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*1051 VEGGIE TALES: PERNICIOUS MYTHS ABOUT PATENTS, INNOVATION, AND CROP DIVERSITY IN THE TWENTIETH CENTURY

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The conventional wisdom, as illustrated for millions of readers in the July 2012 issue of National Geographic, holds that the twentieth century was a disaster for crop diversity. In the popular press, this position is so entrenched that it no longer needs a citation. We conduct a study of all vegetable and apple varieties commercially avail-able in 1903 and compare them with all varieties commercially available in 1981 and 2004. We question the conventional wisdom and cast serious doubt on the 1983 vegetable crop diversity study that previous commentators have taken as gospel. We also enter the debate between economists and social scientists on the role that patent law might play in destroying or enhancing crop diversity. Both sides may be wrong. Our data suggest that patent law has not reduced crop diversity, nor is it likely to have significantly contributed to the introduction of new vegetable varieties. The diversity loss thesis espoused by ethnobotanists is as suspect as the incentive-to-invent story told by patent economists, at least regarding the most common vegetable crops. Finally, we provide one of the first analyses of innovation in any comprehensive technology market by identifying the source of all products in the vegetable market and current commercialization rates for all patented innovations. This paper goes significantly beyond our prior three related postings of preliminary data.

> ***1052** [T]he biggest single environmental catastrophe in human history is unfolding in the garden . . . . Loss of genetic diversity in agriculture-- silent, rapid, inexorable--is leading us to a rendezvous with extinction--to the doorstep of hunger on a scale we refuse to imagine. [FN1]

By far the most influential study of vegetable crop diversity was conducted in 1983 by the Plant Genetic Resources Project of the Rural Advancement Fund, Inc. (RAFI). [FN2] Although initially unpublished, its findings were widely publicized and accepted, as evidenced by the quote above from Pat Mooney and Cary Fowler, who headed the International Conference and Programme on Plant Genetic Resources at the Food and Agriculture Organization (FAO) of the United Nations. [FN3] Mooney and Fowler published the RAFI study findings in their classic book, Shattering: Food, Politics, and the Loss of Genetic Diversity. [FN4] The RAFI study compared a comprehensive 1903 United States Department of Agriculture (USDA) inventory of seeds found in commercial seed catalogs with the 1983 holdings in the National Seed Storage Laboratory (NSSL). [FN5] Mooney and Fowler summarized the study as follows, “RAFI found that approximately [ninety-seven] percent of the varieties given on the old USDA lists are now extinct. Only [three] percent have survived the last eighty years.” [FN6] The study was the centerpiece of a recent National Geographic article [FN7] decrying crop diversity loss, and the three percent survival rate is the iconic crop diversity statistic produced in the twentieth century. [FN8]

***1053** Our own data, reported here, reveal that the RAFI study and "lessons" drawn from it suffer from several serious problems. First, the ***1054** twentieth century was not, in fact, a disaster for crop diversity. Our work comparing the varietal availability of the same forty-two crops studied by RAFI shows 7218 varieties available in 1903 and 6916 varieties available in 2004. We demonstrate that diversity has been sustained by the addition of thousands of new or reintroduced varieties, undermining the widely accepted diversity erosion thesis. We also find that this varietal replacement was not accomplished via hybridization or patented biotechnology.

Second, the RAFI study itself did not compare "apples to apples." The 1903 inventory of commercial catalogs [FN9] was compared to the 1983 U.S. government holdings in a seed bank, [FN10] rather than to any parallel comprehensive inventory of commercial seed catalogs. [FN11] Our comparison of the 1903 commercial seed catalogs with a comprehensive 2004 study of commercial seed catalogs [FN12] establishes a survival rate for older varieties that is twice the rate reported by Mooney and Fowler.

Finally, Mooney and Fowler's original "shattering" three percent figure is the result of a significant math error that we report for the first time. In their book, they correctly list the raw numbers collected by RAFI, but somehow mis-added or mis-divided the figures. The error is easily seen by recalculating the survival rate from the numbers they provide. The actual 1983 survival rate in the "apples to oranges" RAFI study should have been reported as 7.4%. [FN13]

As a law professor and an anthropologist studying law, our initial interest in crop diversity stemmed from the desire to test two contradictory theses about patent law posed by economists and ethnobotanists. Conventional economics assumes that patent law stimulates innovation, resulting in increased diversity of goods. [FN14] According to this thesis, new federal intellectual property rights granted in plants in the United States ***1055** in 1930 (Plant Patent Act), [FN15] 1970 (Plant Variety Protection Act), [FN16] and 1985 (patent office acceptance of utility patents on plant material) [FN17] should have stimulated the production of new varieties. [FN18] Anthropologists and ethnobotanists, however, have long argued that patent law leads to monoculture, genetic erosion, and diminished varietal diversity. [FN19]

By looking at data from the historical collection of commercial seed and nurserymen's catalogs at the National Agricultural Library in Beltsville, Maryland, [FN20] we hoped to prove one thesis or the other wrong. Instead, we found that neither thesis can be supported as regards common vegetable crops and the one fruit we studied, apples. We find that the twentieth century is marked by both high levels of innovation and varietal diversification (contra the ethnobotanists' thesis) and that federal intellectual property rights in plants played little or no role in that innovation***1056** (contra the economists' thesis). More research needs to be done on the distinctly different behavior of corn, but we can offer a preliminary hypothesis as to why patents seem, on the surface, to matter more in the corn seed market.

In Part I of this Article, we briefly set forth the federal legal regime that developed over the twentieth century to provide plant breeders with intellectual property rights. Then, we explain our methodology, which includes (1) the first comparison of crop varieties available in 1903 with those available in 2004, and (2) the creation of a unique data set that accounts for all patents and plant variety protection (PVP) certificates ever issued for common vegetable crops, as well as all patents ever issued for apples. We also describe the sources from which we estimate, for the first time, commercialization and obsolescence rates for patented plants and the rate of natural varietal change over time.

In Part II of this Article, we set forth our findings and provide the first accurate snapshot comparing varietal diversity at the beginning of the twentieth century with varietal diversity at the beginning of the twenty-first. We then chart diversity gains and losses by analyzing all commercially available vegetables in 2004 and all commercially available apples in 2000. In Part III, we conclude that patents play a very minor role in varietal diversity and provide full patent data on all crops studied. We report, for the first time, current commercialization rates for all the pat-ented varieties. To our knowledge, this is one of the only such studies conducted in any discrete technological field. [FN21] In Part IV, we investigate the sources of the diversity that we identify and estimate what percent of varietal diversity is due to patented innovations, unpatented local innovations, imports, or preservation of heirloom varieties. We also add the year 1981 to our study in order to capture the rate of varietal turnover over time, and learn that our snapshots in 1903 and 2004 miss thousands of varieties that came and went during the twentieth century.

In Part V, we conclude the Article by speculating why corn, which was serendipitously counted as a vegetable in the 1903 USDA study, has attracted more patenting activity than all other vegetable crops combined. Since our non-corn data strongly show that massive innovation can occur without federal intellectual property rights, we hesitate to draw a necessary patent/innovation link with corn and other cereal grains. We examine existing studies by agricultural economists and suggest a limited range of innovation that might be due to utility patents. We conclude that the acquisition of PVP certificates, and probably utility patents, for corn is driven by rent-seeking that may be unrelated to increased innovation.

***1057** I. Legal Protection for Plants and Study Methodology

Because we attempt to measure the influence of legal changes on varietal diversity of crops, Section A begins with a brief description of the legal regime for the protection of plants and explains which hypotheses we chose to test. Then, Section B describes our methodology.

A. IP in Plants: The Conventional Wisdom and Hypotheses to Be Tested

In 1930, the United States passed the Plant Patent Act (PPA), the first law designed to provide some level of legal protection for plant breeders. [FN22] The PPA, however, provided protection only for asexual means of reproduction, like grafting or budding. [FN23] In other words, a breeder who successfully creates a novel and distinct apple tree has the sole right, under the corresponding plant patent, to propagate and commercialize the tree by taking cuttings from it and grafting them on to new rootstock. [FN24] Although the law appears to provide relatively narrow protection, the main object of protection, fruit trees, nut trees, and roses, do not breed true-to-type. Therefore, the only way for a competitor to appropriate a new variety of apple, for example, is to steal a cutting from the new tree, which is precisely what the law penalizes.

The law targets the only realistic way to misappropriate because taking an apple, for example, from a new tree and planting its seeds is an ineffective method of misappropriation. Each seed will grow into a different tree genetically, and the chances are infinitesimal that one of them will produce the desired fruit. [FN25] This facet of the PPA functions much like copyright law in that it only protects new works from direct copying, [FN26] but since one cannot reverse engineer an apple, peach, or almond tree, or a rose bush, the PPA provides the reasonable sort of protection. As a practical matter, of course, it is difficult for patentees to identify those who engage in illegal grafting of a protected plant variety. Recent improvements in genetic analysis make identification much easier, [FN27] although***1058** there is seldom an economic incentive to sue if close substitute varieties are widely available. [FN28]

The PPA provides no cause of action against those who “copy” a new variety of plant by collecting its seeds, planting, and then harvesting them. [FN29] It was passed at the urging of fruit tree and rose growers, most prominently Stark Brothers Nursery, the nation's largest seller of fruit trees, who saw no need to have their seeds protected. [FN30] Federal protection for sexual reproduction, including seeds, was not enacted until 1970. [FN31] The Plant Variety Protection Act (PVPA), the new 1970 statute, tasks the USDA, not the Patent Office, with issuing certificates to the creators of novel, distinct, and uniform plants. [FN32] Seed from a protected variety may not be planted and used to produce a competing seed without the permission of the certificate holder. [FN33] Although protection may provide a competitive advantage, the benefits of the PVPA to breeders are limited by a farmer's exemption, which permits seed saving by farmers for replanting on their own lands during subsequent growing seasons, [FN34] and a research exception that allows the use of protected germplasm in the breeding of a new variety that is not “essentially derived” from a protected variety. [FN35]

In this sense, the PVPA also functions more like copyright law than a traditional utility patent. [FN36] It seeks to prevent piracy and counterfeiting rather than to establish absolute protection for a particular genotype or phenotype. As with copyright protection for software, the creator can prevent a competitor from verbatim copying and mass replication but cannot prevent a competitor from independently creating a product with the same function. [FN37]

Utility patents have been available for new, useful, and nonobvious plants, including plant genes and seeds, since 1985. [FN38] Protection under a ***1059** utility patent is stronger than under the PVPA certificate, because reverse engineering and independent discovery are not defenses to patent infringement, and there is no broad statutory research exemption. [FN39] And, unlike the PVPA, there is no farmer's exemption. [FN40] In addition, since protection can be granted for a single gene, infringers breeding very different varieties or even species of plants may be found to be infringing if the patented gene is present. [FN41] The requirements for a utility patent, however, are more difficult to meet than those imposed by the PPA or PVPA. The plant must be nonobvious in light of the prior art, [FN42] as opposed to being merely “novel and distinct.” [FN43] In other words, someone skilled in breeding the plant species at issue must perceive the improvement to be not obvious in light of all relevant prior art plants. In addition, section 112 of the Patent Act subjects applications for utility patents to a stringent written description requirement, [FN44] whereas the PPA merely requires that the plant “description is as complete as is reasonably possible.” [FN45] For example, if one improves the smell of a rose, one may have difficulty describing the improvement in a way that satisfies section 112.

Not surprisingly, the purpose of the PPA, PVPA, and utility patents is to stimulate inventive activity by providing incentives for the creation of new objects for innovation. [FN46] As applied to plants, the purpose of federal protection is the production of new and improved varieties, [FN47] and the diversification of the pool of goods that might be amenable for commercialization. Economists agree as to the legislative purpose, but a growing body of empirical literature casts doubt on the extent to which patent laws actually stimulate more research expenditures. [FN48] Empirical work suggests that outside of pharmaceuticals and semiconductors, the patent ***1060** incentive may be quite weak, [FN49] even though it seems clear that strengthening patent law increases patenting activity. [FN50] A key assumption in the patenting debate is that only a small percentage of patents are ever commercialized, [FN51] yet hard evidence of commercialization rates has been elusive to gather. [FN52]

Another group of commentators, led by anthropologists and ethnobotanists, do more than simply doubt the incentive-to-create or incentive-to-commercialize hypotheses. They assert that the twentieth century was a disaster for plant varietal diversity [FN53] and claim that patent law contributed to diminished varietal diversity, genetic erosion, and plant monoculture by concentrating property in the hands of a shrinking number of firms that offer limited choices to farmers. [FN54] Anthropologists, ethnobot-anists, and some sociologists have been particularly active in the international debate over the extent to which plants should be subject to any intellectual property rights. [FN55] The primary international agreement on intellectual property administered by the World Trade Organization does not require that patents on plants be made available, but rather allows for the adoption of sui generis plant laws in each member state. [FN56] Anthropologists and ethnobotanists have been vigorous advocates for weak levels of protection. [FN57]

As keen observers of these important debates, we found ourselves unable to judge the merits of either side without conducting empirical research into the assumptions made by pro-IP advocates and anti-IP activists. After canvassing available data sources, we decided to test four hypotheses:

***1061** 1. The twentieth century witnessed a massive decrease in varietal diversity.
2. Patents negatively affect varietal diversity.
3. Patents stimulate the creation of new varieties. [FN58]
4. Patents stimulate the commercialization of new varieties.

The verification of these hypotheses is not just relevant to international controversies over the proper level of intellectual property protection in plants; it is potentially relevant to the proper shape of legal protection for all kinds of technology.

B. Methodology

Plants present a special opportunity for empirical research on the effect of intellectual property laws for two reasons. First, the debate over legal protection of plants is vigorous at the international level and concerns the provision of basic staples necessary to sustain human life. [FN59] In other words, the answers to our questions matter. Second, unlike other sorts of technology, one can more easily measure levels of innovative and commercialized activity because of a unique cultural artifact of the plant breeding community: plant breeders name their discrete creations in such a way that they can be tracked easily in the marketplace. [FN60] In addition, they advertise their creations in regular historical publications, and often provide information about the legal status of their product (patented or unpatented) and its source (local innovation, import, or heirloom).

It would be extremely difficult to address our four hypotheses in the context of any other technology. Consider, for example, the lithium battery. How would one measure levels of inventiveness and innovation in the lithium battery industry? One could identify all lithium battery pat-ents, as we do for plants, but one could not easily identify the number of unpatented innovations. Neither could one easily identify which improvements had ever been commercialized as actual batteries and sold on the market. [FN61] One could measure changes in battery patenting activity over time but not answer the core question of whether the patents were ***1062** contributing to a more diverse market for batteries. One could also measure research and development expenditures by lithium battery manufacturers over time, but decisions to expend money on research and development depend on many factors other than the state of patent law. Further, R&D numbers do not tell us what consumers actually see on the market.

The plants studied here are different. First, the “distance” between the invention and the commercialized product is much shorter. The pat-ented apple is precisely what will be commercialized, while an improvement to a battery, for example, may be incorporated into a product that might take several forms. Most importantly for the purposes of market analysis, when the breeder of an apple tree or a new tomato creates a new variety, she gives it a name: Ozark Gold (unpatented apple introduced in 1970), [FN62] Crown Empire (apple patented in 2000), [FN63] or Redfield Beauty (tomato introduced in 1885). [FN64] If a plant is patented, its name appears in the patent application and published patent (though corn and cereal grains are an exception). [FN65] If the patented plant is commercialized, it is typically sold under that name in commercial seed or nurserymen's catalogs, all of which are periodically and comprehensively surveyed by the Seed Savers Exchange, [FN66] in The Garden Seed Inventory, [FN67] or The Fruit, Berry, and Nut Inventory, [FN68] respectively. Equally important, the vastly greater number of unpatented innovations are also named and appear in the same publications. In addition, a compendium of both pat-ented and unpatented fruit and nut trees is kept by The American Pomological Society in The Fruit and Nut Register. [FN69] Finally, due to the work of W.W. Tracy [FN70] we have the names of all varieties of sixty-six different vegetable crops sold in U.S. seed catalogs in 1901 and 1902, and from W.H. Ragan [FN71] we have a comprehensive list of all apples mentioned in written publications during the nineteenth century.

Unlike lithium batteries or other technologies, one can get a complete picture of the fruit and vegetable market by tracking plant variety names in commercial catalogs, in registers, and in the patent office. We began our research in the National Agriculture Library in Beltsville, ***1063** Maryland, which has a collection of over 200,000 commercial seed and nurserymen's catalogs dating back to the late 1700s. [FN72] Our initial goal was to sample all catalogs with names beginning with “S” and chart varietal diversity in apples, peaches, strawberries, and tomatoes at five-year intervals from 1900 to 2010, keeping an eye on significant changes occurring after 1930, 1970, and 1985, when federal intellectual property laws protecting plants were enacted. A yearly inventory of all fruit, berries, nuts, and vegetables was beyond our time and resources, but our statistician assured us that we could interpolate confidently from our sample.

Although it took many hours to enter all varieties of our four target species for the year 1900 and even more for the year 1905, we expected for subsequent years to add many fewer new varieties as we watched the apocalypse of diversity loss in the twentieth century unfold. We moved on to 1910, 1915, 1920, and 1925, still adding hundreds of new varieties every year, and for the first time we began to doubt the conventional wisdom about crop diversity loss. We decided to stop our survey, step back, and take two snapshots of varietal diversity for vegetable crops and apples, one at the beginning and one at the end of the twentieth century. We knew about Tracy's comprehensive inventory of sixty-six vegetable crop varieties sold in all commercially available catalogs in 1901 and 1902, and we also knew that the Seed Saver's Exchange had done exactly the same sort of catalog survey in 1981, 1984, 1987, 1991, 1994, 1998, and 2004. [FN73] In the first part of our study, we compare for the first time the contents of Tracy's historic survey, published in 1903, with the most recent modern survey in 2004.

We focus on forty-two vegetable crops common to both surveys. We could not compare all sixty-six crops surveyed by Tracy, because some were omitted in the 2004 Garden Seed Inventory, like burnet, chervil, chufas, dandelion, fetticus, flag, horseradish, martynia, orach, pie plant, rampion, rhubarb, roquette, scolymus, scorzonera, Spanish salsify, skirret, sorrel, Malabar spinach, and husk tomato. [FN74] Varieties of these plants usually occupied less than a page of Tracy's survey, and their omission does not significantly affect the data and statistics presented here. Other omissions include plants, like potatoes, which were surveyed in 2004, but were not included in Tracy's work. [FN75] Finally, other reductions come from combining “mangel beets” into the “beets” category and combining sweet corn, popcorn, and field corn into a category we call “field corn.” [FN76]

***1064** The forty-two vegetable crop species available for comparison make up the vast bulk of popular species at both the beginning and end of the twentieth century. We perform two primary analyses. First, we track which varieties of plants marketed in 1901 and 1902 were still being sold in 2004. Second, we compare the absolute number of varieties of each crop that were commercially available in 1901 and 1902 with the number available in 2004.

Since vegetable crops are typically reproduced by seeds rather than through asexual propagation, we wanted to study at least one fruit or nut crop in order to study the effect of the PPA. We chose apples for several reasons. First, apples are an iconic American product, and the PPA was pushed for hardest by the apple industry. [FN77] In addition, alarmist tales of the destruction of apple diversity are rampant. [FN78] Most important, W.H. Ragan's Nomenclature of the Apple: A Catalogue of Known Varieties Listed in American Publications from 1804-1904, [FN79] provides a data resource that does not exist for other fruits or nuts. Ragan's book, however, is not as immediately useful as Tracy's survey of vegetables because Ragan does not indicate the state of the market at the turn of the century. [FN80] Rather, Ragan surveys the whole of the nineteenth century, listing over 15,000 varietal names but eventually concluding, due to multiple naming practices, that about 7000 distinct varieties had been present at some point in time in the 1800s. [FN81]

Although Ragan's work is invaluable for tracking heirloom varieties of apples currently available on the market, we returned to our own catalog inventory in order to estimate the number apple varieties that were commercially available at the time of his work. As noted above, we inventoried all 1900 and 1905 catalogs beginning with the letter “S” (hereinafter “S Cats”). Although S Cats are typically only ten percent of the total catalogs for any one year, the sample of S Cats gives a snapshot of one-third to one-half of the total market (as confirmed by statistics from ***1065** years where we have information for all catalogs). [FN82] In each of the fifteen different years for which we have full S Cats data, we always capture between one-third and one-half of the market, so we are confident in the bounds of our estimate of apple diversity at the turn of the century. In 1900, 128 different varieties of apples were offered in S Cats, while 140 were available in 1905. Using the larger figure, we estimate that 280-420 different varieties were available in commercial nursery catalogs in 1905.

As with vegetable crops, we first track which varieties of apples marketed in 1905 were still being sold in 2000 (when the most recent issue of the Fruit, Berry, and Nut Inventory was published). Second, we compare the absolute number of apple varieties commercially available in 1905 with the number available in 2000. We also track which varieties described by Ragan were available in 1905 and 2000 in commercial catalogs and create an inventory, for the first time, of which apple varieties in the USDA apple preservation facility in Geneva, New York, [FN83] are also described by Ragan. Since scions of all apples in Geneva are available to the public for free, any additional varieties there might be considered to be commercially available. [FN84]

In the second part of our study, we measure how many varieties of forty-two vegetable crops available in 2004 or apples available in 2000 are subject to any pending or expired federal intellectual property right: plant patent, plant variety protection certificate, or utility patent. The patent office makes searching for plant patents easy by organizing the patents by category of plant. [FN85] Similarly, the USDA organizes PVPA certificates by type of crop. [FN86] Utility patents are slightly harder to identify, but by searching patent abstracts for both the English and Latin names for each vegetable crop, we are certain that we have identified virtually all relevant utility patents. We were able to tally gross numbers of patents or PVPA certificates issued for each plant, and by consulting the Garden Seed Inventory for 2004 and the Fruit, Berry, and Nut Inventory ***1066** for 2000, we were able to obtain commercialization rates for all plants except corn.

In the third part of our study, we attempt to estimate the source of all vegetable and apple varieties available in 2000, categorizing each variety as patented, unpatented American innovation, unpatented import, or heirloom. [FN87] With the exception of the “patented” category, where we used the information collected from the USDA and the Patent Office, we referred to the varietal descriptions contained in the Garden Seed Inventory for 2004 and the Fruit, Berry, and Nut Inventory for 2000. About sixty percent of the descriptions of apples and about forty-five percent of the descriptions of vegetable varieties were detailed enough to permit categorization. With vegetables, we chose to categorize all nonheirloom varieties with Spanish or Asian names as “imports,” whether the description indicated a foreign source or not. It has been established that immigration by Spanish speaking and Asian people significantly impacted plant diversity in the United States in the twentieth century, [FN88] and it seemed likely to us that most new varieties with Spanish or Asian names were likely imported. We explain later why we nonetheless believe we have significantly undercounted imported varieties.

C. Varietal v. Genetic Diversity

We must emphasize that throughout this Article we measure diversity in terms of varietal names. We have been careful to check all available sources to discover multiple names and to prevent double counting. In fact, we are quite certain that multiple naming is less of a problem now than at the turn of the twentieth century. [FN89] Nonetheless, an ideal comparison would occur at the level of DNA, as opposed to varietal names. Take eggplants, for example. We find ninety-seven different varieties for sale in Tracy's 1903 inventory and 102 different varieties in 2004. The fact that the numbers have remained constant does not mean that at the genetic level we have the same amount of diversity. The ninety-seven older varieties might be genetically more diverse and different from each other than the 102 newer varieties, or the opposite could be true. Importation accounts for a large percentage of diversity gains in ***1067** the twentieth century, so new DNA may have been injected into the U.S. genetic pool. We recognize for the purposes of this Article that varietal name diversity is a proxy for genetic diversity. We know of no studies analyzing DNA from random samples of old and new varieties of any of the crops we study, but researchers have expressed concerns about genetic diversity in corn, wheat, and oats. [FN90]

While recognizing the shortcomings of varietal diversity as a proxy for genetic diversity, we also note that the academic research we criticize and prominent popular articles in National Geographic, [FN91] The New York Times, [FN92] and The New Yorker, [FN93] all rely on the RAFI data that measured only varietal diversity.

Finally, we also note that we measure diversity in terms of the availability of seeds or plants to commercial and non-commercial growers, not by tracking what is on grocery store shelves or by the amount of planted acreage. The primary argument for maintaining crop diversity is based on the need to maintain a safety net of genetic diversity--to have a broad supply of genes available to breeders who can create more productive, weather-hardy, insect-resistant, fungus-resistant, and better-tasting crops. [FN94] A variety does not have to be available in a grocery store or ***1068** planted in a significant amount of acreage in order to be available as a resource for breeders to solve the problems caused by insects, disease, and weather. Since the primary argument in favor of maintaining diversity does not require availability in grocery stores or planting in massive acreages, we are satisfied that our survey of commercial seed catalogs provides an adequate measure.

II. Myths About Vegetable Crop and Apple Diversity

The conventional wisdom states that the twentieth century was a disaster for vegetable crop and apple diversity. [FN95] Typical is a recent National Geographic article that decries the “erosion in the genetic diversity of the foods we eat,” [FN96] claiming that “[f]ood varieties extinction is happening all over the world--and it's happening fast.” [FN97] The article seeks to alarm its audience with a specific example: “Of the 7,000 apple varieties that were grown in the 1800s, fewer than a hundred remain.” [FN98] This view is so strongly accepted that the author of the article does not provide a source for his statistic. If he had bothered to check, he would have found that we have counted over 540 apple varieties from the 1800s that are commercially available today. [FN99] Since that number represents more apple varieties than were commercially available in 1900, it is difficult to see how the twentieth century was a disastrous time for apple diversity.

Before we consider federal intellectual property law and its relevance or irrelevance to plant diversity, we will address the myths propagated about plant diversity in the twentieth century. By taking a snapshot of plant diversity at the beginning and end of the century, we put to rest persistent myths and set the table for the analysis of patent law and its effects.

A. The View from 1903: Vegetable Crops

As shown in Table 1 below, of the 7218 varieties of forty-two vegetable crops listed in Tracy's 1903 USDA inventory, only 420 are still available in commercial seed catalogs, a six percent survival rate. In other words, ninety-four percent of the old varieties are no longer available ***1069** from the most common commercial sources. This part of the conventional wisdom is true-- only a few turn-of-the-century varieties are still around today. We provide a complete list of surviving varieties online. [FN100]

Table 1

Vegetable Crop	Total Varieties Available in 1903 Seed Catalogs	1903 Varieties Available in 2004 Seed Catalogs	1903 Varieties Available in 1983 Nat. Seed Storage Lab
Artichoke	34	2	2
Asparagus	46	3	1
Lima Bean	96	10	8
Garden Bean	185	34	32
Beets	466	13	20
Broccoli	34	1	0
Brussels Sprouts	35	2	4
Cabbage	544	21	28
Carrot	287	14	21
Cauliflower	158	3	9
Celeriac	25	2	3
Celery	164	8	3
Collards	28	3	5
Field Corn	789	19	52
Cress	39	8	2

Cucumber	285	15	16
Eggplant	97	4	9
Endive	64	3	4
Garlic	3	0	0
Kale	124	9	9
Kohlrabi	55	3	3
Leek	39	5	5
Lettuce	107	25	36
Muskmelon	338	16	27
Mustard	44	4	5
Okra	38	3	4
Onion	357	21	21
Parsley	82	9	12
Parsnip	75	2	5
Pea	408	19	25
Peanut	31	4	2
Peppers	126	14	13
Radish	463	19	27
Rutabaga	168	5	5
Salsify	29	2	2
Spinach	109	4	7

Squash	341	21	40
Sunflower	14	1	1
Swiss Chard	23	1	1
Tomato	408	45	79
Turnip	237	12	24
Watermelon	223	11	20
Total	7218	420	592

1070** We note that the six percent survival figure is probably a significant underestimate. Tracy, the author of the 1903 USDA inventory, understood that many varieties at the turn of the century had multiple names, lamenting that "[v]ariety names of vegetables in this country are being greatly multiplied every year by the renaming of old varieties." [FN101] In fact, the primary purpose of his study was to help reform varietal nomenclature, rather than to document diversity. [FN102] When he conducted follow-up studies on beans and lettuce, he found that the numbers in his 1903 study could not be trusted as measuring the number of distinct varieties. Of the 578 varieties of garden beans listed in the 1903 inventory, he concluded that only 185 (thirty-two percent) represented distinct varieties. [FN103] Of the 497 varieties of lettuce listed in 1903, he concluded only 107 (twenty-two percent) represented distinct varieties. [FN104] We use his corrected lower figures for beans and lettuce in Table 1. If the bean and lettuce1071** overstatements are representative of all vegetable types in the 1903 study, then the 7218 figure for 1903 varieties is probably greatly exaggerated. And given that multiple naming is less of a problem now than it was at the turn of the last century, [FN105] the six percent survival figure should probably be significantly higher.

B. The View from 1900: Apples

The survival story of apples is completely different, although the conventional wisdom would say otherwise. [FN106] Seventy-five percent of the apples we identified in 1900 and 1905 nurserymen's catalogs were available in the same kind of catalogs inventoried in the Fruit, Berry, and Nut Inventory for 2000. The news is even better regarding apples from the 1800s identified by W.H. Ragan in Nomenclature of the Apple. Of the apple varieties offered by commercial nursery catalogs in 2000, 435 were listed by Ragan. [FN107] In addition, the Fruit, Berry, and Nut Inventory for 2000 also describes as "old-timer" or "heirloom" 44 additional varieties not listed by Ragan. [FN108] An additional 102 different Ragan varieties are available in the USDA orchard facility in Geneva, New York, where the public can obtain grafting scions for free. [FN109] Since our upper estimate of the total number of commercially available varieties in 1905 is only 420, it seems quite clear that more historic varieties (approximately 581) are commercially available now than a hundred years ago. These facts contradict the hysterical claim made this year by National Geographic that less than one hundred varieties from the 1800s survive today.

Our data indicate that apple varieties are substantially more durable than vegetables. Such durability may be due to the long life of apple trees [FN110] and to the work of apple collectors and enthusiasts who actively search for, relocate, and propagate old varieties listed in early twentieth century publications. [FN111] For example, ethnographic research in the southeastern United States has shown that private collectors have played ***1072** a major role in relocating, propagating, distributing, and commercializing many Ragan varieties thought to be extinct as recently as 1980. [FN112] Such collectors have also played a role in the location, propagation, distribution, and commercialization of old varieties that were not listed in nineteenth or early twentieth century nursery catalogs or USDA publications.

Although not relevant in counting commercial availability, private collectors have also maintained many other ancient varieties not listed in the Fruit, Berry, and Nut Inventory or maintained by the USDA in Geneva, New York. A check of just two sources, the list of apples maintained by Horne Creek Farms [FN113] and a list of apples identified by Tom Brown, a southern apple hunter, [FN114] revealed an additional 143 Ragan apples not counted above and many other old-time apples that even Ragan did not know about.

Interestingly, Ragan, after accounting for multinaming, listed approximately 7000 different varieties grown from 1804 to 1904. [FN115] The vast majority of these varieties had already disappeared from nursery catalogs by 1905. [FN116] If there were ever a diversity cataclysm for apples, it must have occurred in the nineteenth century, not the twentieth. [FN117] More likely, as our data suggest, apple varieties came and went over time and there was never a single moment when anything close to 7000 varieties were commercially available. [FN118] Several hundred of Ragan's listed apples were probably available in any given year, with the content of the list changing regularly over the course of the nineteenth century.

C. The View from 2004: Vegetables

Although many vegetable crop varieties listed in W.W. Tracy's 1903 USDA inventory are no longer commercially available, the absolute number of varieties available in 2004 is approximately the same as a hundred years earlier. As shown in Table 2 below, the 1903 inventory counts 7218 varieties of the forty-two vegetable crops we study, including ***1073** corn. Our parallel count of commercially available varieties in 2004 finds 6916. If we exclude corn, then more varieties of the forty-one other crops are available in 2004 (6739) as compared to 1903 (6429). And there are good reasons to exclude corn from the 1903 to 2004 comparison. Our source for 2004 varieties, The Garden Seed Inventory, does not count varieties of hybrid corn [FN119] offered for sale. Since hybridization was a huge source of innovation for new corn varieties in the twentieth century, [FN120] The Garden Seed Inventory vastly undercounts the number of commercially available varieties of corn by ignoring the most commonly planted varieties offered by large seed corn companies like Monsanto and Pioneer. [FN121] Given the number of seeds being offered for sale, growers appear to have had more choices to make in 2004 than growers in 1903.

Table 2

Vegetable Crop	Total 1903 Var.	Total 2004 Var.	1903 Var. Avail. In 2004
Artichoke	34	13	2
Asparagus	46	13	3

Lima Bean	96	69	10
Garden/Field Bean	185	771	34
Beets	466	92	13
Broccoli	34	32	1
Brussels Sprouts	35	14	2
Cabbage	544	81	21
Carrot	287	127	14
Cauliflower	158	55	3
Celeriac	25	14	2
Celery	164	66	8
Collards	28	14	3
Field Corn	789	242	15
Cress	39	29	8
Cucumber	285	133	15
Eggplant	97	102	4
Endive	64	48	3
Garlic	3	274	0
Kale	124	52	9
Kohlrabi	55	15	3
Leek	39	66	5
Lettuce	107	520	25

Muskmelon	338	200	16
Mustard Greens	44	42	5
Okra	38	51	3
Onion	357	222	21
Parsley	82	52	9
Parsnip	75	21	2
Sweet/Field Pea	408	249	19
Peanut	31	21	4
Peppers	126	647	14
Radish	463	138	19
Rutabaga	168	29	5
Salsify	29	3	2
Spinach	109	31	4
Squash	341	456	21
Sunflower	14	110	1
Swiss Chard	23	66	1
Tomato	408	1536	45
Turnip	237	38	12
Watermelon	223	162	11
Total	7218	6916	417

Total w/o Corn	6429	6739	402

***1074** As one can see from the Table, varietal representation is not even over all forty-two vegetables. There are clear diversity winners and losers. Growers of garden beans, garlic, lettuce, peppers, squash, and tomatoes have many more choices in 2004 than they did in 1903. For beans, the number of varieties increased from 185 [FN122] to 771, for garlic from 3 to 274, for lettuce from 107 [FN123] to 520, for peppers from 126 to 674, and for tomatoes from 408 to 1518. On the other hand, growers of beets (only 92 varieties compared to 466), cabbage (81 compared to 544), radishes (138 compared to 463), rutabaga (29 compared to 168), and turnips (38 compared to 237) have vastly fewer choices.

***1075** D. The View from 2000: Apples

As noted above, our high estimate of the number of different apple varieties available in commercial nurserymen's catalogs in 1900 and 1905 was 420. The Fruit, Berry, and Nut Inventory for 2000 lists 1469 different varieties of apples, a massive gain in terms of what growers can easily find for sale. The Plant Genetic Resources Unit of the USDA [FN124] in Geneva, New York, maintains orchards containing an additional 980 apple varieties that are not currently being offered in commercial catalogs. Scions from these trees are typically available to anyone who wishes to propagate the variety. [FN125] The USDA numbers bring the total varieties of apples available to 2450.

The above finding is radically at odds with the conventional wisdom. According to a recent article in The New York Times, “the number of different apples has greatly diminished.” [FN126] If one believes, as The New York Times author apparently does, that 6500 different varieties were available in 1905, [FN127] then the statement would be true. As our catalog survey in the National Agricultural Library collection demonstrates, however, a high estimate for availability in 1905 would be only around 420. Given that, as we note above, more old-time varieties are available today than in 1905, we have certainly seen a significant increase in apple diversity, even on the genetic level. In Part III, we will provide an analysis of the sources of all apple varieties in 2000 by estimating the percent of patented, unpatented, imported, and heirloom varieties for sale at that time.

III. Patents and Crop Diversity

The twentieth century saw massive innovation occurring in the breeding of vegetable crops and apples. Thousands of new varieties were introduced. This varietal explosion is consistent with the story that economists typically tell about intellectual property protection, which was first extended to asexually reproducing plants like apple trees in 1930, to seeds in 1970, and to genetic traits of plants in 1985. In this Part, we examine the role that patents played in the innovation and diversity story, looking first at vegetable crops and then at apples. We look at the raw number of patents and PVPA certificates issued and also rates of commercialization for the underlying inventions.

***1076** A. Patenting Activity in Vegetable Crops

Table 3 below shows the number and types of patents or PVPA certificates that had been issued for each of forty-two different vegetable crops through 2010, with the last two columns on the right indicating how many protected varieties were commercially available in 2004. Two cells are left blank. We found it impossible to discover which protected varieties of corn were commercialized because corn breeders do not name new plants in a way that allows them to be tracked from patent office information onto the market. We will omit corn from our statistics unless otherwise indicated and delay our discussion of that cereal grain for a moment.

Table 3

Vegetable Crop	Total 1903 Var.	Total 2004 Var.	Plant Patents	Utility Patents	PVPA Cert.	Total Fed IP Rights	Commercialized Pats Pend.	Commercialized Exp'd Pats
Artichoke	34	13	16	1	3	20	2	0
Asparagus	46	13	28	0	0	28	0	0
Lima Bean	96	69	0	0	10	10	0	0
Garden/ Field Bean	185	771	0	14	427	441	58	20
Beets	466	92	0	7	0	7	0	0
Broccoli	34	32	0	14	7	21	0	0
Brussels Sprouts	35	14	0	2	0	2	0	0
Cabbage	544	81	0	2	0	2	0	2
Carrot	287	127	0	0	4	4	0	0
Cauliflower	158	55	0	2	17	19	2	1
Celeriac	25	14	0	0	0	0	0	0
Celery	164	66	0	11	20	31	3	1
Collards	28	14	0	0	0	0	0	0

Field Corn	789	242	0	675	889	1564		
Cress	39	29	0	0	0	0	0	0
Cucumber	285	133	0	1	1	2	2	0
Eggplant	97	102	0	0	3	3	1	0
Endive	64	48	0	0	1	1	0	0
Garlic	3	274	3	1	0	4	0	0
Kale	124	52	0	1	0	1	0	0
Kohlrabi	55	15	0	1	0	1	0	0
Leek	39	66	0	0	0	0	0	0
Lettuce	107	520	0	52	311	363	54	6
Muskmelon	338	200	0	4	23	27	0	2
Mustard Greens	44	42	0	6	2	8	0	0
Okra	38	51	0	0	1	1	0	0
Onion	357	222	0	1	59	60	2	5
Parsley	82	52	0	0	1	1	0	1
Parsnip	75	21	0	0	1	1	1	0
Sweet/Field Pea	408	249	0	2	306	308	21	15

Peanut	31	21	0	3	67	70	3	1
Peppers	126	647	6	3	31	40	8	1
Radish	463	138	0	1	6	7	1	4
Rutabag a	168	29	0	0	0	0	0	0
Salsify	29	3	0	0	0	0	0	0
Spinach	109	31	0	0	1	1	0	0
Squash	341	456	0	5	11	16	11	6
Sunflow er	14	110	0	18	35	53	2	3
Swiss Chard	23	66	0	0	1	1	1	0
Tomato	408	1536	4	23	57	84	2	3
Turnip	237	38	0	1	0	1	0	0
Waterm elon	223	162	0	3	33	36	17	3
Total	7218	6916	57	854	2328	3239		
Total w/o Corn	6429	6739	57	179	1439	1675	191	74

***1077** Of the 6739 varieties of forty-two vegetable crops available in commercial catalogs in 2004, only 191 were subject to unexpired issued pat-ents, while another seventy-four had been subject to expired patents. [FN128] Therefore, only 3.8% of varieties available in 2004 had ever been subject to private intellectual property rights. The vast majority of extant diversity in the U.S. vegetable market is due to local innovation or importation. [FN129] Patents seem to play no significant role.

Patent rights seem to play a marginally more important role in some vegetable types than others. For example, of 771 types of garden and field beans available in 2004, seventy-eight of them were subject to pending or expired patents, a rate of slightly over ten percent. [FN130] Similar rates are shown for lettuce and watermelon: 520 available varieties of lettuce were subject to fifty-four expired or pending patents, with 162 varieties ***1078** of watermelon subject to twenty expired or pending patents. [FN131] Peas also approached a ten percent rate (21 of 249 or 8.4%). [FN132] On the other hand, several popular vegetable types have no commercially available varieties subject to pending or expired patents, including asparagus, broccoli, carrots, garlic, and spinach. [FN133] Perhaps the most telling is tomatoes, where 1536 varieties in 2004 were subject to only two pending and three expired patents. [FN134]

In the history of intellectual property rights in plants, some vegetables have been subject to more patenting activity than others. Patents or PVP certificates have issued on 441 varieties of garden and field beans, 365 varieties of lettuce, 308 varieties of peas, and 84 varieties of tomatoes. [FN135] Fewer than five patents, however, have ever issued on new varieties of Brussels sprouts (2), cabbage (2), carrots (4), eggplant (3), garlic (4), spinach (1), and turnips (1). [FN136] Omitting corn, 1675 patents have been issued as of October 2009. [FN137] As noted above, 265 of these patents represent varieties among the 6739 different ones available in 2004. With the exception, perhaps, of corn, the link between federal intellectual property protection and innovation seems to be extremely weak.

B. Commercialization Rates in Vegetable Crops

Omitting corn, sixteen percent (265 of 1675) of all vegetable varieties that have ever been patented were commercially available in 2004. [FN138] This is an intriguing number. Those conversant with the economic literature on patenting are familiar with the assertion that only a small percentage of patents are ever commercialized, perhaps as low as two to five percent. [FN139] Others, as cited by Sichelman, suggest rates as high as fifty percent. [FN140] The low estimate is admittedly a guess based on licensing and litigation rates, while the higher estimates are based on interviews and ***1079** surveys of inventors and firms, and not analyses of entire consumer markets. [FN141] To our knowledge, we provide the most accurate information on commercialization rates in a complete product market. Our data add significantly to the understanding of the relationship between patenting and commercialization activity.

Commercialization rates for particular patented vegetable varieties do not vary dramatically. Exceptions include watermelons, where fifty-five percent that have ever been patented (20 of 36) were still commercially available in 2004. [FN142] Also on the high side are peppers, at twenty-two percent. [FN143] The vegetables that attract the most patenting activity (beans, lettuce, and peas) all hover around the norm. [FN144] On the low side, only about five percent of protected peanut and three percent of protected tomato inventions remained commercially available in 2004. [FN145]

Although data on obsolescence cycles cannot be pinpointed for the varieties studied, the data show that seventy-four of the commercialized varieties in 2004 were subject to expired patents. This means about 4.5% (74 of 1675) of all vegetable patents ever issued subsist in commercialized inventions that are at least twenty years old. If assumptions are correct that less than five percent of patents are ever commercialized, it is remarkable to see almost five percent of plant patents still commercialized after twenty years. Perhaps innovations in vegetable markets have a longer shelf life than non-plant innovations.

C. Patenting Activity in Apples

Patents also seem to play a minor role in explaining the growing number of commercially available apples during the twentieth century. As of 2009, 372 apple varieties have been subject to patents. [FN146] As of 2000, 298 apple patents had issued, with 142 of those varieties available in nursery catalogs in 2000. [FN147] This is slightly less than ten percent of the 1469 total number of apples available in the same set of catalogs. Including the hundreds of other different, nonpatented USDA apples available in Geneva, New York, in the 2000 count would lower this percentage significantly. Our complete list of all patented apples, along with their common varietal names and an indication of availability as of 2000, is available online. [FN148]

***1080** D. Commercialization Rates of Patented Apples

Despite the relatively low percentage of commercialized patented apples (142 or ten percent) available in 2000, the fruit shows some unexpected characteristics. From the 1930 advent of the PPA [FN149] to the year 2000, 298 apple trees had been patented. This means that in 2000, at least forty-eight percent (142 of 298) of all patented apples were commercialized, with the absolute historical number undoubtedly being higher due to apple varieties that may have been commercialized earlier but discontinued by 2000. This is a vastly higher figure than the two to five percent commercialization rate sometimes asserted for patented inventions as a whole, and closer to the fifty percent figure cited by Sichelman. [FN150]

As shown in Figure 1, a high commercialization rate holds for even the oldest patented apples, an even more striking result. For apples patented in the 1930s, thirty-six percent (4 of 11) are still commercially available. For apples patented in the 1940s the figure is thirty-five percent (6 of 17). For the rest of the century: 1950s = thirty-two percent (6 of 19); 1960s = thirty-one percent (10 of 32); 1970s = forty-one percent (21 of 51); 1980s = fifty-seven percent (34 of 60); 1990s = forty-nine percent (46 of 93). Part of this may be explained by the long life of apple trees, which can continue producing for over one hundred years.

***1081** Figure 1

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IV. Sources of Plant Innovation

Both the Garden Seed Inventory and the Fruit, Berry, and Nut Inventory provide detailed information on each variety listed in commercial seed and nurseryman's catalogs. Usually, the source of the variety is provided as a local (U.S.) innovation, an import, or an heirloom/old-time variety. [FN151] By combining the information in these two sources with our comprehensive list of patented varieties, we are able to estimate with some precision the sources of diversity and innovation in vegetable crop and apple markets. Having eliminated patents as a major source of innovation, it is critical to determine the sources of massive diversity that we observe. We look at vegetables in Section A and apples in Section B, and we try to estimate varietal turnover in Section C in order to determine how many varieties came and went between 1905 and 2005, a period not captured by our two-point snapshot.

To our knowledge, no other large innovation and product market has ever been analyzed so completely. A large body of literature documents on a convincing but mostly anecdotal basis the importance of user innovation and nonpatented contributions to various arts, [FN152] but we can ***1082** track with some precision the sources of innovation in plant technology, including new imports.

A. Sources of Vegetable Diversity

In our own analysis of patent data, we found 265 patented vegetables among the 6739 varieties currently on the market (excluding hybrid corn). Varietal summaries in the Garden Seed Inventory expressly describe 745 other varieties as local nonpatented innovation, [FN153] 272 as foreign imports, [FN154] and 950 as heirlooms or old-timers. [FN155] Given that ethnobotanical studies describe immigrants introducing thousands of agricultural plants into the United States from Asia and Latin America during the twentieth century, [FN156] we suspected that the 272 figure for foreign imports constituted a serious undercount. We examined the data more closely and found that many new varieties had foreign language names, although their geographic origin was not indicated in the varietal description. We decided to categorize varieties with entirely foreign names as imports; even so, we believe that we have significantly undercounted the number of imports for the following three reasons. First, we did not count German names as foreign because much of the introduction of new plants by German immigrants occurred in the nineteenth century, and we were concerned with measuring innovation in the twentieth century. Second, when an English word modified a foreign varietal name, we did not count the variety as an import. For example, for peppers, we counted Aji Benito and Aji Dulce as imports, but we did not ***1083** count Aji Omnicolor and Aji Yellow, even though we suspect they might be, in fact, English names for imported varieties. Nor did we count Aji Andean or Aji Colorado because we were not sure that the modifiers were necessarily Spanish names as opposed to their English equivalents.

Third, when an English varietal name seemed to indicate importation we did not count the variety as an import. For example, bean varieties called Manitoba, Mexican Pinto, and Sonoran Pinto were not counted as imports, nor were celery named Chinese Golden and Chinese Giant. We may have missed hundreds of imports due to our conservative choices as to what constituted a foreign language designation. Of course, we undoubtedly misdesignated some U.S. varieties as foreign imports. Some U.S. innovators undoubtedly gave their varieties foreign names, and some Americans with Spanish or Asian family names likely named varieties after themselves. Ultimately, however, we think our bias is systematically on the side of undercounting importation. Under our rules, we concluded an additional 893 varieties were twentieth century imports, bringing the total imports to 1165.

Overall, we were not able to assign a certain source designation to 3842 varieties or about fifty-five percent of the varieties of our vegetable crops. In order to provide an estimate for the entire market, we assume that the unknown varieties are distributed among our three exclusive [FN157] categories (American innovation, import/foreign name, or heirloom variety) in the same proportion as the known varieties (74 to 1165 to 950). Figure 2 below captures the relative percentages of the commercial market for vegetables as of 2004.

***1084** Figure 2

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We also performed individual analyses on the five species of crops that experienced the biggest diversity gains in the twentieth century: beans, garlic, lettuce, peppers, and tomatoes. Figure 3 shows some significant differences among the five.

Figure 3A

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***1085** Figure 3B

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Figure 3C

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***1086** Figure 3D

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Figure 3E

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Imports appear to be the most important source of new varieties, ranging from thirty percent with tomatoes to sixty-four percent for garlic. Heirloom sources are most important with tomatoes (thirty-six percent) and beans (thirty-four percent), but less important with garlic (fourteen percent) and peppers (seventeen percent). The importance of patents as a source varies from 0.7% with tomatoes to thirteen percent with lettuce. Finally, rates of nonpatented local innovation are fairly steady, ranging ***1087** from sixteen to twenty-four percent, except for tomatoes (thirty-three percent).

The high level of importation is notable for two reasons. First, imports provide significant new genetic material into the U.S. market. The number of new varieties we document are unlikely to be the result of "cosmetic breeding" intended to create a trivial new variation that is scarcely distinguishable on a genetic level from an existing variety. A high level of imported varieties indicates that significantly different genetic material is constantly being introduced into the U.S. market. Indeed, the goal of diversification may be best met by the introduction of foreign germplasm. Second, importation is a long-term historical trend in U.S. agriculture. As Kloppenberg notes, "[o]f crops of economic importance, only sunflower, blueberry, cranberry, and Jerusalem artichoke originated in North America." [FN158] He explains that importation "has been an absolute imperative, a biological sine qua non upon which rests the whole complex edifice of American industrial society." [FN159] Our data confirms the importance of imports through the twentieth century.

B. Sources of Apple Diversity

The 2001 Fruit, Berry, and Nut Inventory contains detailed descriptions of about sixty percent of the 1476 total varieties of apples listed. [FN160] In addition to 142 patented varieties and 435 historic apples from the 1800s described by Ragan, 82 varieties are described as imports, 177 are described as unpatented twentieth century U.S. innovations, and 44 are described as old-timers or heirlooms that are not found in Ragan's study. [FN161] Having cross-checked the entire inventory against our databases of all patented and Ragan apples, we can be quite sure that none of the undescribed 596 varieties fall in either of those two categories. The undescribed varieties should be imports or local unpatented twentieth century innovations, but a few could be nineteenth century apples missed by Ragan in his 1903 survey. As mentioned above, the 2000 inventory does reveal forty-four varieties listed as "old-timers" or "heirlooms" which we cannot match up with any variety listed by Ragan. So, using a ratio of forty-four (non-Ragan old-timers) to eighty-two (imports) to 177 (nonpatented local innovations), and assuming the 596 undescribed varieties contain a similar ratio, Figure 4 sets forth the following estimate of the ***1088** complete market of apple varieties available in commercial nursery catalogs in the year 2000:

Figure 4

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Over one-third of present commercial diversity is due to preservation of historic varieties, while only slightly less is due to local innovation. The remaining third of the diversity equation is occupied by imports and patented innovations, with patented varieties constituting slightly less than ten percent of the whole. Unlike with vegetables, foreign importation appears to be significantly less important.

C. Estimating Varietal Turnover in the Twentieth Century: The Heraclitean Stream

The Greek philosopher Heraclitus once said that one cannot step in the same stream twice, and the term "Heraclitean stream" now refers to the notion of constant change in the contents of a thing over time. [FN162] We believe the Heraclitean stream to be the perfect metaphor for crop diversity in the twentieth century. Thousands of varieties are commercially available at any particular point in time, but the varieties themselves are constantly changing, subject to wave after wave of substitution, reintroduction, and evolution. So far, we have concentrated on two snapshots taken at the beginning and end of the twentieth century. Approximately 7000 varieties of vegetables were available in 1903 and approximately the same number were available in 2004, but we find only about a six percent ***1089** overlap in varieties. We therefore suspect that many thousands more varieties came and went during the twentieth century that were not captured in either snapshot. So far, we have only stuck our foot into the stream twice: 1903 and 2004. In order to estimate how fast the varietal stream is flowing, we add another year (1981) [FN163] to our analysis to measure varietal evolution, substitution, and change over time. In Table 4, we set forth the number of varieties of our forty-two vegetable crops that were available in 1981, the number available in 2004, and the number of 1981 varieties available in 2004 in order to get a sense of how quickly varietal replacement happens in the Heraclitean stream.

Table 4

Vegetable Crop	1981 Varieties	2004 Varieties	1981 Varieties Available in 2004
Artichoke	8	13	5
Asparagus	22	13	9
Lima Bean	49	69	31
Garden/Field Bean	469	771	216
Beets	117	92	52
Broccoli	50	32	15
Brussels Sprouts	28	14	9
Cabbage	199	81	56
Carrot	168	127	65

Cauliflower	152	55	30
Celeriac	21	14	5
Celery	74	66	28
Collards	12	14	8
Field Corn	184	242	74
Cress	18	29	11
Cucumber	152	133	66
Eggplant	65	102	22
Endive	48	48	15
Garlic	18	274	12
Kale	53	52	24
Kohlrabi	15	15	4
Leek	70	66	22
Lettuce	277	520	118
Muskmelon	149	200	72
Mustard Greens	26	42	16
Okra	23	51	16
Onion	262	222	104
Parsley	42	52	24
Parsnip	23	21	13
Sweet/Field Pea	480	249	90

Peanut	19	21	9
Peppers	290	647	151
Radish	183	138	79
Rutabaga	27	29	14
Salsify	11	3	3
Spinach	56	31	15
Squash	251	456	149
Sunflower	21	110	16
Swiss Chard	35	66	20
Tomato	574	1536	255
Turnip	64	38	23
Watermelon	130	162	75
TOTAL	4935	6916	2041

***1090** The results of the comparison are stunning. Seventy percent of the varieties commercially available in 2004 were not available in 1981. In just a twenty-three year period, more than half of the varietal stream had changed its contents. Of course, some of the varieties "new" to 2004 were undoubtedly heirlooms making their first appearance in years, or perhaps later innovations that lost popularity in the 1970s and 1980s but regained a following in the new millennium. It is impossible to estimate with accuracy the number of true innovations that came and went during the century, but adding 1981 into our analysis gives the overwhelming sense that looking at only 1903 and 2004 radically undercounts the rate of innovation in the twentieth century.

The importance of this finding for the economic analysis of federal intellectual property law for plants is difficult to underestimate. We have analyzed a seventeen billion-dollar market [FN164] (even omitting nonhybrid corn) where federal legal protection seems to be irrelevant, yet where innovation is vigorous and constant.

***1091** V. Corn Patents and Rent Seeking

Finally, we must address the 800-pound green and yellow gorilla in the room: corn. Unlike forty-one of the vegetable crops studied (and apples), patents seem to play a much more prevalent role with corn. Corn appears to be sui generis among the varieties inventoried in 1903, al-though a cursory look at patenting data suggests that cotton, outside the present study because 1903 data are not available, may be similar. [FN165] First of all, there are almost as many patents and PVPA certificates (1564) for corn as there are patents and PVPA certificates for all other vegetables studied (1675). [FN166] The proportion is even more striking in the field of utility patents, where seventy-nine percent (675 of 854) of the patents studied were issued for new varieties of corn. [FN167]

We have already concluded that patents are an unimportant source of innovation for the rest of the crops that we study. Do our corn data demonstrate that patents are driving innovation in the corn industry? First, because of the failure of inventors to name new corn varieties in patent applications and then sell the patented variety under the same name, it is impossible to tell how many of the varieties listed in the 1564 patents and PVPA certificates have ever been commercialized. We assume, however, that some of the protected varieties have been commercialized, and therefore represent true innovations. Before 1970, when the PVPA system was put in place, corn breeders were actively creating new corn hybrids and selling them on the market. [FN168] Although they were excluded from protection in the original 1970 version of the PVPA, hybrids were included by amendment in 1994. [FN169] The amendment made new hybrids subject to PVPA certification at a low cost, allowing for some protection against copying. There is no reason to think that the newfound ability to acquire federal protection would have resulted in less commercialization than occurred before.

We cannot, however, pinpoint the commercialization rate. A significantly higher commercialization rate compared to other vegetables would indicate that something different is going on with corn. Even if the commercialization rate for federally protected corn were the same or ***1092** even lower than other crops, however, we must acknowledge that some patented varieties of corn have been wildly successful on the market. In Illinois in 2010, for example, ninety percent of farmers grew patented transgenic Bt corn, with ninety-four percent planning on doing so in 2011. [FN170] And in 2006, over forty percent of corn planted in the United States was Monsanto's patented “Roundup Ready” variety. [FN171] Although the patent on some Bt corn is in doubt due to allegedly inequitable conduct in the patent office, [FN172] it is impossible to argue that patented versions of new bio-tech corn have not been highly prevalent in the present market. The soybean and cotton markets are also dominated by patented or formerly patented varieties. [FN173] This was not the case with the other crops we studied. We found no protected variety of any of our forty-one other crops dominating the marketplace in such a fashion. For example, none of the top ten selling apples on grocery store shelves are patented. [FN174]

Corn seems to be different. Safely assuming substantial commercialization of patented varieties in the case of corn, two important questions remain to be asked about the relevance of federal protection: (1) has intellectual property protection been necessary to assure that new varieties of corn are created, and (2) do the new patented varieties of corn increase net social welfare? Put more bluntly, are patented varieties better than competing nonprotected varieties, or are we just observing rent seeking? Below, these important questions are addressed in order.

***1093** A. Has Intellectual Property Protection Been Necessary to Assure that New Varieties of Corn Are Created?

Our data on vegetable crops generally makes us suspicious of claims that intellectual property protection is key to corn innovations. [FN175] Our most significant contribution to the analysis of intellectual property law is the clear demonstration that massive amounts of innovation occur without the stimulus of patent or PVP law. Of the almost 7000 varieties of vegetable crops commercially available in 2004, only four percent had ever been protected by IP, and only six percent were available in 1903. [FN176] That means that at least 6000 varieties available in 2004 were new to the U.S. market in the twentieth century. And, as we have demonstrated immediately above, we can estimate that untold thousands more appeared and disappeared over the course of the century. It is clear that one need not establish intellectual property rights in order to observe massive innovation.

Nonetheless, the World Intellectual Property Organization of the United Nations (WIPO) [FN177] has recently come to the opposite conclusion about the importance of plant protection. It administers an important international treaty, The International Union for the Protection of New Varieties of Plants (UPOV). [FN178] UPOV (known by its French acronym) is the most popular treaty for the protection of new varieties of plants and looks much like the U.S. system under the PVPA, with some minor exceptions. In 2005, WIPO issued the UPOV Report on the Impact of Plant Variety Protection which concludes that intellectual property protection for seeds has been a tremendous success. [FN179] The problem with this report is that it conflates effects on the behavior of firms with effects on innovation.

***1094** The UPOV report shows that when countries establish a system for protecting seeds, firms will use it: new seeds will be registered and protection will be sought. [FN180] The report cannot establish an increase in the rate of innovation, however, without comparing the market before and after the change in the law, which it does not do. It assumes that the creation of all registered seeds was stimulated by the adoption of UPOV simply because the seeds were registered. [FN181] This is a common assumption that also plagues agricultural economics papers. [FN182] At a minimum, this Article demonstrates the folly of such an assumption. We know massive innovation will occur whether or not seeds are registrable in a patent, or patent-like, system. Applying for legal protection may simply be pure rent seeking, a standard business practice, or the result of risk aversion (defense patenting). Given our data, mere use of the registration system cannot be convincing evidence that a change in the law has caused more innovation.

Of greater relevance in the UPOV report is the finding that in some jurisdictions the number of plant breeders increased after the adoption of UPOV. On the surface, this finding may suggest an increase in research and development expenditures, which economists normally assume is related, to some degree, with actual innovation. [FN183] The increase in breeders, however, may be nothing more than evidence of rent seeking--the desire to capture all or some of the value of a new property right. Consider a town without a Mexican restaurant. Investor A has decided to open a Mexican restaurant, expecting to make the sort of profit normally associated with serving good food, plus some bonus for novelty until another Mexican restaurant opens up. This existing incentive is enough to assure that the restaurant will open (as we all know from personal experience!). Now, consider the same town after it passes an ordinance granting a monopoly right to serve Mexican food to the first person to open a Mexican restaurant. This new property right is valuable and should stimulate the creation of several firms racing to open the first restaurant ***1095** and capture the valuable monopoly rent. When Investor B, however, wins the race and the right to exclude the other firms from selling Mexican food, should we conclude that the town stimulated the creation of a new restaurant through its legislation?

The town has surely encouraged the spending of research and development dollars and has increased the number of firms working toward opening a restaurant. Perhaps marginally, the race hastened an actual restaurant's opening date, but the law has not caused the restaurant to be created. As long as sufficient non-monopoly-profit incentives exist, then the town will have a Mexican restaurant anyway. The law has a clear effect on the market behavior of firms seeking to take advantage of the new property right, but it has no effect on restaurant innovation. In other words, the law merely stimulates rent seeking. A recent study of the market for new agricultural varieties comes to a similar conclusion: "[T]he most dramatic implication of correctly accounting for the monopolistic behavior entailed by [intellectual property rights] is not on the overall size of the benefits but on the distribution of the welfare gains from innovations." [FN184] In other words, changes in plant protection law may affect who gets how much of a profitable pie without necessarily increasing the size of the pie itself. A recent paper on the seed industry puts it bluntly: "[P]roperty rights imply new avenues of rents for firms and new types of strategic [behavior]." [FN185] Yet another comprehensive study of field trial data of protected corn varieties concludes that "plant breeders may use utility patents for strategic reasons, to protect themselves from litigation or extract licensing revenues." [FN186]

Considering the size of the U.S. corn market, rent seeking may be a particular concern. [FN187] The value of the 2010 U.S. corn crop was a whopping $65.97 billion, [FN188] while the average value of the entire U.S. vegetable and melon crop over the last eight years was $17.4 billion. [FN189] This is a huge piece of cornbread that will be divvied up, and patents may increase the size of the pieces captured by some lucky owners. The sheer size of the market should stimulate innovation by those seeking to obtain an advantage over their competitors, but it will also stimulate patenting activity by those seeking to increase their share of the overall rents that might ***1096** be earned. An increase in patenting activity is not necessarily evidence that creativity is being stimulated in a way that would not have occurred without protection.

The rent-seeking hypothesis is indirectly supported by other empirical research conducted by agricultural economists on the effect of the PVPA on other types of crops. As Naseem, Oehmke, and Schimmelpfennig summarize:

> Butler and Marion (1985) concluded that the "PVPA has stimulated the development of new varieties of soybean and wheat" but were unable to conclude that total R&D activity had increased. Knudson and Pray . . . also found that PVP has effects on private-sector research priorities and breeding activity but did not relate PVP to yields. Likewise, Srinivasan (2004) and Diez (2002) have found that the impact of Plant Breeder's Right in Europe has been to increase the incentives for private firms to develop new varieties, but they too did not relate the effect of those new varieties on yields. [FN190]

Naseem et al., scratch their heads about the phenomenon of how business activity can be stimulated without any indication of increased overall production, but the story they tell is consistent with our suspicions of rent seeking.

Of course, the possibility of federal law stimulating rent seeking does not mean that legal protection might not result in added innovation. Some inventions may be so costly to create or so expensive to bring to market that an exclusive right must be promised to insure their creation. This is the traditional story told about pharmaceuticals, which is one of the few areas where empirical economists find a link between patent law and innovation. [FN191] If innovation is extremely expensive and improvements***1097** are easy for competitors to appropriate, then inventors may require exclusive rights. [FN192] Steven Smith argues that this may be the case with corn where new, sophisticated means of genetic analysis have made reverse engineering of corn hybrids possible for the first time. [FN193] He argues that utility patents are necessary to replace the substantial protection that used to be offered to breeders by state trade secrecy laws. [FN194]

Interestingly, the existence of legal protection via trade secrecy for corn hybrids may provide an example of rent seeking that predates the formal property rights regimes of the PPA and the PVPA. Improvements to corn may be made via traditional selection and crossing techniques or through hybridization. [FN195] The creation of hybrids, however, is much more attractive to breeders than the creation of open-pollinated varieties because second generation hybrids lose their initial vigor and are therefore not attractive for replanting. [FN196] In other words, farmers will not save hybrid seed and will have to purchase a new supply from the seed company every year. As long as the seed company keeps the parent lines used to create the seed a secret, state law will protect that secret from misappropriation by competitors. According to Kloppenburg, the availability of trade secret protection and the attendant rent seeking drove the creation of the modern seed corn industry structure. [FN197] Whether protection was necessary to stimulate hybridization or whether open-pollinated varieties might have been improved equally impressively remains an open question. Kloppenburg suggests that "it is entirely possible that the road not taken would have been as productive as the hybrid route. If this is indeed the case, hybrid seed-corn sales represent a tax on the farm population." [FN198]

The answer to the question whether property rights are ever needed to foster innovation may boil down to whether corn looks like tomatoes or drugs. In 2004, there were 1536 varieties of tomatoes commercially available, yet there have only been eighty-four tomato patents granted in U.S. history. [FN199] Clearly, innovation does not require a patent system for tomatoes. On the other hand, the general economic consensus is that pharmaceuticals are so expensive to develop and get past the Food and ***1098** Drug Administration that exclusive rights are necessary. [FN200] Are the advances in transgenic corn so expensive to produce that they would never be created and brought to market in the absence of legal protection? Our data cannot answer this question definitively, but it should shift the burden of proving the efficacy of patent protection onto those who advocate for stronger property rights. It also suggests that utility patents for expensive genetic research might be justified, but does little to support the argument that the PVPA is essential.

B. Do the New Patented Varieties of Corn Increase Net Social Welfare?

Even assuming that research into new varieties of corn is so expensive that a legal incentive is required, there is no guarantee that the new products invented will be any better than the old. If proprietary varieties are no more productive than nonproprietary varieties, then patent law for plants is difficult to justify, and yet seed companies have successfully fought off proposals that protection be granted to better varieties. [FN201] We have collected no original data to answer the productivity question, but we will conclude with a brief summary of agricultural economic research into the comparative productivity of proprietary plant crop varieties. Most of this research has not yet found its way into the legal literature, and it is a nice compliment to empirical research in other fields of technology that has cast doubt on whether patents increase productivity. [FN202] It is also consistent with our data that show a limited role for patents in the innovation story.

The most recent study collects field trial data from 1986 to 2005 on patented corn varieties. Moser, Ohmstedt, and Rhode conclude that “most patented corn hybrids produced less corn than comparable hybrids that were already in production: 58.20 percent of hybrids that were pat-ented between 1986 and 2005 produce less corn than the highest-yielding comparison hybrids [and] 55.86 percent generate less income.” [FN203] Moreover, their data also shows that “the size of improvements in yields and income decline over time. More than 70 percent of hybrids patented after 1998 produce less corn than existing varieties, compared with 47 percent before 1998 . . . .” [FN204] Since the field trial data existed before the pat-ents were applied for, the primary effect of patent availability may well be strategic behavior. Why else apply for a patent on an invention known to be inferior?

***1099** In a prominent study of wheat yields, Alston and Venner seriously doubt whether intellectual property protection has had any beneficial effect in that market:

> There is no evidence of an increase in private investments in wheat breeding and no evidence of an increase in the average price premium for wheat seed, which might indicate an increase in inventor royalties to wheat breeders . . . the PVPA has not contributed to increases in commercial or experimental yields of wheat. [FN205]

In support of the rent-seeking thesis propounded above, they conclude that the PVPA merely stimulated investment in and successful applications for intellectual property rights. [FN206] They find no proof of welfare increases, and other researchers have expressed similar doubts. Babcock and Foster (flue-cured tobacco), Perrin et al. (soybeans), and Carew and Devadoss (canola) have all failed to find significant support for the claim that intellectual property rights increase productivity. [FN207] These findings are augmented by Alexander and Goodhue's conclusion that “patented seed innovations do not increase the market power of biotechnology firms in the relevant market for production systems.” [FN208] In other words, the patent system may not provide a financial incentive to innovate. In her unpublished doctoral dissertation, Professor Judith Stallman comes to a similar conclusion about the lack of incentives provided by patent law in the apple market. [FN209]

Other studies come to similar conclusions. For example, in their study of roses protected by the PPA, Moser and Rhode find no increase in innovation and no increase in the number of new varieties of roses introduced in the years after the granting of legal protection for roses. [FN210] They suggest defensive patenting as an explanation for use of the patent system. [FN211] Two law professors studying patenting and licensing under the PVPA, Janis and Kesan, conclude that “rights are burdensome to acquire, and yet the expected post-issuance licensing and enforcement activities***1100** common to any intellectual property regime are virtually non-existent.” [FN212] They conclude that the PVPA “does not provide patent-like ex ante incentives.” [FN213] Along the same lines, Lesser's study of the value of PVPA soybean certificates in the New York market shows that “protection likely provides inadequate incentives for breeding investment.” [FN214] Moschini and Lapan survey the extant literature and find “scant evidence on the hypothesis that the PVPA had a positive effect on plant breeding in the USA.” [FN215]

Some studies do purport to show a positive effect on yields. Naseem et al. find that the PVPA “led to the development of more varieties and that these varieties have had an overall positive impact of PVP on cotton yields.” [FN216] The authors of the study admit, however, that their analysis does not account for several variables, including insect pressure. [FN217] Given that they take their statistics on increasing U.S. cotton yields from the time period when a vigorous nationwide program of pesticide spraying and trapping virtually wiped out the boll weevil, [FN218] the number one cotton pest, their conclusions about a change in the law causing increased yields are doubtful. Kolady and Lesser find the PVPA stimulated the production of privately produced wheat varieties (as opposed to varieties produced by public institutions, primarily universities) and they find that private varieties produced higher yields than public varieties. [FN219] Their conclusions, however, are less than earth-shattering. They find that private varieties of soft winter wheat produce only .01 bushels per acre more on average than public varieties, and the subset of those private varieties that were protected by the PVPA did not produce a statistically significant higher yield. [FN220]

Even purely theoretical models are contradictory. Moschini and Lapan model the welfare effects of intellectual property rights in agricultural plants and show that “conventional methods usually overestimate ***1101** the welfare gains from agricultural innovations.” [FN221] On the other hand, Lence et al. produce a theoretical model that suggests the level of intellectual property protection for agricultural crops in the U.S. is too low. [FN222]

We analyze corn separately because it behaves differently in some ways than the other forty-one crops we study. But in other ways, corn is unremarkable. About forty percent of the PVPA certificates we find are for corn, but given that the value of the corn crop each year is more than twice the size of the value of all vegetables combined, this hardly seems disproportionately large. It suggests, in fact, that the PVPA system may not be an important stimulant of innovation, which is consistent with the research surveyed above. The real difference shows in the number of utility patents issued on corn. One can tell two very different stories about this phenomenon. First, the patents are primarily for transgenic varieties of corn that are very expensive to produce and easy to misappropriate. Legal protection, therefore, stimulated massive innovation that would not have otherwise occurred. The second story explains the patenting phenomenon as inefficient rent seeking or defensive patenting, behaviors that do not result in but-for creation of new varieties.

Without more evidence, we cannot decide which story, or combination of stories paints the truest picture. We note, however, that our data and the studies surveyed in this Section caution against a blind and enthusiastic embrace of the patenting-equals-innovation story. The market is much too complex for policymakers to rely on mere assertions by pro-patent and anti-patent advocates.

VI. Conclusion

Our study began with the goal of settling a conflict between economists who believe that patent law is essential to increasing plant diversity through innovation and anthropologists/ethnobotanists who believe that patents destroyed plant diversity in the twentieth century. Our data demonstrate that both views are misguided. In the seventeen billion-dollar market for vegetable crops, patent law plays an insignificant role in innovation. In addition, those who blame diversity loss on patents are also wrong. Our data show varietal diversity actually increased during the twentieth century, a finding that should change the highly politicized debate over international intellectual property policy. We bracket corn (and perhaps soybeans and cotton), where patents and PVPA certificates seem to play a more prevalent role, but urge caution in concluding that patenting activity in that market is much more than rent seeking.

To support our conclusions, we offer the first complete analysis of several product markets. We study thousands of commercially available ***1102** varieties of forty-two vegetable crops in 1903 and 2004, and apples in 1905 and 2000. We have found no parallel analysis of any market that encompasses all commercially available products and documents the source of all innovations in terms of patents, unpatented innovations, imports, and historical products. This enables us to provide accurate commercialization rates for the first time by looking directly at a market rather than interviewing inventors or surveying firms. In addition, we estimate varietal turnover rates by analyzing vegetable crops in 1981. We hope this unique data set will serve as a baseline against which other full analyses of innovation markets can be compared.

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[FN1]. Cary Fowler & Pat Mooney, Shattering: Food, Politics, and the Loss of Genetic Diversity, at ix (1990).

[FN2]. See Elaine Chiosso, Vegetable Variety Inventory: Varieties from USDA 1903 List of American Vegetables in Storage at the National Seed Storage Laboratory (Oct. 5, 1983) (unpublished) (copy on file with the authors). RAFI is now ETC, which according to its web site "supports socially responsible developments of technologies useful to the poor and marginalized and... addresses international governance issues and corporate power." See About ETC Group, ETC Grp., http://etcgroup.org/en/about (last visited May 24, 2012).

[FN3]. For information on the FAO, see FAO's Mandate, Food and Agric. Org. of the United Nations, http://www.fao.org/about/en/ (last visited May 24, 2012) ("Achieving food security for all is at the heart of FAO's efforts--to make sure people have regular access to enough high-quality food to lead active, healthy lives."). A short biography of Fowler can be found at Staff, Global Crop Diversity Trust, http://www.croptrust.org/main/content/staff (last visited May 24, 2012). A short biography of Mooney can be found at Pat Roy Mooney, Executive Director, ETC Grp., http://etcgroup.org/en/about/staff/pat_ mooney (last visited May 24, 2012).

[FN4]. See Fowler & Mooney, supra note 1, at 64-67 tbl.1.

[FN5]. See Chiosso, supra note 2, at 2. NSSL is now known as the National Center for Genetic Resources Preservation. Originally created to preserve plant genetic data, NGCRP now preserves germplasm of all life forms important to United

States agriculture. History of NCGRP, U.S. Dep't of Agric., Agric. Research Serv., http://www.ars.usda.gov/Aboutus/docs.htm?docid=17890 (last visited May 24, 2012).

[FN6]. Fowler & Mooney, supra note 1, at 63.

[FN7]. See Charles Siebert, Food Ark, Nat'l Geographic (July 2011), http:// ngm.nationalgeographic.com/2011/07/food-ark/siebert-text ("Food variet[y] extinction is happening all over the world--and it's happening fast.").

[FN8]. The following small sample of sources cite and rely on the RAFI study: Stephen B. Brush, Farmer's Bounty: Locating Crop Diversity in the Contemporary World 269-70 (2004); Jerome D. Fellmann et al., Human Geography: Landscapes of Human Activities 267 (9th ed. 2007); Fowler & Mooney, supra note 1, at 64-67; K.V. Krishnamurthy, Textbook of Biodiversity 47 (2003); Laura Krouse & Teresa Galluzzo, Iowa Policy Project, Iowa's Local Food Systems: A Place to Grow 11 (2007); Sue Stolton et al., World Wide Fund for Nature, Food Stores: Using Protected Areas to Secure Crop Genetic Diversity (2006); Lori Ann Thrupp, World Resources Inst., Cultivating Diversity: Agrobiodiversity and Food Security (1998); George J. Armelagos, The Omnivore's Dilemma: The Evolution of the Brain and the Determinants of Food Choice, 66 J. Anthropological Res. 161, 172 (2010); Carol Goland & Sarah Bauer, When the Apple Falls Close to the Tree: Local Food Systems and the Preservation of Diversity, 19 Renewable Agric. & Food Sys. 228, 228 (2004); Ron Kroese, Industrial Agriculture's War Against Nature, in The Fatal Harvest 24 (Andrew Kimbrell ed., 2002); Adrian Phillips & Sue Stolton, Protected Landscapes and Biodiversity Values: An Overview, in Values of Protected Landscapes and Seascapes 8 (Thora Amend et al. eds., 2008); Carolyn E. Sachs et al., Gender, Seeds, and Biodiversity, in Women Working in the Environment 177, 183 (Carolyn E. Sachs ed., 1997); James R. Veteto, The History and Survival of Traditional Heirloom Vegetable Varieties in the Southern Appalachian Mountains of Western North Carolina, 25 Agric. & Hum. Values 121 (2008); Mark L. Winston, Travels in the Genetically Modified Zone, in Critical Perspectives on Genetically Modified Crops 10, 20 (Susan Gordon ed., 2006); John Seabrook, Sowing for Apocalypse: The Quest for a Global Seed Bank, New Yorker, Aug. 27, 2007, at 67; Siebert, supra note 7; Susan Ventura, The Role of Seeds in Preserving Genetic Biodiversity in Agroecosystems (Feb. 24, 2009) (unpublished student work), available at http:// www.scribd.com/doc/37451273/The-Role-of-Seeds-in-Preserving-Genetic-Biodiversity-in-Agroecosystems-Sustainable-Ag-Class-Paper; Biodiversity, Sustainable Table, http://www.sustainabletable.org/issues/biodiversity/ (last visited May 24, 2012); Diminished Crop Diversity, The Bell (Jan. 26, 2010), http://www.thebellforum.com/showthread.php?t=25188; Agence France-Presse, Doomsday Seed Vault's Stores are Growing, The Raw Story (Feb. 16, 2009), http://rawstory.com/news/2008/Doomsday_seed_vaults_stores_are_growing_ 0216.html; Fruit and Veg Cannot be Manufactured How Come We Never Lost the Seeds Through the Ages Wars...?, Yahoo Answers (July 2011), http:// answers.yahoo.com/question/index?qid=20110625222738AAnViXT; Lucas Graves, In the Event of Global Disaster, the Ultimate Crop Backup System, Wired Magazine (May 22, 2007), http://www.wired.com/science/planetearth/magazine/15-06/ff_ seedbank; Margaret Hapooja, Handed-Down Harvest: Grow the Best Heirloom Varieties, Natural Home & Garden (May/June 2011), http:// www.naturalhomeandgarden.com/food-gardens/handed-down-harvest-grow-best-heirloom-varieties.aspx; Fiona Harvey, In Case of Emergency, Break Ice, FT Magazine (Apr. 26, 2008, 1:24 AM), http://www.ft.com/intl/cms/s/0/f53b9c28-1007-11dd-8871-0000779fd2ac.html#axzz1W3nvLpfM; Indigenous Languages in Distress, TierramÉrica (Feb. 18, 2001), http://www.tierramerica.info/nota.php? lang=eng&idnews=2648&olt=354; Ruud Kempers Personal Cargo (Feb. 26, 2008), http://spacecollective.org/RuudKempers/page2; Loss of Genetic Diversity in U.S. Food Crops, In The Cloud, http://inthecloud.gjmueller.com/post/7855123452/loss-of-genetic-diversity-in-u-s-food-crops (last visited May 24, 2012); Magic of Seeds, The Green Girls (May 30, 2011, 9:11 AM), http:// www.thegreengirls.com/blog/post/2011/05/Magic-of-Seeds.aspx; Patricia S. Muir, Diminished Crop Diversity, BI301

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[FN9]. W.W. Tracy, Jr., Bureau of Plant & Indus., U.S. Dep't of Agric., Bulletin 21, American Varieties of Vegetables for the Years 1901 and 1902, at 7 (1903). Readers can enjoy this invaluable publication through Google Books.

[FN10]. See Chiosso, supra note 2.

[FN11]. See Garden Seed Inventory (Kent Whealy ed., 1985) (surveying all varieties of common vegetable crops available in commercial seed catalogs in 1981 in the United States and Canada).

[FN12]. See Garden Seed Inventory (Kent Whealy ed., 2004) (surveying all varieties of common vegetable crops available in commercial seed catalogs in 2004 in the United States and Canada).

[FN13]. See Fowler & Mooney, supra note 1, at 239-40; see also infra Table 1.

[FN14]. See, e.g., Jack Ralph Kloppenburg, Jr., First the Seed: The Political Economy of Plant Biotechnology 131 (2d ed. 2004) (describing those who argue that the PVPA stimulates “a greater number of superior and more genetically diverse varieties”); Richard S. Gruner, Better Living Through Software: Promoting Information Processing Advances Through Patent Incentives, 74 St. John's L. Rev. 977, 981 (2000) (“Patent incentives help to promote greater numbers and diversity of technological discoveries ....”); Robert M. Meeks, Metaphors of Infringement and Equivalence: The Solution of Our Problems, 2 J. Intell. Prop. L. 279, 319 (1994) (“[P]atents help encourage efforts in unconventional directions, protecting them from the crush of the status quo and ensuring technological diversity.”); Stephen Smith, Intellectual Property Protection for Plant Varieties in the 21st Century, 48 Crop Sci. 1277, 1287 (2008) (“Intellectual property protection must be strengthened on a global basis ... to increase genetic diversity....”).

[FN15]. Plant Patent Act, ch. 312, §§1-4, Pub. L. No. 71-245, 46 Stat. 376 (1930) (current version at 35 U.S.C. §§161-164 (2006)) (providing a patent right in any new variety of asexually reproducing plant).

[FN16]. Plant Variety Protection Act, title I, §1, Pub. L. No. 97-577, 84 Stat. 1542 (1970) (current version at 7 U.S.C. §2321 (2006)).

[FN17]. See Ex parte Hibberd, 227 U.S.P.Q. 443, 444-45 (1985) (holding that plants were within the meaning of “manufacture” or “composition of matter” and therefore capable of receiving utility patents).

[FN18]. See Asgrow Seed Co. v. Winterboer, 513 U.S. 179, 181 (1995) (stating the Plant Variety Protection Act was intended "to provide developers of novel plant varieties with 'adequate encouragement for research, and for marketing when appropriate, to yield for the public the benefits of new varieties"); Food, Inc. Movie and Seed Patents, Monsanto, http:// www.monsanto.com/food-inc/Pages/seeds-patent-history.aspx (last visited May 24, 2012) ("If plant breeders were not able to protect the plant varieties they develop from unauthorized reproduction, there would be less incentive for them to develop improved plant varieties.").

[FN19]. See, e.g., Graham Dutfield, Intellectual Property Rights, Trade and Biodiversity 16 (2000); Fowler & Mooney, supra note 1, at 126 ("[T]he FAO secretariat also linked the patenting of seeds to the related issue of genetic uniformity."); Kloppenburg, supra note 14, at 131; (noting those who argue that "the PVPA... contributes to genetic erosion"); Devlin Kuyek, Genetic Res. Action Int'l, Intellectual Property Rights in African Agriculture: Implications for Small Farmers 11 (2002) (arguing that "[plant variety protection] and patents threaten food security and agrobiodiversity"); Niels Louwaars et al., Ctr. for Genetic Res., Report 2009-14, Breeding Business: The Future of Plant Breeding in the Light of Developments in Patent Rights and Plant Breeder's Rights 3 (2009) ("Patent rights, together with the way these are granted and exerted, contributes [sic] to decreasing diversity in breeding companies and threatens [sic] innovation in plant breeding."); The Crucible Group, People, Plants, and Patents: the Impact of Intellectual Property on Biodiversity, Conservation, Trade, and Rural Society 17 (1994) ("IP results in increased genetic uniformity and, where diversity still exists, increased genetic erosion."); Robin Pistorius, Scientists, Plants and Politics: A History of the Plant Genetic Resources Movement 76 (1997) (citing those who "drew attention to the negative effect that utility patent laws covering plants could have on developing countries in the future, and the loss of genetic diversity in these countries"); Peter J. Goss, Guiding the Hand that Feeds: Toward Socially Optimal Appropriability in Agricultural Biotechnology Innovation, 84 Cal. L. Rev. 1395, 1399 (1996) ("Environmentalists fear that ... enhanced intellectual property rights [will] ... contribute to genetic erosion...."); Bonwoo Koo et al., Plants and Intellectual Property: An International Appraisal 306 Sci. 1295, 1295 (2004) ("The era of free and unencumbered access to new crop varieties appears to be passing. This development in intellectual property... has raised a chorus of concerns about the implications for food production and human health ....").

[FN20]. See U.S. Dep't of Agric., Nat'l Agric. Library, http:// www.nal.usda.gov/about-nal (last visited May 24, 2012). The National Agricultural Library is one of the four national libraries of the United States. It houses one of the world's largest and most accessible agricultural collections.

[FN21]. See infra notes 61-71 and accompanying text.

[FN22]. See Stephen P. Ladas, Patents, Trademarks, and Related Rights: National and International Protection 382 (1975).

[FN23]. Plant Patent Act, ch. 312, §1, Pub. L. No. 71-245, 46 Stat. 376 (1930) (current version at 35 U.S.C. §§161 (2006)).

[FN24]. See Kim Bros. v. Hagler, 167 F. Supp. 665, 669 (S.D. Cal. 1958) ("[W]e are of the view that the plaintiff has failed to prove that the trees grown by the defendant were the result of ... appropriation ... [or] to be more specific, during the year 1955 the defendant grafted Sun Grand nectarine scions on other fruit trees ....").

[FN25]. See id. at 670. See also Michael Pollan, The Botany of Desire: A Plant's-Eye View of the World 10-11 (2001).

[FN26]. See Mark D. Janis & Jay P. Kesan, U.S. Plant Variety Protection: Sound and Fury...?, 39 Hous. L. Rev. 727, 735 (2002). Note that there is no derivative work right established by the PPA. A subsequent breeder can use a protected variety in a cross.

[FN27]. See Smith, supra note 14, at 1284 (describing how genetic testing is making trade secrecy an ineffective means of protecting new hybrids because the two parent lines can now be easily discovered).

[FN28]. Few plant patents, at least on fruit and nut trees, confer market power on their owners because consumers freely substitute unprotected varieties. Trademark law is probably more effective in facilitating the capture of rents. Imagine someone who copies the wonderful Honeycrisp® apple. Without the ability to use the trademarked name, it would be difficult for the misappropriator to compete effectively.

[FN29]. See S. Rep. No. 71-315, at 1 (1930) ("[T]he bill provides that any person who invents or discovers a new and distinct variety of plant shall be given by patent an exclusive right to propagate that plant by asexual reproduction; that is, by grafting, budding, cutting, layering, division, and the like, but not by seeds.").

[FN30]. See Cary Fowler, The Plant Patent Act of 1930: A Sociological History of its Creation, 82 J. Pat. & Trademark Off. Soc'y 621, 634-35 (2000).

[FN31]. See Plant Variety Protection Act, Pub. L. No. 91-577, 84 Stat. 1542 (1970) (codified as amended in scattered sections of 7 and 28 U.S.C.).

[FN32]. Plant Variety Protection Act, §1, Pub. L. No. 97-577, 84 Stat. 1542 (1970) (current version at 7 U.S.C. §2321 (2006)).

[FN33]. See id. §111 (current version at 7 U.S.C. §2541 (2006)).

[FN34]. See id. §113.

[FN35]. See id. §114.

[FN36]. See Janis & Kesan, supra note 26, at 750 n.124.

[FN37]. See Computer Assocs. Int'l, Inc. v. Altai, Inc., 982 F.2d 693, 708 (2d Cir. 1992).

[FN38]. See Ex parte Hibberd, 227 U.S.P.Q. 443, 444, 448 (1985).

[FN39]. See 35 U.S.C. §100 et seq. (2006). See also Madey v. Duke Univ. 336 F. Supp. 2d 583, 592 (M.D.N.C. 2004) ("In light of the Federal Circuit's Opinion narrowly construing the experimental use defense ....").

[FN40]. See 35 U.S.C. §101; Monsanto Co. v. Scruggs, 459 F.3d 1328, 1336 (Fed. Cir. 2006).

[FN41]. See Monsanto Co. v. David, 516 F.3d 1009, 1014 (Fed. Cir. 2008) ("The ... patent covering the gene sequence is infringed by planting a seed containing the gene sequence ....").

[FN42]. See 35 U.S.C. §103.

[FN43]. See Plant Variety Protection Act, §42, Pub. L. No. 97-577, 84 Stat. 1547 (1970) (current version at 7 U.S.C. §2402 (2006)).

[FN44]. See 35 U.S.C. §112.

[FN45]. See 35 U.S.C. §162.

[FN46]. See supra note 14 and accompanying text.

[FN47]. See, e.g., Plant Variety Protection Act, Pub. L. No. 91-577, 84 Stat. 1542, 1542 (1970) ("To encourage the development of novel varieties of sexually reproduced plants and to make them available to the public, providing protection available to those who breed, develop, or discover them, and thereby promoting progress in agriculture in the public interest.").

[FN48]. The various studies are collected in James Bessen & Michael J. Meurer, Patent Failure: How Judges, Bureaucrats, and Lawyers Put Innovators at Risk (2008), and discussed in Paul J. Heald, A Transaction Costs Theory of Patent Law, 66 Ohio St. L.J. 473, 474-45 (2005). See also Bronwyn H. Hall & Rosemarie H. Ziedonis, The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995, 32 Rand J. Econ. 101, 106 (2001) ("[E]mpirical studies have failed to find evidence that the strengthening of U.S. patent rights during the 1980s stimulated industrial spending in R&D.").

[FN49]. See supra note 48.

[FN50]. See, e.g., Heald, supra note 48, at 476.

[FN51]. See, e.g., Mark A. Lemley, Rational Ignorance at the Patent Office, 95 Nw. U. L. Rev. 1495, 1501, 1507 (2001) (estimating that only five percent of patents are ever licensed; about two percent are litigated).

[FN52]. See infra notes 139-40 and accompanying text.

[FN53]. See supra note 8 and accompanying text.

[FN54]. See supra note 19 and accompanying text.

[FN55]. See Pat Roy Mooney, Seeds of the Earth: A Public or Private Resource? 69-70 (1979) ("In summary ... 'protection' provides the necessary profit security to encourage multinationals to move into the seed business. To maximize profit, these giant corporations direct their research dollars to hybrid development thus increasing crop uniformity and genetic vulnerability."); Heike Baum%20uller & Geoff Tansey, Responding to Change, in The Future Control of Food: A Guide to International Negotiations and Rules on Intellectual Property, Biodiversity and Food Security 171, 175-76 (Geoff Tansey & Tasmin Rajotte eds., 2008) ("The expansion of patents and plant variety protection, with their various requirements for uniformity and industrial applicability (or 'utility' in the US), is feared to encourage agricultural systems that are further dominated by large-scale monoculture cropping, often primarily for export and are genetically vulnerable to pest, pathogen or environmental changes."); see also Dutfield, supra note 19; Fowler & Mooney, supra note 1, at ix-xiv; Krishnamurthy, supra note 8, at 156-64; Kuyek, supra note 19; Louwaars et al., supra note 19; Koo et al., supra note 19.

[FN56]. See Agreement on Trade-Related Aspects of Intellectual Property Rights, art. 27, Apr. 15, 1994, 33 I.L.M. 1981 (1994), http:// www.wto.org/english/docs_e/legal_e/27-trips.pdf.

[FN57]. See supra note 55 and accompanying text.

[FN58]. We should note that anthropologists and ethnobotanists might concede that propositions 2 and 3 could both be true. Patent law could stimulate new biotech varieties that lead to agricultural domination and monoculture creating a subsequent loss of older varieties through disuse.

[FN59]. See supra notes 8, 19 and accompanying text.

[FN60]. See 7 U.S.C. §1571 (2006) ("It shall be unlawful for any person to transport or deliver for transportation in interstate commerce ... unless each container bears a label giving ... [t]he name of the kind or kind and variety for each agricultural seed component present....").

[FN61]. For example, Patent Number 7,968,230 is for a "high discharge capacity lithium battery." U.S. Patent No. 7,968,230 (filed May 13, 2010). It was assigned to the Eveready Battery Company by its inventor, but there is no easy way to determine whether Eveready has ever marketed the patented technology. See id. The product data sheets on the Eveready web site provide no patent information. See Energizer, Product Datasheet-Energizer L91, http://data.energizer.com/PDFs/l91.pdf. One would have to get the cooperation of every battery company that had ever patented a lithium battery in order to discover which percent had been commercialized.

[FN62]. See Fruit, Berry, and Nut Inventory 123 (Kent Whealy ed., 3d ed. 2001).

[FN63]. See U.S. Patent No. 11,201 (filed May 13, 1998).

[FN64]. Tomato, Redfield Beauty OG, Seed Savers Exchange, http://www.seedsavers.org/Details.aspx?itemNo=1483(OG) (last visited May 24, 2012).

[FN65]. See, e.g., American Association of Nurserymen, Plant Patents with Common Names, 1 Through 2207 (1967).

[FN66]. See Seed Savers Exchange, http://www.seedsavers.org/ (last visited May 24, 2012).

[FN67]. Garden Seed Inventory, supra note 12.

[FN68]. See Fruit, Berry, and Nut Inventory, supra note 62.

[FN69]. See Fruit and Nut Variety Registrars, American Pomological Society, http://americanpomological.org/registrars.html (last updated July 2011).

[FN70]. See Tracy, supra note 9.

[FN71]. W.H. Ragan, Bureau of Plant & Indus., U.S. Dep't of Agric., Bulletin 56, Nomenclature of the Apple: A Catalogue of Known Varieties Referred to in American Publications from 1804-1904 (1905).

[FN72]. See description of special collection at http:// www.nal.usda.gov/speccoll/collectionsguide/nurserycatalogs.shtml (over 200,000 seed and nurserymen's catalogs available with permission for private viewing).

[FN73]. See Garden Seed Inventory, supra note 12, at 4-10.

[FN74]. See generally id. (containing forty-two of the same crops as Tracy's survey).

[FN75]. See id. at 334-40; see also Tracy, supra note 9.

[FN76]. See infra Tables 1-4.

[FN77]. See Fowler, supra note 30, at 628-40.

[FN78]. See, e.g., Miguel Angel Altieri & Clara Ines Nicholls, Biodiversity and Pest Management in Agroecosystems 4 (2004) ("Eighty-six percent of the 7,000 apple varieties used in the United States between 1804 and 1904 are no longer in cultivation...."); Regine Andersen, How International Agreements Complicate the Management of Plant Genetic Diversity for Food and Agriculture in Developing Countries 1 n.1 (2002), https://www.uni-hohenheim.de/fileadmin/einrichtungen/sfb564/afs-files/uplands2002/Paper/Full-Pap-S1-3_Andersen.pdf ("In the USA, 86 % of apple varieties ... that were grown a century ago have been lost...."); Pat Mooney, The Massacre of Apple Lincoln, 212 New Internationalist (Oct. 1990) (claiming "mass extinctions of fruit"); Siebert, supra note 7 ("Of the 7,000 apple varieties that were grown in the 1800s, fewer than a hundred remain."); Kanin J. Routson et al., Identification of Historic Apple Trees in the Southwestern United States and Implications for Conservation, 44(3) Horticulture Sci. 589, 589 (2009); Jeremy Seabrook, Biotechnology and Genetic Diversity, 34 Race & Class 15, 15 (1993) ("[Eighty-five] per cent of all the varieties of apple in the USA have become extinct within a century.").

[FN79]. Ragan, supra note 71.

[FN80]. See id.

[FN81]. See id.

[FN82]. In 1929, we found thirty-six S Cats selling apple trees and 332 beginning with other letters. Of 668 total varieties offered for sale, 217, or thirty-two percent were offered in S Cats. In 1988, S Cats contained fifty-two percent of all varieties of apples offered for sale that year. In 1992, S Cats contained thirty-nine percent of the total market, and thirty-one percent in the year 2000. We also have full data for tomatoes (1903, 1987, 1994, 1998, 2004), strawberries (1988, 1992, 2000), and peaches (1988, 1992, 2000) in multiple years. For those crops in those years, the percentage of the market captured in S Cats ranges from thirty-one percent to fifty-one percent.

[FN83]. Plant Genetic Resources Unit (PGRU), U.S. Dep't of Agric., Agric. Research Serv., http://www.ars.usda.gov/main/site_main.htm?modecode=19-10-05-00 (last modified Sept. 15, 2011) ("The PGRU was formed in 1986 by merging the Northeast Regional Plant Introduction Station (NERPIS) and the National Clonal Germplasm Repository for Apple, Tart Cherry and Grape (NGR). The two missions of the PGRU are the preservation of germplasm of selected crop plants and the breeding and improvement of apples.").

[FN84]. See infra note 109 and accompanying text.

[FN85]. See Class Schedule for Class PLT Plants, U.S. Pat. & Trademark Off., http://www.uspto.gov/web/patents/classification/uspcplt/schedplt.htm #CPLTS161000 (last modified Apr. 12, 2012).

[FN86]. See Status of Certification, Plant Variety Protection Off. (May 4, 2012), http://www.ars-grin.gov/cgi-bin/npgs/html/pvplist.pl?.

[FN87]. For our purposes, heirloom means vegetables dating from the turn of the twentieth century or described as "heirloom" or "old variety" in the literature. For apples, heirloom means apples described by Ragan in his famous study or apples he does not describe, yet which appear to be ancient varieties as described in other sources.

[FN88]. See Virginia D. Nazarea, Heirloom Seeds and Their Keepers: Marginality and Memory in the Conservation of Biological Diversity 99 (2005) (detailing the seed-saving and seed-sharing activities of Vietnamese and Latin immigrants).

[FN89]. See infra note 101 and accompanying text. Modern regulations discourage the use of confusing multiple names.

See 7 C.F.R. §201.12 (2010) ("The representation of kind or kind and variety shall be confined to the name of the kind or kind and variety determined in accordance with §201.34. The name shall not have affixed thereto words or terms that create a misleading impression as to the history or characteristics of the kind or variety.").

[FN90]. See Mark A. Mikel & John W. Dudley, Evolution of North American Dent Corn from Public to Proprietary Germplasm, 46 Crop Sci. 1193, 1204 (2006) ("The propensity of breeders to work elite related material in recycling of inbred lines may over the long-term decrease genetic diversity."); Yong-Bi Fu, et al., Allelic Diversity Changes in 96 Canadian Oat Cultivars Released from 1886 to 2001, 43 Crop Sci. 1989, 1989 (2003) (finding decrease in diversity of Canadian oat varieties on a genetic level); Yong-Bi Fu & Daryl Somers, Genome-Wide Reduction of Genetic Diversity in Wheat Breeding, 49 Crop Sci. 161, 161 (2009) (finding decrease in diversity of Canadian wheat varieties on a genetic level).

[FN91]. See Siebert, supra note 7.

[FN92]. See Verlyn Klinkenborg, Apples, Apples, Apples, N.Y. Times, Nov. 6, 2009, at A30.

[FN93]. See Seabrook, supra note 8.

[FN94]. John Holden et al., Genes, Crops and the Environment 32-39 (1993) ("Modern high-yielding varieties (HYVs) represent the current pinnacle of achievement in adapting crop plants to present needs. However, we should remember that no variety is perfect.... If the fungus possesses a gene for pathogenicity capable of establishing infection on the particular wheat variety, then all plants are liable to be infected and an epidemic can ensue."); David Pearce & Dominic Moran, World Conservation Union, The Economic Value of Biodiversity 110 (1994) ("Genetic and species diversity provide two important benefits to agriculture: a) the value of plant improvements and derived yield increases; b) a form of natural insurance against yield variability of homogenized systems."); Paul Raeburn, The Last Harvest: The Genetic Gamble That Threatens to Destroy American Agriculture 121-50 (1995); Linda Fellows & Anthony Scofield, Chemical Diversity in Plants, in Intellectual Property Rights and Biodiversity Conservation: An Interdisciplinary Analysis of the Values of Medicinal Plants 19, 39-40 (Timothy Swanson ed., 1995) ("The understanding and maintenance of existing variation is important at the present time for several reasons. One is the re-introduction into crop species of defensive traits, many of which were deliberately bred out by our ancestors. There are many examples of where genes from wild relatives have been successfully incorporated into a crop species to improve its natural pest resistance and where some species have adapted to polluted areas but others have not. More important is the retention of the potential to adapt in the face of new climatic upheavals which some scientists predict will occur through global warming. If the gene pool continues to be eroded, large-scale extinctions of species may occur."); Michael Halewood & Kent Nnadozie, Giving Priority to the Commons: The International Treaty on Plant Genetic Resources for Food and Agriculture, in The Future Control of Food: A Guide to International Negotiations and Rules on Intellectual Property, Biodiversity and Food Security 115, 118 (Geoff Tansey & Tasmin Rajotte eds., 2008) ("Plant genetic resources are the foundation for all agriculture--providing the basis for developing new and improved varieties, and thus essential for achieving food security.... It is by screening thousands of varieties that critical traits are found that can save an entire crop and perhaps stave off a national or regional hunger crisis.").

[FN95]. See supra notes 8, 19 and accompanying text.

[FN96]. See Siebert, supra note 7.

[FN97]. Id.

[FN98]. Id.

[FN99]. We posted a short four-page summary of our apple findings on www.ssrn.com a year before the National Geographic article was published. See Paul J. Heald & Susannah Chapman, Apple Diversity Report Card for the Twentieth Century: Patents and Other Sources of Innovation in the Market for Apples, (UGA Working Paper Series, 10-01, Jan. 27, 2010), available at http:// papers.ssrn.com/sol3/papers.cfm?abstract_id=1543336.

[FN100]. See id. at 6-14.

[FN101]. Tracy, supra note 9, at 7.

[FN102]. Id. ("Variety names of vegetables in this country are being greatly multiplied every year by the renaming of old varieties. This practice, as well as the giving to new varieties names similar to names already used, has made the nomenclature of the whole very complex and misleading.... Besides being useful for reference, this list, it is hoped, will bring about some desirable changes, of which the first to be mentioned is the adoption of a single name for all identical varieties.").

[FN103]. See W.W. Tracy, Jr., Bureau of Plant & Indus., U.S. Dep't of Agric., Bulletin 109 American Varieties of Garden Beans (1907).

[FN104]. See Frederick V. Coville, Preface to W.W. Tracy, Jr., Bureau of Plant & Indus., U.S. Dep't of Agric., Bulletin 69 American Varieties of Lettuce 6 (1904).

[FN105]. We tracked 2004 varietal diversity using Garden Seed Inventory, supra note 12. Whealy appears to take great care not to double-count varieties when there are multiple names known. Unlike Tracy, he typically does not list all synonyms separately, but rather lists the primary name of a variety, followed by synonyms in parentheses where they exist.

[FN106]. Even the curator of the USDA apple preservation orchard in Geneva, New York, is misinformed. Michael Pollan quotes him as saying, "[a] century ago there were several thousand different varieties of apples in commerce...." Pollan, supra note 25, at 51. In fact, barely more than 400 different varieties were available in commercial nurseryman's catalogs in 1900 and 1905.

[FN107]. See Ragan, supra note 71.

[FN108]. See id.

[FN109]. For example, request two scions of the apple variety "ACME" here: National Plant Germplasm System, U.S. Dep't of Agric., Agric. Research Serv. (Mar. 28, 2012), http://www.ars-grin.gov/cgi-bin/npgs/acc/request.pl? action=add&acid=1241500.

[FN110]. Apple trees can live over 100 years. See Pollan, supra note 25, at 54.

[FN111]. See generally Susannah Chapman, The Apple of Their Eye: Apple Collectors, Landscape and Memory in the Southeastern United States (Nov. 29, 2007) (discussing the special place of apples in Western cultural memory in a paper presented at the 2007 American Anthropological Association Conference, Washington, D.C.).

[FN112]. See id., at 5-12.

[FN113]. See Horne Creek Farm, N.C. Historic Sites, http:// www.nchistoricsites.org/horne/horne.htm (last updated May

8, 2012)

[FN114]. See Apples Found, Apple Search, http://www.applesearch.org/apples_ found.html (last visited May 24, 2012).

[FN115]. See Routson et al., supra note 78, at 589 ("USDA pomologist W. H. Ragan undertook the task of recording the names and characteristics of every apple cultivar grown in the United States during the 19th century. In his book, The Nomenclature of the Apple (Ragan, 1905), Ragan lists 6654 unique named apple varieties that he found referenced in U.S. literature between the years 1804 and 1904.").

[FN116]. See supra notes 106-11 and accompanying text.

[FN117]. Michael Pollan speculates the temperance movement, which advocated the cutting down of apple orchards to reduce the production of alcoholic cider might have reduced apple diversity in the latter part of the nineteenth century. See Pollan, supra note 25, at 50 ("A far more brutal winnowing of the apple's prodigious variability took place around the turn of the century. That's when the temperance movement drove cider underground and cut down the American cider orchard ....").

[FN118]. For example, we have full data on apples for the year 1929. We count 399 different varieties of apples available in 332 commercial catalogs.

[FN119]. Hybrid corn, or any hybrid for that matter, is the result of the crossing of two different varieties in the hopes of creating a superior strain. Almost all vegetable plants are "open pollinated," in the sense that the plant pollinates itself or is pollinated by a neighboring plant of the same variety. The Garden Seed Inventory, supra note 12, only gathers information on open pollinated plants, so it does not track the deliberately crossed hybrid varieties that are sold by most large seed corn companies.

[FN120]. See Alan L. Olmstead & Paul W. Rhode, Creating Abundance: Biological Innovation and American Agricultural Development 64-67 (2008).

[FN121]. For example, twenty-nine hybrids are suitable for planting in the Athens, GA area. See Corn, Pioneer, http://www.pioneer.com/home/site/us/products/corn/ (last visited May 24, 2012) (enter zip code "30602" in "product location").

[FN122]. See supra note 103 and accompanying text.

[FN123]. See supra note 104 and accompanying text.

[FN124]. See Plant Genetic Resources Unit, supra note 83.

[FN125]. See supra note 109 and accompanying text.

[FN126]. See Klinkenborg, supra note 92.

[FN127]. See id. ("One standard reference, from 1905, lists more than 6,500 distinct varieties. There are apples for keeping, cooking, eating and the making of ciders, with names as colorful as they are various: Scallop Gillyflower, Red Winter Pearmain, Kansas Keeper.").

[FN128]. We include in the category of expired patents, patents that lapsed due to the failure of the patentee to pay renewal fees.

[FN129]. Heirlooms constitute around six percent.

[FN130]. See supra Table 2.

[FN131]. See supra Table 2.

[FN132]. See supra Table 2.

[FN133]. See supra Table 3.

[FN134]. See supra Table 3.

[FN135]. See supra Table 3.

[FN136]. See supra Table 3.

[FN137]. See supra Table 3.

[FN138]. In fact, the historical commercialization rate for patented vegetables is probably higher than sixteen percent, given that some previously commercialized patented varieties almost certainly dropped out of the market before 2004. Of the 265 patented varieties commercialized in 2004, just 74 were subject to expired patents, while 191 were covered by pending patents. Not surprisingly, more recent inventions were more likely to be commercialized, suggesting that a significant number of patented inventions commercialized in earlier years had exited the market.

[FN139]. See, e.g., Lemley, supra note 51, at 1501, 1507 (estimating that only five percent of patents are ever licensed; about two percent are litigated).

[FN140]. See Ted Sichelman, Commercializing Patents, 62 Stan. L. Rev. 341, 362 n.121 (2010) (citing many studies that report commercialization rates around fifty percent). Most of the studies cited by Sichelman were surveys of inventors or firms. Some included definitions of commercialization that included purely internal use of the invention. None identified every invention ever issued in a particular category and tracked its availability on the market in a particular year.

[FN141]. See id.

[FN142]. See supra Table 3.

[FN143]. See supra Table 3.

[FN144]. See supra Table 3.

[FN145]. The tomato numbers may be slightly higher; unlike other vegetables, some of the names of the eighty-four protected varieties could not be tracked down. See supra Table 3.

[FN146]. See supra Table 3.

[FN147]. See supra Table 3.

[FN148]. See Heald & Chapman, supra note 99.

[FN149]. Plant Patent Act, ch. 312, §§1-4, Pub. L. No. 71-245, 46 Stat. 376 (1930) (current version at 35 U.S.C. §§161-

164 (2006)).

[FN150]. See supra notes 139-140 and accompanying text.

[FN151]. See Fruit, Berry, and Nut Inventory, supra note 62, at 81 (listing “Fox Whelp” as first recorded in 1854, “Franklin” as developed by the Ohio Agriculture Experiment Station, and “Freyburg” as developed in New Zealand).

[FN152]. See Eric von Hippel, Democratizing Innovation 19 (2005) (“We see here that the frequency with which user firms and individual consumers develop or modify products for their own use range from 10 percent to nearly 40 percent in fields studied to date.”); Eric von Hippel, The Sources of Innovation 19-26 (1988) [hereinafter von Hippel, Sources] (detailing the results of his studies analyzing process innovations in the fields of scientific instruments, silicon-based semiconductors and the assembly of printed circuit (PC) boards and noting that “[w]e have now found three innovation categories in which it is typically the product user, not the product manufacturer, who recognizes the need, solves the problem through an invention, builds a prototype, and proves the prototype's value in use”); Glen L. Urban & Eric von Hippel, Lead User Analyses for the Development of New Industrial Product, 34 Mgmt. Sci. 569 (1988); Eric von Hippel, The Dominant Role of the User in Semiconductor and Electronic Subassembly Process Innovation, 2 EM-24 IEEE Transactions on Engineering Management 60 (1977); Eric von Hippel, The Dominant Role of Users in the Scientific Instrument Innovation Process, 5 Res. Pol'y 212, 227 (1976) (“We have seen that for both major and minor innovations in the field of scientific instruments, it is almost always the user, not the instrument manufacturer, who recognizes the need, solves the problem via an invention, builds a prototype and proves the prototype's value in use.”); see also John L. Enos, Invention and Innovation in the Petroleum Refining Industry, in The Rate and Direction of Inventive Activity: Economic and Social Factors 299 (1962) (detailing innovation and development efforts in the oil refinery industry in the early twentieth century); Pedro Oliveira & Eric von Hippel, Users as Service Innovators: The Case of Banking Services, 40 Res. Pol'y 806, 813 (2011) (“We have found that, in the case of important banking services, users frequently develop and self provide what they need before banks or non-bank financial service producers offer commercial services to serve their needs.”); Sonali Shah, Sources and Patterns of Innovation in a Consumer Products Field: Innovations in Sporting Equipment 3 (Mass. Inst. of Tech., Sloan Sch. of Mgmt., Working Paper No. 4105, 2000) (“Equipment for the new sport was not developed by existing sports equipment manufacturing companies ... [but rather] by a few early expert participants in those sports, lead users, and also by some of those same lead users after they founded small companies to produce their innovations for sale.”).

[FN153]. See Garden Seed Inventory, supra note 12.

[FN154]. See id.

[FN155]. See id.

[FN156]. See Nazarea, supra note 88, at 98-115.

[FN157]. No variety was assigned more than one source designation. For example, if a variety was described as both an import and an heirloom, we assigned a source designation of import, because from the American perspective, a foreign heirloom seems to be a new product.

[FN158]. Kloppenburg, supra note 14, at 50.

[FN159]. Id.; see also id. at 61 (describing Congressional programs of seed exploration and free distribution); id. at 78 (“Between 1900 and 1930 over four thousand varieties [of soybeans] were obtained from Japan, Korea, and China.”); id.

at 80 (describing plant exploration and introduction into the U.S.).

[FN160]. The Fruit, Berry, and Nut Inventory, supra note 62, claims to list 1513 apple varieties: we have culled some duplicates so our number is lower.

[FN161]. See id.; Ragan, supra note 71.

[FN162]. Heraclitus, Wikipedia, http://en.wikipedia.org/wiki/Heraclitus (last visited May 24, 2012); see also Jay Tidmarsh, Procedure, Substance, and Erie, 64 Vand. L. Rev. 877, 893 (2011) ("Reduced to its simplest expression, Heraclitus's view was that 'all things flow.' Perhaps the most vivid--and certainly the most quoted--statement of his position is that 'you cannot go into the same water twice."').

[FN163]. We chose 1981 because it is the first year after 1903 when data from all catalogs in a particular year are easily available.

[FN164]. See Briefing Rooms on Vegetables and Melons, U.S. Dep't of Agric., Econ. Research Serv., http://www.ers.usda.gov/Briefing/Vegetables/ (last updated Oct. 3, 2011).

[FN165]. Based on a search of the U.S. Patent Office website, there currently exist 134 patents for "cotton" (Gossypium hirsutum) and 404 PVPA Certificates (Aug. 13, 2011). See supra Table 3.

[FN166]. See supra Table 3.

[FN167]. See supra Table 3.

[FN168]. Olmstead & Rhode, supra note 120, at 400 ("[W]ell before plants received patent protection there was a plethora of private-sector inventive activity, where leading farmers and seed companies made significant contributions to plant improvement.").

[FN169]. See Janice M. Strachan, Plant Variety Protection in the USA, in Intellectual Property Rights in Agricultural Biotechnology 73, 76 (F.H. Erbisch & K.M. Maredia eds., 2d ed. 2004) ("Some crops were excluded from protection in the 1970s. Protection for okra, celery, peppers, tomatoes, carrots and cucumbers was added in 1980. The USA joined UPOV in 1981 under the 1978 UPOV Convention. In 1994, the US PVP Act was amended to comply with the 1991 UPOV Convention, which expanded protection to all plants. At that time, tuber-reproduced plants were specifically added to the scope of eligibility and an exclusion against F_1 hybrids was removed.").

[FN170]. See Yes, Growers Use Bt Corn Hybrids, but Refuge Compliance Still Confusing, Farm and Dairy (Mar. 28, 2011), http:// www.farmanddairy.com/news/yes-growers-use-bt-corn-hybrids-but-refuge-compliance-still-confusing/22993.html.

[FN171]. See Roundup Ready Corn Technology to Be Planted on More Than 32 Million Acres, Corn and Soybean Digest (May 2, 2006, 3:03 PM), http:// cornandsoybeandigest.com/roundup-ready-corn-technology-be-planted-more-32-million-acres.

[FN172]. See Bt-Corn Patent Unenforceable Due to Failure to Submit Internal Employee Notes, Patently-O (Jan. 25, 2008, 9:57PM), http://www.patentlyo.com/ patent/2008/01/bt-corn-patent.html?cid=98961278.

[FN173]. See Adoption of Genetically Engineered Crops in the U.S., U.S. Dep't of Agric., Econ. Research Serv., http://

www.ers.usda.gov/Data/BiotechCrops/ (last updated July 1, 2011) (showing ninety-four percent of soybeans planted are genetically engineered and seventy-five percent of cotton planted is genetically engineered).

[FN174]. See U.S. Apple Assoc., Production and Utilization Analysis 14 tbl.8 (2010), http://www.yvgsa.com/pdf/facts/USApple2010ProductionAnalysis.pdf.

[FN175]. Such claims include Smith, supra note 14, at 1288 ("Increased demands are already being made on maize breeders to further improve productivity; future demands will surely be still greater. Demands that will be made on privately funded maize breeders can only be met in an [intellectual property protection] environment in which they can conduct research and product development programs at the level of risk, persistence, and innovation to introduce new improved germplasm from exotic sources into agriculture.").

[FN176]. See supra Table 3.

[FN177]. Convention Establishing the World Intellectual Property Organization, July 14, 1967, 21 U.S.T. 1770, 828 U.N.T.S. 3, available at http://www.wipo.int/treaties/en/convention/trtdocs_wo029.html (WIPO is a specialized agency of the United Nations).

[FN178]. International Convention for the Protection of New Varieties of Plants, Dec. 2, 1961, 815 U.N.T.S. 89, http:// www.upov.int/en/publications/conventions/1991/pdf/act1991.pdf (revised on Nov. 10, 1972, Oct. 23, 1978, and Mar. 19, 1991). The objective of the Convention is the protection of new varieties of plants by an intellectual property right. Welcome, International Union for the Protection of New Varieties of Plants, http://www.upov.int/portal/index.html.en (last visited May 24, 2012). This convention is administered by WIPO. To date, there exist seventy contracting parties to the UPOV Convention, UPOV Contracting Parties, World Intellectual Prop. Org. http://www.wipo.int/treaties/en/ShowResults.jsp?treaty_id=27 (last visited May 24, 2012).

[FN179]. International Union for the Protection of New Varieties of Plants, UPOV Report on the Impact of Plant Variety Protection (2005), http:// www.upov.int/export/sites/upov/about/en/pdf/353_upov_report.pdf.

[FN180]. Id. at 88.

[FN181]. Id. ("A strong argument can be made that the importance of the PVP system and protected varieties can be assessed simply by the occurrence of protected varieties.... Individual country reports have demonstrated increases in the overall numbers of varieties developed after the introduction of PVP.").

[FN182]. Richard Carew & Stephen Devadoss, Quantifying the Contribution of Plant Breeders' Rights and Transgenic Varieties to Canola Yields: Evidence from Manitoba, 51 Can. J. Agric. Econ. 371, 371-72 (2003).

[FN183]. See e.g., John j. Wetter, The Impacts of Research and Development Expenditures: The Relationship Between Total Factor Productivity and U.S. Gross Domestic Product Performance 18 (Elias G. Carayannis ed., 2011) ("R&D is generally the initial measurement tool utilized for innovation...."); Rinaldo Evangelista et al., Measuring the Regional Dimension of Innovation. Lessons from the Italian Innovation Survey, 21 Technovation 733, 734 (2001) ("Two basic families of S&T indicators are commonly used to explore technological innovation at regional level: R&D data--collected through national surveys according to the guidelines set by the Frascati Manual (OECD, 1994)--and patent statistics, the most important body of which is represented by the data provided by the US Patent Office and the European Patent Office.").

[FN184]. Giancarlo Moschini & Harvey Lapan, Intellectual Property Rights and the Welfare Effects of Agricultural

R&D, 79 Am. J. Agric. Econ. 1229, 1241 (1997).

[FN185]. T. Dhar & J. Foltz, The Impact of Intellectual Property Rights in the Plant and Seed Industry, in Seeds of Change: Intellectual Property Protection for Agricultural Biotechnology 161, 161 (Jay P. Kesan ed., 2007).

[FN186]. See Petra Moser et al., Patents, Citations, and Inventive Output--Evidence from Hybrid Corn 4-5 (July 24, 2011) (unpublished manuscript) available at http://ssrn.com/abstract=1888191.

[FN187]. Analysts of foreign direct investment have noted that larger markets capture a disproportionate share of investment. Anthony Venables, Trade, Location, and Development: An Overview of Theory, in Natural Resources: Neither Curse nor Destiny 259, 267 (Daniel Lederman & William F. Maloney eds., 2007).

[FN188]. Nat'l Corn Growers Ass'n, 2011 World of Corn Statistics Book 3 (2011), http://www.ncga.com/uploads/useruploads/woc-metric-2011.pdf.

[FN189]. Briefing Room on Vegetables and Melons, supra note 164.

[FN190]. Anwar Naseem et al., Does Plant Variety Intellectual Property Protection Improve Farm Productivity? Evidence from Cotton Varieties, 8 AgBioForum 100, 100 (2005) (citing L.J. Butler & B.W. Marion, The Impacts of Patent Protection on the US Seed Industry and Public Plant Breeding, N. Cent. Regional Res. Publication 304 (1985)); Mary K. Knudson & Carl E. Pray, Plant Variety Protection, Private Funding, and Public Sector Research Priorities, 73 Am. J. Agric. Econ. 882 (1991); C.S. Srinivasan, Plant Variety Protection, Innovation, and Transferability: Some Empirical Evidence, 26 Rev. of Agric. Econ. 445 (2004); and M.C.F. Diez, The Impact of Plant Varieties Rights on Research: The Case of Spain, 27 Food Pol'y 171 (2002).

[FN191]. See, e.g., von Hippel, Sources, supra note 152, at 53 ("In sharp contrast to the situation pertaining in most other industries and the electronics field in particular, the patent grant often confers significant benefit to innovators in the pharmaceutical field. My discussions with patent attorneys working for pharmaceutical firms brought out two likely reasons for this situation. First unusually strong patents are obtainable in the chemical field, of which pharmaceuticals is a part. Second, it is often difficult to invent around a pharmaceutical patent."); Rebecca S. Eisenberg, The Problem of New Uses, 5 Yale J. Health Pol'y L. & Ethics 717, 720-21 (2005) ("Patent law traditionally takes the lion's share of credit for motivating investments in drug development. The pharmaceutical industry is famously dependent upon patent protection to support its R&D costs and has consistently advocated for stronger patent protection throughout the world."); Andrew V. Trask, "Obvious to Try": A Proper Patentability Standard in the Pharmaceutical Arts?, 76 Fordham L. Rev. 2625, 2629-30 (2008) ("The ability to obtain patent protection covering an approved drug product creates an incentive for pharmaceutical companies to make substantial preapproval investments in research and development, including conducting expensive clinical trials and meeting stringent requirements for regulatory approval.").

[FN192]. See Willam M. Landes & Richard A. Posner, The Economic Structure of Intellectual Property Law 84 (2003).

[FN193]. See Smith, supra note 14, at 1284.

[FN194]. See id. at 1278; see also J.S.C. Smith et al., Use of Double Haploids in Maize Breeding: Implications for Intellectual Property Protection and Genetic Diversity in Hybrid Crops, 21 Molecular Breeding 51, 57 (2008) ("A period of at least 7 and 8 years is potentially now eliminated from the time during which the parental inbred lines of maize hybrids were effectively protected by virtue of the challenges that once existed and which stemmed from access via hybrids.").

[FN195]. See Kloppenburg, supra note 14, at 92-94.

[FN196]. Id. at 105-16.

[FN197]. Id. at 91-129.

[FN198]. Id. at 129.

[FN199]. See supra Table 3.

[FN200]. See supra notes 49, 19, and accompanying text.

[FN201]. See Kloppenburg, supra note 14, at 137 ("The challenge facing the American seed industry was to obtain protection without losing its freedom to release varieties 'of obvious or dubious merit."').

[FN202]. See supra note 48 and accompanying text.

[FN203]. See Moser et al., supra note 186, at 3 ("On average, patented hybrids yield 1.06 less corn and 1.06 less income than the highest yielding existing hybrids.").

[FN204]. Id. at 3-4 ("On average, hybrids that were patented between 1998 and 2005 yield 2.10 percent less corn and 2.00 percent less income than existing hybrids.").

[FN205]. Julian M. Alston & Raymond J. Venner, The Effects of the US Plant Variety Protection Act on Wheat Genetic Improvement, 31 Res. Pol'y 527, 541 (2002).

[FN206]. Id. at 527.

[FN207]. See R.K. Perrin et al., Some Effects of the U.S. Plant Variety Protection Act of 1970, in Economics Research Report, at 36 (N.C. State Dep't of Econ. and Bus. Report No. 46, 1983) ("[I]mprovement .... is significant only at the 16 percent confidence level ...."); Bruce A. Babcock & William E. Foster, Measuring the Potential Contribution of Plant Breeding to Crop Yields: Flue-Cured Tobacco, 1954-87, 73 Am. J. Agric. Econ. 850, 858 (1991); Carew & Devadoss, supra note 182, at 391.

[FN208]. Corinne Alexander & Rachael E. Goodhue, The Pricing of Innovations: An Application to Specialized Corn Traits, 18 Agribusiness 333, 333 (2002).

[FN209]. See Judith I. Stallman, Impacts of the 1930 Plant Patent Act on Private Fruit Breeding Investment (1986) (unpublished Ph.D. dissertation, Michigan State University) (on file with authors) ("[T]he 1930 Plant Patent Act has had very little impact on private investment in fruit breeding.").

[FN210]. See Petra Moser & Paul W. Rhode, Did Plant Patents Create the American Rose? 23 (Nat'l Bureau of Econ. Research, Working Paper No. 16983), available at http://www.nber.org/papers/w16983 ("[T]he data indicate that U.S. breeders contributed fewer varieties after the creation of patents in 1930.").

[FN211]. See id. at 2, 19.

[FN212]. See Janis & Kesan, supra note 26, at 754.

[FN213]. Id. at 775.

[FN214]. W. Lesser, Valuation of Plant Variety Protection Certificates, 16 Rev. Agric. Econ. 231, 231 (1994).

[FN215]. G. Moschini & O. Yerokhin, The Economic Incentive to Innovate in Plants: Patents and Plant Breeders' Rights, in Seeds of Change: Agriculture Biotechnology and Intellectual Property 190, 194 (Jay P. Kesan ed., 2007).

[FN216]. Naseem et al., supra note 190.

[FN217]. Id. at 106 ("Because we have not accounted for other factors that may influence yields, an extension of this study should incorporate the influence of weather, insect pressure, and changes in management practices on yields. For example, if pest pressure in some periods reduced yields, the impact of new yield-enhancing varieties would not be apparent, especially if the yield-reduction effect (from the pests) were greater than the yield-increasing effect (from the new variety).").

[FN218]. See Olmstead & Rhode, supra note 120, at 155-98 (explaining massive pest control program undertaken by the USDA designed to wipe out the boll weevil; over one-half of the entire U.S. expenditure on pesticides were spent in this program in some years).

[FN219]. See Deepthi Elizabeth Kolady & William Lesser, Does Plant Variety Protection Contribute to Crop Productivity? Lessons for Developing Countries from US Wheat Breeding, 12 J. World Intell. Prop. 137, 141, 147 (2009).

[FN220]. Id. at 145.

[FN221]. Moschini & Lapan, supra note 184, at 1229.

[FN222]. See Sergio H. Lence et al., Welfare Impacts of Intellectual Property Protection in the Seed Industry, 87 Am. J. Agric. Econ. 951 (2005).
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