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ABSTRACT

This study is a partial evaluation of the effects of the U.S. Plant Variety Protection Act of 1970 (PVPA). It attempts to determine the effect of the Act on expenditures on crop breeding by the private sector, and on the availability and productivity of soybean varieties. A number of other potential effects of the Act, some of them controversial, are mentioned but not addressed in this study.

The findings were that both the number of non-hybrid crop breeding programs and expenditures on them increased substantially during the 1970s as compared to the 1960s. It seems likely that these phenomena are due to the incentives created by the Act. Examining the productivity of breeding efforts in soybeans, the study found a three-fold increase in the number of varieties submitted for yield tests in the 1970s as compared to the 1960s. It also found the rate of improvement in yields was greater for varieties released after 1970 than for those released before 1970, although the improvement was significantly different from zero only at the 16 percent confidence level.

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SOME EFFECTS OF THE U.S. PLANT VARIETY PROTECTION ACT OF 1970

INTRODUCTION

The Plant Variety Protection Act of 1970 is one of a network of U.S. laws establishing property rights for "intellectual property," such as inventions, musical compositions, literature, etc. The PVPA established property rights that vest in the plant breeder exclusive right to sell, reproduce, and import or export a plant variety protected under the provisions of the Act subject to some limitations, which will be described later.

The arguments advanced for intellectual property rights in general, and for plant breeders' rights in particular, are two-fold. The first is a moral position asserting that the creator of an idea has the moral right to the exclusive use of his creation. The second argument is one of economic efficiency. This argument holds that without such rights, the incentive for inventive activity would be limited to the potential direct benefits of the inventors' own use of the creation as opposed to the much greater potential benefits that would accrue to all the other potential users combined. This limited incentive would cause the inventor to allocate much less of his time to inventive activity than would be productive in view of the potential total social benefits. Property rights would help to

correct this lack of incentive to the extent the inventor could appropriate some fraction of the benefits realized by others through rents, royalties, or some other licensing arrangement.

It is the incentive argument for plant breeders' rights that motivates this study. Given the establishment of a new set of property rights in crop varieties, it is of interest to know what effect the new incentives have had on the level of private plant breeding research, and what payoff may have been realized in the form of better crop varieties and therefore a more productive agriculture. We should note here that an increased level of private investment in plant breeding is not in itself evidence of an increase in economic efficiency. Also of interest are the effects of the new property rights on the amount of and effectiveness of publicly financed or cooperatively financed breeding programs, but this issue is beyond the scope of this study.

THE U.S. SEED INDUSTRY

Although farmers for thousands of years have practiced purposeful selection of breeding materials from the diverse plants in their current crops, plant breeding per se is a product of the advancing genetic knowledge of the current century. Prior to this century, most seed simply was saved from the farmer's previous crop, though there was some specialization by firms that produced and distributed grain for seed. As improved crop varieties have been made available by better breeding techniques, farmers have purchased more seed from others and the seed industry has grown to be a major agricultural supply industry. It accounted for some $3.9 billion in purchases by farmers in 1980, equal to nearly 6 percent of the value of crops sold (Table 1).

Table 1. Farm expenditures on seed, including bulbs, plants and trees, 1960 and 1980

	1960	1980
Expenditures in current dollars ($ million)	519	3,912
Expenditures in constant (1960) dollars ($ million)	519	1,515
As a fraction of all farm production expenses	2.0%	3.1%
As a fraction of cash receipts from crops	3.4%	5.7%

Source: Economic Indicators of the Farm Sector, Statistical Bulletin No. 674, U.S. Department of Agriculture, Sept. 1981.

It would be a mistake to think of the seed and the crop breeding industries as being one and the same. A large fraction of the services of the seed industry are those of seed multiplication, conditioning and distribution. These services can be and often are provided by farms and firms that undertake no experimental or creative

breeding programs. Furthermore, though some breeders are employed by the seed industry, others are employed by USDA and by state agricultural experiment stations. Varieties and cultivars developed by these publicly employed breeders are made available more or less directly to anyone in the seed industry.

Hybrid and Non-hybrid Seed Development

To understand the structure of the seed industry and the effects of the PVPA, one must be cognizant of the differences between the development processes for hybrids as compared to those for non-hybrids, or varieties. The term "variety" as used herein refers to a unique population of plants that is uniform from plant to plant and that will "breed true," producing similar plants from generation to generation. The breeding of a new variety typically begins with the deliberate crossing of plants from two different varieties or lines. The resulting F_1 generation of plants may be somewhat uniform, but after these plants self-pollinate (or cross-pollinate), the next generation (the F_2) will exhibit more heterogeneity. From the resulting array of plant types, the breeder selects those with the most desirable combination of characteristics to provide seed for the following generation. After six to eight generations of such purposeful selection, the plant population will become stable with a high degree of uniformity in plant characteristics, both within a generation and between successive generations. The resulting population can be called a variety. A farmer planting such a variety can save seed from this year's crop with confidence that next year's plants will exhibit the same characteristics.

A hybrid is a cross between two plants of different varieties. In commercial grain crops, however, the term "hybrid" refers more specifically to the first generation (F_1) plant resulting from the cross of two carefully selected or carefully developed varieties.

The F_1 generation of such a cross exhibits both a high degree of uniformity from plant to plant and a hybrid vigor known as heterosis. If the seeds of this F_1 generation are planted, the resulting plants (the F_2 generation) will exhibit a great deal of variability in characteristics, and much if not all of the hybrid vigor will be lost. Therefore, it is not feasible for the farmer to save seed from the crop for the following year.

Among the major U.S. crops, hybrids have become widespread only in corn and sorghum. The reason is that these species are open-pollinated and large scale cross-pollination is feasible, either by removing the anthers of the maternal plant (easily done for corn, in which the tassels are ideally located for removal) or by introducing genetic material that causes the pollen of the maternal parent to be sterile without affecting the fertility of succeeding generations. The traditional method of crossing two self-pollinated varieties is to open the flower of the maternal plant for emasculation, and then to extract the pollen from the flower of the paternal plant and deposit it in the maternal flower. This process is far too tedious to be feasible for the large-scale production of seed for farmers' use as an F_1 hybrid. Research has been underway by several companies to utilize non-traditional methods of producing commercial quantities of hybrid wheat, and though a few such hybrids have been released, success is as yet very limited. Hybrids are also commercially produced and sold for some minor crops such as sunflowers and certain vegetables.

Because of these technical advantages of hybrids and their feasibility in open-pollinated crops, it is not surprising that the first great advances in commercial crop breeding occurred with corn. Also, because F_1 hybrids do not breed true, it is not surprising that private entrepreneurs quickly entered the business of developing and distributing hybrid corn. The developer of a successful hybrid does not need the legal protection of breeders' rights, since he can be

assured that the farmer must return to purchase the F_1 cross seeds if he is to plant the hybrid another year. The breeder then needs only to keep the parentage of the hybrid a secret to enjoy full ownership rights. This is in contrast to the case of a newly developed variety for which the farmer has the option of saving seed for subsequent years once he has purchased an initial quantity.

Private Versus Public Seed Production

Currently, almost all corn and sorghum seeds planted are hybrids produced by private seed companies. Crop breeders on the public payroll at USDA and universities continue to work on some of the more basic research problems in the breeding of these crops and the fruits of their efforts are generally in the public domain. The bulk of commercial corn and sorghum breeding work, however, is conducted by the seed companies.

In contrast, most commercially planted varieties of soybeans, wheat, and other cereals have been developed, until very recently at least, by breeders at USDA and universities. As new varieties were developed at these public institutions, the seed typically has been multiplied and distributed to farmers through the certified seed system, which is regulated and monitored by state and federal agencies. In this system, the first limited quantities of seed ("breeder seed") are multiplied by private individuals or cooperative foundations to become "foundation seed," then multiplied again to become "registered seed," and multiplied further to become "certified seed," which is sold to farmers for commercial production. At each stage, production and conditioning of the seed are monitored by the certifying agency to maintain quality and genetic purity. Commercial farmers can choose to purchase certified seed, to save their own or to purchase non-certified seed. Under the terms of the Plant Variety Protection Act, to be described later, a protected variety may be multiplied and

distributed through this same certification system, or the breeder may maintain direct control of the multiplication process until sale for commercial production.

EVOLUTION OF BREEDERS' RIGHTS

The U.S. Constitution empowers Congress "to promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries." (Art. I Sec. 8.) Although the first patent act pursuant to this provision was passed in 1790, it was not until the 1930 Plant Patent Act (PPA) that the patent statutes were amended to extend to plant breeders, and then patent rights were extended only for the asexual reproduction of plants. In 1970, the PVPA established patent-like protection of sexually reproduced varieties outside the existing patent system. Another potentially important event in the evolution of U.S. breeders' rights was the 1980 Supreme Court decision (Diamond v. Chakrabarty) that expanded application of the basic patent statutes to cover microorganisms. Meanwhile, in Europe, the development of breeders' rights in various countries culminated in a 1961 treaty creating the International Union for the Protection of New Plant Varieties, commonly referred to as UPOV, of which 17 nations, including the U.S., are now members (Batcha and Studebaker).

The Plant Patent Act

The 1930 PPA provided some relatively brief amendments to Title 35 of the U.S. Code, which extended to asexually reproduced (budding and grafting) plant varieties the same patent opportunities given industry through the patent process. Much of the impetus for this amendment was provided by the nursery industry in which breeding activities had been greatly stimulated by the successes of Luther Burbank. Burbank had been a strong proponent of breeders' rights. Thomas Edison testified in hearings on the act that "This bill will give us many Burbanks." (U.S. Congress, 1930.) For its part, the U.S. Department of Agriculture favored the bill on grounds that it

would attract more private investment into plant breeding, permitting public breeding resources to be allocated to more basic aspects of breeding research. The limitation of rights to the asexual reproduction of plants greatly restricted potential effects of the bill, but apparently it was widely felt that patent rights could not practically be extended to sexual reproduction of plants. Testimony in hearings asserted that sexual reproduction would not replicate the parent variety and that enforcement difficulties would arise from this and from difficulties in identifying varieties and monitoring commercial transactions in grain that might be used as seed.

In 1968 an additional amendment was offered to extend patent rights to sexually produced varieties. By this time, however, a presidential commission on the patent system had rejected the patent system as a proper vehicle for plant variety protection, and the amendment died in committee pending further study of an appropriate means of protection. The 1970 Plant Variety Protection Act was the result of these further explorations. Some of the significant features of that act, as amended in 1980, are:

Rights conferred. The owner of a protected variety has the right to exclude others from selling, reproducing, importing or exporting the variety for a period of 18 years (Sections 83, 111).

Exceptions: It is not an infringement of these rights to:

a) save seed for use on the producer's farm (Section 113), or

b) use and reproduce a protected variety for plant breeding or other bona fide research (Section 114).

Limitation: If an owner does not supply "public needs" for the variety at a "fair" price, the Secretary of Agriculture may declare the variety open to public use (with "equitable remuneration" to the owner) if this is necessary to insure an adequate supply of food and fiber (Section 44).

Assignment of rights by owner. Plant protection has the attributes of personal property and the rights may be transferred by sale or licensing (Section 101).

Remedy for infringement of rights. Remedy for infringement is by civil action for damages.

Eligibility of varieties for protection. To be eligible, a variety must have these properties:

a) distinctness in some identifiable characteristics from all prior varieties of public knowledge;
b) uniformity in the sense that any variations are describable, predictable and commercially acceptable, and
c) stability when sexually reproduced, in terms of retaining distinctive characteristics (Section 41).

Establishment of eligibility. The breeder's description of the variety is sufficient to establish that the eligibility criteria are met. No field trials are necessary.

Exempted plants. Section 144 exempted okra, celery, peppers, tomatoes, carrots and cucumbers, but these exemptions were repealed in 1980. Section 42 exempts first-generation hybrids, fungi and bacteria.

Repository seed samples. Viable samples of seed must be deposited and replenished periodically in a public repository (Section 52).

Breeders' Rights in Europe

In Europe several countries had established plant breeders' rights by 1960, but the provisions varied greatly (see Committee on Transactions in Seeds, 1960, Ch. 3). It was the intent of the Paris Convention of 1961 (which established UPOV) to introduce some uniformity among these provisions as countries established and

modified systems of plant breeders' rights. Provisions of the Convention were quite general, permitting member states to specify more extensive rights. The provisions include variety eligibility requirements and owners' rights similar to those of the PVPA. It provides for reciprocal rights for breeders of one member state in each of the other member states, and specifies that the breeder's permission is not required to use a variety in plant breeding.

Although the U.S. PVPA is now acceptable within the UPOV provisions, European systems within UPOV are different from the U.S. system in some important ways (see Bradnock for elaboration of differences). In Europe the test of variety eligibility is based upon official field tests for distinctness and uniformity rather than on descriptions provided by the breeder. This lengthens the time required for processing applications and adds to the costs. Several of the European countries include "compulsory licensing," which permits anyone access to a variety upon payment of a "reasonable" royalty to the breeder. A feature of European seed control systems not related to breeders' rights, but sometimes confused with breeders' rights issues, is the EEC's common catalog requirement dating from 1970 (see Barton 1982). The EEC common catalog is a list of many plant varieties established in official tests to be both clearly distinguishable and an improvement over other varieties. It becomes a violation of the law to sell, and in some cases just to cultivate, a variety not in the catalog (Barton, 1982 and Claffey, 1981). This is a remarkably strong novelty test to impose on the producer's choice of variety to plant. Although this requirement is independent of laws establishing breeders' rights, and is not sanctioned by UPOV, it has become frequently associated with the "European system" of breeders' rights.

ISSUES RELATED TO THE U.S. PLANT VARIETY PROTECTION ACT

The stated intent of Congress in passing the PVPA was to stimulate plant breeding research (U.S. House, 1970). This, in turn, was expected to result in a larger number of improved varieties being made available to farmers, and ultimately in increased competitiveness of U.S. agricultural products in world markets. The larger investments in private breeding research were expected to augment the efforts of public breeders, allowing the latter to concentrate on more basic research.

The most obvious issue relating to PVPA is whether the intent of Congress is being realized. Have private breeders increased their breeding efforts beyond what might have been expected in the absence of PVPA? Are a larger number of varieties available? Are the new varieties more productive than those that would have been developed in the absence of PVPA? Have public breeders concentrated on more basic aspects of research? The first three questions are addressed in this study. Before moving to them, we should note that other issues have been raised with respect to PVPA, primarily during hearings on the 1980 amendments to the Act. The most important of these are the effects of the Act on concentration of firms within the seed industry, on the genetic diversity of U.S. crops, and on the free exchange of genetic materials.

Firm Concentration

The issue of concentration of firms in the seed industry has received attention because of a large number of seed firm acquisitions and mergers that took place during the 1970s (U.S. Congress, 1980, p. 20). The American Seed Trade Association testified that this phenomenon was caused by the financial and tax environments that caused similar takeovers in other industries, and that since

passage of the Act there has been a net increase in the number of private companies doing breeding research despite the mergers (U.S. Congress, 1980, p. 77).

Presumably the reason for concern about firm concentration is the possibility of undue price enhancement in a more concentrated industry. Indeed, testimony was entered showing that from 1965 to 1978 the price index for seed increased at a faster rate than price indexes for other selected farm inputs (U.S. Congress, 1980, p. 27). Of course, the sine qua non of patent protection is to permit higher prices for the protected invention, otherwise there would be no enhancement of incentive for inventive activity. The question then becomes one of "undue" price enhancement. If undue price enhancement were defined as a price premium exceeding the margin of productivity of the new variety over other currently grown varieties, it probably would not occur under PVPA because there would be no incentive for farmers to purchase the seed at such a price. It is difficult to rationalize a weaker definition. In any case, there is little evidence that the PVPA has as yet permitted any new price enhancement in the non-hybrid crops. Data on annual seed price increases by crop (Claffey 1981) indicate that 1970-1980 price increases for wheat, soybeans and barley seed were comparable to those for hybrid seed corn. It might have been expected that the price enhancement permitted by PVPA would have resulted in some catching-up of non-hybrid seed prices to the level of hybrid seed prices, but this does not appear to have occurred.

Genetic Diversity

With respect to genetic diversity, concerns have been expressed about two possible effects of any successful crop breeding effort. The first effect is that farmers and gardeners cease to plant their traditional varieties, with the result that the existing pool of

germplasm may be lost. The second effect is that the discovery of a superior genetic strain might quickly lead to the incorporation of this strain into many, if not most, of the commercially successful varieties of a crop, thus increasing the genetic vulnerability of the crop as a whole. It is clear that both of these effects are undesirable, though their magnitude and significance are subject to much disagreement. As the National Academy of Science's study (1972, p. 129) noted, however, it would be "unthinkable that we would deliberately revert to less productive types of varieties merely for the sake of preserving farmers' seed," when the alternative is to increase efforts to collect, store and preserve germplasm. It would seem to be almost as unthinkable to revert to significantly less productive varieties just to reduce genetic vulnerability by some unknown amount.

Both of these effects of successful crop breeding are perplexing problems and it is not clear how the PVPA would exacerbate them. One argument offered is that the Act will result in less genetic diversity because of the genetic homogeneity required to meet the distinctness and uniformity criteria for protection of a specific variety. This argument is not very convincing because the uniformity required for plants within a new variety in no way implies uniformity across new varieties. The relationships between PVPA and the issues of genetic diversity and genetic vulnerability would seem to require more careful examination.

Exchange of Genetic Material

A final issue being vigorously debated is the effect of PVPA on the free exchange of genetic materials among breeders. Breeders who have discovered potentially useful germplasm may be reluctant to share the material in a competitive environment. As of the 1980 Congressional hearings, public plant breeders were divided as to the legitimacy of this concern, and as yet there have been no published empirical studies on the issue.

INVESTMENT INCENTIVES FOR CROP VARIETY BREEDING WITH VARIETY PROTECTION

Prior to the Plant Variety Protection Act, there was little economic incentive for breeders to invest in a crop variety breeding program. If a superior variety were developed, opportunities to charge a premium for the seed were limited. Once a variety of seed was released and multiplied to some extent, any farmer or seed company could compete in its reproduction for sale as seed. Because of this potential for competition, the ultimate price that could be charged for the seed would be little, if any, higher than the cost of producing and conditioning the seed. Knowledge of this potential would deter farmers or seed companies from paying unusual prices for initial quantities of the seed. A breeder might think to recoup his investment by using the variety to produce the grain commercially, but it is unlikely that any single producer could produce enough to offset the costs of the long breeding investment period. Furthermore, once he has sold a crop on the grain market, all other farmers would have access to his seeds and his competitive advantage in commercial grain production would vanish.

The PVPA gives the owner of a protected variety the right to exclude others from selling or reproducing the variety. It might seem that plant variety protection would provide economic incentives for breeders of non-hybrid crops approximately equal to those for breeders of hybrid crops. This is probably not true partly because non-hybrid seed is essentially a durable good (the germplasm is not used up in a single production cycle), whereas hybrid seed is a non-durable good.

Coase (1972) explains the importance of this distinction. The monopolist producer of a durable good desires to set a price such that marginal revenue equals marginal cost, thus maximizing his profits and realizing economic rents (returns above normal costs).

Having set that price and delivered the corresponding quantity in the first production period, however, he observes that there is opportunity for further profits by lowering the price to some of the remaining demanders. Thus, in the next period the monopolist has an incentive to lower the price to the point where marginal revenue from the remaining demanders equals his marginal cost. Clearly, the monopolist producer of this durable has an incentive to reduce his price each successive year (to practice discrimination through time) until the price falls to the level of marginal variable costs of production and distribution, at which point no further economic rents can be realized. However, to the extent that buyers of the durable are aware of this incentive to reduce prices through time, they will postpone their purchases in anticipation of this reduced price. Coase argues that in the absence of transactions and information costs, buyers will decline to pay any more than the ultimate (competitive) price, so the monopolist producer of the durable will be unable to earn any economic rent.

Although this extreme result is unlikely to prevail in practice, the implication is that producers of durables such as plant varieties face problems in trying to extract economic rents. One solution, as Coase points out, is to make the good less durable. Then, those buyers who can justify paying the monopolist's price the first period are more willing to do so because they will not be bound to that higher price if and when the price falls in future periods. Since they would again be willing to pay that price in the next and succeeding periods, the price need not be reduced and the monopolist would be able to earn economic rents on the non-durable during each period. Hybrid seeds <u>are</u> non-durables, since they do not "breed true" after the first crop, and therefore they provide better opportunities for economic rents than do non-hybrid seeds, even when the latter are protected under the terms of the PVPA.

In addition to the durability problem, producers of protected varieties likely will encounter either more widespread infractions of their property rights or higher costs in enforcing them as compared to producers of hybrid seeds. This is because once a protected variety is produced commercially by farmers, the grain they produce enters the market for non-seed purposes but can be pirated for use as seed. The cost of preventing such piracy could be quite high, and whether prevented or not, it represents an erosion of potential earnings of the non-hybrid breeder not experienced by the hybrid breeder.

We have noted two reasons for expecting economic rents (returns over and above normal costs) for the owners of protected varieties to be lower than those for producers of hybrid seeds, other things equal. It should be obvious, however, that the new property rights created by the PVPA will to some extent increase the ability of the breeder to appropriate the benefits from his variety. This should cause some increase in private investment in the breeding of non-hybrids, though perhaps not to levels comparable to those in hybrid seed crops.

THE 1980 SURVEY OF PLANT BREEDING FIRMS

Given that plant variety protection provides some measure of incentive for private variety breeding research, though probably smaller than the incentive for hybrid breeding, one might expect the effects of the PVPA to occur in three stages. First would be an increase in the level of plant breeding research expenditures by private firms. Second would be the appearance of new varieties resulting from this research. Finally, third, one could expect changes in agricultural productivity resulting from the additional new varieties.

If the 1970 Act were to have any impact on private investment in crop breeding research, that effect should have been apparent by 1980. To explore this, a survey of 214 seed companies was conducted in the summer of 1980 to obtain data on their breeding research expenditures during the period 1960-1979. Firms were selected from the membership lists of the American Seed Trade Association with the assistance of its Executive Vice President, Dr. Harold Loden. All member firms were contacted except those known by Dr. Loden not to have a breeding research program. Of the 214 firms, 127 responded. Seventy-two provided some or all of the data requested, 33 reported they had no breeding program, 19 had a breeding program but would not or could not provide the information requested, and 3 firms had ceased to exist as independent companies. Follow-up contacts were made to 10 of the 87 non-responding firms that appeared to be most likely to have breeding programs. None of the firms contacted had breeding programs for commercial agricultural crops, so no further followup contacts were made.

A copy of the questionnaire sent to the 214 firms is included in the Appendix. It solicits the dollar value of seed sales and breeding research expenditures by crop for the years 1960, 1965, 1970,

1975, and 1979, plus information on the duration of breeding programs, firms' attitudes about the PVPA, and varieties released by the firm.

Of the 72 cooperating firms with breeding programs, 66 provided usable data for the year 1979, and 59 were able to provide data for the entire period (or for the duration of their breeding program if it began after 1960). It is estimated that the 66 firms accounted for 62 percent of all hybrid seed corn sales in the United States, 18 percent of soybean seed planted and 5 percent of cereal seed planted in 1979 (Table 2). The small fraction of soybean and cereal seed accounted for by the surveyed firms suggests that most of these crop seeds are either saved from the farmer's previous crop, purchased from other farmers, or purchased from seed firms not engaged in breeding research.

Hybrid sorghum sales reported by responding firms amounted to $78 million, or $40 million more than our estimate of the value of seed planted. This apparent discrepancy is due to export of sorghum seed, which amounted to 62,000 tons in the 1978-79 crop year and 52,000 tons in the 1979-80 crop year. Taking the average of these and assuming the price of export seed to be the same as that paid by farmers ($.41 per pound), the value of seed exports in 1979 must have been about $47 million. Combining exports and domestic planting, the total value of sorghum seed sold in 1979 is estimated to be $85 million compared to the $78 million reported by firms responding to the survey.

Total reported crop breeding research expenditures by the 59 responding firms was a little over $42 million in 1979 (Table 3). In addition to this, seven firms reporting expenditures for part of the historical period spent (in 1979) $2.8 million for corn, about $0.5 million each for sorghum and soybeans, $0.2 million for forages, $0.6 million for vegetables, and $0.3 million for other crops, bringing the total for 66 firms to about $47 million. Ruttan (1982, p. 185) reports an estimate of private plant breeding research expenditures

Table 2. Seed sales by 66 responding firms in 1979 relative to estimated total seed planted in the United States

Crop	Acres	Estimated value of seed planted: Seed value per acre*	Total seed value	Survey sales[a]	Survey as pct. of total
	(million)	($/acre)	(million $)	(million $)	(%)
Corn	72.4	12.41	898	554	61.7
Sorghum	12.9	2.49	38	78	205.3
Soybeans	70.6	9.19	649	118	18.2
Cereals:					
Wheat	62.5	5.01	313	b	b
Rice	2.9	23.07	67	b	b
Oats	9.7	4.90	47	b	b
Barley	7.5	4.94	37	b	b
		Total cereals:	464	21	4.5

*Source: U.S. Senate Committee on Agriculture, Nutrition and Forestry, Committee Print 79-869, August 1981.

[a]Total sales for 1979 reported by 66 reporting firms.

[b]Totals by crop omitted to protect responses of individual firms.

of $60 to $155 million for the same year. Results of this survey suggest that this range is probably correct. If non-responding corn and sorghum breeders have research programs comparable to those that responded, the non-responders would have spent an additional $15 million in breeding research on these two crops alone, raising the total to over $60 million. Unfortunately, we have no satisfactory way to estimate the percentage of the breeding industry represented by our sample in the case of soybeans, cereal, forages, vegetables and other crops. Total expenditures for breeding of these crops could easily be twice the $21 million reported by firms responding to our survey, putting the total for the industry at $80 million or more in 1979.

Table 3. Crop breeding research expenditures reported by 59 firms[a]

Crop	1960	1965	1970	1975	1979
			(current $ thousand)		
Hybrid corn	1,873	2,710	4,913	10,217	19,745
	(14)	(14)	(18)	(26)	(32)
Hybrid sorghum	448	662	1,202	1,736	2,847
	(6)	(8)	(12)	(17)	(18)
Soybeans	2	33	270	2,069	4,296
	(1)	(4)	(8)	(19)	(21)
Cereals	8	294	1,083	3,112	4,328
	(1)	(3)	(6)	(9)	(9)
Forage and turf grasses	256	572	1,077	1,805	3,049
	(4)	(7)	(9)	(14)	(16)
Vegetables	977	1,406	2,522	4,217	7,517
	(7)	(8)	(12)	(11)	(16)
Other crops	8	24	226	992	878
	(1)	(3)	(6)	(7)	(11)
Total	3,572	5,707	11,293	24,148	42,630

[a]Numbers in parentheses are numbers of firms with breeding programs for the crop specified. Only the 59 firms able to provide information for the full 1960-1979 period were included in this tabulation.

Reported expenditures on crop breeding increased dramatically between 1960 and 1979 for each of the crops as did the number of active breeding programs. As shown in Figure 1, these increases have been substantial even when corrected for inflation.

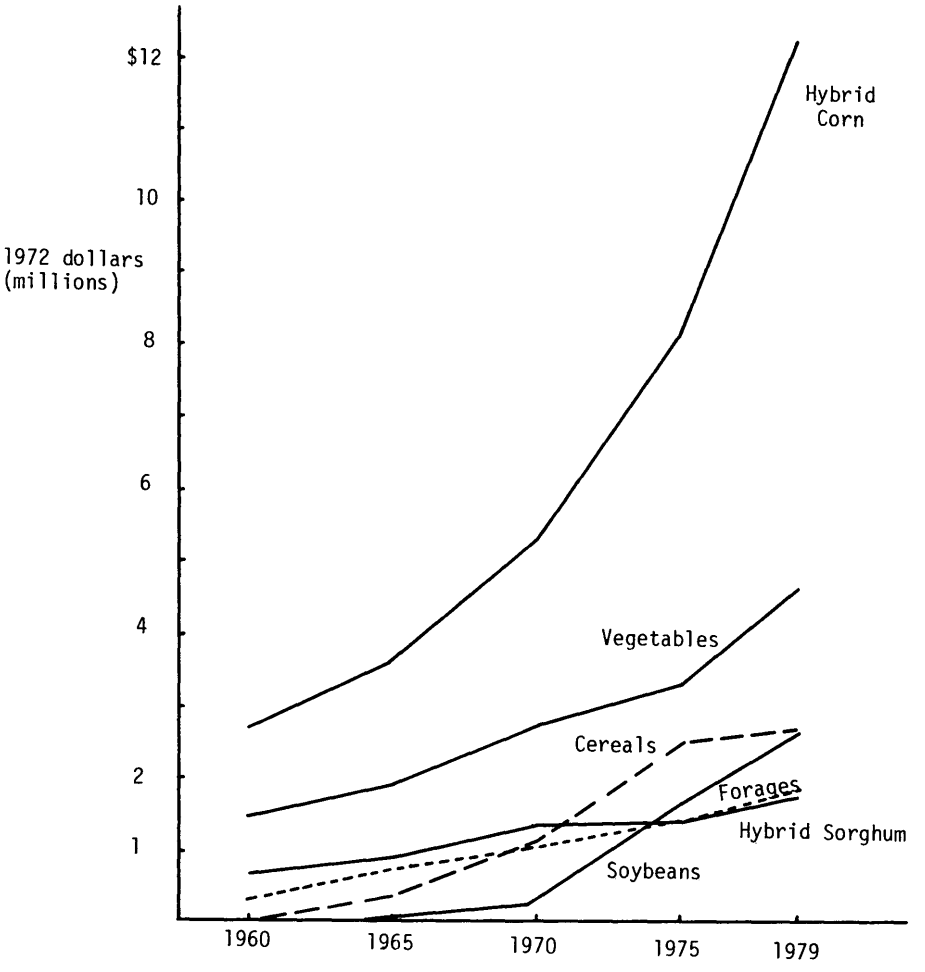

Figure 1. Crop breeding research expenditures by 59 firms for various crops, in constant (1972) dollars (adjusted by Implicit GNP Price Deflator)

Note that these increases are upward-biased estimates of the increases in total U.S. expenditures on private crop breeding because it is likely that some firms doing research in earlier years have gone out of business and could not be reached by our survey process. This bias is probably less significant for the non-hybrid crops than for the hybrid crops, since the breeding programs for the non-hybrids are largely a phenomenon of the last decade.

The intent of this survey was to examine increases in expenditures on the non-hybrid crops since the 1970 enactment of the Plant Variety Protection Act, and to compare this with increases in expenditures on the hybrid crops during the same period. The most dramatic trend apparent in Figure 1 is the increase in research expenditures on hybrid corn. Even allowing for the upward bias in this trend, a quadrupling of expenditures is remarkable. Note that research effort on corn is approximately equal to those on all other crops combined. Even so, there seems to be little doubt that private research on soybeans and cereals was affected positively by the PVPA. Of the 21 soybean breeding programs in existence in 1979, only 4 existed prior to 1970, and some of these firms indicated they initiated their programs in anticipation of plant variety protection. Also, it is possible that the increase in vegetable research between 1975 and 1979 was due in part to anticipation of the 1980 amendment to include the six vegetable crops that previously had not been protected.

By contrast, the steady upward trend in forage breeding research appears to have been unaffected by the Act.

Some of the increase in research expenditures during this time might be attributable to increased commercial importance of the crops. Figure 2 presents trends in reported research expenditures per million dollars of annual U.S. crop value (average of the five years prior to and including the reporting year). Expressed in these terms, the increases in hybrid corn research are less dramatic than Figure 1 indicates because of the great increase in the value of the corn crop.

Despite the much greater relative increase in the value of the soybean crop during this period, however, increases in research on that crop since 1970 still are very evident. Thus, when expressed in terms of dollars of research per dollar of crop value, the evidence is still consistent with the hypothesis that the PVPA has had a significant impact on private variety research.

A final set of figures of interest in evaluating the PVPA are firms' research expenditures per dollar of their seed sales (Table 4). For hybrid crops, this figure has ranged from $30 to $50 of research per $1000 of sales, with no evident trends. For non-hybrid crops (especially, soybeans, cereals and grasses) there is definitely an upward trend, with some very high research expenditures per dollar of sales as might be expected in the early phases of crop breeding programs.

In summary, the data from the survey are consistent with our expectations about the effect of PVPA on private breeding research expenditures. The growth in both the number of research programs and total research expenditures on non-hybrid crops since 1970 is evident. The level of research activity on these crops has not approached that of research on the hybrid crops, which is consistent with our previous conclusions that there are lower incentives for research on protectable varieties than for research on hybrids.

Table 4. Research expenditure per $1000 of sales reported by 56 firms reporting both research and sales amounts.[a]

Crop	1960	1965	1970	1975	1979
			(current dollars)		
Hybrid corn	35.30 (14)	39.06 (13)	39.32 (18)	30.13 (27)	37.83 (29)
Hybrid sorghum	53.52 (9)	42.90 (11)	49.35 (14)	34.20 (17)	43.33 (18)
Soybeans	4.18 (6)	38.64 (7)	88.43 (10)	61.29 (19)	41.00 (19)
Cereals	14.23 (6)	311.77 (6)	187.40 (9)	280.11 (14)	207.55 (13)
Forage and turf grasses	6.60 (6)	8.72 (7)	14.43 (11)	19.24 (15)	17.11 (16)
Vegetables	39.13	42.47	51.94	32.78	47.59
Other crops	0.35	0.96	4.68	14.68	9.16
All crops	23.85	28.66	36.61	33.56	37.74

[a]Figures in parentheses are numbers of firms reporting.

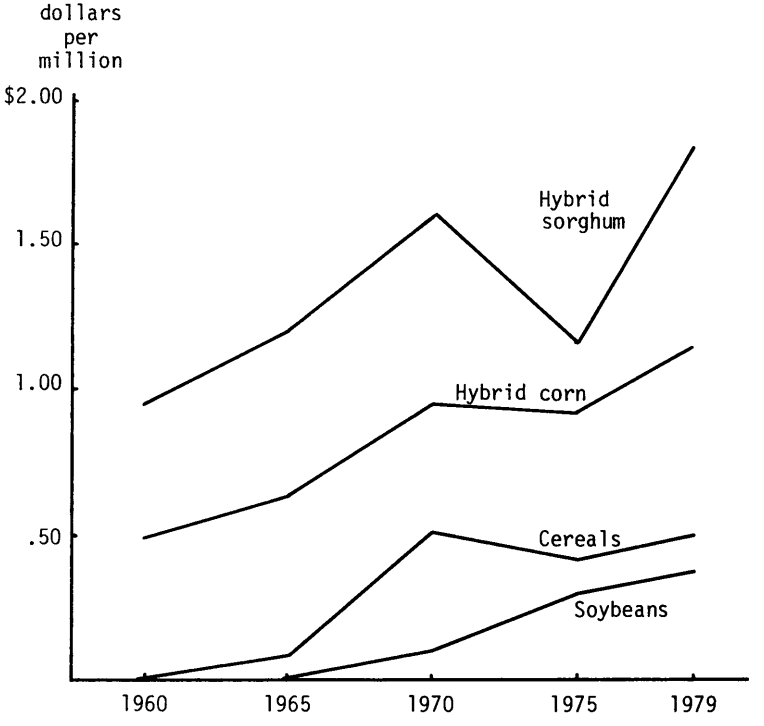

Figure 2. Crop breeding research expenditures (59 firms) per million dollars of annual U.S. crop value in the preceding five years

EFFECTS OF PLANT VARIETY PROTECTION ON SOYBEAN VARIETIES

The 1980 survey of plant breeding firms revealed a dramatic increase in the number of private soybean breeding programs, and in research funds committed to these programs after 1970. It is not unreasonable to anticipate a more rapid rate of variety improvement resulting from this research. Here we examine the fruits of these programs in terms of the number of varieties available and the yields of those varieties in variety test plots in three states.

The 1980 survey indicated that some firms had begun soybean breeding programs prior to 1970 in anticipation of the PVPA. Thus, in the first year in which soybean variety protection certificates were issued (1973), five certificates were issued to private firms, along with eight certificates to public institutions, mainly state experiment stations (Table 5). By 1979, a total of 126 soybean varieties had been protected with about two-thirds of these certificates being issued to private breeding firms. Data reported by Batcha and Studebaker (p. 12) indicate that a total of 243 varieties had been patented by April 1983.

Variety Test Data

To get a more complete picture of the results of the increased soybean breeding efforts, published soybean variety test results in North Carolina from 1963-1979, in Iowa from 1964-1979, and in Louisiana from 1960-1979 were examined. These three states were chosen to represent three major soybean producing areas. Data for these states were obtained from 1979 back to the earliest years for which published data were available. The data in North Carolina were from four distinct producing regions, those from Louisiana were

from throughout the state, and those in Iowa were from the central reporting area (wide-row trials only).

Table 5. Number of soybean variety protection certificates issued by year and by type of owner

Year	Private firms	Public institution	Total
1973	5	8	13
1974	16	6	22
1975	8	5	13
1976	14	0	14
1977	16	5	21
1978	14	8	22
1979	16	5	21
Total	89	37	126

Source: Official Journal of the Plant Variety Protection Office, U.S. Department of Agriculture, various issues.

Number of Varieties Tested

These data included a total of 586 entries which had been tested. The entries included commercially available varieties and brands or blends of varieties, as well as some advanced breeding lines not yet commercially available. Only 56 of the entries were protected varieties, something less than half of the total number of varieties for which certificates had been issued by 1979. In 1964, the first year for which data were available from all three states, some 32 varieties were being tested, whereas by 1978 some 140 varieties were being tested each year. The average yields and numbers of tests by year and state are shown in Table 6.

Table 6. Soybean variety test data--number of entries tested by state and year

Year	Iowa	Louisiana	North Carolina	Total
1960	--	12	--	12
61	--	10	--	10
62	--	9	--	9
63	--	10	17	22
64	7	--	25	32
65	11	10	23	39
66	10	12	25	42
67	17	15	23	48
68	12	15	23	41
69	15	15	23	45
70	20	16	22	48
71	36	16	24	67
72	49	15	25	81
73	68	22	30	107
74	66	22	36	110
75	79	23	35	122
76	60	22	33	102
77	57	23	39	106
78	93	25	42	146
79	89	26	41	140

Source: Iowa Soybean Yield Test Report, Cooperative Extension Service, Iowa State University, Ames, various issues; Performance of Soybean Varieties in Louisiana, 1975-79, Bulletin No. 729, Agriculture Experiment Station, Louisiana State University, 1980 (and earlier issues); and Measured Crop Performance, Department of Crop Science, North Carolina State University, Raleigh, various issues.

These variety trials show that the increase in number of varieties available by 1979 was much greater than indicated by the number of certificates awarded through 1979. There were 586 varieties in the tests, but only 126 varieties were protected through 1979. There are two possible explanations for the appearance of so many unprotected varieties in the tests. First, protection may have been pending for these varieties at the time they were being tested in the test plots (117 varieties received protection from 1980 to early 1983). Second, companies and institutions may be using the state-sponsored variety tests as a part of their evaluation procedure for new lines being developed prior to submitting them for protection.

Rate of Yield Improvement in Tested Varieties

A central question to be addressed using these data is whether the rate of improvement in varieties has increased since the 1970 PVPA. To explore this, the vintage of each tested variety was established as being either the year that the variety was released or the year that the variety first appeared in one of the variety test plots (if the release date of the variety could not otherwise be determined). Average yields of varieties grouped by vintage year are reported in Table 7, which shows an increased yield from 36.6 bushels per acre for three varieties released during or prior to 1948 to 50.7 bushels per acre for the 55 varieties of 1975 vintage.

The data in Table 7 are not easily interpreted because of the confounding effects of test years and test locations. To establish more clearly the trend in variety improvement, we have regressed yields on a spliced function of vintage year, with the splice at 1970. In this regression, the effects of test year and location are held constant with dummy variables. The general form of the regression equation is

$$Yield = aDY + bDL + cPRE71 + dPOST70,$$

Table 7. Soybean variety tests - average yield by vintage of entry.

Vintage Year	Number of Entries	Ave. Yield	Number of Tests
		bu/acre	
1948 or before	3	36.6	9
49	-	-	-
50	1	30.1	1
51	3	36.9	24
52	1	39.9	43
53	-	-	-
54	-	-	-
55	1	34.8	8
56	-	-	-
57	1	38.9	33
58	1	34.2	5
59	-	-	-
60	1	29.0	1
61	3	26.5	7
62	-	-	-
63	16	39.1	233
64	24	35.9	114
65	17	40.7	163
66	11	39.7	118
67	17	45.0	98
68	11	40.8	165
69	19	42.4	146
70	15	43.2	139
71	35	45.0	111
72	43	43.1	289
73	54	45.1	190
74	47	43.1	153
75	55	50.7	119
76	41	39.8	161
77	41	39.6	151
78	74	46.8	195
79	49	43.0	102
Total	586	42.2	2778

Source: see notes, Table 6.

where DY is a vector of dummy variables for test year, DL is a vector of dummy variables for test location, and PRE71 and POST70 are defined as

$$\text{PRE71} = \begin{cases} \text{vintage} & \text{if vintage} \leq 1970, \text{ and} \\ 1970 & \text{if vintage} > 1970 \end{cases}$$

$$\text{POST70} = \begin{cases} 0 & \text{if vintage} \leq 1970, \text{ and} \\ (\text{vintage} - 1970) & \text{if vintage} > 1970 \end{cases}$$

Given these definitions, the coefficient of PRE71 estimates the average annual increase in yield of varieties released in years up to 1970, whereas the coefficient of POST70 estimates the annual increase in yield of varieties released in years since 1970.

The results are presented in Table 8. The last two coefficients are the ones of interest. They indicate that there was essentially no trend in the yields of varieties released in successive years prior to 1970 (-.035 bu./acre/year), whereas, there was a positive trend of 0.12 bu./acre/year improvement in varieties released since then. The low t-ratio of 1.4 indicates that this latter trend is significant only at the 16 percent confidence level, but the result certainly is consistent with the hypothesis that the PVPA has increased the rate of improvement in soybean varieties. An improvement rate yield of 0.12 bu./acre/year may seem small, but it is cumulative, and if it were realized on the entire U.S. soybean crop, the increase would amount to some $54 million (70 million acres X .12 bu. X $6.50/bu.) every year, or $540 million annually after ten years of improvement.

Table 8. OLS regression analysis of soybean variety test yields

Variable	Coefficient	t-ratio
Intercept	41.1	10.9
Dummy variable for year:		
1960	- 6.2	- 2.5
61	- 1.5	- 0.6
62	-16.2	- 6.1
63	- 1.8	- 1.6
64	- 5.2	- 5.0
65	- 1.4	- 1.3
66	- 5.9	- 5.5
67	1.4	1.4
68	- 2.2	- 2.1
69	- 2.3	- 2.3
70	- 1.1	- 1.1
71	1.2	1.3
72	1.9	2.1
73	4.4	5.5
74	- 1.5	- 2.0
75	6.6	8.7
76	- 0.8	- 1.1
77	- 9.4	-13.0
78	1.6	2.5
79	0	-
Dummy variables for location:		
N.C. (Piedmont)	2.6	4.4
N.C. (S. Coastal Plain)	- 1.9	- 3.2
N.C. (N. Coastal Plain)	3.5	5.9
N.C. (Central Coastal Plain)	3.6	6.1
Iowa (Central)	9.7	17.4
Louisiana	0	-
PRE71	- .035	- 0.6
POST70	.117	1.4

N = 2755, R^2 = 0.39, F = 66

SUMMARY AND CONCLUSIONS

The 1970 Plant Variety Protection Act established patent-like rights for breeders of non-hybrid crop species. The purpose of the Act was to provide incentives for plant breeding research by private firms, with the ultimate objective of increasing agricultural productivity through a faster rate of variety improvement.

Theoretical analysis of breeding firm behavior suggests that plant variety protection should indeed create incentives for private breeding of non-hybrid crop varieties, though these incentives should be considerably less than those for hybrid crops with similar demand potential. The difference is because buyers of hybrid seed must return to the breeders to purchase new seed each year, whereas buyers of non-hybrid seed can retain seed from their own crop.

A survey of plant breeding firms revealed a dramatic increase in plant breeding efforts between the decade of the 1960s and 1970s. Breeding research on soybeans and cereal crops is still small compared to that for hybrid corn and sorghum, but the number of breeding programs in soybeans and cereals grew from only a half dozen in the early 1960s to about 30 in the late 1970s. Private research expenditures for breeding these latter crops grew from essentially none in 1960 to about $8.5 million by 1979. These data, plus comments offered by responding firms, leave little doubt that the PVPA was effective in stimulating private investment in the breeding of varieties of soybeans, cereals and vegetables.

Examination of university-sponsored soybean variety trials in three states showed that the number of varieties being tested grew from about 30 during the early 1960s to nearly 150 during the late 1970s, offering further evidence of the impact of the PVPA on soybean breeding. Analysis of the yields of these varieties indicates that during the 1970s new varieties released each year yielded about 0.12 bu./acre more than varieties released the previous year, whereas

there was no trend at all in the yields of new varieties released in successive years prior to 1970. Thus, although agricultural productivity probably has not been significantly affected yet by increased breeding research, there is every indication that soybean productivity will be affected as these varieties are adopted by farmers.

Taken together, our analyses indicated that the PVPA is contributing to the objective of increased agricultural productivity by increasing incentives for private plant breeding research. Other important issues related to the desirability of the PVPA, such as its effects on firm concentration in the breeding industry, on genetic diversity of crop varieties, and on the exchange of breeding materials among breeders, are beyond the scope of this study.

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APPENDIX

QUESTIONNAIRE

North Carolina State University
School of Agriculture and Life Sciences
Department of Economics and Business

SURVEY OF CROP BREEDING RESEARCH

1. Complete the form on page 2 for those crops for which you have breeding programs. In the category of research expenditures, please include current expenses and current depreciation on capital investments (not current capital outlay). If you find it more convenient to report figures for individual crops as a percent of the total dollar figure reported please feel free to do so.

2. On page three, would you list each variety of field crop (not including hybrids) that your company has released since 1960 and indicate the year it was released.

3. To what extent do you believe that the Plant Variety Protection Act has helped or will help your firm to recover plant breeding research expenditures? No effect_____, Small effect_____, Substantial effect_____. Please comment on how or why.

4. Do you have any comments or observations on the adequacy or desireability of the 1970 Plant Variety Protection Act?

5. Would you like to receive a copy of the tabulated results from this survey? (See the enclosed "Reports to be Compiled") Yes_____, No_____.

Please sign below and return in the envelope provided. Thank you for your cooperation.

_____ _____

Signature of person completing questionnaire Date

_____

Name of Company

CROP BREEDING EXPENDITURES AND SEED SALES

Year	Item	Total	Hybrid Corn [1]	Hybrid Sorghum [1]	Soybeans	Cereal Crops	Forage Crops	Cotton	Vegetables	Other Crops (Please Specify)		
		($)	($ or % of total)									
1960	sales											
	research expenditures											
1965	sales											
	research expenditures											
1970	sales											
	research expenditures											
1975	sales											
	research expenditures											
1979	sales											
	research expenditures											
Year Breeding Program: Began: Ended:												

[1] Hybrids are included to provide a comparison with crops protected under the 1970 Act.

VARIETIES* YOUR COMPANY HAS RELEASED SINCE 1960

#	Crop	Name of Variety	Year released
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
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16.			
17.			
18.			
19.			
20.			
21.			
22.			
23.			
24.			

(continue on back if necessary)

*Do not include Hybrids

Agricultural Research Service
North Carolina State University
at Raleigh

D. F. Bateman, Director of Research