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INNOVATIVE WORK IN AGRICULTURAL BIOTECHNOLOGY: A PRELIMINARY INQUIRY

by

Malgorzata Korzycka

Introduction

> And, he gave It for his opinion; that whoever could make two ears of corn, or two blades of grass to grow upon a spot of ground where only one grew before; would deserve better of mankind, and do more essential service to his country, than the whole race of politicians put together.
>
> - Jonathan Swift, A Voyage to Brobdingnag, Gulliver's Travels

> The time is a quarter to midnight . . . . Produce more food, yes —- by all means. But let us never kid ourselves that this is the whole answer
>
> - Dr. Norman Borlaug, winner of the 1970 Nobel Peace Prize

Dr. Norman Borlaug, plant breeder and geneticist, was awarded the Nobel Peace Prize in 1970 for his achievements in fighting world hunger by breeding new varieties of plants. He is often called the father of the Green Revolution. He expressed these words of caution: "The green revolution can't solve all the social problems which already existed before" (Johnson, 1972).

Any type of work that invokes a new idea requires, despite knowledge, a belief in its enduring merit. To clarify this thought, let me refer to Tielhard de Chardin who discusses in The Phenomenon of Man an approach to human discovery and research work in the following words:

> Scientifically we can envisage an almost indefinite improvement in the human organism and human society. But as soon as we try to put our dreams into practice, we realise that the problem remains indeterminate or even insoluble unless, with some partially super-rational intuition, we admit the convergent properties of the world we belong to. Hence belief in unity (Tielhard de Chardin, 1975: 284).

Coming back to Boriaug's work, the idea of moving breeding material through different ecological environments was contrary to conventional ideas about plant breeding.[1] Borlaug recalls one incident when his unorthodox methods came under fire:

> I was sowing the nursery when I was visited by a very eminent and dear professor of genetics and plant breeding. I described how we were moving plants back and forth in alternative generations. He said, "Young man — you didn't absorb the first principles of plant breeding. You are alternately taking one step forward and one backward." Well, not knowing better and believing in the approach, we continued and I believe the results justified our beliefs (Borlaug, 1973: 93).

The power of the emerging genetic technologies, however, depends upon their proper use within the context of sound plant breeding strategies and emphasizes the central strategic role of the modern plant breeder.

Modern biological science seems to permit us to look at plants in a new way, so that we can ask: "How do plants grow?" instead of "How to grow plants." Within the last generation we began to focus on various plant organs and tissues and, more recently, on cellular and molecular approaches.

In reference to agricultural productivity, the physical biomass produced by hectare is not a key goal. A definition of productivity should relate to the net income of farmers and the use of modern science to reduce the cost of producing food, most notably by genetically different capital intensive inputs, such as chemicals (Padwa, 1983).

Three basic directions in agricultural biotechnology can be distinguished as follows:

1. To change (increase) the yield of crops. This was, for example, Borlaug's approach in breeding new varieties of agricultural plants for higher yields. This usually requires high production costs because of higher usage of fertilizers, water, etc. Recalling some failures of the green revolution, we have to remember that a successful usage of some new varieties of plants depends critically on a sufficient supply In production factors and these factors may not be available to many Third World farmers. The real possibility of using new varieties of plants is also closely linked with the socioeconomic structure and infrastructure of agriculture in these countries.

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1 **Borlaug's struggle to implement his unorthodox approach is told in Lennard Bickel's biography, _Facing Starvation: Norman Borlaug and the Fight Against Hunger_ (New York: Readers Digest Press, 1974).**

2. To lower production costs, for example, by lowering the usage of nitrogen fertilizers by obtaining new varieties of plants that can absorb nitrogen from the air. This direction can be much more beneficial for Third World countries where production costs are one of the barriers in development.

3. To change the composition of the agricultural plant is to change the proportion of its chemical composition in relation to the purposes a certain plant serves, for example, corn for fodder versus human consumption. This type of an approach will mostly depend on programs and needs of particular national economies.

All three directions need special institutional arrangements. To enforce these directions, special institutional arrangements are needed which reflect the socioeconomic demands and capabilities of each country.

Gene Banks

Until the mid-nineteenth century, when it was realized that important progress could be made through selection, our ancestors had developed over many thousands of years primitive cultivators of crops. These primitive cultivators were adapted to their environments and to the cultural and economic conditions. When crossbreeding started earlier in this century, this led to a vast increase in the genetic diversity available for use by breeders. A Russian scientists Nicolai Vavilov, made breeders begin to realize the value of diverse material and to use material from these vast reservoirs, or gene pools, which were available in the so-called centers of diversity.

The problem facing us today is that ever since Vavilov's warnings about the value of these reservoirs, or gene pools, they are being depleted as developing countries selectively breed for some characteristics which facilitate economic development but eliminate other characteristics which may give rise to still other potentials. The vast majority of these centers of diversity are in the less-developed countries. It is only reasonable that these countries should begin agricultural development and, therefore, use the new cultivars produced by the breeders. These cultivars have higher and more uniform yields — often with better quality including certain nutritional attributes. Nonetheless, the introduction of highly selected cultivars into these areas runs the risk of phasing out many diverse genetic strains.

On the other hand, modern techniques in genetic engineering also enrich genetic resources. This means that the genetic reservoirs can be enlarged, but it does not mean that they will necessarily be available to the farmers. Whether farmers can obtain new or old cultivars depends on institutional organization in the agricultural economy and breeding research organizations, as well as the very complex market in the seed industry.

Today, many gene collections are held by large research centers, such as the very large collection of rice breeding stocks held by the International Rice Research Institute. Nevertheless, there is a danger that the genetic stock Is being eroded at a rapid rate. Much of the genetic material is, in fact, available only In the more remote areas of the less-developed countries.

J. T. Williams (1981) has observed that in the early 1970s, in one country in Africa, a particular scientist was able to collect samples of African rice strains for approximately one U.S. dollar per sample. In countries where communication is difficult, where energy costs are high, etc., some of the samples, that have been collected In the 1980s, cost on the order of four hundred dollars each; and these costs are escalating at an Increasing rate. Hence, people are beginning to realize that germ plasm is valuable, probably for the wrong reason; by recognizing their monetary value rather than their value in plant breeding.

There are two major principles concerning the collection of genetic material defined by the Food and Agricultural Organization (FAO). One is that when material Is collected In a country, a subsample is left in that country for national use. Secondly, there is the principle that the availability of the genetic materials shall be guaranteed to all bona fide workers.

We have recognized that genetic material Is obviously a common pool resource, where exclusion is infeaslble and jointness of use is highly subtractible (V. Ostrom and *E.* Ostrom, 1978). However, in some cases where aspects of national economies are Involved, some restrictions occur with the use of wild and primitive material. For Instance, the government of Ethiopia has banned the export of coffee germ plasm so coffee beans can be considered as a regulated common pool resource there.

Some extreme opinions on genetic maintenance and uniformity have to be noted. These are expressed by Bennett (1979) and Mooney (1979). Both of them have argued that rights to plant variety lead to a destruction of the Vavilov centers and an erosion of genetic material throughout the world through increased genetic uniformity. They argue that the consequence of this will be control over germ plasm by multinational companies and the dependence by Third World countries on such firms for the provision of complementary variety and input endowments. Mooney has suggested that rights to plant variety encourage genetic uniformity, with the long-term possibility of total crop failures.

Some Remarks on Hew Technologies in Genetic Engineering

The notion of Improving quantity and quality as well as promoting stability and resistance against the elements and disease In plants — agricultural and ornamental — through the utilisation of breeding techniques has long been known to man. Formerly, man selected from among the different species over a long period of time (breeding via selection). Since the eighteenth century, systematic breeding has been developed on an ever increasing scale. Present day technology consists primarily of four methods of breedings (1) selection, (2) combination, (3) hybridization, and (4) mutation.

The science that forms the framework upon which genetic engineering technologies are built is mainly based in cellular and molecular biology. It is not limited to molecular biology. Advances in both areas are now proceeding at a very rapid pace, and, in combination, are achieving a more fundamental understanding of plant genetics, biochemistry, and physiology.

In the field of plant cellular biology, perhaps no other single development generated more research activity than the ability to culture plant cells and tissues in vitro. Since the early experiments with carrots and tobacco, a large body of knowledge has been compiled that demonstrates the use and value of cell and tissue culture technology for: (1) in vitro cloning of plant genotypes; (2) mutation and selection for the generation of new genotypes; (3) protoplast isolation, fusion, and culture to achieve asexual hybridization between sexually incompatible genotypes; (4) generation of new genetic variability via spontaneous somatic cell variation; (5) establishment of host cells for genetic transformation by exogenous DNA; (6) generation of haploids and dihaploids via one another or pollen culture; (7) production of secondary metabolites in vitro; and (8) many basic studies in plant biochemistry and physiology.[2] These are the methods of genetic modification that have obvious near-term applications in plant breeding. The techniques in molecular biology are more precise. They are based in large part on recent developments in recombinant DNA technology, comprise molecular techniques to identify and purify genes from one organism, and thus are prepared for transfer to another organism which is then transformed with isolated genes. This ability to manipulate DNA was made possible by the discovery of several classes of enzymes, perhaps the most useful being the restriction endonucleases, which have the ability to cut double-stranded DNA at particular nucleotide sequences, resulting in a series of well-defined pieces which have sticky ends. These pieces of DNA, perhaps containing a gene of interest, can be covalently linked in the presence of the enzyme DNA ligase with other DNA molecules containing similar sticky ends. Using these or other enzymological tools, such as DNA polymerase and reverse transcriptase, it is possible to construct, or engineer if you wish, vectors in the form of plasmids containing specific genes. These vectors are used to transfer the genes to a host cell which, for this presentation, would be a plant cell in culture or perhaps a protoplast.

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2 For a detailed discussion on this issue see Robert H. Lawrence, Jr. (1983).

On a practical level, however, molecular techniques have led to the ability to transfer specific genes from one organism to another. Transformation of plant cells by insertion of foreign genes is still in the "model system" stage. For broad application to crop plants, several important areas of research must be developed (Lawrence, 1983).

Impact of the Reward System on Agricultural Research

Among many problems in modern plant breeding, one of the key questions is the reward system in agricultural research. It can be a barrier to or a stimulator of innovation. Let me exemplify that problem by showing some of the aspects of the research work in agriculture in the Third World, especially because of the many weaknesses that occur there.

One explanation as to why research institutions in the Third World have been ineffective in producing improved agricultural technology is that research workers have tended to concentrate on the more theoretical research problems rather than working to solve production problems confronting farmers. Most research workers in the Third World with advanced degrees received their academic training at foreign universities, primarily in the United States and Europe. Many of these research workers may have been influenced (socialized) by the "publish or perish" reward system that is common to large, research-oriented colleges of agriculture in the United States (Swansea, 1975).

In the United States, research concerned with generating knowledge (science) is primarily carried on within the public sector (universities), whereas much of the applied research with technological applications is carried out in the private sector (industry), as well as in agricultural experiment stations affiliated with state universities. While research workers who conduct technological applications have much less opportunity to publish in scientific journals and to gain professional recognition from their colleagues, salary schedules in the private industry have traditionally been higher than in public research institutions. Thus, in the overall agricultural research system of the United States, there is, to some extent, a trade-off between scientific and economic rewards.

In the Third World, most of the national agricultural research capability is located within the public sector, generally within a ministry of agriculture,, university, or a research institute operated as a parastatal organization. Agricultural research workers receive salaries according to the bureaucratic procedures and criteria followed by parastate research institutions, not according to economic returns derived from research productivity. Therefore, there is little potential within the research institution itself for inducing research workers (through economic rewards) to pursue career patterns oriented toward more applied, technological research objectives.

The spirit of cooperation is frequently missing from national research institutions. Scientists may tend to think in terms of achieving personal rather than institutional credit. To develop improved agricultural technologies requires considerable interdisciplinary cooperation; but in this case, the credit accrues to the research team, not to the individual. If this credit for the achievement of research teams is usurped by the research director, or the team leader rather, than being shared by the team members, individual research workers will not be encouraged to work together on future endeavors (Swanson, 1975: 37-38). The problem then arises as how to strengthen the research centers in the Third World. Real capacities for research using new technologies exist only in a few Third World countries, like Egypt, India, Philippines, and Thailand. A state monopoly in the breeding research area leads to governmental control over seed prices.

The latter is one of the important problems in Poland, where most of the research work in agriculture is going on within teams working, and at the same time, in large organisational structures. Only so-called socialized units organized as collective instrumentalities have enough financial resources to undertake a breeding research on a large scale. Private producers would rather deal with less money, organization, and efforts consumed in breeding work, e.g., fruits, flowers, and vegetables. The main new grain crop varieties are bred by the state employees at universities and in state enterprises. A system of financial rewards for researchers, a so-called premium system, is not satisfactory as an incentive system to reward individual needs and aspirations. Sometimes it can even be problematical as to who is really the developer of a new variety because so many individuals are involved in the whole breeding process.

Patent Protection

A new variety of plant can be protected by patent or a special property right, which is similar to patent in legal construction. Provisions for the granting of property rights for developing new plant varieties have been established in the following countries: Argentina, Austria, Belgium, Chile, the Democratic Republic of Germany, Denmark, Ireland, Finland, France, Hungary, the Federal Republic of Germany, Israel, Italy, Japan, the Netherlands, New Zealand, Poland, Romania, South Africa, Spain, Sweden, Switzerland, the UK, the USA, and the USSR.

A legal definition of patent, which we can find in a law dictionary, is the granting of a right to one who makes an invention to exclude others from the making, using, or selling of an invention during a specified time; it constitutes a legitimate monopoly.

The first patent rights were granted in Venice in 1474 to establish an reward for innovation. Providing an inventor with exclusive ownership and control over the invention created opportunities to recover the costs invested in innovative efforts and to profit from the innovation.

Patent rights are obviously an artifactual human institution to reward a particular social and economical role. The reason we do recognize special property rights to innovative types of work are the following:

- Individuals are assumed to be the primary source of innovations;
- An individual is rewarded for invention;
- A reward via the patenting process encourages further innovativeness; and
- An individual should be compensated for publicly recognizing their innovative work by extending exclusive rights to benefit from an innovation for a limited period of time.

Often it seems that patent protection is in conflict with the conditions necessary for the efficient functioning of a competitive market. Patents may be barriers to market entry, or they may impede the flow of information and the mobility of factors of production. Evaluation of the patenting system is essentially a benefit-cost analysis. The benefits that flow to society must be weighed against the costs of creating statutory monopolies. Costs include monopoly rents and market inefficiencies which accompany them, the possibility that resources may be misallocated to activities which are unnecessary or duplicative, and externality or third-person effects which may be overlooked.

It also has to be said that a patent system is likely to be most useful in inducing innovation in those situations where imitation lags are short, innovative rivalry is not presents or where potential profits from innovations are small relative to the costs of innovation. Turning to the cost side of the patent process, one of the major costs to society is the ability of patent owners to extract monopoly rents. This is particularly true when the invention or innovation is conceptually new and there are no substitutes. In a perfectly competitive industry, there are few incentives to invest in research and development without a patent system.

But we also have to remember that innovations do not always achieve easy recognition A good example of this is C. F. Carlson, the innovator of xerography, who offered his innovation to more than 20 firms between 1939 and 1944. He met "an enthusiastic lack of interest" everywhere.

A specific situation in innovative type of work exists in the socialist countries. Because of nationalisation of the basic means of production,, the majority of innovators are employed in the state-owned entities (enterprises, universities, research institutes, etc.).

There, patent rights usually accrue to the employer (state-owned entity), and the innovator gets only a special certificate and monetary reward.

General Information on Protection of New Varieties of Plants in the United States

I would like to show some of the complex problems of innovative work and its legal regulation as well as its institutional structure, taking as an example the protection of new varieties of plants.

This is the basic information about the protection of new varieties of plants in the United States: Registration of varieties under the Plant Variety Protection Act (PVPA), 1970, which provides patent-like protection to plant breeders who developed or discovered distinctly new plant varieties which are reproduced by seed, is based on the international criteria set forth by the Union for the Protection of New Plant Varieties (UPOV)3 of:

- novelty (distinctivness) — able to be distinguished from all the species;
- uniformity — does not exhibit significant variation between individuals of the variety; and
- stability — reproduces reliably across generations.

The certificate of protections issued by the Plant Varieties Protection Office of USDA, gives plant breeders: (1) the exclusive right to sell or advertise and to license other persons to sell plants of the registered new variety and/or the reproductive material of those plants and (2) the right to levy and collect royalties from persons selling or using new varieties registered under the Act. In other words, this protection grants the breeder or his successors the right to exclude from sellings offering for sale, reproducing, importing/exporting, or using the variety in the production of a hybrid or different variety (U.S. Congress, 1970).

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3 The International Union for the Protection of New Varieties of Plants (UPOV) is a little known intergovernmmental organization from European initiatives. Its basic document is the International Convention for the Protection of New Varieties of Plants, signed in Paris on December 2, 1961. The purpose of UPOV is to protect the breeders of new plant varieties, giving them patent-like protection by establishing an international legal regime. The main obligations for member states under the UPOV convention are to maintain or introduce a plant breeders' rights system and to grant plant breeders' rights in the form of patents, or of special certificates which are equally valid in each member state.

The nature of the above-mentioned exclusive right can be better expressed by pointing out what will be an infringement of plant variety protection, as follows:

1. Sell the novel variety, offer it, or expose it for sale, deliver it, ship it, consign it, exchange it, or solicit an offer to buy it, or any other transfer of title or possession of it;

2. Import the novel variety into, or export it from, the United States;
3. Sexually multiply the novel variety as a step in marketing (for growing purposes) the variety;

4. Use the novel variety in producing (as distinguished from developing) a hybrid or different variety therefrom;

5. Use seed which has been marked "propagation prohibited" or "progeny thereof" to propagate the novel variety;

6. Dispense the novel variety to another in a form which can be propagated, without notice as to being a protected variety under which it was received;

7. Perform any of the foregoing acts even in instances in which the novel variety is multiplied other than sexually, except in pursuance of a valid United States plant patent; or

8. Instigate or actively induce performance of any of the foregoing acts (U.S. Congress, 1970).

The following acts are specifically deemed not to be infringements:

1. The use and reproduction of a protected variety for plant breeding or other bona fide research (U.S. Congress, 1970);

2. The saving of seed produced from seed obtained, or descended from seed obtained, by authority of the owner of the variety for seeding purposes and the use on the individual's farm, or for sale (U.S. Congress, 1970);

3. A bona fide sale for seed used for other than reproductive purposes, made in channels usually used for such other purposes, produced on a farm either from seed obtained by authority of the owner for seeding purposes or from seed produced by the assent of such farm from seed obtained by authority of the owner for seeding purposes (U.S. Congress, 1970). In the event that there is an infringement of plant variety protection, the owner of the plant variety may seek damages by way of a civil action infringement.

Enforcement of PVPA is the sole responsibility of the plant breeder through civil law. The government has no responsibility for enforcement of the program. Legal protection extends for 18 years. If it is determined, at any time during the 18-year period of protection, that the variety is needed by the public, USDA has the authority to declare it open to use and make It available to the public. In Section 44 of the Plant Variety Protection Act, entitled "Public Interest in Wide Usage," we read that the office of the Secretary of Agriculture may declare a protected variety open to use on a basis of equitable remuneration to the owner, not less than reasonable royalty, when he determines that such a declaration is necessary In order to ensure an adequate supply of fiber, food, or feed In this country and that the owner is unwilling or unable to supply the public needs for the variety at a price, which may reasonably be deemed fair. Such a declaration may be with or without limitation; with or without designation of what the remuneration is to be; and shall be subject to review as under section 71 or 72 (any finding that the price is not reasonable being reviewable); and shall remain in effect for not more than two years. In the event litigation is required to collect such remuneration, a higher rate may be allowed by the court. To date, the USDA has not exercised this authority.

An interesting digression mentioned above about UPOV is the following opinion taken from a study prepared at the Department of Political Science, Western Michigan University, before the United States joined UPOV in 1980. It turns our attention to the situation of the Third World, which is a rich source of germ plasm (Guske, 1980). Why? Among other arguments, it was posed that if the United States joined UPOV (which finally happened), there would then be a major push by the seed multinationals to penetrate Third World markets, gradually convincing them that their own public plant breeding programs, as well as the efforts by the World Bank OGIAR (Consultative Group for International Agricultural Research) agricultural centers, are secondary and inferior to the "superior" seeds sold or franchised by this producer. Third World countries (along with developed countries) would become increasingly dependent upon monoculture agricultures which requires larger amounts of energy and capital and is potentially damaging to the environment. More important, we would all suffer from the loss of basic plant genetic materials as monocultures replaced traditional crops. The severe risks of this have been spelled out in several National Academy reports. Poor countries, and especially the poor peasant farmers in them, will increasingly lose control over the very seeds which provide them with their daily bread.

Some Remarks on the Patent System for Plants and the Seed Industry Organization in the United States

In order to have exclusive rights there must be a set of features. If the features are novel and distinct, it is a patentable variety. Sometimes It might turn out to be of little value. With some effort, a competing private breeder can, however, take an existing variety and, by backcrossing, remove or alter one or more of the features defining existing varietal rights. This is referred to as "cosmetic breeding." This has no use to a farmer and is only useful to those who claim exclusive patent rights. Certain multiline and composite varieties are by definition nonhomogeneous and are ruled out as a breeding approach, not because they are always inferior performers but because they do not meet the administrative requirements for a private right; they make the information costs too high.

In a purely competitive markets competing breeders who make cosmetic copies would drive the price down and prevent recovery of research costs. In a world of oligopoly., which is quickly forming with the rush of seed company mergers, this is less of a problem (Butler and Marion, 1983). The most oligopolistic of the lot, hybrid corn seed companies, seems to have succeeded quite nicely without patents* Hybrids are unpatentable. Companies can afford to tolerate oligopolistic competition so long as their seed competition from farmers is eliminated. Even if the patent eliminated other breed copiers, the perfect substitute is provided by a farmer who can save his own seed (Schmid, 1984).

Theoretically, social costs of PVPA may result from several factors: monopoly rents, duplication of research investments, an increase in product differentiation and barriers to entry, and a reduction in the exchange of scientific Information about germ plasm.

There are basically two ways to encourage plant breeding: public and private Public promotion Involves financing a number of experimental stations and plant breeders who seek on a long-term basis to develop new varieties that are more productive, nutritious, and adaptable to local conditions. The private approach to plant breeding tends to focus on flowers, fruits, ornamentals, and increasingly hybrid corn and wheat. While the large number of local and Independent seed companies serve the interests of the public well, the trends toward corporate concentration, takeovers, and vertical monopolization, which are all encouraged by the establishment of plant patenting, raise serious questions regarding the protection of the public interest.

In addition to directly encouraging one or both approaches, governments also strongly Influence private sector activities through their consumer protection activities. These may range from regulations on false advertising to extensive testing and registration of seeds prior to approval for sale. Particularly, in regard to the latter, there is the risk that private interests promote protection for themselves under the label of consumer protection. This is what appears to have happened in Europe, where the Common Market Is systematically removing many traditional plant varieties from the market and actually prohibiting their sale. This discrimination against small firms in the name of "consumer protection" seems to be mainly to the advantage of the large firms.

In today's world of technological monopolization by many very large and powerful international corporations, plant breeding is taking place in an increasingly less competitive context as a result of vertical mergers and the like.

An interesting conclusion was reached by L. J. Butler and B. W. Marion (1983) in their study on impacts of patent protection on the U.S. seed industry. It has been stated that the available evidence provides no indication that PVPA has significantly affected public plant breeding. At least to date, it has not led to a dominance of plant breeding by private enterprises at the expense of public institutions. There is also little evidence that current market shares of privately protected varieties or of leading companies seriously hamper competitive forces in the open-pollinated seed species. This is primarily because public varieties still dominate most seed species and are generally produced and sold by a large number of seed companies. Privately protected varieties account for a relatively small portion of acres sown for most crops. The open-pollinated crops that private plant breeding tends to dominate are cotton, tobacco, alfalfa, peanuts, and sugar beets. Of these, cotton has the largest number of privately protected varieties.

The development of a dealer network for protected varieties represents a major barrier to entry into breeding and marketing protected varieties. Hybrid seed corn companies, which have well-developed dealer networks, may be able to use these for protected varieties of open-pollinated species.

PVPA increased the incentive to advertise and promote privately protected varieties. In the opinions of both industry and university plant breeders surveyed, PVPA has resulted in a significant increase in advertising and promotion by seed companies.

Because protected varieties represent a small share of most seed species, overall price indices may be little affected by the prices for protected varieties.

Survey respondents feel that the exchange of scientific information and plant breeding materials has increased since 1970, except for the flow from private companies to universities. Public plant breeders feel PVPA has had a significant, negative effect on the exchange of scientific information and material. Industry respondents felt PVPA has enhanced scientific exchange. Theoretically, it is expected that PVPA has reduced the flow from companies to universities and has increased the flow in the opposite direction as private plant breeders have aggressively searched for information and germ plasm developed in the public sector. Public plant breeders interviewed indicated that the exchange of scientific material has always been asymmetric -- primarily from Agricultural Experiment Stations to private companies -- with little reverse flow. If public institutions discontinue their breeding activities in some species, the exchange of scientific information and material is likely to be substantially reduced.

Conclusions

Most of the countries that have implemented a plant variety rights scheme maintain that the principal benefits have included: (1) an increase in the number of new varieties available to growers, (2) an improvement in the access to foreign plant varieties, and (3) a constant improvement in the line of varieties.

A danger exists that private firms will simply seek to duplicate existing varieties without attempting to develop improved plant varieties. That is, while many varieties of a plant species appear to be available through product differentiation by brand name, some could be very similar genetically. Such an outcome may well result from an industry structure that fails to encourage advances in plant development through competition. Hence, it would be beneficial if a plant variety rights scheme incorporated the requirement that a new variety for use in commercial agriculture be an improvement over existing varieties to be eligible for the issue of a grant.

A real achievement in the long run will be the possibility to be able to draw a kind of genetic "map," so it would be easy to find out how much of a new, different variety of plant really exists. In this way, there will be a good chance of avoiding the problem of "cosmetic breeding" that affects the seed industry market.

The development of superior crop varieties, which offer users the potential to increase productivity and realize higher net returns per hectare, would result in a reduction in the effective cost of seed (i.e., the increase in the value of output from better varieties would more than offset the increased cost of seed). Alternatively, if plant variety rights foster the development of an industry where firms simply duplicate existing varieties,, then the effective cost of the seed input could rise.

The funding of plant breeding activities by public institutions remains an important issue regarding patent rights to new varieties of plants. Since the output from government-financed research institutions represents a public good, there are grounds for arguing that property rights should not be exercised over the release of such varieties. The option to secure returns from varieties so released would at the same time assist the financing of research activities undertaken by such institutions. The relationship of biotechnologies to institutions, such as patent rights, raises important questions about the way such institutions affect the rate of technological innovation, public access to advances in biological research, and increased productivity in the agricultural sector and to the aggregate pool of genetic materials. The pattern of relationships is a complex one where we can expect variable institutional arrangements to have important effects in different societies,. The relationships of institutional arrangements to biotechnologies is an important issue deserving of serious consideration in the years ahead, especially with reference to countries of the Third World.

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