United States
Department of
Agriculture

Economic
Research
Service

Agricultural
Economic
Report
Number 654

Intellectual Property Rights and the Private Seed Industry

Mary Knudson and
LeRoy Hansen

It's Easy To Order Another Copy!

Just dial 1-800-999-6779. Toll free (in the United States and Canada). All other areas please dial 301-725-7937.

Ask for *Intellectual Property Rights and the Private Seed Industry(AER-654).*

The cost is $8.00 per copy. For non-U.S. addresses (including Canada), add 25 percent. Charge your purchase to your VISA or MasterCard, or we can bill you. Or send a check or purchase order (made payable to ERS-NASS) to:

ERS-NASS
P.O. Box 1608
Rockville, MD 20849-1608.

We'll fill your order by first-class mail.

Intellectual Property Rights and the Private Seed Industry. By Mary Knudson and LeRoy Hansen. Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 654.

Abstract

Laws protecting intellectual property rights encourage private sector seed research and development. This report examines the Plant-Variety Protection Act (the PVPA) of 1970 as well as the Plant Patent Act (PPA) of 1930 and other forms of research protection, such as utility patents (UP's) and trade secrecy. The report explores the relative profitability to farmers of using purchased seed rather than bin run seed (the previous year's harvest), since the use of purchased seed encourages private seed research and development. To compare profits, winter wheat yields are regressed against the source of seed and other variable inputs for three sections of the United States in 1986/87 and 1987/88. The results show that, on average, farmers who use bin run seed could increase yields by using purchased seed. Also, profits would probably increase both for farmers who begin purchasing seed and for the private seed research sector.

Keywords: Plant-Variety Protection Act, Plant Patent Act, utility patents, PVPA's, PPA's, UP's, intellectual property rights, bin run seed, purchased seed, seed research and development

Washington, DC 20005-4788 November 1991

Contents

Summary

This study examines the intellectual property rights that provide seed companies with property ownership to the seed varieties and hybrids that they develop. The report examines the yield differences between purchased and bin run winter wheat seed in 1986/87 and 1987/88 and the value of these differences, as a possible opportunity for private sector seed development. Winter wheat yields and seed use are analyzed for the Plains, the Pacific Northwest, and the Corn Belt States. The estimated yield functions indicate that purchased seed generated higher yields, on average, than did bin run seed. Per acre profits would have averaged $2.19 higher in the Plains States in 1986/87 and $11.59 higher in the Pacific Northwest in 1987/88 if purchased seed had been substituted for bin run seed.

Plains States have the most winter wheat acreage but the lowest portion of acreage planted to purchased seed. Thus the Plains States hold the greatest potential for growth in commercial sales. Differences in seed source selection within regions were tied to input prices and output prices. Other selection factors also appear to be important, such as advertising, extension services, and the costs of seed storage, cleaning, and testing.

To encourage private sector seed development, seed firms must be assured of maintaining property rights on the seed varieties that they develop. The Plant-Variety Protection Act (PVPA), the Plant Patent Act (PPA), utility patents (UP's), and trade secrets are discussed as means of maintaining property rights, and a particular emphasis is placed on the tradeoffs between PVPC's (Plant-Variety Protection Certificates) and UP's. While UP's offer more protection, they also require more disclosure than the PVPC's. The choice among these by the seed industry may eventually decide research directions and the rate of seed development. Such a choice will ultimately also affect the productivity of the farmer.

Intellectual Property Rights and the Private Seed Industry

Mary Knudson
LeRoy Hansen*

Introduction

The seed industry can be credited with providing agriculture with a diverse choice of higher yielding, more disease-resistant, and hardier seeds. These efforts have their rewards. In 1988, for example, value for seed planted worldwide exceeded $51 billion (Kidd, 1989). However, only 63 percent of this seed is supplied by private firms or public institutions involved with the development and dissemination of seed technology (Kidd, 1989). Other sources of seed are grain saved from previous harvests and the buying or trading of seed between farmers. Both are classified as bin run seed.

To the dismay of private developers of seed technology, bin run seed makes up a significant share of seed used. In the United States, for example, significant portions of wheat and soybean varieties have been grown from bin run seed. However, these varieties originally came from private or public seed suppliers.

Firms that develop new seed technology are concerned about competition from bin run seed of varieties that they themselves have developed.

The acknowledged social gains from improved seed varieties have generated laws that grant a firm or institution intellectual property rights (IPR's) to its new seed variety. However, a potential weakness of these laws is that they allow the use of bin run seed. This report examines the competitiveness of bin run seed relative to purchased (certified) seed by determining the value of the yield differences between the two. This report will also provide an overview of the IPR's for seed technology and the institutional structure within which such seed firms operate. Other factors that influence the choice of purchased seed, as well as some means by which seed firms might exploit these factors, are also discussed.

Four IPR's that are available to firms and other institutions can secure returns to varietal seed research. This report will emphasize one of these IPR's, the Plant-Variety Protection Act

*Mary Knudson is an economist with the Institute of Public Policy Studies. LeRoy Hansen is an agricultural economist with the Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture.

Table 1--Acreage planted in winter wheat and share of acreage that used purchased seed, by region, 1986/87 and 1987/88

Region	Acreage planted		Share of acreage that used purchased seed	
	1986/87	1987/88	1986/87	1987/88
	--Thousand acres--		-----Percent-----	
Corn Belt	2,809	3,960	62	67
Plains	4,199	10,148	13	33
Pacific Northwest	2,230	2,157	63	64

(PVPA) of 1970. This act gives patent-like protection to developers of pure-line varieties. The PVPA specifically protects sexually reproducing pure-line varieties.[1] The increase in the number of private sector varieties released since 1970 suggests that the increased appropriability of property rights provided by the PVPA may help to promote private seed varietal research. From 1970 to 1979, the number of private soybean and wheat varieties available for sale rose from 3 to 36 (Butler and Marion, 1985).

The other three forms of IPR's are the Plant Patent Act (PPA) of 1930, which protects all asexually reproducing crops;[2] the Supreme Court's 1981 decision in Diamond v. Chakrabarty, which grants utility patents (UP's) to micro-organisms, which was extended by the 1985 decision in ex parte Hibberd to include parts of plants; and trade secrecy, which protects a product by nondisclosure of technical processes. For example, seed firms prevent other firms from copying hybrids by not disclosing the parent seeds.[3] Together, these four forms of protection secure rights to most asexually and sexually reproducing plants, parts of plants, genes, specific traits processes, and seeds (U.S. Congress, Office of Technology Assessment (OTA), 1989).

The PVPA will be chiefly considered here, however, because genetically identical seed is easily obtained under PVPA's domain and because sufficient time has passed for the effects of the PVPA to become known. The PVPA attempts to limit farmers to two sources of seed, bin run seed and purchased seed. Therefore, it

---

[1]A pure-line variety is the product of four to nine generations of self-fertilization. Offspring from asexual reproduction and pure-line breeding are genetically identical to the parent plant.

[2]Asexually reproducing plants are those plants that reproduce through grafting, budding, cuttings, layering, division, and the like. Reproduction via seeds is sexual reproduction.

[3]A hybrid is the first generation from a cross between two genetically unlike parents.

is important to know if the PVPA helps the private seed sector secure a high enough return on its research investment to induce it to do more varietal development.

To address this question, this report will estimate field-level yields between purchased seed and bin run seed and then analyze the resulting yield differences for their implications on the competitiveness of purchased seed relative to bin run seed. In particular, the report will explore yield differences between seed sources for winter wheat in 14 major winter wheat States for the growing seasons of 1986/87 and 1987/88.

The 14 States considered here are grouped into three regions, the Pacific Northwest, the Plains, and the Corn Belt, based on the class of wheat grown in the State.[4] In 1987 and 1988, nearly all winter wheat was soft red winter (SRW) in the Corn Belt, hard red winter (HRW) in the Plains, and 80-90 percent white with the rest HRW in the Pacific Northwest. Purchased seed was used on 63, 13, and 62 percent of the 1987 winter wheat harvested acreage and on 64, 33, and 67 percent of that in 1988 for the Pacific Northwest, Plains, and Corn Belt,[5] respectively (table 1).

In the following sections, the four intellectual property rights applicable to seed research are described. The competitiveness of bin run seed relative to purchased seed is discussed and modeled. The factors that affect a farmer's decision to buy certified seed are considered, along with the results of such a choice and the implications for seed research.

Intellectual Property Rights

Patents in the United States have been available since 1790. But, only since 1930 have plants been patentable. Before 1930, plants were not considered patentable because of the belief that they did not reproduce identically and because they could not be described in the detail necessary for general patent statutes (U.S. Congress, OTA, 1989). Any buyer could replicate a purchased variety and then legally sell it to others. Such practices reduced the returns of plant breeders' research investment and, hence, served as a disincentive to varietal development. However, through the efforts of Thomas Edison,

---

[4]States within each grouping are Washington, Oregon, and Idaho in the Pacific Northwest; Ohio, Indiana, Illinois, Missouri, and Arkansas in the Corn Belt; and Oklahoma, Texas, Nebraska, Kansas, Montana, and Colorado in the Plains States. There are five classes of wheat: hard red winter, soft red winter, hard red spring, durum, and white winter wheat.

[5]Purchased seed and certified seed are terms used interchangeably in this report, although seed firms may sell seed that is not certified. However, certified seed sets a standard against which other seed must compete. The seed firm hopes that its brand name stands for quality.

Luther Burbank, and Paul Starks in the 1920's, Congress passed the Plant Patent Act (PPA) in 1930.

The PPA protects asexually reproducing crops, excluding potatoes and the jerusalem artichoke. Potatoes and the jerusalem artichoke were exempted because, in these plants, the tuber is used both for food and for planting (Cooper, 1982). Sexually reproducing crops were excluded because Congress believed at that time that sexually reproducing crops did not breed true (U.S. Congress, OTA, 1989) and because monopoly power over staple crops might result (Kloppenburg, 1988). To acquire a plant patent (PP) under this act, a breeder must prove that the variety is distinct; it may then be described in botanical terms (as opposed to the regular patent descriptions). No one but the PP holder can asexually reproduce, sell, or use the plant (U.S. Congress, OTA, 1989). Nevertheless, under this act, protection does not extend to seed produced by the protected plant, and others may replicate the plant through sexual reproduction. A plant patent lasts for 17 years from the date of its issuance by the Patent and Trademark Office.

A second law, the Plant-Variety Protection Act (PVPA), was passed in 1970. By this date, Congress had become convinced that sexually reproducing varieties could breed true. This law provided patent-like protection for sexually reproducing varieties, excluding celery, tomatoes, bell peppers, cucumbers, carrots, and okra. Several soup-vegetable species were omitted because of objections raised by canners and freezers (Ruttan, 1982, p. 195). These objections arose from the supposition that costs as well as prices would escalate if these vegetables were protected. To gain a Plant-Variety Protection Certificate (PVPC), granted by the U.S. Department of Agriculture (USDA), a breeder must prove that the variety is distinct, uniform, and stable. Protection begins when the breeder applies for a certificate (as opposed to when it is issued) and lasts for 17 years. However, in some cases, the Secretary of Agriculture can declare a particular variety open for public use, such as during a drought or a devastating disease in a particular crop, so as to guarantee an adequate supply of food and fiber.

The PVPA contains two additional exemptions. The first exemption is that farmers whose primary occupation is growing crops can use their harvested seed for planting and selling (crop exemption). This exemption has two weaknesses. First, 49 percent of a harvest can be sold as seed. In the case of <u>Asgrow Seed Co.</u> v. <u>Kunkle Seed Co., Inc., et al.</u>, a district court ruled, and a Court of Appeals for the Federal circuit sustained, that the defendant could sell seed from a protected soybean variety because less than 50 percent of his income came from such sales. Yet, this defendant had already sold 1.42 million pounds of this seed variety and appeared to be increasing his farm production only to increase his seed sales (U.S. Congress, OTA, 1989, p. 75). Farmers can also trade such seed among themselves for services or for other seed. The second exemption is that protected varieties can be used in research programs.

The PVPA was amended in 1980, but not without heated debate concerning increasing industry concentration and higher seed prices (Doyle, 1985; Kloppenburg, 1988). The amendment extended the time of protection from 17 to 18 years to be consistent with the Union for the Protection of New Varieties of Plants (UPOV), and the protection now included the six vegetable crops.[6]

In the 1980 Diamond v. Chakrabarty case, the Supreme Court ruled that micro-organisms were patentable. Chakrabarty had genetically engineered a bacteria so that it degraded oil. In 1985, the ex parte Hibberd case extended the Chakrabarty ruling to plants, seeds, tissue cultures, hybrid plants, and hybrid seeds (U.S. Congress, OTA, 1989). Plants now could be protected with a utility patent (UP) provided they show utility, novelty, and nonobviousness. A UP applies to both asexually and sexually reproducing crops, lasts for 17 years, and is issued by the Patent and Trademark Office. In addition, a UP does not contain a crop or research exemption clause, and it can cover multiple varieties or individual components of a variety (Kloppenburg, 1988; U.S. Congress, OTA, 1989).

A UP has some disadvantages not found with a PP or PVPC. First, the patent holder must provide full disclosure of the technology, and provide a detailed description that meets regular patent requirements. Second, a patent holder must have the patented material stored in a depository. While depositories exist, most are set up for micro-organisms; few want to take on seeds or full plants for the time that is required, about 35 years. Third, the filing fee and issue fee for a UP are both much greater than for either a PP or a PVPC (Bagwell, 1989) (table 2). Fourth, protection begins only after the UP has been granted (U.S. Congress, OTA, 1989).

A final form of protection comes from trade secrecy. Trade secrecy is possible when information on the technology used to produce the output is not apparent in the result. In crops, trade secrecy is often relied on in preserving hybrid technology. The most famous example of this is hybrid corn.

The Seed Industry and Intellectual Property Rights

Before UP's were available, the choice of which type of IPR to use was fairly simple. A research organization would use a PP for an asexually reproducing plant, a PVPC for a sexually reproducing plant that breeds true, and trade secrecy for hybrids. Today, however, a research organization chooses an IPR

---

[6]UPOV provides an international framework for developing plant breeders' rights. The UPOV recommends protection be given for 15 or 18 years, depending on the crop. It was created in 1961 by Belgium, Denmark, France, the Federal Republic of Germany, Israel, Italy, the Netherlands, South Africa, Sweden, Switzerland, and the United Kingdom. The United States became a member in 1978 (Cooper, 1982).

Table 2--Fees for plant patents, Plant-Variety Protection Certificates, and utility patents, March 1989

Type of property rule	Filing fee	Issue fee	Maintenance fee After 3-1/2 years	After 7-1/2 years	After 11-1/2 years
			Dollars		
PP[1 2]	250	155	0	0	0
PVPC[1 3]	250	2,150	0	0	0
UP [1 2]	370	210	490	990	1,480

[1]PP, PVPC, and UP stand for plant patent, Plant-Variety Protection Certificate, and utility patent, respectively. All fees are as of March 1989. For the PP and UP, the filing and issue fees are half this cost for small entities, which are defined as organizations that have fewer than 500 employees. For the PVPC, the issue fee is split into $1,900 for examination and $250 for issue.

[2]Source: Bagwell, 1989.

[3]Source: USDA, AMS, 1989.

because of its need for broad protection and its attitude towards disclosure, licensing control, and research and crop exemption.

For example, a plant breeder of a greenhouse rose may decide to apply for a UP rather than a PP. The advantage of this choice is that the cut flowers are protected under a UP but not under a PP. The domestic cut flower industry loses much of its market to foreign countries that can produce cut flowers at a much cheaper rate than can the United States. In some cases, growers other than the PP holder take protected plants abroad to reproduce sexually and then export them back into the United States. The holders of the PP cannot prevent this practice and, hence, lose the returns on their investments in plant-breeding research.

Congress' Office of Technology Assessment (OTA) recently surveyed 39 biotechnology and seed companies, nurseries, and universities about their attitudes toward these different property rights. Except for universities, all found trade secrecy a good form of protection. Universities, however, felt such protection slowed the growth of technology and the exchange of germplasm. Biotechnology firms used all forms of protection, but generally preferred UP's to PP's and PVPC's because UP's have fewer exemptions and can be more broadly applied. Nurseries used both PP's and UP's, although they indicated that they will probably use more UP's in the future, since UP's provide more protection. Finally, nonaffiliated seed firms (those firms not affiliated with a chemical or pharmaceutical company) preferred PVPC's over

UP's because a UP has no research exemption clause, thus limiting germplasm exchange. However, if UP use in research were more available, such as it would be in compulsory licensing, nonaffiliated seed firms would favor UP's.[7] Affiliated seed firms like each of the three forms of protection: the PVPC's, UP's, and PP's.

The seed industry is made up of public and private sectors; each develops varieties for commercial release. To ensure a standard of seed quality and purity, each State has a seed-certifying agency which "establishes the procedure by which each class of seed may be produced and the standards of purity for each class of each crop within their state" (Poehlman, 1979, p. 450). The certification process varies among States. There are four classes of seed: breeder, foundation, registered, and certified. The last three vary in level of purity and generation level from breeder seed (see Poehlman, p. 450, for more information). The first three classes are ultimately used to produce certified seed, the class sold commercially. In addition, the Association of Official Seed Certifying Agencies, a national organization, sets minimum certification standards. Public varieties must go through the certification process before they are commercially distributed. Private varieties do not have to go through this process, although the Federal Seed Act requires all seed sold interstate to be labeled (by brand name, variety name, or the like). Only those varieties undergoing the certification process can be labeled "certified," which carries the guarantee that the seed will be of high purity, with known germination.

Seed firms compete against farmers and against each other. A farmer who intends to plant a newly released pure-line variety of winter wheat must purchase the seed from a dealer. If the pure-line variety has been introduced in earlier years, there is a choice: that of purchasing the variety from a seed dealer, of using seed from another farmer, or of using grain that was left from an earlier harvest. Purchased seed, compared with bin run seed, has a higher purity and a known germination. Farm grain storage facilities, if without adequate control of moisture or of insect or rodent damage, can reduce the bin run seed's germination rate. Purchased seed also allows farmers a much broader selection of seed varieties. The use of purchased seed is vital to the seed developers. It is the ability of seed firms to make an adequate return on their research and development that encourages such firms to develop new and better varieties.

Seed firms, aiming for adequate returns, develop seed varieties that offer the farmer production advantages over previous varieties. Such advantages include higher yields, resistance to new diseases, or an increased ability to endure weather extremes. The effect of such improvements can be impressive. Wheat yields increased from 10 bushels per acre in 1940 to 35 bushels per acre in 1980. Over half of this increase has been attributed to

---

[7]Compulsory licensing is the granting of a license for use of a patented plant or plant part to anyone who applies for a license.

public sector breeding programs (Dalrymple, 1980).[8] New rust diseases, a principal pathogen to wheat, appear about every 5 years, and therefore demand for new varieties resistant to those diseases follows the same pattern. Seed firms also strive to increase demand for their products. Federal and State extension services and seed-certifying agencies let farmers know what is available and encourage the buying of superior seed on a more frequent basis. The farmers also know that the seed-certifying agencies ensure seed of high quality. The demand for and supply of new varieties has helped seed firms gain market space.[9]

Estimating Productivity Differences Between Purchased and Bin Run Seed

Yield models have been developed, based on field, county, State, and national time series and cross-sectional data. Though many functional forms for yield functions have been proposed, general agreement across disciplines has concluded that inputs are likely to show diminishing and possibly negative returns.

Linear yield functions (with nonlinear measures of some independent variables) are the most common yield functions applied in economics (Menz and Pardey, 1983; Reed and Riggins, 1982; Lin and Davenport, 1982; Narayana and Parikh, 1987; Offutt, Garcia, and Pinar, 1987; and Houck and Gallagher, 1976), with the Cobb-Douglas the most common alternative (Huffman, 1974; de Janvry, 1972). In this analysis, the linear form was found superior to the Cobb-Douglas (as indicated by the adjusted R-squared). Thus, the general form of the estimated model is written as:

$$Y = b_0 + b_1 BIN + b_2 CORN + b_3 LEG + b_4 FAL + b_5 LnN + b_6 RATE + b_7 RATESQ + b_8 MAN + b_9 NOTIL + b_{10} HERB, \quad (1)$$

where Y is the bushel per acre yield of the sampled field, BIN is a zero-one dummy variable indicating use of bin run seed; CORN, LEG, and FAL are zero-one dummy variables indicating the previous crop as corn, a legume such as alfalfa or soybeans, or fallow, respectively; LnN is the natural logarithm of the nitrogen application rate in pounds per acre; RATE is the seeding rate in pounds per acre; RATESQ is the seeding rate squared; MAN is a

[8]The public sector was the principal developer of wheat varieties until the PVPA was passed in 1970. The number of private wheat varieties used on more than 500,000 acres jumped from 4 in 1979 to 10 in 1984 (Dalrymple, 1988, p. 34). Since one can expect a 10- to 15-year lag on agricultural research and development, the effect of private sector seed varieties has just begun.

[9]Of course, advertising, the extension service, and the seed-certifying agencies also benefit public sector plant-breeding programs. The issue of public and private sector competition is a complicated one, and is not addressed in this report.

zero-one dummy with one indicating manure use; NOTIL is a zero-one dummy with one indicating no-till seeding; and HERB is a zero-one dummy with one indicating herbicide use.

Data

Observations on cropping practices come from USDA's 1987 and 1988 Cropping Practices Survey. This survey is an area frame sample of planted acreage that gathers information on inputs used in production of winter wheat and other crops. Only the major producing States are surveyed.

Information is gathered on yield, seed source, seeding rate, previous crop, tillage practices, fertilizer use, and herbicide applications. The number of observations vary by State but are usually more than 100 for any one State. The total number of observations for 1986/87:1987/88 are 294:304 for the Pacific Northwest, 583:786 for the Plains States, and 299:336 for the Corn Belt. Estimation is done by weighted least squares, with weights equal to the inverse of the probability of being selected, to account for differing sampling rates across States (Holt, Smith, and Winter, 1980).

Results

Regression results are presented in table 3. Some key points are:

1. The BIN coefficient was significantly different from zero only in the Plains region in 1986/87 and in the Pacific Northwest in 1987/88.

2. The RATE and RATESQ coefficients were most significant in the Pacific Northwest in both seasons.

3. The signs on the coefficients for RATE and RATESQ in the Corn Belt in both seasons, on HERB in the Corn Belt in 1986/87, and on FAL in the Pacific Northwest in 1987/88 are contrary to what one would expect.

4. The adjusted R-square indicates that over half of the variation in yields in the Pacific Northwest is explained by the estimated model, 17 and 20 percent in the Plains States is explained, but less than 10 percent in the Corn Belt is explained.

Table 3--Estimation results on winter wheat yields by region, 1986/87 and 1987/88

Variable	Corn Belt 1986/87	Corn Belt 1987/88	Plains 1986/87	Plains 1987/88	Pacific Northwest 1986/87	Pacific Northwest 1987/88
Intercept	64.1*	59.9	23.1	17.1	-43.1	-43.3
	(4.66)*	(5.86)**	(3.75)**	(5.91)**	(3.45)**	(2.22)*
BIN	-1.61	-2.13	-3.54	-1.17	-2.11	-6.14
	(.94)	(1.41)	(2.56)*	(1.31)	(.94)	(2.39)*
RATE	-.25	-18	.09	.16	.50	.65
	(1.45)	(1.27)	(.61)	(1.83)	(6.49)**	(3.49)**
RATESQ	.0008	.0005	-.0008	-.0007	-.0006	-0.0015
	(1.25)	(1.04)	(.77)	(1.14)	(5.43)**	(1.39)
CORN	8.53	5.53	4.74	10.6	15.3	12.4
	(2.58)**	(2.18)*	(1.30)	(2.64)**	(.77)	(1.13)
LEG	9.78	4.06	10.1	4.24	22.2	48.7
	(3.74)**	(2.29)*	(5.43)**	(1.44)	(5.39)**	(2.37)*
FAL			11.6		.9	-10.2
			(10.5)**		(.22)	(3.26)**
LnN	.23	.91	1.46	2.64	13.6	12.6
	(.14)	(.93)	(1.98)*	(9.30)**	(6.11)**	(8.69)**
MAN	8.77	8.74				
	(2.48)*	(2.48)*				
NOTIL		-12.3		-17.1	8.3	12.8
		(2.88)**		(3.45)**	(2.95)**	(1.13)
HERB	-7.05					
	(2.41)*					
Adjusted R-square	.075	.045	.199	.172	.616	.520
Observation	299	336	583	786	294	304

* Significant at the 95-percent level.
** Significant at the 99-percent level.
Note: t-statistic is in parenthesis.
BIN = Dummy variable indicating the use of bin run seed.
RATE = Seeding rate measured in pounds per acre.
RATESQ = Square of the seeding rate.
CORN = Dummy variable indicating corn as the previous crop.
LEG = Dummy variable indicating soybeans or alfalfa as the previous crop.
FAL = Dummy variable indicating no crop the previous season.
LnN = Natural logarithm of the pounds of nitrogen applied per acre.
MAN = Dummy variable indicating the application of manure.
NOTIL = Dummy variable indicating no tillage of the previous crop stubble.
HERB = Dummy variable indicating herbicide use.

Implications of Seed Source

The use of purchased seed was expected to positively affect yields in all three regions in both growing seasons. Relationships were as expected, but the statistical significance of the coefficients varied among regions and across years. Use of certified seed contributed, in 1986/87, a significant 3.5 bushels per acre on average to yields in the Plains States, and in 1987/88, 6.1 bushels per acre on average in the Pacific Northwest. These yield differences represent approximately 11 percent of annual average yields for both regions. Purchased seed was used on a much lower percentage of acreage in the Plains States than in the Corn Belt and Pacific Northwest.

To understand the implications of the estimated coefficients on BIN to private sector seed development, we focus on two questions. First, is agriculture's present level of purchased seed use cost-effective? And second, what factors influence the choice of purchased seed other than its output? The answer to this last question might help seed firms encourage use of purchased seed.

The Yield Effect of Bin Run Seed

In the 1986/87 results, the BIN coefficients are negative across all three regions, but not statistically different from zero for the Pacific Northwest or the Corn Belt. Negative coefficients suggest that bin run seed produced lower yields, as expected. However, the statistical insignificance of the BIN coefficient for the Pacific Northwest and the Corn Belt suggests that the average quality of their bin run seed was quite high. Since farmers in the Plains planted a much smaller portion of their wheat acreage with purchased seed, it is not surprising that more significant yield gains could have been made there by eliminating the lowest quality bin run seed.[10]

In the 1987/88 results, the BIN coefficient remained negative. But now, yields in the Pacific Northwest, instead of the Plains, responded significantly to seed source. The loss in significance of the Plains coefficient may be due to the greater portion of acreage planted with purchased seed. Wheat farmers in the Plains increased the amount of purchased seed from 4,199,000 planted acres (13 percent) in 1986/87 to 10,148,000 planted acres (33 percent) in 1987/88, as product price and export demand for hard red winter wheat increased (table 1). Approximately 60 percent of the acreage in the other two regions was planted with purchased seed for both seasons.

Factors Influencing the Choice of Seed Source

A primary factor that probably influences the choice between bin run and purchased seed is profit. From the estimated coefficients, the cost-effectiveness of purchased seed can be seen by comparing the revenue gained from the greater yield with the higher costs of purchased seed. Negative coefficients on BIN indicate that lower yields are obtained from bin run seed. The two cases where statistically significant yield differences were found are examined below to provide insights on the potential magnitude of the cost-effectiveness of purchased seed.

The coefficient on BIN in 1986/87 for the Plains States indicates a gain in yield of 3.5 bushels per acre when using purchased seed instead of bin run seed. The value of this additional yield, based on a conservatively low output price of $2.17 per bushel, translates into a $7.60-per-acre gain. On the cost side, a

---

[10]The coefficient on a zero-one dummy, such as BIN, estimates the average yield differences found between the two alternatives. Thus, on average, farmers using certified seed had 3.5 bushels per acre higher yields than farmers using bin run seed. Since bin run seed varies in quality, some bin run seed may have yielded substantially lower than this 3.5-bushel-per-acre difference and some higher.

Table 4--Winter wheat acreage planted and yields by region, 1986/87 and 1987/88

Region	Acreage planted 1986/87	Acreage planted 1987/88	Yield 1986/87	Yield 1987/88
	Thousand acres		Bushels per acre	
Corn Belt:				
Arkansas	930	1,120	41.0	53.0
Illinois	1,100	1,300	59.0	54.0
Indiana	750	840	58.0	50.0
Missouri	900	1,650	46.0	50.0
Ohio	850	1,000	58.0	50.0
Total acreage	4,530	5,910		
Weighted average[1]			52.4	51.4
Plains:				
Colorado	3,100	2,500	37.5	33.0
Kansas	10,700	10,200	37.0	34.0
Montana	2,300	2,450	36.0	19.0
Nebraska	2,200	2,300	44.0	36.0
Oklahoma	7,200	7,000	27.0	36.0
Texas	6,800	6,300	28.0	28.0
Total acreage	32,300	30,750		
Weighted average[1]			33.3	32.1
Pacific Northwest:				
Idaho	860	820	75.0	66.0
Oregon	780	700	66.0	71.0
Washington	1,900	1,850	57.0	62.0
Total acreage	3,540	3,370		
Weighted average[1]			63.4	64.8

[1]Regional average is weighted by planted acreage.
Source: USDA, NASS, 1989.

seeding rate of about 1 bushel per acre[11] and per-bushel seed costs of certified seed and bin run seed at $7.38 and $2.17,[12] respectively, translate into a per-acre seed cost difference of $5.21 (tables 4 and 5).[13] Thus, per-acre net income would have

[11]No statistical difference was found in seeding rates between bin run and purchased seed.

[12]Bin run seed costs given here are conservative, since these do not include any storage, cleaning, or treatment costs.

[13]Prices received were the prices listed in September of that season, since this is the latest price farmers could use as an expected price for their crops. Prices paid were the actual prices paid for seed that year. All prices cited in the text are these prices, which are found in table 5.

Table 5--Prices paid for certified seed and prices received for winter wheat by region, 1986/87 and 1987/88

Region	Prices paid for certified seed 1986/87	Prices paid for certified seed 1987/88	Prices received for harvest 1986/87	Prices received for harvest 1987/88
	Dollars per bushel			
Corn Belt:				
Arkansas	5.91	6.06	2.35	3.09
Illinois	7.36	7.55	2.27	2.50
Indiana	7.36	7.55	2.32	2.53
Missouri	5.81	5.83	2.24	2.45
Ohio	6.29	6.46	2.24	2.58
Weighted average[1]	6.55	6.60	2.28	2.61
Plains:				
Colorado	7.36	7.55	2.12	2.30
Kansas	7.46	7.65	2.14	2.38
Montana	5.91	6.06	2.32	2.57
Nebraska	7.46	7.65	2.32	2.30
Oklahoma	6.98	7.16	2.16	2.40
Texas	8.14	8.35	2.15	2.32
Weighted average[1]	7.38	7.55	2.17	2.37
Pacific Northwest:				
Idaho	6.69	6.86	2.40	2.63
Oregon	6.69	6.86	2.43	2.68
Washington	6.59	6.76	2.27	2.51
Weighted average[1]	6.64	6.81	2.34	2.58

[1]Regional prices paid are acreage-weighted averages based on acreage planted in the current crop year. Regional prices received are acreage-weighted averages based on acreage planted in the previous crop year. Both prices paid and prices received are those observed by farmers at planting.

Source: USDA, NASS, June 1988.

averaged $2.39 ($7.60 - $5.21) higher on the bin run acreage had it been planted to purchased seed.

By similar calculation, the difference between the planting costs of purchased seed and bin run seed for the Pacific Northwest in 1987/88 can be determined as $4.24 per acre. If a net value of $2.58 per bushel is assumed, the gain in yield of 6.15 bushels per acre translates to a $15.87-per-acre gain in potential revenue and a net gain in profit of $11.59 per acre. It appears to have been profitable for farmers in the Plains in 1986/87 and in the Pacific Northwest in 1987/88 to use purchased seed. For the seed firm, any greater use of purchased seed increases the return for its research in seed development.

The regional variations in the relative differences between grain and seed prices (and, thus, cost-effectiveness of purchased seed) may explain, in part, the greater use of certified seed in the Pacific Northwest and the Corn Belt (tables 4 and 5). On average, farmers in the Pacific Northwest and Corn Belt paid lower prices for purchased seed and received higher prices for grain (which could have been used for bin run seed). These two factors combined decreased the cost savings of using bin run seed. Furthermore, the higher prices these farmers expected to receive (relative to the Plains States) increase the value of any gain in yield offered by purchased seed. As a result, Pacific Northwest and Corn Belt farmers planted a greater portion of purchased seed than bin run seed.

Higher prices for the hard red winter wheat may explain the large increase in use of purchased seed in 1987/88 for the Plains. Average prices increased from $2.17 per bushel in September 1986 to $2.37 per bushel in September 1987, and acreage using purchased seed increased from 13 percent to 33 percent of the total wheat land planted. Increased exports of hard red winter wheat to the Soviet Union, China, and Latin America, due to the Export Enhancement Program, could have contributed to this price increase. The previous two seasons experienced record 15-year lows in hard red winter wheat export activity (USDA, ERS, Sept. 1987). In addition, wheat importers may demand high-quality wheat, with wheat grain free of weed seed. The purity of certified seed is one way to obtain a high-quality harvest.

Some Potential Determinants of Seed Choice

Additional factors affect seed choice. Some of these factors are mentioned here, although such topics need further research.

First, seed choice may be affected by regional differences in the costs of storing and cleaning seed. In the above discussion, storage and cleaning costs of bin run seed are not included because we have no data on such costs. But, such costs could make the use of purchased seed even more profitable. Also, storage and cleaning costs probably vary across regions. In particular, farmers who produce wheat on a large scale, such as in the Plains States, can spread their costs--of grain storage, of cleaning facilities, and of seed germination rate tests--across a greater quantity of seed. This would make bin run seed more competitive in those areas. Grain elevators that deal with a large number of wheat producers may also achieve economies of scale in grain cleaning.

Another factor that affects farmers' choice of seed is advertising. In the Pacific Northwest, State certifying agencies actively promote use of certified seed. In 1984, Washington State extension agents examined 96 samples of winter wheat seed, 25 of which were certified, from drill boxes, trucks, and bins. The certified seed was of good quality. However, the bin run seed varied greatly in quality, and it also suffered from high levels of weed seed and seed from other crops.[14] This survey indicates that some bin run seed is of considerably lower quality than certified seed. The BIN coefficient in 1987/88 in the Pacific Northwest certainly supports this difference. The Washington State Crop Improvement Association, Inc., uses these results to promote certified seed sales (Washington State Crop Improvement Association, 1986).

In the Corn Belt, an extensive commercial communication system brings together the corn seed dealer and the farmer, since farmers purchase all corn seed. Corn varieties are highly location-specific, and, hence, vary considerably across even such small areas as counties. Corn seed companies have set up a network of seed dealers in these locations, who sell their seed while acting as "extension agents" on behalf of the seed companies. As a result, seed dealers and farmers have a close relationship. This relationship lets seed dealers inform the farmers of the advantages of purchased seed, while familiarity with seed dealers may encourage farmers to follow the dealers' advice.

Implications of Seed Research and Development

This study suggests that growth in the market for purchased seed and the ensuing growth in returns on seed development depend on commodity price trends, as well as on other factors. However, the regions vary in how they respond to different circumstances. Farmers in the Plains seem especially responsive to product price. There, purchased seed acreage increased when product prices increased.

Of the three regions, the Plains holds the biggest potential for market growth in purchased seeds. The Plains States not only have the smallest portion of their acreage planted with purchased seed, but they also have the largest area of winter wheat acreage (tables 1 and 4). If product prices increase due to growing export or domestic demand, the purchased seed market in the Plains could significantly increase. Seed companies in the Plains could gain market share by employing such tactics for increasing seed sales as those that are presently being used in the other regions. Also, the estimated coefficients on BIN for the Plain States suggest that farmers also could gain measurably by increasing their use of purchased seed.

Since Federal and State budgets are tight, a policy that helps the private sector find adequate returns on investment could

---

[14]Weeds were cheatgrass, fiddleneck, gromwell, and wild oats. Other crops were barley and oats. In one sample, there were over 500 weed seeds present in a pound of bin run seed, which, at a seeding rate of 60 pounds per acre, translates to 30,000 weed seeds per acre (Washington State Crop Improvement Association, Inc., 1986). Non-desirable seeds decrease both yield and quality of harvest, and both decrease the return to the farmer.

substitute for some direct Government spending on research and development. However, because of the long lagtime between the development and the release of new seed varieties, the effectiveness of the PVPA, the PPA, and UP's in promoting private sector seed development is hard to assess. From the Asgrow Seed Co. v. Kunkle Seed Co., Inc. ruling, we know that the crop exemption clause weakens the protection the PVPA provides. Also, from the 1989 OTA survey of various research organizations, we know that many such organizations favor the protection of a UP over that of a PVPC and, therefore, may make greater use of UP's than PVPC's.

Some researchers have supposed that a social loss will occur if UP's are used in lieu of PVPC's. Germplasm exchange may then decrease, which may decrease the number of varieties to be released or reduce the sources of disease resistance available for quick development. Farmers may lose by a reduced selection of seed varieties and by increased seed prices. Some social scientists claim that, with greater use of UP's, smaller firms cannot compete, and therefore, the seed industry will come to consist of a few large firms. With such limited competition, seed prices may increase.

However, others argue that the opposite will happen: Increased protection from the UP's will increase incentive to invest, resulting in more and better quality products; germplasm exchange will not decrease but only become more formal; and, with the UP's full disclosure of technology, more technological knowledge will be transferred than occurs with a PVPC, and other research organizations may gain. If these positive effects of the UP's should come to pass, then the major difference between a UP and a PVPC will be the crop exemption. The UP will benefit firms in limitation of seed sales, greater enforcement, and legal costs.

The provision of incentives for private research and development (R&D) programs can encourage expansion in seed technology. But, such private R&D should not replace public R&D programs, since social returns to public R&D are quite high (Ruttan, 1982; Evenson, Waggoner, and Ruttan, 1979). This report shows that there is more involved in farmers' seed selection than a trading off of the net profitability of purchased seed over bin run seed. Other factors--extension and other public efforts among them--play an important part in encouraging the use of purchased seed.

In the Plains, particularly, the use of certified seed could increase farm incomes as well as encourage private sector investment in new wheat varieties.

Implications of Other Factors Affecting Wheat Yields

Regression results also provide insight into the yield effect of other variables. The signs of the statistically significant coefficients were as expected except for FAL, a dummy indicating that the land was fallow in the previous growing season. Within each equation, variables that had t-statistics of less than one were dropped from the model (table 3).

Seeding rates were significant in the Pacific Northwest and indicate that farmers were not overseeding. Seeding rates averaged under 89 pounds per acre in Idaho and Oregon and around 65 pounds per acre in Washington.

Yield tended to be higher on fields where wheat was raised following corn or a legume such as soybeans or alfalfa. While a positive effect on yield was expected from the nitrogen fixing of the legumes, we only suspected that nutrient carryover from corn production would positively affect yields.

The nitrogen application rate was measured as the natural logarithm of the pounds applied to allow for positive but diminishing returns. The results for the Plains and the Pacific Northwest support the assumption, but results for the Corn Belt show no significant yield effect from nitrogen. However, if nitrogen carryover after corn and soybeans provides most of the nitrogen needs of wheat in the Corn Belt, then the lack of significance of LnN should be expected. In fact, the USDA's Cropping Practices Survey Data indicate that, in the Corn Belt, 89 percent of the acreage of winter wheat followed a corn or soybean crop, compared with less than 5 percent in the Pacific Northwest or in the Plains States. Furthermore, the significance of MAN for the Corn Belt suggests that, in this district, farmers effectively use this other source of nitrogen, which also is not measured by LnN.

Finally, the effect of no-till agriculture on wheat yields was uncertain. Many studies have been carried out on the productivity effects and cost-effectiveness of no-till and conservation tillage, but no firm conclusion has been reached (see Maclean, 1984, for a bibliography). The differing effects by region may indicate why some controversy continues, but suggest no conclusions on this issue.

References

Bagwell, Robert. Personal communication, Patent and Trade Office, Sept. 1989.

Butler, L.J., and B.W. Marion. The Impacts of Patent Protection on the U.S. Seed Industry and Public Plant Breeding. National Central Regional Research Center, North Central Regional Research Publication 304. Sept. 1985.

Cooper, I.P. Biotechnology and the Law. New York: Clark Boardman Company, Ltd., 1982.

Dalrymple, D.G. Development and Spread of Semi-Dwarf Varieties of Wheat and Rice in the United States. AER-425. U.S. Dept. Agr., Econ. Res. Serv., 1980.

_______________. "Changes in Wheat Varieties and Yields in the United States, 1919-1984," Agricultural History 62 (1988): 20-36.

de Janvry, A. "Optimal Levels of Fertilization Under Risk: The Potential for Corn and Wheat Fertilization Under Alternative Price Policies in Argentina," American Journal of Agricultural Economics (1972): 1-10.

Doyle, J. Altered Harvest. New York: Viking Press, 1985.

Evenson, R.E., P.E. Waggoner, and V.W. Ruttan. "Economic Benefits from Research: An Example from Agriculture," Science 205 (1979): 1101-07.

Holt, D., T.M.F. Smith, and P.D. Winter. "Regression Analysis of Data from Complex Surveys," Journal of the Royal Statistical Society Ser. A, 143 (1980): 474-87.

Houck, J.P., and P.W. Gallagher. "The Price Responsiveness of U.S. Corn Yields," American Journal of Agricultural Economics 58 (1976): 731-34.

Huffman, W.E. "Decision Making: The Role of Education," American Journal of Agricultural Economics 56 (1974): 8597.

Kidd, G.H. "Seed-Delivery System for Plant Biotechnology" Ag. Biotech 89. Proceedings. Arlington, VA, Mar. 28-30, 1989.

Kloppenburg, J.R. First the Seed. Cambridge, England: Cambridge Univ. Press, 1988.

Lin, W., and G. Davenport. "Analysis of Factors Affecting Corn Yields," Feed Outlook and Situation Report. FdS-285. U.S. Dept. Agr., Econ. Res. Serv., May 1982, pp. 9-14.

Maclean, J. "Conservation Tillage, Quick Bibliography Series." U.S. Dept. Agr., National Agricultural Library, 1984.

Menz, K.M., and P. Pardey. "Technology and U.S. Corn Yields: Plateaus and Price Responsiveness," American Journal of Agricultural Economics 62 (1983): 874-88.

Narayana, N.S.S., and K.S. Parikh. "Estimation of Yield Functions for Major Cereals in India," Journal of Quantitative Economics 3 (1987): 287-312.

Offutt, S.E., P. Garcia, and M. Pinar. "Technological Advance, Weather, and Crop Yield Behavior," North Central Journal of Agricultural Economics 9 (1987): 49-63.

Poehlman, J.M. Breeding Field Crops. Westport, CT: AVI Publishing, 1979.

Reed, M.R., and S.K. Riggins. "Corn Yield Response: A Micro-Analysis," North Central Journal of Agricultural Economics 6 (1982): 95-104.

Ruttan, V.W. Agricultural Research Policy. Minneapolis: Univ. of Minnesota Press, 1982.

U.S. Congress, Office of Technology Assessment. New Developments in Biotechnology. Patenting Life--Special Report. OTA-BA-370. Apr. 1989.

U.S. Department of Agriculture, Agricultural Marketing Service. Plant Variety Protection Office Official Journal 17 (1), 1989.

______________, Economic Research Service. Wheat Situation and Outlook Report. WS-278. May 1987.

______________, Economic Research Service. Wheat Situation and Outlook Report. WS-279. Sept. 1987.

______________, Economic Research Service. Wheat Situation and Outlook Report. WS-281. May 1988.

______________, Economic Research Service. Wheat Situation and Outlook Report. WS-282. Aug. 1988.

______________, National Agricultural Statistics Service, Agricultural Statistics Board. Agricultural Prices: 1987 Summary. June 1988.

______________, National Agricultural Statistics Service, Agricultural Statistics Board. Crop Production: 1988 Summary. Jan. 1989.

Washington State Crop Improvement Association, Inc. "Survey Compared Seed Quality." Mimeo. Oct. 1986.