S. private university that evidently has great expectations of continuing to benefit from licensing fees and royalty income, the number of staff with this function is now approximately one per ten faculty members.

To illustrate my concerns and the practical problems caused by patents, let me review a situation that we now face at Rutgers and which I am sure is paralleled elsewhere. A most successful plant breeding program at Cook College is a turfgrass-breeding program led by Reed Funk. This program has been responsible for a number of leading varieties that are widely grown in North America. In the course of developing a transformation method for one of the turf grass species — *Agrostis palustris* or creeping bentgrass — we made use of the *bar* gene for resistance to the herbicide bialaphos (Hartman et al. 1994). The *bar* gene is widely available for research use but two patents cover commercial use, as a selective marker in the laboratory, for recovering products of transformation, or for field use to confer herbicide resistance. We have also worked with several other herbicide resistance genes that have been introduced into the same grass species. Following greenhouse and field trials, we had expected to begin discussions with the owners or licensees of these patented genes to explore how the most promising lines we had selected might find their way into the hands of commercial grass breeders. During the course of several years of meetings, correspondence and telephone calls, we have encountered a number of problems that have made this a far from easy task. Among the problems were the following. The patent owners:

1. Have other plans for the use of the gene in more important crops.
2. Fear that herbicide-resistant creeping bentgrass, a species commonly used on golf course greens, might escape as a weed and invalidate the use of these herbicides on other more important crops.
3. Are concerned that horizontal spread of the genes, by cross-hybridization with other native *Agrostis spp.* that are weeds, could more seriously compromise the use of these genes and their relevant herbicides in combination.

4. Some of the owners are concerned about development, and other costs, to obtain a registration label authorizing the use of their herbicide on a new crop species.
5. In other cases, research agreements prevent us from publicly acknowledging that we have certain genes and are working with them and may even prevent publication of our findings.

The first is clearly beyond our control. The second we naively thought would be resolved by the lack of any record in the literature that *A. palustris* is a weed species. It has been recorded as a weed in Kentucky bluegrass lawns but the absence of any reports that it is not a weed of field crops seems to be of little comfort. The third has been in part addressed by hybridization studies carried out by breeders to introduce new genetic variation into creeping bentgrass. The fourth question is a legitimate concern. Although bentgrass is not part of the human food chain, the environmental impact of increased herbicide use on golf course greens and eventually on lawns must be considered even though the newer herbicides we work with are environmentally benign. They are used at low doses, are rapidly biodegraded in the soil, and have very low mammalian toxicities.

Even when a public sector unit isolates and clones its own genes, which it may well decide to patent, there are still other problems. I am grateful to Ken Barton of Agracetus, Inc., for the following example. A new genetically engineered cultivar arising from work of this kind has to take account of additional patents and protection as follows:

1. The Cohen-Boyer patent for cloning DNA in a plasmid in *E. coli*, even though it only has several years left to run, underpins the technology of recombinant DNA.
2. The method of transformation is also subject to patent protection: For example, the gene gun is covered by the Sanford & Wolf patent (for grasses and ornamentals) whereas the DuPont Co. has patent rights for other plant species.
3. The plant material to be transformed may be covered by patents. For example an Agracetus patent, that is presently being disputed, gives the company rights to all transformed cotton cultivars no matter how they are produced. If a named crop cultivar is used, and the new cultivar is essentially similar except for the new gene, the owner of the original cultivar has rights that must be respected.
4. I have already discussed the question of ownership of the gene, or genes, that give a genetically engineered cultivar its new features. Nearly all single gene traits that have been cloned are protected. However, other genes may be required that are owned by other parties. For example, markers such as kanamycin resistance, the glucuronidase gene (*gus*)

and herbicide resistance may be needed. In order to ensure maximal expression at the appropriate stage of plant development, the introduced genes must be controlled by elements such as the CaMV 35s promoter, an organ or tissue specific promoter, or be used with an expression enhancer such as the omega sequence from tobacco mosaic virus (TMV).

Each interested party, or patentee, has to agree to the proposed use of their materials under license. Each will expect either an up-front fee, or a share of royalty income, which have to be negotiated individually. Small wonder that public sector programs with limited resources and experience in negotiating licensing fees are finding it increasingly difficult to compete with large companies who are patent holders, and thus have bargaining chips to use in negotiating deals with each other. In theory, the patent system is supposed to make material available for further research by protecting the interests of the patent holder. In practice, the patent holder can find many ways to block distribution of the patented materials and to limit the uses made of it.

Are patents as useful as publications for evaluating faculty for tenure and promotion? Probably not, but they are unlikely to hurt an academic candidate and could be regarded as an indicator of his or her awareness of the relevance of their work. Patents are, of course, much more important in industry. Judging the quality of awarded patents is much more difficult. Patents are examined by patent office specialists. They are not peer reviewed, and their treatment is entirely different to that given journal articles or grant proposals.

Are Present Intellectual Property Laws a Barrier to Exchange and Access ?

In my view, these laws restrict meaningful access to genetic information. Before patent protection is filed for, the investigators are unable to describe their work to others for fear of invalidating their patent claims. Even after the patent is filed and granted, access to the material can be denied by failure to answer requests. Such access as may be granted may not be meaningful since profitable use of the materials may be prohibited and, even if allowed, is subject to restrictions. The result is that the laws sometimes limit, or even prevent, beneficial applications. This is the cost of protecting private sector investment in plant improvement. Without it, private plant breeding would not have flourished.

What of the trend among universities to patent and protect information gained with taxpayer support? Although some have been critical, many believe that universities should benefit from the income accruing to such protection. They believe that it will reduce the tax burden, enhance facilities for teaching and research, reward and encourage faculty inventors, and create wealth and jobs for the community. However, these incentives can distract university faculty from teaching, research and more traditional forms of service to the

community. There is the danger that they may become more concerned with raising capital, establishing and managing external development or manufacturing facilities, and lining their own pockets. Negotiating contracts, licenses and royalties has now become so complex that research universities must employ specialists in these areas to protect their interests and maximize returns. A senior faculty committee at Rutgers recently spent much time in revising its scheme for dividing the spoils from royalty income between the university central administration and the deans, department chairs and researchers themselves.

Present 'Day' Role of 'Public Sector' Breeding Programs

Some years ago the late William Brown of Pioneer Hi-Bred International, Inc., was concerned about the reduction in plant breeding in U.S. land-grant colleges. He was worried by the prospect that the private sector would be unable to recruit young men and women trained in the technology. During several annual seminars organized by Pioneer Hi-Bred in the 1970s that brought together public and private scientists, it became clear that training in plant breeding would increasingly become the province of private sector breeding companies. Their new recruits would have had training over a broader range of subjects than before. This would include not only the traditional subjects such as genetics, plant physiology, agronomy and statistics, but also molecular biology, biotechnology, biochemistry and cell biology. Much like engineering trainees, they would learn the idiosyncrasies of individual crops, the practice of selection and the management of trials in company plots and fields. I believe that this is working well. I am less optimistic about the technology transfer of the products of long term basic research in plant molecular biology carried on in our universities. The separation between basic research and the technologies that need it and can make best use of it means that they are uncoupled in our universities. The problems and pitfalls involved in patenting exacerbate this situation. Even producing new breeding lines for release to commercial breeders is no longer simple.

I will finish by reviewing my own experience in the UK. In a sense it represented for me the culmination of the introduction of Plant Variety Rights. I joined the Plant Breeding Institute in Cambridge in 1979. At the time its varieties dominated or were prominent on the UK national recommended lists for winter wheat, spring barley, potatoes, marrowstem kale, and oilseed rape (canola). The National Seed Development Organization (a state organization) distributed these, and other products of public plant breeding, collected the royalties and passed them on to the Treasury. By the early 1980s the PBI's share of these royalties exceeded its annual

grant-in-aid from the state. Some of the UK private sector breeders resented the success of "Her Majesty's Plant Breeders" who were supported in part by the taxes they paid on their profits. Unlike the system in The Netherlands, where state breeders offered the private sector advanced breeding materials and were prevented by law from releasing finished varieties, the PBI breeders' best materials went right through to the ultimate test — the farm and the marketplace. The competition between state and private breeders, although not on an equal footing, was good for the British farmer. For example, there had been a steady increase in the proportion of homegrown wheat in bread-making grists brought about by systematic breeding for breadmaking quality coupled with high yield. The end came when the government realized that the generation of royalty income was a salable asset and the PBI was privatized in 1987. In my view, the most damaging result was the uncoupling of theory (genetics, plant molecular biology and plant pathology) and practice that resulted. The dialogue between breeders and others at PBI was at times difficult and unrewarding, but in the long run was responsible for the achievements made over 75 years.

If we are to benefit from current technologies, that were pipe dreams 15 years ago, we must facilitate and enhance the coupling between discovery and its broad use. Where intellectual property rights and agreements hinder this we must strive to find ways to make things work fairly and efficiently.

References

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