This is to certify that the

dissertation entitled

The Impacts of the 1930 Plant Patent Act

on Private Fruit Breeding Investment

presented by

Judith I. Stallmann

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Agricultural Economics

A. Allan Schmid
Major Professor

Major professor

Date October 25, 1986

IMPACTS OF THE 1930 PLANT PATENT ACT ON PRIVATE FRUIT BREEDING INVESTMENT

By

Judith I. Stallmann

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1986

ABSTRACT

IMPACTS OF THE 1930 PLANT PATENT ACT
ON PRIVATE FRUIT BREEDING INVESTMENT

By

Judith I. Stallmann

Patents are considered most effective in increasing research investment when imitation of an invention is expected to be rapid and widespread, or when invention costs are high relative to oligopolistic returns. But for the patent to be effective in these circumstances, the returns must be appropriable.

Breeding of fruit species has high investment costs because of the juvenile period and the size of the plant. Many plants also have high exclusion costs due to the ability of the farmer/grower to produce and use the needed genetic material. Long-term investments and inability to police the patent lower the present value of income.

For this reason the 1930 Plant Patent Act has had very little impact on private investment in fruit breeding. To lower costs, private breeders tend to select species with smaller plant size and shorter juvenile periods, use resources frugally and shorten testing time. But returns are very low and most often negative. Most private breeders began breeding as a hobby or in response to a particular problem in the species. Although they were not economically motivated when they began work, most apply for a patent as a means of obtaining some repayment for their costs.

Because of high exclusion costs, nurseries are severely contrained in their ability to pass royalty payments on to the grower.

Only large nurseries carry patented plants and appear to pay royalty charges out of their economies of scale cost savings.

As technological advances such as genetic engineering shorten the time needed to breed a new variety, private investment may increase. Alternatives to patents for increasing investment in fruit breeding include public breeding or public subsidies to private firms (both direct and indirect). New institutional forms such as vertical integration of growing and breeding also hold promise. Public testing of private varieties should also be considered.

Patenting of public sector varieties may provide additional research funds for major programs but is unlikely to provide any substantial funds for programs directed at smaller markets. In addition, patenting may destroy the current perception of the public sector as an unbiased judge of variety quality, particularly if the breeder benefits from the patent. Also, the current division of royalties in the public sector is such that it may encourage public breeders to produce lower quality varieties.

ACKNOWLEDGMENTS

I would like to give a particular thanks to my dissertation advisor Al Schmid, whose piercing logic kept me from making several major breakthroughs in economic theory. I would also like to thank the other members of my committee--Larry Libby, Mike Weber, Frank Dennis, and Bruce Pigozzi--who were always ready to provide insights into arcane questions and do so with a sense of humor. The support of Resources for the Future, the USDA and the Department of Agricultural Economics at Michigan State University was greatly appreciated.

A special thanks goes out to the private fruit breeders who spent hours with me in their test plots and on the telephone: Hershel Boll, R. T. Dunstan, Norman Good, Lon Rombough, Lucille Merrill, Bill Smith and Elmer Swenson. I would also like to acknowledge the assistance of the many public breeders and private nurserymen who consented to personal interviews, and all the respondents to the mail survey.

It is customary to thank one's spouse for the extra considerations given and the additional burden's borne. In reality, my spouse was not overly understanding and considerate during this process. Rather he insisted that I do my share of the housework so that he would have time to write his own dissertation. I suspect that he beat me by ten days in our race to defend through sabotage, deliberately using more dishes when it was my turn to wash and more paper plates when it was his. If misery loves company, I had good company.

Eileen van Ravenswaay has been a special friend throughout this period. I would also like to thank Carolyn McCommon and Edgardo Derbes for their words of wisdom which have kept me going through the bleakest times: "It's the ticket to the circus" and "That's life in the tropics, kiddo".

TABLE OF CONTENTS

<u>Appendix</u>

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

BACKGROUND OF THE RESEARCH

1.1 Need For The Research

The United States Congress in 1980 held hearings to consider amendments to the 1970 Plant Variety Protection Act, which granted originators of new varieties of sexually propagated plants exclusive rights to those varieties for a period of time. The Act had been passed without discussion in the closing days of the 1970 Congress. During the 1980 hearings to amend the Act, members of Congress were surprised to hear witnesses questioning the law itself, rather than addressing the proposed amendments. Opinions were quite polarized. Opponents predicted the future monopolization of food production, increasing dependence on chemicals, and declines in genetic diversity which would adversely affect long-run food production. Proponents predicted that the stimulation of investment in genetic improvement would lead to the creation of wonder plants, increasing food supplies, and more efficiency in the food system.

That same year, the Supreme Court held in Diamond v. Chakrabarty 100 S.Ct. 2204, 2210 (1980) that man-made micro-organisms were patentable. This decision also caused considerable debate in some circles. Since this research began, the decision by the Patent Office Board of Appeals in Ex parte Hibberd 227 USPQ 447 (1985) has held that all plants are eligible for patent protection. Laws similar to the

1978 Plant Variety Protection Act were also passed in Western European countries during the sixties and seventies.

However, these are not the first forays into the unknown territory of intellectual property rights in plants[1]. Asexually reproduced plants have been patentable in the United States since 1930 under an amendment to the Patent Act. The Supreme Court did consider this law in making its 1980 decision extending patent protection to micro-organisms, but the debate surrounding the 1970 Plant Variety Protection Act has completely ignored its existence.

Of the countries granting intellectual property rights in plants, an economic analysis of the laws has been attempted only for the United States (Butler and Marion 1985; Perrin, Kunnings and Ihnen 1983). Both Canada and Australia have attempted to evaluate _a priori_ the impacts of such legislation as part of their parliamentary consideration of such legislation. (For Australia see Godden 1981, and Senate Standing Committee on Natural Resources 1984. For Canada see Cooper 1984, and Lyons and Bagleiter 1984). The _a priori_ analyses have been based upon theoretical propositions and analogy with patent law impacts in other sectors of the economy and in other countries.

Congressional debate on the 1970 Plant Variety Protection Act did not include reference to the 1930 Plant Patent Act

---

[1]'Intellectual property rights' refers to a group of laws which establish property rights in, or control over, the _use_ of an idea. An idea itself cannot be the subject of a property right unless it is put into tangible form such as paintings, writings, blueprints, machines, products, plants, etc. Conferring intellectual property rights means to give the originator of the idea control over the tangible products resulting from that idea. There are different kinds of intellectual property rights, including trademarks, copyrights, patents, design patents, and plant variety protection. Conferring of an intellectual property right is often called granting protection.

and its impacts, although an empirical study may have been instructive, since the two laws are analogous structures. As a result of the controversy Congress did fund a study of the impacts of the 1970 Plant Variety Protection Act. The investigators concluded that a comprehensive assessment was difficult after only ten years given the time lag needed for breeding and disseminating new varieties of plants (Butler and Marion 1985). An assessment of the economic impacts of the 1930 Plant Patent Act may now be possible given that 50 years have elapsed since its passage.

1.2 Problem Statement

Intellectual property rights have been a source of controversy for several centuries. The equivocal position of many economists concerning intellectual property rights is due to uncertainty regarding the costs and benefits of the system. This position was best stated by Machlup while addressing the specific question of the impact of the patent system for a large industrial country such as the United States.

> If we did not have a patent system, it would be irresponsible, on the basis of our present knowledge of its economic consequences, to recommend instituting one. But since we have had a patent system for a long time, it would be irresponsible, on the basis of our present knowledge, to recommend abolishing it. (Machlup 1958).

The issue of intellectual property rights in plants is important today as many of the major national economies of the world now grant certain protection to some plants. The question has become more important in the United States since the 1980 Supreme Court decision <u>Diamond v. Chakrabarty</u> extending patent protection to micro-organisms and the 1985 Patent Office Board Of Appeals decision <u>ex parte Hibberd</u> extending patent protection to all plants . The United States now has three laws granting protection to plants, but not all plants can be protected under all laws. Most asexually and sexually reproduced plants are protectable under two laws. Thus the originator may choose under which law to file for protection. Micro-organisms, hybrids and tubers are protected only under the Patent Act.

Although extension of protection to plants has moved fairly rapidly, very little empirical information exists concerning intellectual property rights in plants. This study specifically examines the impact on fruit breeding of the 1930 Plant Patent Act, which allows the patenting of asexually reproduced plants.

1.3 Objectives Of The Study

The objectives of the study are to:

1. Develop a framework for analyzing the impacts of granting intellectual property rights in plants
2. Apply the framework to a specific law (the 1930 Plant Patent Act)
3. Draw implications from the analysis as to the impacts of other laws granting intellectual property rights in plants. The analysis should also be useful to other countries, such as Canada and Australia, which are contemplating enacting protection for plants.

1.4 Research Plan

This study employs the public choice paradigm of situation, structure, conduct and performance. Situational characteristics of plants which are of interest include the investment costs required for breeding and the exclusion costs of reproductive materials. The economic actors whose conduct is of interest are originators of new varieties, nurseries and commercial fruit growers. The structure is the 1930 Plant Patent Act. Performance is the result of conduct by the actors whose opportunity sets are determined by the interaction of structure with situation.

The background of the 1930 Plant Patent Act is discussed in Chapter Two and the economic aspects of the various historical debates are examined. Chapter Three reviews the literature on the impact of patents with specific emphasis on the question of intellectual property rights in plants. This includes an analysis of the situational characteristics of plants which interact with the patent structure to influence the impacts of the intellectual protection granted.

The institutional framework for the analysis is explained in Chapter 4. The research design was modified after preliminary research indicated that investment costs were more important than exclusion costs in determining private investment in breeding. The secondary data available were not detailed enough to address some of the research questions; therefore additional data were obtained through a mail survey of private and public fruit breeders and nurseries were surveyed by mail.

The analysis of data and results of the study are presented in Chapters Five and Six. The implications of this research for other laws and for other types of plants are discussed in Chapter Seven. The public sector has been moving in the direction of seeking more protection for its varietal releases. This raises ethical as well as economic issues.

1.5 Definitions

The following definitions will be used in the discussion of the research. "Variety" will be used to include variety, strain and hybrid since such a definition was used by Congress in debates concerning the 1930 Plant Patent Act. The definition for the 1930 Act differs from that used in the 1970 Plant Variety Protection Act and from that used by horticulturalists. "Tree" should be understood to include trees, vines and plants. "Orchard" includes orchards, vineyards and fields.

The time from first breeding investment until the variety is offered for sale is development time. Much of the literature on patents divides this period into research and development periods. Initial experiments are carried out during the research period, while the commercial product is constructed in the development period. This distinction has little practical meaning in the case of asexually reproduced plants, since once the plant is produced it does not require further development.

CHAPTER II

BACKGROUND OF THE 1930 PLANT PATENT ACT

2.1 History Of Horticulture In The Nineteenth Century

Horticulture went through several cycles of growth and decline in the United States during the eighteenth and nineteenth centuries. These cycles were related principally to economic cycles and the spread of fruit diseases. The latter created a demand for disease resistant varieties. Although little scientific work had been done in this area, growers observed that some varieties were resistant to a disease while others succumbed rapidly. For instance, in the late 1800s pear growers shifted production from higher quality European pears to lower quality Asian pears which had higher disease resistance (Magness 1937).

Response to outbreaks of disease occurred at several levels. State and Federal Departments of Agriculture began eradication campaigns--usually destroying all infected and abandoned trees. Research was sponsored at the Land Grant Universities and within the United States Department of Agriculture (USDA) to determine causes of the diseases. A second line of attack was to find or develop disease resistant varieties. The United States had been importing plants from around the world since becoming a nation. The USDA took over this function and funded plant explorations, particularly to China and Russia, in hopes of finding disease resistant varieties. Breeding was used to develop new varieties with disease resistance. The science of breeding was not well developed and Mendel's work on genetics was not rediscovered until 1900. Although the crossing of different varieties was known to produce new varieties with some combination of the parental characteristics, how or why these characteristics sorted out was unknown. Private individuals had been breeding new fruit varieties for over a century. Public breeding programs were begun in the Land Grant Universities and in the USDA between 1890 and 1935 (Table 2.1).

During the nineteenth century many private breeders, both in Europe and in the United States created new fruit varieties. These were mainly educated men and gentleman farmers for whom breeding was a hobby. Methods ranged from open pollination to controlled cross pollination. Some breeders made a few crosses over a short time period while others produced thousands of seedlings over a lifetime. The most famous private breeder, Von Mons of Belgium, began breeding pears in 1785. He is said to have had more than 80,000 seedling trees in 1825 and over his lifetime introduced more than 400 varieties of pears (possibly not all of his own development), 40 of which were of lasting value (Magness 1937).

Breeders in the United States worked on a smaller scale, but made many valuable contributions. Over 100 breeders who worked mainly in the nineteenth century can be documented (Bailey 1919, Darrow 1966, Hedrick 1950, Geiser 1945 and Yearbook of Agriculture 1937. See Appendix B). For unknown reasons, the private breeder began to disappear and in 1917 Garfield wrote to the American Pomological Society that ". . . the amateur was strongly in evidence before 1880

TABLE 2.1 Public Breeding Programs at Land Grant Universities and the United States Department of Agriculture Begun From 1867 to 1935

TIME PERIOD	NUMBER OF PUBLIC PROGRAMS BEGUN
1867	1
1880-1889	4
1890-1899	4
1900-1909	15
1910-1919*	14
1920-1929*	12
1930-1935	14
Unknown date	3
TOTAL	67

Source: Yearbook of Agriculture 1937

*Period includes two programs for which dates are estimated. The programs could have begun earlier than estimated.

but seems to have disappeared." Whether the decline in private breeding was the cause or the effect of the initiation of public breeding programs is unknown.

2.2 First Discussions Of Protection For New Varieties

The problem of low returns to plant breeding was brought to the public attention in the 1860s when agricultural and horticultural journals devoted considerable space to discussions of legal protection for the originators of new horticultural varieties. As early as 1868 the Lake Shore Grape Growers' Association in New York appointed a committee to look into getting a patent law for new horticultural varieties (Newman 1931). The industry was by no means unanimous on this issue. Some disputed the claim that returns to originators were low. Many horticulturalists, while accepting the justice of the claim for protection, rejected it as being impractical.

Liberty Hyde Bailey, a public sector horticulturalist, opposed the proposals because of the difficulty of defining a variety or what was new. Bailey also observed that most new varieties were not the result of breeding, but merely fortuitous finds. Bailey stated, "When the time comes that men breed plants upon definite laws and produce new and valuable kinds, then plant patents may possibly become practicable" (White 1975). Luther Burbank, a private breeder, while supporting the idea of protection for new varieties, also expressed doubts about the feasibility of patenting a plant because plants, unlike machines, were constantly changing. In addition, plants reproduce themselves so that the patent would be of no practical use given the high costs of policing it. Joseph Moore, a private grape breeder, suggested that experiment stations test the new varieties to prove their distinctiveness (White 1975).

2.3 Trademarks

Some proposals called for registration of a variety with the USDA or registration under the Trademark Law, which had been passed in 1881. However, this only protected the name of the variety. In the late 1800's some nurseries did begin to use the Trademark Law to obtain protection for the names of their varieties. The most famous of these is the "Delicious" trademark of Stark Brothers Nursery. The name was originally given to the Hawkeye apple in about 1894. In 1914 Stark Nurseries acquired the rights to a yellow apple which they trademarked Golden Delicious in hopes that it would gain more rapid public acceptance by association with their already successful trademark (Carlson et al 1970). Since that time, Stark has given the name "Delicious" to varieties of several other fruits. Other firms followed Stark's lead and began trademarking fruit.

A trademark is defined as ". . . any word, name, symbol, or device or any combination thereof adopted and used by a manufacturer or merchant to identify his goods and distinguish them from those manufactured or sold by others" (Kintner 1975).[1] The trademark is a source of information for the consumer because it identifies the source of the goods and saves the costs of information search.

There are two levels of protection available for these marks--the primary register and the supplemental register. Marks on the primary register are used to distinguish the goods of one manufacturer or merchant, items on the supplemental register are marks "capable of distinguishing" an item (Kintner 1975). A trademark can be renewed indefinitely as long as it is still in use.

Once a mark has been on the primary register for more than five years, the legal grounds for challenging it are narrowed and the holder has the assumption of a valid trademark. A trademark can be challenged if it has become a generic term for the item. Owners of trademarks must defend their mark against such use or lose their rights. To defend its trademark Xerox Corporation has placed advertisements in major newspapers pointing out that the term "Xerox" should not be used to mean "photocopy". The trademark "Delicious" has become a generic name for that type of apple.

Neither the intent to infringe nor actual customer confusion of trademarks need be shown in an infringement case. Only the "likelihood of confusion" need be shown, although the case is stronger if intent or actual confusion can be shown (Kintner 1975). In finding infringement and assessing penalties, the judge will consider how strong or weak the trademark is. For example the word "Kodak", a coined word, is considered a strong trademark while "Mustang", a common word which has been used to sell a variety of items, is not (Kintner 1975). The penalties for infringement include an injunction against the use of the mark in a manner that is likely to cause confusion, monetary compensation up to triple damages plus the profits the defendant derived from use of the mark.

---

[1]This discussion centers on the Trademark Act of 1946, also known as the Lanham Act. The original Trademark Act was passed on March 3, 1881 and revised February 20, 1905.

The passage of the 1930 Plant Patent Act temporarily brought an end to trademarking of fruit, since it was commonly accepted that a patented plant could not be trademarked. This point of view was upheld by the courts in Dixie Rose Nursery v. Coe U.S. App. D.C. 131 F.2d 446. The court refused to allow the trademarking of a patented plant because "it would tend to prolong appellant's monopoly, beyond the life of the patent, by making it difficult for a newcomer to break into the field . . ." (Toulmin 1949).

However, this ruling was reversed in the late 1950s and nurseries often both patent and trademark a variety. This has caused some confusion for growers (some observers claim that was the intention) and some experts in the field consider it a set-back for the standardization of nomenclature which the industry had worked so hard to achieve at the turn of the century.

Both patenting and trademarking are not unique to horticulture, but is a common practice in many branches of industry. The public is perhaps most familiar with this practice in the pharmaceutical industry. In order to limit the monopoly of a drug company after its patent has expired, Congress has passed a law making it legal for a pharmacist to provide the client with the generic drug from another firm, unless the doctor specifies that only the trademarked drug may be given.

Since a trademark can be renewed indefinitely, neither actual confusion nor intent to infringe need be proven, and penalties for infringement are more severe than for a patent, in some cases the trademark will be a more attractive alternative for protection than a patent. In addition firms may combine a patent and a trademark, often using the patent to give them time to establish the trademark which will in turn prolong the monopoly begun by the patent.

2.4 The 1930 Plant Patent Act

In 1930 Congress passed an amendment to the Patent Act extending patent protection to asexually reproduced plants. The amendment was supported by the widow of Luther Burbank and by Thomas Edison, who was breeding goldenrod hopes of producing rubber (Rossman 1931). The amendment was also supported this time by Liberty Hyde Bailey because ". . . men were breeding plants upon definite laws and producing new and valuable kinds" (White 1975).

The amendment granted a patent to:

> Any person . . . who has invented or discovered and asexually reproduced any distinct and new variety of plant, other than a tuber-propagated plant. (Public Law No. 245, 71st Congress).

Congress found it necessary to amend several sections of the Patent Act in order to make its intentions clear.[1] Section 4884 was amended to specifically confer ". . . the exclusive right to asexually propagate the plant" (U.S. Senate 1930). Plant patents were exempted from the exact descriptions required by section 4888 as long as the description was as complete as reasonably possible (Figure 2.1). Any plant introduced prior to passage of the law was not eligible for a patent. The Department of Agriculture was directed to aid the Patent Office with its expertise in the area. The final

---

[1]The Federal Code has been revised since the amendment was passed so that section numbers have changed. The original amendment was inserted into the Patent Act itself. With the revision of the Federal Code, amendments are now added at the end of the act. See Appendix A for exact wording of currently applicable law.

TEXT OF PLANT PATENTS LAW

[PUBLIC—No. 245—71ST CONGRESS]

[S. 4015]

An Act To provide for plant patents

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That sections 4884 and 4886 of the Revised Statutes, as amended (U. S. C., title 35, secs. 40 and 31), are amended to read as follows:

"SEC. 4884. Every patent shall contain a short title or description of the invention or discovery, correctly indicating its nature and design, and a grant to the patentee, his heirs or assigns, for the term of seventeen years, of the exclusive right to make, use, and vend the invention or discovery (including in the case of a plant patent the exclusive right to asexually reproduce the plant) throughout the United States and the Territories thereof, referring to the specification for the particulars thereof. A copy of the specification and drawings shall be annexed to the patent and be a part thereof.

"SEC. 4886. Any person who has invented or discovered any new and useful art, machine, manufacture, or composition of matter, or any new and useful improvements thereof, or who has invented or discovered and asexually reproduced any distinct and new variety of plant, other than a tuber-propagated plant, not known or used by others in this country, before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof, or more than two years prior to his application, and not in public use or on sale in this country for more than two years prior to his application, unless the same is proved to have been abandoned, may, upon payment of the fees required by law, and other due proceeding had, obtain a patent therefor."

SEC. 2. Section 4888 of the Revised Statutes, as amended (U. S. C., title 35, sec. 33), is amended by adding at the end thereof the following sentence: "No plant patent shall be declared invalid on the ground of noncompliance with this section if the description is made as complete as is reasonably possible."

SEC. 3. The first sentence of section 4892 of the Revised Statutes, as amended (U. S. C., title 35, sec. 35), is amended to read as follows:

"SEC. 4892. The applicant shall make oath that he does verily believe himself to be the original and first inventor or discoverer of the art, machine, manufacture, composition, or improvement, or of the variety of plant, for which he solicits a patent; that he does not know and does not believe that the same was ever before known or used; and shall state of what country he is a citizen."

SEC. 4. The President may by Executive order direct the Secretary of Agriculture (1) to furnish the Commissioner of Patents such available information of the Department of Agriculture, or (2) to conduct through the appropriate bureau or division of the department such research upon special problems, or (3) to detail to the Commissioner of Patents such officers and employees of the department, as the commissioner may request for the purposes of carrying this Act into effect.

SEC. 5. Notwithstanding the foregoing provisions of this Act, no variety of plant which has been introduced to the public prior to the approval of this Act shall be subject to patent.

SEC. 6. If any provision of this Act is declared unconstitutional or the application thereof to any person or circumstance is held invalid, the validity of the remainder of the Act and the application thereof to other persons or circumstances shall not be affected thereby.

FIGURE 2.1 Original Text of the Plant Patent Law
(Underlining of the text of the amendment added by the author)

addition, a rather standard proviso, stated that if the amendment were found unconstitutional this would not affect the constitutionality of the entire patent statute. All other requirements of the general patent statute also apply.

2.5 Criteria Of Patentability

In order to enact the law, Congress had to resolve several legal issues. Is a new plant an invention in the constitutional sense of the word or an act of nature? Is it possible to establish ownership of a plant when the offspring are not like the patented parent? How can the originator of a new plant describe it in sufficient detail so that someone with average skill in the subject matter can reproduce it?

2.5.1 The Standard Of Invention

Questions of what constituted invention of a plant had been expressed long before legislation was enacted. Reproduction of chance occurences of nature and even breeding were not considered beyond the ordinary level of skill in the art since only standard reproduction techniques are required. Many felt that labelling such actions as invention exceeded the Constitutional powers granted to Congress. The Congressional Committee Reports make two points in this regard: (1) other inventors who make a chance find (citing the case of a chemist) can patent those finds, and (2) the chance occurence and the bred variety will not be reproduced without direct human action, and it is this action which Congress wished to encourage (U.S. House and U.S. Senate 1930).

A further question of what constitutes invention arose in the case of wild plants 'discovered' by plant explorers and the distinction between a wild plant and a chance seedling. Both Congressional Committee Reports stated that wild plants were not covered in the legislation (U.S. House and U.S. Senate 1930). However, wild plants and chance seedlings remained a topic of considerable controversy. Initially the Patent Office allowed chance seedlings to be patented, but the Office reversed itself in 1951, stating that chance seedlings were found in their natural state and not patentable (Jeffery 1977 and U.S. House 1930). The Patent Office Board of Appeals in Ex parte Forster 90 USPQ 16 (1952) rejected a variety found in its natural state and asexually reproduced (Jeffery 1977).

In 1954 the act was amended to specifically include chance seedlings and exclude findings of wild plants.

> Whoever invents or discovers and asexually reproduces any distinct and new variety of plant, including cultivated sports, mutants, hybrids, and new found seedlings, other than a tuber propagated plant or a plant found in uncultivated state . . . [Underlining added to show text of the amendment.] (U.S. Senate 1954.

The legal reason for distinguishing chance seedlings and wild plants is that the wild plant is already in the public domain. The intent of the patent is to add to public knowledge, not to privatize what already belongs to the public. Although the 1954 amendment clarifies the intent of Congress to distinguish between cultivated chance seedlings and wild plants, it ignores the fact that in order to be exactly reproduced the wild plant needs a human act just as does the chance seedling.

On a practical level the question of 'how wild is wild' has not been answered. For example, a tree found growing in a fence row was granted a patent. Furthermore, it is doubtful that the distinction can be enforced. The plant could be removed from the wild and claimed as a chance seedling or grafted onto another plant and claimed as a sport.

2.5.2 Asexual Reproduction

Congress resolved the issue of proving ownership of progeny by limiting the patent protection to asexually reproduced plants, so that the progeny would be exactly the same as the parent. Dun v. Ragin v. Carlile 50 U.S.P.Q. 472, 474 PTO Bd. Int. (1941) held that the plant must be asexually reproduced and the progeny shown to have the distinguishing characteristics before a plant can be patented. Asexual reproduction proves that the patent can actually be practiced and is not just a theoretical possibility (Toulmin 1949).

2.5.3 Definition Of A Variety

Although not contained in the original bill, the Congressional Reports accompanying the bill defined a "variety" as ". . . sports, mutants and hybrids." A "mutant" is ". . . the new and distinct variety result[ing] from seedling variation by self pollinization of species" (U.S. House 1930). The definitions do not correspond to the definitions of variety and mutant used by horticulturalists. Most horticulturalists would say that seedling variation is the result of sexual propagation and not a mutation. A "sport" is a mutation and is considered a strain rather than a variety. A "hybrid" is not a variety at all because it is not stable. In fact the 1970 Plant

Variety Protection Act does not include hybrids as varieties. Throughout this paper, the term "variety" will be used in the manner defined by Congress unless modified by adjectives or the context of the sentence to refer only to varieties in the stricter definition of the word.

Most scientists will admit, as Bailey pointed out, that defining a variety is very difficult. Britain struggled with this problem while enacting variety protection legislation and Parliament considered a recommendation to strike the word from the bill. A variety was finally defined as any clone, line, hybrid or genetic variant. Dworkin (1983) states that this is like having no definition at all, but it was acceptable to politicians.

The broad definition of "variety" used by Congress allows plants with very small differences to be patented. This means that a competitor may patent a variety with characteristics very similar to those of an already patented plant. In fact, patents have been issued for sports which originated from patented varieties, as well as for second and third generations of sports. The patenting of very similar plants weakens the monopoly granted to other patent holders by allowing close substitutes to be marketed.

2.5.4 Novelty

There appears to be very little controversy concerning the meaning of "new", since Congress explicitly states defining conditions in the patent statute (35 U.S.C. Section 102, See Appendix B). These criteria concern whether the exact invention has been previously known to the public. If the criteria are not met, the invention is not new and a patent cannot be issued. The attempt to differentiate between wild plants and chance seedlings is partly due to the novelty requirement of the general patent statute.

2.5.5 Distinct Vs. Useful

Until the plant amendments were added to the patent statute, patentable inventions had to be "new and useful". It was commonly accepted that plants also had to meet the useful criterion and this question was clarified only in the past decade. In Yoder Brothers, Inc. v. California-Florida Plant Corp. 537 F.2d 1347, 193 U.S.P.Q. 264 (5th Cir. 1976), the court pointed out that the law, as written by Congress, uses the words "new and useful" for all other classes of patents, but changes to "distinct and new" for plant patents. A closer reading of the Senate Committee Report indicates that Congress did not intend to apply the useful criterion to plants.

> On the other hand, in order for the new variety to be distinct, it must have characteristics clearly distinguishable from those of existing varieties, and it is immaterial whether in the judgement of the Patent Office the new characteristics are inferior or superior to those of existing varieties. Experience has shown the absurdity of many views held as to the value of new varieties at the time of their creation. (U.S. Senate 1930, emphasis added)

With this statement, Congress shows that it is choosing the distinct criterion over the useful criterion for plants. This criterion is not so clear as one might expect, since the patent examiner must decide how different a new variety must be from a known variety before it is distinct. This judgement has to be balanced with the broad definition of variety given by the Congress. Patent office examiners appear to use the criteria applied by plant taxonomists for distinguishing varieties (Bagwell, personal communication).

As the number of known varieties increases, criteria for distinguishing between varieties must also be increased or refined through better measurement techniques which can detect smaller differences. Britain has found it necessary to increase the number of descriptors as the number of plants submitted for protection has increased (Sparrow 1981). Electrophoresis, a chemical fingerprinting process, is currently being evaluated for its feasibility of distinguishing plants. This is opposed by many nurseries because smaller differences will be detectable and perhaps patentable, further decreasing the monopoly value of the patent. The Patent Office position is that electrophoresis patterns may be useful in identification, but a chemical difference is not sufficient for a patent because taxonomists do not rely solely on such differences and too much of a burden would be placed on the public to make such distinctions in purchases (Bagwell, personal communication).

2.5.6 Distinct And Non-obvious

The non-obvious requirement of section 103 of the Patent Act has also been problematic. Section 103 states that a patent may not be obtained if the differences between the invention ". . . and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains." (35 USC Section 103) That is, the patent covers not only the exact item patented, but also equivalent items which economists would call substitutes. Product space is the area of consumer preferences covered by an item and its substitutes. Thus a patent is not granted only on a product or process but also on the product space surrounding it. This increases the monopoly value of the patent.

In Yoder the court found that the non-obvious criterion overlapped the distinct criterion. Although it did not reject the non-obvious criterion for plants, the court could find no meaningful way for it to be applied (Jeffery 1977). Without the non-obvious criterion, varieties must only be new and distinct. "New" means that they cannot be exact copies and "distinct" means they must differ enough to be called a variety within the broad definition given by Congress. There is no exact measure defining how large the difference must be for a plant to be considered a new variety. Thus, plant patents have a much narrower product space than other patents which must meet the non-obvious requirement.

2.5.7 Claims

The tendency towards granting only a narrow product space for plant patents is reinforced by the claims required for the plant patent application. Patent law requires the inventor to point out and claim the improvement(s). In a regular patent, an unlimited number of claims may be made. The claims delimit the extent to which an invention is protected (Cook 1936a) and (in economic terms) define the product space. Common practice is to make an initial broad claim followed by several narrower claims. Even if the broad claim is rejected, one or several of the narrower claims may be accepted.

Patent Office rules allow only one claim to the entire plant. Ex parte Van Over U.S.P.Q. PTO Bd. Int. (1941) found that a patent may be obtained for a "new variety of plant" and that the intention of Congress was to grant a patent on a living plant and not on a part. The plant is claimed as a unit rather than as a collection of integrated parts. It is the particular combination of parts is claimed as an innovation (Cook 1936a). New parts cannot be claimed individually, so the new part may be used in another combination which is patented by a competitor. Any change in the combination would qualify for a separate patent. This interpretation is also true of some chemical products. The chemicals used are known, but the manner of combining them may be new (U.S. Senate 1930). A regular patent may also be granted on a mechanical device which combines old things in new ways (Allyn 1943). The requirement that the plant be asexually reproduced would preclude obtaining a patent on a group of plants unless each plant had been asexually reproduced. Since only one claim is allowed, each plant would have to be patented separately.

Perhaps the administrative decision (later codified into law) to allow only one claim is based partially upon the biological characteristics of plants. A trait may be the result of several possible gene combinations. Taking as an example fruit color, whether the same color in two plants is the result of the same or different gene combinations is impossible to determine at present. Due to such uncertainty, a single claim may allow for more flexibility in administering the law as well as increasing breeding investment and competition in the nursery industry.

2.6 Infringement

The broad definition of variety, the distinct requirement, the finding that the non-obvious requirement was inapplicable, and the single claim for the entire plant all indicate that plant patent protection applies for a very narrow product space. Close substitutes do not legally infringe the patent and can also be patented. Basically, a plant patent appears to protect only exact copies of the plant, thus weakening the monopoly value (and hence market value) of the patent. This generalization is reinforced by court findings in infringement cases.

"Infringement" includes the unauthorized use, sale, or asexual reproduction of the patented plant. The court ruled in Yoder that the unauthorized sale of cuttings from a patented plant was infringement. The defendant had argued that the patent applied to a mature flowering plant and not to the immature plant. He also argued that since the claim covered the whole plant, only the sale of the whole plant was forbidden, but not the sale of parts of the plant. The court held that cuttings must be included under the patent, or the patent would have no value. The sale of parts of patented plants for non-reproductive purposes is not usually considered infringement since the seller implicitly confers all normal uses (Bagwell, personal communication). This includes the sale of fruit and cut flowers. But as Cook (1930b) points out, stems of cut flowers could be used as propagating material.

In Yoder, the defendant admitted that the plant parts being sold were from the plaintiff's patented variety. In other infringement cases, the question has been whether the alleged infringing variety is distinct from the patented variety. In the cases which have come before the courts, if the plants in question were found by the court to differ in any respect, no infringement was found. In these decisions, the courts appear to hold to the doctrine of one clonal line obtained directly or indirectly from the patented plant. In other words, only exact copies infringe on the patent.

The requirement that infringing material must come directly or indirectly from the patented plant leaves open the possibility that independent discovery is not infringement. This is contrary to general patent practice (Barrows 1936). Cole Nursery v. Youdath Perennial Gardens 17 F. Supp. 159, U.S.P.Q. 95 (N.D. Ohio 1936) and Yoder held that independent discoveries are not infringement while Pan American Plant Company v. Andy Matsui, d.b.a. Andy Matsui Nursery 433 F. Supp. 693, 198 U.S.P.Q. 462 (N.D. Cal. 1977) held that independent discovery may be infringing (Jeffery 1977). In all three cases, the plants in question differed in some respect, so while similar varieties may have been discovered independently, the same variety was not. Allowing independent discovery might increase investment since investors would know that research results could be used even if already obtained by someone else. At the same time this decreases the value of the patent. Allowance of independent discovery may also reflect recognition by the courts of biological uncertainty. As noted above, even if two plants look exactly the same, their characteristics may result from different genetic combinations.

2.7 Protection For Other Plants

In December of 1930 a bill (HR 15423) was introduced to provide patent protection for cereal plants. The bill was referred to the Committee on Patents, but was never reported out of committee (Newman 1931). Again in 1967 a bill was proposed to allow the patenting of sexually reproduced plants. Finally, in 1970 sexually reproduced plants were granted protection under the Plant Variety Protection Act. To be protected the plant must meet the criteria of distinctness, uniformity and stability, in contrast to the criteria discussed above for asexually reproduced plants. The law provides a very narrow product space and appears more similar to a copyright than to a patent. The original act excluded six major vegetables. A 1980 amendment extended coverage to those vegetables and was also the occasion for much public discussion. As a result Congress requested a study of the impacts of the law; this was carried out by Butler and Marion (1985).

Bacteria were rejected as patentable subject matter under the Plant Protection Act by the Court of Customs and Patent Appeals in In re Arzberger, 46 U.S.P.Q. 32 (1940) C.D. 653, 521 O.G. 272, 112 F 2d 834 (C.C.P.A. 1940). The bacteria which had been developed were superior to the bacteria then in use for the manufacture of acetone, butanol, and ethanol. The Court held that common usage of the word "plant" did not include bacteria, that Congressional reports accompanying the bill did not directly mention bacteria nor were the methods of asexual propagation listed by Congress applicable to bacteria. Further, the Court held that the law was meant to benefit agriculture, and it did not see that bacteria benefitted agriculture.

However, micro-organisms were granted patent protection under Section 101 of the Patent Act after the 1980 Supreme Court decision in Diamond v. Chakrabarty in which the court held that bacteria were "compositions of matter" and thus patentable subject matter. Many patent authorities felt that this decision opened the door to patenting of all plants under Section 101. Patent Office practice following the decision was to allow plants not patentable under Section 161 or the Plant Variety Protection Act to be patented under Section 101. These plants include bacteria, tubers and hybrids, and must meet the criteria of new, useful and non-obvious as set forth in the general patent law. In September of 1985, the Patent Office Board of Appeals ruled in Ex parte Hibberd that all plants are patentable under Section 101 of the Patent Act. This opens the possibility for a wider product space for plants and thus a more valuable monopoly, but the patent may be more difficult to obtain because of the non-obvious requirement. It is difficult to predict the impact of this ruling without examination of Patent Office rules on how changes will be implemented. It is also very unclear how the three laws will interact.

CHAPTER III

THE ECONOMICS OF PATENTING PLANTS

3.1 History Of Patents

The first known patents for inventors were granted by the Republic of Venice beginning in 1474. In the 1600s German princes granted patents, the terms of which were based upon consideration of the utility and novelty of the invention versus the burden imposed upon the public due to the patent monopoly. Patents were granted not only for new inventions but also for introduction of crafts and techniques from other countries. Patents for introductions were often used to encourage infant industry. Interestingly, some of these patents granted protection from competition, thus increasing monopoly power, while others granted exemptions from guild rules, thus decreasing monopoly power. At other times patents were granted to reward favorites of the monarch. Such grants became very common in England after 1560. In 1623-24 Parliament prohibited the granting of monopolies except to inventors (Machlup 1958).

Patents became the subject of intense controversy during the second half of the nineteenth century. Between 1849 and 1863 Switzerland rejected patent proposals five times. The Netherlands repealed its patent law in 1869 and did not reinstitute patents until 1910. England also considered abolishing or severely restricting patents. In 1873 the anti-patent movement was defeated through the combination of a propaganda campaign by proponents of patents and a change in world economic conditions. A depression led to the rise of protectionism and nationalism while the anti-patent movement had always been closely associated with the free-trade movement. In addition, the anti-patent movement was willing to accept compulsory licensing as a compromise (Machlup and Penrose 1950). However, compulsory licensing has never been as widely employed as the anti-patent movement had hoped. Some countries such as the United States have never legislated licensing, although the courts have often required it (Machlup 1958).

The collapse of the anti-patent movement brought a strengthening of patent laws and enactment of laws in additional countries. Machlup and Penrose (1950) discuss the four justifications given as the legal basis for patent law in various countries. French law recognized a natural property right in a person's own ideas which the state is morally obligated to protect. In fact, the word 'property' was specifically chosen rather than 'privilege' to break the association in the public mind of patents with other monopoly privileges granted by the crown, or the proposal would have failed. Opponents pointed out that if such a natural right exists, there is no moral ground for limiting that right in time or space (Penrose 1951).

The second justification for patents (United States) is that a person should be rewarded in proportion to services rendered to society and that society should help secure that reward. This argument is based upon the assumptions that invention is the result of an identifiable person's work, and that total revenue of a monopolist is the correct measure of usefulness of an invention. Opponents of this position argued that inventions have a social origin, and thus the individual should not be rewarded. If the inventor is an innovator, then the time lag required for imitation should be sufficient for the inventor to receive a reward. It was also argued that other means exist for rewarding inventors.

A third justification (Austrian) for patents is that invention was necessary for industrial progress but would not be forthcoming without incentives. Patents are the simplest way for society to create these incentives. But a patent system is not a costless method of reward because of the administration required. In addition, it deprives others of the right to use and evolve the patented item. It is also obvious that many investments are made without patent protection, and some German and Swiss economists have claimed that their countries industrialized rapidly because they did not have patents.

The fourth justification (British) is that inventions are necessary for industrial progress and the best way to make these advances available for others to use was to reward the inventor for disclosing the advances made. Opponents pointed out that even with a patent system, the inventor may still elect to keep the invention a secret. Thus the bargain between the state and the inventor is one-sided, since the inventor will disclose only those inventions which it is difficult to keep secret. Opponents also argued that a patent system encourages secrecy, since findings which otherwise would have been published in order to gain recognition and fame would not be disclosed until they had been reduced to practical use and patented (Machlup and Penrose 1950).

Some countries restrict the areas in which patents may be granted, often excluding food and human medicines. If patents are used because they increase invention, the question arises why would a society not want to encourage investments in these areas? If patents are ethically intolerable in these areas, doubt is cast upon the value of the whole system to the society.

Some of the American colonies granted patents and the Constitution of the United States (1787) gave Congress the power:

> . . . 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.

At the time of drafting the Constitution, James Madison proposed that the government establish and pay a premium for inventions (Machlup 1958). This would be similar to an inventor's certificate as used in some countries. The first patent law was passed in 1790 and amended in 1793 when the three members of the cabinet who had previously examined all patent applications found this to be an overwhelming demand on their time. From 1793 to 1836 the patent system was basically a registration procedure, in which the word of the inventor that the invention was new was uncontested. The Patent Office was created in 1836 and the examination system re-established because the registration system had resulted in too many trivial patents.

3.2 The Economics Of Patents

The principal economic argument for patents is that the system has the potential to increase technological change by making marginal investments in research more profitable. Firms may invest even without a patent system if there are natural imitation lags, if there are advantages of competitive product leadership, and if there are barriers to the emergence of a competitive market structure.

> Patent protection will be most important . . . [1] when there are large numbers of probable imitators or [2] when development costs are expected to be high in relation to the stream of quasi-rents the innovation could support under favorable (e.g. oligopolistic) pricing conditions. (Scherer 1980)

If a firm invests in research without a patent system and there are a large number of imitators, prices will be driven down towards the cost of production. If the inventing firm tries to raise the price, it will be driven out of the market by competitors who can sell more cheaply because they do not have to recover research costs. The function of the patent system is to balance the interests of society in encouraging invention with the need to compensate the inventor sufficiently to encourage further invention. This is accomplished by granting a limited monopoly. The term of seventeen years is an historical artifact, derived as a compromise between the years necessary to train two or three sets of apprentices (14 and 21 years, respectively). As patent life is extended, invention is encouraged. But more inefficiencies are also created in the economy due to the monopoly on information. Nordhaus (1969) used net surplus as a measure of social welfare to determine the optional life of a patent. Nordhaus assumes that the returns are "appropriable", i.e. that exclusion costs are low. Using varying elasticities of demand for "run of the mill" cost-saving processes which do not result in a price increase, he found that "the welfare index is insensitive to the life of the patent once a life between six and ten years has been reached." (Nordhaus 1969) But for "run of the mill" inventions the losses from monopoly of the current patent system are small compared to the gains from invention.

The monopoly right is expected to allow the patent holder to control supply and increase price sufficiently to recover research costs. The maximum a patent holder can increase price is an amount equal to the increases in productivity engendered in the new product/process. Because research is production under uncertainty, no guarantee exists that the value of a productivity increase in the resulting product will be sufficient to recover the costs of research. But a patent is not a sufficient condition to guarantee research investment even under the conditions in which Scherer suggests they would be most important. Situations under which a patent is not sufficient to induce research investment are high exclusion costs, high investment costs and high information costs. If high information costs result in uncertainty concerning the amount of productivity increase, the customer will be unwilling to pay the full value.

There are no pure monopolies, including the patent monopoly. The strength of a monopoly depends upon the availability and closeness of substitutes. There are always some substitutes available (including doing without). In the case of a new product or process, a substitute is often the old product or process. In the long run more substitutes become available, particularly if monopoly pricing makes entry attractive.

By definition, if a close substitute exists, the smaller is the increase in productivity engendered in the new product/process. The patent law and its administration and adjudication determine how close new substitutes can be to the patented product/process and how close the patented product/process can be to existing substitutes. In other words, what is patented is a product space encompassing the specific product/process and similar products/processes. The dilemma for the competitor is how to get close enough to the patented product/process so that the customer perceives the item as a substitute while at the same time not getting so close as to infringe. In contrast to the general patent, the plant patent covers a very narrow product space, perhaps limited to exact copies (Section 2.6). There is no established definition of how close is too close or which characteristics are to be compared to determine if a supposed substitute is an exact copy. Final decisions rest with the courts. The interpretation affects the competitiveness of the market.

If the price charged by the patent holder, though within the value of the productivity increase, is high relative to the costs of production, competitors may enter the market with substitutes by "inventing around" the patent. These substitutes are not necessarily inferior to the original product and may contain improvements of the original. In addition, competitors have the option of infringing by copying the patented product/process. This is likely to happen if the price charged is high relative to the costs of production and if it is difficult (costly) for the patent holder to detect or prove infringement. Such costs incurred by the patent holder are called enforcement or exclusion costs.

Patents are part of civil law, thus the burden of enforcement falls on the patent holder. Enforcement or exclusion costs are high or low relative to the expected return on enforcement. The return for proving infringement of a patent is triple damages (royalties). If exclusion costs are high relative to the expected damages, it is not worthwhile for the patent holder to pursue the infringer. Inability to enforce the patent decreases its value to the holder because imitation cannot be deterred.

One way to prevent the entry of competitors, either with a substitute or with an exact copy, is to use limit pricing. Limit pricing is used to limit entry by competitors and can be thought of as a trade-off between short-run and long-run profits by the firm holding the patent. The less heavily the firm discounts future earnings and the more rapidly it expects substitutes to arise, the more likely the firm is to use limit pricing (Scherer 1980). The use of limit pricing means that the firm will not collect the full value of a productivity increase.

Contrary to Scherer's assertion, the patent may not encourage innovation when research costs are high relative to returns with oligopolistic pricing if high exclusion costs do not allow such pricing. With high exclusion costs, there will be no investment even if costs are much lower than the quasi-rents if costs exceed expected returns under oligopolistic pricing. With the long term investment needed in fruit, the present value of a future stream of income may be too low to make the investment economical.

Inability of the inventor to charge the full value of the productivity increase does not prevent recovery of the research costs. Research costs may have been lower than the full value of the productivity increase, or even of that portion which the inventor did collect. Even when the full value of the productivity increase can be collected, if research costs are high relative to the increase in productivity, research costs are not fully recoverable. Thus the patent is in no way a guarantee that the investment will be profitable to the inventor, nor is it a guarantee to the public that the inventor will earn no more than the invention cost.

3.3 The Costs Of Development

An investment cycle can be divided into three periods: development, payback and profit (Figure 3.1). For breeders these periods correspond respectively to the breeding and testing of a new variety, and to the reproduction and selling of the variety.

In any investment decision the potential investor must look at the discounted flow of future benefits compared with the current costs. If the expected future benefits do not exceed the costs, the investment should not be made. Even if the full increase in productivity can be collected, the uncertainty of the research production function may mean that the final result is worth less than the research costs. The development may take so long that the discounted value of the future benefits is too low to cover costs. Thus being able to collect the full value of the productivity increase is no guarantee of being able to pay for the research.

Development		Payback	Profit
Juvenile Period	Testing Time		
Breeding Variety and Testing		Propagation and Selling Variety	

Figure 3.1 Three Periods of an Investment

In addition to the discounting of future benefits there are several other factors also influence the expected future benefits, including the inability to collect the full productivity increases from the invention due to competition in the market and the unwillingness of customers to pay because of high information costs.

The development costs for a new fruit variety are influenced by the heritability of traits, which is the likelihood that a trait will be passed to the progeny. Hansche (1983) developed models for estimating the heritability of a trait and the number of progeny which must be reared for a given level of improvement of that trait to occur with a given level of probability. The larger the seedling population screened, the higher the probability that a seedling with the desired characteristics will be found. While many fruit and nut crops have high heritability for some important traits, the cost of testing a large number of progeny reduces the number that are tested and hence the probability of obtaining the desired characteristics (Hansche 1983).

Progeny testing in fruit is expensive because of the size of the plant and the juvenile period. Because of plant size, land costs can be substantial. For purposes of this study, the juvenile period extends from when the cross is made until the progeny first bears fruit. The juvenile period delays selection of seedlings for some years, extending the time necessary to achieve a given amount of improvement. "Juvenility increases the cost of improvement in almost direct proportion to the length of the juvenile period." (Hansche 1983) Because of uncertainty in the research production function, there is no guarantee that the desired characteristic will occur in the progeny, in which case a second breeding cycle is needed which will entail equal costs. (Actually breeders make crosses every year so there are several different cycles going on at all times.) Once a variety fruits and is selected as having market potential, it is usually propagated for further testing of its characteristics. Thus even under the more fortuitous circumstance, the development time for a new fruit variety is approximately equivalent to two juvenile periods.

Unfortunately, the heritability of specific characteristics is not documented for many fruits. Thus the breeder must work without even a general guide as to how many progeny should be tested. Hansche (1983) recommends that tree size and juvenile period be reduced to decrease breeding costs. He contrasts the increase in yield from 15 to 100 tons per hectare of California strawberry breeding stock over fifteen years to no measurable increase in the yield of peach breeding stock as evidence of the impacts of such costs on progress in fruit improvement. Strawberries have a shorter juvenile period, are a smaller plant and produce more seeds per individual cross than peaches. More research on heritability would reduce uncertainty as might research on gene transfer technology.

3.4 Payback Period

The payback period is the time required for the investment to break even (with appropriate discounting). The length of the payback period depends upon total demand and the originator's ability to gain market share and to price for maximum revenue.

3.4.1 Total Demand

Market demand is the total value of plants of a particular fruit demanded over a specific period of time (in this case one year). One component of the number of plants demanded is the density of planting, which has increased in recent years as semi-dwarf and dwarf trees have become more common and as new cultural methods have been adopted. A second component of total demand is new plantings and replantings. Both are a response to consumer demand for fruit. In addition, replanting depends upon the economic life of the variety and the economic life of the plant.

The economic life of a variety is influenced by consumer demand for specific fruit characteristics. In certain cases, some of these characteristics can be induced by cultural practices, such as using specific growth hormones to prevent seed formation in an otherwise seeded grape. However, such practices do increase costs of production. Even though a plant bears well, if the particular type of fruit is not demanded the producer must replant. Although the upper limit of the economic life of a plant is its natural life, the practical limit is also influenced by market considerations. For example, the 1984 freeze in Florida so reduced the expected supply of citrus that growers who were not affected by the freeze found it profitable to maintain older trees which would otherwise have been destroyed. Some of the trees affected by the freeze were maintained because the higher prices made them profitable despite their lowered production potential.

The decision to replant is influenced by the costs of a new tree, of establishing the new tree and the value of production foregone (if an old orchard is destroyed). These costs are compared with the costs of maintaining the old plant. Examples of substitutes in production for a new planting include using new herbicides to control weeds in strawberries so that the beds are less frequently replanted, or using chemicals to control diseases rather than planting resistant varieties. If the price of complements for the old tree is low, there may be less replanting. The old tree with its complements is a substitute for the new tree and limits the ability of nurseries to raise price.

Advertising can be used both to increase total demand and to increase the individual firm's market share. One example of advertising used to increase total demand is the promotion of high density plantings by nurseries. Because of the additional managerial skills needed, some fruit production specialists argue that the evidence on profitability of these systems for most growers is not convincing (Ricks, personal communication).

3.4.2 Market Share

A firm is interested not only in total market demand, but also in its share of the market. The firm's ability to increase its market share depends upon the substitutes available in the market and its ability to enforce its patent rights--what it costs the firm to enforce its rights relative to what it earns from enforcement.

The availability of close substitutes will limit the firm's ability to gain market share. One objective of a patent is to limit imitation by competitors. The patent may postpone the time before competitors enter the market with a substitute. This is particularly true in cases where the productivity change of a new variety or sport is large. Other firms are excluded from the market while they search for a substitute. Yet the firm must limit supply of the productivity-raising plant in order to collect quasi-rents. If supply is not limited, prices will fall and quasi-rents will disappear.

Since the strength of the monopoly granted to an innovator depends upon the number of substitutes available, patent laws usually contain a "non-obvious improvement" or "equivalents" clause, the purpose of which is to regulate the closeness of substitutes allowed on the market. If this clause is interpreted broadly many possible substitutes are excluded from the market, and the patent holder has a better chance of gaining market share. However, a narrow interpretation of the clause allows other substitutes to enter the market, thus weakening the monopoly.

In the particular case of the 1930 PPA, there is no "equivalents" clause. As a result, the patent applies only to the exact item being patented and does not exclude any close substitutes. As a result the possibilities for gaining a large market share are low. In addition, growers plant several varieties in order to spread production more evenly throughout the season, making it even more difficult for one variety to obtain a large market share.

Price enhancement from monopoly power of the patent should not be confused with higher price paid for a new item (often called the novelty value), which can be explained in terms of short run supply and demand. As supply (quantity supplied) increases, often due to entry by competitors, the price falls and quasi-rents disappear.

3.4.3 Exclusion Costs

In general, the literature on patents has ignored the importance of exclusion costs in determining whether a patent is an effective mechanism for increasing research investment in a specific area. Perhaps exclusion costs have been overlooked because patent studies have focused on products/processes which have low exclusion costs or because economic theory implicitly assumes that goods have low exclusion costs goods and relegates those with high exclusion costs to a perfunctory discussion of "market failure." Schmid (1985) has called attention to the importance of exclusion costs in the specific case of plants.

Exclusion or enforcement costs are high or low relative to the value of the item in question. The factors which influence value of the good are the change in productivity resulting from use of the item, and the number of substitutes available (i.e., the level of competition). If the patent holder polices the patent against infringement, the benefit of that action (as provided by patent law) is triple damages (lost royalties). If the good is not of high value, enforcement costs can exceed returns to enforcement.

The critical situational characteristic of plants for the purpose of this research is the exclusion costs of the propagules (propagating material)--the cost to the originator of policing her/his rights to use reproductive materials for multiplication. Since propagating materials can be used either to produce food or to produce more propagating materials, the originator cannot easily police the distribution and use of the material once it is sold. The originator is interested in excluding several groups of potential competitors--breeders, nurseries and growers--from using the material for propagation.

Excluding nurseries (multipliers) and other breeders from propagating a plant is difficult, since they are specialists in that work. Fruit growers are not specialized in propagation and multiplication. Whether growers will buy reproductive materials from the originator or obtain such materials from other sources depends upon the attributes of the reproductive materials. If the grower has ready access to mature, reproductively stable materials in the normal course of production, these materials will likely be used rather than purchased them from the originator. If the genetic material available to the grower is unstable, if the grower does not ordinarily produce mature reproductive material, or if special skills are required, reproductive materials are likely to be purchased from the originator. If these skills are easily acquired or if prices are high, it may be profitable for a grower to acquire these skills and put them to use. But once the necessary skills have been acquired, it is extremely difficult to exclude the grower from propagating a variety.

The costs to the originator of excluding growers from using plant materials for reproductive purposes are a function of their stability and accessibility. The interaction of stability and accessibility can be illustrated with a matrix (Figure 3.2). Plants with low exclusion costs are those for which the grower does not have access to the reproductive materials (Cells 6 through 10), and/or those which are not reproductively stable (Cells 1, 2, 6 and 7). The combination of these two factors gives the lowest exclusion costs (Cells 6 and 7);

Accessibility of Reproductive Material	STABILITY OF REPRODUCTIVE MATERIALS				
	Unstable		Stable		
	Sexual Reproduction			Asexual Reproduction	
	Heterozygous		Homozygous		
	F-1 Hybrid	Other Cross-Pollinated	Self-Pollinated	Plants	Micro-Organisms
Grower Produces Mature Reproductive Material	Cell 1 Corn Sorghum Wheat Apple Peach	Cell 2 Corn Rye Cotton Apple	Cell 3 Wheat Soybeans Oats Barley Peach	Cell 4 Roses Tubers[+] Strawberry Apple Peach	Cell 5 Sold or released into environment
Grower Does Not Produce Mature Reproductive Material	Cell 6 Forage Vegetables	Cell 7 Forage Fodder Vegetables Sugar beets	Cell 8 Seedling rootstocks Beans Tomatoes Squash	Cell 9 Clonal rootstocks Strawberry (without runners) Virus-free material	Cell 10 Factory use only
Structure	Patent Act[+++]	1970 Plant Variety Protection Act or Patent Act[++]		1930 Plant Patent Act or Patent Act[++]	Patent Act[+++]

[+]Tuber propagated plants are specifically excluded from the 1930 Plant Patent Act. Since 1980 they can be patented under the general Patent Act.

[++]By opinion of the Patent Office Board of Appeals, 1985.

[+++]By 1980 Supreme Court Decision Diamond vs Chakrabarty

FIGURE 3.2 Factors Affecting Exclusion Costs of Various Plants growers will purchase the needed reproductive materials rather than produce them. If the market is large enough, there may be private breeding investment in plants with low exclusion costs even without a patent. This is true of hybrid corn, forage crops and vegetables. Firms will choose to produce a plant in the manner which provides the lowest exclusion costs. Private breeding investment in wheat is also directed toward hybrids. While apples are cross-pollinated and should have low exclusion costs, these costs are actually higher because apples can be asexually reproduced. Because cross-pollination and self-pollination are relative terms, there is also variation within a cell.

The bottom row of Figure 3.2 indicates which law confers property rights for each plant. Since plants exhibit varying degrees of exclusion costs, a law is not expected to have the same impacts on all the plants which it covers. Instead, the impacts of a law will be plant specific. The particular law of interest in this research is the 1930 Plant Patent Act. Under this act, fruits with both low and high exclusion costs are covered. Investment costs will also influence private breeding investment.

The second group of competitors which the owner of a variety wishes to exclude is nurseries, but reproduction is their area of specialization. However, policing costs are not as high since there are many fewer nurseries than growers. Other factors which decrease enforcement costs include the tradition in the industry for major firms to publish catalogs which become public information, industry associations which can use peer pressure to ensure compliance, and selective enforcement through court cases. Nurseries also use limit pricing to keep competitors from entering the market.

3.4.4 The Distribution Of Gains From Breeding

The patent constitutes an attempt by government to change the distribution of research benefits from what they would have been in a more competitive market. Questions of the size of gains from research and how these gains are distributed have been of interest to agricultural economists, particularly because of the publicly financed agricultural research system. The justification for patents is that in a competitive market the breeder cannot capture the gains from research. This research concentrates on whether the patent actually increases the breeder's ability to capture gains from research.

Berlan and Lewothin (1983) have set forth a framework for analyzing the maximum price increase possible given high exclusion costs and how the price increase is distributed between breeders, nurseries and growers. The concept of limit pricing is used to show that even the price increase suggested by Berlan and Lewothin may not be possible. The following analysis is a modification and extension of their work.

When growers buy trees they acquire two sets of features:

1) The genetic traits of the variety/strain which are the result of breeding and discovery. Examples of these traits include bloom period, taste, stress tolerances, ripening date, and disease resistance.

2) The plant attributes which are the result of nursery multiplication. These attributes include vigor, freedom from disease, and rootstock and scion combinations.

In some cases, such as dwarfism, the two sets of features may be substitutes. That is, dwarfism may be a genetic trait or may be induced by rootstock and scion combinations.

Once a plant has been purchased, the grower has control over the genetic traits so there is no need to pay for them again. However, the purchase of a plant does not give the grower control of the plant attributes for future propagation; thus these attributes must be obtained each time they are needed. Possibilities for acquiring access to plant attributes include grower propagation of the plant or purchase from a nursery. Naturally the grower will consider which source provides the desired set and levels of plant attributes at the lowest cost. Apparently nurseries can produce these traits more cheaply than growers, since specialization between growers and nurseries of horticultural crops has existed much longer than, for instance, specialization in seed multiplication for field crops.

If growers are unwilling to pay more than once for a given set of genetic traits, does a patent in any way change the potential returns to the breeder? It does not prevent use of the genetic traits without paying for them unless the patent owner is willing to expend considerable resources to enforce the patent. However, most growers still need the services of the nursery to get the plant attributes. Nurseries might use this as an opportunity to charge the grower for the plant attributes as well as to pass along the charges for genetic traits.

Nurseries are constrained in their ability to pass along the royalty charge, since the grower is only willing to pay for the plant attributes. The maximum price which the grower is willing to pay is limited by what it would cost the grower to produce those same attributes or to obtain them from another source such as a competing nursery.

If nurseries can produce the plant more cheaply due to specialization and resultant economies of scale, they can sell more cheaply than the grower can propagate and still make a profit.

Given:

g, n, and s = subscripts representing Grower, Nursery, and Small nursery

P = Price per seedling

C = Variable costs of producing a seedling with given attributes.

E = Economies of scale cost savings

M = Marketing and distribution costs from the nursery to the grower per plant

F = Fixed costs per plant

A = Profits per plant

R = Royalty charge per plant

I = Risks of infringement

If the grower produces a plant, no marketing costs are incurred. Fixed costs for the grower can be assumed negligible since the propagation enterprise is likely to be very small and to use many inputs jointly with other orchard enterprises. The maximum price a grower is willing to pay a nursery is the cost of producing the plant attributes.

(1)

$$P_g \leq C_g$$

The minimum price a nursery charges must at least equal the nursery's variable costs of production and marketing in the short run. In the long run this price must also cover fixed costs.

(2)

$$P_n \geq C_n + M_n + F_n$$

The difference in propagation costs of a plant for the grower and the nursery are due to economies of scale. These are the economies of scale cost savings of the nursery and are the source of the nursery's profits.

(3)

$$C_g - C_n = E_n$$

$$C_g = E_n + C_n$$

The grower will buy from a nursery only if the price is less than the grower's costs to propagate the plant.

(4)

$$P_n \leq C_g$$

Substituting equations (2) and (3) into (4) gives:

(5)

$$C_n + M_n + F_n \leq E_n + C_n$$

$$M_n + F_n \leq E_n$$

Marketing and fixed costs of the nursery must be less than its economies of scale cost savings or it could not provide the plant more cheaply than the grower's cost of production. As stated above, the nursery makes its profits from the economies of scale. But as seen in equation (5), the economies of scale cost savings must also pay for the marketing and fixed costs of the nursery.

(6)

$$A_n \leq E_n - M_n - F_n$$

If a royalty for the breeder/discoverer is included in the nursery's costs, equations (2), (5) and (6) can be written as:

(7)

$$P_n \geq C_n + M_n + F_n + R$$

(8)

$$M_n + F_n + R \leq E_n$$

(9)

$$A_n \leq E_n - M_n - F_n - R$$

This shows that the royalty charge reduces profits of the nursery. The nursery must set price, which includes the royalty, at a level to keep the grower from infringing.

(10)

$$P_n + R \leq C_g$$

As long as (8) holds, the nursery can provide the product. But if the royalty charge exceeds the available savings from economies of scale, the nursery will go out of business.

(11)

$$R \leq E_n - F_n - M_n$$

The firms which have achieved the largest economies of scale cost savings will stay in business.

3.4.5 Limit Pricing

In a less than perfectly competitive market with firms of various sizes, larger firms may have some pricing power. If prices are set such that at least some of the smaller firms can earn economic profits by infringing, they will have an incentive to expand their capacity and achieve lower unit costs (Scherer 1980). The large firm ". . . must abandon its attempt to maximize short-run profits, instead reducing its price to a level at which new entry and the expansion of fringe members are discouraged" (Scherer 1980). "The current prices of monopolized products will be kept lower the more rapidly substitution [and infringement] is expected to occur as a result of high prices, and the less heavily firms with monopoly power discount future earnings" (Scherer 1980).

While nurseries may find it relatively easy to eliminate growers who are not specialized in production and hence have higher costs, it is more difficult to eliminate other nurseries. To eliminate other nurseries the price charged by the large nursery must be less than that charged by the smaller nursery.

(12)

$$P_n \leq P_s$$

The price charged by each nursery must be greater than its costs.

(13)

$$P_s \geq C_s + M_s + E_s$$

(14)

$$P_n \geq C_n + M_n + F_n$$

Substituting equations (13) and (14) into equation (12) gives:

(15)

$$C_n + M_n + F_n \leq C_s + M_s + F_s$$

The difference in average total costs between the two nurseries is the economies of scale cost savings of the large nursery.

(16)

$$C_n + M_n + F_n - (C_s + M_s + F_s) = E_n$$

As long as the large nursery charges a royalty less than the value of the economies of scale cost savings, it can undersell the small nursery.

(17)

$$R \leq E_n$$

If the nursery charges any royalty, it can be undersold by a nursery of the same size which infringes and does not have the added royalty cost. If the nursery charges a royalty equal to the economy of scale cost savings, a smaller nursery with higher production costs might be able to undersell the large nursery by infringing and not paying a royalty.

If the large nursery wishes to maintain its market share, it must set price to keep both the grower and other nurseries from infringing. The maximum price which the grower is willing to pay is the lowest price charged by a nursery. The small nursery has the incentive to infringe and sell at a lower price in order to expand production and achieve a lower unit price. This incentive is offset by the risk of prosecution.

(18)

$$P_n \leq C_s + M_s + F_s + I_s$$

In order to keep its market, the large firm can pay a royalty only marginally greater than the difference between its own costs and those of the small firm. The smaller nursery generally will not risk prosecution if the pricing advantage is small. Thus we would expect only large firms to offer patented varieties, since only they have the economies of scale cost savings large enough to pay the royalty and yet undersell competitors. Such strategic pricing by the large firm is called limit pricing. The larger nursery does not want to create a margin large enough to tempt small nurseries to infringe and take the risk of prosecution.

Whether the small nursery produces the same plant traits at the same levels as the large nursery is open to question, particularly with respect to plant vigor and freedom from disease. However, the grower appears to make an attributes-costs tradeoff.

Thus the analysis began with the proposition that the maximum which a grower would be willing to pay for a new variety is the value of the productivity increase engendered in the variety. However, the factors discussed above indicate that the amount which the grower is actually willing to pay and which therefore, the breeder can collect is considerably less. Because the grower is no longer willing to pay the value of the full increase in productivity once access to the propagation material has been obtained, the nursery can charge only what it would cost the grower to propagate the plant. But as long as another nursery is willing to sell for less than the grower's cost of propagation, all nurseries will have to compete at this price level. In the end nurseries are squeezed between the breeder's demands for royalties and the grower's unwillingness to pay.

As seen in Equation (9), royalties reduce profits of the nursery. What is the incentive for the nursery to participate in patenting?

Patenting is part of the advertising strategy of nurseries. Patents are used both to create the image that the firm is in the forefront of the industry and as a quality indicator. The 1984 Catalog of Stark Nurseries makes this strategy very clear. ". . . [M]ake sure the cultivar was good enough to patent. . . ." As long as royalties are low and do not constitute a large percentage of firm costs, patents may form part of a very effective advertising strategy.

3.4.6 Information Costs Of Fruiting Plants For Growers

Fruit trees are a fixed asset for growers. The fruit grower will be more careful in selecting varieties than the cereal/grain farmer because of the effects of asset fixity. Both growers and farmers obtain their information about new varieties from several sources: private firms offering such varieties, test plots by private firms, the agricultural extension service, public test comparisons, the experience of peers, and their own experimental plantings. Grain farmers often plant a few acres to a new variety on an experimental basis, but for a fruit grower such experimentation is much more costly because of higher planting costs and the lengthy period before the plant bears fruit. In addition, the grower may wish to observe the orchard performance of a tree for several more years before making a committment to a new variety.

Rather than incur this expense, many growers prefer to observe the experience of other growers--the early adopters. For these growers, the high information costs entail a certain degree of risk. The compensation for risk taking may be a price premium or cost reduction (if the variety is a good one), or substantial losses (if it is not). The risk is generally shared with the nursery, which charges a price less than the potential quasi-rent in order to encourage purchase by growers.

Public testing lowers growers' information costs and risks. It would be expected that nurseries would support such testing, since with reduced risk and more certain knowledge of the variety's potential value, nurseries could charge a price which captures more of the potential quasi-rent.

3.5 Summary

Currently the research period dominates investment decisions in fruit breeding. A profit-oriented firm will not invest if the research period is so long that the discounted stream of potential future benefits approaches zero. If this is true, even under oligopolistic conditions there will be no investment either with or without a patent system. A shorter investment period may allow a positive net benefit stream, but high exclusion costs can also reduce the discounted stream of future benefits.

Thus the interaction of investment costs and exclusion costs determine the value of the stream of future benefits. Investment in breeding can be predicted based upon where a fruit falls in a matrix of investment costs and exclusion costs (Figure 3.3). There is likely to be investment even in the absence of a patent if both investment and exclusion costs are low. Similarly, if investment and exclusion costs are high, investment is unlikely even with a patent. If investment costs are high, low exclusion costs may allow such costs to be recovered. The same is true if investment costs are low and

Investment Period	Exclusion Costs	
	Low	High
Short	Investment Expected Without Patent	Marginal
Long	Marginal	No Investment Expected

FIGURE 3.3 Investment Period and Exclusion Costs in Fruits

exclusion costs are high. The latter two cases are marginal cases, and since the patent system is expected to impact at the margin, it is in these areas that we should look for impacts. More specific hypotheses will be stated in Chapter 4.

The axe, hammer and wheel each constitute clear proof that people invent in the absence of a patent system. Nor does the patent guarantee that costs are recoverable. Thus, the patent is neither a necessary nor a sufficient condition for invention. In addition, administration of the patent system is not costless. The objective of the patent is to redirect the gains from research to the inventor. Without the patent such gains would have gone elsewhere; that is, the inventor's gain is another's loss. The return is the benefit to society of increasing the rate of technological change by encouraging research investment.

Using the patent to increase the rate of technological change, by making marginal investments more profitable, introduces some distortions into the economy.

1) Rather than determining which are the marginal investments and rewarding only those, many intra-marginal investments are also rewarded.

2) Investments which are not protected by patents, such as basic research into natural laws or items specifically excluded from patent protection, may not be made because investment in patentable areas is potentially more profitable.

3) The resources (human and monetary) that are attracted to research by the patent would have been invested in some other part of the economy.

A patent is not the only method available to society to increase research investment. Other methods include public research, certificates of invention, and public subsidy of private research. Currently many of these are used but there has been little research into which is the best method in a given area. Not only may one method be better than others, but a particular method may be completely ineffective. If a long term investment and high exclusion costs greatly reduce the present value of future income, the patent may not have the intended impact on investment and other methods of increasing investment might be preferred.

CHAPTER IV

RESEARCH DESIGN AND DATA COLLECTION

4.1 Conceptual Framework

Public policy issues arise because interdependencies among members of a community create conflicts of rights. Public choice theory provides a paradigm for the analysis of these policy issues. The elements of this paradigm are situation, structure, conduct and performance. Performance of the system is the result of conduct by economic actors whose opportunity sets are determined by the interaction of structure with the situation. Situation defines the relevant set of technical and economic characteristics of the good in question which are the source of interdependence. Structure is the institutional environment created by society to govern production, distribution and use of the good.

There are two situational characteristics of interest in the breeding and patenting of fruit species. Breeding requires long-term investments; thus the present value of the future income stream may be low. The patent may have high exclusion costs because it is easy to propagate the plant; therefore, policing all of the potential infringers is costly. The costs of detecting and proving infringement are often greater than the damages allowed by law. When the long investment period is combined with high exclusion costs, the present value of income is reduced further because of the difficulty in raising prices sufficiently to recover research costs.

The actors include originators who breed new varieties/strains (breeders) and who find them as sports or chance seedlings (finders). Such persons may apply for a patent. Propagators reproduce the variety once it has been bred or found, and include other breeders, nurseries, specialized grafters and budders, and commercial fruit growers. Nurseries commonly buy patents from plant originators. Commercial growers generally buy patented trees from nurseries, but occasionally deal directly with the originator, and in some instances infringe by propagating the variety for their own use.

The structural variable of interest is the 1930 Plant Patent Act which allows patenting of asexually reproduced plants. Conduct and performance of the actors in response to this law are the subjects of this research. Performance variables of interest include investment in plant origination (breeding and finding) and the products of that investment in terms of varieties. Also of interest are measures taken to ameliorate some of the consequences for the actors of the situational characteristics.

4.2 Research Design

There has long been controversy about the impacts of patents in general. Taylor and Silberston (1973) state, "These are obviously highly complex issues on which rational discussion unaided by facts is likely to be inconclusive." Patents are not a necessary condition for invention since inventions were made before patents existed, and even with a patent system some inventions are not patented. In analyzing the effects of patent policy, Machlup (1958) points out that all inventions cannot be attributed to the effects of patent law. Many of these would have occurred without the patent. Figure 4.1 presents an adaptation of Machlup's scheme with examples drawn from the current research on plants.

As can be seen in Figure 4.1, some varieties which are currently patented would have been developed even without the patent so that not even all patented inventions can be attributed to the patent system. Schmid (1985) points out that some types of plants are not developed because the patent system has biased research in the direction of technologies and plants which are patentable. These instances are difficult to document but we can draw upon a few related cases. Borlaug (1983) suggests that the breeding of open pollinated corn was discontinued with the development of F-1 hybrids, even though open pollinated corn yields may have equaled hybrid yields had breeding continued. The development of penicillin put an end to much of the concurrent research on antiseptics (Jewkes _et al._ 1969). This may also have biased medicine toward curative rather than preventive

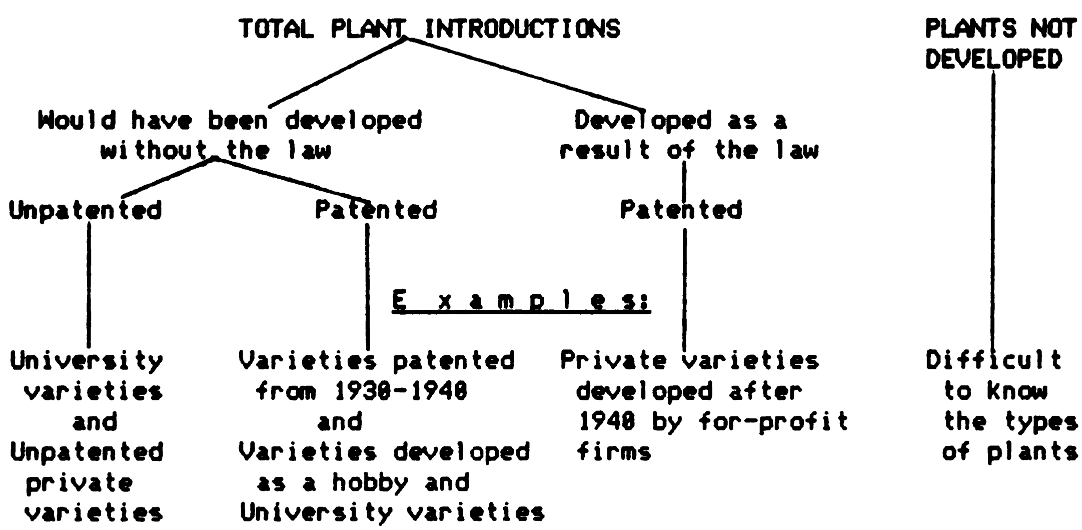


FIGURE 4.1 Impact of the 1930 Plant Patent Act on Fruit Introductions

measures. In the particular case of the 1930 Plant Patent Act, fruit originators are expected to choose those techniques which result in patentable products and eschew those which do not. Marginal benefits of the patent system are not the value of all patented inventions but the difference in value between those inventions induced by the law and the opportunity cost of those not invented because of the law.

In order to sort out the impacts of the patent Machlup (1958) suggests the ideal experiment.

> Let us duplicate our world, so that we have two worlds, identical in every respect, except that one shall have a patent system and the other shall not, then let us observe, for 50 years or so, these identical twin worlds and see what happens.

The experiment described by Machlup is unrealistic, but it does suggest a general research design. Originally this research contemplated using a with and without quasi-experimental design comparing two countries, the United States with a plant patent and another country without a plant patent in order to ascertain the impact of the patent on exclusion costs and thus on investment. Such a study faced a number of threats to its internal validity due to different historical patterns of each country--the countries were not twins as Machlup suggested. The time and expense required for such a design made it infeasible. The without patent comparison also became less important as preliminary research indicated that exclusion costs were not the major factor affecting private investment in fruit origination.

The intent of a patent is increase the present value of future income by allowing the patent holder to increase prices. However, competition restrains the ability to charge high prices. Competition can come from two sources--close substitutes allowed by law and infringement made possible by high exclusion costs. All patented plants experience competition from legal substitutes, but the exclusion costs of each differ as discussed in Chapter 3. An attempt to raise prices when exclusion costs are high may create an incentive to infringe. Given a patent system, an infringer bears an increased risk of prosecution. If exclusion costs are high, this risk is low. Thus the patent may only marginally lower exclusion costs for the patent holder (by decreasing the number of potential infringers), but the impact may be sufficient to encourage investment in the marginal case.

If exclusion costs are used as the major explanatory variable, investment in fruit origination would be expected to be inversely related to exclusion costs. The plants in order of expected investment are: rootstocks, pears, apples, and peaches. Little or no private investment was expected in grapes and strawberries (see Figure 3.2). However, preliminary research found private investment in peaches, grapes and strawberries with little or no private investment in apples, pears and rootstocks. This investment pattern was the opposite of that predicted on the basis of exclusion costs.

The search for other explanatory variables led to consideration of investment costs. Between fruits, total investment in fruit breeding is expected to be inversely related to a fruit's expected development cost of a new variety. High development costs result from plant size, long juvenile period, and additional testing time. Because of the long term investment required for breeding many fruits, the present value of future income is low. The length of investment period is sufficient to deter private investment in breeding. A comparison between countries is not useful in this case because investment costs are similar in all countries employing similar technology.

The research design became a comparison among major fruits in the United States' fruit industry which also differed on investment and exclusion costs. Citrus fruits were omitted because of the difficulty of obtaining information. Chapter Three concluded with a summary of the combined effects of investment and exclusion costs upon the present value of the future income stream. Choice of fruit for breeding investment can be predicted based upon where a fruit falls in a matrix of investment and exclusion costs (Figure 4.2). Both investment and exclusion costs are divided into low, medium and high categories and fruits are placed in the appropriate cell of the matrix. This matrix could also be used to predict private breeding investment in other plants.

Apples and pears have long juvenile periods, leading to high investment costs. Wine grapes and rootstocks require additional testing time, resulting in higher investment costs than for table grapes as do varieties which will be used for scions rather than rootstocks. Because of the investment cost, no private, for-profit investment is predicted in fruits which fall in the high investment cost row of Figure 4.2. Private introductions in these plants will be the result of finds rather than breeding.

The decision to invest in fruits with medium investment costs will be influenced by their exclusion costs. Private, for-profit

INVESTMENT COST	EXCLUSION COSTS		
	Low	Medium	High
Low	Runnerless strawberry		Strawberry
Medium		Peach	Grape
High	Rootstocks	Apple Pear	Wine Grape

FIGURE 4.2 Fruits by Investment Period and Exclusion Costs

investment in grapes is not expected because of high exclusion costs. With medium exclusion costs, peaches are a marginal case in which investment may respond to a marginal lowering of exclusion costs due to the patent. Private, for-profit investment is expected in fruits with low investment costs, with more investment in those fruits having lower exclusion costs. Thus, more private breeding investment is expected in ever-bearing strawberries which produce few runners than in June-bearing strawberries.

These expectations are tested in Chapter 5 by correlating length of juvenile period (a major determinate of investment costs) with measures of private fruit breeding investment and output. Similar correlations are performed for the public sector which is not expected to respond to profit incentives as does the private breeder. Thus, there will more likely be public investment in rootstocks, pears, and apples than private investment in these fruits. Data to test these hypotheses were obtained from the Register of New Fruit and Nut Varieties (Brooks and Olmo 1972) and from a survey of public and private breeders.

Private breeders are also expected to attempt to reduce their investment costs. Although the length of the juvenile period is beyond the control of breeders, individual breeders can reduce costs by decreasing additional testing time. This expectation was tested using regression analysis. Because the impacts of the Plant Patent Act are expected with some time lag, additional testing is expected to show a decreasing trend over time. The public sector is not expected to decrease testing time unless technological change decreases the benefits of a longer testing period. Public sector testing time is included as a proxy for technological changes which may also cause a decreasing trend in testing.

Lacking systematic data prior the passage of the law, a quasi-experimental design of an interrupted time series testing for differences in pre- and post-law impacts is possible for only a few variables in this study. One problem with the interrupted time series quasi-experimental design is that changes in the performance variables cannot always be confidently attributed to the structural change due to intervening historical events. At the same time, lack of change might be due to a historical factor working in the opposite direction as the structural change. For instance, the growth of public breeding programs may have decreased the profitability of breeding while the intent of the patent was to increase profitability for private breeders. In the particular case of testing, inclusion of the public sector as a proxy for technological change increases confidence in attributing changes in testing to private sector profit incentives. Private breeders are also expected to carefully control their annual variable costs.

Breeders' responses to market factors, such as annual tree sales, value of fruit production and profitability in the fruit industry, were also examined using interrupted time series. If the patent has increased the profitability of breeding, more varieties are expected to be introduced over time for a given level of each factor.

While Chapter Five examines the question of whether private investment in fruit breeding responds to economic incentives, Chapter Six discusses the profitability of fruit breeding. This includes the questions of whether private breeders create anything of value, whether the patent allows them to capture any of the productivity gain if they do, and whether that portion of the productivity gain which is captured is sufficient to recover investment costs.

First, annual budgets are examined for profitability and evidence that private breeders carefully control annual costs. Since the single observation on profitability obtained from a survey for the year 1984 could be idiosyncratic, the most profitable firms in 1984 were selected for an in-depth study of their lifetime costs and income. Additional information was obtained for these firms from personal interviews. The magnitude of the total net income stream is an indication of the firm's ability to capture productivity increases. The lifetime profile also indicates the impact of investment costs on the present value of the future income stream.

The market for trees in the California fresh peach market is used to examine in more detail questions of productivity gains and their capture. The histories of specific varieties are traced to detect how a variety gains market share and how competitors respond with new varieties and/or infringement. The estimated sales of a variety are combined with actual royalties to examine recovery of investment costs. The value of a particular productivity increase is estimated and compared with royalties to test whether breeders can capture productivity increases. Similar estimates are made of economies of scale cost savings and limit pricing compared with actual royalty levels to determine: (1) which pricing mechanism is used, and (2) effectiveness of the patent in reducing competition. These data are obtained from the California Tree Fruit Agreement and from a survey of breeders and nurseries. A comparison of the California fresh and processing peach markets illuminates the principal market characteristics required for private breeding investment.

Lacking a controlled experiment, no single piece of evidence can conclusively determine the effects of an institutional change such as the plant patent. However, the examination of a broad range of evidence within the general conceptual framework will help to determine the direction of such effects and give some indication of their magnitudes. Within the general research design comparing various fruits, various quasi-experimental designs were used, depending upon the hypothesis and the data available to test the hypothesis. Each quasi-experimental design has its strengths and weaknesses. Combining various quasi-experimental designs can increase our confidence in making causal attributions.

4.3 Data Collection

4.3.1 Secondary Data

Ideal data to investigate the major research questions would be disaggregated to the level of variety and strain. A search of the customary data sources for agricultural statistics turned up little of sufficient detail to directly address the research questions. The annual statistics published by the USDA provide physical production and value of production statistics for the major fruits, but do not provide information on tree sales or numbers of trees in orchards. Since 1946, acreage statistics are reported only for berries.

National data on tree sales are available only in the Special Census of Horticulture which has been taken only six times since 1890. Data are by species only, not by variety, and are available in this detail in only four of the six censuses.

The Census of Agriculture (at approximately five year intervals) provides data on total trees in orchards as well as numbers of non-bearing trees. Data are by fruit only and not by variety. The number of non-bearing trees was used as a proxy for tree sales in analysis of factors influencing private breeding output. The number of finds was regressed on total trees to determine if any statistical relation existed.

Price data on fruit trees were secured from the nursery catalog collection of the National Agriculture Library. Due to time limitations it was possible to gather data for only three firms at five year intervals from 1900 to the present. These data were used to compare pre- and post-law price ranges between new and old varieties.

Price indexes for fruit trees and small fruits compiled by the American Association of Nurserymen run for only twenty years and do not include patented varieties.

The one source which does provide detailed data on annual sales of fruit trees by variety/strain is the California Tree Fruit Agreement, the marketing order for California fresh fruit. These data, while very detailed, have several limitations. First, only twenty-one years of data, 1965-1985, were available to the author. Second, the data represent only major fruit nurseries located in California. Estimates of the percentage of trees sold by smaller nurseries and of the number of trees shipped into California from out of state were not available. Many of the trees bred specifically for California do not grow well in other areas (Schuering 1983) so that the number of trees of major varieties which are propagated in California and shipped out of state is probably small. For the peach industry, these data show typical acceptance curves for new varieties, competition among substitutes for market share and expected sales of varieties during the patent term.

Another major source of data, The Register of New Fruit and Nut Varieties, contains descriptions of the origin and characteristics of varieties. The data on variety origin were coded for each of the five fruits on which this study concentrates. The information which was coded includes dates of cross, find or selection, and commercial introduction; sector and technique of origin; patent number (if any), and parent variety if the introduction is a sport. This provided the only systematic pre-law data available concerning fruit breeding and was used in both correlation and regression analysis to determine the average juvenile and development periods for each species. Public sector introductions are probably more comprehensively registered than private sector introductions. The Register does not include all varieties introduced. "Only varieties which have shown promise of becoming important commercially, or that appear to have unusual characteristics useful to the breeder are included." (Brooks and Olmo 1972) Since the Register was first published in the 1940s, introductions of the 1920s and 1930s may be under-reported. Introductions during the 1970s may also be under-reported as only irregular updates are available since that time.

4.3.2 Primary Data

Although some secondary data were available on fruit production inputs and outputs, no data were available on private fruit breeding. Historical sources were searched for names of private fruit breeders of the nineteenth and early twentieth centuries (see Appendix B). A mail survey was used to gather information on current private breeders. The questionnaires are presented in Appendix C.

A list of private breeders was compiled from various sources. Public breeders were asked to provide names of private breeders in their specialties or geographic areas. One public breeder provided a list of thirty private grape breeders and other public breeders were able to provide several names. Some of the private breeders were contacted by letter and asked to provide names of other private breeders. Additional names of private breeders were secured from the plant patents granted over the last ten years. An advertisement was placed in Pomona, the newsletter of the North American Fruit Explorers Association, but only one reply was received.

A list of sixty-four private breeders was compiled from the above sources. Respondents to the survey were asked to supply names of other private breeders whom they knew, and this information was used to check the completeness of the original list. Twenty-three additional names were received and seven of these were contacted. The remaining sixteen were not contacted because their names were received too late or because addresses were incomplete.

Out of a final list of eighty-seven possible breeders, seventy-one were contacted. Forty-five responses were received, fourteen of which indicated the respondent was not a breeder, the breeder had terminated the program or the breeder was deceased. Two people refused to participate and three responses were too incomplete to be usable, leaving twenty-six usable responses (Table 4.1). How many of the non-respondents or of those not contacted are not breeders is unknown. Some people reported to be breeders are instead variety collectors or had patented a chance seedling.

Nearly one-third of the responding private breeders were personally contacted to obtain more detailed historical information on their particular firms. Some contacts consisted of a series of telephone interviews while in other cases the author personally visited the breeder and toured the test plots. These personal contacts also increased the author's confidence in the replies receives by giving a close view of typical firms.

TABLE 4.1 Response to Mail Survey

	RESPONDENTS		
	Private Breeders	Public Breeders	Fruit-tree Nurseries
Number contacted	71	60	100
Total responses	45	49	43
Not a breeder or nursery	14	--	3
Response not usable	3	3	--
Refused to participate	2	--	11
Usable responses	26	46	29

Many public breeders were contacted by telephone at the beginning of the research to secure background information on breeding and the fruit industry. Several breeders were interviewed personally at Michigan State University and at the Geneva New York Experiment Station. Public breeders were also surveyed by mail to make comparisons between the public and private sector. The questionnaire sent to public breeders contained a subset of the questions asked of private breeders.

The director of each state experiment station was asked to distribute up to five questionnaires to the five largest fruit breeding programs in the state and to provide the author with the names of the breeders so that any follow-up mailings could be sent directly to them. All fifty directors replied, twenty-one reporting no fruit breeding programs in the state. The other twenty-nine directors provided a list of sixty public breeders, forty-nine of whom returned the questionnaire. Three questionnaires were not complete enough to be usable, resulting in forty-six usable questionnaires from the public sector.

Because of the small amount of data available to the public concerning the fruit nursery industry, major fruit nurseries were also surveyed. The questionnaire concentrated on the nursery's use of patents and contained some questions identical with those of the breeders' questionnaire. Each questionnaire contained a separate insert in case the nursery also had a breeding program. The insert was a subset of the questions sent to private breeders to avoid repeating those already in the nursery questionnaire. Only two nurseries reported breeding programs and their replies are included with the private breeders.

A list of one hundred fruit nurseries was compiled from the patents assigned over the last ten years, the American Fruit Grower's annual growers' buying guide, and the membership list of the Mailorder Association of Nurserymen. The latter list tended to include smaller nurseries selling primarily to the home-gardener while the former lists included mainly nurseries wholesaling to the commercial grower and to smaller nurseries and garden centers.

One hundred nurseries were contacted. Eleven nurseries declined to participate and three were no longer in business or do not sell fruit trees. There were twenty-nine usable questionnaires. These twenty-nine firms accounted for nineteen percent of the 88.9 million dollars in sales of deciduous fruit trees and small fruit plants reported in the 1978 Census of Horticulture.

The design and mailing of questionnaires was guided by the Total Design Method recommended by Dillman (1978). Each respondent received a letter explaining the purposes of the study and asking for his/her voluntary cooperation in completing the survey. A week to ten days later a reminder was sent, again asking for their cooperation. Two weeks later a second reminder was sent with a duplicate of the questionnaire. The use of two follow-ups nearly doubled the response rate.

A problem occurred with the nursery questionnaires. About half of the questionnaires were printed with one page missing and another page duplicated. This was not noticed until some of the questionnaires were returned. All nurseries were immediately sent a replacement page explaining the error and apologizing for the mix-up. The questionnaires were checked carefully before the second follow-up was sent. As a result of the error some questionnaires are incomplete, because about half of the firms which had already responded did not complete the replacement page. In addition, this error may have adversely affected the response rate by making the questionnaire and the study appear to be poorly organized.

In addition to business data, all three groups were asked to state their opinions concerning the Plant Patent Act and the utilization of patents by the public sector. The responses provided many useful insights which were discussed with selected public and private breeders and nurseries. These insights and discussions were important in formulating the conclusions presented in Chapter Seven.

The various data sets have their own strengths and weaknesses. Where possible, more than one data set was used to analyze a specific hypothesis in order to increase confidence in the analysis.

CHAPTER V

THE DEVELOPMENT PERIOD AND PRIVATE BREEDING INVESTMENT

5.1 Investment In Plant Origination

The discussion in Chapter Three of private fruit breeding investment divided investment into three periods: development, payback, and profits. This chapter begins with the influence of the patent on the choice of technique to be used during the development period. As suggested by Schmid (1985), originators are expected to choose those techniques which result in a patentable product and eschew those which do not. The discussion then turns to length of the development period and its affect on choice of fruit. As shown in Chapter Three, high investment costs are a sufficient condition to deter investment in some fruits. All fruits are patentable and a patent may marginally reduce the exclusion costs of some fruits. The marginal reduction in exclusion costs may be sufficient to induce investment in fruits with relatively lower investment costs. Chapter Six analyzes the impact of the patent on net present value of the investment. This includes discussion of whether gains exist to be captured, how much of the gain is capturable, and whether the portion of gains captured is sufficient to repay investment costs.

Given the value of a new variety/strain, originators are expected to employ those techniques which produce a marketable result at lowest cost. Costs include both time and monetary investments. If the PPA has made fruit breeding investment potentially profitable by increasing the ability of the originator to capture gains, the law may have influenced investment in those techniques which result in a patentable product and away from those which do not. In addition, private originators are expected to concentrate their investment in fruits which require a shorter development period in order to produce a marketable product, and/or seek ways to reduce the length of the development period to reduce costs.

In order to explain trends in choice of techniques, section 5.2 examines the relative costs of various techniques. The analysis is based upon the assumption that all techniques can result in a product of equal value. (This assumption is relaxed in later analysis.) Once the potentially profitable techniques are isolated, the discussion returns to the institutional issue of which of these techniques results in a patentable product so that returns are potentially capturable.

After the techniques have been narrowed to those which are both low-cost and produce a patentable product, the influence of investment costs on choice of fruit is examined in section 5.3. The analysis begins with the assumption that all fruits have the same potential return and differ only in their investment costs. This assumption is later relaxed and the potential returns of each fruit are examined. The fruits that show a potential gain are again examined in Chapter Six with regard to the institutional question of whether the originator can capture any gains.

Costs to the firm of breeding a new variety are estimated in Section 5.4. The need to test a new variety after it has been found or bred increases the development period and costs. Private breeders are expected to try to lower these costs in order to make their investment more profitable. Once questions surrounding the development period have been analyzed, the discussion turns to the payback period in Chapter Six.

When a new variety or strain is made available for commercial use, it is called a 'release' or an 'introduction'. An introduction is not an exact unit of measure since there is no standard which must be met in order for a variety to be introduced. Some introductions differ significantly from existing varieties while others incorporate only minor changes. However, classifying introductions in terms of major or minor physiological changes is unsatisfactory since an introduction involving only a minor change may have a major commercial impact. Also, a change may be so major that it is unacceptable to producers or consumers. For lack of a better measure we are left with the inexact measure of introductions.

During this analysis two further points must always be kept in mind. First, private breeders did exist before the passage of the PPA, and appear to have been at least as common in the nineteenth century as they are today (See Appendix B). Thus, a patent is not a necessary condition for private investment in fruit breeding. Second, in the late 1800s and early 1900s public breeding programs were initiated. While public breeding probably was intended to increase total investment in fruit origination, it may have had a negative impact on the level of private investment. Public programs, which are not dependent on profits for their continued existence compete with the private programs which must generate profits (hobbyists excluded). Public sector competition may have reduced the level of profitability in private breeding and may have led to passage of the 1930 PPA. In fact, public breeders recognize private breeders as competitors and vice versa.

5.2 Choice Of Technique To Obtain A New Variety

5.2.1 Costs Of Techniques

Given the expected value of a new variety, private originators are expected to favor techniques which are less costly and/or require less time to produce a marketable product. New varieties/strains may originate from several different techniques. They may be caused by human intervention through controlled cross-pollination, purposeful open pollination or induced mutation, or they may be found as sports (mutations), chance seedlings and existing old or wild plants. In all cases, they must be propagated by a human act in order to reproduce exactly.

The cost of each technique is influenced by the time needed to develop a new variety/strain. The development period is composed of a juvenile period and a testing period (Figure 5.1). Juvenile period is defined as the time from when the parents are crossed until the new variety fruits. The juvenile period varies among species and is discussed in more detail in Section 5.3.1. Once the variety has fruited, it must be further tested to verify its characteristics. A sport or chance seedling also must be tested after it is found. As can be seen from Figure 5.1, the development period of bred varieties is longer than that of finds because of the juvenile period. Thus, bred varieties generally have higher monetary costs than do finds.

In monetary terms, the least costly techniques are finding sports, chance seedlings and old or wild plants[1]. The distinction between a chance seedling and an existing old or wild plant is a purely legal distinction since old and wild plants generally originate as chance seedlings. (This distinction will be discussed in Section 5.2.2). Prior to the find of a sport or chance seedling, the only investment required is observation of orchards, which is part of routine production management. At the point a find is made, the finder must invest some effort to secure a preliminary evaluation of the merit of the variety/strain. This is usually accomplished with very low cost by calling the find to the attention of a fruit tree nursery. Only if the preliminary evaluation is positive is it necessary to make any large monetary investment. If the nursery feels the find has some value, it is usually willing to cover the costs of further testing in return for exclusive rights to the variety/strain.

All major nurseries recount receiving unsolicited fruit samples, photographs, letters and telephone calls reporting private finds of sports and chance seedlings. This type of activity was not unknown before 1930, and at that time nurseries also solicited such information by sponsoring fairs and exhibitions. The Red Delicious apple, a chance seedling, came to public notice as a result of two fruit exhibitions sponsored by Stark Brothers Nursery (Terry 1966).

---

[1]An old plant may be a variety that was introduced at one time and was forgotten or it may be a new variety which has grown into a mature specimen, but remained unknown to the general public, although it is known to a small number of people.

DEVELOPMENT PERIOD OF BRED VARIETIES

```
                    Year First
                     Fruited
Year     !              !                           !  Year of
Parents  !______________!___________________________!  Commercial
Crossed  ! Juvenile Period !     Testing Period     !  Introduction
```

DEVELOPMENT PERIOD OF SPORTS AND CHANCE SEEDLINGS

```
                Year     !                           !  Year of
                 of      !___________________________!  Commercial
             Discovery   !       Testing Period      !  Introduction
```

FIGURE 5.1 Development Periods of Bred Varieties and Found Varieties

Unsolicited reporting of finds apparently has increased because nurseries no longer need to sponsor events in order to receive information on new finds.

The introduction of sports has increased since the 1920s (Table 5.1). One contributing factor may be a change in the recording system. Before standardization of nomenclature, seedlings (particularly sports) of a variety were sold under the name of that variety. Nomenclature standardization stressed the importance of distinguishing between these and the original variety. Passage of the Plant Patent Act in 1930 may have provided an incentive for more precise recording because seedlings and sports were now patentable.

On the other hand, the increase in the number of sports brought to public attention may not be simply the result of a reporting change. According to Upshall, there was little public interest in the search for sports before the 1921 discovery of the StarKing Delicious apple and its subsequent popularity (Carlson _et al_. 1970). The

Starking is a sport of the original Red Delicious. As a further indication of the rarity of sports in the industry before this time, Dorsey, a horticulturalist from Illinois, speaking of the Starking said, "Only once in millions of times do we find this [a bud sport] and there are only a few instances where varieties have been produced in this manner." (Carlson et al. 1970). After the discovery of the Starking, Stark Brothers encouraged growers to look for more sports in their Delicious orchards.

Growers apparently began to pay more attention to sports as the possibility of payoff for their efforts increased. Because of their low cost, sports may provide a net return comparable to that of a variety resulting from a more costly technique. Particularly in apples, sports have captured a large share of the market. "The commercial impact of these casually collected, spontaneous mutants has been far greater than of apple cultivars derived from breeding programs . . . Spontaneous mutants have almost completely replaced the original Delicious." (Pratt 1983).

To the author's knowledge, no studies exist comparing mutation rates among species. A major difficulty in resolving such a question is the impossibility of knowing the number of sports that are unreported or unfound. Section 6.4.2 contains a discussion of an econometric model to relate finds to the number of trees in orchards. Results show no statistical relation between the two. Thus the issue of whether an increase in sport introductions is attributable to the patent remains unresolved.

Sports are more likely to be noticed in some fruits than in others because of production practices and the physical size of the plant. The strawberry plant is small and so densely planted that the likelihood of noticing a sport is low. Annual severe pruning of grapes decreases the likelihood that a sport will be noticed before it is pruned. Once a limb is established on a tree it is permanent. If the limb sports, it will be in the orchard for many years, increasing the likelihood that the sport will be noticed.

Although the costs of finding chance seedlings compared with old or wild plants at first appear to be similar, a closer look reveals a difference. As more land is brought under cultivation, as disease control campaigns eradicate old orchards and wild stands, and as more intensive production systems eliminate all trees not in the row, the probability of survival for these plants decreases. The original Red Delicious tree was cut down twice because it was not growing in the row. Both times the tree resprouted and the finder finally decided to let it grow (Carlson et al 1970). The decreased probability of survival implicitly increases the cost of finding chance seedlings and old or wild plants. Thus, compared with sports, this is a higher cost technique.

Old and wild plants have always been a minor source of new introductions, but have declined from a total of 9 such introductions during the 1920s to one per decade in the 1960s and 1970s (Tables 5.1 and 5.2). At one time the public sector was very active in the search for existing superior specimens, both domestically and in other countries, and introduced more of these plants than the private sector. Such specimens also have proved useful in public breeding programs. This type of activity appears to have declined in

TABLE 5.1 Private Introductions of Five Fruits[*] by Technique during Each Decade, 1920-1979.

TECHNIQUES	1920	1930	1940	1950	1960	1970[**]	TOTAL PRIVATE INTRODUCTIONS 1920-1979 Number
	DECADE BEGINNING IN Number (Percent)						
FINDS:							
Sports	28 (20)	52 (24)	41 (19)	81 (25)	63 (24)	46 (32)	313
Chance seedling	40 (29)	49 (23)	52 (25)	67 (20)	61 (24)	17 (11)	286
Old or Wild Plant	2 (1)	1 (1)	2 (1)	4 (1)	1 (0)	1 (1)	11
BREEDING:							
Controlled Cross	21 (15)	30 (14)	43 (20)	88 (27)	81 (31)	65 (44)	328
Open Pollination	5 (5)	7 (3)	18 (9)	47 (14)	18 (7)	8 (5)	103
UNKNOWN	42 (30)	74 (35)	55 (26)	41 (13)	35 (14)	10 (7)	257
TOTAL INTRODUCTIONS	138 (100)	213 (100)	211 (100)	328 (100)	259 (100)	149 (100)	1298

Source: Brooks and Olmo 1972 and <u>HortScience</u> 1974-1983.

[*]The five fruits include apples, grapes, peaches, pears and strawberries.

[**]Introductions during the 1970s may be under-reported (Section 4.3.1).

importance overall, but may still be of importance in specific public programs.

Chance seedlings have fallen from nearly 30% of private introductions in the 1920s to only 11% in the 1970s (Table 5.1). Absolute numbers are declining more slowly than the percentages. At first glance finding appears to be a much cheaper technique than breeding, but this may be because only monetary costs have been included. If the objective is a new variety with a particular characteristic, breeding may be a cheaper method than waiting for a sport or chance seedling with that characteristic, particularly when opportunity costs of time are taken into account. For the person who does not have such an objective, a lucky find has low costs and can result in positive net gains.

The use of open pollination as a method of breeding is also declining, both in absolute numbers and as a percentage of introductions. With the rediscovery of the work of Mendel and the subsequent advances in genetics, open pollination was abandoned in favor of controlled cross pollination. The fastest way to produce a new variety with specific characteristics is to purposely cross parents with known characteristics rather than relying on random crosses (Hanshe 1983).

The percentage of introductions resulting from controlled crosses has increased over time in both the private and public sectors (Tables 5.1 and 5.2). Controlled crosses have almost completely replaced open pollination in public breeding programs. The public sector converted to controlled crossing more quickly than the private sector because the advances in knowledge on which it is based originated in the

TABLE 5.2 Public Introductions of Five Fruits* by Technique during Each Decade, 1920-1979.

TECHNIQUES	DECADE BEGINNING IN 1920	1930	1940	1950	1960	1970**	TOTAL PRIVATE INTRODUCTIONS 1920-1979 Number
	Number (Percent)						
FINDS:							
Sports	2 (1)	1 (1)	4 (2)	3 (2)	5 (2)	0 (0)	15
Chance Seedling	9 (6)	4 (2)	8 (3)	4 (2)	3 (1)	2 (1)	30
Old or Wild Plant	7 (5)	5 (2)	1 (0)	0 (0)	0 (0)	0 (0)	13
BREEDING:							
Controlled Cross	111 (71)	141 (64)	200 (79)	166 (89)	218 (86)	136 (96)	972
Open Pollination	25 (16)	48 (22)	26 (10)	12 (7)	22 (9)	4 (3)	113
UNKNOWN	2 (1)	20 (9)	14 (6)	1 (1)	6 (2)	0 (0)	43
TOTAL INTRODUCTIONS	156 (100)	219 (100)	253 (100)	186 (100)	254 (100)	142 (100)	1210

Source: Brooks and Olmo 1972 and HortScience 1974-1983.

*The five fruits include apples, grapes, peaches, pears and strawberries.

**Introductions during the 1970s may be under-reported (Section 4.3.1).

public sector. Because of the time lag between making a cross and introducing the resulting variety, the use of open pollination as a breeding technique probably declined a decade or two sooner in each sector than shown in Tables 5.1 and 5.2. Most of the open pollination in the private sector was used by peach breeders.

Introductions resulting from finds of chance seedlings and of existing old or wild plants have declined over time because changes in production methods have reduced the survival possibility of these plants, implictly increasing the cost of the technique. Open pollination has been replaced by controlled cross pollination because advances in genetics have made the controlled cross a cheaper method of producing a plant with a given characteristic. In addition, the controlled cross is a surer and perhaps cheaper technique than relying upon a find for producing a new variety with specific characteristics. Tables 5.1 and 5.2 show the expected decline in the use of more expensive techniques.

5.2.2 The Patentability Of Results

Given the expected value of a new variety/strain, the private breeder picks the least-cost technique. However, the expected value of new variety/strain may be affected by whether the least cost technique results in a patentable product. A time lag will occur between enactment of the PPA and any changes it may have caused because of the time necessary to create or find and test a new variety. For example, most plants patented during the 1930s existed before the law was passed. Thus, gradual rather than abrupt changes can be expected.

Of the above techniques, only the finding of an old or wild plant does not result in a patentable product. The distinction between a chance seedling and an old or wild plant is a purely legal distinction since old and wild plants probably originated as chance seedlings. All require a human act in order to be exactly reproduced. The legal distinction is based upon the novelty requirement of the patent law. Old and wild plants are not novel because an old plant is already part of public knowledge, at least in the local area, and a wild plant is already part of the public domain. The legal distinction between a chance seedling and an old or wild plant is probably unenforceable. Such a find could be propagated and later claimed as a chance seedling or a whole tree mutation. Finds of old or wild plants have always been a minor source of introductions. Given the limited enforceability of the legal distinction, any decline in introductions of old and wild plants since 1930 is attributed to their decreased probability of survival.

A small voluntary organization, The North American Fruit Explorers, is dedicated to identifying and maintaining superior old or wild plants. For example, a member of this organization has identified an apricot tree growing 200 miles farther north than had been thought possible for apricots. Some public breeders are also members of this organization.

Chance seedlings and open pollinated varieties are patentable; thus declines in their use must be due to factors other than the patent. Section 5.2.1 showed that changes in production practices and breeding techniques have made these relatively more expensive ways to obtain new varieties, causing a decline in their use. Continued use has been limited in the public sector, which until recently did not respond to patent incentives.

Sports and controlled crosses are patentable and have increased in importance since 1930, both in percentages of total introductions and absolute numbers. Due to advances in breeding technology, the controlled cross has replaced open pollination as a cheaper method of achieving a desired breeding result. Controlled crossing has also increased in the public sector.

Although the cost of sports has remained relatively stable, the number of sports introduced by the private sector appears to have increased. Sports have remained a stable, but very minor source of public sector introductions. Some of the private sector increase may be due to the patent. As shown in Section 6.4.6, sports provide nurseries with a cheap source of substitutes for a competitor's patented variety or strain. Without the patent there would be no incentive to bring close substitutes onto the market since all nurseries would have access to the original. Sports which differed markedly from the original might still be introduced, but those which differed little would not.

Inducing mutations through irradiation may become more important as this technique is refined. Attempts to produce new varieties of flowers by exposing them to x-rays were made several decades ago but these attempts were unsuccessful. The procedure has now become more successful and two fruit sports, both apples, produced by this method were introduced in the 1970s by one firm. As the technique is perfected it may be a surer and faster way of producing a close substitute than waiting for a natural sport.

5.2.3 Summary Of Choice Of Technique

Introductions of finds of old and wild plants have decreased because of their lower probability of survival rather than because of patent questions. The percentage of introductions originating as chance seedlings decreased even though these varieties are patentable. Similar reductions in their importance in the public sector indicate that technological change has caused the decline. Although both techniques result in patentable products, the importance of controlled crossing has increased while open pollination has decreased in both the public and private sector, indicating that technological developments in breeding are the source of this change and not patentability. The number of introductions originating as sports has remained a minor and stable source of public introductions, but has increased in the private sector. There is some evidence that the patent system may have contributed to this increase because sports are a cheap source of close substitutes for patented varieties or strains held by the competition.

Knowing that a sport may have some value, certain people (particularly commercial growers) may look for sports as part of their routine orchard management. In general people who find sports and chance seedlings are not engaged in producing new varieties/strains, but rather are taking advantage of a fortuitous circumstance. Persons interested in producing a new variety/strain will not rely upon sports and chance seedlings which are not easily induced by human action. Instead they will choose between inducing mutations, open pollination or controlled cross pollination.

5.3 Investment Costs And Choice Of Species

For those interested in producing a new variety/strain with specific characteristics, the current technical choices include inducing mutations, open pollination and controlled crossing. Technological change and economics have a much larger influence on choice of technique than does the patent. Since all fruits are patentable, the same level of private investment might be predicted in all of them. When preliminary research indicated this was not the case, and that investment did not follow the pattern predicted by the exclusion costs of each fruit, investment costs were added to the analysis. Fruits are expected to show differential investment in relation to investment costs.

Private breeders currently work on a variety of fruits. It is not uncommon for one firm to work on several different fruits. Usually the fruits are very similar, such as pome fruits, stone fruits, or small fruits. However, there are a few firms which work on very dissimilar fruits such as apples and peaches or cherries and grapes. Private sector breeders are compared with public sector breeders who are not expected to respond to profit motives when establishing breeding programs. Thus, the public sector is more likely to invest in fruits with high investment costs than is the private sector.

The numbers of breeding programs in each sector (shown in Table 5.3) are best estimates based upon the survey, patents granted, information from Experiment Station Directors, and names submitted by private and public breeders. The number of breeding programs is probably underestimated due to inability to identify the entire population and non-response to the survey. If a breeder (public or private) reported working with more than one fruit, each fruit was counted as a separate program. This included some of the minor public programs because public breeders often work on several fruits.

Given undercounting in both sectors, the public sector still appears to cover more fruits than does the private sector. The two sectors do not give the same relative importance to particular fruits. For example, grapes rank first in the private sector and fourth in the public sector. The public sector also has more programs in high investment cost plants such as apples and rootstocks. Although the private sector appears to have more pear programs, several of these are continuing testing of a one-year breeding experiment. Within the private sector there is considerable variation of investment among fruits. The remainder of this chapter analyzes factors affecting the choice of species by private breeders. In this analysis the public sector is used as a control group to show differences in investment choices when profit from breeding activities is not an investment criterion.

5.3.1 Juvenile Period And Investment Costs

The return on investment is affected by the time period over which the investment must be made before any benefits can be expected. Investments of twenty years or more require very high benefits in order for the discounted net benefit stream to be positive. Private investment will favor those projects which produce a marketable product in the shortest development time. Because a plant is commercially worthless if it does not produce at least a minimum

TABLE 5.3 Estimated Number of Public and Private Fruit and Nut Breeding Programs in 1984.

SPECIES	PRIVATE	PUBLIC
Grape	46	13
Peach/Nectarine	13	12
Apple	8	15
Pear	6	4
Strawberry	6	17
Brambles	6	15
Plums	5	3
Cherries	4	3
Almond	3	--
Apricots	2	3
Black Walnut	2	1
Blueberry	1	10
Pawpaw/Papaya	1	2
Rootstock (all species)	--	3
Other Fruits and Nuts	6	7

quality fruit, the minimum investment must last at least until the plant bears its first fruit. In this respect the most obvious difference between species is the varying rate at which they mature. The time between crossing the parents and fruiting of the progeny is known as the juvenile period. While this period does vary between varieties of the same species, it varies more between species.

An average juvenile period was calculated for each fruit using data from the Register of New Fruit and Nut Varieties (Brooks and Olmo 1972). The juvenile period was calculated by subtracting the year a cross was made from the year the variety first fruited. If the seed was stored for several years, the beginning date used was one year before the seed was planted. If the actual date of first fruiting was not given, the year the variety was selected for further testing was used. This procedure may lead to some ove-estimation of the juvenile period because the likelihood that the plant was not immediately selected for further testing upon first fruiting is greater than the probability that the variety was selected before it first fruited. The average juvenile period ranged from 2.5 years for strawberries to 10.8 years for pears (Table 5.4).

Analysis of variance was used to test for differences between juvenile periods of the five fruits. Tests were carried out for significant differences between pairs of means (Bhattacharyya and Johnson 1977). Except for the pair comparison of apples and pears, all other pairs of means were statistically different from each other at the .05 level of probability.

The juvenile period is the minimum investment time needed to produce a new variety by breeding. Actual investment time is usually longer because the variety is propagated for further testing. The total development time for a variety developed by breeding is the juvenile period plus the testing period (Figure 5.1). Estimates of total development time are two to four times as long as the juvenile period.

Because of missing data, three methods were used to calculate the development time for bred varieties. The methods allowed the use of two overlapping subsets of data from the Register (Brooks and Olmo 1972) and the use of information obtained from the survey of breeders. For bred varieties with complete data, the year parents were crossed was subtracted from the year of commercial introduction. The average development period for each fruit is given in the second row of Table 5.5.

The second method estimated the date of a cross by subtracting juvenile period for the species from the date the variety was selected

TABLE 5.4 Average Juvenile Periods for Five Fruits

SPECIES	JUVENILE PERIOD	NUMBER OF OBSERVATIONS
Strawberry	2.5	120
Peach/Nectarine	4.3	161
Grape	5.8	78
Apple	10.1	81
Pear	10.8	20

ANALYSIS OF VARIANCE

	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
Between Species	4	3666.7	916.7
Within Species	455	4756.7	10.4
Total	459	8423.3	

F Ratio	87.7
Probability of F Ratio	.00

Source: Brooks and Olmo 1972

for further testing. The estimated date of the cross was subtracted from the year of commercial introduction. The second estimate of the development period is presented in the third row of Table 5.5.

The survey of breeders was used to make a third estimate of the total development period for bred varieties. The number of years which the breeders report testing varieties after first fruiting is added to the juvenile period for that species to obtain an estimate of the development period. This third estimate is presented in the fourth row of Table 5.5.

Estimates of the development period for each species vary. Because varieties within a species have varying juvenile periods and because some characteristics require longer testing than others, these estimates might indicate the expected minimum and maximum years of development. The estimates of development time for apples and pears

TABLE 5.5 Alternative Estimates of Average Years of Testing by the Private Sector for Bred Varieties and for Finds, 1920-1979.

	SPECIES				
	Strawberry	Peach	Grape	Apple	Pear
JUVENILE PERIOD	2.5	4.3	5.8	10.2	10.8
DEVELOPMENT PERIODS FOR PRIVATELY BRED VARIETIES:					
From Cross to Commercial Introduction	9.5	12.9	8.8	22.1	28.3
From Estimated Cross to Commercial Introduction	9.7	8.9	13.5	16.8	24.8
Juvenile Period plus Years of Testing	8.5	12.0	13.2	--	20.8
DEVELOPMENT PERIOD FOR FINDS:					
Discovery to Commercial Introduction	--	7.5	8.9	10.6	15.0

Source: Brooks and Olmo 1972

are over twenty years, indicating that the present value of returns on the investment are likely to be low.

Finds of sports and chance seedlings are tested from time of discovery until they are commercially introduced (Figure 5.1). The average testing time for private finds was calculated from data given in the Register (Brooks and Olmo 1972) and is given in the final row of Table 5.5. The development period of a find tends to be half to two-thirds of the time needed for a bred variety. Because of its shorter development time, an investment in finds may result in a higher present value of income than an investment in breeding for the same species.

5.3.2 Juvenile Period And Choice Of Techniques

As stated above, private investors will select techniques and fruits with shorter development periods in order to lower investment costs and increase the present value of income. The techniques have already been narrowed to inducing mutations, open pollination and controlled crossing. Based upon estimated juvenile and development periods, private breeders are expected to prefer strawberries, peaches and grapes to apples and pears.

Examination of total private introductions for each fruit is not sufficient to test this hypothesis since introductions result from various techniques. The hypothesis must be tested using only those introductions resulting from breeding techniques. The percentage of introductions from private finds (non-breeding techniques) is expected to be highest in fruits which have the highest breeding costs. The largest percentage and absolute number of introductions from sports occurs in apples which also have high breeding costs (Table 5.6). Sports are found mainly among trees (rather than vines or small plants) because they have a higher chance of being noticed (Section 5.2.1).

Grapes, strawberries and peaches show the highest percentage of introductions from breeding, supporting the hypothesis that private breeders prefer fruits with shorter development periods. A more rigorous test of the hypothesis is needed which directly relates length of the investment period with output.

The juvenile period was chosen as a proxy for investment costs because it is not as subject to control by the breeder as are the

TABLE 5.6 Private Introductions of Five Fruits by Technique, 1920-1979.

	SPECIES				
	Strawberry	Peach/ Nectarine	Grape	Apple	Pear
JUVENILE YEARS	2.5	4.3	5.0	10.2	10.8
			Percent		
FINDS:					
Sports	4	19	8	48	20
Chance seedlings	19	22	15	22	37
BREEDING:					
Controlled Cross	59	24	67	8	18
Open Pollinated	7	12	3	3	4
UNKNOWN:	12	22	7	19	21
TOTAL INTRODUCTIONS	100	100	100	100	100
(Number)	(165)	(597)	(104)	(452)	(71)

Source: Brooks and Olmo 1972

testing and development periods. Hansche (1983) also points out the importance of the juvenile period as a component of investment costs. Several tests were made of sensitivity of statistical results to various proxies for investment costs, and results were fairly stable.

As a test of the hypothesis that private breeding investment is influenced by the juvenile period of the fruit, the percentage of all public and private introductions from 1920 to 1979 resulting from private breeding was correlated with the juvenile period for each of the five major fruits. A negative correlation was expected. Given five observations, the correlation of -.91 was significant at the 5 percent level, and the sign of the relation was in the predicted direction (Table 5.7).

A similar test was performed to investigate if the percentage of private introductions resulting from finds (which have lower monetary costs) is positively correlated with juvenile period of the fruit. The coefficient of .72 was statistically significant at the 10 percent level (Table 5.7). This provides further evidence that the private sector investment is influenced by investment costs. There is little private breeding investment in species with high investment costs. Private sector investment in these species is generally limited to testing finds.

5.3.3 Juvenile Period And Breeding Investment

In the previous section a relation was shown between juvenile period of a fruit and the type of private investment in that fruit. The techniques used to produce introductions were used as an indicator

TABLE 5.7 Juvenile Period and Private Introductions from Breeding and Finds, 1920-1979

SPECIES	JUVENILE YEARS	PERCENT OF ALL INTRODUCTIONS FROM PRIVATE BREEDING	FINDS
Strawberry	2.5	.263	.090
Peach/Nectarine	4.3	.267	.295
Grapes	5.0	.261	.086
Apple	10.2	.060	.432
Pear	10.8	.124	.310
Correlation Coefficient		-.91*	.72**

Source: Brooks and Olmo 1972.

*Statistically significant at the .95 level.

**Statistically significant at the .90 level.

of the type of investment. Fruits with long juvenile periods have low levels of investment and most introductions in such fruits are the result of finds rather than breeding. This section concentrates specifically on current private breeding investment to test whether current investment levels are influenced by the costs of investment as measured by the juvenile period.

To test whether current investment in fruit breeding is negatively correlated with juvenile period of each species, the historical data on juvenile periods were combined with current cross-sectional data on breeding investment obtained from a survey of private breeders. Both physical and monetary measures of private investment were used. Because all private breeding programs could not be identified and the number of responses was small (particularly on certain variables), in all cases the numbers reported should not be interpreted as industry totals, but rather as indicative of relative magnitudes of investment among species.

The physical measures of investment are thought to be more reliable than monetary measures because there is less incentive for firms to attempt to conceal this data. Corroborating this expectation, physical data were much more completely reported on the questionnaire than financial data. Physical measures of investment include the number of private breeding programs, total acres in test plots and total seedlings tested (Table 5.8). Monetary measures of private investment include total current capital investment, cash expenditures and salaries for 1984 (Table 5.9).

Of the physical measures, acreage in test plots is expected to be most reliably reported because it is measurable and does not require recall or record searching as does the number of seedlings tested. Acres in test plots may underestimate investment in some fruits such as strawberries, where seedlings can be tested using relatively little land, but this underestimation is biased against (rather than for) the hypothesis.

In some cases the program has been functioning for so long and/or the number of seedlings tested is so large that recall is probably not accurate. Nor is it likely that historical records were searched in order to reply to the survey. The cost of testing a seedling varies with species so that number of seedlings tested is not a standard measure of investment. As Hansche (1983) pointed out, testing of strawberry seedlings is much less costly than for the other four fruits because the seedlings mature more rapidly and require less land for testing. This would bias the result in the expected direction so strawberry seedlings were omitted when calculating the correlation coefficient between the juvenile period and the number of seedlings tested.

The number of persons working in the firms was calculated on a full-time equivalent basis by multiplying part-time workers by .5. This probably overestimates the actual number since personal interviews with breeders indicated that they tend to hire help only during peak seasons. However, the numbers may reflect relative magnitudes of employment among the various fruits.

The number of breeding programs for each species is probably the least reliable physical indicator of private investment in fruit

TABLE 5.8 Correlation of Physical Measures of Private Investment in Breeding with the Juvenile Period, 1984.

FRUIT	JUVENILE YEARS	PHYSICAL MEASURES OF INVESTMENT: Number of Breeding Programs	Acres in Test Plots	Seedlings Tested	Persons (Full Time Equivalent)
Strawberry	2.5	6	41.0	--**	9.5
Peach/Nectarine	4.3	12	52.0	934245	29.0
Grape	5.8	46	40.8	59750	10.0
Apple	10.2	6	2.5	3645	2.5
Pear	10.8	5	7.5	2532	0.5
Correlation Coefficient		-.24	-.92*	-.76**	-.66

Source: Survey of Private Fruit Breeders

*Statistically significant at the .95 level

**Strawberries were not included when calculating this correlation because testing costs are not comparable to other fruit seedlings.

TABLE 5.9 Correlation of Monetary Measures of Private Investment in Fruit Breeding with Juvenile Period, 1984.

Juvenile Period With:	Correlation Coefficient	Number of Observations
Current Capital Investment	-.64	4
Cash Expenditures in 1984	-.74	4
Salaries in 1984	-.71	5

Source: Survey of Private Fruit Breeders breeding because of the difficulty in identifying private breeding programs and because these programs vary greatly in size and effort but are each counted as one unit.

Financial data were incomplete for many firms. Firms which did include this information often used best estimates since they either engage in another activity which shares finances with the breeding activity or do not keep financial records. For the monetary measures of investment only correlation coefficients are presented to protect the confidentiality of respondents and because the limited data may create a false impression of magnitudes (Table 5.9). However, there is no indication that missing data were biased by firm size.

All financial data reported were attributed to the major fruit even though a firm may have reported breeding work on more than one fruit. Only 8 private breeders reported working on more than one fruit, and of these only one gave complete financial data; while most failed to report sufficient detail on minor fruits to allow allocation of percentage of the total to them. In addition, distributing the data among all the fruits reported by the breeder (when there were sufficient data to do so) did not greatly change the totals, but did slightly increase the correlation coefficients in the hypothesized direction.

All measures of private investment are negatively correlated with juvenile period, but only the correlation between the juvenile period and acreage in test plots was statistically significant at the 5 percent level (Table 5.8). Since all signs on the correlation coefficients are in the hypothesized direction and the variable believed to be most reliable--acres in test plots--is statistically significant, there is support for the hypothesis that private breeding investment is negatively correlated with the juvenile period of the species.

5.3.4 Juvenile Period And Current Public Breeding Investment

Correlation does not prove causation, but the case for causation is stronger if other factors can be eliminated as possible causes. Public breeders are used as a control because they do not have the same profit incentive as private breeders. Public sector breeding, while influenced by cost considerations, also responds to the importance of a fruit to the economy of the state. Therefore, public investment is not expected to show as strong a negative correlation with costs as does the private sector. Positive correlation of the juvenile period and investment in the public sector would be convincing evidence that private breeding investment is influenced by investment costs.

There were a larger number of responses from public breeders, and for the most part data were more completely reported. However, public breeders found estimation of current capital investment and cash expenditures difficult because facilities and budgets are often shared among several programs. As with private programs, the number of public breeding programs does not accurately reflect variation in size among the various programs. Total seedlings tested may be a somewhat more reliable measure of public investment, but also difficult for public breeders to report since most public programs have a long history and records are incomplete. The variables expected to be reported most reliably are salaries, number of employees, and acreage in test plots.

Cash expenditures show a statistically significant positive correlation with juvenile period as expected if the public sector responds to the importance of the fruit within the state (Table 5.11). Acres in test plots, thought to be reliable, shows a low positive correlation (Table 5.10). All other variables show negative correlations, none of which is statistically significant.

As hypothesized, the juvenile period alone is not sufficient to explain public investment in fruit breeding. Since public investment does not have to show a short-run profit as does a private firm, the public sector investment most likely takes a long-run view which includes not only investment costs but also the importance of the fruit within the state in its investment decision. This view is reinforced by the statistically significant positive relation between cash expenditures and juvenile period. A long juvenile period means breeding will be more expensive and if the public sector is investing in the more expensive species because of their importance then investment levels must be high. The low negative correlations between public sector investment and juvenile period when compared with the higher correlations of the private sector support the hypothesis that private sector investment is influenced by the differing investment costs among fruits.

5.3.5 Juvenile Period And Private Breeding Output

The two previous sections showed that a negative relation, which may be causal, exists between the juvenile period and current private

TABLE 5.10 Correlations of Physical Measures of Public Investment in Fruit Breeding with the Juvenile Period, 1984

		PHYSICAL MEASURES OF INVESTMENT			
SPECIES	JUVENILE YEARS	Breeding Programs	Acres in Test Plots	Total Seedlings Tested	Persons (Full-Time Equivalent)
Strawberry	2.5	14	13	(1155700)*	8.5
Peach/Nectarine	4.3	12	208	773000	20.5
Grape	5.8	12	77	492800	13.0
Apple	10.2	13	199	664000	14.0
Pear	10.8	4	70	71000	4.0
Correlation Coefficient		-.64	.28	-.61*	-.36

Source: Survey of public fruit breeders

*Strawberries were not included when calculating this correlation because testing costs are not comparable to other fruit seedlings.

TABLE 5.11 Correlations of Monetary Measures of Public Investment in Breeding with the Juvenile Period, 1984

SPECIES	JUVENILE YEARS	MONETARY MEASURES OF INVESTMENT (in Dollars)		
		Current Capital Investment	Cash Expenditures	Salaries
Strawberry	2.5	50000	12000	108536
Peach/Nectarine	4.3	4270000	57500	406518
Grape	5.8	243000	61118	204900
Apple	10.2	700000	94500	346518
Pear	10.8	110000	216000	78725
Correlation Coefficient		-.30	.85*	-.08

Source: Survey of public fruit breeders

*Statistically significant at the .95 level breeding investment. This section analyzes the relation between breeding output by existing private firms and the juvenile period. Since investment is related to juvenile period, the output of that investment is expected to show a similar relation. This differs from the analysis in section 5.3.2, which used historical introductions resulting from various techniques to show the relation between the juvenile period and choice of technique.

Species with a shorter investment period are expected to display a higher level of output (since they also displayed a higher level of input). The 26 firms which replied to the survey have introduced a total of 327 new varieties/strains over their lifetimes. Ten firms have introduced no varieties while one has introduced 75. Seven firms introduced 280 of the 313 new varieties/strains. The total number of introductions by current private breeding firms is negatively correlated with the juvenile period of the species and is statistically significant at the ten percent level (Table 5.12).

The beginning of this chapter discussed the problem of determining the quality of an introduction. One attempt to do so was to ask private breeders how many of their introductions were commercial successes. Although dependent upon each breeder's subjective judgement, this is at least a minimal measure of quality. Using only "quality" introductions as the measure of output, the correlation of output with juvenile period is much weaker, although the sign of the correlation is in the expected direction (Table 5.12). Output of private breeders appears to be correlated with investment costs.

TABLE 5.12 Total Introductions of New Fruit Varieties by Current Private Breeding Firms

SPECIES	JUVENILE YEARS	INTRO-DUCTIONS	COMMERCIAL SUCCESSES
Strawberry	2.5	78	24
Peach	4.3	163	107
Grape	5.8	32	7
Apple	10.2	2	1
Pear	10.8	5	3
Correlation Coefficient		-.74[x]	-.54

Source: Survey of private fruit breeders.

[x]Statistically significant at the 10 percent level

5.4 Costs Of Breeding And Testing

Aggregate levels of private investment are related to the costs of breeding as shown in the previous section. The objective of this section is to use data provided by individual firms to calculate the costs of developing a single variety. Attempts by private breeders to reduce the costs of breeding are also examined.

5.4.1 Costs Of Breeding And Testing A Single Variety

Several measures of inputs were used to determine the costs of producing a single variety (Table 5.13). Time is a cost and it has already been shown how fixed costs of the juvenile period affect investment. Most firms spend many years before they have a variety worth releasing. Although years are required to breed and test a new variety, when a firm has been in business for some years, it may introduce varieties with some regularity since new crosses are constantly being evaluated. Several of the larger peach/nectarine breeders introduce a new variety nearly every year. The same is true for strawberry breeders. Grape breeders, who tend to work part time, introduce a new variety only once every eleven years. Only two apple varieties have been introduced by private firms and one is the result of a one-time experiment. Two of the five pear introductions were also the result of one-time experiments. The very low end of the ranges on these fruits is due to these one time-experiments. While some firms are successful with a one-time experiment, others work for years without introducing a variety. Firms which have not introduced a variety are included in both the average and the range. The most years that a single firm has worked without success is also listed in the table.

TABLE 5.13 Indicators of Costs of Breeding a Fruit Variety

	SPECIES				
	Strawberry	Peach	Grape	Apple	Pear
YEARS OF BREEDING PER INTRODUCTION:					
Average	1	1	11	26	9
Range	.8-1.4	.3-30	2-47	1-30	.5-30
Maximum without Success	--	30	47	30	30
SEEDLINGS TESTED PER INTRODUCTION:					
Average	10385	5767	1867	1023	633
Range	357-16000	10-24000	100-10000	10-1250	10-1250
Maximum without Success	--	2000	10000	1000	10

Source: Survey of private fruit breeders

There is considerable range in the number of seedlings tested per introduction among firms breeding the same fruit, and this range is given in Table 5.13. The number of seedlings tested per introduction decreases as juvenile period increases. The number of seedlings tested would be expected to decrease as costs increase, but this does not an explain the relationship found.

The effort to calculate cost of a single introduction was hampered by incomplete reporting. Thus, only a range of cash costs could be calculated for a limited number of species. Firms which breed more than one species were eliminated since there was no way to determine the proportion of costs to be allocated to each. Apportioning total costs according to the total number of seedlings tested per species was rejected because the assumption was directly contrary to the central point of the research. Elimination of these firms meant that costs could not be calculated for apples, pears and strawberries. The costs of firms which have not introduced a variety were not included in these calculations.

The cost per introduction was calculated by multiplying 1984 costs by the number of years the firm has been breeding and then dividing by the number of introductions produced. This assumes that 1984 was a typical year for the firm and that costs do not vary greatly from year to year, or over the lifetime of the firm. In addition, all costs are stated in 1984 dollars rather than discounting back to the year of establishment of the firm so that the costs of each firm are in equivalent dollars.

The out-of-pocket cost of a grape introduction ranged from $2,700 to $122,500. Peaches showed a much narrower range of cash costs

($36,000 to $40,500) per introduction. Since firms only reported cash costs, these figures should considered minimum estimates and are best interpreted as relative ranges of costs within and between species.

5.4.2 Differences In Testing Between The Public And Private Sectors

Private breeders tend to be extremely frugal, as will be seen from firm budgets in Chapter Six. In addition to maintaining close control of annual cash costs by not fertilizing and using unpaid family labor and minimal machinery, private breeders are expected to further decrease costs by shortening the time varieties are tested. The public sector is used as a standard with which to compare the testing practices of private breeders because it does not have a short-run profit motive.

Analysis of variance was used to test whether differences exist between testing time of public and private breeders. Testing time was defined as the time from when a variety is selected for further testing until it is introduced. The data on testing time were taken from the Register (Brooks and Olmo 1972). A separate analysis of variance was calculated for each species. Although the number of observations in the two sectors for each species is uneven, there is some indication that public breeders do test longer than private breeders (Table 5.14). The evidence of testing differences between the two sectors is particularly strong in the case of peaches.

In addition, current private and public breeders were asked how long they normally test a variety after it first fruits. Although the number of observations is too small to provide a valid statistical

TABLE 5.14 Average Testing Time From Selection to Introduction for Private and Public Introductions

	ANALYSIS OF VARIANCE				
	AVERAGE YEARS OF TESTING			NUMBER OF OBSERVATIONS	
SPECIES	Private	Public	Sig. of F	Private	Public
Strawberry	7.2	7.6	.38	62	216
Peach/Nectarine	4.6	8.4	.00	154	225
Grape	7.7	11.4	.02	31	107
Apple	6.6	13.2	.002	34	179
Pear	14.0	10.9	.46	3	33

Source: Brooks and Olmo 1972

test, the responses again provide some evidence that public breeders test longer than do private breeders (Table 5.15).

Although the results are not statistically significant in all cases, the above analysis gives some support to the hypothesis that the private sector tests for a shorter time than does the public sector. Because of the shorter testing period some private breeders may release varieties which later prove to be inferior. This tends to be a general opinion expressed by public breeders concerning the work of private breeders. Although it might be true in individual cases, the commercial success of some private varieties should dispel this opinion as a general rule.

Private breeders realize the importance of wider testing but admit that they have neither the money nor the contacts necessary. Public breeders seldom test private varieties because they feel the varieties are not worth testing or because of ideological convictions concerning the separation of the public and private sectors. The few

TABLE 5.15 Average Testing Time After the Variety First Fruits as Reported by Current Private and Public Sector Breeders.

SPECIES	AVERAGE YEARS OF TESTING Private	Public	NUMBER OF OBSERVATIONS Private	Public
Strawberry	6.0	8.7	2	6
Peach/Nectarine	7.7	9.5	6	8
Grape	7.4	10.1	9	8
Apple	5.0	15.0	1	7
Pear	10.0	10.0	1	2

Source: Surveys of private and public breeders

private breeders who have managed to secure public testing of their varieties have succeeded in doing so only after years of contact with public breeders. Most public breeders did not know any private breeders or even claimed that there were no private breeders of the species on which they work.

In one case several private breeders have formed a corporation for the express purpose of widening testing of their varieties. They also contract to test varieties of other private breeders of the species. This procedure has not been without its problems. One breeder complained that his variety was not being fairly evaluated because he was not a member of the firm. A public breeder finally confirmed the evaluation of the corporation, but apparently friendships were strained.

5.4.3 Changes In Private Testing Over Time

As the patent went into effect and the private sector became more aware of the potential for patenting, private breeders may have had an incentive to move from a hobby to a professional enterprise. In an effort to make the enterprise economically feasible, the testing period may have been shortened. A relatively slow trend toward shorter testing, rather than an abrupt change, is expected because of the time lag in breeding. This trend is expected to be most pronounced in the fruits with the most private investment--grapes, peaches and strawberries. Because of extended investment periods of 20 years or more, apple and pear breeding are conducted mainly by hobbyists, so that less change in breeder actions is anticipated in these fruits.

Technological advances which allow for earlier and more rapid screening for particular traits, such as disease resistance, may also lead to a shorter testing period. Since such technological advances are most commonly developed within the public sector, these techniques are expected to be adopted more rapidly and pervasively through the public than the private sector. The testing practices of the public sector are included to control for technological change.

It is expected that private and public breeders will show different trends in testing over time. If public breeders also show a decline, due to technological change, any private sector testing decline must be larger than that of the public sector for any of the decline to be attributed to the patent. The hypothesis was tested, using a multi-variate regression equation of the following form:

Years of Testing = Constant
+ Private Sector Dummy
+ Year of Commercial Introduction
+ Private Dummy X Year of Commercial Introduction

Two equations were estimated for each fruit using the development period and testing time as dependent variables. Development time is defined as the time from the cross to the commercial introduction (Section 5.3.3). This definition can include only varieties which were bred. Testing time is the period from first fruiting or discovery until commercial introduction. Varieties from all origins are included in this variable. The dummy variable was set to one for the private sector and zero for the public sector.

The slope shifter for the private sector is expected to be negative. If the public sector slope coefficient is also negative, the slope coefficient of the private sector should be more negative. Coefficients on the dummy variables are differences from the base coefficients and must be added to the base coefficients to obtain the intercept and slope coefficients for the private sector. If the dummy intercept and dummy slope coefficients are statistically significantly different from zero the hypothesis that the two sectors have the same testing length is rejected (Gujarati 1978).

The hypothesis that the two sectors have equal development or testing time cannot be rejected in the case of apples because both dummy coefficients were not statistically significant in either of the apple equations (Table 5.16). Yet, the two equations show the same pattern. Both sectors have a positive slope, indicating that testing time is increasing with the rate of increase lower for the private sector.

TABLE 5.16 Comparison of Private and Public Sector Testing Patterns, 1920-1979, Using Regression Analysis**

SPECIES	DEPENDENT VARIABLE	COEFFICIENTS OF INDEPENDENT VARIABLES				R2
		Constant	Private Dummy	Commercial Introduction	Slope Dummy	
Apple	Development Time	9.66 (2.71)*	.90 (8.07)	.25 (.05)*	-.05 (.13)	.17
	Testing Time	-9.92 (2.44)*	3.70 (3.22)	.48 (.05)*	-.17 (.06)*	.25
Grape	Development Time	17.57 (3.31)*	.86 (16.93)	.04 (.05)	-.19 (.24)	.14
	Testing Time	.93 (2.36)	11.05 (4.35)*	.19 (.04)*	-.25 (.08)*	.13
Peach/ Nectarine	Development Time	8.86 (1.31)*	14.76 (4.83)*	.07 (.02)*	-.24 (.08)*	.05
	Testing Time	-.25 (1.85)	3.78 (2.18)*	.15 (.03)*	-.08 (.04)*	.06
Pear	Development Time	12.88 (4.28)*	8.24 (28.11)	.19 (.08)*	.04 (.05)	.11
	Testing Time	-4.18 (5.79)	3.23 (8.66)	.34 (.10)*	-.02 (.17)	.15
Straw-berry	Development Time	9.63 (1.09)*	-5.68 (3.81)	.02 (.02)	.06 (.06)	.01
	Testing Time	4.77 (.98)*	-3.13 (1.59)*	.05 (.02)*	.06 (.03)*	.08

Source: Brooks and Olmo 1972

**Numbers in parenthesis are standard errors of the coefficients.

*Standard error indicates that the coefficient is statistically significant at the .95 level.

Strawberries display the reverse pattern of apples. The rate of increase in private sector testing time is higher than that of the public sector. The second equation indicated a statistically significant difference in testing between the two sectors.

The equations for grapes and peaches/nectarines show testing decreasing over time in the private sector while it is increasing in the public sector. The differences were statistically significant for both peach equations and for the second grape equation.

Statistically significant differences were not found between the public and private sectors in either pear equation. Both sectors have positive slopes, but the relative magnitudes of the slopes of each sector are reversed in the two equations. Because of the low number of observations the first equation cannot be interpreted with confidence.

The negative slopes for private testing of grapes and peaches were as expected. The positive slopes for the public sector for these species indicate that decreases in private sector testing cannot be attributed to technological change. Peaches and grapes are areas of major private investment in breeding and breeders may be attempting to cut their costs by reducing testing time.

A negative slope was also expected for strawberries, but the slope was positive and increasing at a faster rate than the public sector. The explanation lies in the domination of private strawberry breeding by one firm, owned by a grower's organization. This firm's emphasis is on making strawberry production profitable, rather than breeding. In this case, the incentive is to test longer to protect growers from inferior varieties[1]. Because it is owned by growers, this firm is responding to growers' needs in a manner similar to a public institution. Therefore, its testing practices should move in the same direction as those of the public sector.

The positive slopes in apples and pears might be explained by the few private breeders of these species, most of whom are hobbyists. Apples are sold by variety more than any other fruit except wine grapes, making it difficult for a new variety to enter the market unless testing has shown it to be superior.

Some of the differences in testing might be explained if the two sectors were working on different characteristics. For their major species, all breeders were asked to list the most important characteristics for which they are selecting. Spearman's Rank Correlation Coefficient was used to test the hypothesis that public and private breeders concentrate on different characteristics. For apples peaches/nectarines and pears this hypothesis was rejected.

A statistically significant difference of characteristics (at the one percent level) between public and private strawberry breeders should be interpreted with caution since only two private breeders responded to the question. The statistically significant difference (at the five percent level) between public and private grape breeders can be accepted with more confidence because the total number of breeders is larger and more evenly divided. This difference might be attributed to public breeders working with wine varieties in addition

---

[1] Information conveyed in a telephone conversation with the director of research of the firm in question.

to table varieties while most private breeders do not have the resources to test wine grapes.

An additional observation is based upon information which was lost in coding. Public breeders tend to list the broad characteristic while private breeders tend to concentrate on a point along the continuum of that characteristic. For example, a public breeder might list a broadened temperature tolerance while a private breeder is more likely to mention the direction of the temperature tolerance, such as cold hardiness, and may even specify a temperature range. This would conform with a further hypothesis that private breeders tend to work in a market niche.

5.5 Summary

5.5.1 Impacts Of The Patent

Originators of new varieties will search for the lowest cost techniques, assuming that all techniques produce varieties of equal value. Finding chance seedlings and old or wild plants has become a relatively more costly technique due to changes in production practices. Open pollination has become a more costly method of breeding compared with cross pollination. As the technique for inducing mutations is perfected it may become more important. Of the lowest cost techniques, originators will select those which result in a patentable product. Only finds of old and wild plants are not patentable. Since all other techniques may result in a patentable product, declines in use of any other technique must be attributed to technological change influencing relative costs. Introductions of sports, particularly in fruits with high breeding costs, may have increased as a result of the patent system.

Differences were observed in investment among the various fruit species, all of which are patentable. The investment pattern was opposite that predicted by exclusion costs because of the importance of investment costs in determining private breeding investment. High investment costs (low potential net return) are a sufficient condition to affect the allocation of investment, but negative returns do not eliminate private breeding.

5.5.2 Impacts Of Investment Costs

The major determinant of investment cost is length of the development period, which includes the juvenile period and the testing period. Species have different development periods due to their varying juvenile periods. Private breeders select those species with shorter juvenile periods. The public sector was used as a control group to verify this conclusion. The public sector responds to the importance of the fruit within the state and has a different investment pattern than the private sector.

Both the costs of producing a single introduction and physical production relations were estimated. Attempts to estimate monetary costs were hampered by lack of data. Private breeders are very frugal and keep annual cash costs to a minimum. In addition they tend to shorten the testing period to decrease costs and perhaps to increase the present value of future income.

Because of high investment costs, there is little private investment in apples, pears, wine grapes and rootstocks. Based upon the length of the juvenile and development periods, the highest private investment is predicted in strawberries; however, private investment in strawberries differs little from that of peaches or grapes. When investment costs are medium to low, the combination of investment and exclusion costs influences private investment. It is this combination which explains the similarities in investment of strawberries, peaches and grapes.

Private breeders do respond to economic incentives in selecting a species for breeding investment. By selecting techniques which produce a patentable product, they are marginally increasing the value of any returns which might be received. Chapter Six examines the profitability of fruit breeding by determining whether there are gains from fruit breeding and how exclusion costs influence the amount of gain which can be captured by the breeder.

CHAPTER VI

THE PAYBACK PERIOD AND RETURNS TO PRIVATE BREEDING

6.1 The Payback Period

The investment cycle was divided into three periods: development, payback and profits. The net present value of the investment is affected by the length of the development period and level of investment costs, and by the size and timing of the income flows once payback begins. The analysis in Chapter 5 of the impact of development period length on private fruit investment found that private breeders respond to economic incentives when selecting a species for breeding investment. This chapter looks at the payback period and how the timing and size of income flows affect the profitability of breeding.

During the development period, costs are incurred but no income is received. In the particular case of fruit breeding, the development period begins when crosses are made with the objective of achieving a variety with certain characteristics and extends until the variety is commercially introduced. The development effort produces very little of commercial value before introduction. Some firms develop a joint enterprise, such as fruit and seedling sales, which generate income necessary to sustain the breeding effort. Firms which have released varieties have progressed at least into the payback period. As shown in Chapter 5, some firms have never released a variety and remain in the development stage.

The payback period begins when income is earned from the investment. Costs incurred during the development period become sunk costs. Payback is completed once the sunk costs from development and costs incurred for propagation have been recovered. This cycle is presented as a linear process, but a real firm may exhibit characteristics of all three periods, since firms make crosses every year. Thus, the payback period of one variety is entered while other varieties remain in the development period.

Once a variety is introduced, the major activity changes from breeding to propagation. The actors also change when the variety is introduced. A breeder produces the variety and generally sells it to a nursery which then propagates the variety and sells it to commercial growers or home gardeners. The change in actors raises questions of how gains (if there are any) are shared. There may be conflicts between the parties since their self interest is not necessarily compatible.

The timing and size of income flows are affected by demand for the variety. Ability to set prices at a level sufficient to cover breeding costs is affected by the competitiveness of the market and exclusion costs. A patent may not permit the breeder to price the variety high enough to cover breeding costs if the market is otherwise competitive. Before profits can be obtained, all breeding costs plus all reproduction costs must be recovered. During the profit period, costs are also incurred, but income needs only to be sufficient to cover current costs, with the excess as profit.

6.2 Annual Budgets Of Typical Firms

During the payback period, the firm must recover both current costs and sunk costs from the development period. This section and the one following examine the ability of private firms to set prices at cost recovery levels. Budgets of typical firms are constructed, first to examine annual income and costs, and then to determine if sunk costs are recovered over the lifetime of the firm.

Budgets reported by the firms for 1984 are analyzed with respect to profitability. If 1984 was a normal year in the industry, firms should have been at all different stages of their life cycle--from starting to closing down--and should demonstrate a wide range of profitability. The analysis is based upon budgets for typical firms; some firms did not provide complete financial information so that a more rigorous statistical analysis was not possible. In this way the author can also include personal knowledge of firms which did not provide complete information. The typical firm is based mainly on the modal values of budget items, and actual range of values is also presented. Breakdown of budgets by species is not possible because of the need to preserve the confidentiality of individual replys.

From their 1984 budgets, the twenty six firms which responded to the survey fell into three size categories (Table 6.1). The majority of firms might be called amateur or small firms (although by most standards all of the breeding firms would fall into the small firm category). All of the grape breeders as well as the apple, pear, and some of the peach breeders are amateur firms. There are several large or professional firms, mainly breeding peaches, nectarines and plums.

TABLE 6.1 Characteristics and 1984 Budgets of Typical Firms and Ranges of Actual Values by Firm Size

	FIRM SIZE		
	SMALL	MEDIUM	LARGE
CHARACTERISTICS			
Number of Firms	18	4	4
Breeders, full time (FT)	0	1	2
part time (PT)	1	0	2
Range	(1 PT to 1 FT & 2 PT)	(1 PT to 1 FT)	(1 PT to 4 FT & 2 PT)
Employees, full time	0	0	2
part time	0	1	4
Range	(0-4 PT to 1 FT)	(1 PT to 1 FT)	(1 PT to 2 FT & 25 PT)
Years of Breeding	25	20	40
Range	(3-64)	(13-50)	(20-50)
Acres in Test Plots	4	6	20
Range	(.25-7.5)	(6-15)	(1-35)
Capital Investment	$40000	$25000	$1000000
Range	(2000-50000)	(1000-25000)	*
ANNUAL BUDGET			
Breeder salaries	0	$10000	$100000
Range	(0)	(0-14400)	*
Employee Salaries	0	$2000	$70000
Range	(0-500)	(400-20000)	*
Other Cash Expenditures	$750	$7500	$150000
Range	(300-2000)	(5000-9250)	*
Total Cash Expenditures	$750	$19500	$320000
Royalties in 1984	0	$5000	$160000
Range	(0-2000)	(0-15000)	*
LIFETIME TOTALS			
Lifetime Royalties	0	$25000	$1300000
Range	(0-6000)	(0-550000)	*
% Years Income Exceeded Expenses	0%	10%	30%
Range	(0-25%)	(0-50%)	(20-50%)

Source: Survey of private fruit breeders
*Not printed to preserve the confidentiality of individual firms

Many of these firms were founded and are still owned by a grower and/or packer. The several medium-sized or semi-professional firms breed mainly strawberries, brambles, and peaches. These firms constitute breeding programs operated by nurseries and grower-packers or else they began as amateurs and expanded when they had some success. The conjecture that firms expand as they achieve some success is supported by the age distribution of firms. The smallest firms range in age from 3 to 64 years, the medium-sized firms are at least 13 years old, and large firms are at least 20 years old. As firm size increases so does the breeder's labor input, the number of other employees and the acres in test plots. The low capital investment reported by medium-sized firms may be a result of the species which is bred, the sharing of facilities with other enterprises or simply careful use of capital.

As noted above, if 1984 was a typical year in the industry, firms should be in various stages of their life cycles. Several firms have been in the business for only three years. Four other firms have terminated their breeding programs but continue to test advanced selections from the programs. In a cross section of the industry, a range of profitability is expected because some firms will be investing, others will be receiving some income and still others will be leaving the industry because of low returns.

As shown by the budgets, all firms have very low annual cash expenditures, even the large firms. Besides restricting the testing period, private breeders attempt to maintain cash expenditures at a minimum by using unpaid family labor, particularly the breeder's own labor, and using or sharing old equipment with other enterprises. In addition, most breeders make minimal use of fertilizers and chemical products. This may be justified if breeding is carried out to test the plant under stress conditions or its resistance to disease and pests.

Firms do not include the costs of owned resources--the opportunity costs of labor, land and equipment--in their annual budgets. Even with under-reporting of true costs, only four of twenty-six firms showed a positive cash flow in 1984, ranging from $15 to $80000. Another two firms, which did not report 1984 income, most likely had a positive cash flow. An additional firm is not oriented to making a profit on its breeding program. These firms are mainly medium and large-sized firms. Small firms with a positive cash flow sell fruit or seedlings from test plots, while the income of larger firms is exclusively from royalties.

Based on the annual budgets and responses to a question of how many years income has exceeded cash expenses, clearly the vast majority of firms never show a positive cash flow and in fact never earn royalties. A few firms have shown an occasional positive cash flow, but the cash surplus generally does not exceed the combined cash costs of two or three years. No small firm had more than an occasional year of profit. Thus the hypothesis that the net present value of the benefit stream is most likely negative is upheld. Several firms reported that the firm experienced a positive cash flow only after the breeder retired and cash costs decreased. It is probable that in most cases any income is immediately re-invested to expand the breeding program. But a few firms report sufficient years of profits such that their investment may have a positive net present value. These firms will be examined in more detail below to determine whether they have been able to recover development costs.

In addition to royalty income, several firms sell produce from the test plots, and one firm sells seedlings of a species which is not yet commonly sold by variety. In this case the buyer knows the parents of the seedlings being offered for sale. These are good ways of getting income earlier in the investment period and thus improving cash flow. If customers are allowed on the breeding plots, the breeder does run the risk of losing control of breeding material. In a very competitive market, some firms may not be able to take this chance.

The annual budgets reflect the cash costs of the firm but do not include ownership costs of labor, land and capital. Yet most firms have never experienced a positive cash flow. Even the most successful firms have required 15 to 39 years to obtain a positive cash flow. The data are considered to be reliable because the author established personal contacts with one-third of the firms. These contacts provided an in-depth view of individual firms and served as a basis of comparison for data received from other firms.

6.3 Net Present Value Of "Successful" Firms

The majority of private fruit breeding firms have never obtained a positive net cash flow. Several medium and large-sized firms have had positive cash flows for some time and potentially have a positive net present value. Lifetime cash flow profiles were constructed based upon the potentially most profitable medium and large size firms to determine whether these firms have been successful in recovery of breeding costs.

Since firms tend to think only in terms of cash costs and to neglect ownership costs in their accounting--particularly the opportunity costs of owned resources such as labor, land, machinery and buildings--two estimates of net present value are calculated. The first is based on cash costs and the second includes the opportunity costs of labor. Responses to the questionnaires provided lifetime royalty earnings and 1984 royalty earnings and cash costs. Firms were also asked to estimate the number of years that income has exceeded cash expenses.

Several additional assumptions are made in order to construct the profiles given in Tables 6.2 and 6.3. Royalties were assumed to increase linearly since the year of the first royalty until the firm began to break even and from that point to 1984 levels. Costs were also assumed to increase linearly until the breeder increased or decreased his labor input. Cash costs and income are given in Columns 4 and 5 of Tables 6.2 and 6.3.

The salary of a public breeder was used to estimate the opportunity cost of labor for a private breeder. This is felt to be a reasonable estimate of labor opportunity costs because some private breeders have worked as public breeders and others have the qualifications to do so if they wished. The salary of a full time public breeder is given in the third column of Tables 6.2 and 6.3. The public breeder is assumed to retire on a pension of one-third his final annual salary.

Table 6.2 Net Present Value of Medium-Sized Firm Using a Five Percent Discount Rate

YEAR	LABOR OPPORTUNITY COST[x]			ANNUAL BUDGET		PRESENT VALUE OF NET INCOME	
	Nominal Full-time Salary	Nominal Part-time Salary	Present Value of Part-time Labor	Cash Costs	Income	Costs Include Cash Only	Costs Include Cash and Labor Opportunity
1944	2500	600	600.00	50	0	-50.00	-650.00
1945	3000	750	714.00	100	0	-95.20	-809.20
1946	3500	900	816.30	150	0	-136.05	-952.35
1947	4000	1000	864.00	200	0	-172.80	-1036.80
1948	4500	1100	905.30	250	0	-205.75	-1111.05
1949	5000	1200	940.80	300	0	-235.20	-1176.00
1950	5500	1400	1044.40	400	0	-298.40	-1342.80
1951	6000	1500	1066.50	500	0	-355.50	-1422.00
1952	6500	1600	1083.20	600	100	-338.50	-1421.70
1953	7000	1700	1096.50	700	200	-322.50	-1419.00
1954	7500	1900	1166.60	800	300	-307.00	-1473.60
1955	8000	2000	1170.00	900	400	-292.50	-1462.50
1956	8500	2100	1169.70	1000	500	-278.50	-1448.20
1957	9000	2200	1166.00	1250	750	-265.00	-1431.00
1958	9500	2400	1212.00	1500	1500	0.00	-1212.00
1959	10000	2500	1202.50	1750	3000	601.25	-601.25
1960	11000	2750	1259.50	2000	5000	1374.00	114.50
1961	12000	3000	1308.00	2500	7000	1962.00	654.00
1962	13000	3250	1352.00	3000	9000	2496.00	1144.00
1963	14000	3500	1386.00	3500	11000	2970.00	1584.00
1964	15000	3750	1413.75	4000	13000	3393.00	1979.25
1965	16000	4000	1436.00	4500	15000	3769.50	2333.50
1966	17000	4250	1453.50	5000	17000	4104.00	2650.50
1967	18000	4500	1467.00	5500	19000	4401.00	2934.00
1968	19000	4750	1472.50	6000	21000	4650.00	3177.50
1969	20000	5000	1475.00	6250	23000	4941.25	3466.25
1970	21000	5250	1475.25	6500	23000	4636.50	3161.25
1971	22000	11000	2948.00	6750	24000	4623.00	1675.00
1972	23000	11500	2932.50	7000	24000	4335.00	1402.50
1973	24000	12000	2916.00	7250	25000	4313.25	1397.25
1974	25000	13000	3003.00	7500	25000	4042.50	1039.50
1975	26500	14000	3080.00	7750	26000	4015.00	935.00
1976	28000	14500	3045.00	8000	26000	3780.00	735.00
1977	29500	15000	3000.00	8250	27000	3750.00	750.00
1978	31000	16000	3040.00	8000	27000	3610.00	570.00
1979	32500	17000	3077.00	8500	28000	3529.50	452.50
1980	34000	17500	3027.50	8750	28000	3330.25	302.75
1981	35500	18000	2952.00	9000	29000	3280.00	328.00
1982	12000	12000	1884.00	9250	29000	3100.75	1216.75
1983	12000	12000	1788.00	9750	30000	3017.25	1229.25
1984	12000	12000	1704.00	10000	30000	2840.00	1136.00
NET PRESENT VALUE IN 1944			70113.30			87512.10	17398.80

[x] The labor opportunity cost of a private breeder is assumed equal to the full or part-time salary of a public breeder.

Table 6.3 Net Present Value of a Large-Sized Firm Using a Five Percent Discount Rate

YEAR	LABOR OPPORTUNITY COST[x]			ANNUAL BUDGET		PRESENT VALUE OF NET INCOME	
	Nominal Full-time Salary	Nominal Part-time Salary	Present Value of Part-time Labor	Cash Costs	Income	Costs Include Cash Only	Costs Include Cash and Labor Opportunity
1935	1600	375	375.00	50	0	-50.00	-425.00
1936	1700	400	380.80	100	0	-95.20	-476.00
1937	1800	425	385.47	150	0	-136.05	-521.52
1938	1900	450	388.80	200	0	-172.80	-561.60
1939	2000	475	390.92	250	0	-205.75	-596.67
1940	2100	500	392.00	300	0	-235.20	-627.20
1941	2200	525	391.65	350	0	-261.10	-652.75
1942	2300	550	391.05	400	0	-284.40	-675.45
1943	2400	575	389.27	450	0	-304.65	-693.92
1944	2500	600	387.00	500	0	-322.50	-709.50
1945	3000	750	460.50	600	0	-368.40	-828.90
1946	3500	900	526.50	700	0	-409.50	-936.00
1947	4000	1000	557.00	800	0	-445.60	-1002.60
1948	4500	1100	583.00	900	0	-477.00	-1060.00
1949	5000	1200	606.00	1000	0	-505.00	-1111.00
1950	5500	1400	673.40	1500	50	-697.45	-1370.85
1951	6000	1500	687.00	2000	100	-870.20	-1557.20
1952	6500	1600	697.60	2500	200	-1002.80	-1700.40
1953	7000	1700	707.20	3000	300	-1123.20	-1830.40
1954	7500	1900	752.40	3500	500	-1188.00	-1940.40
1955	8000	2000	754.00	4000	700	-1244.10	-1998.10
1956	8500	2100	753.90	4500	900	-1292.40	-2046.30
1957	9000	2200	752.40	5000	1100	-1333.80	-2086.20
1958	9500	2400	782.40	5500	1300	-1369.20	-2151.60
1959	10000	2500	775.00	6000	1500	-1395.00	-2170.00
1960	11000	5500	1622.50	6500	2000	-1327.50	-2950.00
1961	12000	6000	1686.00	9000	2500	-1826.50	-3512.50
1962	13000	6500	1742.00	10000	3000	-1876.00	-3618.00
1963	14000	7000	1785.00	12000	4000	-2040.00	-3825.00
1964	15000	7500	1822.50	14000	5000	-2187.00	-4009.50
1965	16000	8000	1848.00	16000	7000	-2079.00	-3927.00
1966	17000	8500	1870.00	18000	9000	-1980.00	-3850.00
1967	18000	9000	1890.00	20000	11000	-1890.00	-3780.00
1968	19000	9500	1900.00	22500	13000	-1900.00	-3800.00
1969	20000	10000	1900.00	25000	15000	-1900.00	-3800.00
1970	21000	10500	1900.50	27500	20000	-1357.50	-3258.00
1971	22000	11000	1903.00	30000	25000	-865.00	-2768.00
1972	23000	11500	1886.00	35000	35000	0.00	-1886.00

Table 6.3 (cont'd.)

YEAR	LABOR OPPORTUNITY COST[x]			ANNUAL BUDGET		PRESENT VALUE OF NET INCOME	
	Nominal Full-time Salary	Nominal Part-time Salary	Present Value of Part-time Labor	Cash Costs	Income	Costs Include Cash Only	Costs Include Cash and Labor Opportunity
1973	7660	958	148.49	40000	42500	387.50	239.01
1974	7660	958	142.74	45000	50000	745.00	602.25
1975	7660	958	136.03	50000	60000	1420.00	1283.96
1976	7660	958	129.33	55000	70000	2025.00	1895.67
1977	7660	958	123.58	60000	80000	2500.00	2456.41
1978	7660	958	117.83	65000	90000	3075.00	2957.16
1979	7660	958	112.08	70000	100000	3510.00	3397.91
1980	7660	958	106.33	75000	110000	3885.00	3778.66
1981	7660	958	101.54	80000	120000	4240.00	4138.45
1982	7660	958	96.75	75000	140000	6565.00	6468.24
1983	7660	958	91.96	70000	150000	7680.00	7588.03
1984	7660	958	87.17	65000	160000	8645.00	8557.82
NET PRESENT VALUE IN 1939			39089.66			7739.70	-31349.96

---

[x] The labor opportunity cost of a private breeder is assumed equal to the full or part-time salary of a public breeder.

The private breeders began work on a quarter-time basis because they also worked at other occupations. It is assumed that the breeders switched to half-time when the firm started to have some success. The breeder in the medium-sized firm switched to half-time in 1971 and to full-time when he retired from his other employment in 1982. The breeder in the large firm switched to half-time in 1960 and retired in 1973, but continues to test advanced selections from the breeding program (working about one-eighth time). The column labelled "opportunity cost of labor" is the amount the private breeder could have earned working the same time in the public sector.

Net present value is calculated using a five percent discount rate. When only cash costs are considered, there is a positive net present value for return to owned resources for both firms. For the medium size firm, this net present value of $87,512 is slightly larger than the net present value ($70,113) of salaries which could have been earned in the public sector. For the large firm the return to owned resources is $7,740, lower than the $39,090 the breeder might have earned working the same amount of time in the public sector.

The opportunity cost of labor is subtracted from the net present value of cash costs and returns to obtain the net present value of economic returns to owned capital. For the large firm with capital investment of one million dollars (Table 6.1), this net present value is negative (Table 6.3). The medium size firm shows a positive net present value of returns to capital. currently estimated at $25,000 (Table 6.1). Although the pattern of capital investment is unknown, a net present value of over $17,000 with a current investment of $25,000 may mean the firm has been profitable.

Even though modeled on the most successful firms, the net present value of these firms shows that fruit breeding generally is not an economically viable investment. Private breeders were asked their motivations for initiating a breeding program. Fourteen breeders reported that they had seen a need in the industry for a particular characteristic, e.g. shipping quality, climatic adaptation or lengthening the marketing season. Eight listed love of the fruit, the challenge, or the hobby value of the activity as their motivation for breeding. Five breeders reported that their enthusiasm for breeding was inspired by the work of another private or public breeder. Two private breeders had received some formal training in plant breeding and three others had been public breeders. Only one breeder listed the patent system as a motivation to initiate a program. (The total is more than 26 because of multiple responses.)

When specifically asked about the influence of the patent on their investment decisions, ten breeders responded that the patent had had no impact whatsoever upon their activities. They would be breeding whether or not patent protection existed. Of the sixteen whose decisions had been influenced by the patent, two stated that the patent had been important in the decision to begin the breeding program while three others indicated the importance of the patent in relation to the long term nature of the investment. The others spoke in terms of the patent providing the possibility of getting some return on their investment.

Not all privately developed varieties/strains are patented, although the practice is becoming more common. These 26 firms have introduced 288 varieties of which 246 are patented. Most of the patents (239) are held by eight firms. Fourteen firms have never patented a variety and one firm has patented 75 (some of which have expired).

A recent survey of Australian inventors revealed similar motivations and responses to the patent. Of 586 respondents, 411 began inventing to solve a specific problem, 428 wished to be useful to society, while 328 mentioned the desire to make money. Once an invention had been developed, 436 of the respondents did apply for a patent in hopes of achieving some return. It may be that ". . . the patent grant does not so much stimulate inventive activity as provide a potential means of converting the fruits of that activity into some sort of financial benefit." (Phillips 1984).

Given the similarity of responses from private fruit breeders in the United States and a broad spectrum of inventors in Australia, this interpretation may be valid. The interpretation is reinforced by the above findings that breeding generally is not profitable and the observation that any returns are usually re-invested in the program (Section 6.2). That is, the patent may be sufficient to defray some breeding costs, thus making breeding a somewhat less expensive service or hobby.

The consumption utility of breeding activity should not be ruled out since many of the breeders spoke in terms of a hobby or a challenge. A private grape breeder stated, "I decided to play grapes instead of golf." (Dunstan, personal communication) In this case the breeder is not interested in profitability but any return makes the hobby less expensive. Hobbyists can keep costs low by choice of species or by keeping the program small. In the more expensive species such as apples and pears, only hobbyists operate, and then on a very small scale.

If private breeders are producing varieties of benefit to society out of a desire to solve a specific problem but are unable to capture enough of that benefit to recover costs, they are subsidizing producers and/or consumers. Whether such behavior will continue given anticipated technological change in the industry is considered in chapter 7.

6.4 The Present Value Of Income

The discussion above concerns the annual profitability of breeding and the impact of a long investment period on the net present value of private fruit breeding firms. Profitability could be increased if the stream of income from an investment were received earlier or if the stream were increased. Related ways to increase the present value of income are to increase the firm's market share, or to directly increase royalties. Market share can be enhanced by increasing the sales of a single variety or by increasing the number of varieties offered. The originator can offer several varieties at one time in hopes of reaching different segments of the market. Both a peach and a nectarine breeder in California have had as many as ten varieties on the market at one time. The patent was meant to allow plant originators to protect a variety's share of a market. Advertising can increase sales of a variety, but the breeder who sells the variety to a nursery is unable to affect advertising.

6.4.1 Timing of Income Flows

Advances in biotechnology could decrease length of the investment period if specific genes could be inserted into a known variety. This would produce a variety with known characteristics, whereas breeding gives no guarantee that the desired characteristic is transmitted to the offspring or that it is accompanied by other desired characteristics. Whether use of such techniques will be profitable depends upon demand for the varieties.

As noted above, some breeders have already taken steps to bring in income earlier by selling fruit or seedlings from the test plots. One small breeder covers half of his yearly operating expenses from such sales.

6.4.2 Market Size

Market size is critical as an indicator of potential income for some fruits. Markets for such fruits as saskatoon or gooseberry may not support even a single breeding program. Other fruits may provide a large enough market, but there may be competition from many other breeders. Thus the breeder must consider both market size and market share.

Production of all five fruits studied has increased since the early 1900s. Improvements in management practices have increased production per standard-sized plant. As a result, private breeders have operated in a diminishing market for fruit trees throughout much of the century (Table 6.4). Since the 1950s, the total number of apple trees and grape vines in commercial orchards/vineyards has increased. The grape increase is attributed to expansion of the

TABLE 6.4 Total Number of Plants in Commercial Orchards, 1910-1982

YEAR	APPLE	GRAPE	PEACH	PEAR
		Thousands of Plants		
1910	217115	277389	136784	23975
1920	151504	253151	87264	20700
1925	137996	381491	89035	23198
1930	116304	366847	79064	21271
1935	100054	341045	67069	19436
1940	71663	299181	68867	14460
1945	65776	299181	66470	13876
1950	50587	294465	54461	12358
1954	31843	255084	36913	9829
1959	28981	272067	40227	10524
1964	26125	274691	28994	10357
1969	31975	265000	28108	11003
1974	38384	355025	24463	10091
1978	46920	337091	24674	10187
1982	59004	442625	25194	10196

Source: Census of Agriculture

wine industry. The recent increase in apple trees (although only one-fourth of 1910 levels) may be due to expansion of the industry and/or to use of smaller trees which produce slightly less per tree but are planted more densely per acre. Peaches and pears show a decreasing trend which has stabilized in recent years. Similar data are not available for strawberries.

Of more specific interest to private fruit breeders is the number of trees sold annually. Scarcity of data makes documentation of trends difficult in this market. There have been six special censuses of the horticultural industry since 1890. Only four of these include data on numbers of plants sold for all five fruits (Table 6.5). With so few observations, assessing whether the data accurately reflect trends in the industry or merely reflect yearly oscillations is

TABLE 6.5 Number of Fruit Plants Sold Annually, 1930-1978

YEAR	APPLE	GRAPE	PEACH	PEAR	STRAWBERRY
		Thousands of Plants			
1930	5847	12275	7011	2033	27166
1949	3082	5934	4707	1029	14772
1959	3689	10084	6431	1598	21801
1970	5171	7978	4601	1359	19109
1978	NA	10401	NA	NA	NA

Source: Census of Agriculture, Special Census of Horticulture

difficult, but the general pattern is similar to that of total plants in orchards (Table 6.4).

A proxy variable for number of plants sold annually is the number of non-bearing plants in commercial orchards. (These data are not available for strawberries). Non-bearing plants include all plants sold during previous years which have not yet produced fruit. Although the non-productive period varies by species, for each species average annual sales will be some constant fraction of the number of non-bearing trees. Recent use of more precocious trees may decrease length of the non-productive period, but this may be offset somewhat by current planting of one-year-old trees, as opposed to two- to four-year-old trees earlier in the century (NAL Nursery Catalog Collection).

The number of non-bearing plants of all species fluctuates around a downward trend (Table 6.6), but grapes and apples show an upturn in more recent years. Only in grapes does the current number of non-bearing vines equal that observed at the beginning of the century.

TABLE 6.6 Number of Non-Bearing Plants in Commercial Orchards, 1910-1982

YEAR	APPLE	GRAPE	PEACH	PEAR
		Thousands of Plants		
1910	65792	52741	42272	8804
1920	36195	27395	21618	6052
1925	34299	(58991)*	(28081)	(6159)
1930	27455	24653	20134	5228
1935	17519	16643	12995	2741
1940	13511	18515	21720	2046
1945	(13085)	(17774)	(16171)	(2264)
1950	11089	22108	13408	2241
1954	6780	12837	7908	1856
1959	8716	27583	9172	2859
1964	7213	18934	5415	3021
1969	9278	14325	5388	2396
1974	8759	54899	4560	1439
1978	11484	23089	4944	1477
1982	17424	46903	4652	1511

Source: Census of Agriculture

*Numbers in parenthesis are estimates.

For the other three fruits, numbers of non-bearing trees are considerably below numbers earlier in the century, although apples are again moving upward. These patterns of non-bearing plants are similar to those of annual tree sales from the horticultural census (Table 6.5) and of total plants in commercial orchards (Table 6.4).

The data on non-bearing trees are for commercial orchard only and do not include home orchards. In order to use non-bearing commercial trees as an estimate for the entire market, the home market must be assumed to be some constant ratio of the commercial market. This is plausible since non-bearing plants and total annual sales of plants show similar patterns. Estimates of the size of the home orchard market were not available. For the nurseries which replied to the survey, approximately 50 percent of 1984 sales were to commercial growers. Twenty-nine percent of sales were direct to home orchardists and the remaining twenty-one percent to other nurseries and garden centers. Most of the latter sales were probably resold to home orchardists for fruit production and/or as ornamentals.

Regression analysis was used to test whether demand for fruit plants affects private investment in fruit breeding. Two separate dependent variables (introductions resulting from finds and introductions resulting from breeding) were used as measures of private investment. Introductions for the five years prior to the agricultural census were totaled since the main independent variables (numbers of non-bearing and of all trees in commercial orchards) were available only at five year intervals and represent some fraction of total tree sales in the previous five years. When the agricultural census changed to four year intervals, the dependent variable was also summed over four years.

Private introductions from breeding are expected to be positively related to number of non-bearing trees, and to some measure of profitability in the fruit industry. Alternative measures of profitability include the deflated average value of production for the previous five years, and the five year average of fruit prices received by farmers minus the prices paid by farmers for production inputs. Given the long investment period required, equations with various lags were also estimated.

Introductions from finds (sports and chance seedlings) are expected to be positively related to total number of trees planted and to profitability in the fruit industry. Lags are expected to be shorter than those for introductions from breeding.

Bivariate and multivariate equations of the following forms were estimated as follows:

$$Y = a + b_1x_1$$

$$Y = a + b_1x_1 + b_2x_2$$

$$Y = a + b_1x_1(-1)$$

$$Y = a + b_1x_1(-1) + b_2x_2(-1)$$

Where: Y = number of breeding introductions , or number of introductions from finds

x_1 = number of non-bearing plants, or number or plants in commercial orchards

x_2 = alternative measures of profitability of fruit production

(-1) = a lagged independent variable

In all cases at least one of the coefficients was not of the expected sign. Lags were usually not statistically significant. In some cases there was no statistical relation between the dependent and independent variables (the adjusted multiple coefficient of determination was nearly zero).

There are several possible explanations for such results. First, the operational variables used may not accurately measure the theoretical relationships. Of particular concern is the use of non-bearing plants in commercial orchards as an estimate of total tree sales. Second, the scarcity of data necessitated the use of five-year annual intervals and the resulting 15 observations limited the use of more complex lag structures because of the few degrees of freedom.

If the hypothesized relations exist, even with minimal data one would expect to observe the relationship, although perhaps not at a statistically significant level. Instead, coefficients were observed to change signs between formulations, and many equations showed no statistical relation whatsoever. This leads to the third and fourth possible explanations: the theoretical relations are misspecified (See section 6.4.3) or private investment in fruit breeding is not influenced by general market forces. This latter explanation is reinforced by the previous analysis of firm budgets and net present values which show that private fruit breeding is not a sound economic investment and the discussion of non-financial motivations of many private fruit breeders.

6.4.3 Market Share

Major questions concerning the potential profitability of fruit breeding center on the market share that a variety can obtain and how long it can maintain that share. To answer these questions the California fresh peach market will be examined in detail. Two factors make this market appropriate for detailed analysis. The patent was predicted to have a marginal impact on peach breeding investment, and there are several breeders working in the California fresh peach market (in addition to which the market is well documented).

The fresh fruit marketing order, known as the California Tree Fruit Agreement (CTFA), reports production and tree sales by variety. Annual tree sales by variety are collected from the major fruit tree nurseries. Since varieties bred specifically for California do not grow well elsewhere in the United States and _vice versa_, this list will give a fairly accurate estimate of the total sales of the variety, at least for major varieties (Schuering 1983). A second accuracy check was made by comparing sales of individual varieties as reported by the CTFA with sales reported by the breeder of that variety.

The expected lives of an average and of a superior variety are traced using the actual adoption patterns of four varieties (Figure 6.1). These patterns are fairly typical of other varieties. The data set begins in 1965, so that sales of varieties three and four prior to 1965 are not available. Sales are to early adoptors and levels of these sales may be influenced by the promising outlook of a new variety and the reputation of the breeder. After the third or fourth year sales drop as all early adoptors have entered the market and other producers wait to observe the variety. If the variety does not perform up to expectations, sales never recover and in a few more years the variety is obsolete (Variety #1). If the variety performs well, sales increase sharply as later adopters enter the market. Sales again drop dramatically when the market is saturated (Variety #2).

Most growers maintain a mix of early, mid and late-season varieties in order to distribute production operations over a longer time period. Within these broad categories producers will select several varieties with slightly different ripening periods in order to have nearly continuous production. This management technique makes it unlikely that a single variety will capture a major share of the market. Peach trees in California can produce well for fifteen years, but most orchards are replaced at ten years in order to change

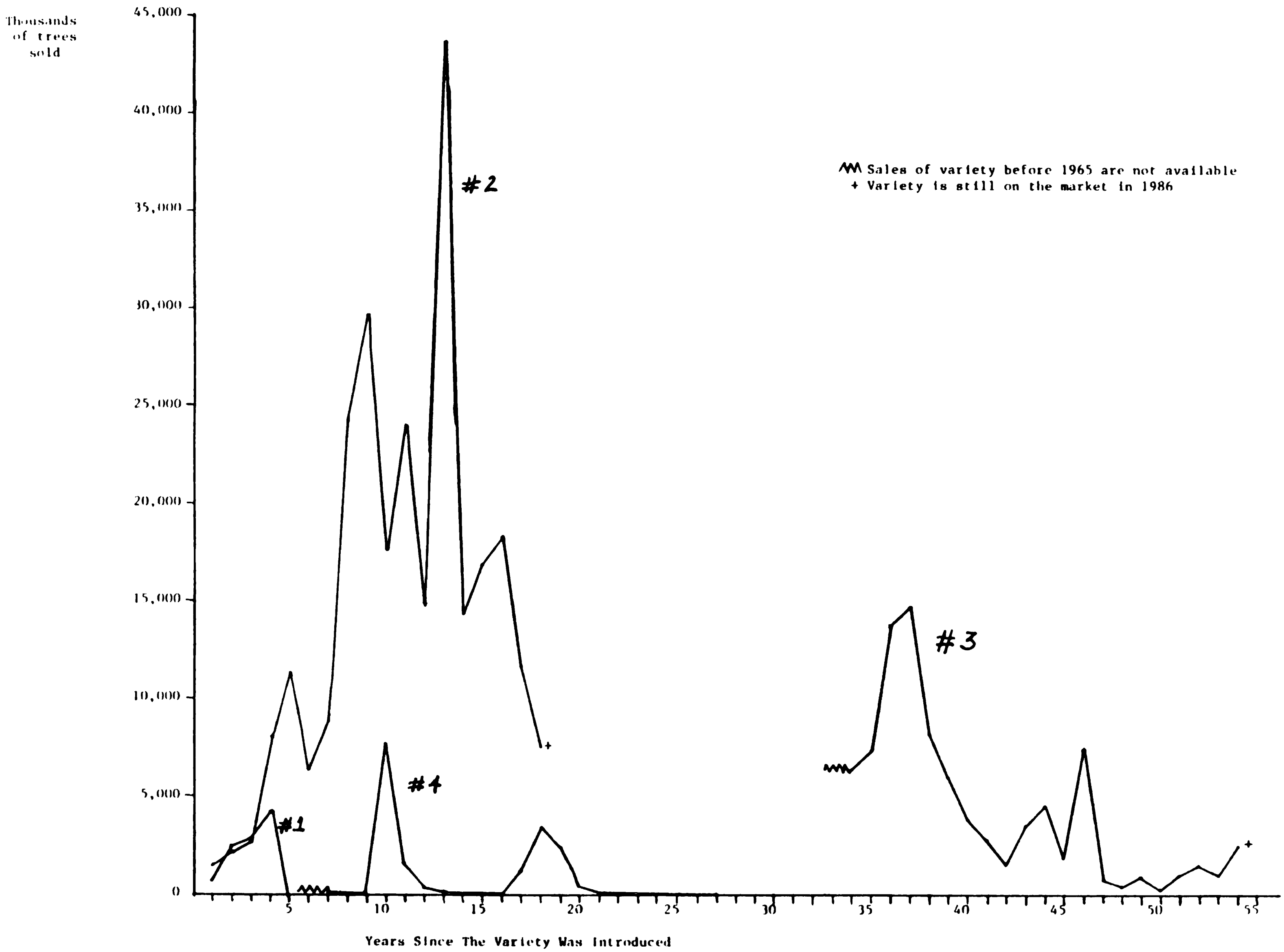


FIGURE 6.1 Adoption Curves Of Typical Peach Varieties

varieties. With a one dollar premium per box for delivering a specific type of peach on the market a few days early, growers are constantly searching for new varieties, and find it profitable to turn over orchards faster than is biologically necessary. Only an extraordinary variety stays in the orchard fifteen years or is replanted in an orchard. Variety #2 may be such a variety, and the next few years will indicate its long term viability. As replanting occurs sales will again peak. Sales for replanting can be substantial for many years as is the case for Variety #3, which was introduced in 1933 and has been a popular variety for many years.

In addition there are some varieties which continue to have small residual sales because they fit particularly well into the production system of some growers due to their specific timing, disease resistance, soil tolerance, or other factors (Variety #4).

When a variety becomes popular--most commonly introduced with an exclusive license if it is privately bred--a competing breeder and/or nursery would like to enter the market. The competitor has two options, to breed or discover a close substitute or to breed a superior variety. Either method has its costs. Breeding a close substitute takes time and the popularity of the original variety will most likely have peaked before the competitor's variety can be put on the market. Given the costs and uncertainties of breeding it is doubtful that people attempt to breed close substitutes. It is possible that a similar variety may be discovered as a sport or chance seedling or that the breeder may have been working on that market niche and have a similar variety ready to market.

If a sport is found it can be marketed in hopes of benefiting from the popularity of the new variety. Marketing a sport is not costless. Because sports cannot be predicted and usually take some years to appear, the sport probably will not reach the market before the popularity of the original variety has peaked. Thus, substitutes will be competing with an already established variety in a declining market.

The above points are illustrated in Figure 6.2, using four varieties. Suncrest was introduced by the public sector in 1959 as a large, productive, good quality peach but its surface was sensitive to bruising. Although this limited adoption by growers, its sales reached a certain level and remained steady. The number of Suncrest trees in orchards still make it one of the top-selling fresh market varieties (Schuering 1983 and Table 6.8). Preuss's Suncrest, a sport, was introduced in 1967. It has a sweeter flavor and a darker red color at the suture, but ripens ten days after Suncrest. But by the time the sport appeared the popularity of Suncrest had already peaked and Preuss's Suncrest could only obtain a share of a declining market.

The second option of the competitor is to offer a superior variety which replaces the original variety. This variety can be offered at the same price as the original variety and still gain market share because it is providing more for the same price. New varieties are rarely sold at a substantial premium.

In 1975 the public sector introduced Flamecrest which is firmer and has more red color but is smaller than Suncrest. By the time Flamecrest was introduced Suncrest had been on the market sixteen

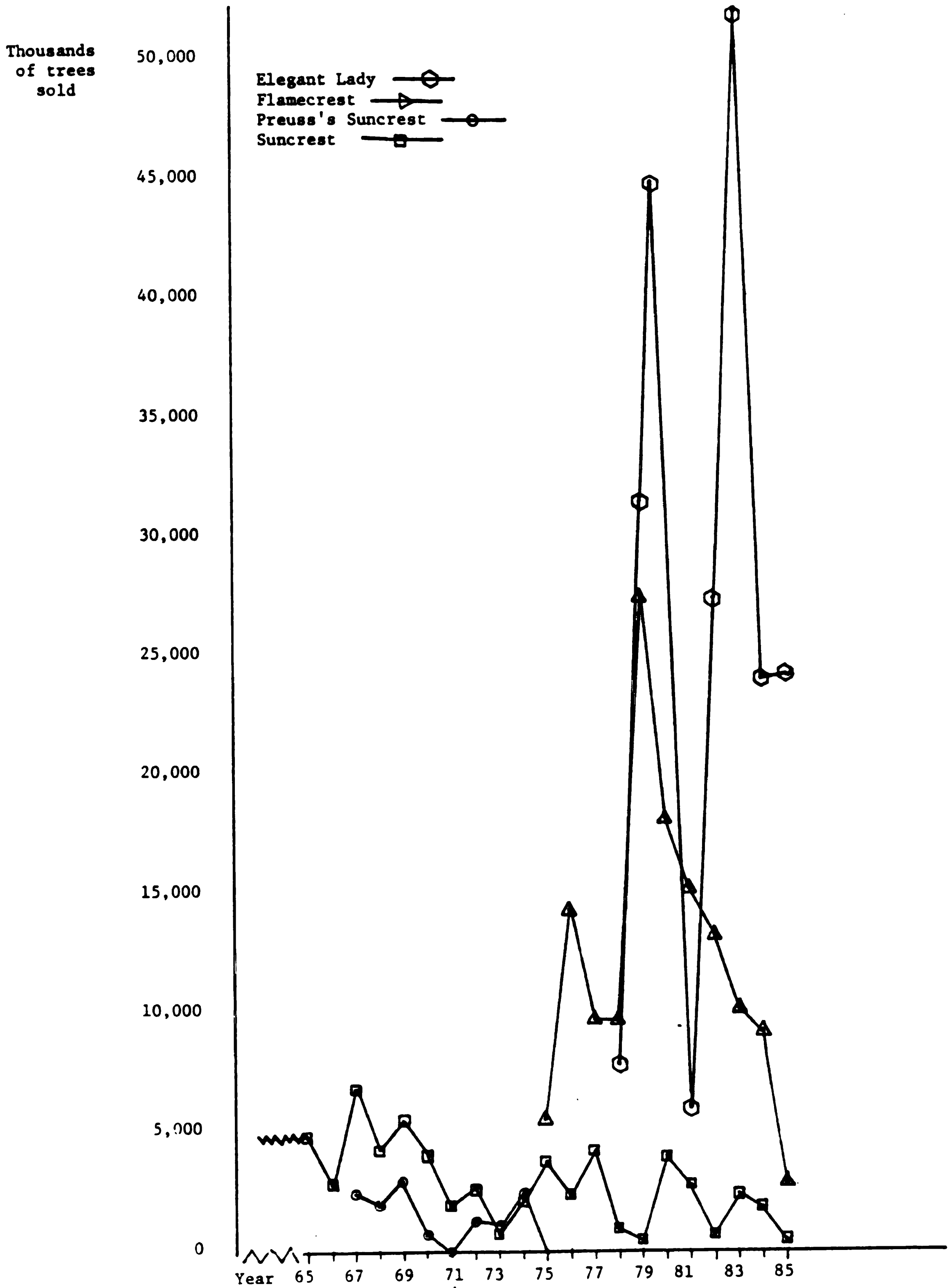


FIGURE 6.2 Competition Between Peach Varieties For Market Share

years. Flamecrest may have captured some of the re-plant sales which otherwise would have increased the sales of Suncrest.

The competition for market share intensified in 1978 when Elegant Lady was introduced by Merrill, a private breeder. Elegant Lady is firm and both larger and redder than Flamecrest, but ripens a few days after Flamecrest. Because it is superior to all three previous varieties in color, size and firmness, Elegant Lady has almost completely replaced all three varieties.

The adoption curves of varieties with various degrees of popularity have been shown, and the competition among varieties for market share has also been discussed. Sports generally tend to occur after popularity of the original variety has peaked and can only share in a declining market. Varieties superior to the original can replace it.

From Figures 6.1 and 6.2 some idea can be gained of the expected sales of a variety, but these varieties were chosen to illustrate other points. Using varieties which were introduced in the California market between 1965 and 1984, Table 6.7 shows the sales level a variety can be expected to obtain over its lifetime. Sales range from zero to more than 400,000 trees. The number of varieties introduced but which had a sales level of zero is unknown, causing the number of varieties with a low level of sales is probably underestimated. Any variety in Table 6.7 with sales of less than 20,000 trees (nearly half of the varieties introduced in the last twenty years) is already obsolete. The vast majority of varieties never achieve sales of 100,000 trees.

TABLE 6.7 Peach Varieties Introduced Between 1965 and 1984 with Volume of Tree Sales in California From 1965 to 1985

NUMBER OF TREES SOLD	NUMBER OF VARIETIES
Less than 1000	5
1000-4999	4
5000-14999	3
15000-19999	5
20000-49999	7
50000-99999	7
100000-199999	3
200000-299999	4
More than 400000*	1
TOTAL	39

Source: California Tree Fruit Agreement, various years

*Discontinuity also exists in the sales of trees.

Since sales of most varieties are low, private breeders cannot rely upon a single variety, but must have many different varieties on the market at one time to provide sufficient annual income for the firm. From 1965-1985 one firm normally had ten or more peach varieties on the market at any one time, with variety maturation distributed throughout the production season. A nectarine breeder followed a similar strategy in that market.

A second reason for the breeder to offer several varieties is that it is always uncertain which variety will be successful. If the minimum cash costs of breeding a variety are $36,000-$40,500 (Section 5.4.1), and the royalty is $.50 per tree, even with sales of 100,000 trees the costs of breeding a single successful variety are barely equal to revenues. If only one-fifth of all varieties reach this level of sales (Table 6.7), there are many varieties which never come near achieving cost recovery.

The private breeder needs a market with fairly rapid varietal turnover for two reasons. First, the faster is varietal turnover, the larger is the market for new varieties and the easier it is to break into the market. Second, a breeder also wants his own varieties to turn over fairly rapidly, because any sales after the seventeenth year do not earn a royalty. At that time the breeder would prefer that growers switch to another variety, preferably from the same breeder.

That the private breeder needs a market with these characteristics seems clear when the California processing and fresh peach markets are compared. In 1983, 50,000 acres were planted to processing peaches and 30,000 to fresh market peaches (Schuering 1983). Of the nine major processing varieties, the two newest were introduced in 1964 (Table 6.8). Of the six major fresh market varieties, only one was introduced prior to 1959. Two of the top fresh market peaches were privately bred while all of the top processing varieties were publicly bred. In fact no private breeder is working specifically for the processing market while several are working in the fresh market, despite its smaller acreage.

Differentiation may bring a premium in the fresh market, but since processing destroys many of the individual characteristics of a variety, differentiation is nearly worthless in the processing market. The processor prefers a uniform product in order to minimize processing costs. Since fresh fruit requires special handling in any

TABLE 6.8 Major Processing and Fresh Market Peach Varieties in California, 1983 (Based on production)

VARIETY	YEAR INTRODUCED	SECTOR	TECHNIQUE OF ORIGINATION
Processing Varieties			
Paloro	pre-1920	Unknown	Unknown
Halford	1921	Private	Unknown
Carolyn	1942	Public	Breeding
Corona	1942	Public	Breeding
Carson	1943	Public	Breeding
Loadel	1950	Private	Sport of Lovell
Starn	1950	Private	Chance seedling of Paloro
Andros	1964	Public	Breeding
Klamt	1964	Public	Breeding
Fresh-Market Varieties			
Fay Elberta	pre-1920	Unknown	Unknown
Suncrest	1959	Public	Breeding
Redtop	1961	Public	Breeding
June Lady	1968	Private	Breeding
O'Henry	1968	Private	Breeding
Springcrest	1969	Public	Breeding

Source: Schuering, 1983

case, that market is better equipped to handle differentiation. Success of the two most recent processing introductions is attributed to retention of their superior taste after processing (when compared with other processing varieties). Because there is no premium to the grower for product differentiation in the processing market, varieties do not turn over rapidly. Thus, private breeders are not interested in the market.

This analysis also may explain some of the unexpected results from the regression analysis, which showed no relation between number of introductions and market size. The variable of interest to a breeder is not the number of trees sold in a year, but rather the specific market for new varieties. Processing peaches provide a larger tree market, but the variety turnover is very slow, making it an unattractive market for the private breeder. This means that theoretical relations were misspecified in the regression analysis. Using the specific case of California peach trees, the model should be specified in the following manner:

Introductions for California market = intercept
+ tree sales of new varieties
(possibly with a lag)

Two equations would be estimated, one for the fresh market and one for the processing market. Introductions for the California market might be defined as introductions by California breeders. These data are probably available by careful reading of varietal descriptions in the Register. The definition of 'new variety' is unclear, but any definition including varieties of 17 years or less could be justified. In order to work with various lag structures, at least thirty years of data are needed for both markets. Although not currently available to the author, such data might be obtained for California.

Only a very limited number of varieties achieve high sales, and even when successful their adoption is limited by the grower's need to spread production throughout the season. By the time a variety achieves total sales of 200,000 trees, it probably has been on the market 20 years or more. Additional sales then do not benefit the breeder because the patent has expired. Thus the breeder is limited in gaining market share and increased income by both production considerations and the term of the patent. An indirect benefit to the breeder is that a long-lived variety will enhance the breeder's reputation and may lead to more rapid acceptance of future varieties.

Several private breeders and some nurseries suggested increasing the term of the patent so that the breeder might collect royalties over a longer period and thus increase the present value of the return to breeding. The estimated impact of such a policy change can be examined using data from the California fresh peach market. The age distribution of varieties in the California market between 1965 and 1985 is given in Table 6.9. Because of incomplete reporting of private varieties in the Register (Brooks and Olmo 1972), the majority of varieties listed as "unknown" in Table 6.9 probably originated in the private sector. If that is true, a higher percentage of public than private varieties remain on the market for more than 20 years. This suggests that the average public variety is of better quality than the average private variety. Some privately originated varieties have had very long economic lives (up to 100 years in the case of Elberta). Most of these long-lived private varieties were found in the early 1900s, but the Merrill firm also has some varieties dating from the 1950s which still have significant market share.

The above analysis shows that few varieties last more than 17 years. Of those which last longer, few have substantial sales (Table 6.10). In the case of peaches, this suggestion might be more useful to public institutions which tend to have a higher percentage of their varieties on the market for more than 20 years than for the private sector.

Apple and pear varieties do not turn over as rapidly as do peaches, perhaps because both the non-productive period and the natural life of the tree are longer. Yet only extraordinary varieties achieve high sales levels over a long period. After seventeen years, the present value of additional income will be very low.

As varieties turn over more rapidly, increasing the term of the patent will be of less help to private breeders. An expert in strawberries estimated that varieties turn over every six years. California fresh market peach trees are replanted every ten years because of varietal change.

One circumstance under which a longer patent might be useful is if the breeder is vertically integrated with production and the varieties are produced to the specifications of a particular market niche. A longer patent keeps competitors who wish to enter this specific market from gaining a cheap entry by picking up the older varieties as their patents expire. If competitors must do their own

TABLE 6.9 Age distribution of Fresh Market Peach Varieties on the California Market between 1965 and 1985, by Sector of Origin

YEARS ON MARKET	SECTOR OF ORIGIN Public	Private	Unknown*
	Obsolete Varieties		
1-10 years	1	14	18
11-20 years	3	6	1
More than 20 years	4	13	0
	Current Varieties		
1-10 years	5	3	0
11-20 years	3	4	0
More than 20 years	5	9	0
TOTAL	21	51	19

Source: California Tree Fruit Agreement, various years, and Brooks and Olmo 1972

* Never achieved sufficient market position or too recent to be in the Register. Most of these varieties probably originated in the private sector.

TABLE 6.10 Total Sales After Expiration of Patent for Peach Varieties Whose Patents Expired Between 1960 and 1984

SALES OF TREES	PRIVATE	PUBLIC*
No Sales**	17	1
Less than 10,000 trees	8	6
10,000-40,000 trees	5	4
More than 100,000 trees	2	1

Source: California Tree Fruit Agreement, various years.

*For public varieties sales are from 17 years after introduction.

**Includes varieties which are obsolete although the patent has not expired.

breeding, they will probably find it too expensive to enter the market niche, especially since the niche must be shared with an established firm.

Some breeders have used legal methods to obtain a slightly longer life from their patent. The variety can be introduced one year before applying for the patent. Subsequently there is a delay while the patent is approved. Generally approval of a patent requires approximately a year, but there can be additional delays in the patent office for various reasons. It is not uncommon for the patent to be issued three years after the variety is introduced, effectively extending the patent term for the breeder.

Since competitors cannot legally propagate the plant for sale until the patent expires, this procedure delays entry into the market for another marketing season or two after expiration (depending upon the time of year the patent expires). This may no longer help the breeder, since the legality of charging a royalty after the patent has expired is unclear. But the nursery holding the license has an additional year or two of monopoly on the variety. It is illegal to restrict distribution of the variety after the patent expires so competitors must be given access to it. If the patent holder continues to charge a royalty, buyers would switch to a competitor offering the same variety.

Trademarking a name for a variety is another way in which the nursery protects market position of the variety, although there is no evidence that such a practice is of any value to the breeder. Since all advertising is done under the trademarked name, any competitor who sells the variety after the patent has expired will have to invest in advertising to promote an unknown name or will have to buy a license to use the trademark. Since nurseries, rather than the breeder, own the trademark this does not increase returns to the breeder.

Another suggestion made by private peach and nectarine breeders was to eliminate sports as patentable subject matter so that they do not compete with the parent variety. These breeders referred to patenting of sports as "legal infringement". This change was not recommended by any of the nurseries, since they find patenting of sports to their advantage because it allows them to enter the competitor's product space or to protect their market share if they own the original variety. One major nursery admitted that most people in the industry would not be able to tell the difference between its strain of Red Delicious and that of a major competitor. In another instance, a major nursery patented three strains of Red Delicious which a public breeder said he could not distinguish. This type of action is typical of a firm trying to protect its product space and is also common in the pharmaceutical industry.

Grape, pear and strawberry breeders, with only 9, 15 and 6 sports respectively from 1920 to 1980, do not find themselves in competition with sports. On the other hand, 26 and 12 percent respectively of the introductions of apples and peaches are sports. To test the contention that sports are legal infringement upon the product space granted to the parent variety, the years a sport was found and introduced were compared with the year of introduction of the parent variety. Many of the major apple varieties were introduced long before 1920, when the <u>Register</u> begins, and any sports of these varieties which were introduced before 1920 would not be included. The major apple varieties introduced near or after 1920 whose sports should be included in the register are Golden Delicious, Cortland, and Idared. Introduced in 1914, sports of Golden Delicious did not appear until the 1950s. Cortland was introduced by the Geneva Experiment Station in 1915 and the first sport was introduced in 1957. The register lists no sports of the Idared, which was introduced in 1942.

Other sources of information concerning sports of older varieties were examined. Red Delicious was introduced in 1894, but the first sport reported by Carlson (1970) was discovered in 1919 and introduced in 1926. The Red Delicious has approximately 200 known sports (of which 80 are listed in the register) and many of these are sports of sports, sometimes into a fifth generation. Sports have completely replaced the original Red Delicious variety (Pratt 19830. The Northern Spy was introduced in 1840 and nearly a century later only 13 sports had been reported. The Red Spy, a popular sport, was introduced in 1895. For older varieties, such as Jonathan (1826), Mcintosh (1811), Rome Beauty (1816) and Winesap (1817), documenting early sports is difficult because the parent variety, sports and seedlings of the parent variety were often included under the varietal name since nomenclature was not standardized. For apples, no case was found in which a sport was either discovered or introduced within 17 years of the parent variety's introduction. However, there are many instances of sports of the same variety (notably Red Delicious) competing with each other in the same product space at the same time, but never with the parent variety.

The situation is quite different for peaches. There were 115 sports of 42 named varieties and several unnamed peach seedlings. For 19 varieties, at least one sport was discovered less than 17 years after the variety was introduced. For 16 of these varieties at least one sport was introduced within 17 years of the introduction of the parent variety. Three sports of the variety Coronet were introduced within 17 years, the first two in the ninth year. Two sports of Springtime were introduced, one in the seventh year and one in the fourteenth year. During the seventeenth year that Redhaven was on the market, two sports were introduced. In all, 22 of 115 sports (20 percent) were introduced within 17 years of the parent variety and would have legally shared the same market space with the parent variety even if the parent had been patented. The CTFA does not provide evidence that these sports have done major damage to the market position of the parent variety before its patent expires.

Peach breeders may be more sensitive to this issue than other breeders because of a court case Kim Bros. v. Hagler 167 F. Supp 655 120 U.S.P.Q. (S.D. Cal 1958) disputing the origin of a variety. The defendant claimed to have a sport of popular variety, while the plaintiff charged that the defendant had grafted the plaintiff's variety to another tree and then claimed it as a sport. Although the judge found in favor of the defendant, most breeders felt that the plaintiff was correct.

Disallowing patenting of sports would have very little impact on the breeder of the original variety because few sports have a major market impact before the parent's patent has expired. However, the number of sports introduced and the income of those who find sports could be affected. This action could have a major impact on the apple market in general and specifically upon major apple nurseries, in which sports are major sellers. Superior sports would still be introduced, but they would be in the public domain. Nurseries might be more willing to promote new varieties than public domain sports.

Adoption of even the most successful varieties is limited by their geographic adaptability and by fruit production considerations. Thus breeders offer many varieties to cover different market niches. Lengthening the patent term will have little impact on the income of most breeders because of rapid variety turnover and the low present value of the additional income. Several apple sports of the same variety do compete for market share, but this is uncommon in other fruits.

6.4.4 Actual Royalty Levels

It has been observed that overall profitability for fruit breeding is low. The above section dealt with how a single variety obtains market share and how a breeder uses several varieties to obtain market share for the firm. A breeder is not interested in market share for its own sake, but as an important determinant of revenue. Revenues also depend upon product price, or in this case the royalty. In maximizing revenues, there is a tradeoff between quantity and price. As price increases, sales will fall. How quickly sales fall depends on the competitiveness of the market.

Most commonly a royalty is charged per plant, and at times a license fee is also charged. Royalties can be increased by charging a higher license fee and/or royalty per plant or by creating another royalty procedure which may generate more income than a per plant fee. Charging a percentage of gross sales of the patented plant is a fairly common procedure. A less common procedure for plant patents (not uncommon for industrial patents) is a charge based upon yearly production from the plant. Some combination of the above may also be used. One firm does not charge royalties in the U.S. market, but does obtain revenues from sales of overseas rights.

Per plant royalties within a species are limited to a narrow range, for example, twenty-five to forty cents per grapevine and ten to fifty cents per apple tree. Per plant royalties are sometimes combined with a one time royalty or license fee. For apples these fees range from $2000 to $200,000 and are usually associated with a lower royalty per tree. For small fruits the license fee ranges from $50 for a grape variety to $5400 for a raspberry variety to $40,000 for a strawberry variety. Since the license fee tends to be combined with lower per plant royalties, the actual range per plant is even narrower than appears in Table 6.11. Many license agreements contain no license fee, but the nursery buying the license pays all patenting costs, which average about $2000 per patent.

Royalties paid as a percent of gross nursery sales of the variety range from 10 to 20 percent. Since most nurseries insist upon an exclusive license, charging a per plant royalty or a percentage of gross nursery sales simplifies policing for the breeder because only one license must be enforced. If a breeder has many varieties on the market in the hands of various nurseries, policing may become more expensive.

TABLE 6.11 Royalties Reported by Private Breeders and Nurseries for Their Best-Selling Variety, 1984

FRUIT	PER PLANT ROYALTY Range in Dollars	LICENSE FEE Range in Dollars
Apple*	.10 - .50	0 - 200,000
Grape	.25 - .45	0 - 150
Peach/Nectarine	.25 - .50	--
Strawberry	.003 - .03	0 - 40,000

Source: Surveys of private fruit breeders and fruit nurseries

* All the apples are private finds.

Production royalties on the gross sales of fruit from the plant are usually under 5 percent. When a production royalty is charged to growers, the policing task increases because each grower must be policed individually and annually. The breeder must also have some method of ascertaining production of the licensed varieties. The task appears insurmountable for the individual breeder because of high information costs. However, this system of royalty is found only in California, which has a marketing agreement for fresh tree fruits. Grades and standards are set by variety, so fruit is sold by variety. In this case the breeder can require sales receipts as proof of production and charge accordingly. Even with the added institutional backup of the marketing order, the production royalty system is used only with a limited number of growers.

Estimates were not available for total royalties earned under a production royalty procedure. Total royalties paid to or received by orginators under the other two procedures are given in Table 6.12. Nurseries were asked to report royalties paid on the best selling

TABLE 6.12 Total Royalties Received per variety by Breeders or Paid by Nurseries, Compared with Breeding Costs, 1984

SPECIES	TOTAL ROYALTY EARNED* Highest-Selling Variety (Range in Dollars)	Lowest-Selling Variety (Dollars)	COST OF BREEDING A VARIETY (Range in 1984 Dollars)
Apple	2750 - 250,000	NA	NA**
Grape	4650 - 10,000	50	2700 - 122,500
Peach/Nectarine	3000 - 60,000	200	36,000 - 40,500
Strawberry	1313 - 310,000	350	8300 - 548,000

Source: Surveys of private and public fruit breeders and fruit nurseries

* Nominal dollars in year earned. Most date from 1970 to 1984.

** All the apples are private finds.

patented variety and breeders were asked to report royalties received on both their highest and lowest-selling varieties.

Table 6.12 also reports the range of costs in 1984 dollars (see Section 5.4.1) for breeding a new variety. The total royalties reported are the sum of nominal dollars over the years in which the royalty was received. Since most royalties reported are recent, the two sets of numbers are comparable, although costs include only cash costs. Even the best selling varieties do not always earn sufficient royalties to cover breeding costs.

The first sections of this chapter showed that breeding is not profitable for most firms in the industry. Section 6.4.4 reinforces this conclusion by comparing royalties earned with estimated average breeding costs of a new variety. Costs often exceed the revenue earned from even the best selling varieties. The royalties used for comparison were obtained mainly from per plant royalties, although a license fee was also charged in some cases. Some royalties are charged as a percent of gross plant sales or as a percent of annual production from the plant. Breeders using these royalty procedures feel that revenues are higher. Unfortunately, data were insufficient to compare the revenue potential of the various procedures.

6.4.5 Maximizing Royalty Levels

Revenue for the breeder is a function of quantity sold and price (the royalty). Because the quantity sold of any variety is limited by production considerations, the breeder trys to maintain several varieties for different segments of the market, in order to increase the quantity sold by the firm. Breeders would like to know how much price can be increased without losing clients, or in other words, how much growers are willing to pay for a new variety. The maximum royalty a grower would be willing to pay is equal to the expected increase in income from the new variety. If the breeder attempts to collect a royalty above this amount, the grower will switch to another variety. Growers may be unwilling to pay this maximum amount if competitors make substitutes available at lower prices.

A one dollar per box premium for early peaches of a given type is used to calculate an example of a maximum royalty. The calculations are shown in Table 6.13. The premium is available only until the market is saturated with the variety. Based on the adoption cycles discussed earlier, early adopters can receive a premium for approximately the first five years. An average tree can produce four boxes but needs several years to reach that production level.

TABLE 6.13 Net Present Value of the Increase in Grower's Income Resulting From Adoption of a New Variety During its First Year

YEAR	PRODUCTION in boxes	ROYALTY per tree	INCOME INCREASE	DISCOUNT FACTOR	PRESENT VALUE OF INCOME
1	0	.50	0	1.0	0
2	0		0	.9524	0
3	1		1.0	.9070	.91
4	2		2.0	.8638	1.73
5	3		3.0	.8227	2.47
6	4		4.0	.7835	3.13
7	4		4.0	.7462	2.98
NET PRESENT VALUE		.50			11.22

Although the grower nets one dollar more per box, these returns must be discounted back to the year of original investment in order to analyze the return on investment. The net present value of discounted returns is the maximum which a grower should be willing to pay as a royalty.

This return is a quasi-rent which is lost as output of the fruit increases and the grower no longer receives the premium. The gain is then captured by the consumer rather than the producer or the breeder. Value of the variety to those who adopt in each of the next four years is $8.24, $5.11, $2.64 and $.91 respectively. Growers who adopt after the fifth year receive no premium and should not be willing to pay a royalty.

The present value to the breeder of these royalties is much lower because the initial breeding investment was made approximately ten years earlier (Table 5.5). The net present value to the breeder is calculated by multiplying annual tree sales of a high-selling variety by the maximum royalty for each year. This value is discounted to the year of the initial breeding investment. The cash costs of breeding a peach variety were estimated as $40,000 in 1984 dollars (Section 5.4). Breeding costs are assumed to be incurred in equal annual amounts over the ten year period. For a high selling variety, the present value of the maximum royalty is $355,435, compared with $32,436 for the present value of breeding costs (Table 6.14). In the absence of high exclusion costs, peach breeding is a potentially profitable investment.

How profitable peach breeding would be in the absence of high exclusion costs depends on the rate at which the breeder can produce high-selling rather than low-selling varieties. Table 6.15 presents estimates of the net present value of a low-selling variety. The income increase to the grower is assumed to result from a cost savings of twenty-five cents over the life of the tree. This cost savings would be available to all adoptors (and thus potentially to the breeder) for the full seventeen years if the variety remained on the market for the full term of the patent. Even without high exclusion costs, low-selling varieties offer better income to the breeder, perhaps not even recovering patenting costs.

For breeding to break even, approximately one variety in every ten introduced would have to be a high seller. Although private breeders reported that about two-thirds were commercially successful (Table 5.12), The California Tree Fruit Agreement makes it clear that high selling varieties are not the norm (Table 6.7).

TABLE 6.14 Present Value to the Breeder of the Maximum Royalty of a High-selling Peach Variety Using a 5 Percent Discount Rate

Year	Present Value of Costs	Maximum Royalty	Number of Trees Sold	Present Value of Income
1	$4000			
2	3808			
3	3628			
4	3456			
5	3292			
6	3136			
7	2984			
8	2844			
9	2708			
10	2580			
11		$11.22	7900	$54424
12		8.24	31550	152084
13		5.11	44950	127940
14		2.64	6000	8395
15		.91	27400	12595
Present Value	$32436			$355435

Source: Sales data from _The California Tree Fruit Agreement_

TABLE 6.15 Present Value to the Breeder of the Maximum Royalty on a Low-selling Peach Variety Using a 5 Percent Discount Rate

Year	Present Value of Costs	Maximum Royalty	Number of Trees Sold	Present Value of Income
1	$4000			
2	3808			
3	3628			
4	3456			
5	3292			
6	3136			
7	2984			
8	2844			
9	2708			
10	2580			
11		$.25	$2905	$446
12		.25	1425	208
13		.25	100	14
14		.25	0	0
15		.25	1050	133
16		.25	2250	271
17		.25	2000	229
18		.25	240	26
19		.25	0	0
20		.25	350	35
21		.25	190	18
22		.25	50	4
Present Value	$32436			$1384

Source: Sales data from <u>The California Tree Fruit Agreement</u>

Comparison of Tables 6.11 and 6.13 shows that net present value of the income increase is substantially higher than the royalty paid to the breeder. Why is the breeder not extracting the maximum amount the grower would be willing to pay? Several possible explanations are given below. Each will be discussed in more detail in the remainder of this chapter.

1) In most cases the increase in income for the grower is very small, because the variety is only marginally better (a close substitute) than varieties on the market. Although this may be true in some cases, particularly for sports, it does not explain why breeders do not obtain higher royalties in cases such as that shown in Table 6.13.

2) Growers have imperfect information concerning the increase in income from the tree, which is a fixed asset. The lower price compensates a grower for the high information costs and the associated risks.

3) A competitive market structure keeps prices low. In a competitive market, prices are forced down towards the cost of production as nurseries cut prices to increase sales. In this particular case, prices are pushed down towards the cost of producing a tree. The research costs of producing a new variety are sunk costs which may not be entirely recovered because the increase in price necessary to recover costs would make the firm uncompetitive. In this case, the maximum amount that could be recovered would not exceed the economies of scale cost savings of the nursery (Berlan and Lewonten 1983 and 1985, discussed in Section 3.4.4).

4) If the industry is composed of firms with varying levels of costs, the firm may not even be able to recover the entire economies of scale cost savings. To do so would mean that other firms with similar cost structures could undersell the firm charging the royalty. To avoid such underselling, the firm will use limit pricing.

6.4.6 The Value of Close Substitutes

Even for a firm with a patent, there is competition from substitutes on the market. These substitutes may be existing unpatented varieties or new patented varieties offered by the competition. Without the patent, all nurseries could offer the same variety. With a patent system, each nursery must have a variety which is different from those offered by its competitors. The patent law sets a minimum standard which must be met in order to receive a patent. In the case of a plant patent, this standard is quite low because of the broad definition of variety, the distinct requirement and the allowance of only one claim. The low standard encourages competitors to patent varieties which differ only slightly from existing varieties. Thus, the number of introductions is expected to increase with the patent even though there may be very little difference between introductions. Many sports which are close substitutes for the original variety are patented. A major nursery acknowledges that its top selling apple strain and that of the competition are nearly identical. Small changes in patented varieties mean that the increase in grower income will be low, thus the maximum royalty which can be charged is low.

While the market appears to encourage cosmetic variation, not all product differentiation is cosmetic. A major point of differentiation is the harvest period. Even though the actual difference may only be a matter of a few days, this is important for growers. Over time changes in harvest period have dramatically extended the peach harvest from a few weeks to six months (Schuering 1983). This has considerably extended the time that fresh fruit is available to consumers. How much of that change is due to private breeding (and how much of that breeding is due to the patent) is unknown since there are both public and private varieties throughout the season. In the particular case of nectarines, much of the improvement in size of fruit and lengthening of season is attributable to the work of one private breeder, Fredric Anderson. His breeding program began before 1930 and how much of his later investment is attributable to the patent is unknown.

6.4.7 Uncertainty Concerning the Income Increase

Most fruit plants are fixed assets for the grower and any misinformation can be costly. As a result, the grower is hesitant to adopt a new variety. In compensation for the risk to early adopters, the nursery may have to charge a price that does not extract all of the income increase. Other growers lower their information costs by observing performance of the plant in the orchards of early adopters.

If the price increase slows adoption of the variety, the nursery may not earn as much as at a lower price which increases adoption rates. Nurseries have to make a pricing decision which will maximize sales over the 17 year life of the patent. This may lead to early prices near propagation costs, as nurseries attempt to gain market share so that a variety has run through the major part of its adoption curve before the patent has expired.

Once information costs are lowered, the breeder should be able to extract the value of the income increase from later adopters. Yet the price of a variety almost never increases (except for inflation) after it has been on the market for five years. One reason may be that most of the income increase is available only to early adopters, as was the case of the premium for the peach in Table 6.13. The second reason is that substitutes or improved varieties may have become available, so that a price increase will mean a loss of sales. Third, the planting of a variety means that the breeder no longer has control over a considerable quantity of propagating material. The material is now in a considerable number of orchards and available to anyone who wishes to use it. A price increase at this time might make the use of this material (infringement) profitable to the grower or a competing nursery. These possibilities are discussed in the following sections.

6.4.8 Pricing Under Competition

The patent law was instituted in order to grant the originator of a variety a monopoly. It was thought that monopoly power would allow an originator to obtain a higher price for the product and thus recover costs of producing the new variety. However, there are no true monopolies, since some degree of substitution is always available (including doing without). The strength of a monopoly based on the plant patent system depends upon the closeness of substitutes to the patented variety. If the market has some competitive elements, even with a patent the patent holder may not be able to raise prices sufficiently to recover costs.

Several factors indicate that the market for new varieties approximates a competitive market. First, a large number of varieties (most of which are not patented) are on the market at any particular time. Some of these varieties are very similar.

Second, low cost substitutes such as sports enter the market at the same price as varieties with higher development costs, rather than undercutting the latter's price in order to gain market share. In most markets a substitute gains market share by competing on price. For example, in the personal computer market, clones of major name brands often sell for one-quarter to one-half the price of a major brand computer. Such is not the case in fruit. Substitutes are offered at the same price as the original variety. Unless the substitute offers some important advantage to the grower's particular production system, there is no reason to buy a substitute when the original variety is available for the same price. The fact that close substitutes are not offered at a price discount indicates that prices in the market are already very close to the cost of tree propagation. A price cut would entail a monetary loss for the nursery.

Third, higher cost varieties from breeding generally do not enter the market at a substantial price premium, indicating that competitive forces may be keeping prices near the cost of tree propagation. When even superior varieties cannot command a price premium (Section 6.4.5), the market must be very competitive, keeping prices near the cost of propagation. Initial price of a variety appears to be determined mainly by short run supply and demand for varieties in any given year.

Further evidence that prices are near costs is given in Table 6.16. Ranges of average variable costs of propagating a plant and royalties are compared with the range of prices for the tree/plant. The prices presented are based on per plant prices for the largest lot offered to the commercial grower. The largest lot was selected for comparison to minimize the effect of handling costs of breaking units and processing small orders. In general, larger nurseries (as measured by total sales) reported lower costs per tree/plant than smaller nurseries, indicating economies of scale in propagation of varieties.

Nursery propagation costs ranged from 30 to 88 percent of total costs for individual nurseries in 1984 with a mean of 51 percent. This compares with a range of 22 to 88 percent for 1978 and a mean of 45 percent. Differences in propagating costs as a percent of total costs are related to the species being propagated, to the percentage of stock purchased from other nurseries and to the size of the nursery. If the propagation costs are doubled or tripled to include other costs of the firm (based upon reproduction costs as a percentage of total costs), prices are not far above the costs of production.

If the wholesale or retail firm offers patented varieties, an additional cost to the firm is a royalty to the patent owner. Total royalties paid in 1984 by the nurseries responding to the survey averaged six-tenths of one percent of their total costs and did not exceed four percent of total costs in any instance. Royalties were

TABLE 6.16 Variable Costs to Propagate a Tree in 1984 Compared with Royalties and Prices in 1985 .

FRUIT	VARIABLE COSTS OF PROPAGATION	PRICE RANGE*	ROYALTY RANGE
Apple	$2.00-3.75	$2.70-5.95	$.10-.50
Grape	.50	1.05-2.60	.25-.45
Nectarine	2.00-2.50	3.30-4.40	.25-.50
Peach	.75-2.50	2.45-4.95	.25-.50
Pear	1.05-2.75	2.70-5.00	NA
Strawberry	.015-.035	.062-.085	.003-.03

Source: Survey of Fruit Nurseries and 1985 Nursery Catalogs

*Per tree price to commercial grower for largest lot.

equal to five percent of total sales of patented varieties--further evidence that royalties are low.

Sales of patented varieties were 13 percent of fruit plant sales in 1984 and seven percent of total sales. Patented varieties are offered mainly by firms with over one million dollars in 1984 sales (Table 6.17). Sales of patented varieties range from less than one percent of total sales to thirty percent, but for the majority of firms such sales are less than ten percent of total sales.

Because a royalty is an additional cost, prices of patented varieties should be higher than unpatented trees, or prices in general should be higher for nurseries offering patented varieties. Since most nurseries offering patented varieties are large, 1985 catalog prices of large nurseries with patented varieties were compared with those of small nurseries without patented varieties. Large firms do

TABLE 6.17 Number of Firms Offering Patented Varieties by Total Sales in 1984

TOTAL SALES[*]	FIRMS OFFERING Patents	No Patents
Less than $100000	0	7
$300,000-$700,000	3	1
More than $1,000,000	11	2
Unknown Value of Sales	2	2

Source: Survey of Fruit Nurseries

[*]Sales categories are discontinuous due to discontinuities in the data.

TABLE 6.18 Per Plant Price Ranges by Firm Size Based on 1985 Prices

SPECIES	PRICE RANGE Large Firms	Small Firms
Apple	$3.80-6.30	$3.93-5.95
Grape		1.05-2.00
Nectarine	4.55-5.40	3.95-4.00
Peach	3.50-4.80	3.90-4.95
Pear	3.80-5.90	3.90-5.00
Strawberry		.06-.085

Source: Survey of Fruit Nurseries and 1985 Nursery Catalogs

[*]Lot size is 100 plants and tree size is 3/8-1/2 inch diameter.

offer substantial discounts on large orders, but there is little evidence that prices differ between large and small nurseries when lot size and tree size are the same (Table 6.18).

In addition, no clear price difference exists between patented and unpatented varieties within the same nursery. Most firms have several price tiers for any given fruit. New varieties, both patented and unpatented (usually publicly developed varieties), are in the highest price tier. However, some antique varieties which are nearly 100 years old and currently available in limited quantities can also be found in this price tier. The second price tier contains patented varieties which have been on the market about five years as well as other popular varieties which are not patented or for which the patent has expired. The lowest price tier includes the less popular varieties, both patented and unpatented. In addition firms offer sales on excess varieties. A further pricing consideration of firms is the rootstock on which the variety is grafted. This appears to be the major price consideration for small nurseries. The pricing structure of large firms is often a matrix of several categories of rootstock and the three tiers of varieties.

New varieties have always entered the market with some price premium reflecting limited supply. This premium tends to last about five years. Table 6.19 presents historical trends for the highest priced apple variety as a percentage of the lowest priced apple variety for three major nurseries. The data were collected from the nursery catalog collection of the National Agriculture Library. All three firms are major firms which offer patented varieties. The data show no evidence that the patent has allowed firms to increase

TABLE 6.19 Historical Trends in Price Ratios of Apple Varieties for Three Major Fruit Nurseries, 1900-1980

	FIRM #1	FIRM #2	FIRM #3
	(Highest/Lowest x 100)		
1900	NA	NA	250
1905	NA	NA	200
1910	250	NA	160
1915	113	NA	100
1920	156	400	100
1925	250	167	100
1930	167	133	100
1935	154	121	125
1940	138	133	100
1945*	111	NA	135
1947	175	104	NA
1950	159	182	125
1955	159	182	117
1960	146	129	114
1965	159	117	111
1970	NA	110	120
1975	153	107	NA
1980	153	109	NA

Source: Nursery Catalog Collection of the National Agriculture Library

*Both 1945 and 1947 are given (if available) because of the impact of price controls during the war.

prices on patented varieties. In fact, the price premium may have decreased over time.

Thus, little evidence exists that the patent provides monopoly power sufficient to raise prices. The higher prices in the initial years that the variety is on the market appear to be result from limited supply. Price drops as the variety becomes established in grower's orchards and becomes readily available to anyone who wishes to use it for propagating material. At a higher price growers would switch to a substitute. The single case in which a patent may allow the nursery to raise price is if the variety is substantially better than existing varieties, i.e. the existing varieties are not good substitutes. Nevertheless, if price is increased too much above the costs of reproducing the tree, competitors could eventually enter the market by infringing the patent and undercutting price, or growers might propagate the tree themselves. Thus the holder of a patent must not set price so high as to make infringement worthwhile.

Prices of fruit plants appear near cost of production and there is no price difference between nurseries which offer or do not offer patented varieties. Even within a firm, there is little price difference between patented and unpatented varieties, and there is no historical evidence that patents have allowed long-run price increases above those indicated by supply and demand.

6.4.9 Economies Of Scale And Limit Pricing

The cost ranges in Table 6.14 indicate economies of scale in tree propagation, with larger firms tending to exhibit lower costs. Economies of scale calculated from the range of variable costs for each species are given in Table 6.20 along with a range of royalties. Royalties do not exceed the economies of scale cost savings. Large firms tend to have lower unit costs and are also the firms most likely to offer patented varieties (Table 6.17). These observations support the argument made by Berlan and Lewonten (1983 and 1985) that royalties are paid from the economy of scale cost savings of the firm and are not related to an increase in present value of the grower's income (See Section 3.4.4).

Even with a patent, the firm may not be able to increase price if close substitutes exist or if high exclusion costs give competitors the option of infringement. However, if the firm has a scale cost advantage over its competitors, it can set price at their cost of production. This keeps competitors from entering the market while allowing the firm to charge a price above its costs of production.

TABLE 6.20 Economies of Scale and Royalty Levels

FRUIT	ECONOMIES OF SCALE COST SAVINGS	ROYALTY RANGE
Apple	$1.75	$.10-.50
Grape	NA	.25-.45
Nectarine	.50	.25-.50
Peach	1.75	.25-.50
Pear	1.70	NA
Strawberry	.02	.003-.03

Source: Surveys of fruit nurseries and private and public fruit breeders

That is, price is determined by the marginal firm while the more efficient firm earns rents which are extracted by the breeder.

Berlan and Lewonten (1983 and 1985) assume two types of competitors, commercial reproduction firms with economies of scale cost advantages and farmers(growers). They also implicitly assume that all firms within each sector are homogeneous. By calculating its costs savings, the commercial reproduction firm can estimate the level at which to set price so that infringement will not be advantageous to the grower sector. It is also implicitly assumed in the analysis that the firms in the commercial reproduction sector have a tacit agreement not to cut price. Without such price agreement, some firms could undersell others while still selling above their own cost of production.

However, in the nursery industry the range of production costs and firm sizes make these assumptions untenable. If the lowest cost firm attempts to collect the entire cost savings differential between its own price and that of the highest cost firm, it will be underpriced by other low and medium cost firms which have an incentive to expand in order to obtain economies of scale. These firms can sell close substitutes at a lower price or can infringe the patent and sell the same variety at a lower price. Thus rather than trying to collect the entire cost savings, the low cost firm will use a limit pricing scheme to limit entry into the market by a similar variety or by infringement of the variety.

The example given in Table 6.21 is based upon costs reported by nurseries producing apple trees. If the large firm prices above $3.75, it is more profitable for a grower to infringe by propagating her own trees than to buy from the large firm. If other nurseries price at $3.75 or less, the grower will find it more profitable to buy from them rather than from the large nursery. If the large firm prices between $3.75 and $2.50, the grower will not infringe. However, the large firm can be undersold by one or both of the other nurseries.

The only way a large nursery can guarantee that it will not be undersold is by pricing at a level which will deter entry by other firms. The limit price a firm can set without encouraging expansion of competitors is $2.50. This means that such a firm can pay a royalty of $.50 to the breeder. In fact royalties for apples range from $.10 to $.50 rather than $1.75 (the economies of scale cost savings). The firm might set price at $3.00 if it felt that revenue could be maximized at this price even with expansion into the market by a medium nursery.

The range of firm sizes and production costs within the nursery industry indicates that a large firm cannot capture the full economies of scale cost savings between its own cost and the highest cost

TABLE 6.21 Hypothetical Cost Structure of Firms Producing Apple Trees

FIRM	PER-TREE COSTS
Large Nursery	$2.00
Medium Nursery	2.50
Small Nursery	3.00
Grower	3.75

Source: Survey of Fruit Nurseries

(marginal) producer. If such an attempt is made, the firm may be undersold by firms with an intermediate range of costs. These firms have an incentive to undersell the larger firm in order to expand their own production and achieve economies of scale cost savings. Thus the large firm will use limit pricing to determine a price level which will deter entry by competitors, or will at least limit entry to a certain share of the market. The amount of cost savings collected for a royalty may or may not cover the costs of breeding. Table 6.12 suggests that current royalty levels on the best selling varieties do not guarantee that breeding costs will be recovered.

6.4.10 Infringement And Exclusion Costs

Nurseries can compete by providing close substitutes for a patented variety or (by infringement) by providing an exact copy of a patented variety. Nurseries listed commercial growers and wholesale nurseries as the major infringers (Table 6.22). Commercial growers infringe by budding and grafting from patented trees in their orchards or by contracting grafters and budders to perform the operations. Commercial growers may also cut budwood from patented trees and contract with a local nursery to bud and grow the trees. The nursery may or may not know (or may not care to know) the exact variety being budded. Many nurseries (including major wholesale nurseries) offer custom growing services. This is particularly useful for a grower who wishes to use an unusual combination of rootstock, interstem and scion, but also makes it possible for wholesale nurseries to infringe patented varieties of other nurseries. Nurseries generally do not publicly advertise the availability of such varieties.

TABLE 6.22 Number of Nurseries Reporting Severity of Infringement Damages Suffered from Each Source

DAMAGE CAUSED BY	EXTENT OF DAMAGE SUFFERED Extensive	Some	None
	(Number of Nurseries)		
Wholesale Nurseries	5	2	6
Commercial Growers	5	6	3
Retail Nurseries	3	1	9

Source: Survey of Fruit Nurseries

Retail nurseries were listed as the least important source of infringement. Often these nurseries purchase rather then propagate their stock and as a result do not have the facilities or expertise necessary for budding and growing trees.

One nursery replied that it considered infringement as an advertising cost. If the variety is good, people will want to infringe. If it is not, there will likely be no infringement. Infringers thus make other growers aware that the variety is worthwhile.

Some private breeders do not bother patenting their varieties, although this practice has become less common. Those who do not patent contend that the cost of patenting (about $2000) is greater than expected royalties from the variety. Others contend that the patent is not worthwhile because of high costs of policing the patent. In one case, a breeder reported sales of 180,430 trees of a patented variety, while the California Tree Fruit Agreement reported sales of 259,737 trees of the same variety. In other words, thirty percent of sales of this variety were illegal infringement. Royalties of the infringement sales to the breeder would have been worth about $25,000.

Patent law currently allows triple damages in cases of proven infringement. The value of damages is usually consider to be equal to lost royalties. With litigation costs estimated at $200,000 per case and a royalty of fifty cents per tree, infringement would have to exceed 135,000 trees before prosecution is worthwhile. Since for example California fresh peach market data shows that only special varieties have sales of over 100,000 trees (Table 6.7), litigation is not generally worthwhile. Some firms have selectively prosecuted in hopes of discouraging other infringers.

In addition, patent holders have complained that proving infringement is nearly impossible. There is some natural variation in each variety which is usually undocumented and which might be used to claim that an alleged infringing variety is not the patented variety. In addition, proving that the alleged infringing variety is not a sport of the patented variety or of some other variety is difficult. In this instance, the peach infringement case discussed above is often cited. In Kim Bros. the defendant claimed to have found a sport while the plaintiff claimed that the sport was really his variety grafted to another tree. The small number of cases brought under this law in the past fifty-five years would indicate that infringement is so difficult and expensive to prove that no one brings suit. The evidence indicates that infringement is too expensive to prove relative to the expected returns.

Calculation of the ratio of profits to total sales provided no evidence that patents have a positive or negative impact on profitability of nurseries (Table 6.23). Profitability ratios ranged from -.12 to .68. The firm with the highest profitability ratio uses unpaid family labor so that the ratio also indicates returns to labor.

Major nurseries try to sell their varieties as superior because they are patented. In fact Congress specifically rejected any requirement that a variety had to be superior to existing varieties in order to be patented. Major nurseries also use advertising to convince growers that their trees are of superior quality compared to those offered by competitors. In addition to health, vigor, and well-developed root systems, major nurseries emphasize virus-indexed trees. This means that the propagating material was certified free of certain viruses (those for which tests have been developed) before the material was propagated and that a virus control program was instituted in the orchards. This is not a guarantee that such a tree purchased is free of these viruses. In addition the value of virus-free trees has not been proven for many species, although the impact of certain cherry viruses on production is known. If the virus were

TABLE 6.23 Profitability Ratios of Nurseries Offering Patented and Unpatented Varieties

PROFIT TO SALES RATIO	NURSERIES OFFERING	
	Patents	Unpatented
-.12 - -.05	2	2
.01 - .09	3	2
.10 - .19	1	1
Greater than .20	1	2

Source: Survey of Fruit Nurseries

completely eradicated, it would be advantageous to growers. However, a virus-free tree may experience more severe production setbacks if it becomes infected with the virus than would a tree which was infected from the beginning. Some viruses may be beneficial for the tree or for the fruit. Many major nurseries support industry regulations which would require planting of virus-free trees because growers and small nurseries would thus be eliminated from competition.

6.5 Summary

Even with extremely frugal use of resources and minimal testing time, breeding is not a profitable activity for most firms. The principal reason for the absence of profit is the long investment period necessary to produce a new variety. Since investment is usually not profitable, it is not surprising that no relation was found between size of market and investment in breeding. Rather, breeding investment appears to be more closely related to the specific market for new varieties which itself is heavily influenced by varietal turnover due to product differentiation.

In order to increase revenues, firms should have several varieties on the market at one time in order to cover the various market segments and thereby increase total sales. The economic life of most varieties is less than seventeen years, and thus extending the length of a patent will be of little help to most breeders. Varietal turnover is becoming more rapid. Sports are close substitutes for the parent variety. It is rare for a sport to obtain a large market share during the patent life of the original variety. Sports are more important in the apple market than in other fruits.

Another method of increasing revenues is to increase royalties. The maximum royalty a grower might be willing to pay is equal to the amount of increased net income generated by the new variety. Because of uncertainty concerning the value of a new variety, the grower may be unwilling to pay the full value of an expected income increase.

In a competitive market a price increase may actually reduce total revenue, because sales will fall as prices rise. If there is competition in the market, the breeder will not be able to charge the full income increase as royalty because prices are pushed towards the cost of production. Competition results from the narrow product space granted by the patent, existing varieties, public varieties and grower access to propagating materials. The nursery firm which pays royalties incurs higher costs, and competitors may capture market share if the nursery attempts to recover royalty costs. Only if economies of scale in propagation exist will a low cost firm be able to pay royalties out of cost savings.

However, the firm cannot collect the full economies of scale cost savings if there are other firms with intermediate cost levels. Intermediate firms can undersell the low-cost firm if the latter attempts to collect the full economies of scale cost savings. These firms would have an incentive to undersell in order to increase production and lower costs. In order to limit entry by other firms the low-cost firm must use limit pricing. The probable royalties available under limit pricing conform more to actual royalty levels than do the levels of economies of scale cost savings. Current royalty levels do not appear to be sufficient to cover breeding costs for even the best-selling varieties.

CHAPTER VII

IMPACTS OF GRANTING INTELLECTUAL PROPERTY RIGHTS IN PLANTS

7.1 Summary Of Study Findings

The principal objective of a patent system is to increase the rate of technological change by rewarding the output of research investment. In 1930 Congress passed an amendment to the Patent Act--the Plant Patent Act--to encourage the development of new plant varieties. The objectives of this study are to develop a framework for analyzing the impacts of granting intellectual property rights in plants, apply the framework to the 1930 Plant Patent Act in order to analyze its impacts on investment in fruit breeding and the creation of new varieties, and draw implications from this analysis for other laws granting intellectual property rights in plants which might be of use not only to the United States, but also to other countries contemplating such laws.

The study--as originally planned--was to determine the impacts of the 1930 Plant Patent Act by using a with and without quasi-experimental design. The United States,which has a plant patent system, was to be compared to a country without a plant patent system, such as Canada or Australia. The study design was modified when preliminary research indicated that other factors were likely to prove more important in influencing private investment in fruit breeding than the patent. The analysis was reorganized to formulate a comparison between the effects on various species within the United States. The breeders of these species all work under a patent system and within a similar environment, but breeding investment differs among fruits.

Where data were available, a before and after the law design was used. This design cannot rule out other historical factors which may have affected private fruit breeding. In particular, the growth of public breeding may have influenced private breeding in the opposite direction to that intended by the law. The public system has historically provided low-priced varieties to the public which are substitutes for privately bred varieties.

One control for changes in historical circumstances was a comparison of public and private breeding. Public breeding was not expected to respond to profit incentives created by the patent law. In addition changes in breeding and testing technology over time were controlled for by comparing the public and private sectors.

Part of the before and after analysis was identification of current and nineteenth century private breeders. From published sources, approximately one hundred private breeders were identified who performed most of their breeding work during the nineteenth century. This compares with seventy-four individuals identified as current private breeders. Since only published works were used to identify nineteenth century breeders, the number of private breeders during that period is probably underestimated. There is no indication of a major increase in the number of private breeders since passage of the Plant Patent Act. Although size of current individual private programs could be larger than in the nineteenth century, no investment data are available from the earlier period for making the comparison. Given extremely small size of most current programs, they are unlikely to be substantially larger than programs of the nineteenth century.

The Register (Books and Olmo 1972) provides data on fruit introductions from 1920 to 1980. Introductions during the 1920s are probably underestimated since compilation of the Register began in the 1940s. With this in mind, only peaches show a substantial increase in number of introductions per decade since the 1920s. This conforms to the expectation that fruits with low to medium investment and exclusion costs were likely to show more investment as a result of the law.

Predictions of relative investment levels for each fruit were developed from a matrix of investment and exclusion costs (Figure 4.2). Private investment in specific species is negatively correlated with juvenile period, which is the major determinant of investment costs. The correlations between investment and species were not always statistically significant because of the additional factor of exclusion costs, which lower expected returns even when investment costs are low.

High investment costs are a sufficient condition for not investing in a specific fruit or type of plant. Long term research investment causes low present values of future income. There is no private investment in rootstocks and wine grapes because the extra testing required increases research time to between twenty and thirty years. Any private introductions in these areas have resulted from breeding investment for other purposes in which an unexpected result has produced a rootstock or a wine grape. There is also little private investment in apples and pears because of the substantial investment time required.

In response to the high investment costs in apple breeding, one firm has been using irradiation to induce spur-type sports. This type of mutation has occurred naturally in sports of several varieties, and is particularly common in Red Delicious apple sports. The firm is concentrating on producing this characteristic, which has recognized market value . Its potential value is high for apple varieties in which such a sport has not yet occurred. In addition to a spur-type Red Delicious Sport, the firm has produced two sports of Granny Smith, a variety in which such a sport has not occurred naturally. A further advantage of this work is that the sport is introduced into a market already familiar with the variety, and the firm does not have to promote a completely new introduction.

Another attempt by private breeders to cut investment costs is to decrease the length of the testing period. This trend is particularly pronounced in peaches, while grapes show a similar trend. These two fruits have investment costs low enough to make breeding potentially profitable. Years of testing by the public, used as a control for technological change in testing, does not show a decrease over time. Private testing of strawberries displays an increase over time at a rate faster than the increase in public testing time. This is attributed to dominance of a single firm. Because it is grower-owned, the firm does not seek profit in the breeding enterprise, but rather in the production of fruit. To protect the fruit production investment, new varieties are carefully tested before being disseminated for production.

Low investment costs are a necessary but not sufficient condition for investment in breeding a species, because the species may have high exclusion costs. Strawberries and grapes have high exclusion costs because it is relatively easy for the grower to propagate these plants by planting runners (strawberries) or by rooting canes (grapes). The major investment in strawberries, as discussed above, is by a firm which is not oriented to making a profit on the breeding enterprise and which releases varieties only to the growers who own the firm. Any infringement by an outsider, if detected, is vigorously pursued. Other private strawberry breeders lower exclusion costs by breeding for the home gardener market, in which the incidence and magnitude of infringement are lower. In addition, some of these breeders attempt to limit the number of plants sold to any individual in an effort to make access more difficult for someone who may buy with the intention of infringing. One large nursery does not carry grapes (although a lot of grapes are produced in the state in which it is located) because infringement is so easy in that fruit.

Peaches have medium levels of investment and exclusion costs. This is the fruit in which major private investment is concentrated and which has shown a substantial increase in the number of privately bred varieties introduced since the 1920s.

Once an investment has been made and a variety introduced, the theoretical maximum which the breeder can collect as a royalty is an amount equal to the value of the increase in grower income resulting from use of the variety. A theoretical maximum estimated for a peach variety was $11.22 per tree, yet royalties rarely exceed $.50 per tree, and are usually lower.

One reason for low royalties is the small increase in grower income due to the new variety, as is the case with sports that are usually very similar to the parent variety or with similar sister seedlings. This does not explain low royalties on varieties which contribute to a larger increase in grower income such as the peach case discussed above.

A second reason for low royalties is the information cost to the growers who invest in a fixed asset. When a new variety enters the market--particularly a private variety--there is no information on the variety other than that provided by the breeder, who cannot be considered an unbiased judge. Information costs for early adopters are subsidized by the breeder in the form of low royalties. Once growers have observed the performance of a variety in the orchards of early adopters, information costs are reduced. However, prices are not subsequently raised. The threat of competition, either from old varieties, new substitutes, or infringement of the variety keeps prices from rising. Because a significant amount of genetic material is now out of the control of the breeder, a price increase might make infringement worthwhile for growers.

As indicated by the above discussion, high exclusion costs can also cause royalties to remain low. Exclusion costs are high because the plant produces not only fruit, but also the genetic material necessary to propagate the plant. As shown by Berlan and Lewontin (1983 and 1985), once a grower has acquired the genetic material, there is no physical imperative to purchase it again. In this case the grower is willing to pay only for characteristics of the plant, not for its genetic traits (Section 3.4.4). The maximum which the grower is willing to pay under these circumstances is the cost to the grower of producing the same quality plant using the genetic material at hand. The maximum amount which the breeder can extract as a royalty is the difference in costs of propagation between the nursery and the grower. For peaches, apples and pears this difference was estimated at approximately $1.75. Actual royalties are even lower.

Scherer (1980) suggests that in a less than perfectly competitive market which has firms of various sizes and various cost structures, the firms with the largest economies of scale cost savings may have to set their price in such a way as to limit entry or expansion by other firms. The nursery industry shows a range of firm sizes and cost structures (Table 6.20). Reported royalties of fifty cents per tree or less correspond more to the practice of limit pricing than to the economies of scale cost savings between the nursery and the grower. The largest firms set price based upon cost structures of close competitors, a practice which corresponds with limit pricing. If Berlan and Lewontin's (1983 and 1985) framework is modified to use other nurseries as the pricing reference, the same result is achieved as that predicted by limit pricing.

In accordance with the concept of limit pricing, it is mainly the large nurseries with economies of scale cost savings which offer patented varieties. Smaller nurseries with higher costs can not pay the additional royalty cost without pricing themselves out of the market. But firms with similar cost structures could undersell a firm which is paying a royalty. One reason why large firms do not undersell each other is because their catalogs are public information, so that overt advertising of a competitor's patented variety would be immediately detected. A more compelling reason is that the firm can usually acquire a close substitute to the competitor's variety without legally infringing. Representatives of major nurseries tour each other's test plots so that they know what their competitors will be introducing in the near future.

In addition, firms which are already large and have low per unit costs cannot lower their costs significantly by expansion, so there is less incentive to infringe than for a firm trying to lower its cost structure. The firm may make more profit by selling a close substitute at the going rate than infringing and cutting price. The difference between a legal substitute and infringement is, of course, a matter of policy.

Royalties paid to breeders are extracted from the nursery's economies of scale cost savings, thus lowering profit rates. Most firms look upon patenting and royalty costs as advertising expenditures. Royalties tend to form only a small part of annual costs. Nurseries use patents to create a progressive image for the firm and to create a perception in the mind of the grower that a patent is a mark of quality. There may also be something of a lottery mentality involved. Occasionally a new variety is introduced such that there are no close substitutes on the market. In this case, the introducing nursery is the sole legal source of the variety, and the variety may be maintained in an upper price tier (set to keep out most competition) for the full seventeen years. Such a variety brings a higher return to the nursery than a variety which has close competitors and whose price tends to drop after five years.

The low royalties which breeders can extract from nurseries are insufficient to repay the research costs in most cases. For breeders who are not interested in a profit, royalty income is welcomed as making the hobby less expensive. If the firm was initiated as a hobby enterprise and then evolved to a for-profit enterprise, the breeder is usually interested only in recovering those costs incurred since that time. But firms exist which claim that their original and continuing motivation is profit. This study has documented that breeding was not profitable in the vast majority of cases. Returns are probably lower than reported because breeders tend not to include fixed assets shared with other enterprises or opportunity costs of owned inputs such as land and labor, and do not use discounting to calculate lifetime returns.

Of the five fruits studied, substantial for-profit breeding investment exists only in peaches/nectarines. Because of the long juvenile period (leading to high investment costs), apples and pears exhibit little private investment. There is no private investment in rootstocks and wine grapes because of the additional testing time required. Private investment in strawberries and grapes is less than would be predicted based upon investment costs alone. High exclusion costs of these fruits lower the potential returns. Most investment in grapes is by amateurs or hobby firms. Strawberry investment is concentrated in the home gardener market where infringement is less likely and in a firm owned by growers which is not interested in profit from the breeding enterprise and which carefully controls dissemination of its varieties to members only. Peaches/nectarines have medium levels of both investment and exclusion costs, and may be marginally profitable.

High exclusion costs lower returns to breeding investment because the breeder loses control of the genetic material when plants are sold to growers. The patent narrowly defines the product space so that close substitutes are legally available. High information costs of the plant to the grower may also lower returns to the breeder.

7.2 Conclusions

Because high investment and exclusion costs lower net returns, the patent system has not increased private breeding investment in most fruits. Besides changes in the patent law, increased investment in fruit breeding can be achieved through other institutions if current levels of investment in fruit breeding are judged insufficient to achieve policy objectives.

Extension of the patent beyond seventeen years would be useful only for the unusual variety with substantial sales beyond that period. The present value of additional royalties collected would be low. For example, a fifty cent royalty discounted at five percent for seventeen years (to the year the royalty was negotiated) has a net present value of only twenty-three cents. If a ten year research period is assumed and royalties are discounted for twenty-seven years, net present value is only fourteen cents.

Lowering enforcement costs will remain difficult as long as the state of science is such that a plant cannot be completely described, especially since a plant may have different phenotypic expressions in different environments or plants of different genotypes may display the same phenotype. Enforcement costs could be shifted to the public sector (as has been done in France), but public breeding may be cheaper than shifting enforcement costs to the public sector. Because of high exclusion costs, consumers capture most gains from breeding. This is further justification for more extensive public breeding to be supported by the taxpayer/consumer who is the principal beneficiary.

Because the law permits only a very narrow product space, many close substitutes can be sold and even patented. Because of high investment costs, fruit breeders do not deliberately attempt to produce a variety similar to one which has gained acceptance in the market place. Sports (which are close substitutes) may be intentionally produced through irradiation, but the practice is not common. Nevertheless, close substitutes are introduced because breeders were already working on similar varieties, or because a sport was found.

Several private breeders have suggested that sports not be patentable because they "legally infringe" the parent variety. There would be no impact on strawberries and grapes because few sports of these species are introduced. For apples, peaches and pears, this suggestion would have little direct impact on income from the original variety because most sports are not introduced until the patent of the original variety has expired. In the longer run, this change could reduce the number of second and third generation sports on the market. Such a reduction in total number of substitutes reduces the competitiveness of the market and in the longer run could lead to higher prices. It may also increase nursery demand for new varieties to replace the current demand for sports of existing varieties. These impacts would be greatest in apples where sports hold an important share of the market.

The product space protected by the patent could be broadened by allowing parts of a plant to be claimed. This would prohibit varieties containing the same characteristic from entering the market unless a license was obtained from the patent holder of that characteristic. Again a problem of the state of science arises. What will be patented, the phenotype or the genotype? A patent on the phenotype may rule out many other genotypes which have the same phenotype. A patent for the genotype would be nearly impossible since, in most cases, the genes which impart particular characteristics have not yet been identified.

The question of whether the patent should be broadened cannot be answered without addressing the question of what is a fair return to the breeder. It might be argued that current law does not provide a fair return to breeders because returns are low. On the other hand, changing the law might provide an unfairly high return. The recent decision by the Patent Office Board of Appeals (ex parte Hibberd 227 USPQ 447 (1985)) extending patent protection to all plants has effectively broadened patent protection. Breeders may now elect to apply under the general patent statute which provides protection against close substitutes and allows parts to be patented. This will be discussed further in the next section.

Total investment in fruit breeding can be increased by expanding public programs. The impact of high exclusion costs is immaterial if varieties are released to the public. If there are large economies of scale in breeding as Hansche (1983) indirectly suggests, it may be socially preferable not to encourage private breeding since these small firms are inefficient producers of new varieties and may be duplicating effort. Kitti (1986) suggests auctioning research rights to an area to avoid such problems. Public research could also be used to attain the same ends. The size of public breeding programs may have to be adjusted to achieve economies of scale. Coordination among public breeders may generate increased output with very little additional expenditure and reduce duplication of research. Responses to the survey indicate that many public breeders were not aware of other public programs in their specific species. One example of coordination in fruit is the Purdue-Rutgers-Illinois (PRI) program in apples. Public programs in tomatoes and cucumbers are coordinating some basic research to avoid duplication of effort (Dennis, personal communication). Although it may be too early to judge the success of these efforts, they are promising institutional arrangements.

If expansion of the public sector is restricted by funding constraints, performance similar to that of the public programs might be obtained through grower ownership of breeding programs. The objective of such a program is to make fruit production (rather than breeding) profitable. When production and breeding are not vertically integrated, it is in the breeder's interest to shift costs to growers by shortening the testing period. With grower ownership, the grower bears the testing costs but also receives an optimally tested product.

The exact institutional arrangements for such a program are beyond the scope of this paper but should be the focus of further research.

Private breeding could be directly or indirectly subsidized through tax benefits, investment credits and government contracts to private breeders. Other indirect subsidies include public investment in basic research, which in the long run lowers investment costs for both the public and private sectors. Areas of basic research include heritability of traits, gene mapping, and gene transfer technology. Investment costs might be lowered sufficiently to allow recovery even with high exclusion costs.

Making germplasm available to private breeders would also lower private breeding costs. Sometimes due to past thefts, many public programs greatly restrict private access to their collections. However, there is no apparent justification for restricting access to pollen. Even if pollen were not provided at subsidized rates, many private breeders would be willing to pay the cost of pollen collection. When providing a patented variety as breeding stock to a private breeder, some universities require that the breeder take out the same license as that required of a commercial nursery. While it is understandable that universities wish to control distribution of patented varieties, such stringent requirements have encouraged theft. A distinct contract could exist for private breeders wanting to use the variety as breeding stock.

Public testing of varieties would also reduce research costs for the private breeder. This procedure has the added advantage of lowering information costs to the grower. However, a potential for conflict of interest exists if the public sector also patents its own varieties.

Some public breeders have expressed a philosophical disagreement with public testing of private varieties, which they see as an unacceptable public subsidy to private firms. Ironically, these same breeders orient their breeding programs to the needs of private fruit growers. The positions are clearly contradictory. There is no essential difference between subsidizing a private breeder versus a private grower. The public sector has tested privately developed varieties of cereals and grains for years. Opposition by public fruit breeders to public testing of private varieties may actually be an attempt to limit access to the market by the sector which public breeders consider their competition--the private breeders, or may reflect an attempt to avoid spreading public budgets too thinly.

Another reason given for opposition to public testing is that privately developed varieties are inferior and are not worth testing. The number of worthwhile varieties which have come from the private sector make it clear that such a blanket statement is not true. Public breeders who have had little or no contact with private breeders tended to express this view. In one case this view was expressed by a public breeder who did not understand that the private breeder in question works in the home gardener market while the public breeder works in the commercial grower market.

Unwillingness to test private varieties is understandable if the public breeder faces budget cuts. Obviously, public testing would increase budget requirements. Initially there would be a flood of requests for public tests of private varieties. Private breeders would become more selective in what they submit for public testing after the first several negative evaluations of their varieties are published.

There is a conflict of interest between public testing and public patenting, particularly if the breeder stands to gain from the patent. In this case the public sector can no longer be presumed to be an unbiased judge of quality. Objectivity of the extension system can also be called into question under such circumstances. A grower testing organization such as operating in New York State may ameliorate the problem. Transferring testing programs to state departments of agriculture is risky because governmental bodies are more subject to political pressure by private companies than are universities.

Several private grape breeders have affiliated to establish a private testing organization with a group of growers. While evaluations of varieties developed by breeders within the organization can be assumed to be unbiased, this is not true if varieties developed outside the organization are tested. Such a conflict has already arisen in one case, but the negative evaluation was confirmed by a public breeder.

Thus, an organization which stands above accusations of conflicts of interest is needed in order to evaluate varieties. Not all costs need be borne by the public. Several private breeders expressed a willingness to pay testing costs in order to have the variety evaluated publicly and in various locations. Some states have already implemented testing charges for new grain varieties.

As public support for funding of agricultural research declines, universities may turn to patenting in order to maintain revenue levels. Growers are more supportive of royalties which go directly to the research program than to the general fund of the university. In addition, objectivity can be maintained to a large degree as long as the breeder does not directly benefit from the patent.

This discussion brings up the further point of the structure of patent agreements between universities and employees. Such agreements currently give breeders a higher percentage of the first royalties received than of later royalties (Kelly and Schmid 1986). One public breeder suggested that the way to increase his personal income is to release a new variety which replaces the old variety when the royalties reach the level at which the breeder's percentage of the royalties drops. If universities wish to encourage high quality releases, the breeder should receive a larger percentage of later royalties than of early royalties. Universities might find other rewards more appropriate to a public employee than a percentage of royalties. Such rewards include promotions and pay increases based upon breeding success and more academic status for breeders, who are currently often considered poor cousins of the basic sciences.

The manner in which the public sector licenses varieties can have impacts on structure of the nursery industry. Requiring a license fee rather than a per-plant royalty may block small nurseries from obtaining a license. Exclusive licenses on public varieties are justified with the argument that nurseries will not adequately advertise the variety without an exclusive license. Larger nurseries are favored for exclusive licenses because they have larger advertising budgets. Successes of recent public varieties (without exclusive licenses and some without patents) demonstrate that this is not the case. As long as the university maintains its unbiased position, the extension service recommendations of public varieties may be all the advertising that is needed.

A further argument made by universities is that the large nursery license ensures a wider distribution of the variety. Yet since most varieties are bred for a specific geographic region, national distribution is not needed. There is no evidence that smaller nurseries distributed throughout a region provide less distribution than a single large nursery.

The public sector has also argued that access to the variety must be controlled in order to ensure that quality is maintained. This issue has not been a concern of universities in the past and it is unclear why this is more important for patented than for publicly released varieties. This research uncovered as much evidence of improper labelling and lack of quality among large as among small nurseries. Most arguments advanced by universities in favor of controlling access to varieties have very little logical basis and appear to be attempts to justify favoring large firms.

With rapid technological change, it is likely that larger firms will enter fruit breeding as has happened in grains and cereals. Initial investment requirements will be higher, but small breeders can continue to use traditional breeding methods. However, larger firms will likely have some degree of vertical coordination with nurseries, which will close marketing channels to small breeders. These small breeders are currently subsidizing producers and consumers. If small breeders disappear, prices of trees and fruit will be higher.

7.3 Implications For Other Laws Granting Intellectual Property Rights In Plants

In the United States there are presently three laws granting intellectual property rights in plants: the 1930 Plant Patent Act for asexually propagated plants except tubers and bacteria; the 1970 Plant Variety Protection Act for sexually reproduced varieties except F-1 hybrids and bacteria, and the Patent Act for all plants. Thus breeders of some plants may choose between two laws when seeking protection. Each of these acts has different criteria which must be met before protection can be granted. The requirements of the 1930 Plant Patent Act are discussed in Chapter 2, as are the requirements of the Patent Act. The standards for protection under the 1970 Plant Variety Protection Act will be discussed below.

Even with differences between the laws, the two general issues concerning intellectual property protection for plants which this study illuminates are the importance of investment costs and exclusion costs. Some investments are extra-marginal and the granting of a patent will not increase investment. Only when technology changes will the investment become feasible.

For example, private investment in genetic manipulation of plants exhibited a dramatic increase when advances in technology lowered costs. What was previously an unknown industry became a growth industry which expanded rapidly in the late 1970s even without patent protection. The industry has concentrated mainly on annual crops and micro-organisms which require a much shorter growth and testing time than fruits. To the author's knowledge, only the public sector is applying these techniques to fruit breeding.

A patent grant does not shift or change enforcement costs, although the patent holder can pursue infringers in court. Goods with high exclusion costs will continue to present enforcement difficulties (Figure 3.2) and thus exhibit lower levels of investment. Goods with low exclusion costs may experience high levels of investment, even without patent protection. For example, investment in hybrid corn breeding has been high for many years. Micro-organisms utilizable in industrial production have also been an area of research for many years without patent protection of the organism, although the industrial process which uses the organism could be protected. The French plant variety system has shifted enforcement costs for field crops to the public sector. through a variety of regulations formulated ostensibly to ensure seed quality.

The United States is the only country to extend intellectual property protection to all plants and to allow patenting of plants. Most countries grant protection to plants under very similar laws called Plant Variety Legislation and restrict the species to which the law applies (Office of Technology Assessment 1984). The 1970 Plant Variety Protection Act is such a law. Standards for protection are distinctness, uniformity and stability, which differ from those of the patent law. These standards are very similar across countries.

While ostensibly granting monopoly powers to the owner of the variety, the standards of protection in fact ensure a very weak monopoly position. In practice, distinctness has allowed the protection of plants incorporating very small (even cosmetic) changes, whether or not the changes contribute to agronomic performance (Schmid 1985). The laws do not contain a "non-obvious" clause as in patent law, which would broaden the product space. While the resulting large number of substitutes on the market lowers the monopoly power of the variety owner, it is confusing for the farmer. There is evidence that advertising is used to convince farmers to purchase inferior varieties because the information necessary to distinguish among varieties is not available. Some testing mechanism is needed.

The uniformity and stability requirements imply that the progeny produce the same performance as the parents over several generations. While intended to enable identification of protected varieties, these requirements make it easier for the farmer to save grain for seed because they are assured of the same performance.

The French system has instituted variety trials to determine differences in agronomic performance. Only those varieties with differences judged to be significant can be sold. This lowers information costs to the farmer and also broadens the product space for the variety owner, thus increasing monopoly power. Since farmers are major competitors, monopoly power is weak unless the farmer can be eliminated as a competitor. Under the guise of ensuring seed quality, a series of laws have been passed which further increase monopoly power of the variety owner (Berlan 1983). A recent law makes it illegal to clean and process grain into seed for a fee. This makes it more difficult for farmers to use their own grain for seed (Berlan personal conversation).

The narrow definition of product space under the Plant Variety Protection Act can now be avoided by filing for protection under the Patent Act. The impacts of this development will depend upon Patent Office regulations for applying the "non-obvious" clause to plants. Patent office practice with respect to micro-organisms since 1980 indicates that care will be taken to not grant protection so broad as to include plants which do not have the characteristics claimed in the patent (Bagwell personal conversation).

The broader product space granted by the patent may increase monopoly power of the patent holder by reducing the number of substitutes on the market. This may induce a price increase for the farmer, particularly if farmer-saved seed is considered infringement. Under the 1930 Plant Patent Act, grower propagation of patented varieties constitutes infringement. Enforcement against farmers will be more difficult for seeds such as cereals than for asexual propagation, because use of grain for seed does not require special skills of the farmer. As always, there are conflicts over the distribution of rents between the breeder and the farmer.

Since the Patent Act was recently extended to all plants, Patent Office regulations are still being defined as of 1986. Of major interest is how the three laws will interact. If a plant is rejected for a patent, can the breeder reapply under another law? Will the broader product space granted by the patent keep plants which otherwise would have qualified for protection under the other laws from being protected because such plants infringe the product space of the patented variety? If it does not, what is the value of the patent? In time, utilization of the Patent Act may make the other laws obsolete.

Canada and Australia have recently considered and rejected Plant Variety Legislation. A discussion of such legislation logically begins with an examination of the impacts of the patent system on the country. Taylor and Silberston (1973) conclude that the British patent system has had very little impact upon ". . . the rate and direction of inventive and innovative activity undertaken by industry . . ." except for the chemical industry.

Penrose (1951) points out that a patent system might not be beneficial to a small country.

> . . . [A]ny country must lose if it grants monopoly privileges in the domestic market which neither improve nor cheapen the goods available, develop its own productive capacity, nor obtain for its producers at least equivalent privileges in other markets. No amount of talk about 'economic unity of the world' can hide the fact that some countries with little export trade in industrial goods and few, if any, inventions for sale have nothing to gain from granting patents on inventions worked and patented abroad. (Penrose 1951)

Studies of the Canadian patent system indicate that the situation is similar to that described by Penrose and that its net effects for Canada may be negative (Lyons and Begleiter 1982).

Few studies exist of the impacts of Plant Variety Legislation in other countries. Butler and Marion (1985) found minimal impacts in the United States due to the countervailing input of the public research system. Berlan (1983) stresses that France uses considerable supporting legislation and regulation to make the system function for the variety owner, but there has been no study of the net impacts for society of the French system.

The present study suggests that intellectual property rights will not provide the expected returns to research if the plant has high exclusion costs. If exclusion costs are low, a patent is not needed to encourage research, as evidenced by investment in hybrid corn. High investment costs relative to value of the varietal improvement will also deter investment in certain areas unless technological change makes the investment feasible.

APPENDICES

APPENDIX A

EXCERPTS FROM TITLE 35 OF THE UNITED STATES CODE

§ 100. Definitions

When used in this title unless the context otherwise indicates—

(a) The term "invention" means invention or discovery.

(b) The term "process" means process, art or method, and includes a new use of a known process, machine, manufacture, composition of matter, or material.

(c) The terms "United States" and "this country" mean the United States of America, its territories and possessions.

(d) The word "patentee" includes not only the patentee to whom the patent was issued but also the successors in title to the patentee.

§ 101. Inventions patentable

Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title.

§ 102. Conditions for patentability; novelty and loss of right to patent

A person shall be entitled to a patent unless—

(a) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for patent, or

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of the application for patent in the United States, or

(c) he has abandoned the invention, or

(d) the invention was first patented or caused to be patented, or was the subject of an inventor's certificate, by the applicant or his legal representatives or assigns in a foreign country prior to the date of the application for patent in this country on an application for patent or inventor's certificate filed more than twelve months before the filing of the application in the United States, or

(e) the invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for patent, or on an international application by another who has fulfilled the requirements of paragraphs (1), (2), and (4) of section 371(c) of this title before the invention thereof by the applicant for patent, or

(f) he did not himself invent the subject matter sought to be patented, or

(g) before the applicant's invention thereof the invention was made in this country by another who had not abandoned, suppressed, or concealed it. In determining priority of invention there shall be considered not only the respective dates of conception and reduction to practice of the invention, but also the reasonable diligence of one who was first to conceive and last to reduce to practice, from a time prior to conception by the other.

§ 103. Conditions for patentability; non-obvious subject matter

A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

§ 112. Specification

The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor of carrying out his invention.

The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

A claim may be written in independent or, if the nature of the case admits, in dependent or multiple dependent form.

Subject to the following paragraph, a claim in dependent form shall contain a reference to a claim previously set forth and then specify a further limitation of the subject matter claimed. A claim in dependent form shall be construed to incorporate by reference all the limitations of the claim to which it refers.

A claim in multiple dependent form shall contain a reference, in the alternative only, to more than one claim previously set forth and then specify a further limitation of the subject matter claimed. A multiple dependent claim shall not serve as a basis for any other multiple dependent claim. A multiple dependent claim shall be construed to incorporate by reference all the limitations of the particular claim in relation to which it is being considered.

An element in a claim for a combination may be expressed as a means or step for performing a specified function without the recital of structure, material, or acts in support thereof, and such claim shall be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof.

CHAPTER 15—PLANT PATENTS

§ 161. Patents for plants

Whoever invents or discovers and asexually reproduces any distinct and new variety of plant, including cultivated sports, mutants, hybrids, and newly found seedlings, other than a tuber propagated plant or a plant found in an uncultivated state, may obtain a patent therefor, subject to the conditions and requirements of this title.

The provisions of this title relating to patents for inventions shall apply to patents for plants, except as otherwise provided.

§ 162. Description, claim

No plant patent shall be declared invalid for noncompliance with section 112 of this title if the description is as complete as is reasonably possible.

The claim in the specification shall be in formal terms to the plant shown and described.

§ 163. Grant

In the case of a plant patent the grant shall be of the right to exclude others from asexually reproducing the plant or selling or using the plant so reproduced.

§ 164. Assistance of Department of Agriculture

The President may by Executive order direct the Secretary of Agriculture, in accordance with the requests of the Commissioner, for the purpose of carrying into effect the provisions of this title with respect to plants (1) to furnish available information of the Department of Agriculture, (2) to conduct through the appropriate bureau or division of the Department research upon special problems, or (3) to detail to the Commissioner officers and employees of the Department.

APPENDIX B

PRIVATE FRUIT BREEDERS IN THE EIGHTEENTH CENTURY

B.1 Nationally Known Private Fruit Breeders

Breeders listed in this section were nationally known. Sources for this section are Bailey (1919) and Hedrick (1950). The notes after each name follow the description of the person's work found in those texts.

Adlum, John (1759-1836). Grape experimenter, introduced (but did not originate) the Catawba.

Allen, John Fisk (unknown). Allen's Hybrid Grape.

Bartram, John Sr. (1699-1777). First American to perform successful hybridizing. Sons John and William may also have been breeders.

Berckmans, Prosper Julius (1830-1863). Bred several fruit species.

Brinckle, William Draper (circa 1800-1863). Originated Cushing, Wilder, President, Cope, and Draper Strawberries; Wilmington and Catherine Gardette Pears and a yellow-fruited raspberry.

Budd, Joseph Lancaster (1835-1904). Improved many native fruits. He was a private breeder who became a public breeder.

Bull, Ephriam (1805-1895). Concord and several other grapes of lesser renown.

Campbell, George Washington (1817-1898). Grapes--Triumph, Delaware, Lady, and Campbell's Early.

Caywood (unknown). Grape breeder.

Clapp, Thaddeus (circa 1860). Clapp's Favorite Pear.

Cooper, Joseph (circa 1799). First person in U.S. with breeding as life's work. Developed Lady Lucy Plum. In addition, bred peas, corn, lettuce and watermelon.

Curtis, Joseph (1786-circa 1856). Originated a number of choice varieties.

Dana, Francis (circa 1854). Dana's Hovey Pear.

Dartt, Edward Harvey Schuler (1824-1903). Nurseryman who became a public breeder.

Downer, John S. (1809-1873). Downer and Downing Strawberries. Downer's Prolific Plum.

Edwards, Governor Henry Waggoman (1779-1847). Eleven varieties of pears.

Evans, James Calvin (1833-1909). Evan's Peach, Evan's Raspberry, Evan's Crab Apple, Miller Persimmon. Gave assistance and advice to the South Mississippi fruit experiment station on apples. That work was carried on by his son.

Fuller, Andrew S. (1828-1896). Brooklyn Scarlet, Monitor, Colonel Ellsworth Strawberries.

Gano, William Grover (1839-1910). Introduced new varieties and produced new seedling varieties. Gano Apple.

Gideon, Peter M. (1818-1899). Bred hardy apples by crossing the Siberian crab with the common apple. Wealthy Apple.

Hovey, Charles Mason (1810-1887). Hovey Strawberry, a major breakthrough in commercial strawberries.

Jaeger, Herman (1844-1896). Grape breeder of 100 varieties which served as foundation stock for other breeders.

Kerr, Jonathan William (1842-1919). Bred plums, apples, and peaches.

Kirtland, Jared P. (1793-1877). Bred 30 cherry varieties including Governor Wood, Kirtland's Mary, Black Hawk, Pontiac, Powhatan, Tecumseh, Osceola, Red Jacket, and Rockport. Also bred pears.

Lewelling, Seth (1819-1897). Originator of a number of fruits, including the Bing and Black Republican Cherries, and a golden prune.

Longworth, Nicholas (1783-1863). Introduced the Ohio Everbearing Raspberry. May have been a nurseryman rather than a breeder.

Lord, Orville Morell (1826-1906). Selected Rollinstone Plum from a wild variety. Established several varieties of hardy apples.

Lyman, Henry Martyn (1828-1902). Developed open-pollinated apple varieties, including Lyman's Prolific Crab and Evelyn.

Manning, Jacob Warren (1826-1904). Introduced many large and small fruits. Cutler Seedling Strawberry, Dracut Amber Grape, John Sweet and Granite Beauty Apples, also pears.

Miller, Samuel (1820-1901). Martha, Black Hawk, Eva, Louise Grapes. Captain Jack Strawberry. Josephine Persimmon.

Moore, Jacob (1836-1908). Development of new fruit by scientific plant breeding. Hooker Strawberry. Diploma and Red Cross Currants. Brighton, Diana Hamberg, Moore's Diamond Grapes. Barr Seckel Pear. Thousands of other varieties. Tried to get a plant patent law passed.

Munson, Thomas Volney (1843-1913). Grape breeder.

Prince, William II (unknown). Originator of new varieties by careful selection of seedlings. Prince's Yellow Gage, Imperial Gage, Washington plums. St. Germain pear. His son William III created many new varieties from seed.

Pringle, Cyrus Guernsey (1838-1911). Bred many types of plants including fruits.

Ragan, Reuben (1793-1869). Disseminated many hardy varieties of fruits.

Ricketts, James H. (unknown). Contemporary of Rogers (listed below). Bred a score of grape varieties.

Rock, John (1836-1904). Originated many worthwhile varieties.

Rogers, Edward Stanford (1826-1890). Grape breeder. Developed the first Lambrusca Vinifera crosses. Introduced 45 hybrids. "Rogers gave an impetus to grape breeding and 100 or more men began crossing grapes...by the end of the century 2000 new varieties of grapes had been introduced." (Hedrick 1950: 437)

Rommel (unknown). Grape breeder.

Stark, James Hart (1792-circa 1800). Introduced and disseminated new varieties. May have been a nurseryman rather than a breeder.

Stayman, Joseph (1817-1903). Produced hundreds of new varieties, including Clyde and Stayman Strawberries, Ozark Grape, and Stayman Winesap Apple.

Strong, William Chamberlain (1823-1913). Important in the pear and grape industries. May have been a nurseryman rather than a breeder.

Stutevant, Edward Lewis (1842-1898). Experimenter with cattle, corn and muskmelon. First director of Geneva Experiment Station.

Teas, John C. (1827-1907). Originated and introduced many new varieties in all branches of horticulture.

Terry, H.A. (1826-1909). Bred fruits, especially plums. Americana plum species: Admiral, Schley, Bomberger, Bryan, Champion, Golden Queen, Hawkeye, Nellie Blanch, Terry, and White Prune. Munsoniana plum species: Downing, Hammer, Milton.

Valk, Dr. William V. (circa 1845). Bred grapes, including Ada Grape.

Wilder, Marshall Pinckey (1798-1886). Bred several types of plants, and produced several new pears including the Anjou.

Wilson, James. (circa 1854). Wilson Strawberry.

B.2 Strawberry Breeders

Breeders listed in this section were nationally known strawberry breeders. The source for this section is Darrow (1966). The notes after each name follow the description of the person's work found in that text.

Beaver, J. F. (unknown). Originated the Nich Ohmer as a seedling and introduced it in 1898.

Black (unknown). Originated Joe Strawberry, introduced in 1889.

Boyden, Seth (circa 1850). Strawberry grower and breeder. Friend of Durand.

Bubach (unknown). Selected open-pollinated seedlings and in 1882 obtained Bubach Strawberry.

Cloud, Robert L. (1854-circa 1915). Bred for shipping quality and short photo period of the South. Started breeding about 1880 and continued nearly until his death. Cloud and Klondike were his major varieties. Did not hand pollinate.

Cruse (unknown). Selected open-pollinated seedlings and obtained Aroma Strawberry in 1889.

Downer, Charles Downing (unknown). Downers Prolific and Kentucky.

Durand, Elias W. (circa 1850). New Jersey Scarlet.

Etter, Albert F. (1872-1950). Breeder and nurseryman. At the age of thirteen started breeding dahlias, red currants and gooseberries. Made his first strawberry cross at the age of 15. Discontinued breeding about 1926, probably due to diseases in his test plots. Developed 52 main varieities and selections. Showed importance of hybrid vigor. In later years concentrated on apple and plum breeding and may also have worked on pears and cherries.

Ewell (unknown). Found Marshall in 1890.

Gandy (unknown). Open-pollinated seedlings, from which he selected the Gandy in 1885.

Gohn (unknown). Found Missionary and intorduced it in 1906.

Haley (unknown). Several varieties.

Haverland (unknown). Open-pollinated seedlings, and in 1882 introduced Haverland.

Hoffman (unknown). Found Hoffman in 1884.

Hovey, Charles Mason (1810-unknown). Strawberry breeder, nurseryman, and editor. Also originated camelias, trees and shrubs. May only have bred strawberries for about five years. In 1835 he wrote that in the previous 20 years over 200 varieties of strawberries had been introduced.

Howard, Arthur B. (1836-1907). Systematic Strawberry breeder who had in mind the ideal strawberry. The Howard 17 was ideal for his location and time, and is the parent to many other varieities. Tested over 25,000 seedlings and sent them to other breeders for testing. Also named and introduced the Howard Apple, Bay State Tomatoes and some flowers. Everett Howard carried on his father's work and actually introduced the Howard 17 after his father's death. Everett Howard also bred the Howard Supreme.

Kuhns, J. E. (unknown). Bred and tested varieties.

Neuman (circa 1868). Several varieties.

Permalee (circa 1870). Found Crescent. Was probably a grower.

Reasoner, Rev. John Rogers (1835-1925). Began breeeding in 1886 and concentrated on it only from 1901. Originated the Dunlop in 1890. For a time was director of the Illinois State Horticultural Society Cental District Experiment Station.

Rockhill, Harlow (1866-1944). Bred strawberries, bush cherries, plums and plum-peach hybrids, raspberries, nuts, and flowers. The Progressive was his leading everbearing plant. Bred pistallate varieties.

Sharpless (unknown). In 1872 selected the Sharpless from seedlings.

Thompson (unknown). Found Lady Thompson in 1894.

Warfield (unknown). Found Warfield about 1882.

Wilder, Marshall (1798-1886). Continuously bred strawberries for 30 years and open-pollinated thousands of seedlings.

Wilson, James (unknown-1855). Made only one series of crosses, but derived the Wilson which became a major commercial variety.

B.3 Private Breeders in Texas, 1838-1910

Breeders listed in this section were nationally known. Source for this section is Geiser (1945). The notes after each name follow the description of the person's work found in that text.

Austin, J. W. (unknown-1908). Developed new varieties of several species.

Blanchard, C. C. F. (unknown-circa 1912). Originated the Blanchard Peach.

Bledsoe, James (unknown). Originated the Bledsoe Apple.

Boon, Joel (1856-1937). Originated the Boon Cling and Augbert Peaches.

Bruce, Albert Lee (1864-1926). Originated a number of plums, including some seedlings and some hybrids.

Dixon, Sam Houston (1855-1941). Originated the Cremo, Hogg and Toto Plums.

Ellis, Thomas L. (unknown-circa 1912). Originated the Ellis Plum by crossing.

Gaston, Anderson Lewers (1845-1909). Originated the Gaston Apple.

Guinn, Frank Benton (1855-1932). Originated the seedling peach Guinn. Developed a superior persimmon as a selection from the native species.

Guinn, Dr. J. N. B. (1820-1892). Experimented with plums, grapes, peaches. Improved blackberries by cultivation and selection of wild strains.

Haupt, William Walton (1828-1907). Specialized in selecting peaches and plums from seedlings. Alice Haupt Peach, Haupt Hybrid Berry, and a plum.

Howell, John Mashman (1849-1925). Originated peaches, Sam Dixon plum, and blackberries.

Hunt, P. W. (unknown-1931). Originated the Bertha Plum by crossing.

Kerr, John Steele (1847-1925). Originated apples, pears, peaches, plums, and cherries.

Kirkpatrick, Elbert W. (1844-1924). Originator of peaches, plums, blackberries, dewberries, pecans, and black walnuts.

Krause, Ernest William (1828-1918). Domestic-foreign crosses of grapes.

Leyendecker, John Frederick (1838-1908). Originated the Cleveland Peach and the Katy Pear.

Lipscomb, Dr. A. S. (circa 1860). Originated the Lipscomb Pride Peach.

Mosty, Louis A. (1851-1913). Originated Mosty's Free and Mosty's Cling Peaches, plus pecans, cypress, and junipers.

Nimon, James (1849-1905). Originated the Parker Earle Strawberry and the Robison Blackberry.

Norvell, Lipscomb Jr. (1884). Selected open-pollinated seedlings.

Onderdonk, Gilbert (1829-1920). Peach and plum breeder.

Page, J. A. (unknown). Originated the Page's Pomery Peach.

Parker, Barnes (unknown). Originated the Barnes Peach.

Perkins, W. H. (unknown). Originated the Julia May Plum.

Ragland, Dr. Andrew McFerrin (1845-1919). Originated the San Jacinto Apple and the Dayton Plum.

Ramsey, Frank Taylor (1861-1932). Father and son originated varieties of apples, peaches, plums, apricot, and nectarines.

Ringelstein, Caspar (1822-1896). Selected apples, pears, peachs, and grapes.

Sanders, Louis Thompson (1845-1902). Originated the Frances Peach.

Sneed, John Franklin (1857-1927). Origianted the Juneberta Peach.

Stubenrauch, Joseph W. (1852-1938). Originated a dozen new varieties of peaches.

Tacker, Jacob William (circa 1814-1894). Originated the Tacker Peach, a seedling which reproduces itself very closely from seed.

Tucker, Philip Crosby Jr. (1826-1894). Experimentd with citrus fruits, grapes, berries, figs, plums, apricots, peaches and guavas.

Watson, David H. (1859-1898). Bred plums and originated Nona, Yates, Preserver, Holland, Ragland, and Watson.

Whitaker, Dr. J. T. (1868-circa 1894). Origianted the Whitaker Plum, a seedling of Wild Goose.

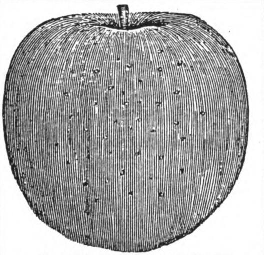
Wood, C. W. (circa 1904). Originated the Yellow Swan Peach.

Yates, William Arthur (1862-1940). Bred plums.

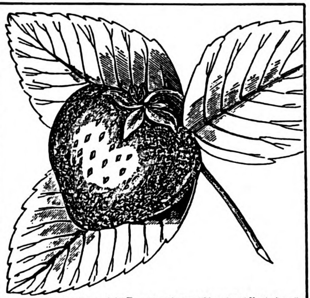
APPENDIX C

QUESTIONNAIRES

C.1 Questionnaire For Private Fruit Breeders


Example of the earliest illustrations of American fruits. Esopus Spitzenberg, figured by Coxe in 1817.

STUDY OF THE 1930 PLANT PATENT ACT


The original picture of the Hovey strawberry. "Magazine of Horticulture," August, 1840.

PRIVATE FRUIT BREEDERS

QUESTIONAIRE

PLEASE RETURN TO:

FRUIT PATENT STUDY
DEPT. OF AGRICULTURAL
ECONOMICS
18A CHITTENDEN HALL
MICHIGAN STATE UNIVERSITY
EAST LANSING, MI 48824

PRIVATE BREEDERS QUESTIONNAIRE

This survey of private breeders is to help us understand the impacts of patenting on fruit breeding. Please answer the following questions as completely as possible. Where exact data are not available please use the best estimates possible. Feel free to write additional comments in the margins and on the back page. If the item is not relevant to your program write "Not Applicable" in the space.

1. Of the following activities, please check those in which you (your firm) engage(s).

_____Breeding of new fruit varieties
_____Sport inducement (by irradiation etc.)
_____Search for sports
_____Variety testing for others
_____Variety collecting
_____Custom growing for commercial fruit producers
_____Commercial nursery (selling to home gardener or commercial grower)
_____Commercial fruit production (from orchards specifically for that purpose)
_____Other (please specify) ______________________________

If you have never been a fruit breeder, but do hold a fruit patent, please skip to question 15.

If you are not a breeder and hold no fruit patents, please write "Not Applicable" on this page and return the questionnaire in the return envelope so that we can remove you from our mailing list.

BREEDING: This section concerns the breeding work you or your firm have done

2. If you currently have or in the past have had a fruit breeding program, in what year was the program started? 19________

3. Please list the factors which influenced your (the firm's) decision to begin the breeding program.

4. Did the existence of patent protection influence the decision to begin, continue, or expand your breeding efforts? Please explain.

5. If the breeding program has been closed down, in what year was the breeding program terminated? 19__________

6. Please give the reasons for terminating the program.

7. Which is the fruit on which you have done the most work? (Circle one)

(1) APPLES	(2) GRAPES
(3) PEACHES/NECTARINES	(4) PEARS
(5) STRAWBERRIES	(6) OTHER________________________

8. List the most important characteristics which you are selecting for in breeding this fruit.

   (1)____

   (2)____

   (3)____

9. On average how long after a new variety fruits do you prefer to test it before introducing it? ________(YEARS)

10. In the following chart, use one line to summarize your breeding work on each fruit. If exact historical data are not available, please give your best estimates.

Fruit	Years of breeding	Total seedlings tested	Releases or introductions	Commercial successes	Number of patents	Total royalties earned
1.						
2.						
3.						
4.						
5.						

11. How do you distribute your finished varieties? (circle as many as apply)

(1) THE VARIETIES ARE RELEASED FOR PUBLIC USE
(2) THROUGH EXCLUSIVE PROPAGATION AND SALE BY YOUR NURSERY.
(3) UNDER AN EXCLUSIVE LICENSE WITH A SINGLE NURSERY.
(4) UNDER NON-EXCLUSIVE LICENSES WITH NURSERIES.
(5) THE VARIETIES ARE USED FOR COMMERCIAL PRODUCTION EXCLUSIVELY IN ORCHARDS UNDER YOUR CONTROL.
(6) OTHER (PLEASE SPECIFY)________________________________

____

12. Please indicate the amount of breeding material you have exchanged or received from the sources listed. (0=NO MATERIAL, 1=SOME MATERIAL FLOW and 2=A LARGE FLOW OF MATERIAL.)

_____ MATERIAL YOU HAVE RECEIVED FROM PUBLIC PROGRAMS
_____ MATERIAL YOU HAVE SENT TO PUBLIC INSTITUTIONS
_____ MATERIAL YOU HAVE RECEIVED FROM PRIVATE BREEDERS
_____ MATERIAL YOU HAVE SENT TO PRIVATE BREEDERS

13. For 1984, please estimate as closely as possible the value of the following items for your breeding program. (Do not include nursery or other activities of the firm.)

a) Number of breeders (including self) FULL TIME_____ PART TIME_____

Number of other employees FULL TIME_____ PART TIME_____

b) Total salaries paid to breeders $____________________

Total salaries paid to other employees $______________

c) Other cash expenditures $____________________

d) Royalties earned $____________________

e) Sales of fruit from test plots $____________________

e) Acres in breeding test plots ______________

f) Total value of current capital investment (buildings, land, machinery, etc.) $____________________

14. For each of the following years, please indicate by checking the appropriate column whether income from the breeding program was greater or less than breeding expenses. (Income may include both royalties and sales of fruit from test plots.)

	INCOME GREATER	EXPENSES GREATER
1984	___________	_____________
1975	___________	_____________
1970	___________	_____________
1965	___________	_____________
1960	___________	_____________
1950	___________	_____________
1940	___________	_____________

PATENTING(Answer this section if you have a patented variety or have submitted a patent application. Otherwise skip to Question 20.)

15. How many fruit patents do you currently hold?
(Do not include those which have expired.) ____________

16. On average what does it cost you to patent a variety?

a)patent office fees____________

b)lawyer fees ____________

c)other fees ____________________________________

(please specify) ____________________________________

17. Based upon your experiences, which parts of patent law or patent office regulation would you change? Please explain how these points have caused you difficulty in the past or will help your firm in the future.
help your firm in the future.

18. If you have a patented one or more varieties please answer the following questions. If you have more than two patented varieties select your most and least commercially successful varieties of a single fruit.

	MOST SUCCESSFUL	LEAST SUCCESSFUL
a) Fruit:	________	________
b) Varietal Name:	________	________
c) Year patented:	________	________
d) If the patent has been licensed or assigned, please list to whom	1.________	1.________
	2.________	2.________
	3.________	3.________
e) Lump sum royalty received (Give total for all licenses)	________	________
f) Royalty per plant (Give average for all licenses)	________	________

19. To the best of your knowledge please record the total number of trees/vines/plants sold for each year that you received a royalty while the patents for the two varieties were in effect.

Years the patent was in effect	NUMBER SOLD OF MOST SUCCESSFUL	NUMBER SOLD OF LEAST SUCCESSFUL
First three years (1-3)	________	________
Next five years (4-8)	________	________
Second five years (9-13)	________	________
Last four years (14-17)	________	________

OTHER OCCUPATIONS: We would like to know more about your background and how your other occupations relate to breeding.

20. What other occupations, in addition to breeding, do you practice? (Circle all that apply)

(1) NURSERYMAN
(2) COMMERCIAL FRUIT GROWER
(3) FARMER
(4) OTHER (PLEASE SPECIFY)________________________________

21. Do you use machinery, tools, and other items from these occupations in your breeding program?

1. NO
2. YES

22. If you run a nursery, do you sell only your own varieties?

1. NO
2. YES

23. If you are a commercial fruit grower, do you grow only your own varieties?

1. NO
2. YES

OPINIONS AND ATTITUDES: Finally, we would like your personal observations on the effects of patenting.

24. As a private breeder what are your major problems?

25. Should public breeding programs continue to produce and introduce finished varieties? Please Comment

26. What do you see as the effects of universities patenting?

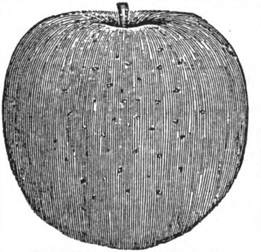
27. Could you list names and addresses of other private breeders whom you know?

NAME	ADDRESS	FRUIT

If you would like to comment on other aspects of fruit breeding or patenting which you feel are important, please include them here. Your comments are helpful to us in interpreting the survey results.

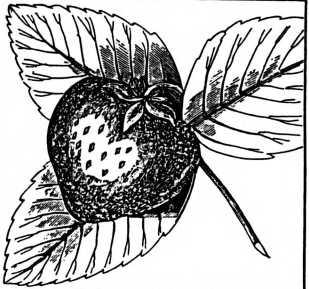
Thank you for your cooperation in completing this survey. If you wish a summary of the results please print your name and address on the back of the return envelope (please do NOT include them on the questionnaire). Once again, thank you.

C.2 Questionnaire for Public Breeders



Example of the earliest illustrations of American fruits. Esopus Spitzenberg, figured by Coxe in 1817.

STUDY OF THE
1930 PLANT PATENT
ACT



The original picture of the Hovey strawberry. "Magazine of Horticulture," August, 1840.

PUBLIC FRUIT
BREEDERS

QUESTIONAIRE

PLEASE RETURN TO:

FRUIT PATENT STUDY
DEPT. OF AGRICULTURAL
ECONOMICS
18A CHITTENDEN HALL
MICHIGAN STATE UNIVERSITY
EAST LANSING, MI 48824

PUBLIC BREEDERS QUESTIONNAIRE

This survey of public breeders is to help us understand the impacts of patenting on fruit breeding. Please answer the following questions as completely as possible. Where exact historical data are not available please use the best estimates available. Feel free to write additional comments in the margins and on the back page. If the item is not relevant to your program write "Not Applicable" in the space.

BREEDING: The first questions concern the breeding program.

1. Please circle the fruit which you breed. If you breed more than one fruit, circle the fruit designated by your experiment station director. In answering the following questions include information for this program only. (Circle one.)

   (1) APPLE (2) GRAPES
   (3) PEACHES/NECTARINES (4) PEARS
   (5) STRAWBERRIES (6) OTHER________________________

2. How many other public institutions have breeding programs for this fruit? ________

3. In what year was the breeding program for this fruit started at the university? 19__________

4. If the program has not been continuous, during what period(s)was it interrupted? ____

5. Year in which you were hired into the program. 19____________

6. List the most important characteristics on which you are working for this fruit.

   (1)____

   (2)____

   (3)____

7. On average, how long after a new variety fruits do you prefer to test it before you are ready to release it? ________(YEARS)

8. For 1984, please estimate as closely as possible the value of the following items for the breeding program of this fruit only. (Do not include time and expenses for the breeding of other fruits or other activities of the breeder such as teaching or other fruit research.)

a) Number of breeders (including self) FULL TIME_____ PART TIME_____
Number of other employees FULL TIME_____ PART TIME_____

b) Total salaries paid to breeders $__________________

Total salaries paid to other employees $__________________

c) Other cash expenditures $__________________

d) Royalties earned $__________________

e) Sales of fruit from test plots $__________________

f) Acres in breeding test plots __________________

g) Total value of current capital investment (buildings, land, machinery, etc.) $__________________

h) Funding from private sources $__________________

9. Please indicate the amount of breeding material you have exchanged or received from the sources listed below.
(0=NO MATERIAL, 1=SOME MATERIAL FLOW, 2=LARGE MATERIAL FLOW)

_____ MATERIAL YOUR HAVE RECEIVED FROM PUBLIC PROGRAMS
_____ MATERIAL YOU HAVE SENT TO PUBLIC PROGRAMS
_____ MATERIAL YOU HAVE RECEIVED FROM PRIVATE BREEDERS
_____ MATERIAL YOU HAVE SENT TO PRIVATE BREEDERS

10. How do you distribute your finished varieties?
(Circle as many as apply.)

(1) THE VARIETIES ARE RELEASED FOR PUBLIC USE
(3) UNDER EXCLUSIVE LICENSE TO A SINGLE NURSERY
(4) UNDER NON-EXCLUSIVE LICENSE TO NURSERIES
(6) OTHER (PLEASE SPECIFY) ______________________________

____

11. Although exact historical data may not be available, please give your best estimates.

	SINCE PROGRAM BEGAN	DURING LAST FIFTEEN YEARS
a)Total seedlings tested	____________	____________
b)Number of introductions	____________	____________
c)Number of commercial successes	____________	____________
d)Number of varieties patented	____________	____________
e)Total royalties earned	____________	____________

12. If you are responsible for breeding more than one fruit, please list the other fruits which you also breed.

(1)____________________________________

(2)____________________________________

(3)____________________________________

(4)____________________________________

PATENTING: (If your program has not patented any varieties you may skip to Question 15 on the next page.)

13. If you have a patented one or more varieties of this fruit, please answer the following questions. If you have more than two patented varieties of this fruit select your most and least commercially successful patented varieties.

	MOST SUCCESSFUL	LEAST SUCCESSFUL
a) Varietal Name:	______________	______________
b) Year patented:	______________	______________
c) If the patent has been licensed or assigned, please list to whom	1. ______________ 2. ______________ 3. ______________	1. ______________ 2. ______________ 3. ______________
d) Lump sum royalty received (Give total for all licenses)	______________	______________
e) Royalty per plant (Give average for all licenses)	______________	______________

14. To the best of your knowledge please record the total number of trees/vines/plants sold for each year that you received a royalty while the patent was in effect.

Years the patent was in effect	NUMBER SOLD OF MOST SUCCESSFUL	NUMBER SOLD OF LEAST SUCCESSFUL
a) First three years (1-3)	______________	______________
b) Next five years (4-8)	______________	______________
c) Second five years (9-13)	______________	______________
d) Last four years (14-17)	______________	______________

OPINIONS AND ATTITUDES: Finally, we would like your personal observations on public breeding and the effects of patenting.

15. As a public breeder what are your major problems?

16. Should public breeding programs continue to produce and introduce finished varieties? Please comment

17. What do you see as the effects of universities patenting?

18. If your university has a policy of patenting, are there any aspects of the licensing agreements which you feel are counterproductive?

19. Based upon your experiences, which parts of patent law or patent office regulation would you change? Please explain how these points have caused you difficulty in the past or will help your program in the future.

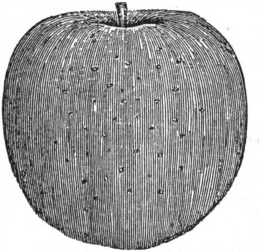
20. Could you list names and addresses of private breeders whom you know? (Continue on the back if needed).

Name	Address	Fruit

If you would like to comment on other aspects of fruit breeding or patenting which you feel are important, please include them here. Your comments are helpful to us in interpreting the survey results.

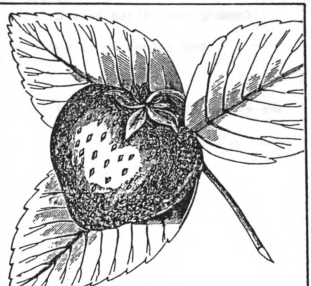
Thank you for your cooperation in completing this survey. If you wish a summary of the results please print your name and address on the back of the return envelope (please do NOT include them on the questionnaire). Once again, thank you.

C.3 Questionnaire For Fruit Nurseries



Example of the earliest illustrations of American fruits. Esopus Spitzenberg, figured by Coxe in 1817.

STUDY OF THE
1930 PLANT PATENT
ACT



The original picture of the Hovey strawberry. "Magazine of Horticulture," August, 1840.

NURSERY

QUESTIONAIRE

PLEASE RETURN TO:

FRUIT PATENT STUDY
DEPT. OF AGRICULTURAL
ECONOMICS
18A CHITTENDEN HALL
MICHIGAN STATE UNIVERSITY
EAST LANSING, MI 48824

NURSERY QUESTIONNAIRE

This survey of fruit nurseries is to help us understand the impacts of patenting on fruit breeding and propagation. The questionnaire consists of two parts, the main body centers on the nursery operation and the importance of patents. An insert at the end concerns the fruit breeding program of the firm and need be filled out only if your firm has, or in the past has had, such a program.

Please answer the following questions as completely as possible. Where exact data are not available please use your best estimates. Feel free to write additional comments in the margins and on the back page. If the item is not relevant to your program write "Not Applicable" in the space.

1. Of the following activities, please check those in which your firm engages.

_____Breeding of new fruit varieties
_____Testing of new varieties and sports
_____Propagation of fruiting trees, vines, bushes or plants
_____Propagation of ornamental plants
_____Custom growing (to specifications of particular grower)
_____Orchard supply
_____Wholesaling (to commercial growers, nurseries and garden centers)
_____Mailorder retailing
_____Storefront retailing
_____Commercial fruit production (from orchards specifically for that purpose)
_____Other (please specify) ______________________________

PATENTS: (Complete this section even if you do not offer patented varieties. Write "Not Applicable" where appropriate.)

2. Please give the following information on patented and unpatented varieties for the top four selling fruits in 1984 beginning with your best selling fruit.
(Use one column for each fruit.)

	# 1	# 2	# 3	# 4
Fruit (please name)				
Is the top selling variety patented? 1. no 2. yes				
Is the top selling variety trademarked 1. no 2. yes				
Total number of varieties offered				
Number of patented varieties offered				
On how many patented varieties do you hold an exclusive license?				
Number of trademarked varieties offered				

	# 1	# 2	# 3	# 4
Fruit (please name)				
How many varieties whose patents have expired do you carry in your catalog?				
Quantity sold of patented varieties				
Value of sales of patented varieties				
Total quantity sold				
Total value of sales				
Royalties paid				
Number of varieties licensed to others				
Royalties received				
Average costs of propagating a tree/vine/plant				

3. Of the patented varieties which you offer, please answer the following question for the patented variety which has the best sales to date.

	BEST SELLING
a)Fruit:	______________
b)Year patented:	______________
c)Lump sum royalty paid	______________
d)Royalty per plant	______________
e)Advertising costs to date	______________

4. Please record the total number of trees/vines/plants sold during the following periods that the patent was in effect for the above variety.

Years the patent was in effect	NUMBER SOLD
a)First three years (1-3)	______________
b)Next five years (4-8)	______________
c)Second five years (9-13)	______________
d)Last four years (14-17)	______________

5. Indicate the extent of damage due to infringement by the following groups. (0=NO DAMAGE, 1=LITTLE DAMAGE, 2=EXTENSIVE DAMAGE)

_____COMMERCIAL GROWERS

_____RETAIL NURSERIES

_____WHOLESALE NURSERIES

_____OTHER (PLEASE SPECIFY) ______________________________

6. Select your two best selling fruits in 1984 to answer the following questions.

Fruit	What is your top selling variety?	List the major varieties offered by other nurseries which compete with this variety
______	________________	1.________________________ 2.________________________ 3.________________________
______	________________	1.________________________ 2.________________________ 3.________________________

SALES:

7. We ask the value of sales for the current year and for 1978, which is the date of last horticultural census. We will use this information to check our coverage of the industry.

Value of annual sales	1984	1978
a) Total Sales	__________	__________
b) Sales of fruit plants	__________	__________
c) Sales of patented varieties	__________	__________

8. Destination of fruit plant sales in 1984	Percent of total sales	Percent of sales which are patented
a) Other nurseries and garden centers	__________	__________
b) Custom growing	__________	__________
c) Commercial growers	__________	__________
d) Home gardener	__________	__________
e) Other________________	__________	__________

COSTS:

9. Please record the number of employees for 1984.

a) Permanent employees FULL TIME _____ PART TIME_____

b) Seasonal employees SPRING _______ FALL _______

10. Annual Expenditures

	1984	1978
a) Total costs (including capital costs)	_________	_________
b) Nursery (propagation) costs (including capital costs)	_________	_________
c) Purchases of fruit plants	_________	_________
d) Advertising costs for fruits	_________	_________
e) Royalties paid	_________	_________

11. Please estimate the current value of your nursery investment

$___________________

OPINIONS AND ATTITUDES: Finally we would like to ask your opinions about the nursery trade and patenting.

12. As a nursery what are your major problems?

13. Based upon your experiences, which parts of patent law or patent office regulation would you change? Please explain how these points have caused you difficulty in the past or will help your firm in the future.

14. If it were decided to eliminate either patent protection or trademark protection for fruit varieties, which would you retain? Please give your reasons.

15. Should public breeding programs continue to produce and introduce finished varieties? Please comment.

16. What do you see as the effects of universities patenting?

17. Do universities have any rules on releasing or licensing their varieties which you feel are counterproductive?

18. Could you list names and addresses of private breeders whom you know?

NAME	ADDRESS	FRUIT

BREEDING: If the firm has, or in the past has had, a fruit breeding program, we ask that you take a few more minutes to complete the attached insert, or list below the name of the person whom you have designated to complete this part of the questionnaire.

____(name)

NOTE: If your firm has never had a fruit breeding program, merely write "Not Applicable" on the insert and return it with the main questionnaire. You have now finished the questionnaire, but feel free to add additional comments on the back cover.

If you would like to comment on other aspects of fruit breeding or patenting which you feel are important, please include them here. Your comments are helpful to us in interpreting the survey results.

Thank you for your cooperation in completing this survey. If you wish a summary of the results please print your name and address on the back of the return envelope (please do NOT include them on the questionnaire). Once again, thank you.

BREEDING QUESTIONNAIRE

If your firm has never had a fruit breeding program, you do not need to answer this section.

20. During what years did (has) the company maintain(ed) a fruit breeding program? 19______ to 19______

21. Did the existence of patent protection influence the decision to begin, continue, or expand your breeding efforts? Please explain.

22. If the breeding program has been closed down, please give the reasons for terminating the program.

23. In the following chart, use one line to summarize your breeding work on each fruit. If exact historical data are not available, please give your best estimates.

Fruit	Years of breeding	Total seedlings tested	Releases or introductions	Commercial successes	Number of patents	Total royalties earned
1.						
2.						
3.						
4.						
5.						

24. List the fruit on which there has been the most breeding, and the most important characteristics for which you are selecting.

FRUIT ________

(1)____

(2)____

(3)____

25. On average how long after a new variety fruits do you prefer to test it before you are ready to introduce it? ________(YEARS)

26. Please indicate the amount of breeding material you have exchanged or received from the sources listed.
(0=NO MATERIAL, 1=SOME MATERIAL FLOW and
2=A LARGE FLOW OF MATERIAL.)

_____ MATERIAL YOU HAVE RECEIVED FROM PUBLIC PROGRAMS
_____ MATERIAL YOU HAVE SENT TO PUBLIC INSTITUTIONS
_____ MATERIAL YOU HAVE RECEIVED FROM PRIVATE BREEDERS
_____ MATERIAL YOU HAVE SENT TO PRIVATE BREEDERS

27. For 1984, please estimate as closely as possible the value of the following items for your breeding program.
(Do not include nursery costs or other activities of the firm.)

a)Number of breeders (including self) FULL TIME______ PART TIME_____

Number of other employees FULL TIME______ PART TIME_____

b)Total salaries paid to breeders $____________________

Total salaries paid to other employees $______________

c)Other cash expenditures $_____________________

d)Royalties earned $_____________________

e)Sales of fruit from test plots $_____________________

e)Acres in breeding test plots ______________

f)Total value of current capital investment in the breeding program (buildings, land, machinery, etc.) $_____________________

28. For each of the following years, please indicate by checking the appropriate column whether income from the breeding program was greater or less than breeding expenses.(Income can include both royalties and sales of fruit from the test plots.)

	INCOME GREATER	EXPENSES GREATER
1984	__________	___________
1975	__________	___________
1970	__________	___________
1965	__________	___________
1960	__________	___________
1950	__________	___________
1940	__________	___________

29. If you have a patented one or more varieties <u>from your breeding program,</u> please answer the following questions. If you have more than two patented varieties from the breeding program select your most and least commercially successful varieties of a single fruit.

	MOST SUCCESSFUL	LEAST SUCCESSFUL
a)Fruit:	__________	__________
c)Year patented:	__________	__________
d)Has the patent been licensed to other nurseries?	1. NO 2. YES	1. NO 2. YES
e)Lump sum royalty received (Give total for all licenses)	__________	__________
f)Royalty received per plant (Give average for all licenses)	__________	__________

19. To the best of your knowledge please record the total number of trees/vines/plants sold for each year that you received a royalty while the patent was in effect.

Years the patent was in effect	NUMBER SOLD OF MOST SUCCESSFUL	NUMBER SOLD OF LEAST SUCCESSFUL
a)First three years (1-3)	__________	__________
b)Next five years (4-8)	__________	__________
c)Second five years (9-13)	__________	__________
d)Last four years (14-17)	__________	__________

Please return to: Fruit Patent Study
Department of Agricultural Economics
18A Chittenden Hall
Michigan State University
East Lansing, MI 48824

REFERENCES

Allyn, Robert Starr, 1934. The First Plant Patents: A Discussion of the New Law and Patent Office Practice Abstracts of 84 Patents and History of the Law. Brooklyn: Education Foundation, Inc.

__________, 1943. "Patentable Yardsticks." Journal of the Patent Office Society 25: 791-816.

__________, 1944. Plant Patents, 1934 to 1943: Abstracts of Plant Patents 85 to 610. A Supplement to The First Plant Patents (Nos. 1 to 84). Sandy Creek, New York: The Corse Press, Inc.

American Fruit Grower, 1984. 104(7): 51-62

Bagwell, Robert E., Patent Office Examiner. Personal Conversation.

Bailey, Liberty Hyde, 1919. "Horticulture." in Liberty Hyde Bailey (ed.). The Standard Cyclopedia of Horticulture, 3rd ed. Vol. III. New York: The Macmillan Company. pp. 1501-1520.

Barrows, Keith C., 1936. "A Defense of Basic Plant Patents From the Plant Breeder's Point of View." Journal of Heredity 27(12): 475-478.

Berlan, Jean-Pierre, 1983. "L'Industrie Des Semences, Economie et Politique." Economie Rurale 158: 18-28.

__________. Personal Conversation.

Berlan, Jean-Pierre and Richard Lewontin, 1983. "Breeders Rights and the Patenting of Life Forms." Université d'Aix Marseille II: Centre d'Economie du Développement Comparé. Unpublished.

Berlan, Jean-Pierre and Richard Lewontin, 1985. "He Sowed, Others Reaped: The Value of Genetic Resources". Paper presented for the Office of Technology Assessment.

Bhattacharyya, Gouri K. and Richard Johnson, 1977. Statistical Concepts and Methods. New York: John Wiley and Sons.

Borlaug, Norman E., 1983. "Contibutions of Conventional Plant Breeding to Food Production." Science 219(4585): 689-693.

Brooks, Reid M. and H.P. Olmo, 1972. Register of New Fruit and Nut Varieties, 2nd ed. Berkeley: University of California Press.

__________, 1971-1982. "Register of New Fruit and Nut Varieties." Lists 26-32. HortScience.

Bureau of the Census, Department of Commerce. Census of Agriculture. Washington, D.C.: United States Government Printing Office.

__________. Census of Agriculture: Special Census of Horticulture. Washington, D.C.: United States Government Printing Office.

Butler, L.J., and Bruce W. Marion, 1985. "The Impacts of Patent Protection on the U.S. Seed Industry and Public Plant Breeding." Madison: North Central Project 117, Monograph 16.

Burpee, David, 1936. "More About the Double Nasturtium Patent." Journal of Heredity 27(7): 271

California Tree Fruit Agreement. 701 Fulton Ave., Sacramento, California 95825.

Carlson, R.F. et al., 1970. North American Apples: Varieties, Rootstocks, Outlook. East Lansing: Michigan State University Press.

Cook, Robert C., 1930a. "A Plant Patent Bill Before Congress." Journal of Heredity 20(2): 80-81.

__________, 1930b. "The Plant Patent Law." Journal of Heredity 20(7): 319-322. Continued in 20(8): 357-362, 369-370.

__________, 1933b. "The Commissioner Replies." Journal of Heredity 24(4): 163-164.

__________, 1936a. "What is a Basic Patent?" Journal of Heredity 37(5): 213-216.

__________, 1936b. "Plant Patent 110 Declared Invalid." Journal of Heredity 27(10): 394-400.

Cooper, Pamela, 1984. "Plant Breeders' Rights: Some Economic Considerations." Economic Working Papers, Agriculture Canada.

Darrow, George M., 1966. The Strawberry: History, Breeding and Physiology. New York: Holt, Rinehart and Winston.

Dennis, Frank, Professor of Horticulture, Department of Agricultural Economics, Michigan State University. Personal conversation.

Dillman, Don A., 1978. Mail and Telephone Surveys: The Total Design Method. New York: John Wiley and Sons.

Dunstan, R.T., Private grape breeder. Atachua, Florida. Personal Communication.

Dworkin, G., 1983. "The Plant Varieties Act: 1983." European Intellectual Property Review 10: 270-275.

Garfield, Charles, 1917. "Revive Amateur Pomology". Proceedings of the American Pomological Society 35: 191-193.

Gausewitz, Richard L., 1983. Patent Pending: Today's Inventors and Their Inventions. Old Greenwich, Connecticut: Divin-Adair Publishers.

Geiser, Samuel Wood, 1945. Horticulture and Horticulturalists in Early Texas. Dallas: University Press.

Godden, David, 1981. "Economic Issues Concerning Plant Variety Rights: General and Australian Perspectives." Department of Agricultural Economics and Business Management, University of New England, Armidale, New South Wales, Australia: Agricultural Economics Bulletin No. 26.

Godden, David and Roy Powell, 1981. "Economic Aspects of Plant Variety Rights: Models for Examining Their Effects." Brisbane, Australia: Symposium on the Economic Aspects of the Australian Patent System. 151st ANZAAS Congress.

Gujarati, Damodar, 1978. Basic Econometrics. New York: McGraw-Hill Book Company.

Hansche, Paul E., 1983. "Response to Selection." in James Moore and Jules Janick (eds.). Methods in Fruit Breeding. West Lafayette, Indiana: Purdue University Press. pp. 154-171.

Hedrick, Ulysses P., 1950. A History of Horticulture in America to 1860. New York: Oxford University Press.

Jeffery, Donald D., 1977. "The Patentability and Infringement of Sport Varieties: Chaos or Clarity?" Journal of the Patent Office Society 59(10): 645-658.

Jewkes, John, David Sawers, and Richard Stillerman, 1969. The Sources of Invention. New York: Nortona and Co.,Inc..

Kelly, John F. and A. Allan Schmid, 1986. "Varietal Release and Royalty Allocation Policy Survey". Agricultural Economics Staff Paper 86.5. East Lansing, Michigan: Michigan State University.

Kinter, Earl W. and Jack L. Lahr, 1975. An Intellectual Property Law Primer. New York: Macmillan Publishing Co., Inc..

Kitti, Carole, 1986. "Patent Life and the Optimal Timing of Innovations", in George S. Tolley, James Hodge and James F. Oehmke (eds.), The Economics of R&D Policy. New York: Praeger.

Lyons, R.M.A. and A.J. Bagleiter, 1984. "An Examination of the Potential Economic Impacts of Breeders' Rights on Canada." Quebec, Canada: Consumer and Corporate Affairs.

Machlup, Fritz, 1958. "An Economic Review of the Patent System." Study No. 15 of the Subcommittee on Patents and Trademarks and Copyrights. Committee on the Judiciary, United States Senate.

Machlup, Fritz and Edith Penrose, 1950. "The Patent Controversy in the Nineteenth Century." Journal of Economic History 10(1): 3-29.

Magness, J. R., 1937. "Progress in Pear Improvement." in United States Department of Agriculture. Yearbook of Agriculture: 1937. Washington, D.C.: United States Government Printing Office.

National Agriculture Library. Special Collection of Nursery Catalogs.

Neagley, Clinton H., Donald D. Jeffery and Anthony B. Diepenbrock, 1983. "Section 101 Plant Patents, Panacea or Pitfall?" Patent Law Association Selected Legal Papers 1(2): 81.

Newman, Magdalene R., 1931. "Plant Patents: A Brief Historical Survey with References." Agriculture Library Notes 6(Feb): 35-42.

Nordhaus, William D., 1969. Invention, Growth and Welfare: A Theoretical Treatment of Technological Change. Cambridge, Mass.: MIT Press.

North American Fruit Explorers, Inc. North American Pomona.

Office of Technology Assessment, 1984. Commercial Biotechnology: An International Analysis. Washington, D.C.: United States Government Printing Office.

Parker, Charles B., 1940. "Bacteria Held Not Patentable Under the Plant Patent Act." Journal of the Patent Office Society 22(8): 622-630.

Penrose, Edith, 1951. The Economics of the International Patent System. Baltimore: Johns Hopkins University Press.

Perrin, R.K., K.A. Kunnings, and L.A. Ihnen, 1983. "Some Effects of the U.S. Plant Variety Protection Act of 1970". Economics Research Report No. 46. Raleigh: North Carolina State University, Department of Economics and Business.

Phillips, J., 1984. "Patents and Incentives to Invest". Endeavor. New Series 8(2): 90-94.

Pratt, Charlotte, 1983. "Somatic Selection and Chimeras", in James N. Moore and Jules Janick. Methods in Fruit Breeding. West Lafayette, Indiana: Purdue University Press.

Ricks, Donald, Professor of Agricultural Economics, Michigan State University. Personal Conversation.

Rossman, Joseph, 1931a. "Plant Patents." Journal of the Patent Office Society 31(1): 7-22.

Scherer, F.M., 1980. Industrial Market Structure and Economic Performance. 2nd ed. Chicago: Rand McNally College Publishing Company.

Schmid, A. Allan, 1985. "Biotechnology, Plant Variety Protection, and Changing Property Institutions in Agriculture." North Central Journal of Agricultural Economics 7(2): 130-138.

Schuering, Ann Foley (ed.), 1983. A Guide Book to California Agriculture. Berkeley: University of California Press.

Senate Standing Committee on National Resources, 1984. Plant Variety Rights. Canberra: Australian Government Printing Service.

Sparrow, D.H.B., 1981. "Some Biological Implications of Plant Variety Rights in Australia", in Plant Variety Rights in Australia. Proceedings of a National Conference held at Waite Agricultural Research Institute. Glenn Osmond, Australia.

Stark Bro's Nurseries and Orchards Co., 1984. "Stark Bro's Fruit Tree Catalog and Guide for the Professional Grower". Louisiana, Missouri: Stark Bro's Nurseries and Orchards, Co.

Taylor, C.T. and Z.A. Silberston, 1973. The Economic Impact of the Patent System: A Study of the British Experience. Cambridge: Cambridge University Press.

Terry, Dickson, 1966. "The Stark Story: Stark Nurseries 150th Anniversary". The Bulletin. Special Publication. St. Louis, Missouri: Historical Society.

Toulmin, Harry Aubrey, Jr., 1949. Handbook of Patents. New York: Van Nostrand Co, Inc.

United States Congress, 1983. Title 35 of the United States Code (1982 ed.). Vol. 13. Washington, D.C.: United States Government Printing Office.

United States Department of Agriculture, 1937. Yearbook of Agriculture: 1937. Washington, D.C.: United States Government Printing Office.

_________. Agriculture Statistics. Washington, D.C.: United States Government Printing Office.

United States House of Representatives, 1930. "Plant Patents, House Report No. 1129". Seventy-first Congress, Second Session.

_________, 1954. "Patenting of Plants". House Report No. 1455. 83rd Congress, 2nd Session.

United States Senate, 1930. "Plant Patents, Senate Report No. 315". Seventy-first Congress, Second Session.

_________, 1954. "Patenting of Plants". Senate Report No. 1937. 83rd Congress, 2nd Session.

White, Richard P., 1975. A Century of Service: A History of the Nursery Associations of the United States. Washington, D.C.: The American Association of Nurserymen, Inc.

Court Cases

Cole Nursery v Youdath Perennial Gardens 17 F. Supp. 159, U.S.P.Q. 95 Ohio 1936).

Dixie Rose Nursery v Coe U.S. App. D.C. 131 F. 2d 446.

Diamond v Chakrabarty 100 S.Ct. 2204, 2210 (1980).

Dunn v Ragin v Carlile 50 U.S.P.Q. 472, 474 PTO Bd. Int. (1941).

Ex Parte Foster 90 U.S.P.Q. 16 (1951).

Ex parte Hibberd 227 U.S.P.Q. (1985).

Ex parte Van Over U.S.P.Q. PTO Bd. Int. (1941)

In re Arzberger 46 U.S.P.Q. 32 (1940). CD. 653, 521, O.G. 272, 112 F. 2d 834 (C.C.P.A. 1940).

Kim Bros v Hagler 167 F. Supp 655 120 U.S.P.Q. 210 (S.D. Cal 1958)

Pan American Plant Company v Andy Matsui, d.b.a. Andy Matsui Nursery 433 F. Supp 693, 198 U.S.P.Q. 462 (N.D. Cal. 1977).

Yoder Brothers, Inc. v California-Florida Plant Corp. 537 F. 2d 1347, 193 U.S.P.Q. 264 (5th Cir. 1976).