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# Socioeconomic Obstacles to Establishing a Participatory Plant Breeding Program for Organic Growers in the United States

**Ruth Mendum and Leland L. Glenna ***

Department of Agricultural Economics and Rural Sociology, Penn State University, University Park, PA 16802, USA; E-Mail: rmm22@psu.edu

* Author to whom correspondence should be addressed; E-Mail: llg13@psu.edu; Tel.: +1-814-863-8636; Fax: +1-814-865-3746.

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**Abstract:** Proponents of participatory plant breeding (PPB) contend that it is more conducive to promoting agricultural biodiversity than conventional plant breeding. The argument is that conventional plant breeding tends to produce crops for homogenous environments, while PPB tends to be directed at meeting the diverse environmental conditions of the farmers participating in a breeding program. Social scientific research is needed to highlight the complex socioeconomic factors that inhibit efforts to initiate PPB programs. To contribute, we offer a case study of a participatory organic seed production project that involved a university breeding program, commercial organic seed dealers, and organic farmers in the Northeastern United States. We demonstrate that, although PPB may indeed promote agricultural biodiversity, several socioeconomic obstacles must be overcome to establish such a program.

**Keywords:** agricultural biodiversity; socioeconomic context; plant breeding

## 1. Introduction

Agricultural biodiversity is critical for the world's food system because the loss of biodiversity in agricultural crops increases the vulnerability of the food system to pests and fungi. It is also important for efforts to develop crops for poor soil fertility and drought resistance, as well as for generating a diverse diet and stable food production system [1-3]. However, our current agriculture system is moving towards less biodiversity. Altieri contends, "modern agriculture is shockingly dependent on a handful of varieties for its major crops" [2]. The decline in agricultural biodiversity is primarily a product of industrialized countries, but which threatens food security in developing countries [4]. This threat includes a lack of diversity of crop cultivars, as well as non-crop plants and animals inhabiting agricultural lands [5]. Since the early 20th century [e.g., 6-8] plant breeders have warned that conventional plant breeding, that is, exclusively crossing between elite germplasm lines, would drive diverse cultivars and non-domesticated plants from the planet. Climate change may exacerbate the crisis. An FAO report warns that climate change is very likely to have negative effects on agricultural ecosystems and that this will heighten the need for diverse genetic resources in agriculture [3].

Though agricultural biodiversity is often treated as a technical matter, scholars are increasingly acknowledging the socioeconomic dimensions of this problem. Indeed, there is a growing recognition that agricultural sustainability, in general, and biodiversity, specifically, is the product of the dynamic interaction of "healthy ecosystems, vital economies, and social equity" [9]. Fowler has pointed to the need to understand the socioeconomic conditions that have created the problem [1]. Gepts claims that the high-input, mass production agricultural system is "the single most important threat to biodiversity" [10]. The argument linking the socioeconomic organization of agriculture to agri-ecological conditions is important because it shifts attention from a focus on individual farmers, individual agricultural scientists, and technological quick-fixes to a focus on the socioeconomic contexts that are promoting problematic outcomes. Existing research funding policies, knowledge and technology transfer policies, institutional incentives, and university researcher relationships are in place to promote the current high-input conventional agricultural system. If it is as Busch *et al.* have argued, that "societies or communities constitute nature" [11] then it is necessary to consider how to alter those socioeconomic relations of agricultural research that inhibit the promotion of sustainable interaction between society and nature.

The creation of a seed bank in an island off the coast of Norway has been one well-publicized effort to stave off crisis from the loss of agricultural diversity. Many nations, and universities and agricultural organizations within nations, have storage facilities to preserve diverse seed varieties, many of which are no longer planted by farmers. The Svalbard Global Seed Vault, however, serves as a repository for a diverse array of seeds that could presumably withstand a global catastrophe [12,13]. The rationale behind these seed storage facilities is that when crops are ravaged by a novel form of a fungus, for example, plant breeders will be able to search the seed vaults for varieties that are resistant to the fungus and breed it into the crop.

A second vital strategy for preserving seed relies on networks of farmers and gardeners who share rare varieties of food and ornamental crops with each other in the hope that, if one geographic area experiences crop failure, the varieties will survive elsewhere. In the United States the most prominent of these organizations is Seed Savers Exchange, which has saved thousands of otherwise rare vegetable, herb, and flower varieties that may not have been saved in the US national gene bank.

Although saving diverse seeds using a vault or a geographic network strategy may serve as a reassuring backstop in the face of global crisis, it must be recognized that such approaches are insufficient. After all, it would take years to convert seeds stored in a vault or held by individual farmers and gardeners into something that could begin to address wide-scale crop collapse. Furthermore, the network approach presumes that hundreds of widely disbursed individuals have the skill, land, time and expertise to maintain pure varieties in perpetuity. A more effective approach to the problem of the loss of agricultural biodiversity is to expand the genetic diversity of the crops currently in production. However, such a transformation requires reform of the agricultural system [11].

Recognizing the need for reform to address the problem is welcome. One promising approach to addressing the problem is participatory plant breeding (PPB). PPB refers to "a type of breeding which is done in collaboration with farmers and is based on selection for specific adaptation" [4]. Although PPB is a promising model, there is limited social scientific research on the socioeconomic obstacles that need to be overcome to establishing a PPB program. This paper focuses on a PPB approach to developing organic seeds that might serve as a model for the types of socioeconomic reforms conducive to agricultural biodiversity. After describing key features of the high-input, globally integrated agricultural system that have promoted the loss of agricultural biodiversity, we turn to a case study of a promising participatory approach to agricultural research in the U.S. and highlight obstacles that had to be overcome to establish the program. We also point to obstacles that contributed to the termination of the program.

## 2. Socioeconomic Interconnections of Agricultural Research and Agricultural Biodiversity

One of the goals of scientific agriculture in the United States, especially with the establishment of the US Department of Agriculture, was to discover and diffuse new and diverse crop varieties. Originally, those seeds were distributed free of charge. However, as Busch *et al.* observe, "As U.S. agriculture has been transformed, the diversity of crops growing in the field has been modified and usually narrowed in response to the changing demands of an increasingly industrialized society" [11]. In a general sense, this occurs because industrialization has led to fewer farmers specializing in fewer crops. However, there are also at least three ways that the socioeconomic organization of agricultural research contributes to this loss of biodiversity.

The first is that agricultural industrialization tends to promote homogenization of crop germplasm. In the interests of supporting the large conventional farmers and the transnational seed industry, plant breeders tend to select for germplasm that meets industrial goals of maximizing yield, uniformity in the field, and productive efficiency. Crop and soil scientists have argued that declining genetic diversity has been an indirect goal of conventional crop breeding, as plant breeders have generally developed crop varieties for homogeneous optimal environments. The assumption is that inputs, such as synthetic agricultural chemicals, can make marginal cropping environments conducive to growing a few high-yielding varieties or that by boosting the productivity of prime farmland, marginal lands can be used for other purposes [14-22].

The second is that the scaling up and standardization of agricultural production methods has created a paradoxical role for agribusiness in the agricultural research arena. Kloppenburg describes this paradox at work in the example of the development of hybrid corn [23]. He explains that hybrid corn provided a kind of biological patent to its developer, because the seed from hybrid corn could not effectively be saved and replanted the next year. Therefore, promoting hybrid corn offered an incentive for private industry to invest in agricultural improvements, since they could charge for the seeds year after year. Kloppenburg contends that the patent protection that accompanies genetically engineered crops provides a similar incentive for private investment in agriculture. The problem is that, although private investment and potential private profit may bring energy to the research process, it will also tend to narrow the scope of the research to those things that can be commercialized.

Welsh and Glenna describe how universities have traditionally been responsible for research on minor crops and traits that may be socially valuable, but with limited commercial potential [24]. However, they point out that the rise of genetically engineered crop research may be altering the university's public-interest focus. Private sector firms have dominated the research, development, and commercialization processes for genetically engineered crops. According to their findings, as universities collaborate with private companies to conduct research on transgenic crops, university research on those crops has increasingly mirrored the research profile of for-profit firms.

The third challenge is that the narrowing of the agricultural research focus to a smaller number of commercially profitable crops has led to a decline in the number of university plant breeders and the demise of the agricultural extension system that once connected those breeders to farmers. The hyperbole about genetically engineered crops bringing solutions to world food problems has led to the decline in funding for classical plant breeding and in numbers of classical plant breeders, and shifted research efforts from public to private efforts [25]. The interests of small, sustainable, and organic farmers have received little attention from universities that have increasingly focused on high-input, mass-production agricultural research [26-32]. Studies often emphasize that the land-grant university system favors conventional agriculture, making it necessary for farmers interested in organic and more sustainable agriculture to conduct their own research and to share the information through interactions with other farmers [26,30]. Farmers recognize that there may be local social, economic, and ecological conditions that can best be addressed through conversations with others who are dealing with the same conditions [26,28-30].

An alternative approach does exist. Terms used to describe this approach include, PPB, evolutionary-participatory plant breeding, or decentralized plant breeding [22,33-36]. As noted earlier, Ceccarelli defines PPB as plant breeding that involves collaborations with farmers to select for specific adaption [4]. Though details often vary with the labels, the approach generally involves professional plant breeders, either university or international crop improvement center employees, working together with farmers in various ways to develop new plant varieties.

PPB emerged primarily to address issues for the developing world, with specific applications for poor farmers in marginal areas [37]. However, it is also applicable to low-input and organic farmers in the U.S. Although the participatory programs operating in developing countries tend not to explicitly serve organic farmers, low-input and organic farmers in industrialized nations can benefit from participatory research. PPB programs serving low-input and organic farmers promote agricultural biodiversity in developing or industrialized nations, because they replace breeding for homogenous environments with breeding for heterogeneous environments [22,35,38]. The implication is that breeders under the PPB paradigm seek to fit crops to environments, not environments to crops.

The benefits of agricultural biodiversity emerge from the emphasis on adapting crops for particular areas, not for broad spatial applications [37]. Proponents of PPB recognize the inherent evolutionary aspects of plant breeding. For example, Ceccarelli observes that plant breeding is human-guided plant evolution and that human beings and plants have evolved together for millennia [4]. Farmers living in diverse environments grew crops and saved seed each year for thousands of years, which generated crops that were well suited for the particular environments. In contrast, the high-input, mass-production approach to production promotes homogenization. To restore the biodiversity-enhancing aspects of plant breeding, expert plant breeders collaborate with farmers involved in crop production and seed selection to meet the needs of their diverse environments. Relatively variable populations are maintained so that any given farmer facing specific challenges and using particular production methods will be able to cultivate a successful crop [35]. Therefore, this method of plant breeding would serve to promote diversity of crop varieties as each farmers select seeds for heterogeneous environments.

This study focuses on a PPB program that set out to collaborate with organic vegetable farmers in the Northeastern U.S. This program is important because it was the first attempt to adapt PPB methods to organic vegetable crops in a region of the U.S. that involves primarily small farmers facing variable and difficult climate and terrain. Until now, much of the PPB work has been done on grain crops. Examples include wheat and barley crops that were developed for marginal conditions, such as drought [35,37]. Like other PPB programs, this program is relevant because its founding members conscientiously sought to reform socioeconomic relations of agricultural research. As we have noted, PPB involves collaborations between plant breeders and farmers. The program we studied fit that description, but it also established collaborations with small seed companies. Furthermore, through interaction with farmers and seed companies who sought to incorporate or anticipate consumer tastes, this PPB program came to include efforts to adapt for consumer preferences as well as environmental conditions. Our case study of this PPB program illuminates general obstacles that university researchers need to overcome to establish a PPB program in the U.S.

## 3. Method

Data for this study were collected over four months during the summer of 2006. It included intensive interviews with project participants, analysis of documents (including grant application materials, material transfer agreements, and letters of support from participants), and participant observations at meetings, workshops and field days. Approximately 250 farmers in the Northeast took part in the Seed Project over the course of the project. For this study, we interviewed 15 farmers on their farms or at Seed Project workshops. Of those 15 farmers, seven had farms smaller than 20 acres, and eight had larger farms. The larger farms were about 100 acres each, with one almost 1,500 acres. Most farmers sold to multiple outlets, but four sold through their CSA, and two sold only through farmers’ markets. Farmer informants were almost evenly split between men and women (eight men and seven women). Both men and women held leadership positions in the farmer's organization and four women farmed without men working in their businesses, except as occasional labor.

Other participants involved in the project included PhD breeders, the technical staff that did much of the daily breeding work, and USDA personnel who supported the project. Considerable time was spent at the primary university observing the work involved in field-based plant breeding over the course of a season. Face-to-face interviews were conducted with 45 people (See Table 1). Interviews were generally one hour in length and were transcribed for analysis.

**Table 1.** Characteristics of informants interviewed.

| Type of Informant | Number Interviewed |
|---|---|
| University-based Breeders | 10 |
| University-based Technical Staff | 4 |
| Other University-based | 4 |
| Farmers, non-breeders | 16 |
| Farmer/Breeders | 2 (2) |
| Farmer's Representatives | 3 |
| Industry-based Breeders | 5 |
| USDA Personnel | 1 |
| Total | 45 |

## 4. Case Study: Results and Discussion

The research described here under the rubric of the Seed Project began as an outreach component of a much larger government funded genomics grant won by a well established, tenured plant breeder at a land-grant university in the Northeastern US. The project was funded as an expanded, national stand-alone project with the stated goal of expanding developing vegetable varieties for organic growers in all relevant regions.

The Seed Project consisted of a package of PPB activities that included four stages: product design, product development, product testing and product marketing (for discussion on the four stages of PPB, see [19]). These were supplemented by several specific additional activities including: intellectual property management, providing equipment and training with small scale seed cleaning machinery, coordinated network-building among all involved institutions and participants, and expanded outreach that included what might be called consciousness raising among growers and alternative agriculture supporters about breeding opportunities for non-professional breeders. The project made research results and training materials available to the general public on a website.

Although it ended because of an inability to secure additional funds, the Seed Project did yield outputs in addition to training and information, largely because the project team was able to harness resources from a number of other ongoing projects. In 2007, the final funded year of the program, eight projects associated with the Seed Project had produced new varieties or breeding lines. These crops included cucumber mosaic virus resistant peppers, improved Costata Romanesca squash, improved heirloom melons and cucumbers, and a superior organic broccoli. Other projects were in earlier stages, including one project focused on tomato and two involving seed potatoes. Given the very short duration of the program, these were considerable results.

In both of its three-year iterations, the Seed Project sought to connect five distinct classes of agents into a multi-directional network: the host university, a group of small seed companies, the Experimental Station, the regional farmers' association, and individual farmers. Some of the seed used by the project had come from seed companies originally, but was passed through the project so that the trialing results could be tracked by the university staff.

The collaboration between academics, seed companies, and farmers enabled participants to do more work collectively than if the university scientists had worked alone during the outdoor growing season, which begins in late winter and ends after the last frost in September or October. The breeding process at its most basic requires that plants be grown out, selected, and (cross) bred. Then the seed from the resulting fruits are grown out in turn. A big greenhouse facility can save time by allowing breeders to grow out a generation over the winter. Even with that sort of assistance plant breeding remains a slow process that takes years. For all practical purposes a program like the Seed Project would be cycling countless types of vegetables: sweet peppers, squash, broccoli, and tomatoes. Within each breeding project, there might be specific goals. For example, they might be trying to develop a squash with a shape like a conventional zucchini, but with better flavor and disease resistance.

The Seed Project was able to speed the process by sharing responsibilities with the participating farmers and seed companies. Over the winter, the Seed Project distributed to participating farmers lists of varieties that had been divided into A, B, and C categories. The A lists included many varieties that were already on the market through participating small seed companies who wanted feedback from farmers about the performance of their product. The B list contained less developed materials. And the C list was explicitly experimental seed. For each packet of seed the farmers received, they were asked to return an evaluation form which was then uploaded into a database and collated. The university was also willing to license unfinished materials to seed companies who desired to do their own breeding. The only request was that the licensing fee be paid to the university if the material was integrated into a new variety that was successful.

The farmers responded to the Seed Project initiative with information about Northeastern US organic conditions, their specific breeding goals, the results of on-farm seed trials and breeding goals. The farmers' association served primarily as a networking agent. However, as the project entered a second phase, and as a third phase was considered, the representatives of that group sought to incorporate the perspectives and opinions of their membership to the professional breeders.

In the science studies literature, there is often an emphasis on networks being generated through a decentralized, co-constituitive process [39]. However, in this instance, the network that emerged was deliberately initiated and organized by a well-placed and experienced academic. This is not to say that the idea was imposed upon the farm community. The letters of support for the second grant application written by the then-executive director of the farmer's organization was five pages long and outlined the needs and expected impact the project would have on farmers. Furthermore, there were preexisting relationships between farmers and seed companies. Some farmers had existing relationships with university breeders and experiment station staff.

Despite some preexisting relationships, one of the first obstacles that the program needed to overcome was the lack of established collaborations between the organic farmers and the university. The farmers interviewed were small, organic farmers who had received relatively little assistance from land-grant universities and generally felt neglected. When asked what kind of relationship organic farmers had to research entities, a key representative of the farmers' association responded:

> I think there hasn't been one. You know, because organic farming in this country started to develop in the early '70s and until the mid '90s, it was so low on the radar, nobody was paying much attention to it in the academic community, certainly not breeders who were, again going with market forces desperately. Just in terms of commercial breeding, they were breeding for large scale vegetable operations. So I think that there hasn't been

> a relationship at all, and that's certainly true not just of breeders, but most of the research—or the entire research community. So this is all new.

From this farmer's perspective, the small-scale organic community was "off the radar", unnoticed by and isolated from researchers. To bridge the gap, the academic plant breeders had to reach out to these alienated farm groups.

Despite the need to overcome estranged university-farmer relations at the outset, the Seed Project eventually received strong support from farmers and small seed companies. Both famers and companies expressed a need for assistance from university breeders in their letters of support. The list of seed company supporters in the first grant proposal included large companies as well as six small seed companies that serve the Northeastern organic market. Letters from those small companies, which were written in 2000, outline organic farmers' needs for access to plant germplasm. The letters indicated explicitly that loss of agricultural biodiversity is already a problem for small seed businesses. And they indicated an inability to address the situation without the help of university researchers. An excerpt from one letter is illustrative:

> Ten years ago we…realized we would have to move into small-scale primary seed production, even though we had no such intentions when we founded the company 23 years ago. It was the only way we could find and retain the specialty varieties now demanded by our customers that were otherwise disappearing from the trade. We have combed the Seed Savers Exchange and other seed-saving organizations for unusual specialty varieties and old regional favorites and bootstrapped our way into primary seed production. Today we control production of about 11% of our line. But we need help. Our growers could benefit from better germplasm with more disease resistance, they need technical support to increase their expertise and make their operations more economically feasible, and many need to be able to grow on a larger scale to meet our growing needs and the increased interest shown by the burgeoning sustainable agricultural network.

This company began its life as a seed distributor, buying seed from producers in bulk, then repackaging and selling smaller quantities to gardeners and farmers mostly in the Northeastern US. The circulation of usable germplasm had become so constricted in the intervening period that they were forced to become seed producers, contracting directly with growers to produce varieties.

This indicates how the intersection between the concern about genetic erosion and organic farming directly overlap. Small scale and organic farmers are pushing the limits of what the conventional plant breeding and distributing sectors can provide. Organic farmers could once use the varieties in commercial circulation. However, by the mid-1990s, according to this seed company founder, genetic erosion had occurred, so that specialty and regionally adapted varieties were no longer available. Germplasm circulation had become so constrained that alternative farmers and gardeners were forced to look to small companies willing to engage in primary seed production for their seed. As a small company this business would not have the resources to engage in extensive plant breeding itself. Instead it searched through the seed resources of the Seed Savers Exchange and other related groups for varieties that could be transformed into usable commercial varieties. Unfortunately those sources fall short of the resource base needed to serve organic farmers. The letter also highlighted the problem of the loss of university-based traditional plant breeders:

> Who will serve these growing needs? Only a handful of classical plant breeders from a few universities remain. Few are working with superior open-pollinated cultivars, and not all of this limited work is even getting out to the sustainable farming community which it could so benefit. ... the Principal Investigator proposes to open up the riches of her university's classical breeding program, one of the last good ones and one of the best, to the sustainable farming communities. Until now, small seed companies ... have not had access to its breeding pipeline. ... our company, while still very small by industry standards, has an influence disproportionate to its size, and has often been at the cutting edge of reintroductions of heirloom and open-pollinated varieties which caught on with a larger consuming public and spread to other sometimes larger, seed houses.

The important insight here is that organic farmers and small seed companies have become disconnected from the germplasm and expertise in university breeding programs. The seed company representative made clear that while this particular company had begun bringing older varieties back onto the market, they were handicapped by limitations in expertise and access to disease resistance.

A plant breeder from a different company pointed to two additional barriers that keep plant breeding knowledge and germplasm resources from reaching the organic community: the tendency of large commercial entities to breed for optimal conditions and homogenous environments and the lack of communication between public breeders and those who work on heirloom varieties.

> In the commercial vegetable seed industry, there has been an alarming trend in recent years to conduct research in new variety development that is very specific to the needs of the largest market segments. In vegetable crops this ultimately means we are breeding for the environmental conditions and cultural management techniques of the large-scale California farmer. These growers use a large number of chemical inputs and have very specific mechanized management practices. Because of this, the varieties that are successful under their systems are often what breeders call “prima donna” varieties, varieties that stand out only under very specific, favorable conditions. Consequently, much of the plant breeding of the past, that developed “workhorse” varieties that were hardy across a range of environments, even under less than optimal conditions, is diminishing in its importance at the large seed companies. Meanwhile, on a weekly basis, I get complaints from growers in other market areas of North American that are frustrated by the lack of adaptable, sturdy vegetable varieties that are suited to their market needs.

Since 2001 when this letter was written the organic market in California has expanded and there may be some breeding directed towards those needs [40]. However, even when organic seeds are developed for the California market, they are developed for large-scale systems and for California’s climate. These characteristics are not necessarily useful for the northeastern part of the US. Vegetable crops can sometimes need to vary within very small geographic spaces. In some cases, geographic variation might be driven by consumers. For example, one plant breeder explained how variable consumer demand for squash can be:

> But in terms of horticultural types, particularly in squash, the subtlety of differences in pigmentation, in fruit shape and size, can change a market 50 miles apart in one part of the country; it is very narrowly defined. You'll get customers that say, oh, it has too much speck; no, not enough speck; oh, it's just not the quite the right shade of green...

The key point here is that a particular kind of knowledge, how to create workhorse varieties that will thrive in diverse conditions, is no longer circulating. Even in cases where the germplasm was available, the breeding capacity was locked up in large companies where it was directed toward other goals. The existence of the germplasm itself is only part of what is required to ensure the flow of appropriate varieties to the commercial markets and on to organic farmers. Because the varietal breeding networks have left farmers, seed companies, and public breeders isolated from each other and unmotivated or unable to bridge those gaps, there is a systemic obstacle to developing agricultural biodiversity. In the absence of the kind of work that the Seed Project set out to do, the quality of the organic seed bank will continue to decline.

The Seed Project helped to bridge some of those systemic gaps. This enabled farmers to gain access to expertise and germplasm. At the same time, it is important to recognize how the collaboration with farmers changed the university plant breeders' research agendas. The farmers interviewed for this research often harvested and processed their crops by hand or had members of their Community Supported Agriculture organizations do that work. Because all but one of the farmers had farms under 200 acres (half under 50), the key to their economic viability was to reduce capital inputs as much as possible. On the positive side, they were all selling locally and so they did not need crop varieties with some of the shipping characteristics that California organic enterprises would need. Yet, farmers repeatedly mentioned the need for organic seeds to meet the tastes and interests of their consumers.

Since culinary interests of consumers were being represented by the farmers, the university plant breeders were encouraged to breed for non-agronomic plant characteristics. For example, a farmer with twenty years of experience described her efforts to meet the culinary demands of her customers:

> We grow two squashes that probably nobody else grows, zucchini and yellow squash. We grow odd varieties. One that we like better that probably has maybe uniqueness to it. I mean, everybody has the standard green zucchinis and standard yellow squash and we like to trial and find ones that taste better, or—I don't know if a zucchini can taste better, but—sometimes the skins are tough, and so we've chosen a couple of varieties that we like better. People come up and say, "What is that?" And it gives you an opportunity to say, "Well, these are varieties that we've trialed and we like better and we think they taste better and they're more tender and less seeds inside." ... They usually ask or they usually look weird at the bin—but they usually read our signs. We're pretty good at marketing and putting signs out so people know, "new variety of zucchini" or "give it a try" or something like that.

Important in this informant's observation is the way in which she uses unique varieties to enter into conversations with her customers. Because most of the farmers in this study were selling directly to their customers in markets where fresh vegetables are relatively common in local grocery stores, varietal variation and uniqueness combined with a personal relationship with the customers were frequently cited in interviews as a crucial factor in seed selection. Without diverse seed it becomes more difficult to differentiate one's product from others, according to the farmers.

Again, however, the ability of the farmers to develop these different varieties was constrained by their lack of expertise and access to germplasm. As the farmers and seed company representatives pointed out, the quality of the varietal selections is diminished when university breeders are not involved. Farmers and seed company breeders need access to disease resistance and other features that can be found in research collections. Those collections reflect adaptations crafted by earlier generations of both farmers and breeders. However, many of those materials are not currently publically accessible. A seed company that supplied these farmers characterized the issue this way:

> Many of the growers in the specialty and organic market segments are turning to heirloom vegetables as an alternate source of varieties for their markets. While the heirloom varieties may have desirable traits like superior flavor, good texture, beautiful color, and may even have some strong adaptive qualities, they often lack the disease resistance, yielding ability or type of plant habit to make them suitable as modern cultivars. Unfortunately, many of these growers are unaware of the existence of improved public varieties that university breeding programs ... are still producing.

Without skilled intervention and broad access to genetic material, organic farmers are at undue risk for crop failure. Germplasm for crucial traits must be publically available to be used. Farmers and others will have difficulty collecting the material they need because it is already owned by someone else or because collection work is expensive and involves travel, storage and benefits from expert analysis. Small regional companies too lack the time and money to breed enough to fill the increasing demands. Moreover, farmers need training to ensure that they maintain varietal integrity. Such training is especially important for organic farmers entering the profession with no previous farming experience. In other words, the existing socioeconomic relations of agricultural research needed to be transformed to enable the development of this program.

Another important obstacle that had to be addressed was the post-harvest processing: cleaning, processing and storing seed for sale. Several farmer/breeders described how seed cleaning, separation, and harvesting machines were hard to find. If one could find the old machines that operated on a small enough scale, maintaining and learning to operate the machines without any accompanying instructions or replacement parts demands significant technical and mechanical expertise.

As a result of this need, the Seed Project included in its initial and follow-up grant applications the request for funding to purchase and provide instruction on small-scale commercial seed cleaning and separating machinery. The experiment station's primary role in the project was to house the seed cleaning machinery and train growers in its use. On-farm workshops were also used. At one on-farm workshop led by the staff of the USDA experiment station that served the lead university, all of the machinery purchased by the project was demonstrated using seed that the host farmer had provided or that the attendees had brought with them. Participants were given the chance to juice tomatoes, blow chaff out of brassica seed, and examine the resulting products. One of the workshop presenters inadvertently demonstrated the risks of small scale processing when a piece of the air column used to separate chaff from seed came undone, blowing several cups of seed into the demonstrator's hair and clothes. Everyone laughed but the victim told the story of a similar incident when a workshop participant brought a laboriously collected handful of seed from a variety no longer commercially available. As the priceless and irreplaceable seed blew out into the air, the demonstrator realized that some of the seed had stuck to her wool sweater she was wearing. Thanks to the sticky characteristics of wool, the seed could be rescued.

These incidents illustrate how much seed saving and plant breeding are influenced and possibly derailed by a series of technical and mechanical processes. Intentionally or not, the infrastructure that takes a seed from germination to replanting has withered, leaving behind underserved farmers, overburdened small seed companies, and an increased danger that the diversity of domesticated crops necessary for a healthy vegetable producing farm sector, will disappear. The testimony of farmers and seed companies indicates that a comprehensive and integrated approach needs to include the post-harvest processing and storage issues as well as the actual breeding itself.

*Enduring Obstacles to the Project's Success*

The subsequent discussion highlighted several obstacles that university plant breeders faced when generating a PPB program. These obstacles are indicative of broad societal trends. The tendency for university scientists to conduct research more useful for large farmers and large agribusiness and to neglect smaller farmers and organic farmers is national phenomenon, after all. Some of these obstacles were mechanical and technical problems, which could be overcome with concerted efforts. Some of the relational obstacles, such as the estranged relations between organic famers and university breeders, could also be overcome when plant breeders made efforts to build the relationships. However, additional socioeconomic obstacles were more difficult to overcome. One such obstacle, which we mentioned earlier, is the decline in the number of traditional plant breeders. Without trained plant breeders, it is unlikely that PPB programs will emerge around the U.S. or globally. Two additional obstacles also emerged in the course of the Seed Project's existence: intellectual property policies and federal funding policies for university research. Unlike the relational problems, these obstacles are entrenched in legal and policy structures.

As we noted earlier, university agricultural research has a paradoxical relationship with the private sector. University research is expected to produce public goods that are accessible to all. However, private agribusinesses and private farmers seek to profit from their activities. Legislation, such as the 1980 Bayh-Dole Act, sought to convert the products of university research into intellectual property, so that the private sector can use it [23]. One of the challenges that this creates is that establishing intellectual property for germplasm may limit the germplasm's availability to small seed companies and farmers. On the other hand, establishing intellectual property for germplasm may protect that germplasm from biopiracy.

The Seed Project overcame the dilemma by retaining control of the intellectual property, even when the property rights being protected were owned by a private company. By retaining control, the university was able to promote accessibility. The Seed Project also streamlined the approach and made the process of obtaining farmer consent easier. However, the improved property agreements, called materials transfer agreements, were not developed to ease farmer concerns. They had been created several years earlier because seed companies, large and small, had expressed discontent with the long, legalistic documents. The technical administrator who oversaw the simplification of the documents explained how, at first, a researcher who worked on a wide variety of programs for many kinds of seed companies alerted him to the problematic language of the agreements that was creating an oppositional relationship between the university and the seed companies:

> ... [in] 1999, when a member of the faculty who was a vegetable breeder came to me and said I'm up to my eyeballs with this licensing frustration here, and I'm sick of dealing with a group of lawyers who don't pretend to understand what it is we do or how we do it. ... they are limiting my ability to get my work into use because they're terrorizing companies with these pages and pages of paper that they send out.

What this administrator is describing is the importance of refining legal documents to promote respectful and cooperative socioeconomic relationships between the university and private corporations. It demonstrates that even in an economic exchange, there are long-term relationship factors at play. Seed companies were less interested in accessing materials from a university that they believed was overly restrictive and protective. The more user-friendly material transfer agreements were also useful when approaching small organic seed companies and organic farmers.

By the time the Seed Project was in operation, the standard form was one-page long, written in clear English, and stated only that if germplasm belonging to the university was used in the creation of new materials, the university must be notified and the appropriate fees paid. Those fees were 5% of net profit, which was used to pay for summer field help. Not all the organic farmers supported the idea of intellectual property protection. However, many did. For example, when asked if he felt comfortable signing such agreements, a farmer with many years of experience, replied: “I'm fine. I trust the—I sort of believe in the process so I'm happy to do so.” He added later that the royalty seemed fair, “since we've—we're cooperating with one another…”

Not all seed companies were entirely vigilant in paying their licensing fees. One of the project’s technical administrator’s responsibilities was to review seed catalogs to ensure that if one of the project’s new varieties emerged from a company where parent seed had been sent, the company in question could be called and gently reminded of their responsibilities.

One important factor in the collaboration was that the seed companies participating in the Seed Project were not transnational agribusinesses. They were small, farmer-friendly, organic and untreated seed providers. These were the same companies from which the farmers routinely bought their seed. Furthermore, organic farmers are themselves small business people who believe that breeders should be compensated for the work that they do. Even when they raised concerns about current U.S. intellectual property policies, farmers expressed what they described as the fairness of paying commercial and university-based breeders for the seeds they produced, just as farmers want to be paid for their produce. As the one farmer put it in the above quotation, he considered it “fair” within a cooperative relationship between the farmers and the university.

Although the intellectual property obstacle was overcome with bureaucratic streamlining and improved communication, the challenge of long-term funding became insurmountable. The national policy shift from formula funding to competitive funding privileges short-term, cutting-edge research that is defined as important at the national level, as opposed to long-term research projects directed at solving state-level problems [41]. The Seed Project's existence was tied directly to its funding source and was sustained by two phases of grant funding. In the text of the first grant application the Seed Project was described under the heading, “Integration of Education and Extension Activities with Proposed Research.” It is important to understand the distinction here between research and extension as it is used in this case. Although some faculty at land-grant institutions engage in extension education research, the principal investigator in this case was a plant breeder and geneticist and as such was not responsible for extension research. Her laboratory produces plant varieties that can be promoted by extension agents in the state extension system among other things, but her scientific work is on the biology of plants, not the efficacy of extension. She can also engage in extension activities directly, as she did in this case. But those activities do not represent plant breeding or genetics research.

The emphasis on research and outreach created benefits and obstacles to pursuing research funding for the principle investigator. Competitive research funding requires that the project set out to do something new, and combining research with outreach to develop the seed project introduced something new. However, the maintenance of that network becomes constrained, since it is often difficult to package an on-going project as something new for a competitive grant process.

This situation created problems in the efforts to renew the proposal. Academics involved in the project were discussing ways to develop something new. To secure funding for the second round of the Seed Project, the decision was made to expand the Seed Project from a regional to a national project. When considering applying for a third round of funding, discussions moved into marketing processes. A representative from the farm group expressed concern about “veering away from the activities”, because he thought that bringing new ideas into the project would make it unworkable. The farmer did not understand that the project had to innovate in order to secure additional funding. By contrast, the academics were savvier. Commenting on the need for “newness” in the competitive process, one breeder stated:

> In reviewing this new call I actually think this was written to avoid us to some extent, and I’m kinda not kidding. I don’t mean to sound paranoid but I think when we think about where this was at the beginning, this was written around the project to some extent and I understand exactly why and I would have done exactly the same thing so I’m actually hearing and seeing a lot of not only social but economic pulls here and I wonder, I think if we try to come in as [Seed Project] II, we’ll get shot down right away. So, I think strategy-wise we really have to focus on thinking ourselves, getting clear to ourselves what it is we have created that will not go away when [the Seed Project] terminates and then begin to look at the consequences of those implementations, I think it is more that developments or what ever it is already, that is deriving potential benefits from a production marketing channel and a sales revenue perspective.

What this breeder is alluding to is the nature of the grants process, one which this person even endorses, namely, that the purpose of a call for proposals is to elicit new ideas. In this case, the breeder is implying that the Seed Project had been successful and, because the funding agency knew of its success, it had written the call for proposals so that it would not be eligible for funding. Because the plant breeder is a seasoned grant applicant, she approached the situation pragmatically.

For the academic breeders at this particular meeting, the call for proposals served as a means of communication between the funding agency and the plant breeders. "We have to focus on ... what will not go away when [the Seed Project] terminates. . ..I'm hearing and seeing a lot of not only social but economic pulls..." What this breeder is suggesting is that the funding agency was communicating that, if the Seed Project is indeed successful, it is time to expand the project to address some broader socioeconomic factors, including production and marketing.

However, this effort to expand to meet the expectations of the funding agency created challenges. As the project was expanded to pursue competitive grants, the participating farmers became disillusioned with the whole process. The lead farm representative responded to the proposed expansion of the program with distress:

> Not to minimize the importance of marketing or production techniques, not at all, but to me this seems like it is veering way off from Seed Project activities. Not to say that the choice of replicated trials and the choice of participatory breeding projects shouldn't be informed by market conditions but to try and join all of those things together is to make a very unwieldy project.

This observation makes sense when we consider how a successful farm builds its reputation and consumer base over the course of years. From this farmer's perspective the core work had been proven effective. Now was the time to continue a proven program rather than risk diluting the effort by taking on projects that would stray into other areas. His definition of research was the process of producing new varieties, which was insufficient within this funding situation. The lack of shared understanding of what constitutes fundable research led to disappointment. The Seed Project had led participating farmers to believe that university researchers would once again serve small farmers like them. These farmers were able to influence the research trajectory. Vegetable qualities, such as taste and texture, were added to the list of agronomic characteristics on which university researchers tended to focus. Farmers recognized that working in a network with other farmers, university researchers, and seed companies enabled them to share information that would not have been available to isolated individuals. Now, just as the project was beginning to bear fruit from a farmer point-of-view, however, funding was running out and discussions about how to continue were moving into new terrain.

## 5. Conclusions

There has been a growing recognition that socioeconomic reform of the agricultural research system is necessary to address problems of agricultural biodiversity. The claim is that the loss of agricultural biodiversity is the product of an industrial system that is directed at the mass production of a few crops for mass consumption. Within this system, a dwindling number of large farms supply the vast majority of agricultural commodities. An even smaller number of large agribusinesses, motivated primarily with the goal of profit accumulation, emphasize the production of a few major crops that will be more likely to garner a greater return on their research investment. And land-grant university researchers focused on solving problems in the industrialized agriculture system tend to be participants in the process of reducing agricultural biodiversity. The implication of this position is that socioeconomic change is necessary to resolve the problem of loss of biodiversity.

Given the socioeconomic nature of the problem of biodiversity, it is important to recognize that improving agricultural biodiversity is not merely a technical matter or a simple matter of plant breeders choosing to change their research behaviors. Technical and personal initiatives of plant breeders are important, but only initially. Because the dominant socioeconomic context for agricultural plant breeding is directed at breeding in collaboration with large agribusinesses to produce a few crops for homogenous environments, new relationships need to be established to promote new research goals and to promote the distribution of new crop varieties. PPB represents an intriguing approach to promoting these kinds of socioeconomic reforms.

We contend that our study of the PPB program is important because it illuminates some of the many socioeconomic obstacles inhibiting reforms that show promise in improving agricultural biodiversity. By establishing a network of university researchers, small seed companies, and farmers, the Seed Project overcame a long history of neglect of organic farmers by the plant breeding establishment. While farmers were in general eager to work with breeders, the Seed Project had to build a network of relationships and expectations from scratch, which demanded time. The university-based plant breeders used workshops to establish those relationships. Beyond establishing contact, the workshops addressed a number of specific skill areas. They included using seed cleaning machinery and saving seed, education on how to breed a farmer's own varieties, taste testing popular vegetables like tomatoes, potatoes or melons, and plant selection and trialing. Many of these workshops were held on farms or at research facilities located near cooperating universities. In addition there were field days held by the larger plant breeding program at the lead university, but which included organic varieties. Seed Project companies participated in those activities. Some larger conventional seed companies that were not actual participants in the Seed Project inspected the organic fields. Seed companies were, thus, able to see potential new varieties before they reached the finished stage.

We recognize that there are other examples of PPB programs in the U.S. and around the world. Each of them might be studied to indicate obstacles specific to their geographic and socioeconomic context and to highlight creative approaches to overcoming those obstacles. Our purpose here is merely to highlight socioeconomic factors that might serve as a foundation for future research.

Although the Seed Project achieved some success, we recognize that there are many obstacles that remain. One such major obstacle is the competitive grant funding process. In order to make such projects possible and sustainable over the long term, the USDA may need to begin establishing long-term block grants. Furthermore, we want to be clear that we do not think that it will be sufficient merely to establish the agricultural research socioeconomic structures conducive to promoting biodiversity. We agree with Busch *et al.* [11] that it is still necessary to instill an ethic of care for the future of life on the planet as a value among individual agricultural scientists and as an institutional norm for universities.

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