The Pennsylvania State University
The Graduate School

THE SCIENTIFIC SEED: COLLABORATIVE PLANT BREEDING AND THE ENHANCEMENT OF BIODIVERSITY

A Dissertation in
Rural Sociology
and
Women's Studies
by
Ruth M. Mendum

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

August 2009

The Dissertation of Ruth M. Mendum was reviewed and approved* by the following:

Carolyn Sachs
Professor of Rural Sociology and Women's Studies
Dissertation Advisor, Chair of Committee, Head of the Department of Women's Studies

Leland Glenna
Assistant Professor of Rural Sociology

Richard Stedman
Assistant Professor of Natural Resource Policy and Management, Cornell University

Kathy Brasier
Assistant Professor of Rural Sociology

Nancy Tuana
Professor of Philosophy and Women's Studies

Stephen M. Smith
Professor of Agricultural and Regional Economics
Head of the Department of Agricultural Economics and Rural Sociology

*Signatures are on file in the Graduate School.

Abstract

This dissertation is a qualitative case study of a participatory plant breeding project ("The Seed Project") in the Northeastern United States. The study focused on the circulation of scientific knowledge between university-based plant breeders, organic farmers, an organic farmers' association and a group of seed companies which serve the region. Data was collected primarily from the Northeast, although the study did expand nationally. Four research questions were posed: How can organic farmers and plant breeders work together? How does participatory plant breeding function in the United States? What are the social and organizational mechanisms needed to overcome the existing barriers that prevent the circulation of knowledge and germplasm between farmers, breeders and small seed companies? Does participatory plant breeding enhance the agrobiodiversity of vegetable crops? Methods used to collect data included in-depth interviews, participant observation, and document analysis. Using a feminist science studies framework, it emerged that farmers and breeders were isolated from one another on either side of a philosophical divide about the nature and purpose of scientific agricultural research and farming technology. For reasons having to do with the existing funding structures and the history of plant breeding, breeders had failed to understand and connect with a constituency that had become increasingly important in the marketplace over the last thirty years. Farmers, for their part, sometimes engaged in a discourse of naturalism that kept them from advocating effectively for access to research resources. The Seed Project showed that these barriers can be overcome using flexible program design and judicious use of technical staff. While the project enhanced the vegetable varieties available to farmers, interviews with participants revealed that enhancing agrobiodiversity is an issue related to, but different from, the needs of commercial farmers. What is required for optimal agrobiodiversity is the resuscitation of a diverse and vibrant seed system that reaches far beyond the farming sector alone.

Contents

List of Figures viii
List of Tables viii
Acknowledgements ix

Chapter 1
Introduction **1**

Chapter 2
Plant Breeding as Technoscience **11**
2.1 The Fusion of Technology and Science: Defining Technoscience 11
2.1.1 The social construction of science affords possibility of shifting norms 13
2.1.2 Technoscience as a fusion term 14
2.2 Technoscience Disrupts Exposing What Can Be 16
2.2.1 The stewardship tradition as a better model for integrating techno-scientific plant breeding 18
2.3 Participatory science practice and the feminist tradition 19
2.3.1 The legacy of Barbara McClintock and the integration of women into plant breeding science 22
2.4 Actor-network-theory: a method for uncovering emergent plant techno-science 24
2.5 Material, discursive, and social elements 27
2.5.1 Organic farmers in context 28
2.5.2 Plant breeding for low-input systems and other innovations . . . 28
2.5.3 Participatory plant breeding: theory and practice 30

2.5.4 Plant breeding: a negotiated science 32
2.5.5 Versions of participation: a continuum of options 34
2.6 Formal plant breeding: how it works 37
2.7 Lessons learned from the developing world 40

Chapter 3
Methods **42**
3.1 Emergent science 42
3.2 Data collection 47
3.2.1 Time frame 47
3.2.2 Informants 48
3.2.3 Sequence of Data Collection 49
3.2.3.1 Fieldwork at the lead university 49
3.2.3.2 Accessing farmers 54
3.2.3.3 Additional experts 56
3.2.3.4 Non-human agents 57
3.3 Measuring circulating knowledge 58
3.3.1 Analysis 59
3.3.1.1 Coding 59
3.3.1.2 Analysis 59
3.3.1.3 Documentary research 61
3.3.1.4 Contributions of feminist methods 61
3.3.1.5 Strengths and limitations of the analysis 61

Chapter 4
Agrobiodiversity: A Troubled Taxonomy **63**
4.1 Biodiversity and agrodiversity: ecological language that explains ecosystem functioning 63
4.2 Agrobiodiversity: a working definition 65
4.2.1 Agrobiodiversity: Giving a new name to an old concern 66
4.3 The History of Agrobiodiversity 67
4.3.1 Plant collecting prior to modern plant breeding 67

4.3.2 Genetic erosion becomes geographically more disbursed 69
4.3.3 Agrobiodiversity in the 21st century from the scientific breeding point-of-view 71
4.3.4 Concern about agrobiodiversity enters the public arena 75
4.3.5 Articulating measures of agrobiodiversity 77
4.4 Measuring Agrobiodiversity in the bodies of plants: molecular vs. phenotypical biodiversity 78
4.4.1 Implications of the molecular/phenotypical divide 81
4.5 Agrobiodiversity and organic farmers 83
4.6 Commercial agrobiodiversity gone missing 89
4.6.1 Organic seed availability as a subset of commercial agrobiodiversity concerns 92
4.7 Experimental Agrobiodiversity 94
4.8 Conclusion 98

Chapter 5
Circulation of Scientific Knowledge **100**
5.1 Overview 100
5.2 Plant breeding as a human science 101
5.2.1 Experimental plant breeding's inherent vulnerabilities 101
5.2.2 Farmers' networks are insufficient to preserve germplasm 104
5.2.3 The Seed Project shares experimental seed stocks with farmers . 105
5.2.4 The thirst for knowledge: other sources of traits and seeds . . . 106
5.3 The Seed Project: A model of distributed varietal development 108
5.3.1 The network's point-of-origin 108
5.3.1.1 The second iteration: national expansion 114
5.3.2 Garnering support: seed companies and farmers speak up 119
5.3.3 The Seed Project: A Model for PPB in the US for the benefit of the organic sector 125
5.3.4 Rationale and program structure 126
5.3.5 Program goals 127

5.3.6 Program functioning and mechanisms 128
5.3.6.1 Funding: The point of origin 130
5.4 The farmers' perspective 137
5.4.1 The benefits of the Seed Project to farmers 137
5.4.2 Barriers to the circulation of knowledge 143
5.4.2.1 The Crisis of Traditional Plant Breeding 143
5.4.2.2 Intellectual property 152
5.5 Conclusion 162

Chapter 6
Conclusion **163**
6.1 Feminism, science studies, and the discursive space of plant breeding for organic farmers 164
6.1.1 Science studies and the innovations inherent in participatory plant breeding 164
6.1.2 Stewardship trumps naturalism among organic farmers 165
6.2 Key insights into the circulation of scientific knowledge 167
6.2.1 Redefining progress 168
6.2.2 Overcoming mistrust: building a better participatory plant breeding model 169
6.2.3 Agrobiodiversity consumers vs. agrobiodiversity conservators: which role do commercial farmers play? 172
6.2.4 Farmers as businesspeople 173
6.2.5 Farmers and intellectual property 175
6.2.6 Varietal insecurity is unnecessary 176
6.3 Improving on compromises 177

Bibliography **179**

List of Figures

5.1 Institutional Relationships 110
5.2 Division of labor 111
5.3 Central role of the principal investigator 115
5.4 National expansion of the project 117

List of Tables

3.1 Interview Informants 48

5.1 Letters of Collaboration and Support 112

6.1 Key Findings 167

Acknowledgements

I thank my committee members for their patience and assistance over the years it has taken to complete this study. My profound gratitude is due to the farmers, breeders, and many others who shared their insights with me formally and informally. The genesis of this project was the many hours I spent as a child reading Mother Earth News and helping my mother garden, save seed, can and pickle. Who knew where our odd family hobbies would lead? Thank you to my colleagues at my day job whose encouragement kept me going, in particular Janet Haner and Lew Jillings. Thank you to Wenda Bauchspies for her insights into science studies and her unflagging support. My brother Ted provided endless tech support and insightful ideas. Last but not least, my partner Alexa read each chapter for coherence, while my children Noah and Vera kept themselves entertained so Mama could write.

Dedication

This Dissertation is dedicated to my children Noah and Vera, my partner Alexa, and my brother Ted.

Chapter 1

Introduction

In February of 1914, a few short months before the beginning of World War I, Prof. Dr. Erwin Baur shared with a gathering of his colleagues in Berlin his urgent concern that Europe was losing essential crop varieties.

> For many years already we have lived from the varietal selection of our old domesticated plants, especially our grain varieties, that are changing in a specific direction. In place of the many old landraces are being planted singular highly bred and without question valuable varieties. . . . As much as the improvement of our varieties has economic benefits, and as much as the national wealth (*Wohlstand*) increases with the planting of these highly bred varieties, this process has its shadow side. That shadow side is that when this continues, our capacity for further improvement of domesticated plants will be cut off (Baur, 1914, p. 104, translation my own).

The advent of modern crop varieties and their broad dissemination as described by Baur was leading farmers to abandon traditional landraces (a landrace is a locally adapted, regional variety) in favor of modern varieties that have higher yield or desirable characteristics like disease resistance. Later in the speech, Baur says that his profession will eventually come to accept Mendelian genetics[1] but in the meantime the urgent work

[1]The rediscovery of Mendel's theories of inheritance in the early 20th century is frequently cited as the beginning of modern plant breeding and genetics (Mayr, 1982; Carlson, 2004). By 1914 it would have

of saving disappearing varieties must commence. From 1914 onward Baur's warnings would be repeated over and over again by plant breeders who shared his concerns. Other breeders who shared his concerns included N. I. Vavilov in Russia who directed an institute in St. Petersburg beginning in the 1921, now named in his honor the N.I. Vavilov Research Institute of Plant Industry, which collected seeds from around the world to document his theory about centers of origin for crops (Vavilov, 1992; N. I. Vavilov Research Institute for Plant Industry, 2009). In 1936 H.V. Harlan and M.L. Martini warned that the phenomenon of losing varieties, which we now call genetic erosion, was continuing unabated (Harlan and Martini, 1936). H. V. Harlan's son continued his father's work with an article in 1971 entitled *The genetics of disaster* (Harlan, 1971). Just a year previously O.H. Frankel and E. Bennett together with four other colleagues including the younger Harlan, published a scholarly handbook devoted to the conservation of all useful plant materials including forest crops (Frankel and Bennett, 1970). Frankel published an appeal in the pages of the journal *Genetics* just a few years later begging the scientific community to accept their responsibility for genetic preservation (O.H.Frankel, 1974). And as recently as 2006, Peter Gepts, a respected emeritus plant breeder from UC Davis again advanced the thesis that even in the age of molecular genetics and biotechnology, preservation of the biodiversity of domesticated crops remains crucial (Gepts, 2006a). Although some today argue that hybridization, the Green Revolution, or the advent of genetic engineering are responsible for the decreased diversity of domesticated plants (Shiva and Moser, 1995; Shiva, 1993), Baur's early speech and the work of those who followed in his wake demonstrates that the problem is much more fundamental. Perhaps from its inception, but certainly no later than the late 19th century, humankind's capacity to create improved crop varieties for use in agriculture has led to the concern that varieties judged less valuable or outmoded were being abandoned and might become extinct.

Sir Albert Howard, a contemporary of Baur's and a plant breeder, arrived in India in 1905 to begin what would be a 19-year career working for the British colonial government breeding a wide range of crops (Howard, 2006 (original publication date 1947)). While there, he observed superior production methods practiced by local peasants which became the basis of what came to be known as the organic movement. Sir Howard's un-

---

been understood by someone of Baur's stature in the German speaking world but would have been still relatively unknown to the general public. Baur's comments in this piece imply that he sees his peers slowly but steadily accepting the applicability of Mendel's work to plant breeding for agricultural purposes.

derstanding of soil fertility and its impact on plant and human health was necessarily produced by his work as a plant breeder. He explained many years later how he came to understand the importance of soil quality:

> In pursuance of the principle I had adopted of joining practice to my theory, my first step was to grow the crops I had to improve. I determined to do so in close conformity with local methods. Indian agriculture can point to a history of many centuries: there are records of the same rice fields being farmed in north-east India which go back for hundreds of years. What could be more sensible than to watch and learn from an experience which had passed so prolonged a test of time? . . . In pursuit of this idea I found I could do no better than watch the operation of the peasants as aforesaid and regard them and the pests of the time being as my best instructors (Howard, 2006 (original publication date 1947), p. 3).

When we consider that this passage was written in the late 1930s by a British civil servant and a scientist, the statement is rather remarkable. Having just arrived in the tropics from England, Sir Howard adopts the position of one who must first learn the local conditions and habits. He presumes that his ability to breed a better crop will depend on understanding the methods in place, looking with respect both to historical records and current peasant practices and the behavior of non-human actors, in this case pests. Howard knows that he has the capacity to improve crops but only within the social, physical, and agronomic contexts in which he finds himself. In this sense Howard's approach is both democratic, and perhaps unbeknownst to him, anti-colonial, to the extent that he understands himself to be in possession of useful, but partial and contingent scientific training which can best be applied in combination with local historical records and current practices. In this sense Howard is unusual for someone working as part of a colonial government because he investigates local knowledge and local practitioners. The Indian peasant becomes a source of wisdom that can be augmented rather than overruled. In this regard the attention that Howard pays to active farmers and the time he spends soliciting their expertise parallels Baur's call for plant breeders to preserve and value the investments that the farming community has created over time.

In addition, Sir Howard uncovers the production methods that will later ground the organic farming movement because he understands the constraints of plant breeding and the benefits to be gained from place-specific knowledge. He situates himself as a supplement to the best practices current in the professional plant breeding community and looks for solutions that can be expanded. Howard suggests that plant breeding needs to be part of a suite of agricultural research methods. Plant breeding thus conceived, as a mode of supplementing other agronomic and social practices of farmers, led to the sustainable agriculture movement as it is practiced today. Indeed, it is very possible to use Sir Howard's compost methods today essentially as written based on observations now over a century old (Martin and Gershuny, 1992).

What is missing from Sir Howard's analysis is any concern that the use of improved plant varieties on a large scale will threaten the diversity of domesticated crops. He does discuss the importance of attending to the production of "suitable" varieties by focusing on soil quality. He, for example, argues that proper soil fertility supports the flourishing of such varieties in sugar cane plantation (Howard, 2006 (original publication date 1947), p. 106). But nowhere in his otherwise extensive text does Sir Howard consider directly the effects of the promulgation of the modern varieties he is breeding nor the fate of older or wild varieties. One can speculate why this is the case. Perhaps in the India of that time the process of plant improvement and the monopoly of modern varieties may have been difficult to observe or possibly Sir Howard was so focused upon soil fertility which affects both modern and landrace varieties that he could not take into account the kind of threat to biodiversity that some of his colleagues in Europe were concerned about. I am at pains to point out that while Howard omitted a careful study of varietal diversity, his work is all the more important for us to examine because his approach to soil fertility has led directly to the modern day organic movement, which ironically enough, is taken today to be the bastion of biodiversity protection.

Furthermore, what Howard does that Baur does not do is question the colonial, industrial agricultural model. In the following passage, he tellingly advocates on the behalf of farming and gardening as activities with life-restoring proprieties and vast political implications.

> Why has civilization proved such a disastrous failure? The answer is simple. Our industries, our trade, and our way of life generally have been based first on the exploitation of the earth's surface and then on the oppression of one another–on banditry pure and simple. The inevitable result is now upon us. The unsuccessful bandits are trying to despoil their more successful

> competitors. The world is divided into two hostile camps: at the root of this vast conflict lies the evil of spoliation which has destroyed the moral integrity of our generation. While this contest marches to its inevitable conclusion, it will not be amiss to draw attention to a forgotten factor which may perhaps help to restore peace and harmony to a tortured world. We must in our future planning pay great attention to food– the product of sun, soil, plan, and livestock– in other words, to farming and gardening (Howard, 2006 (original publication date 1947), p. 257)

I have begun with the brief histories of these two early plant breeders to demonstrate that at one point in the early 20th century, two related but separate trajectories of critical thought were begun within the plant breeding profession. One group was concerned about the tendency of modern varieties to displace older ones, resulting in radically reduced biodiversity. A second group, represented primarily by Sir Howard and his followers, adopted traditional Indian soil fertility practices to form a far-reaching critique of crop production methods including the use of artificial fertilizers and pesticides. At the time of their inception, the two concerns: the biodiversity of domesticated crops and organic production, were not identical. What the two positions did share in common was an awareness that industrial agricultural processes and agricultural research urgently needed reexamination.

Altering the course of the status quo, even at the beginning of the 20th century, was an uphill battle because of the entrenched power of large agricultural interests and the desire of research scientists to retain their central position in agriculture. Sir Howard describes how professional plant breeders working on cotton reject his views on soil management because, ". . . the method called in question the soundness of the two main lines of work on cotton–the improvement of the yield and quality of the fiber by plant breeding methods alone. . . (Howard, 2006 (original publication date 1947), p. 245)." In other words, many breeders felt professionally threatened by the idea that breeding is but one tool among many that help farmers to succeed.

The professional hostility towards the emerging possibility of alternative agriculture, and the organic movement in particular, became solidified over the course of the 20th century as the plantation monoculture of the British Empire morphed into the current model of industrial agricultural practices. Although some professional breeders and other academics continued to sound warnings about genetic erosion (Fowler and

Mooney, 1990; Nabhan, 1989; Nazarea, 2005), the majority of plant breeders failed to recognize the way their scientific practice was supporting the transformation of the agricultural sector.

This tale unfolds clearly when we look at an equation by which breeders characterize their thinking. For breeders, the expression G x E is a shorthand for two sets of variables that define what interacting constraints have to be taken into account in any breeding project. Professional plant breeders have become used to defining their work as selecting for standardized genotypes (G) that could be planted successfully in standardized environments (E). Specifically, E equals the environment which is presumed to be a set of conditions which can be optimized for a particular crop while G equals the genetic variation from which the best possible traits can be extracted and stabilized (Jain and Kharkwal, 2004; Mayo, 1987). If a breeder can assume that the environment will be adjusted to accommodate the needs of a particular crop, via irrigation, strategic fertilizer application, and chemical pest control, the task of choosing the optimal traits becomes considerably less complex. However, by assuming that the highest quality selection can happen when the environment is held constant, breeders limit the conditions under which their improved varieties will flourish to those that can be precisely controlled to multiple specifications. Arguably, modern breeders working under this understanding of G x E have defined breeding for anything other than industrial conditions out of their area of expertise (Desclaux et al., 2008). Just as professional plant breeders working on cotton in the 1930s rejected a vision of their profession that included organic soil management techniques, the structure of current conventional professional plant breeding directs the attention of most breeders *away* from low-input or organic plant breeding. As the number of crops and potential types of farmers served constricts because of economic, institutional and property regulation (Kloppenburg, 2004; Pistorius and van Wijk, 1999; Duvick, 2004; Lindner, 2004), the construction of plant breeding as a discipline further reinforces these trends.

Standardized G x E driven plant breeding produces varieties that are inappropriate for marginal lands in developing countries. Those who recognized this problem included a sub-sector of plant breeders and social scientists who attempted to study and reestablish the connection between plant breeders and farmers (Zimmerer, 1996; Brush et al., 1992; Brush, 1991, 1992, 1996, 2000a; Brush and Meng, 1998; Brush and Stabinsky, 1996; Ashby et al., 1996; Biggs and Gauchan, 2001; Ceccarelli et al., 1996; Courtois et al., 2000; Witcombe and Joshi, 1996). The breeders involved developed a form of breeding called participatory plant breeding (PPB). This kind of breeding integrates the environmental factor represented by individual farmers' experience and the conditions in specific regions, by recruiting farmers to participate in the breeding process itself. Conceived as a means to serve poor farmers working marginal lands whose need for improved varieties would never be profitable to multinational seed companies (Ceccarelli et al., 1996; Mangione et al., 2006; van Eeuwijk et al., 2001; Ceccarelli et al., 2000, 2003; Ceccarelli and Grando, 2007; Ceccarelli et al., 2001; Ashby et al., 1996; Biggs and Gauchan, 2001; Courtois et al., 2000; Almekinders and Elings, 2001; Atlin et al., 2001; Dawson et al., 2008; Murphey et al., 2004; Sperling et al., 2001; Bishaw and Turner, 2007; Vernooy, 2003; Witcombe and Joshi, 1996; Joshi et al., 2001; Brush, 1992; Brush et al., 1981), participatory plant breeding *can* look like a second tier solution to instances where mainstream breeding methods are too expensive. Participatory plant breeding has been less frequently practiced in the US and developed countries except perhaps among economically very marginalized rural communities (Nabhan, 1989; Serageldin and Persley, 2003; Howard, 2003).

Indeed, applying participatory plant breeding methods to a US context could be understood as a radical act of democratization, radical in the sense that Sir Howard's call for organic production methods demonstrated that the prevailing use of inorganic fertilizers and pesticides was unnecessary. If Sir Howard was an accidental anti-colonialist, participatory plant breeding in the US could potentially provide tools that would aid in the reintegration of farmers into crop improvement. As such, PPB is radically democratic. The implications of such a move are far-reaching from altering the definition of breeder's roles, to the structure of land-grant universities to raising the possibility of a much enhanced organic sector that might alter current estimates about the ability of organic and sustainable agriculture to feed the world's population.

Is it possible to redirect plant breeding towards new needs and new modes of interaction? Does the participatory approach allow for a convergence between the long-standing tradition of concern for the impact of genetic erosion and the organic and sustainable agriculture communities? This dissertation examines one plant breeder's grant-supported project, which I am designating The Seed Project, that sought to make plant breeding responsive to the US organic vegetable sector. My study examines the ways in which the Seed Project adapted and expanded existing participatory approaches and the barriers that such work had to overcome. In doing so, I focused on four key research questions. How can organic growers and plant breeders work together? How does participatory plant breeding function in the United States? What are the social and organizational mechanisms needed to overcome the existing barriers that prevent the circulation of knowledge and germplasm between growers, breeders and small seed companies? And finally, does participatory plant breeding enhance the biodiversity of vegetable crops?

To answer these questions I blended two theoretical traditions: actor-network-theory (ANT) and feminist critiques of science. Actor-network-theory provided me with a particularly concrete method to track the emergence of a new network of actors that this project created while feminist science studies provided an alternative vision of expertise altered and improved by including farmers' voices.

Although PPB has been practiced on many crop types in the developing world, the most prominent US practitioners work on grains (Dawson et al., 2008; Murphey et al., 2004; Jones and Murphy, 2008), not vegetables, leaving few guides for comparison. ANT was useful for its emphasis on the question of who does the work within a scientific venture and for its attention to non-human actors. Feminist theory provided several essential components. First, the feminist discussions of the blending between science and technology and the questions feminists have raised about path dependence[2]and the gendered impacts of technological innovation were helpful for assessing the role of this participatory plant breeding project within sustainable agriculture. Secondly, feminist science studies scholarship has called attention to the partial nature of scientific knowledge and the power implications for social structures when partial understandings are

2

Path dependence is a term that emerged out of the natural sciences but which has been applied to the social sciences in several ways. James Mahoney, a scholar working in historical sociology defines the term as follows: "I argue that path dependence characterizes specifically those historical sequences in which contingent events set into motion institutional patterns or event chains that have deterministic properties (Mahoney, 2000, p, 507-08)." A famous example of this phenomenon is the invention of the QWERTY keyboard which was originally designed to decrease typing speed on a manual typewriter and has been maintained ever since because changing the technology wasn't compelling enough in light of its wide-spread adoption. A very recent article by Reinstaller and Holzl discusses on-going controversy about the QWERTY case ultimately showing that indeed social and historical contingencies were responsible for its adaptation and survival as a keyboard (Reinstaller and Holzl, 2009).

taken to be complete. Scholars in this area are particularly sensitive to the implications of power relations for non-human actors, a position that is shared by ANT. Thirdly, I examine Evelyn Fox Keller's work on hierarchies of science to understand the role of plant breeding within the scientific community and Helen Longino's concept of tempered expertise. Finally, I examine the changed role of women within plant breeding as exemplified by the story of Barbara McClintock as contrasted with scientifically trained participants in the Seed Project including the principal investigator (PI). I look at the ways in which increased gender diversity at both the land-grant university and within the alternative agriculture movements has altered the kind of breeding science that it is possible to practice as well as demanding new skills from men and women who breed professionally.

My analysis begins in chapter two with an in-depth discussion of plant breeding as a form of technoscience that can be best understood as a form of situated knowledge as that term is understood by feminist critics. I will discuss the social construction of a range of plant breeding approaches and their relationship to concepts of expert, private and participatory science respectively. This chapter also examines how the role of female plant breeders has changed as it became possible for women to enter the profession and the impact that has had on the way plant breeding technoscience is practiced. Finally, I will examine the role of agrarian thinking in the organic movement and the implications of how competing conceptions of the movement's function impact the ability and willingness of farmers to participate in collaborative breeding ventures. Chapter three will describe the qualitative methods that I used to collect and analyze empirical data that I collected. The fourth chapter describes the circulation of scientific knowledge that occurred over the duration of the Seed Project. I outline the efforts made by the project to promote a diversity of views and participants both within the host university and among other participants. I discuss how the project dealt with issues of intellectual property and the difficulties presented by the embattled state of the conventional plant breeding profession. I document the specific mechanisms utilized by the project members to reach across considerable material and social barriers. In chapter five, I discuss the complex issue of agrobiodiversity, focusing in particular on the different types of agrobiodiversity and the importance of understanding that such basic terms as "genetic" may vary in significant ways. Finally, I draw conclusions based on the data about the nature of the model that the Seed Project developed and the skills and efforts that were involved to create this model. I stress that plant breeding is a socially constructed science struggling for survival and legitimacy. In this beleaguered state it may be difficult to imagine expanding access to the plant breeding process to non-breeders but studying one successful example may help to demonstrate how such work can be accomplished.

Chapter 2

Plant Breeding as Technoscience

2.1 The Fusion of Technology and Science: Defining Technoscience

> *They might have been otherwise*: This is the key to our interest and concern with technologies. Technologies do not, we suggest, evolve under the impetus of some necessary inner technological or scientific logic. They are not possessed of an inherent momentum. If they evolve or change, it is because they have been pressed into that shape. But the question then becomes: why did they *actually* take the form that they did (Bijker and Law, 1992a, p. 3 (emphasis original))?

Since the late 1980s an interdisciplinary group of what has come to be known as science studies scholars have advanced the proposition that technological and scientific innovation are not products of an inevitable logic buried in the material nature of the world, nor a linear trajectory of optimal rational choices. Instead, this school has demonstrated that the history of technological innovation and scientific discovery is shaped and formed by the intersection of particular social/cultural contexts within which technical and material understandings could unfold. Slight changes in circumstances, even in some cases, chance, could have directed the course of a particular invention or series of discoveries into an alternative course than the one which in fact took place. At the same time, the course that our collective history has taken was "pressed into shape" in most circumstances by an array of factors which are the subject of a new study of science and technology. A critically important group of these scholars work from or within the feminist tradition which has long held that technologies reflect and reinforce existing gender relations (Cowen, 1983; Bijker and Law, 1992b; Bijker, 1995). These feminist science and technology scholars, many working in history of technology development, argue that the existing technological artifacts enforce gendered and class oppression and that changing those realities will require explicitly political work (Bijker, 1995).

This rejection of technological determinism in all of its forms (Wyatt, 2008) operates on two levels. First, science studies scholars reject the assertion that the social and the technological operate as discrete realms which intersect only at certain defined moments (Latour, 1999b, 2005; Bijker and Law, 1992a; Hackett et al., 2008; Law, 2002). In particular, they reject the approach to sociology of science that examines the impact of social or political forces as an after-the-fact or external-to-science phenomena. Instead, science and technology are posited as inherently social from their moment of inception and many studies have been done demonstrating the course of such developments (Biagioli, 1999; Hackett et al., 2008; Bijker et al., 1987; Bijker and Law, 1992a; Bijker, 1992; Latour, 1999a). Secondly, these scholars shift the focus of sociology of science toward the building of networks and bundles of association that include scientists, engineers, lay people, and non-human entities like microbes and Bakelite (Callon, 1999; Bijker, 1995).

Bringing social construction into science and technology studies creates a framework for considering plant breeding as a form of technical and scientific innovation that is particularly appropriate. It is now possible to disturb the distinctions between basic and applied science which have principally served to reinforce a hierarchy of science that privileges those kinds of research that are most abstract, least applied, or least social (Fox Keller, 2007). In particular, the work on the history of laboratory science reveals not only the many ways in which laboratory work is formed by social conditions but also shows that the purpose of such research is to alter the political landscape, thereby dissolving any interior/exterior, social/scientific distinction (Latour, 1999b; Hackett et al., 2008; Bijker and Law, 1992a).

Once we understand that all scientific practices are inextricably social, that all scientific results reflect social attributes such as place and association (Callon, 1999), the idea that some sciences are less tainted by the association with social attributes, like individual affiliation or access to resources, falls away. I will show how the corrosive effect that keeping "the social" out of science has had negative impacts for plant breeding both in terms of its legitimacy as a science and in terms of the ways in which plant breeders have tried to enhance their status as "real" scientists.

Biological sciences in general face a new challenge because, as Evelyn Fox Keller has argued, physical scientists have migrated into the field, bringing with them a preference for work that unearths universal laws rather than allowing for description of contingent circumstances (Fox Keller, 2007). This tendency to valorize what other scholars have called theory-centered over a model-centered approaches (del Rio, 2008), means that biologists are being pushed to look for laws of general applicability where it would be more appropriate to examine the diversity of explanations that evolution has created in various environments (Fox Keller, 2007). In my introduction, I discussed briefly how privileging a universal application of G x E–a law that resembles physical science's approach to explanation–has led plant breeders to ignore the creativity and positive attributes of variability that breeding for diverse environments can inspire. Fox Keller's article on hierarchies puts this tendency into a larger perspective although she does not discuss plant breeding directly in that piece. Instead she is arguing that biology should not be looking for reductive, theory-driven, universally applicable answers to pertinent questions. To her position, I would like to add that the search for universal laws makes the work of relocalizing plant sciences to respond to highly variable conditions, physical and social in origin, all the more difficult. It is important, however, when examining working biological scientists, for empirical investigations to take into account the social context within science; in this case, the power that theory-driven biology enjoys as a beneficiary of received wisdom from the physical sciences (del Rio, 2008).

2.1.1 The social construction of science affords possibility of shifting norms

The relatively new understanding of science and technology as socially constructed brings with it opportunities to study interactions that were previously hidden. We have begun to understand the interlocking systems of technological infrastructure and the ways in which existing patterns of use become favored. Judy Wajcman captures that phenomenon:

> The more technologies are adopted and their problems resolved, the better

> their performance, and the greater their adoption. This clearly generates a powerful path-dependence over time, one that marginalizes competing or new technologies (Wajcman, 2004, p. 35).

The resulting calcification of existing systems because of path dependence, not only in terms of physical built constructs but also in terms of modes of problem solving, make large systems vulnerable when incremental improvements are no longer sufficient. The organic and sustainable farming movements, for example, have argued that industrial agriculture and the research structure that supports it is in crisis. Under the model outlined above, it is possible to see why fair evaluations of organic and alternative agricultural needs would be difficult for the existing research structures, imbued as they are with a kind of path-dependence towards supporting industrial systems. We will see how this issue plays out in the Seed Project's attempts to chart a new path forward and work constructively with organic farmers.

Another key strength of the feminist science studies approach and actor-network-theory has been attention paid to the best methods for studying those instances where social and scientific impulses converge and result in significant change from existing norms. This emphasis on emergent science and the methodological considerations that arise will be discussed in greater detail in the chapter on methods. Here I merely want to emphasize that the focus on emergent science is itself a byproduct of a larger shift away from technological determination and towards a broader search for possible cases of innovation. This shift reflects an historically appropriate questioning of existing technological and social structures at a time when the status quo, particularly the viability of the industrial agriculture system is receiving greater public scrutiny.

2.1.2 Technoscience as a fusion term

The final contribution of science studies that I would like to discuss has been the willingness to blend the study of technology and science into a hybrid, sometimes called technoscience. Technoscience is a fusion term which makes it grammatically annoying to some but which does have its purposes. Namely, by placing the two terms, techno-, a truncated form of technology, and science, in one word, scholars who use the term are insisting that both the production of abstract knowledge and the production of artifacts cannot ever be separated from each other (Campbell, 2004; Gane, 2006; Haraway, 1991, 1997; Wajcman, 2004; Anderson and Adams, 2008).

Secondly, technoscience, because it is a fusion term, always implies renegotiation between what we can know and what we can produce. One of the important differences between artifacts and abstract knowledge is that artifacts are subject to wear. Our car's brake pads disintegrate under the friction produced by stopping, our computer networks exceed capacity and have to be rebuilt, just two examples of the ways in which technological artifacts in use generate information about their limits and demand repair or suggest needs for improvement. Plant varieties do the same. Each year, pest pressure, diseases, weather or picky customers weed out some innovations, leaving gaps and indications of what might work in the next generation. A scientific discipline that is inextricably attached to a technical product is also one which is constantly receiving feedback.

Finally, technosciences by their nature can be practiced by all interested parties. While expert insight and facilities can and do speed up the process, the fact that artifacts end up in the hands of the multitude opens up the potential for those users to become innovators. The refashioning of machines and gadgets is an honored practice in developing nations where resources are scarce[1], but the potential for refashioning exists everywhere. Evidence from participatory plant breeding projects indicates that farmers, even those with limited formal education, can make substantial contributions to crop improvement, if given the opportunity (Ceccarelli et al., 1996; Mangione et al., 2006; Ceccarelli and Grando, 2007; Ceccarelli et al., 2001).

There does exist a danger that using a term that blends technology and science might seem to preclude counter terms like nature, ecology, and grassroots, indigenous, or citizen knowledge, which have been used to describe seed saving or agrobiodiversity. (Nazrea, 1998; Nazarea, 2005; Purdue, 2000; Irwin, 1995). However, I do not see technoscience as an idea that is antithetical to ecological or grassroots practice. If we understand the term technoscience as a product of a larger move to disrupt the hierarchical valuations of scientific and technological innovation as expert knowledge practiced by a few in a socially cleansed environment, it can be understood as part of a larger movement to democratize science and the food system (Wynne, 2002; Hassanein, 1997; Rowe and Frewer, 2000; DuPuis and Gillon, 2009; Kloppenburg and Hassanein, 2006; Hassanein, 2003; Levkoe, 2006). What the term does destroy is the illusion that grassroots

[1] See the Afrigadget website for some excellent examples: AfriGadget.com.

science practice is inherently more natural and therefore preferable. The destruction of this illusion can have its benefits. In other words, by situating technoscience as a practice available to all, I am arguing that even the most ecologically sensitive individual is a product of a modern technologically equipped society. Technoscience does undermine the idea of naturalness and innocence. And yet technoscience contains within it the possibility for integrating the best of model-driven science with farmer-derived knowledge to produce a more sustainable and biodiverse agricultural system.

2.2 Technoscience Disrupts Exposing What Can Be

In my Introduction I discussed the dominant paradigm–GxE–used by mainstream plant breeders who conceive of their profession as serving the predominant form of agriculture, the modern industrial, globalized food system. Such plant breeders see their task as providing the best possible varieties for use in an agricultural setting where the environmental conditions are controlled as much as possible (Desclaux et al., 2008). Minimizing the environmental variation allows breeders to maximize the genetic variation in plants as efficiently as possible producing the quickest possible returns for time spent breeding. At the same time, this interpretation of breeding efficiency precludes asking the larger questions such as those originally posed by Sir Howard who enraged his fellow breeders by suggesting that some production problems needed to be served by enhancing soil fertility rather than pushing breeding goals in isolation from other factors. Breeders who take the narrow view of their profession are attempting as much as possible to ignore the technoscientific nature of their work. That is, they focus on maximizing their contribution to plant improvement without asking how the artifacts they produce will alter the organization of the farming communities into which they will be imported or benefit certain kinds of food chains over others. Those kinds of "social" questions are deemed external to their responsibilities.

Organic farmers' organizations too draw boundaries by referring to their activities as natural farming or or farming which harmonizes with the natural world. They do so to draw a distinction between themselves and industrial agricultural practices which involve the use of large scale production methods and industrially generated fertilizers and pesticides. In doing so they tap into a branch of agrarianism that emphasizes farmers as exemplars of life in harmony with nature. The historians of agrarianism tell us that the tendency to glorify farmer as being closer to a state of nature, resistant to the corruption of the cities, and sometimes literally closer to a state of grace that in the Christian tradition becomes identified with the Garden of Eden, goes back to the earliest written records (Montmarquet, 1989; Glacken, 1967; Douglas and Isherwood, 1979). It is therefore easy to understand how that very old tradition came to be taken up and applied to a relatively new set of fears, that genetic erosion could lead to ecological and agricultural disaster. This kind of rhetoric is particularly evident in the publications generated by the seed saving movement that has to its credit, single-handedly and without any institutional support, saved thousands of plant varieties from extinction (Adelmann and Hughes, 2007; Adelmann et al., 2007; Ashworth, 1991; Whealy and Adelmann, 1986; Adelmann et al., 2006; Carolan, 2007; Connolly, 2004). Advocating for domesticated plants as technoscientific entities would seem to be rejecting this central distinction in organic discourse. Yet I would argue with Donna Haraway that there are greater dangers inherent in using inappropriately naturalist language to describe what is essentially a functional social/biological/technological relationship (Haraway, 1991). Rather than defending organic methods on the grounds that they are closer to nature and divorced from technology, I would contend we need a vastly more sophisticated science that acknowledges the co-constitutive basis of domestication and crop cultivation. That is, agriculture can be reframed as a process of working within material frameworks established by mutual agreement rather than unilateral decision-making on the human side. The risk entailed by imposing a naturalist discourse on a relationship which is structured and functional is that nature becomes an idealized point of origin that serves as a constant and limiting goal. Rather than asking what can be done with the networks now existent, one can be distracted by the vision of what might once have been, a stultifying form of nostalgia.

In the case of both the mainstream plant breeders and the organic farmers, I argue that profound investments in particular paradigms or master narratives, prevent some in each respective group from understanding the co-constitutive nature of agriculture. The mainstream scientists fail to see that end-users are more than just consumers of their breeding expertise and thus define their profession as one that is of use to only a specific sub-group of farmers and eaters. Some organic farmers define themselves as "natural" or use language that implies that modern scientific practice is not relevant to them, thereby blocking themselves from accessing the skills that professional plant breeders could provide. The investments that the two groups hold in their own identities and work responsibilities reinforce the institutional and economic isolation that exists, making even basic dialog difficult to initiate.

This idea of master narratives and the damage they do is particularly important to untangling the troubling ways in which information flows, or fails to flow, between various parties to the seed system. Because the list of parties is so heterogeneous in terms of scale (from small organic farmers to transnational life sciences corporations, and kind; from PhD scientists and skilled farmer/breeders to business managers with no biological training) the potential for ignorance across disconnected narratives is great. To the extent that one group may believe themselves to be in possession of a key narrative, that group (or individual) can be isolated from, even destructive to, other possible participants in the system.

2.2.1 The stewardship tradition as a better model for integrating technoscientific plant breeding

A second strain of agrarianism is better than the naturalist tradition for integrating technoscientific plant breeding into modern organic farming. This branch of agrarian thinkers argue that humans have a responsibility to care for land that will then be passed along to future generations and be the basis of a stable rural society. For example, Eric Freyfogle defines agrarianism as follows:

> Agrarianism, broadly conceived, reaches beyond food production and rural living to include a wide constellation of ideas, loyalties, sentiments, and hopes. It is a temperament and a moral orientation as well as a suite of economic practices, all arising out of the insistent truth that people everywhere are part of a land community, just as dependent as other life on the land's fertility and just as shaped by its mysteries and possibilities (Freyfogle, 2001, p. 5).

In this version of agrarianism, taking care of the land is a human moral responsibility to preserve and nurture fertility despite the fact that the source of that fertility is not entirely known or knowable. Although the rhetoric of this kind of stewardship based agrarianism is very different than the language of technoscience, there is an understanding common to both positions that co-existence with the non-human world is essential to the flourishing of all. If technoscience posits a negotiation between material artifacts and humans, stewardship agrarianism suggests a similar integration between soil, plants and animals within the context of responsible agriculture.

From this perspective, a technoscientific stance is a powerful tool for describing the conceptual position of the domesticated vegetable plant. Although such plants do not visibly mimic the shape of the human body, they owe their current appearance, growth patterns, fruit production, seed fertility and many, if not all, other distinguishing traits, to human interactions with them and their ancestors (Stoskopf et al., 1993; Jain and Kharkwal, 2004; Hobhouse, 1985; Beinart and Middleton, 2004; Evans, 1993; Vavilov, 1992; Mayo, 1987). That process has been co-evolutionary; that is, the plants have exercised non-linguistic agency on behalf of themselves and their progeny (Pollan, 2001; Finckh, 2007), but that does not change the fact that individual plants and certainly distinguishable varieties, are technical artifacts, physical creations organized toward functional ends. They are technoscientific products whose radically human-altered-nature is cloaked in plant cells. The differences between modern sweet corn and its wild cousin tiosente is a clear example of how fundamental the differences can be between pre- and post-contact plants (Fussell, 1992). Unfit for human consumption, tiosente has six to eight marble-hard, starchy grains on a single stalk, compared to sweet corn which has many row of sugary seed that stay inside their tightly wrapped husk until humans choose to harvest them. The older crop grains can only be eaten if ground, soaked, or cooked, whereas a perfectly fresh cob of sweet corn can be munched uncooked off the cob. The change between the two plant populations is entirely a function of breeding a human intervention that in its early stages would have used no laboratory tools. This kind of alteration makes domesticated plants among the most ancient of technical products and certainly takes the idea of the technoscience out of the age of computers and transposes it back to the centers of origin for food crops (Vavilov, 1992).

2.3 Participatory science practice and the feminist tradition

If socially constructed technoscience answers the question, “What is science?”, then participatory science practice asks the question, “Who creates technoscience?”, and feminist participatory science theory examines, “For whom must technoscientific products function or serve?” What can be difficult is answering the who creates and for whom questions within the context of creating knowledge. It is not enough to advocate for diverse individuals to obtain access to scientific thought or to have technologies designed for their use. Instead, we must examine the much harder question of how does the mode of technoscientific knowledge creation change when the identities of its creators and the object of its assistance diversify, and how does that process increase the validity of the outcomes, particularly in terms of prediction? This challenge is particularly difficult because of the claims mainstream scientific discourse has made about its own socially neutral objectivity based on the assumption that good science is a primarily cognitive, rational, disembodied activity. Donna Haraway has addressed the importance of contesting the discipline of biology as a political force.

> But, if we are committed to remembering that biology is a *logos*, is literally a gathering into knowledge, we are not fooled into giving up the contestation for the discourse. I subscribe to the claim of Foucault and others that biopolitical modes of fields of power are those which determine what *counts* in public life, what counts as a citizen, and so on. We cannot escape the salience of the biological discourses for determining life chances in the world. . . .We’ve got to learn how to make alliances with people who practice in those terrains, and not play reductive roles with each other (Penley and Ross, 1991, p. 5).

Making alliances with scientists is a tricky business because of a phenomenon feminist philosopher Helen Longino has called the rational-social dichotomy (Longino, 2002). This dichotomy presumes that that which is social is actually pure advocacy, an expression of power over others, while the rational is an abstract process that can be separated from the individual interests of the practitioner (Longino, 2002). Longino argues that the “gathering into knowledge”, to use Haraway’s term, must proceed within what Longino calls “knowledge-production practices” (Longino, 2002, p. 97-98) which take place in public venues, require serious uptake of opposing views and public standards of evidence, observational methods and theoretical engagement (Longino, 2002, p. 129-130). Taken together, these ground rules for interaction lead to what Longino has called “tempered equity”, that is, the wider participation of diverse points-of-view within a structure that requires rigorous engagement by all parties. In short, the social is transformed from identity politics to a meaningful source of information and analysis because of the mode of interaction within which the collaborations occur. Longino explains:

> The exclusion of women and members of certain racial minorities from scientific education and the scientific professions constitutes not only a social injustice but a cognitive failing.. . . a community must not only treat its acknowledged members as equally capable of providing persuasive and decisive reasons and must do more than be open to the expression of multiple points of view; it must also take active steps to ensure that alternative points of view are developed enough to be a source of criticism and new perspectives. Not only must potentially dissenting voices not be discounted; they must be cultivated (Longino, 2002, p. 132).

In essence Longino's position holds much in common with a long tradition within feminist standpoint theory that has argued that opening scientific practice to women and other excluded members increases the validity of the expected outcomes (Harding, 1986, 1991, 2004; Rose, 1983; Hartstock, 1987; Harding, 1987). Where she differs, and where her position is particularly important for evaluating participatory plant breeding, is her insistence that participating in the process of inquiry requires a willingness on the part of all participants, even those previously excluded, to engage in open, public debate, subject to criticism and scrutiny. Hence the term, tempered equity:

> Equality is, nevertheless, tempered in several respects. While the criterion imposes duties of inclusion and attention, it does not require that each individual, no matter what their past record or state of training, should be granted equal authority on every matter. The public standards . . . are intended partly to protect inquiry from such cacophony, for their obligations cut two ways. Subscription to them does impose obligations on members of a knowledge-productive community to attend to criticism that is relevant to their cognitive and practices aims. But it also limits the sorts of criticisms to which a community must attend to those which affect the satisfaction of its goals (Longino, 2002, p. 132-133).

Longino's articulation of standards for interaction between participants in a knowledge-creation community parallels the specific work that has been done on the democratization of the sustainable food and agriculture movements (Hassanein, 1997, 2003; Kloppenburg, 1991; Kelkar, 2007; Feldman and Welsh, 1995). Within that scholarship, much work has focused upon the genesis of credible knowledge to be gathered as part of the satisfaction of distinct sets of goals. In other words, what kinds of structure does an inclusive, participatory research project need to display in order to constitute meaningful scientific inquiry and produce appropriate technoscientific artifacts? Some have argued that specific knowledge of work processes provide information that otherwise would slip from consideration (Kloppenburg, 1991; Nerbonne and Lentz, 2003); others have contended that alternative agriculture requires new methods of observation and measurement in order to be properly evaluated (Carolan, 2006b,a). A third group of scholars look at the role played by various facilitators within formal or informal extension systems (Henke, 2006; Warner, 2008, 2005; Duram and Larson, 2001). Taken together, these studies are cumulatively sketching a landscape in which previously excluded partners, defined in terms of individual identity factors, such as gender, or group identity, such as being organic farmers, can be included into the research arena in such a way that outcomes are improved. From the beginning of plant breeding as a science, we have seen that adherence to certain ideas about what constituted a breeder's responsibility and rejection of other kinds of innovation, such as organic soil fertility enhancement, have limited the applicability of of plant breeding science to the full needs of the food system. Before I discuss plant breeding proper, I will take a moment to examine a specific example of the kind of enhanced outcomes that have become possible within plant breeding because of the inclusion of women.

2.3.1 The legacy of Barbara McClintock and the integration of women into plant breeding science

Barbara McClintock won the Nobel Prize in 1983 for her work on corn genetics and more generally on mobile genetic elements (Nobel Prize Foundation, 2009). Her story had been chronicled by Evelyn Fox Keller in her book *A Feeling for the Organism* published some five months before the prize was announced (Fox Keller, 1983). More than a biography, Fox Keller's book is, in her words:

> . . . the story of the interaction between an individual scientist, Barbara McClintock, known to her colleagues as a maverick and a visionary, and a science, genetics, that has been distinguished in recent decades by extraordinary growth and dramatic transformation (Fox Keller, 1983, p. xvii).

McClintock, in Fox Keller's telling, endured extreme isolation and discrimination, beginning at Cornell where she was forced to earn her PhD in botany because plant breeding was not open to women at the time (Fox Keller, 1983; Kass, 2003; McGrayne, 1993). Her career options were limited by the unwillingness of science departments to hire and their reluctance to tenure women. This latter question of tenure has been disputed since Fox Keller wrote her book. Lee Kass has contended that McClintock was not denied tenure, rather she was only offered tenure after she had received a counter offer from Cold Spring Harbor (Kass, 2003). Kass claims that the archival evidence that McClintock was offered tenure at that later point demonstrates that Fox Keller is wrong about the degree of resistance that women in the profession faced. In my view, Kass' evidence does not alter Fox Keller's ultimate point that McClintock did not feel she was wanted nor would be valued for her research skills in a university setting. The lesson she had learned well before the tenure episode, and which Fox Keller clearly documents, was that a woman in scientific research must be able to function effectively though extreme periods of isolation, guided only by her own abilities to discern what others were missing about gene function. Luckily for McClintock, she seems to have had what Fox Keller calls a "capacity to be alone" from childhood. Whereas other women in her circle left research in order to have personal lives, McClintock devoted herself wholeheartedly to her work, sometimes publishing nothing for years on end (Fox Keller, 1983).

The principal investigator on the Seed Project belongs to a newer generation of women in science. By the 1980s when she earned her PhD in Plant Breeding at Cornell the university had lifted its ban on women in that department. Indeed, by the 1980s, it was possible for a talented female plant breeder to earn tenure at a land-grant institution and aspire to positions of leadership within agricultural research in general. Similarly, one of the key representatives on the farmers' side of the project, Ann, also had earned a PhD, in her case in Sustainable Agriculture, a discipline that did not exist in McClintock's era. On the surface these two women, the successful academic plant breeder and the farmer/activist, are fairly dissimilar. The farmers' representative had left academia because she told me that the land-grant mission would never truly welcome the alternative agricultural perspective. The PI had stayed in academia and had become one of the leaders in her field. Despite this difference, I see similarities between these two women, when compared to Barbara McClintock, of the sort that Helen Longino would applaud. Whereas McClintock was, by personality and bitter life experience, someone who worked alone, both the PI and the farmers' representative were aware of and eager to establish collaborative networks between their institutions. They both possessed a set of skills which would have eluded McClintock, namely the capacity to forge alliances with those whose institutional and political allegiances were sometimes deeply at odds. My point here is more than just an empirical example of two individuals, what we see in this brief example are the results of a knowledge-production process that has become more inclusive. Not only does having women in leadership positions in organizations change who does the work, with that change in identity comes a raft of new skill requirements. A scientist who could endure the conditions of an earlier era, who was shaped by that era but also in the rewarded for her persistence, would not have been able to initiate a participatory project like the Seed Project. The human skills, the capacity to bridge cultural, ideological, and material chasms would not have been within McClintock's reach. Instead the somewhat more open academic venue of the 1980s made it possible for certain determined women to master both the technoscientific and the networking skills to initiate a form of plant breeding that in turn opened the discipline to yet more input from men and women organic farmers.

2.4 Actor-network-theory: a method for uncovering emergent plant technoscience

Earlier in this chapter I mentioned that having abandoned the idea that social influences are monolithic and that they descend upon scientific innovation after the technological artifact has been produced, science studies scholars have redirected their work towards observing innovation at its moments of inception. The emphasis on studying emergent science especially as advocated by Latour, (Latour, 2005) made this kind of approach particularly useful for my study.

The pilot project, what I am calling the Seed Project, brought together individuals whose status in relation to one another was ambiguous. I could have created a hierarchy of relationships based on a theory of power. Organic farmers in the Northeast, could have been presumed to be operating from a position of lesser power because of their relatively limited financial means and lack of institutional backing. While this power analysis approach would not have been *per se* incorrect, I will show in this section and the next, ANT is a more useful approach. Pure power analysis might have lead one to overlook organic farmers sources of independence, namely, they are capable of surviving without institutional affiliations and much money. In a very real sense, establishing context, especially economic context, might have blurred the data collection process and have led to the tendency to underestimate the power of farmers. Latourian ANT counters that potential problem by looking for points of collection, intersection, and translations between actors in a way that refrains from passing hasty judgment about the nature of the interconnectedness of specific parties. Translation, as the term is used by ANT theorists, means the process by which knowledge and networks and produce that knowledge are organized and created anew. Michael Callon has outlined that process as having four steps: becoming indispensable; *intressement* or locking in alliances; enrollment or defining and coordinating roles; and finally, mobilization and production of symmetry. The task of the sociologist, as presented by Callon, resembles the hunter in the forest following a bloodhound retracing each step. The track, obscure and covered with litter, winds its way unexpectedly through a clutter of images, objects, sounds, and sensations. Constructing, or reconstructing, the path forward consists of linking one slight signal with another into a chain of relationships as well as determining the full scope of agents, people, plants, animals and/or objects, involved. The sociologist, like the tracker, knows something about the nature of prints, disturbance, and what might constitute a meaningful sign. At the same time, while not claiming some kind of absolute objectivity or lack of preconceived knowledge, the sociologist/tracker consciously pays attention to that which is emergent. Latour has said most recently,

> . . . social aggregates are not the object of an ostensive definition—like mugs and cats and chairs that can be pointed at by the index finger—but only of a performative definition. They are made by the ways and manners in which they are said to exist (Latour, 2005, p. 9).

In this framework, social aggregates, function like linguistic signs in classical semiotic theory (Culler, 1986). Just as the meaning of a word is always emergent, always changing, a social aggregate coheres as we watch, and by watching, we participate in the process of consolidation. Our purpose as analysts is to map the new connections between agents and to understand the nature of the translation and the information exchanged, when these new connections are established, while yet recognizing that our maps become part of the framework upon which the aggregate's future work will hang. Of course, ANT theorists have acknowledged that agential translations do not happen in a vacuum, rather that frameworks of standards, epistemological definitions, and institutional incentives intervene to influence and demarcate translation work (Bowker and Star, 2002; Latour, 1999a, 2005; Law, 1991). However, as Emma Whelan pointed out in a comprehensive review article in 2001, ". . . . mainstream STSs blackbox questions of social inequality. . . " (Whelan, 2001). Thus key figures like Bruno Latour can publish a book like *Reassembling the Social* without the term "feminism" in the index. More distressingly, he footnotes Donna Haraway only twice and in both cases does not address her very outspoken, and at this point, 10-year-old, objections to feminists' exclusion from science studies.

> Either critical scholars in antiracist, feminist cultural studies of science and technology have not been clear enough about racial formation, gender-in-the-making, the forging of class and the discursive production of sexuality through the constitutive practices of Technoscience production themselves, or the science studies scholars aren't reading or listening—or both. . . It is past time to end the failure of mainstream and oppositional science studies scholars to engage each other's work. Immodestly, I think the failure to engage has not been symmetrical (Haraway, 1997).

Whelan agrees with Haraway and demonstrates in nuanced ways that it is mainstream science and technology studies's discomfort with feminism that has caused those scholars to neglect feminist science studies not the other way around (Whelan, 2001). In the intervening years since Whelan's article was written, the intellectual landscape has not shifted dramatically. A key point of contention between feminist science studies scholars and ANT remains, namely, what Whelan calls the principle of generalized agnosticism. ANT argues that, " . . . .the investigator should not take sides in the technical or social aspects of the controversy being studied;. . . (Whelan, 2001)." Latour himself is adamant about the importance of refraining from imposing any preconceived notions of institutional context or power relations upon the data collection process, arguing that to do so shifts the knowledge collection process away from that which is emergent and towards that which is reified (Latour, 2005). From a feminist point-of-view it is odd to imagine the performative creation of knowledge taking place without power relations or cultural context. Indeed, the feminist/queer theory work on performative social aggregation would seem to demonstrate that to the contrary, performance requires a stage, metaphorically or otherwise (Butler, 1993, 2004).

Despite the failure of ANT to account for what one might call context or the network stage, it does remain a powerful methodological tool for investigating plant breeding as a technoscience. In particular, ANT's focus on studying networks as they are forming, or being formed enables one to examine a pilot endeavor, like the Seed Project, which is engaged in work that is rare and undervalued, like traditional plant breeding of varieties appropriate for organic farmers in the Northeast. In doing so the ANT methods provide the sociologist with grounds and methods to explicate what matters about this kind of behavior. Indeed, unlike Haraway whose work is too speculative to be useful in the field, Latour's cookbook approach to data collection and his insistence upon taking seriously the agency of non-human actors was particularly useful in answering the question, "Why does the Seed Project matter?" Even ANT's agnosticism about power relations was useful at the data collection stage because it enabled me to ask the questions over and over again: How do you do your work? Who do you gather information from? How connected are you to others? The metaphor of the circulation of scientific knowledge, and the accompanying assumption that science can be practiced by anyone, opened up an aspect of seed saving and agricultural biodiversity that has not be explored in the literature.

2.5 Material, discursive, and social elements

A significant literature sheds light on the participating groups in the Seed Project. The purpose of this section is to provide an overview of of that literature, both because contextualizing Seed Project participants is helpful to understand the interview and other data collected, and also because the discourses and institutions, such as farmers markets or organic farmer knowledge chains, form the infrastructure within which the informants interacted with each other and reflected upon their experiences to me.

2.5.1 Organic farmers in context

Organic farming and seed saving are two movements that came into being as a product of the late 1960s early 1970's back-to-the-land movement (Whealy and Adelmann, 1986). Since that initial period much has changed, the USDA now supervises organic certification and there exists large scale commercial organic vegetable farming in California (Fromartz, 2006; Guthman, 2004; Nestle, 2002). Despite the claims from some critics that organic farming is not as sustainable, as small scale, as farmer-friendly as it may claim to be, (DeGregori, 2004) the organic farms that I visited as part of my study were in may ways part of an alternative lifestyle/food culture that has blossomed in the Northeast over the past 20 years (Katz, 2006; Hall et al., 2004; Carlson, 2008). From the scattered references in the scholarly literature and from the farmers' own websites and publications, it is clear that in some places, small, alternative, organic farms are providing Northeastern vegetable customers with fresh produce at farmers' markets (Griffin and Frongillo, 2003; Brown et al., 2006; Hunt, 2007), through Community Supported Agriculture schemes, by selling to restaurants and other mechanisms (Smith and Henderson, 1998; Henderson and North, 2004; Stock, 2007; Lien et al., 2007) .

From one study we also know that even if organic farmers started out life as conventional farmers, the process of converting to organic farming transforms the ways in which one obtains and uses knowledge (Morgan and Murdoch, 2000). Morgan and Murdoch explain that conventional farming is governed by three components: economic and strategic rationale, political and administrative commitment, and technological innovation as a source of all increased productivity (Morgan and Murdoch, 2000). Organics, at least of the kind we have been discussing above, require far more interaction and thus a wholly different mode of operation for farmers (Morgan and Murdoch, 2000). Even the extension-to-farmer relationship changes when the mode of farming shifts (Grundens-Schuck, 2000).

2.5.2 Plant breeding for low-input systems and other innovations

The current conventional seed system serves primarily big markets, which in the US for vegetables means that much of the plant breeding and seed production is being done with optimal growing conditions for California in mind. An alternative approach does however exist. The practice is called by several names and varies in its details in important ways but for the time being we can lump together a group of farmer-directed and farmer-inclusive practices called: participatory plant breeding, evolutionary-participatory plant breeding, or decentralized plant breeding (Dawson et al., 2008; Murphey et al., 2004; Ceccarelli and Grando, 2007; Mangione et al., 2006; Zeven, 1999; Zimmerer, 1996). All of these techniques involve professional plant breeders, sometimes university employees, sometimes employees of the international crop improvement centers, working together with farmers in various ways to develop new plant varieties. In the United States, Steve Jones, a wheat breeder at Washington State University, is the most outspoken and well-published breeder who works to provide varieties specifically intended for US low-input farmers. The literature on participatory plant breeding (PPB) for organic farmers is almost exclusively directed at providing crops for poor farmers in the developing world although there are some scholars such as Witcombe and Virk who do also publish scholarly work on PPB that can be applied to developed world organic farming needs (Witcombe and Virk, 2001; Witcombe et al., 2005; Joshi et al., 2001; Sperling et al., 2001; Elings, 2001; Zeven, 1998, 1999; Dawson et al., 2008; Desclaux and Hedont, 2006).

The vast majority of published studies on participatory plant breeding focus on breeding for poor farmers in the developing world, in particular those who struggle with arid conditions (Ceccarelli et al., 2000, 2003; Morris and Bellon, 2004)(David, 2004) or who face isolation from the mainstream seed system (Mangione et al., 2006; Ceccarelli et al., 2001; Baenziger and Cooper, 2001). These studies address a wide range of subjects which could be of interest to organic farmers working with plant breeders in the US or with plant breeders working to design effective participatory programs for the first time. This is true despite the fact that many of the programs operating in developing countries do not serve organic communities, they do, however, serve low-input farmers whose use of inputs is often similar to the approaches used by organic farmers in the US. Given that most plant breeding programs in the US do not currently engage with the organic community and that therefore most US trained plant breeders do not have the opportunity while in graduate school to learn the details of running this kind of breeding program, it is unfortunate that much of this descriptive and analytic materials is published relatively infrequently and in mostly European journals. The issues addressed include: how to build on traditional approaches (Gibson et al., 2008), farmers' valuation of crop diversity (Brush and Meng, 1998; Brush, 1991, 1996), farmers' breeding for durable disease resistance (Daniel et al., 2007) and comparative work that can help to guide the decision when and for what purpose PPB or other farmer-inclusive methods should be used (Atlin et al., 2001; Vernooy, 2003). Almkinders and Elings' 2002 article provided a particularly comprehensive overview of the question when and how farmers should be engaged in participatory plant breeding vs. participatory varietal selection. The distinction is essentially at what point in the multistage breeding process should farmers be engaged under specific kinds of environmental circumstances (Almekinders and Elings, 2001). The variables that will determine which methods are appropriate vary by crop type, the extent to which the germplasm available is developed, the extent to which the germplasm varies and therefore to what degree farmers can begin to breed without importation of external sources of desired traits, and a whole host of other technical and social/economic issues.

2.5.3 Participatory plant breeding: theory and practice

Participatory plant breeding is a reinvention and reworking of a process that until the late 19th century was the norm in crop improvement. From the first instance of crop domestication until that time, farmers had selected and saved the seed from their fields and used that material or similar varieties that they might have traded with neighbors to produce the next year's crop (Kloppenburg, 2004; Smith, 1995; Pistorius and van Wijk, 1999; Fussell, 1992). While it is true that there existed a flourishing international trade in seeds and plants, especially on the heels of European colonial expansion, (Flitner, 1995; Beinart and Middleton, 2004) those efforts were directed at capturing and maintaining monopoly over specific varieties rather than breeding *per se*. Two countries, the United States and Germany, led the transformation of plant breeding from an on-farm activity conducted by practitioners to a research activity led by academically trained scientists (Wieland, 2006; Kloppenburg, 2004; Pistorius and van Wijk, 1999; Rosenberg, 1961; Fitzgerald, 1990). This process was gradual. Initially plant breeders would release varieties when they still contained significant amounts of variation which farmers could then use to fine-tune varieties to match their own circumstances (Dawson et al., 2008; Jones and Murphy, 2008). Today the varieties released are stabilized and contain very little variation. Some contend that hybridization is the main cause of reduced variation but that idea remains contested. Some plant breeders argue that hybridization *per se* does not eliminate the need for diverse seed stock as a source for useful traits nor do hybrids necessarily reflect a genetically narrow base particularly in the last 10-15 years when diversity issues have received more attention (Smale, 1997, 2006; Smale et al., 2002).

By the end of the 1930s the new science of plant breeding had become ensconced in national state-run institutions which, in the case of the United States, meant the USDA extension system and the land-grant universities (Kloppenburg, 2004; van Wijk, 1998; Fitzgerald, 1990). There the majority control over the direction of plant breeding, its research objectives, chosen methods of work, and control of the baseline materials with which these scientists bred, rested with public plant breeders employed by institutions with a mandate to serve the public good, however that might variously have been defined (Kloppenburg, 2004; Pistorius and van Wijk, 1999). Kloppenburg is particularly emphatic that from the 1930s onward, private enterprise chafed under the limitations placed upon them by the control exercised by plant breeders who were not subject to their influence. That tide has decisively turned since the early 1980s when a series of intellectual property regulations, a significant reduction in public funding for plant breeding, together with numerous technological innovations have transferred much of the control over international breeding priorities and policies to private companies (Kloppenburg, 2004; Duvick, 2004; van Wijk, 1998).

Beginning in the late 1990s, another trend began to emerge that was concerned with developing plant varieties for poor and subsistence farmers in developing nations. Breeding for developing countries has been a contested arena for some time. For example, I mentioned above the conflicts surrounding the Green Revolution that began in the 1940s and extended into the 1960s. While grain production soared in areas like the Punjab, critics like Vandana Shiva and others contend that the new hybrids use undue quantities of fresh water, require dangerous and uneconomic amounts of artificial fertilizer and pesticides and shift production to export crops at the expense of more diverse plantings for local consumption (Shiva and Moser, 1995; Shiva, 1993, 2007). However one may choose to judge the performance of those modern varieties, it was becoming clear to some breeders that farmers located outside of prime farmlands were not being served by the international seed system nor their respective national seed development systems. Because breeding was now securely in the hands of trained scientists working for governments or private corporations, most breeders would have little knowledge of the needs and preferences of marginal farmers. As we have seen from the example of Erwin Baur, certain breeders have always been concerned about genetic erosion especially in areas of high altitude like the Andes, or arid regions, like the Middle East, where poor and subsistence farmers were using seed that was either bred for conditions vastly unlike their own, or using local landraces that might not be optimal for their conditions (Ashby et al., 1996; Zimmerer, 1996; Mangione et al., 2006; Cleveland and Soleri, 2002). In various locations, most notably the International Center for Agricultural Research in Dry Areas (ICARDA) in Syria, breeders initiated programs that had as their goal not only developing better plants but doing so in coordination with and with the input of end-user farmers.

2.5.4 Plant breeding: a negotiated science

> Distilled to its essence, plant breeding is human directed selection in genetically variable populations of plants. . . . If successful, selection results in a population that is phenotypically and genetically different from the starting populations. William Tracy, Department of Agronomy, College of Agricultural and Life Sciences, University of Wisconsin-Madison, speaking at the 2003 Summit, Seeds and Breeds for 21st Century Agriculture.

> Plant Breeding is a fascinating science because it's very complex; it requires tremendous knowledge of related disciplines, including real sociology, and we have to use a lot of almost instinct to figure out how to breed better crops. . . . Jake, academic plant breeder

Tracy's definition emphasizes the transformative center of plant breeding, the task of moving one variable population of plants towards an end product that looks and is genetically different from the original. Within the constraints of the germplasm of the original population, any given population A can yield output populations with significantly different characteristics. That is, any two plant breeders working with the same population might well produce finished varieties that are unlike. What will determine the shape of the finished variety will be two things above and beyond the biological limits of the plants: the skill and judgment of the breeder, what Barbara McClintock called a "feeling for the organism" (Fox Keller, 1983) and what Tracy calls the breeder's eye

(Tracy, 2003) and, the information that a breeder can collect about the needs of the end-user. It is this second category that participatory breeding addresses in innovative ways by shifting farmers from consumers of market-ready products to co-determiners of plant breeding outcomes. It is vital to understand, however, that all plant breeding, even the most conventional, requires a feedback loop from end-users to breeders in order to insure that varieties developed are those most desired. Indeed, Jake, the breeder quoted above, is describing non-participatory breeding which he indicates requires a capacity to survey the sociological needs and contexts of end-users. Social scientists working within the international crop development system agree and suggest the need for broader assessment criteria of plant breeding impacts with particular attention to social questions such as distribution of potential benefits and the need to diversify decision-makers within the global breeding system (Morris and Bellon, 2004; Morris and Heisey, 2003).

One of the central variables which breeders aim to improve is crop yield and it is here that we can see how influential management decisions can be. In the case of crop yield, Cleveland has demonstrated that value judgments made by plant breeders about the socioeconomic factors that affect farmers' management decisions, may in turn impact choices that breeders make in crafting cultivars (Cleveland, 2001). What we see then is that plant breeding is a scientific practice that requires some level of contact with non-scientist end-users, and which requires that judgments about social and economic needs of end-users be integrated into a subtle understanding of how plant germplasm can be selected over a series of generations to produce cultivars whose performance is distinctly better by some measurable criteria. Breeders are trained in methods of manipulating the course of plant biology but a significant contribution to their success may lie in their ability to assess and quantify human needs and desires, a task for which they are not particularly educated and for which they may not be granted more than marginal support. Certainly the capacity for critical social analysis displayed by some experienced plant breeders appears to be accrued outside of formal educational channels. Plant breeding seen from this perspective is an on-going series of negotiations between interested parties operating within and on the margins of their formal expertise, reacting to the biophysical products that selection of a given population produces.

2.5.5 Versions of participation: a continuum of options

As I mentioned in the Introduction, participatory plant breeding enjoys many forms around the world. Witcombe *et al.* and Biggs and Gauchan have argued that an unnecessary dichotomy has sprung up between those who claim to be explicitly involved in participatory breeding and those who are not, which leads to unnecessary balkanization within the profession (Witcombe et al., 2005; Biggs and Gauchan, 2001). These authors propose that there exists a tradition of working closely with farmers as research participants in developing countries and that the actual techniques labeled as participatory (Atlin et al., 2001) might be better described as more or less client-centered approaches.

The benefit of Witcombe *et al.'s* analytic framework lies in the relative ease with which it lends itself to outcome assessment of the sort essential for plant breeders working within the formal breeding sector. For example, the breeding process can be broken down into four product innovation stages: product design, product development, product testing, and product marketing, with an additional fifth stage of customer feedback (Witcombe et al., 2005). At the product design stage, farmers, seed company representatives, possibly consumers or food processors, would be consulted about their specific needs and desires for a particular crop. Breeders could then take that information back to their institutions and proceed as they would normally reemerging only at the very last stage of the product testing, or participatory varietal evaluation, to ask farmers to trial relatively finished varieties in their fields. Morris and Bellon have called this the efficient participatory breeding model because they contend that it makes the best use of the respective talents and time of farmers and professional breeders (Morris and Bellon, 2004). In their words:

> The distinction between ends and means is important. During some stages of the breeding process, there is no reason to believe that increased participation by end users will necessarily be beneficial. For example, most trait improvement work (i.e. pre-breeding) and even many types of cultivar development work can be carried out very efficiently by station-based plant breeders using well-established scientific selection strategies and statistically valid analytical procedures. It is difficult to imagine how involving farmers in these activities will lead to improvement in breeding efficiency (Morris and Bellon, 2004, p. 33).

The concern here is two-fold: to ensure that outcomes of the participatory process are of a quality equivalent to what they would have been had the process been all done on-station, and to avoid wasting the time and limited resources of farmers who are already presumed to be stretched to their limits working marginal lands. At the same time, empirical work done in a number of locations seems to indicate that farmers may in fact be more capable of participating in the more complex portions of plant breeding than previously suspected (Mangione et al., 2006; van Eeuwijk et al., 2001; Ceccarelli et al., 2000, 2003; Ceccarelli and Grando, 2007; Ceccarelli et al., 2001; Baenziger and Cooper, 2001; Almekinders and Elings, 2001; Daniel et al., 2007; Gibson et al., 2008). The work done over many years in Syria at ICARDA is particularly notable because it demonstrates that farmers with relatively low levels of education by developed country standards (high school) can in fact track complex data, are willing to do so if they perceive a tangible outcome, and do in fact prove capable of nuanced selection choices and decisions which would qualify as product development under the Morris and Bellon scenario (Ceccarelli et al., 2000; van Eeuwijk et al., 2001; Ceccarelli et al., 2003). In a specific assessment of costs at ICARDA, the participatory program reached its breeding targets a full three years earlier than the centralized equivalent, which means that the overall costs became essentially the same (Mangione et al., 2006). The potential for other programs could reach a cost savings of between 5 and 28% (Mangione et al., 2006). More fundamentally, however, the client-centered model presumes that formally trained scientists based at experiment stations, universities, international and national breeding institutions and other research organizations, will provide leadership and maintain ownership of participatory breeding projects. Although this has been a common model, there exists an alternative, farmer-led participatory breeding which has compelling benefits (Sperling et al., 2001).

Farmer-led plant breeding such as the efforts of the Organic Seed Alliance in the United States, work in concert with formally trained breeders to various degrees but the goals and duration of the projects are determined by farmer needs and timeframes rather than by the constraints of research funding and publication requirements. Sperling *et al.* describe the formally-led PPB initiatives as those which, ". . . invite farmer participation in formal research (Sperling et al., 2001, p. 428)." But where the primary goals include data that meet scientific standards of applicability and validity, ". . . scientists involved in formal-led programs are usually expected by the scientific community to extrapolate their methods, if not the varieties per se, beyond the individual community with which they work (Sperling et al., 2001, p. 441)." To that, I would add from my data that the current funding climate in the US further constrains US-based university breeders for whom the primary source of research support are competitive grants. Grants are directed towards seed funding for cutting-edge or pilot projects rather than long-term support of proven development methods. The most recent example of this is the NSF Basic Research to Enable Agricultural Development program which funds only what it calls, "basic research to lay a foundation for sustainable agriculture in developing countries (National Science Foundation, 2009b)" without requiring that farmers or even developing country scientists participate. My data is supported by observations of eminent senior plant breeders on the state of their profession and an Iowa State survey that observed similar negative trends (Duvick, 2004; Frey, 2000). Furthermore, tenure and promotion tend increasingly to privilege publications over the production of varieties as proof of academic productivity. The differences between the client-centered model and the formal vs. farmer-led model of analysis stem from differences in assessing the shortcomings of the existing centralized plant breeding system. All parties agree that while plant breeding for optimal growing conditions have raised yields of certain commodity crops, lesser grain crops such as sorghum or versions of major crops that can grow in profoundly challenging climatic circumstances or poor soils, such as maize for arid climates, have not benefited from centralized approaches (Biggs and Gauchan, 2001; Ceccarelli et al., 1996; Mangione et al., 2006; Baenziger and Cooper, 2001; Courtois et al., 2000; Desclaux and Hedont, 2006; Elings, 2001; Almekinders and Elings, 2001; Atlin et al., 2001; Witcombe and Virk, 2001; Ghaouti et al., 2008; Navazio, 2008). Many vegetable varieties grow in such small regions or are consumed in relatively small quantities from the perspective of a transnational life sciences corporation, and so have been neglected. Furthermore there remains significant disagreement about the degree to which low-input or organic farming systems need varieties adapted to those specific sets of conditions which may vary as much between locations as they do from high-input systems (Dillon, 2008; van Bueren, 2008). Cleveland's work on the social construction of yield stability cited earlier demonstrated that more than resource limits may have been involved in the neglect of what are now underserved crop types.

We can see from this brief overview of the literature that PPB is very much a science in its infancy. While some work has been done in developing countries, even some supporters of participatory plant breeding limit the role of farmers to narrow kinds of input. Others have understood that farmers are indeed far more capable of working closely with scientists to determine outcomes. The more effectively farmers can be incorporated into the decision making process that is at the heart of plant breeding, the more likely are the results to mirror their needs. However, given that plant breeders for the most part have moved away from working with farmers directly and towards a more distanced approach, one of the challenges of the Seed Project became reestablishing unfamiliar relationships with a group of farmers whose input had been marginalized.

2.6 Formal plant breeding: how it works

The outspoken team at ICARDA describe their fellow plant breeders who work only in centralized modes and for optimal conditions as having the following limitations:

• they generally produce genetically uniform cultivars (pure-lines, clones, hybrids)

• they are largely conducted either in good environments or in well-managed experiment stations where growing conditions are optimum or near-optimum

• in most grain crops selection is almost exclusively for grain yield and disease resistance

• they promote cultivars which can be grown over large areas (widely adapted in a geographical sense)

• they do not involve the clients (the farmers) in any of the steps which will eventually lead to new cultivars, except perhaps in the final field testing of a few promising lines.

Assumptions of formal breeding programmes are that:

• selection must be conducted under good growing conditions where heritability is higher, and therefore response to selection is also higher

• yield increases can only be obtained through replacement of locally adapted landraces (Busch et al., 1991) which are low yielding and disease susceptible

• breeders know better than farmers the characteristics of a successful cultivar

• when farmers do not adopt improved cultivars it is because of ineffective extension and/or inefficient or insufficient seed production capabilities; the hypothesis that the breeder might have bred the wrong varieties is rarely considered (Ceccarelli et al., 1996, p 100).

It is important to note that these observations were made in the mid-1990s when skepticism of, if not outright resistance to, participatory plant breeding practices was undoubtedly much greater (Cleveland et al., 2000). However, in a very recent article, Dawson, *et al.* address some of the same concerns. They conclude, for example that G x E (genotype x environment interactions, or the relative interaction between the DNA of the plant and the environmental conditions of its planting) are still being used as a justification to only breed in optimal conditions (Dawson et al., 2008). Essentially, proponents of breeding in optimal conditions argue that only under those circumstances will the breeder be able to distinguish those traits that are truly genetic in origin rather than just the temporary impact of this year's growing conditions. Dawson, *et al*. respond that:

> Selection for specific environments involves a positive interpretation of G x E interaction, where top performing lines are selected in each target environment (Dawson et al., 2008, p. 145).

In other words, a decentralized breeding program that puts experimental material in many locations can then select the most effective cultivars in each set of challenging circumstances. If that decentralized breeding plan happens also to be a participatory breeding project which involves trained farmer participants who are skilled in working in those difficult environments, the results of the increased data flow are likely to be much better. There appears to be no credible short cut around the necessity of maximizing both the volume of data and the number of experts having selection input into the system when it comes to developing varieties for difficult climates or for low-input systems (Ashby et al., 1996; Biggs and Gauchan, 2001; Ceccarelli et al., 1996; Mangione et al., 2006; Baenziger and Cooper, 2001). Another aspect of the ICARDA team's analysis that appears to have stood the test of time is far more radical, namely the contention that farmers who have chosen to prize varieties that are less improved or essentially untouched by the centralized plant breeding system, do so not out of ignorance but for logical reasons. The varieties that farmers retain frequently have some set of characteristics that are culturally or economically relevant to their farming system, perhaps the capability to produce consistently even in the worst years, perhaps the capacity to produce compensatory byproducts like animal feed if the commercial crops for human consumption fail. Increasingly, these farmer desires are being recognized and recorded in international symposia and in the scholarly literature (Zeven, 1998, 1999) where both farmers and their breeder advocates argue that the food system needs a more diversified seed stock and that reintegrating farmers into the breeding process is a part of that decentralization process (Dawson et al., 2008; Desclaux and Hedont, 2006).

Relocating expert knowledge and innovation at the level of farmers does require a reevaluation of the distance that has grown up between scientifically trained breeders and their farmer clients. Particularly, the farmer-led initiatives represent a fundamental reversal of the model in which highly trained experts in centralized institutions collect a wish list of needs from farmers and then provide an answer to those needs with the accompanying assumptions about the use of agricultural inputs, water, diversity of production on individual farms and a whole host of other factors which become logical extensions of the socio/economic model that breeders presume farmers are using. The ICARDA team refers to PPB by yet another name, "demand driven research", highlighting the ways in which even in research circumstances where formally trained plant breeders are providing a base of operations for gathering data, coordinating results, and publishing and/or sharing results, large numbers of formerly silent farmers are given the opportunity to have direct input into the development of the seed upon which their livelihood depends.

In a very pragmatic way, PPB done well represents a democratization of science in the service of better adapted crop cultivars across a range of environments that a more centralized system would be unlikely to afford to serve or perhaps even inclined to notice. Very closely related to the question of creating better adapted cultivars using democratic modes of participation is the issue of diffusion of those cultivars. Once a variety or a genepool is determined to be ready for release, does the fact that it was developed using a collective participatory process affect the distribution process? Moreover, when the participatory breeding process involves distributing experimental or proprietary materials, does that in turn make it more difficult to retain rights over those materials? In short, does PPB lead to a leaky system of intellectual property rights and if so, is that a bad thing? These are not questions that can be answered here but it is important to note that if PPB leads to freer circulation of plant materials this could become yet another source of resistance to the centralization of intellectual property. At the moment the world seed market is dominated by large multinational seed companies that have a strong interest in maintaining control over what they regard as their property, although farmers do still save seeds for their own use (David, 2004; Duvick, 2004; Dillon, 2008).

The degree to which farmers save their own seed, and thereby potentially circumvent intellectual property regulations, is highly dependent on crop type. Commercial wheat farmers in the US, for example, are far more likely to save their own seed than maize farmers because commercial maize varieties are all hybrids and wheat varieties are not. Vegetable farmers, even small scale organic farmers who are underserved by the commercial seed market, are estimated to save less than 10% of their seed (Dillon, 2008). The most crucial observation that must be made about PPB and distribution of seed is that PPB-improved varieties need to achieve distribution beyond their location of development. Although the virtue of PPB developed varieties is specific adaptation to difficult conditions, it may also be greater genetic variability which is of use to farmer-breeders in other challenging locations. It is thus vital that a full-fledged PPB program incorporate reasonable diffusion mechanisms in order to maximize breeding outcomes (Lindner, 2004; Joshi et al., 2001).

2.7 Lessons learned from the developing world

In some very real ways, the groundwork for a US-focused organic seed development program has been laid by the work done by participatory plant breeders and farmers in the developing world. By taking the lessons learned from that literature, particularly the experiences at ICARDA, and transforming those methods into a framework that provided improved vegetable varieties for the US organic sector, the Seed Project serves as a form of technoscience transfer back into the United States from some of the poorest locations on the planet. The process of adapting the developing world model to first world conditions was significantly challenging as we will see in later chapters. Nonetheless, it is important to notice that PPB came into being initially because scientist-driven development was either too expensive or not available. The adaptation that the Seed Project engaged in required enhanced qualities of leadership and networking on the part of all participants but especially on the part of the project's leadership team. Even just understanding the reasons why organic farmers need a more inclusive, decentralized breeding approach was not on the table until plant breeders were able to recognize the value of a broader range of agricultural goals such as support for the vegetable production outside of California. We see a clear example of how shifting ideas about who should farm and where they should do so, as well as, who should breed and toward which goals they should aim, meshed with an increasingly sensitized academic plant breeder and an increasingly vocal farming sector, to produce a new kind of participatory plant breeding technoscience.

Chapter 3

Methods

3.1 Emergent science

This dissertation was conceived as a qualitative case study of a plant breeding project that was itself singular. As far as the principal investigator (PI) on the project was aware, and subsequent investigation of the published literature seem to substantiate her impression, there has not been a participatory plant breeding project aimed at producing appropriate vegetable varieties for organic farmers in the United States. Because of the bounded nature of the object of study and the defined period of time in which the research could occur, the case-study approach was justified (Creswell, 1998). From a reflexive feminist perspective, I was particularly interested in the means by which the daily interactions between individuals reproduced or challenged the relationships between a land-grant university and farmers. When I began the study I was and had been for many years an exempt staff member at Penn State. My own experiences as a women, non-PhD employee in at a land-grant institution made me sensitive to the ways in which gender, educational credentials and class membership determine a given individuals' opportunities in higher education and ability to effect change. In addition, a feminist case study analysis fit with the actor-network focus on studying a phenomenon in its emergent stage with attention paid to the interactions that create what will become an operating node in a larger network of technoscientific relations (Latour, 2005). Dorothy Smith argues, and I believe that her analysis fits my study well, that individual cases are sociologically important as a portal onto a series of social relations and subjective experiences that allow the sociologist to reflect on circumstances and networks far beyond the limited data that is studied.

> The particular 'case' is not particular in the aspects that are of concern to the inquirer. Indeed, it is not a 'case' for it presents itself to us rather as a point of entry, the locus of an experiencing subject or subjects, into a larger social and economic process. The problematic of the everyday world arises precisely at the juncture of particular experience, with generalizing and abstracted forms of social relations organizing a division of labor in society at large (Smith, 1987, p. 157).

Smith and Bruno Latour, a key proponent of actor-network-theory (ANT), as I will later show, emphasize the importance of looking to the actual work done by individuals on a daily basis as the essential data point in any sociological study (Latour, 2005; Smith, 1987).

Daniel Kleinman, in his book *Impure Science,* recounts that Jo Handelsman, the scientist whose lab he was studying, insisted that he participate in the work of the lab despite his lack of training (Kleinman, 2003). Her logic was that some degree of experience with the actual work of science was essential to understanding the context in which it happened. Professor Handelsman's position can be seen as a version of the feminist injunction to reflect upon one's status as a researcher and how that might change the behavior of one's research subjects. Handelsman, as a research subject, created a situation in which the sociologist studying her work could observe his own reactions to the work of the laboratory and thus better understand the behavior he would see in others. In my own research, I learned the validity of that approach first hand. Originally I had planned a relatively structured interview approach which is reflected in the questions listed in the Appendix . Within hours of arriving at the field house which the staff at the host university used as its base, I realized that I needed to immerse myself in both the technical knowledge that plant breeders use and the actual work that occurs in fields and greenhouses, if I were going to understand the logics that drove the work I was observing. Indeed, my first conversations with the technical staff felt more akin to an international cross-cultural experience than anything else. Although my informants were eager to share their insights and happy to provide me with any possible information I could use, their answers to my questions presumed so much prior knowledge that I could not follow the analysis. Somewhat shell-shocked and definitely worried after my first day of data collection, I returned to my tent in the rain to read Latour and Smith, searching for clues for how to proceed. Those two texts became handbooks representing as they do two approaches to understanding phenomena which are deeply hidden within the fabric of society but may be accessed by watching and experiencing the work process as it happens.

Initially I looked to Latour's instructions on how to look for spokespeople and trace regroupings among actors as they were happening (Latour, 2005, p. 30-31). Because my informants were interacting with each other in new ways, ways they had not considered prior to the advent of the project, it was possible to explicitly ask informants how they came to work together and the nature of the affiliations they now had as a result of the project. A second vital lesson learned from Latour, and eventually from other ANT theorists, was the importance of including the material world in my analysis. To that end, I reorganized my data collection such that I could spend as much time as possible with each informant doing the work that they did. Moreover I took home extra plants from the project and planted them in my own garden, spending time teaching myself to look at plants in a new way. Prior to this research I had been most concerned with the differences between plant types–is this plant a tomato or a potato? Plant breeders and farmers have taught me to look for a range of variables within a species–is this tomato determinate or indeterminate? can it survive without staking? does it germinate quickly but then grow slowly or the reverse? Today I grow open genepools which vary widely in order to continue to learn the distinctions that matter and the variables that can be altered. In a sense what I have learned is the social construction of vegetable plant variation, namely, how to notice what matters about vegetable plants and characterize and classify those distinctions.

Smith's work contributed the idea of looking for lines of rupture between, ". . . experience and the forms in which experience is socially expressed. . . (Smith, 1987, p. 50)." This rupture or line of fault points to power differentials between men and woman but also, as in my case, between those who possess the legitimacy and credentials to speak on their own behalf and those that did not. In later chapters I will discuss the specific gender dynamics of this project but for now it is important to say that as I watched a new network of actors form an identity and negotiate the roles they would play, I inserted new questions into my interviews that probed the range of actions available to different types of individuals. So I asked, for example, a former graduate student of the

PI if she felt that an untenured professor like herself could initiate a project of the scope that the Seed Project represented or if one needed tenure. I asked the farmer representatives what they felt was the relative advantage offered them from having access to a PhD breeder specifically, as opposed to benefits derived from the whole of the project. These emergent questions helped piece together a picture of the dynamics that set the project in motion and kept it functioning.

In addition, qualitative feminist methodologists emphasize that as one looks for ideas and themes to emerge from the data it is important to interrogate who has power and who is allowed to speak with authority (Hesse-Biber and Leavy, 2007)(Smith, 1987, 2005). Within an institution like a university where educational credentials define an individual's status as a knowledgeable speaker incorporating the experience of individuals with less formal education became a "fault line" in Smith's sense, that is, some individuals knew far more than their formal educational credentials would have predicted. Outside of the university in the alternative agriculture community it was interesting to observe the considerable respect that women enjoyed particularly in mixed-sex farming couples. Several men went out of their way to be sure that I understood how central the women were to the decision-making on the farm.

Of course feminist theory also warns us that there is never a research interaction that occurs without the identity of the researcher playing a role (Lumsden, 2009)as I have already mentioned. It may therefore have been the case that when I asked who works on the farm and what are their roles, some of the men may have felt it important to assure me that their female partners were fully involved in the key decision-making because they were speaking to a female researcher. In one instance a female informant went out of her way to point out that she had bought her farm before she had met her husband with the clear implication that the farm belonged to her and his participation was only secondary. This seemed to be confirmed while I was on the farm when he came and explicitly asked for instructions during the time I was interviewing. On female-only farms all the women addressed the importance of their autonomy, again perhaps because of who I was, since this was not a question I raised with them directly. Taken together, this pattern of affirming the autonomy, independence and decision-making power of women among my informants might have been different had I been a male researcher but, at the same time, the pattern was so consistent on farms where women were involved that it did lead me to conclude that women's roles were important to the farmers I interviewed and not just a function of my sex.

The other complication which led me to significantly expand the number and kinds of questions I asked had to do with the nature of my informants. All of my informants were eager to engage in a conversation rather than simply answer a list of questions. This was particularly true of the farmers whose farms I visited but also the breeders and technical staff with whom I ended up needing to spend considerable time in order to understand their work. The individuals involved in this particular project were eager to present a full accounting of the project and its impact and were therefore unwilling to allow me to walk away with misperceptions about the nature of plant breeding, the realities of organic growing or any issue related to a question I might have asked. As a result although I did ask most of my prepared questions of most informants, our conversations were far more expansive and included many more topics than I had originally intended because the informants themselves resisted reductive questioning.

Initially, because of the relatively small number of participants, I planned to conduct interviews with university-based personnel, organic farmers, and seed company representatives and supplement those interviews with participant observations of project workshops and coordinating meetings. While I did conduct extensive in-depth interviews and did observe meetings and workshops, those two activities alone were insufficient because of the technical nature and complexity of plant genetics. It also wasn't possible to interview some of the informants I had originally thought crucial, therefore, I extended my study to include document analysis, actual field work with the technical staff, attendance at farmers' association annual meetings, attendance at the centennial conference of the Cornell University's Plant Breeding Department, and examination of project outputs such as number of farmers served and related data. My literature review, of necessity, included extensive review of the plant breeding and agricultural production journals in order to understand the technical details of the issues that my research subjects were discussing. I have sent each of my empirical chapters to several key informants for their review in order to be sure that I have represented both the project and the underlying science correctly.

3.2 Data collection

3.2.1 Time frame

The data for this study was collected over four months over the summer of 2006 during which time I engaged in in-depth interviews and on-site observations. I had been able to make one trip to a workshop in the Southeast the previous Spring and I was able to make several shorter trips in the fall of that year. It is important to note that the Seed Project was coming to an end during the time I was interviewing because the grant funding that had made it possible was ending. During the time I was collecting my data, there was an attempt made to submit a proposal for funding from a federal source which ultimately was not successful. The PI on the project had taken a leading administrative position at another university just before my investigation began and although her project continued to run for another two years, her management had to occur from a distance. Despite this fact I was able to interview her several times about the project. By the final six months of the project, most of the technical staff and others working on the project were searching for other work and the program has now ended. Overall it appears that the lead university did the vast majority of the project breeding although individuals from other locations participated as well. For all of these reasons, my research occurred primarily at the lead university and on farms and at locations around the Northeast despite the fact that the project was technically a national project. I did interview and speak with several university-based plant breeders who were working on the project from their respective institutions around the country but when I discuss my results I confine my conclusions to the Northeast because the vast majority of my data was collected there or in reference to conditions there.

A second important issue to keep in mind about my analysis of the Seed Project is that because the project was winding down, I was retroactively studying a project at its late stages, not participating in the early stages or even observing it while it was in its prime. On the other hand, the outcomes of the project and the ability of the project members to assess the project as a whole, was enhanced by the fact that so much work had been done and it could therefore be evaluated. The PI invited me to study the project and in doing so said that she had wished to have a social scientist involved earlier in the project. Both she and all of her staff as well as virtually everyone I interviewed or observed were extraordinarily eager to be of assistance and to share whatever they knew.

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

Table 3.1. Interview Informants

Even when discussing differences and tensions among themselves it was clear that all of the participants, even the most critical, felt considerable regret that the project might be ending and thus my interviews are infused with a certain bittersweet sadness that I judge to be a reflection of the time period in which those conversations were held. In a very real way, my data collection seemed to be functioning as a late stage documentation, a for-the-record commentary on an attempt to do something that hadn't been done before and that all of the participants with whom I spoke would have been glad to continue.

3.2.2 Informants

Table 3.1 shows the number of each type of informant with whom I conducted a direct fact-to-face interview. I interviewed 45 people whom I taped. The interviews were then transcribed by a professional court reporter. Interviews were generally one hour in length although with the technical and other staff they were a great deal longer and occurred over several weeks. I also spoke with the farmers' representatives on repeated occasions. There were only five farmer/breeders who participated in the entire Seed Project as far as I was able to document. I was able to speak with two in person. Two had been interviewed and taped by members of the project who provided me with those unedited tapes. It is also the case that one of those individuals has published on issues related to the Seed Project.

Another indirect source of information was the presentations made over the several years that I have been attending farmers' conferences of various kinds. For example, one of the leading farmer/breeders on the east coast, Brent Grossangel, was not a direct participant in the Seed Project. However, his genepools, especially Even Star Tatsoi, were trialed by the Seed Project and his conceptual work within the organic farming community was a topic of much discussion.

The other key source of information about plant breeding was the Cornell University Centennial of the Department of Plant Breeding and Genetics which was held in the summer of 2006 and is available at `http://www.ctl1.com/publicaccess/calscentennial/presentationlist.cfm`. This conference brought together graduates of one of the premier plant breeding programs in the United States and one of the few that maintains strengths in both molecular genetics and traditional plant breeding. Perhaps it reflects the contested nature of the field that what could have been a nostalgic recitation of triumphs from the past, was instead a rare and fascinating opportunity to hear plant breeders from around the world reflect critically on their work and the status of their profession. The eclectic collection of presentations included a detailed philosophical analysis of the differences between those plant breeders who do selectionist breeding vs. those who prefer the genetic engineering route given by Jim Coors of the University of Wisconsin. Bob Heisey of United Genetics gave a a biting attack on the overuse and over reliance on expensive and ineffective biotechnological methods. These presentations, together with the Proceedings of the Seeds and Breeds conferences and the Organic Seed Alliance conferences, also available on the web (Miles et al., 2008), are one of the best sources for first hand information about the status of plant breeding, germplasm creation and preservation and related scientific and agricultural issues (Tracy, 2003; Dillon, 2008).

3.2.3 Sequence of Data Collection

3.2.3.1 Fieldwork at the lead university

From the first trip I made to the lead university, it became clear that I needed to interview university personnel in multiple positions and in different places in the hierarchy of the project. To that end, I spent several weeks working with the technical and field crew as they engaged in the physical work of planting, fencing, pollinating and otherwise performing the daily work of applied plant breeding. This participant observation/field labor served several purposes: first, it helped me to understand the physical and scientific complexities of plant breeding as I have already mentioned. Secondly, the interviews that I was able to conduct on-site took into account specific examples of issues that the project was facing, particular breeding challenges, for example. Thirdly, since there exists only very limited literature about the component parts of the plant breeding process and how organic breeding might differ from conventional breeding, working with breeders allowed me some insight in that regard.

While working and interviewing the university staff I learned that the breeders and the technical staff doing the organic work were the same individuals who were spending much of their time working on conventional projects including some that involved biotechnology approaches. It also became clear that the Seed Project benefited from pre-existing institutional structures especially those that were intended to connect conventional breeding projects with seed industry representatives. In particular, at the lead university, there exists an organization that operates as a free-standing institute which sponsors a field day every year that brings representatives from seed companies from around the globe to that university's research plots to examine the results of each year's experimental trials. Smaller seed companies of the sort that participated in the Seed Project do send seed representatives to this field day but the majority of the participants are breeders from large transnational corporations. It was at those field days, both from simply observing the interactions between staff and visiting breeders, and from direct interviews the second year, that I was able to have the most contact with industry-based plant breeders. Unfortunately, the seed company representatives from the smaller companies who participated in the Seed Project were impossible to interview in this context because they were twice as busy as the conventional breeders. They needed to see the results from both the conventional and the organic plots. Moreover, at small companies, the representatives cover all vegetable types whereas the representatives from commercial companies have more specialized responsibilities.

The value of speaking with breeders at field days, was first, that I was able to speak with representatives of companies that did not participate in the project as well as those who did. This gave me a broader understanding of the field as a whole and made me aware of the challenges facing the discipline of plant breeding. Also, the three days consisted of walking around fields, looking at mostly dead plants and rotten fruit, and listening to presentations by breeders. Repeatedly I was told that this was one of the few places that breeders from competing companies could associate with one another in a relatively relaxed environment and thus the atmosphere was one of careful but convivial conversation. Moreover, the presentations by the public plant breeders to the seed company representatives gave me insight into the kind of contact that takes place between university-based breeders and seed companies outside of the Seed Project. The upshot of these two kinds of events was a window onto the way in which seed companies can collect information about both the performance of their current varieties as well as the performance of experimental varieties that are in the development pipeline.

My time and financial constraints prevented me from reaching out to the breeders from small companies in other ways but I did find an excellent source of their views in three places: first, the farmers' association that participated in the Seed Project sponsored a vegetable variety round table at their annual conference where seed company representatives attended and shared their views and described the logic of their varietal decisions. Secondly, the PI on the grant was willing to share the grant applications that funded the two projects including the extensive letters of support from representatives of the seed companies that participated in the project. These detailed and articulate letters answered most of the questions that I would have asked the breeders if I had had a chance to speak with them directly. Finally, Fedco Seeds, one of the most prominent small seed companies in the Northeast serving the organic farming market, publishes a yearly catalog that is filled with detailed essays relevant to the issues covered in this dissertation. The author of most of these essays, C.R. Lawn, is considered a spokesperson for the Northeastern organic farm movement by all of the farmers and the farmers' association representatives that I spoke with, and his views are widely supported in that community. This support includes the decision by Fedco to discontinue carrying Seminis seeds when that company was bought by Monsanto.

One of the most unexpected things I learned while at the university was the centrality of the technical staff to the scientific work of plant breeding. This is where Latour's injunction became most useful:

> . . . you have to 'follow the actors themselves', that is try to catch up with their often wild innovations in order to learn from them what the collective existence has become in their hands, . . . (Latour, 2005, p. 36)

Latour and other ANT theorists argue that by looking at where work and coexistence occur, there too, emergent science is taking place. In my case, the technical staff, in particular the head of that staff, had, by the late stage of the project that I observed, become the hub of the project. With the PI far away, this relatively small group of staff people became the filters through which information passed back and forth between the farmers and the breeders. This process was reinforced by the fact that the project had hired two members of the farmers' association to run the organic trial plots and to do some of the organizational work in conjunction with the university technical staff. Thus the technical and field crew who worked on conventional and organic projects and the farmers' representatives who worked only on the Seed Project rubbed shoulders literally in the field house and on the fields of the lead university's research plots. These individuals were almost indistinguishable, men with ponytails, women with dark tans, everyone wearing the same standard issue jeans and work boots. However modest and sometimes grubby we may all have looked after a long day of planting, the plant breeding knowledge of the the technical staff and their farmer compatriots was prodigious.

It was by "following the actors themselves" as Latour urges, that I learned of the vast practical knowledge networks possessed by these these staff members. For example, at the beginning of the main season I helped them to plant out transplants which had been grown in the greenhouses into research fields. These fields contain some of the worst soil, highest concentration of rocks, and heavy disease load of any in use anywhere according to my informants. They were also surrounded by forests filled with hungry deer who had to be kept at bay with electric wires which we strung around the fields with the help of a pick-up truck. Planting involved falling to one's knees on the rocky wet soil, digging a hole through a layer of black plastic, and inserting plants into soil. The trick was to be sure that the plant had soil around it as well as rocks. Each hole would be damp from liquid fertilizer which smelled strongly of fish in the organic fields. Later in the season plants would have to be irrigated which required setting up sprinkler systems in a race against the sun on a particularly hot day. About the same time, I learned how to pollinate crops like squash, learning to tell the difference between male and female blossoms and then the technique involved in hand pollinating and ensuring that access would be denied to natural pollinators after we were done. In the process of doing at bit of manual labor, I was able to learn a great deal about plant cultivation, genetics, and efficient farming skills.

Again, the ANT/feminist perspective guided my data collection as it became increasingly clear that the work performed by the staff included critical judgments and evaluations that are the creative genesis of science. For example, one informant, Jane, a woman with a high school education, was tasked to evaluate the relative tastes of various melon varieties. In her discussion of this job, she explained her frustration that there did not exist standards and agreed upon degrees of deviation from those standards in terms of given attributes of taste, muskiness, sweetness etc. In her view, without those benchmarks, the evaluations upon which further selection choices would be made was vulnerable to unnecessary individual subjectivity because of the lack of mutually shared and defined definitions such as the ones which exist for sugar content. As Bowker and Leigh Starr have detailed at length, it is precisely this kind of mutually intelligible and transferable standard setting which creates the frameworks within which further innovation can occur (Bowker and Star, 2002). But Jane's job did not include the opportunity for her to create and promulgate standards. Jane's educational level was the overt reason that she was not expected to fill in the gap she saw in standards although her access to education was very much a function of her gender and social class which feminists point out are used to justify their own dominance.

> Dominant groups are especially poorly equipped to identify oppressive features of their own beliefs and practices, as standpoint methodologies have argued (Harding, 2004). Their activities in daily life do not provide them with the intellectual and political resources necessary to detect such values and interests in their own work (Harding and Norberg, 2005, p. 2010).

It should be noted that one of Jane's co-workers told me that the PI had attempted to help Jane enter a university program intended to assist staff obtain formal degrees. Jane confirmed this had happened but said that her life was too complex, her commute to work too long and she was simply unable to contemplate such an undertaking.

This is just a small anecdotal example of the sort of scientific thinking that was fairly standard among technical staff working on this project. Although I have not been able to discover how much of this sort of scientific work occurs in labs and field houses I would suggest that the phenomenon was so widespread on this project that it could well be fairly common. That is, it may well be the case that a great deal of the scientific innovation that occurs in university-based projects is done by technical staffs whose existence is unknown outside of their local communities.

3.2.3.2 Accessing farmers

Approximately 250 farmers in the Northeast took part in the Seed Project over the course of the project. Because of the benefits I had reaped working with the technical staff and because I was interviewing in the summer when farmers are very busy, I made the decision to interview farmers on their farms. This meant that I spoke to fewer farmers, 21 in total, and that my geographic reach was necessarily smaller. In return, however, I believe that I learned a great deal more about the nature of their operations and gained a fuller appreciation of the role that varietal selection played in their overall operations. I should also note that the farmers' representatives were also farmers themselves and I talked with them about their own operations as well as larger issues pertaining to the project.

Having made the decision to interview in person, I approached the farmer representative who functioned as the key liaison between the university technical staff and the farmers. She was a former academic who had left the academy because she felt that it was not an institution that would ever adequately serve the alternative farming movement. Her own farm is located in a beautiful valley about 45 minutes from the lead university where I met with her several times and attended a seed saving and processing workshop. This woman was key to the success of my project although she would deny this fact as she denies almost all credit for the considerable contributions she has made to the Seed Project and her organization. Together we reviewed a list of farmers within reasonable driving reach, a list that I had also discussed with the university-based staff. She made suggestions based on a rough attempt to be representative in terms of size of farm, relative length of time in farming, degree of commitment to the project, and type of farm. As a result, of the 15 farms included in my study, 7 were under 20 acres, 8 larger. The larger farms were about 100 acres each with one almost 1,500 acres. Most farms sold to multiple outlets but 4 sold through their CSA, 2 sold only through farmer's markets. My informants were almost evenly split between men and women with one more woman than man. Both men and women held leadership positions in the farmer's organization and 4 women farmed without any men working in their businesses except as occasional labor.

In the end the more farmers I interviewed, the harder it became to characterize them. This was because the farms I visited varied in ways that I did not anticipate. For example, I expected that farmers would either own or rent the land they used. Instead I discovered that 3 of the 21 farmers I interviewed were farming on land trusts, in one case, the land trust had been established by members of the community supported agriculture scheme that the farm served. Two other farms were small enough that they were able to fold themselves into suburban neighborhoods, which was important because as one of those proprietors told me, he didn't pay any extra for his land over and above the cost of his home. This same farmer told me that because of his location relative to a larger nearby town he had more customers than he could handle despite doubling his yearly share price each year. His suburban location meant that he had no competition from, in his words, "real farmers" with more land and more formal infrastructure.

All of the farms that I visited derived some of their income from vegetable farming, hence their interest in participating in the Seed Project. All of the farms sold something other than vegetables with the exception of the two largest and oldest operations. In most instances the other sales were meat products, ranging from chickens to hot dogs, but other products included goat cheese and bedding plants. The two exclusively vegetable operations were both over 20 years old. They provided their owners with a full-time living and had for many years. In one instance, the farm in question had a 300 member CSA run by a business partnership on land owned by a land trust. The second instance was a family farm run by a couple and their two children that sold exclusively at farmer's markets three times per week year round in northern New York State. Both of these sets of farmers exercised considerable leadership in their local communities and within the farmers' association although that took rather different forms in each case. The CSA farm practiced biodynamics and engaged in on-farm seed saving and breeding whereas the farmers' market family focused on marketing and building networks of local production expertise though evening field walks and wintertime discussion circles. The farmers' market family was deeply concerned with helping other farmers to make farming a financially viable livelihood which they felt was a matter of know-how and sharing technical and management information. The CSA lead grower has also been very active in building farmer knowledge primarily via an almost 20 year publishing career. Her books, often written in cooperation with, and representing the best practices of, fellow organic farmers in her region, provide rigorous guidance about the hands-on details of organic farming practice in the Northeast including seed saving and plant breeding. In some ways, her publications and others of her farmers' association, other farmers' organizations and small farmer-organized presses and research organizations like Rodale

Institute, provide a crucial network of information and communication between farmers that I will address shortly.

One final variable that I did not track *per se* but which clearly would be an important issue for further investigation is the precise relationship between market outlets and ability to participate in breeding activities and desire for plant breeding services. Across my sample, farmers regardless of market, wanted better varieties and felt that organic or low-input systems had been neglected in this regard. My sample was too small to effectively measure if type of market actually altered the desire new varieties or if the definition of "improved" varied between farmers depending on their end buyer. However, several farmers did speculate on this subject and I believe that it would be a useful point for further research together with a comprehensive survey of the varietal use of organic farmers in general. Several informants felt that, for example, the more personal contact they had with their customers the more likely they were to be able to tempt them to try odd varieties. I discuss specific examples of this issue in the chapter on agrobiodiversity. Others felt that farmer's market customers wanted recognizable products and therefore those who sold there, particularly the biggest farm that supported a family working full-time from farmer's market sales, that their varietal interest was directed at disease resistance in vegetables with conventional appearance. These are all issues for further investigation.

I also attended another other event during the course of my research which allowed me to observe interactions between groups in a context that turned out to be somewhat confrontational. The first of these events was a vegetable round table held at the annual conference of the farmers' association in the Northeast that I have mentioned previously. The roundtable took place in a small, hot, hotel conference room during a January blizzard. Seed company representatives listened as farmers discussed the relative merits of various varieties. Considerable and heated give-and-take allowed me insight into the candor with which organic farmers describe their relative successes and frustrations with seed. It also gave me a clear sense of the kind of pressure that small seed companies find themselves under from their commercial customers.

3.2.3.3 Additional experts

There were two informants who deserve particular mention: one was a molecular biologist who worked in the lab portion of the Seed Project and second was an administrator who ran a conventional breeding and licensing program for the department and who was deeply knowledgeable about intellectual property issues. The first person became a kind of scientific guide to me about the biology of biodiversity as that applied to plant breeding. She also explained to me the mechanics of plant breeding which helped to explain the blurred lines between certain kinds of manipulation which count as biotechnology, those which do not, and those which fall into a gray area. She also reviewed my empirical chapter on agrobiodiversity for accuracy. The administrator had been part of the plant breeding world for many years both as a farmer, a seed company employee, and finally as the director of an institute at the lead university that was responsible for bringing new plant breeding developments to the attention of the seed industry and soliciting feedback from the industry about current needs and preferences. From his collective experiences he was able to provide crucial historical perspective, especially on the status of the organic farming movement within the conventional farming community and the fact that plant breeders had been slow to accept organic farming as a legitimate part of the commercial market. He also had been involved in a number of the licensing innovations that the Seed Project had taken advantage of and was able to explain the nature of the relationships that govern interactions between plant breeders and the seed industry.

3.2.3.4 Non-human agents

In keeping with the theoretical and methodological commitments of this dissertation it was important to me to account for non-human agents, in this case, domesticated vegetable plants, whose agency was central to the work that the humans involved performed. This raised the question how does one measure or study non-verbal, non-human agents as objects of sociological investigation? I have discussed how I worked to train my eye for vegetables by actual work on farms and in experimental fields. Much of what I learned was about the nature of the physical farm labor, often under pressure due to weather or impending darkness. Some of what I learned was about the stubbornness of plants, their capacity to survive terrible soil (in the university research plots) and withering heat when the crucial parts for the irrigation system went missing. Much of what I learned about the agency of plants however, came from my interviews with farmers and with breeders who were very clear that in traditional selectionist plant breeding, a dance occurs between the breeder with her goals and the plant with its goals. Breeding, in this scenario, is a process of negotiation, an exchange of one set of traits against another. The Wolf pumpkin, for example, has strong handles almost three inches thick on every jack o'lantern, yet to achieve that end the plant has had to grow long strong vines. Wolf is not a miniature variety which demonstrates the kinds of trade-offs that pumpkin plants impose on farmers. It is not possible to have strong handles *and* compact plants that can grow in smaller spaces. Furthermore, while some traits may be caused by a single gene, many are not, and even those that are, may be subject to epigenetic effects from co-existing with other genes within the same organism. In these two ways, plants express their agency through a series of constraints and counteroffers that they proffer the breeder, offering, but also requiring choices and willingness to accept compromise.

3.3 Measuring circulating knowledge

The data collection for this study reflects a concerted attempt to answer the Actor-Network-Theory (ANT) injunction that sociological studies of science focus upon two key components of network creation: the choice of association between agents and the translations that occur when agents interact as part of a network. In other words, my research questions examined the kinds of new relationships that were created by the Seed Project and how those relationships were acted upon. As a feminist I looked for input from participants at all levels of institutional hierarchies and how various individuals interacted with each other in light of their status differences.

My chapter, Plant Breeding as Technoscience, outlines the ways in which it is helpful to remove plants from a naturalized master narrative and to understand plant breeding and the creation of varieties adapted for organic agriculture products of technoscience. Here I will describe how I operationalized an ANT/feminist approach to studying the circulation of knowledge and why it was useful for a significant portion of my work. As I have said before the ANT thinker I find most useful methodologically is Bruno Latour whose strength and his shortcoming lie, in my view, with his cultivated agnosticism towards structural power relations among agents and his contention that agency is most interesting at the moment in which new networks are created. Feminist analysis, on the other hand, acknowledges that even when new relationships are being created the actors themselves preexist their new relationship. That is, plant breeders come to a participatory organic project with a raft of scientific and institutional assumptions about how to create new varieties and the appropriate role of end users in the breeding decision-making process. As I will show, even the question of who is qualified to breed has been a controversial area within plant breeding including the issue of women's participation. Similarly, organic farmers have a fraught history with the agricultural research establishment which colored their willingness and ability to work with university personnel. Neither of these groups is homogeneous; within each are a variety of approaches and positions which impact their participation in cooperative ventures like the Seed Project. At a more conceptual level, ideas about the purpose of research and innovation in contrast to the use of older methods are a significant point of differentiation among participants. The Seed Project won financial backing because it intended to bring together people and organizations that had not had intensive contact prior to the grant in the hope that what differences there might be could be processed over the life of the project.

3.3.1 Analysis

3.3.1.1 Coding

Because the tapes of my in-depth interviews and observations were transcribed for me by a court reporter she was also able to do an automated keyword index. The indexes highlighted certain key terms namely biodiversity, landraces, domestication, crop improvement, which were used consciously or unconsciously to very different effect by the participants. What the indexes could not do was capture the structure of the positions that various informants took as I asked them about their relationships to the project and the logic of their decisions to participate. When I went back and looked at the kinds of questions that had spontaneously arisen during the open-ended portion of the interviews a key question I found I had asked was why are you part of this project? What value does it bring to you and your farm? I also had altered my opening questions to farmers to reflect the fact that we were meeting on their land. Each of those conversations had begun with a request to describe their farm and the structure of their business which yielded much unexpected data about the function of agrobiodiversity in organic production and the problem of accessing labor–a question I had not intended to discuss.

3.3.1.2 Analysis

On the second pass through the data, I began developing flow charts of relationships between entities and individuals. For example, farmers mentioned that they could and did contact small seed companies to discuss varieties and characteristics they were looking for and that they had no trouble getting quick and reasonable responses although companies were often unable to actually produce new varieties they desired. When examining evidence of content I used Law's distinctions between power over and power to, as a means of judging the effect that association between actors had upon individuals participating (Law, 1991).

Once I had my charts from the interview data in place, I sought to add the non-human component. This required looking at all of my data to assess how plants, soil, seeds, and other non-human elements participate in the breeding process. This was also a point at which some of the technical knowledge of plant genetics came to be integrated. This portion of the analysis I then read together with perspectives gained from feminist theories of technoscience.

I also looked again to Smith and to Donna Haraway's concept of situated knowledge to examine both the relationships each informant had and those missing pieces that might point to incompleteness. What I mean by that specifically, is that in certain instances it emerged that key terms were being used in very different ways and that these differences of usage had not been explicitly acknowledged nor perhaps even recognized. In the chapter on agrobiodiversity I discuss in detail how the differing versions of biodiversity or agrobiodiversity caused participants to speak past one another. Thus, at the last stage of analysis I stepped back from an examination of one-on-one interactions between agents and worked to chart the situatedness of individuals and larger groups.

It was in this second stage of reevaluating relationships that I looked specifically for evidence of affiliation and cooperation among unlike actors. For example, the farmers had relatively little contact with the PI or other PhD breeders. Their direct contacts at the university were the technical stuff, at least one of whom, Joe, has been publicly named as the co-breeder of an award winning variety in the pages of seed catalogs although Joe does not have a degree in plant breeding. The job title "plant breeder" thus became a loose term which addressed the activities of project members rather than their formal credentials. Within the project there seemed to be status directed towards those who had been most invested in the project regardless of institutional standing. Once I became aware of this tendency I looked for other examples of the same phenomenon.

3.3.1.3 Documentary research

The grant documentation which the PI generously shared with me contained a great deal of evidence justifying the Seed Project and explaining the need for participatory plant breeding for the organic sector. Especially the letters written by small seed company representatives spoke more clearly than any interview about the limitations that a failing public plant breeding sector is having on seed companies and inevitably farmers. From the literature I know that distribution of seed is a vital component to diversity in seed availability but too little is known about the mechanics of this important sector.

3.3.1.4 Contributions of feminist methods

The most important goal of feminist methods for me is the way in which feminist social scientists are able to utilize the data we gather to give voice to a members of overlooked groups, be they women or others, and suggest possible routes to ameliorate the discrimination or neglect that those individuals experience. While that project is rife with potential for misinterpretation and mistakes, it is the essential function of feminist qualitative social analysis to articulate a plan of action that can lead to concrete social change. In this way we differ rather significantly from other approaches within Women's Studies where the emphasis remains at the previous step of pure critique. In my case I uncovered histories of gender discrimination within plant breeding but also thoroughgoing class-based discrimination within the university which individual best efforts could not abolish. These are issues which future participatory projects would do well to address directly by seeking to equalize input into project decision-making. The Seed Project took vital first steps in this direction as I will discuss in later chapters. I also see potential for the outcomes of this study to inform public policy towards the preservation of agrobiodiversity and the enhancement of the organic farming sector via participatory plant breeding which has substantial potential to alter the course of agricultural production in the US if properly pursued.

3.3.1.5 Strengths and limitations of the analysis

The strength of this study is most simply that I was able to capture the motivations and mechanisms which enabled breeders and organic farmers to bridge their differences. The data I collected demonstrated that farmers have detailed vegetable variety concerns and are well situated to explain the nature of their seed needs. Similarly, I hope that I have given voice to a group of breeders who are intent upon pragmatically opening the breeding process to a neglected farming population and were willing to discuss the institutional and interpersonal creativity and cooperation necessary to achieve those goals.

.

The greatest limitation of the study is its scope. While other participatory plant breeding projects exist in the US, the literature is not large making comparative work difficult. In addition, the Seed Project linked more than just breeders and farmers (the usual participatory plant breeding constellation) and attempted to build farmer/breeder and seed saving infrastructures.

The other limitation of this study is that it is a pilot study of a pilot project. As such I see this work as laying groundwork for what I hope will be far more studies of more interdisciplinary programs like the Seed Project. More fundamentally, I would have liked to interview more farmers. Over 250 participated during the 6 years the project ran. My informants were selected for greatest possible variety. I spoke with new farmers, experienced farmers, those who sold to farmer's markets, those who utilized other venues, farms run by single individuals, heterosexual families, and groups of business partners. The land ownership patterns varied from rural backyards, to landtrusts. The size of farms varied from 1 acre to over 100. By the end of my interviewing season I had reached the point where I felt comfortable that I had reached a real diversity of opinions and positions. What I cannot say with certainty it how frequently a given position may be represented in the farmer participant pool. Another option would be to conduct a survey to see how many other farmers agreed with the positions espoused by my individual informants.

Chapter 4

Agrobiodiversity: A Troubled Taxonomy

4.1 Biodiversity and agrodiversity: ecological language that explains ecosystem functioning

Biodiversity is a term which originated in the discipline of biology and the interdisciplinary field of ecology to describe and refer to relative frequencies of material entities, be they plants, animals, or landscape conditions, within an ecosystem. Hawkes *et al.* paraphrase Edward Wilson's (Wilson, 1992) definition as follows:

> Biodiversity is the total variation found within all living organisms, along with the ecological complexes they inhabit. It encompasses diversity at all levels of biological organization: communities, species, genes (Hawkes et al., 2000, p. 2).

Wilson and Hawkes *et al.* equate biodiversity with variations of several kinds. First, the variations that occur between living organisms, the difference between tigers and earthworms for example. Secondly, they cite an organizational kind of variation that can occur when related species react to different geographic conditions, or alternatively, when different communities form within a given ecological niche. Finally there exists a level of genetic diversity that occurs between otherwise like individuals of a species.

This broad definition of biodiversity is inclusive of all organisms and does not distinguish between plants and animals or domesticated and non-domesticated organisms. Brookfield *et al.* trace the development of two newer terms: agrobiodiversity and agrodiversity. These new terms attempted to capture the specific concerns relevant to the study and preservation of biodiversity within managed agricultural systems (Brookfield et al., 2002). Brookfield himself had initiated the term agrodiversity in the mid-1990s to distinguish it from Wilson's earlier, broader term, biodiversity (Brookfield and Padoch, 1994). As Brookfield explains, quoting himself in a later book from 2002, agrodiversity is:

> The many ways in which farmers use the natural diversity of the environment for production, including not only their choice of crops but also their management of land, water, and biota as a whole (Brookfield et al., 2002, p. 9).

Almkinders *et al.* independently developed a similar term a year later which Brookfield acknowledged. Almkinders focused more specifically upon variation rather than farmers' use, defining agrodiversity as:

> The variation resulting from the interaction between the factors that determine the agro-ecosystems (Almekinders et al., 1995, p. 128).

In comparing these two early definitions it is possible to already see a tension that complicates attempts to apply the lessons learned from biodiversity and ecology more generally, to the specifics of agricultural processes and needs. Brookfield's approach looks at farmers and the work that they do and its impact upon their land, the water resources they access or impact, and the other aspects of the environment affected by farming. Almkinders' definition is not in opposition to Brookfield but it emphasizes a theoretically measurable attribute, variation, and the outcome as measured by that attribute upon agro-ecosystems. The strength of all of these authors' work taken together is the way in which they draw attention to the integrated impacts that food and fiber production have upon ecosystems as a whole. Overall, the innovation represented by all definitions of the term agrodiversity meshes well with the aims of the organic and sustainable farming movements which have had from the outset an interest in considering agricultural production within the larger context of its ecosystem or holistic effects.

One difficulty posed by the two approaches to defining the term is one of measurement. Does an evaluation of agrodiversity impacts in a given system have to focus on the entirety of the farming system in question, or, is it sufficient to isolate and quantify specific factors and behaviors and their individual impact on particular kinds of variation? What do we conclude when farmers' management processes do not necessarily map perfectly upon the measurable increase in variation within an ecosystem? There has been considerable, although insufficient, study over the last 15 years that has looked at the impact of different farming regimens upon agro-ecosystems which answer these methodological questions in different ways (Wood and Lenne, 1997; Gomiero et al., 2008; Gibson et al., 2007; Dale and Polasky, 2007; Norton et al., 2009). The results of each of these studies have indicated that increased ecosystem diversity and effective functioning have complex relations to the methods of farming used, although in general it is fair to say that farming methods which take into consideration ecosystem functioning lessen the generally negative impact of the current industrial approach (Tscharntke et al., 2005; Scherr and McNeely, 2008; McNeely and Scherr, 2003; Straub et al., 2008; Taylor and Morecroft, 2009; Hole et al., 2004; Norton et al., 2009).

Definitions of these terms are below:

Biodiversity: original term used to designate total variation of living organisms.

Agrodiversity: defined in two ways: as the total variation within an agro-ecosystem, or, as the means by which farmers manage their production environments to maintain total variation

Agrobiodiversity: the total variation of plants and animals used for cultivation. This chapter discusses two means of assessing the degree of agrobiodiversity: phenotypical and molecular agrobiodiversity, and two means of assessing the access farmers have to improved plant materials: commercial and experimental agrobiodiversity.

4.2 Agrobiodiversity: a working definition

Wood and Lenne, who advocate for agrobiodiversity as a separate concept have a wide definition:

> . . . all crops and livestock and their wild relatives, and all interacting species of pollinators, symbionts, pests, parasites, predators and competitors. . . (Wood and Lenne, 1997, p. 1-2)

Agrobiodiversity therefore eliminates from direct consideration undomesticated animals and plants (including weeds) except to the extent that pollinators and pests may be wild and weeds may be wild relatives of domesticated crops. Understood this broadly, agrobiodiversity could arguably be little different from biodiversity proper as that process plays out within a circumscribed area designated for food and fiber production. However, in using the designations "crops" and "livestock" Wood and Lenne point to a category of plants and animals which enjoy a different status than do those organisms which have not be adapted for human use. Agrobiodiversity emphasizes that those living things that contribute directly to human sustenance experience variation in regard to their standing within the human community. The status of a given plant can change and must be considered contingent. It is estimated, for example, that while the world's population now eats only 100 crop types, historically over 7000 were eaten (Gepts, 2006a).

I will be considering a subset of organisms included by Wood and Lenne, namely currently cultivated vegetable crops. Admittedly there exists a blurry line between crops currently under cultivation and wild relatives or crops that were once eaten, but since have been abandoned. As needed I will discuss evidence taken from other crops types and the importance of wild genepools. However, I would now like to consider the historical pre-conditions for the variability of domesticated crop agrobiodiversity.

4.2.1 Agrobiodiversity: Giving a new name to an old concern

Agrobiodiversity, the focus of this study, is a much older tradition that either biodiversity or agrodiversity although the term itself was not used until 1990s. Even today it is not frequently used by European scholars and some US plant scientists who tend to use "genetic diversity" or "variation in plant genetic resources" (Khlestkina et al., 2004; Hammer and Teklu, 2008; Pistorius and van Wijk, 1999; Gepts, 2006a). I prefer agrobiodiversity to the other two options because it can be understood to include farmer choices and management strategies akin to Brookfield's use of agrodiversity. "Genetic diversity" implies that it is the material construction of the plant which determines the nature of its variation. Although the plant's inherent capacities and limits are vital to agrobiodiversity, the human/plant interaction and the exchanges between humans on behalf of plants is more pertinent to the discussion of my data. Similarly "variation in plant genetic resources" implies that it is the array of plant materials that is determinate, also leaving little room for consideration of human habits beyond the breeding process itself. I do not wish to imply that those who use these other terms necessarily use them in their most narrow form, rather that I would like to call attention to the interactions between farmers, breeders and plants as agrobiodiversity would seem to do best. As this definitional discussion makes clear, biodiversity, agrodiversity and agrobiodiversity, genetic diversity and variation in plant genetic resources are used interchangeably and in overlapping ways by scholars, journalists, and the interested public. The potential confusion about what is meant by these terms and what the impact should be on agriculture, indeed the disagreements about how environmental impact should be considered and responded to by the food system, is a much broader subject than can be addressed here. Further empirical and theoretical study are urgently needed. For the purposes of this study I will define my position in relation to current scholarship.

4.3 The History of Agrobiodiversity

4.3.1 Plant collecting prior to modern plant breeding

The practice of collecting exotic and useful plants has a long history. The first documented botanical collecting mission was organized by Queen Hatshepsut in 1500 BCE (Gepts, 2006a; Fowler and Mooney, 1990). While Christopher Columbus may have gained his greatest fame by discovering the Americas, the so-called Colombian Exchange refers to the vast exchange of plant matter that included corn (maize), rubber, potatoes, tomatoes and coffee (Gepts, 2006a; Hobhouse, 1985; Crosby, 1972; Fussell, 1992; Mintz, 1986; Pollan, 2001; Smith, 1995; Vavilov, 1992; Zimmerer, 1996). Botanical gardens, especially Kew Gardens in Britain, became depositories for plants from around the world.

Only at the end of the 19th century and beginning of the 20th century with the rediscovery of Mendelian genetics did the collecting of plants for breeding purposes shift. Prior to Mendel plants could be bred for improved qualities but the mechanism by which that improvement occurred was not understood. Mendel's concept of heritability opened a new window onto plant functioning and plant improvement that would radically alter the pace and nature of plant breeding. However, almost at the very moment plant breeders became aware of the nature of the gene, concern was raised about the disappearance of large numbers of domesticated plants. This phenomenon would come to be called genetic erosion.

As I noted in my introduction Erwin Baur's 1914 speech is the earliest example I have found in which the potential for genetic erosion was raised. Baur's concern is that because the new varieties are so attractive to farmers, only the most stubborn will hold out and continue to use traditionally bred varieties or landraces. I should note parenthetically that today a *landrace* is a term used to describe varieties that have undergone some breeding but have not experienced, ". . . modern plant breeding or subject to purifying selection (Brown, 2000, p. 29)." Landraces are presumed to be less uniform and more genetically diverse than are varieties that have been created by the more precise knowledge of the modern breeder (Fowler and Mooney, 1990, p. 1). Although in the passage quoted earlier, Baur cites the crisis in grain production, at later points he expands his discussion to include vegetables and fruits. He is also well aware of the vulnerability of other countries outside of Europe. In this text he mentions central Russia, Persia, the Near East, Japan, China, North Africa and Abyssinia which have concentrations of landraces and utterly unimproved (wild) varieties that he fears will be lost if those areas experience the same displacement as he has watched in Germany (Baur, 1914, p. 107). The speech ends with a call for the protection and collection of vanishing varieties which I read with a certain sadness given the benefit of nearly 100 years of hindsight. In February of 1914, unknowingly on the cusp of the first of two devastating World Wars, Baur looks forward with optimism to the founding of Institute for the study of Heritability (das Institute fuer Vererbungsforschung) which he is certain will be underfunded but will help him to both collect and utilize the vanishing varieties upon which human flourishing depends (Baur, 1914, p. 109).

The modernity of Baur's arguments and concerns is particularly interesting in light of the fact that he predates the publication of the famous Soviet plant breeder N.I. Vavilov whose vast plant collections and theories about centers of diversity and origin for plants continues to influence our understanding of crop migration (Khlestkina et al., 2004; Vavilov, 1992; Hobhouse, 1985; Smith, 1995; J.G.Hawkes et al., 2000, p. 1466). Vavilov argued that crops had arisen in geographically discernible locations which would therefore be the places where one could expect to find more and more diverse varieties of a given crop (Fowler and Mooney, 1990; Vavilov, 1992, p. 32). For example, rice and eggplant originated in the Indian center of origin, whereas, wheat, hemp and spinach came from the Central Asiatic Center (Vavilov, 1992). Scientists working since Vavilov have shifted the parameters of those regions and relationships among centers of origin but the idea that breeders need to have access to plants that have been less improved remains vital. Indeed, the most recent research indicates that the use of wild relatives for crop improvement is actually on the rise over the last 20 years (Hajjar and Hodgkin, 2007). Moreover the advent of molecular genetics has not decreased the need for plant collections indeed using some molecular techniques may make using landraces and wild germplasm easier than ever (Thro et al., 2004; Moose and Mumm, 2008; Cooper et al., 2004). Vavilov's work inspired many collectors in the 1920s and 30s as Khlestkina *et al.* describe:

> In the Austrian Alps, E. Mayr was collecting landraces of cereals in the period 1922-1932 (Mayr 1924, 1928, 1935, 1937). In Germany K.O. Mueller and his group initiated collection missions to Anatolia between 1928 and 1932, A. Schiebe and his group sent missions to the Hindukusch in 1935, A. Herrlich and his collaborators collected in the Himalayas (India, Nepal) in 1937/1938, E. Schaefer and associates went to Tibet in 1938/1939, C. Troll and his group went to Ethiopia and Eritrea between 1937 and 1939 and H. Stubbe and his associates collected in the Balkans (Albania, Greece) in 1941/1942 (Khlestkina et al., 2004, p. 1466).

These collecting missions and others like them resulted in a new wave of genebanks and institutes in Germany and Russia where the varieties that Baur was afraid of losing were stored. Some of these collections survived the wars of the 20th century so that comparisons can now be made between assessions collected in the 1920s and more recent, post-Green Revolution entries (Khlestkina et al., 2004).

4.3.2 Genetic erosion becomes geographically more disbursed

Baur, Vavilov, and the other early 20th century advocates for the preservation of agrobiodiversity were successful in saving some of the materials that they saw disappearing around them. At the same time, by the early 1970s the son of the H. V. Harlan who had raised alarm in 1936 about barley and who was a personal friend of Vavilov's (Fowler and Mooney, 1990, p. 29), Jack Harlan, would feel compelled to raise alarm once again. In an important article written in 1971 together with J. M. J. de Wet, Harlan articulated a system for evaluating gene pools that, ". . . reflected the increasing difficulty in performing sexual crosses and obtaining viable and fertile progenies (Gepts, 2006a; Harlan and de Wet, 1971)". The next year Harlan would publish an even more alarmed article about the dissipation and loss that he, echoing his earlier colleagues, was witnessing (Harlan, 1971). The rhetoric of Harlan's abstract is no less urgent than had been Baur's so many years before:

> Erosion of some of the most vital resources for human survival goes on with no notice from the public and very little attention from the scientific community which should be better informed. The germplasm base required for improvement of the basic food crops that feed the world is being rapidly destroyed. This destruction of genetic resources is caused primarily by the very success of modern plant breeding programs (Harlan, 1971, p. 212).

Harlan was not alone among scientists in his concern for genetic erosion. O. H. Frankel writing in 1974 explained why conservation should not be delayed even in cases where immediate use might not be obvious:

> Genetic conservation has a *time scale of concern*, which extends from a day or a year when there is no need (or plan) for conservation, to infinity. . . But the time scale of concern must not be confused with the *time scale for action*, which clear is now (O.H.Frankel, 1974, p. 53, emphasis original)

Building explicitly on Vavilov's centers of domestication theory, Frankel argued that traditional farmers growing landraces in regions where wild relatives might provide input was the key to modern cultivar improvement. The Green Revolution which had begun bringing modern varieties into developing countries where the centers of origin for many key food crops are located certainly increased the danger that rare varieties might be disappearing, although, as we have seen, the problem of modern varieties replacing landraces predated Borlaug's hybrids or even the technique of hybridization by several decades.

Three years later, D. R. Marshall analyzed the relative benefits of genetic homogeneity in agricultural food crops, concluding that in farmer's fields integrating the need for greater genetic diversity would bring with it risks of reduced yield but that at the same time failing to keep crops diverse was presenting the world with greater vulnerability to disease. He explained the dilemma:

> It is clear that in the developed countries and to an increasing extent in the developing countries, most major crops are markedly uniform genetically and hence markedly vulnerable to disease and pest epidemics. It is also clear that the reintroduction of diversity in crop communities can, in many circumstances, substantially reduce the danger of catastrophic epidemics. It is equally evident, however, that diversity can be introduced into crop communities at a number of levels and in a numbers of ways, each of which has its advantages and disadvantages. . . . Moreover, all the proposed alternatives to the use of single resistance genes in disease and pest control are relatively laborious and demanding of the breeder's time and resources. Therefore, although they reduce the danger of epidemics, because of the limited resources at the breeder's disposal, they also severely reduce his capacity to make gains in other areas (Marshall, 1977a, p. 17-18).

Marshall's point is that monocultures and highly bred, genetically narrow modern varieties are spectacularly effective at producing high yields but they do so for a limited amount of time before pests and disease catch up. Altering the course of plant breeding to hedge the long-term risk may in the short-run lead to reduced productivity. From a breeder's perspective gathering enough information to make a flawless choice is logistically and economically infeasible. Therefore although Marshall shares Frankel and Harlan's concern about genetic erosion and crop vulnerability, he is aware of the compromises that breeders may be uneasy making in an attempt to incorporate the very diversity that they know they need.

4.3.3 Agrobiodiversity in the 21st century from the scientific breeding point-of-view

The most recent developments in plant breeding, including insights generated by molecular genetics, have enhanced our understanding of agrobiodiversity. As I mentioned above, critics of the Green Revolution blame those hybrids for much of the destruction of landraces in the developing world (Shiva, 1993, 2007). There have been some who argue that the later Green Revolution crops are actually more diverse than the earlier ones because breeders learned to include a wider range of local variation into modern improved varieties and that the crops that were displaced by modern hybrids were themselves imported, improved varieties introduced by colonial governments (Smale, 1997; Smale et al., 2002). The activities of the British in India and the process of plant breeding, particularly the introduction of improved wheat varieties is confirmed by Sir Albert Howard. Howard's career began as a plant breeder in India where he bred among other things, wheat, which he proudly recounts was distributed widely (Howard, 2006 (original publication date 1947), p. 3). Smale *et al.'s* essential point, that the Green Revolution became more sophisticated over time and came to include a broad selection of local and landrace genes, is well taken but does not answer the larger question raised by critics. Namely, does the increased spread of modern varieties into areas where landraces were once predominate raise a significant risk to agrobiodiversity? Does it matter that monocultures have been expanded? In other words, the contrast between Brookfield's farmer/production centered analysis of diversity and Almekinders *et al.*'s genetic variation focused analysis becomes relevant. Is agrobiodiversity best measured as a function of land use or genetic analysis? Three recent studies raise relevant issues based on the latest technological changes.

Khlestkina *et al.* did a comparative molecular analysis of wheat varieties collected in the 20s and 30s with those collected post Green Revolution asking the question, is the degree of variability different between the two samples? In other words, has wheat become less diverse? Interestingly they conclude that the difference was qualitative rather than quantitative (Khlestkina et al., 2004, p. 1470). The actual number of genetic units (alleles) hadn't changed but the nature of what those units could do had. The conclusions they draw have particularly interesting implications for conservation efforts:

> The exploitation of the whole range of allelic variation makes it necessary to both maintain the already existing *ex situ* collections and to collect new material. One can only preserve the allelic composition of the present situation, which will change after a certain period of time in nature (Khlestkina et al., 2004, p. 1470).

What this means is that evolutionary change effects plant development in the field in ways which cannot be compensated for by keeping materials in a genebank. Constant re-sampling and maintenance of evolving populations is essential if the full benefit of plant evolution is to be maintained and enhanced. This kind of analysis is only possible because of new molecular tools, but confirms rather dramatically that molecular methods can benefit classical plant breeding and the enhancement of agrobiodiversity if used toward that end (Moose and Mumm, 2008; Reese and Haribabu, 2007).

A second major change in plant breeding and the role of biodiversity is the advent of genetic engineering (GE). I will not devote much space to that issue since my study concerns organic growers who do not use GE technology. Nevertheless it is important to understand that there are many plant scientists who feel that GE technology opens up a 4th genepool by allowing cross-species transformation (Gepts, 2006a; Hammer and Teklu, 2008). A few plant scientists have suggested that organic farmers need to use transgenic technology (Ronald and Adamchak, 2008; Ammann, 2008). Others, particularly those concerned with horticultural crops are concerned that GE technology is either too expensive, less effective than promised, or simply not a substitute for conventional breeding (Alston, 2004; Goodman, 2004; Gepts, 2006a) Some worry that the unregulated gene flow from transgenes into landraces will only exacerbate the already troubling erosion of distinctive landraces (Kotschi, 2008).

Finally there is an group of French plant breeders who have rethought plant breeding and its relationship to society. Plants, they argue, have been transformed into functional units in such a way that transdisciplinary conversations about breeding goals have become nearly impossible:

> So in this compartmentalized and industrialized context, what did the plant become? A 'pool of genes' for the biologist, a 'phenotype' (G expressed in a biophysical E) for the agronomist, a 'technical reality' (that genetic progress has achieved) for the national authorities which evaluate varieties, an 'intellectual property' (to be protected and sold) for the plant breeder, a 'production factor' (at x cost for y yield) for the farmer and for his supply cooperative, a 'data base' (specifying choice of a variety and the appropriate cultivation system) for technical institutes, and a 'quality' (adapted for industrial processing) for food manufacturers (Desclaux et al., 2008, p. 535).

The point is well taken. How can we conserve agrobiodiversity if the parties most intimately concerned with plants have limited their understanding of a plant to that fraction or function which seems most expedient? I have discussed the means by which the Seed Project worked to overcome compartmentalization and create at least dialog between organic farmers and university-based plant breeders. What Desclaux *et al.* are suggesting is a more far-reaching change in the logic of plant breeding rather than the more practical approach taken by the Seed Project.

Desclaux *et al.* argue that low-input farming disrupts the logic of conventional plant breeding and in doing so pushes breeders to revise their most basic equations: G x E (genotype x environment). When breeding for conventional agriculture the assumption is that E (the environment) can be altered almost without limit and therefore G (the genotype or in lay person's terms the genetic configuration of the plant) can be bred to respond optimally within a very limited range of environmental tolerances. We saw that Marshall in 1977 contended that if breeders took any factor into account other than optimal yield, it would result in negative impacts for farmers. Marshall's concern was that long-term viability would be threatened by short-term yield considerations on the part of breeders. Thirty years later, Desclaux *et al.* suggest that markets and risks have changed such that the interference Marshall feared could be an advantage for farmers.

> Within-variety heterogeneity has a number of agronomic advantages, including disease control and better adaptation to uncontrolled variability of the climate-soil environment (Wolfe 1997; Pope De Vallavielle *et al*. 2007). Heterogeneity is also an economic necessity when it enables the diversification or differentiation of final products and markets, particularly in the case of organic farming and of products that valorize particular specifications . . .or a particular local territory labeled with a Geographical Indication . . . The desired diversity of G may imply a search for new Gs, or a search for different functions of G, or of the adaptation of existing or newly-used Gs to the public's taste today (Desclaux et al., 2008, p. 543).[1]

What is being suggested here by Desclaux *et al.* is a third shift in the attitude of breeders

[1]Wolfe, MS (1997) Variety mixtures: concept and value. In: Wolfe MS 9ed Variety Mixtures in theory and practice. European Union Variety Mixtures working group of COST action 817. Online at: http://www.scri.sari.ac.uk/TiPP/Mix/Booklet/default.htm; Pope de Vallavielle C, Belhaj M. Mille B., Meynard JM (2007) Associations de varietes de ble pour stabiliser le rendement et la qualite de la recolte. In prod. Rencontres du Cirad, Journee d'agronomie, 30 aout 2007, ed CIRAD

towards agrobiodiversity. The conservation and valuation of agrobiodiversity began as a collection of exotics to be displayed and replicated then became a source of raw material by which breeders could optimize performance in fields where the environmental factors had been controlled to minimize interference. Now, the long-standing threat to agrobiodiversity taken together with the increased demand for varieties that can flourish in a variety of environments, means that breeders are offered an opportunity to discover virtues they might previously have viewed as impediments.

This brief history of agrobiodiversity within the institutional and scientific domain of plant breeders has demonstrated that the breeding community has been long been concerned about the impact of their profession upon the environment and the genetic materials available to them. The nature of that concern and the motivations for wanting agrobiodiversity to flourish have changed both because of increased technical knowledge and an awareness of social needs. Just as breeders and the scientific establishment have become more aware of social desires, certain segments of the general public have been developing their own concerns about the state of agrobiodiversity. Sometimes in response to issues raised by the scientific breeding community and sometimes for their own reasons, members of the public have involved themselves in the agrobiodiversity issue.

4.3.4 Concern about agrobiodiversity enters the public arena

By the 1970s public concern about biodiversity in general was on the rise. Following the publication of Rachel Carson's *Silent Spring,* environmentalists became active in the drive to save the natural world from the effects of modern industrial society. One subgroup of concerned citizens formed the seed saving movement, establishing organizations such as Seed Savers Exchange and Native/Seed SEARCH (Whealy and Adelmann, 1986). Seed savers were concerned because the number of varieties available for use in gardening or homesteading were radically contracting (Whealy and Adelmann, 1986). In addition these individuals realized that as Americans became more mobile and less rural in their habits, seeds brought to the US from various countries around the world and passed down from generation to generation were being lost (Whealy and Adelmann, 1986).

Seed savers were complemented by the organic and sustainable agriculture movements which sought to provide an alternative and improved system of agricultural production. At its inception the organic movement and professional plant breeding were united. Elsewhere I have discussed Sir Albert Howard's willingness to pay attention to the Indian peasants and his development of a method based on their work that could be applied globally.

Howard's work confirms the contention of Vandana Shiva's, India's outspoken ecofeminist, that prior to the imposition of modern industrial techniques Indian agriculture was sustainable (Shiva, 1993, 2007). Where Howard's account differs from Shiva's is that for him modern plant improvement is not anathema to traditional production practices. What may account for this difference is the degree of change in plant phenotype that post-World War II plant breeding enables when compared with earlier methods. Although I observed considerable alienation between organic growers and professional plant breeders in my study, historically these two groups have been far more connected. Sir Howard's experience also shows that at one point it was possible for a plant breeder to learn from peasant farmers in ways that lead him to rethink the function of breeding for disease and pest resistance. In his new introduction to the 2006 reprint of Sir Howard's *Soil and Health*, Wendell Berry addresses what he sees as the difference between Howard's practice and that of contemporary agricultural scientists:

> He lacked completely the specialist impulse, so prominent among the scientists and intellectuals of the present-day university, to see things in isolation (Howard, 2006 (original publication date 1947), p. xvii).

The Seed Project could thus be seen as reviving a foundational professional practice from which the mainstream has strayed rather than embarking upon an unproven path.

Today organic farming is a flourishing agricultural sector although many of its original proponents who began adapting Howard's ideas in the 70s and 80s now decry the advent of large scale organic operations that meet the minimum USDA organic standards but fail to incorporate the larger goals of sustainability, as contested as that term is (Howard, 2006 (original publication date 1947), see Berry's Introduction). At the same time, small and medium sized seed companies can serve the certified organic sector with varieties that are organically grown, if not always bred for organic conditions.

What we see from this brief history of plant breeding in relation to the initial development of organic ideas is that the Seed Project's task was complicated by different understandings agrobiodiversity. Key areas of difference include: how it is measured, what has been the cause of genetic erosion, and what the role of modern plant breeding has been. Furthermore, the isolation of farmers from breeders has been so significant that my informants were themselves sometimes unaware of the differences between them.

4.3.5 Articulating measures of agrobiodiversity

The data I collected yielded two kinds of concern for agrobiodiversity among Seed Project participants. One set of issues centered around the way in which one chooses to measure how physically diverse plant varieties may be. It should be noted that I have deliberately used the term physical as opposed to genetic. This is because molecular agrobiodiversity and phenotypical agrobiodiversity diverge in the manner by which each chooses to measure the relevant genetic variation. In other words, molecular analysis looks at one type of evidence and draws certain conclusions about the comparative degree of genetic variation between plants, phenotypical analysis looks a a different kind of evidence and draws somewhat different conclusions about genetic variation. As we will see in the next section, these modes of analysis can both be legitimately called "genetic" and yet yield crucially different results.

The second set of issues that emerged from my interviews are less concerned with determining the relationships of plants to each other than with the issue of germplasm availability. Based on information gathered from informants I have christened these two types of agrobiodiversity "commercial agrobiodiversity" and "experimental agrobiodiversity". The first refers to a major concern expressed by the farmers in this study that varieties they needed are not commercially available at a price farmers could afford. The second category, experimental agrobiodiversity, was explained to me by the head of the technical staff at the host university and then confirmed by other breeders. This category refers to the genetic and knowledge resources housed in university labs with long-standing breeding programs. Taken together, these four kinds of agrobiodiversity help us to understand what is at stake for different actors in the seed system.

4.4 Measuring Agrobiodiversity in the bodies of plants: molecular vs. phenotypical biodiversity

The first informant to directly address the differences among the types of genetic, or varietal, diversity was a molecular geneticist working on the lab end of the Seed Project. When I asked her to define biodiversity in domesticated plants, a task I assumed would be fairly straightforward, it turned out that the answer was rather ambiguous. She introduced me to the example of peppers where phenotypical and molecular diversity diverge radically. It seems that one species, *C. annuum*, contains not only sweet bells but also jalapenos, paprikas, and Thai hot peppers; all peppers that look, smell, taste, and grow very differently. The reason for this so-called genetic bottleneck is historical in origin to the best of our knowledge, as she explained:

> ...peppers started in South America, and came back to Spain and Portugal, then they spread to Eastern Europe and Asia, and then Africa, and then came back to the Caribbean and North America. So probably just a few species, went across with Columbus...it's primarily *annuum* that went to Asia and Spain and Portugal, so that's a pretty small, its called a bottleneck...you are starting from a really small platform of diversity, maybe one or two or three different varieties within the same species, and that's sort of where the bulk of peppers we know in this country [have come from].
> Sara

For her, because of her training as a molecular biologist, she said that her thinking was mostly on the molecular level,

> ...that's how I generally think about biodiversity, is how easy or difficult it is to distinguish two different entities from each other on a molecular level, and that will show you how diverse they are.
> Sara

At the same time she was clear that while measuring the molecular differences between two entities might make the most sense for the purposes of her type of research, there was potential for clash with definitions of biodiversity that relied on phenotypical differences. As she explained, two beets that looked similar might exhibit more molecular diversity then two which varied more in their appearance. Furthermore, she reminded me that traditional taxonomy had been based on structural similarities and differences, phenotypically assessed. Thus molecular analysis has the potential to uproot existing matrices of classification that have been used for generations. Moreover, the fact that phenotypical and molecular differentiation might not overlap raised for her the question of use value outside of research.

> So it depends on where you want to draw the line... Just growing a lot of different plants in your backyard is a fabulous thing... you can grow all these sort of orphan crops or neglected crops, and you can grow them in one place, and I think that, that is really biodiversity, where you just, you mix it up, and those are all domesticated plants. Sara

This particular informant and others with her kind of training were consistently careful not to prioritize molecular delineations over phenotypical differentiation. In the exchange cited above, for example, the geneticist explains the existence of the *annuum* bottleneck but then switches back to the level of landscape biodiversity, "just growing a lot of different plants in your backyard is a fabulous thing." For her, the question of biodiversity as a value is not settled or trumped by the relationships encoded in DNA. DNA analysis does not reveal a more "fundamental law" in the sense that Evelyn Fox Keller has defined the term (Fox Keller, 2007), rather it is a form of classification that serves certain ends effectively in this informant's mind.

In a similar conversation with the principal investigator, when I asked her about the relative uses of molecular techniques over traditional breeding, her response was informed by the same careful disinclination to establish hierarchies of classifications. For her, molecular genetics yields tools that are sometimes useful, the benefit being pragmatic rather then inherent in the nature of the information. The two scientists' positions are related in that they are deliberately resistant to a conception of agrobiodiversity and its corollary, a definition of plant breeding, that are located in analysis at the level of the genome. Both informants advocate a need for a diversity of definitions, "it depends on where you want to draw the line" with a clear preference to define the value of (agro)biodiversity within several parallel systems of definition. This is true even when those systems contradict one another. In the beet example, it is perhaps important that two types of beet are phenotypically similar but molecularly dissimilar but that fact does not mean that the molecular standard is necessarily the most meaningful if one considers the needs of the end-user. The molecular standard helps breeders working on disease resistance since molecularly dissimilar variants will yield those kinds of traits. If, on the other hand, a farmer or breeder is trying to decide which seeds to save and she realizes that one field contains red beets and another contains yellow, the fact that the two populations may be molecularly similar may not be the determining factor, since red beets and yellow beets taste and sell differently. Indeed, the molecular insight is perhaps only useful if it allows traits to be shared like disease resistance with the end goal of producing a beet that looks one way but has the resistance of a molecularly dissimilar type.

Plant breeders must reach outside of the assortment of domesticated varieties for their work with some vegetables and fruits. For example, another breeder, this one an employee of a larger commercial seed company that produces primarily treated seed, explained that domesticated watermelons, unlike peppers, have a very shallow genepool. According to this informant, cultivated watermelons have two centers of origin, one in Africa and one in China. There are very few cultivated varieties which means that when watermelon breeders face major weaknesses they face the challenge of using wild varieties which my informant described as "horrendous. . . hard as rock, bitterer than bitter, white. . . flowers in October. . . " Breeding the undesirable traits back out of a watermelon with wild genes is an even longer and more difficult task than ordinary breeding with domesticated progenitors according to this individual. It is also apparently not the case that all types of melons will successfully cross. This breeder also worked on cucuribits (squash and pumpkins) which are more particular in their habits than other types of plants. Interestingly, this breeder said that one of the key challenges in cucurbits rests with the expectations of the growers and end consumer:

> 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. . . James

Here the term "horticultural types" seems to be used to designate phenotypical variation in ways that others would have called genetic. This breeder is also making reference to another major driver of the need for phenotypical diversity in the minds of vegetable breeders, namely, the desires of the growers to fulfill consumer demands rather than some abstract sense that biodiversity is a good in and of itself.

4.4.1 Implications of the molecular/phenotypical divide

What is particularly intriguing about the tale of the pepper clan is the way that it illustrates the layers of discourse that surround the decoding of the genetic relations of plants. The relatively new practice of molecular analysis allows a trained scientist to track a historical pattern of migration of the pepper plant from its species origin, or at least wild, undomesticated types, to the numerous locations and cultures that now consider it essential to their vegetable consumption. The bottleneck among domesticated peppers resulted from the inability of early modern Europeans to transport significant numbers of plants or seeds across the ocean in sailing ships. Perhaps a historian of peppers could explain why only one species made its way around the world while others did not. Whatever the reasons, *Capsicum annuum* has fragmented into highly differentiated varieties that serve dramatically different purposes in the world's cuisines and thrive in equally different farming environments. The phenotypical variation within a single pepper species matters enormously to the producers and consumers of peppers. At the same time, conserving and multiplying the variations within the one family may not particularly serve the purposes that agrobiodiversity as per Baur traditionally serves, things like resistance to new diseases. On the other hand, because phenotypical variation matters greatly to farmers, conservation and improvement of variation within the bottleneck may in fact be just as important as preserving the capacity to breed around the bottleneck. Optimally farmers would like phenotypically varied varieties that have the maximal disease, fungal, and other types of resistance bred into them and to achieve that aim may take much more far-reaching breeding measures than simply crossing phenotypically unlike plants.

The fact that molecular and phenotypical variation could diverge radically, complicated using the term "genetic" diversity at all. The literature shows that phenotypical variation is clearly genetic in origin. For thousands of years plants have been bred based upon color, size of plant, leaf shape and other external expressions of heritage. Prior to molecular analysis, phenotypical variation in plants and fruits would have been the only means by which to distinguish one plant from another (Lawrence, 1955). Indeed the structural appearance of plants determined the divisions and groupings by which plant families were determined (Lawrence, 1955). What then has molecular genetics wrought? Is phenotypical variation now somehow "less genetic" then it once was? Certainly molecular analysis allows for a kind of analysis that visual cues could mask. Does that then mean that the nature of genetic diversity has been altered? It may in fact no longer be possible to speak of genetic diversity as a singular entity but rather of genetic diversities that serve multiple purposes but operate through related breeding procedures and mechanisms.

Even without the issue of molecular vs. phenotypical variation, the pepper bottleneck raised another question about agrobiodiversity. The seed saving movement has from its inception prioritized combating genetic erosion defined as the reduction in the existence of plant varieties (Fowler and Mooney, 1990; Whealy and Adelmann, 1986). Plant breeders have been accused of complicity in the process of erosion because they breed tightly inbred varieties that then are promulgated globally (Busch et al., 1991; Shiva and Moser, 1995; Flitner, 1995; Pollan, 2001; Kloppenburg, 2004; Pistorius and van Wijk, 1999). In the conversation with the molecular geneticist, I probed this point, asking if the Seed Project or plant breeding in general contributed to the enhancement of biodiversity. The answer was no. Breeding does not enhance diversity *per se* even if the aim, as with the Seed Project, was to service a set of small differentiated sub-markets rather than to produce a variety that can be used worldwide. At the same time, breeders can and do enhance diversity when they utilize wide crosses between wild and domestic varieties or when they deliberately breed to maximize diversity as a trait (Smale, 1997).

Breeding, I was told by this informant and many others, involves directing plant development towards a specific set of goals under a defined set of conditions. In this way, breeding is agnostic on the question of diversity. If a variety can be successful in a wide range of conditions then, from a narrow breeding point of view, it may not seem necessary to develop other varieties that can thrive the same way in similar conditions, breeders told me. Indeed from the history of breeding that began this chapter it is possible to see that breeders like Marshall felt that development of widely varying varieties would only hurt breeding outcomes (Marshall, 1977b). From this position, widely held in the plant breeding world, it would seem like a waste of time to develop many varieties that can perform almost the same function under similar conditions, particularly in cases where bottlenecks exist. Agrobiodiversity does matter to breeders who think this way but only because lesser varieties provide a reservoir for genetic traits that one might need should a new disease emerge or growing conditions alter. Overall global agrobiodiversity enhancement of domesticated crops at the molecular level would require going back and circumventing the original bottleneck that cut off, for example, *annuums* from other species of pepper, *chinese*, for example. One might choose to do so in certain cases where the domesticated crop in question was so absolutely in danger that one had no other option, but such crosses would be fraught with challenges.

4.5 Agrobiodiversity and organic farmers

All of the farmers interviewed for this study said that choosing varieties is one of the most important tasks they perform each year. From visiting farms I observed that the number of actual varieties per operation can vary depending on the size of their operation, where they sell their produce (farmer's market, community supported agriculture [CSA], direct sales), how long they have been in business, and how specialized they are. The five farmers in the sample who sold exclusively or primarily at farmer's markets tended to be more conservative, by their own account, in choosing the number of varieties to grow because they told me in a farmer's market situation customers were less likely to experiment with vegetables that were unfamiliar to them or which looked odd. Despite this perception of consumer conservatism, all of the farmer's market farmers emphasized that they too needed to continually revisit their variety choices. One couple, the most experienced of the farmer's market sellers, had flourished over 20 years of growing because, as they both emphatically shared, they were constantly innovating their offerings. For example, they grow two kinds of squash that no one else grows.

> 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. Alice

About an hour away from that farm, a couple who had only been farming for 4 years, were even more concerned with varietal selection. They too sold mostly at a farmer's market in a small local town. For them the issue was taste and production habits. Red lettuce was attractive to their customers but they had been struggling to find a variety or group of varieties that were not bitter. The woman of the couple who was the full-time farmer while her husband worked off-farm, described how she had planted five or six red lettuces that year and then proceeded to do blind taste tests on family members and friends. "I'm pretty picky", she explained. In the end, none of the candidates fulfilled her stringent requirements and she intended to continue looking for a better choice. This farmer also had very specific tomato needs that were forcing her to consider breeding her own variety.

> Last year there was a tomato that I grew that I really liked for me. Being that it's just my husband and myself that do the work, we have to have this give-and-take, and one of the things that he hates to do is he hates to pull out staking in the fall–all the trellises, all of the fencing, all of that. So we grow a determinant red tomato, because the market, everybody wants a standard red tomato, and so we like this determinant variety instead of the indeterminate because it grows low and we don't need to stake it. And I had bought the seed from Turtle Tree [seed company] last year and it did really well. I had actually tried probably six different varieties of tomato. We were also looking for one that would hold up to blight, because we'd had a lot of trouble with blight on our tomatoes. We decided on this one particular variety that –it did better than the one that we had been using before, and I was all set to order it this year. Well, I went to order it, and they didn't offer it. And I talked to them on the phone, I really wanted those tomatoes and they're like well, we're not doing it, do you want to try these? And I'm like yeah, but I wanted this low kind of bush variety. . .They were very nice

> about it, they sent me ten seeds and I just happened to have six seeds from last year. So I have 16 plants in the ground, and I intend to save the seeds so that next year I'll be able to put in a whole 150 foot row of the same tomato. Marisol

This kind of testing was routine for this farmer and both her methods and her dissatisfaction were not unusual. A vegetable round-up was held at the annual conference of the farmer's organization as a central part of the Seed Project. There, farmers had a chance to voice their opinions about existing vegetable varieties in the presence of seed company representatives. Their remarks were uncensored and highly critical. For example, many of the farmers in attendance sold at markets and their assessment of particularly the broccoli offerings was caustic. Later I was able to speak with a broccoli breeder who provided some context. According to him broccoli consumers on the Eastern and Western seaboards have different preferences when it comes to the appearance of broccoli heads. The key determinants, my breeder informant said, seem to be bud size and size of head with Eastern consumers desiring smaller buds and bigger heads and Westerners preferring the reverse. Farmers attending the vegetable roundtable rejected all the currently available varieties because they did not provide big enough heads that were clean of protruding leaves (note that these farmers all served Eastern markets). There were also complaints about the lack of broccoli varieties that could handle the weather challenges of the East Coast. Standard green broccoli is a very ordinary crop that has been bred for some time, so I was surprised by the vehement dissatisfaction the farmers expressed. In this instance the homogeneity of broccoli varieties currently on the market, hurt them because they couldn't produce, under organic conditions, the very specific form and shape that customers desired. This discussion made clear that varietal diversity can empower producers to use a selection of methods (organic vs. conventional for example) to achieve a similar end; a head of broccoli 5 inches across with no leaves and small bud size. Because geographic and weather conditions vary, and because organic methods do create different soil and nutritional conditions for plants, achieving a standard product requires genetic variation in plants in some cases. Organic farmers suffer by their own account when this doesn't happen.

Producers who sold in venues other than farmer's markets speculated that they were able to be more daring in their varietal selection. Farmers participating in community supported agriculture schemes, five out of the total of 15, said that they could include either usual vegetables with unusual characteristics, or that they could include unusual vegetables, burdock, in one case. One of the CSAs, a large and well established entity that served over 300 shareholders, most in a mid-sized metropolitan location, was also actively involved in breeding new varieties and in disseminating a broad range of sustainable agricultural information. Like other CSA farmers, the individuals who ran this farm considered varietal diversity a means to broaden their members' vegetable eating experience. A second CSA, this one located on a land trust in an extremely wealthy area, grew over 50 varieties of tomatoes alone. The chief manager on this farm considered varietal variation to have benefits for both himself and his members.

> It [varietal variation] makes a big difference to me…I think it is the spice of life and I constantly want to try new varieties and our members…I think people in general would respond given a chance but most people who are going back and forth to the supermarkets are…not interested or they don't have time…I think you can encourage people. And our CSA members are actually quite excited by it. They like all this. As part of our literature about what we do, we sort of brag about growing 250 varieties or more.

Here, as in conversations with other CSA operators, the farmer contends that more consumers would like a variety of vegetables if someone brings the diversity of options to their attention. Because CSA members commit upfront to accepting a selection of the available produce all season long, they are capable of being persuaded to try vegetables that they might otherwise reject. This particular farmer recounted how he initially didn't like tomatoes. He now grows 250 varieties saying,

> I've learned to love tomatoes, and our members are thrilled by discovering all these green ones and striped ones and mahogany ones and black ones from Russia. It [the diversity of varieties] is my favorite part of the whole thing really.

The focus for most of these farmers was the marketing benefit of having a wide range of shapes and tastes available. They tended to view their function as a promoter of diversity, blending their educational function into the actual product they sold. Even so, there were some limits even for these farmers. The landtrust farmer cited above said that his members simply would not accept green eggplant. "Orange mini-Turkish eggplants are possible but green eggplants had no takers", he said. He was mystified by the rejection, "...they (the green eggplants) taste about the same but they just don't look like an eggplant." He was at a loss to explain this fact, chalking it up to some indefinable sense of aesthetics.

One particular farmer took the process of consumer education even further. This farmer sold her produce at a stand on her land but also on a weekly order basis at her workplace which was 30 miles away. The system was rather ingenious. She took orders each week from her co-workers based on a list of available produce for that week. The process has grown such that she has individuals taking orders for her at related work sites. Because she sells to people who know each other and who interact during the day and on their lunch breaks, the word can spread about both her availability and the virtues of more exotic items that she may provide. Trust and familiarity between the farmer and her co-workers increased their willingness to try unusual items.

> I've got people at work who know me and are willing to try things and I can get some of them interested in some of this stuff and it's not necessarily a farmers' market situation where they're walking by lots of stands and they're going to say, well I don't know if I should try some of this white eggplant because Paul and Sandy have some very nice purple eggplant. It's sort of like I'm the only person in my [workplace] who's delivering vegetables to their workplace, and if I say white eggplant is good, they might want to try it...it's fun when people start looking for something in particular and they say, I really like that and I want to try that again, or they get somebody else interested. Molly

She went on to describe how customers at work convince each other by sharing recipes and that in turn she was inspired to look for items like a large yellow Italian type frying pepper or the aforementioned white eggplant. Those particular customers were either of Italian descent or just people she described as having traveled or having considerable intercultural experience. The farmer speculated that exposure to ethnic traditions in one's family of origin or as a part of one's education helped pave the way for greater interest in experimentation.

This same farmer had another observation about diversity and the vegetable consumer in regard to tomatoes.

> We're looking for a good red tomato that's not quirky like the heirlooms. It's nice to grow some heirlooms, but they're very gnarly, they become over-mature way too quickly and that's something apparently that's just inherent in heirlooms. I've talked to some plant people at [Seed Project host university]. . . they said the things that made heirlooms good had to do with their quick ripening and. . . you weren't going to get an heirloom with good keeping qualities. . . . some of them are excessively big, they're not very productive. . . I'd say what we're pretty pleased with is Better Boy, which is something that I grew in high school in the 70s. Maybe we don't need to go all the way back to heirloom times, you just need to go back a couple of decades. Molly

Her insight, that what even sophisticated consumers and possibly therefore farmers want, is a red ripe, flavorful, but unmistakably "modern," that is, hybrid tomato, from our actual childhoods rather than a projection of the tomato of previous generations, shed a different light on the heirloom market. She suggests that consumer nostalgia has been misdirected towards a group of varieties whose appearance mark them as unmistakably old-fashioned. The gnarly appearance of heirlooms acts as a badge of authenticity, a clear visual sign that the tomato in question is not the type of tomato that has earned so much scorn in recent years, the tasteless, rock hard, supermarket tomato which was bred for shipping quality and shelf life, not consumption. The implication of her observations is that frustrated consumers and the farmers that serve them want proof that the tomato they are buying or growing pre-dates the breeding process that created the tasteless tomato (Jordan, 2007). Better Boy (a modern hybrid variety from the 70s) and other hybrid beefsteak tomatoes fail to signal their difference from the supermarket tomatoes. Indeed, it isn't clear if Better Boy as that variety is sold today would in fact produce the same taste as Better Boy of 1975 would have. The incremental improvements made to that variety since then may have shifted the hybrid in the direction that consumer concerned about taste do not want. Whatever the empirical situation may be the problem for producers and consumers, the problem for this farmer, is the question how does one signal "this tomato has the rich, full, tomato taste you remember from the past"?

Furthermore, there are material limits to the plant breeding process. This farmer had discovered by talking to the university plant breeders that one can't have an heirloom that is also the shape and size of a Better Boy or other beefsteaks. It may be possible to have a beefsteak hybrid that also retains a rich taste if one were to breed or resuscitate such a variety without having to worry about long-distance shipping quality. To make such a demand, however, would require considerable knowledge of plant breeding and its constraints on the part of the tomato-buying public. Even this farmer, who was employed in a science field and had considerable practical and theoretical expertise, was unsure what the constraints of the germplasm and the breeding process might be. After 10 years of fairly serious growing, she said she was still searching for the ideal tomato.

4.6 Commercial agrobiodiversity gone missing

The term "commercial agrobiodiversity" is of my own devising and reflects the concern that farmers shared about the availability of desirable seed. Both Alice and Marisol in the section above mentioned that not only were appropriate varieties not being developed, acceptable varieties might be withdrawn from the market at any time. Commercial agrobiodiversity captures that need, articulated by many farmers, to have consistent availability of useful varieties. In the literature discussed earlier there has been extended discussion about the consolidation of the seed industry and the resulting reduction in the number of varieties available for sale (Kloppenburg, 2004). The farmers in this study pointed out repeatedly that the degree of genetic erosion occurring globally should not be simply evaluated in terms of genetic existence. From their perspective the existence of varieties in a genebank or in informal networks of circulation like Seed Savers Exchange was of minimal use if those varieties were unavailable for sale in bulk on the open market. The term commercial agrobiodiversity calls attention to precisely this problem. Even among those farmers who save and breed seeds, it is crucial to be able to purchase some percentage of their seed, according to everyone I spoke with. Matt Dillon of the Organic Seed Alliance has publicly said that he expects this trend to continue among organic farmers nationally (Dillon, 2008). Currently varieties come onto and then are pulled off of the market in ways that seemed arbitrary to farmers. One farmer answered my inquiry about seed availability this way:

> Ruth: Do you have trouble getting a hold of seed that you want?
>
> Jean: Oh, very often. I do trials and I plant three or four varieties of some-

> thing, or I plant a variety of something next to something I've been growing for years to see whether it's better or worse, and I put a lot of work and trouble into this and I come to a conclusion and the variety is gone.

Trialing varieties takes time and effort away from the farmer's main production efforts. The record keeping, the need to take extra time to observe plant characteristics, sometimes the decision to leave a crop in the field a little bit longer than usual or optimal to gauge its reaction over time, all of these investments are rendered useless if the trialed varieties are available for a limited number of years farmers said. When I asked Jean why varieties disappeared she gave me an answer that I heard from several others as well.

> . . . things disappear all the time. This is routine. And the catalogs always want to have something new, and then they drop off something old, and the something old may, in fact, have been doing a lot better for you than the something new, but even it if isn't doing better for you, you don't know that until you've had a chance [to trial it]. . . the fact that something did great in their trial gardens doesn't mean it's going to do well in yours, even if they are in the same general climate area, let alone if they aren't. Jean

Breeders working for bigger commercial seed companies confirmed this tendency for their operations. One breeder explained that the breeders themselves didn't particularly like the turnover in the catalogs but that for large companies the challenge was to satisfy investors operating on a quarterly business cycle, an increment that makes no sense in the context of plant breeding. That breeder's comment taken together with the farmers' analysis highlight a disjuncture in the seed system between the need for continuity over years for farmers' purposes juxtaposed with the economic demand for short-term profitability. The smaller regional seed companies from which most of these farmers purchased their seeds also withdrew varieties in ways that disrupted farmers' plans. One major example was the decision by Fedco Seeds to stop offering Seminis seeds when that company was bought out by Monsanto. The farmers seemed to feel this was the proper principled action on Fedco's part but several commented that they simply couldn't find a reasonable substitute for the lost varieties. Fedco handled the situation as well as they could, according to farmers, phasing out the Monsanto varieties over time, giving clear and frequent explanations for the reasons, and offering substitutions as much as possible. However, in some instances farmers felt there was no good alternative although none of them would admit to purchasing the Monsanto varieties from another seed company.

One other thing that Fedco does is list all the varieties that they intend to drop and that they have dropped with detailed explanations. In the 2008 catalog, for example, 48 new varieties were added, 20 older varieties were reinstated, 38 varieties were dropped for various reasons, 18 were dropped because they were Seminis/Monsanto varieties, and 14 varieties were listed as last chance in 2008, most because as part of the Seminis/Monsanto phase out. The catch-all 38 dropped varieties were dropped because of crop failure (16) or no crop (4). One variety was "dropped by the trade", two tested positive for GMOs, three were listed only with a replacement suggestion, four suffered from slow sales, three had off types, and one was dropped because "we like others better". This level of clarity about why and for what reasons varieties are dropped may be part of the reason that Fedco receives high marks from farmers in this study for openness and good business practices in general.

Seed quality was also an access issue that directly impacts agrobiodiversity because farmers cannot afford to use seeds that do not germinate or which are not available in bulk. One of the most experienced framers mentioned that he had gradually shifted his seed buying to one company that he felt was particularly capable of securing higher quality seed from seed farmers. This individual was the only one to mention germination and vigor based on seed company of origin but others did say that they had to be very careful to order early in the season because the quality of purchases made later might not be as high. The one farmer who was particularly sensitive on this issue said that needing to buy early added to the pressure to know exactly what one would need all season long since buying conservatively and running out of seed even in the spring might mean that the variety in question was of poorer quality or not available. This front loading of seed buying and therefore the cost of seed purchasing would be something that a CSA structure would offset since members typically buy a share in the spring. However farmers indicated that they bought seed in January well before even cash from CSA shares would be coming in. The particular farmer who felt that he had to buy his season's seeds early sold only at farmer's markets which meant that he was potentially carrying his seed costs for as many as 12 months before he could realize the profit to offset the outlay. This would be especially true for crops like winter greens which he needs for his fall and winter markets. A more reliable seed market would lower the amount of capital that farmer need to commit to seed as well as reducing the costs associated with long-term seed storage.

4.6.1 Organic seed availability as a subset of commercial agrobiodiversity concerns

Because many farmers in this study were certified organic producers or because they wanted to source their seeds from producers located in their region, many of the farmers interviewed said they had great difficulty accessing sufficient quantities of organic or untreated seeds that were locally adapted. Several farmers said that seed that was available organically one year might only be available as untreated seed the next. The issue of organic vs. untreated seeds elicited several kinds of responses. Organic seed is grown on certified organic land in compliance with all of the organic restrictions on pesticide use and related issues. Untreated seed may be grown conventionally but it is not coated with fungicides and other chemicals that preserve it or protect it from rot. When the Federal regulation of organic certification was introduced, part of the requirements stipulated that organic crops must be grown from organic seed whenever possible. The farmers I interviewed spoke with approved of this decision in general because it encouraged the organic seed market but many said that they used untreated seed, sometimes even when organic seed was available. This is in part because the seed industry has not yet been able to produce enough organic seed to meet the market needs they said. The law allows some leeway for using untreated but conventionally grown seed if price and availability preclude using truly organic seed. My informants were of several minds about the concept of reasonably priced and available seed. Some had actually opted out of the certification process because they wanted to be able to use occasionally use plants grown under conventional conditions. A number said that the Federal standards were inconsistent and incomplete which made the regulations too hard to follow or just nonsensical. In terms of seed access, many of even the certified farmers said that they used untreated seeds in cases where they could find organic seed but the price was so much higher that they couldn't justify the expense. One farmer I interviewed serves on the board of his farmer's association and recounted how he made the decision to withdraw from the certification process:

> I've been involved with [a farmers' organization] for quite a while and so I was really right there in the middle of the national organic program takeover, if we want to call it that, and I was one of the ones. . . our board had to make a decision did we want to continue to certify. I mean under the National Organic Program and yes, we decided we did. But individual members of the board who had been certified farmer, a number of them, much more stern about this than I was said not me, the organization can be involved with certification if they want to but I'm not going to be involved with the USDA program. But I said okay, I'm gonna give it a try and I stuck with it for one or two years and I just found so many discrepancies that I couldn't believe in, I just didn't believe in the way that the thing was operating. I said I can't do that: I'm not gonna do that.

This farmer also pointed out that because his year's expenses were being paid by the membership, he felt buying unduly expensive seed would reduce their share in ways that he couldn't justify.

> I don't always buy organic seed, no. Although I'm not a skinflint who says, if that organic seed's gonna cost–I mean if you're organically certified you have to buy right? So I still pay more. If I have the choice of organic seed, I'm gonna pay more because I believe in it and I want to support it. I probably won't pay five times as much. For instance when it comes to potatoes, there still isn't an adequate supply of seed potatoes on the scale that we need. We order 3,000 pounds of seed potatoes and I can't justify buying all organic seed potatoes despite the fact that I really want to encourage organic seed production. I can't justifying spending the amount. It costs too much. It's three or four times as much. So I order all the organic seed that is reasonable, reasonably close to what conventional seed is.

The question of how expensive was too expensive raised the issue of consensus. A number of farmers cited a price differential of 3 to 4 time as unduly burdensome, most were less specific. Several noted that only the individual farmer can really weigh cost vs. value of the crop vs. varietal choice for her operation. The variables that determine choice of organic vs. untreated seed are dynamic and conditional to such an extent that inflexible rules could disrupt a growing season, according to them. One experienced farmer characterized the situation this way:

> Leah: I should be able to vote with my money…I think you should be making a reasonable good faith attempt to get organically grown seed, but I don't think that should override all other considerations whatsoever about who you're buying something from.
>
> Ruth: Who should be making the decision about those kinds of trade-offs?
>
> Leah: I pretty much think it has to be the farmer because I may be perfectly happy to support Seed Savers [Exchange] and I may not mind paying a little extra for seed from Seed Savers, but I may not want to pay extra for seeds from Seeds of Change…who are also a very expensive source, and who they're supporting is basically M&M Mars.

The difference here for Leah between Seed Savers Exchange's premium and Seeds of Change's was political. Seed Savers is a non-profit while Seeds of Change has been purchased by a major food corporation.

The issue of local production was also complicated by the fact that seed production of certain crops, beans according to some, is not commercially possible in the Northeast right now. All of the farmers who had a preference said that they tended to purchase seed from regional seed companies because they felt that those companies would grow seed in the Northeast if that was horticulturally and economically possible. Many expressed a preference for Fedco Seeds because that company is a cooperative that uses many small seed producers for its seed production. High Mowing and Johnny's Seeds were also very popular among those I interviewed for similar reasons.

4.7 Experimental Agrobiodiversity

"Experimental agrobiodiversity" is a term that I created to account for a kind of agrobiodiversity that is particular to the research process. To understand how plant breeding research generates plant variation that is unique to that research one needs to understand a little bit about the techniques involved.

Traditional plant breeding involves taking two individual plants or populations of plants and fertilizing the female flowers of one with the pollen of the other. The resulting vegetables produce seed which when it is grown out is called the F-1 generation (Jain and Kharkwal, 2004). The self pollinated next generation is called the F-2 (Jain and Kharkwal, 2004). Within each generation there is uncertainty about the results. Until the variety has been bred to the point where it is consistently stable for certain traits, the breeding process can and will produce unexpected results which a wise breeder will notice and capitalize upon. I learned this from Joe the plant breeder who was head of the technical staff at the lead university of the Seed Project who told the following story about the breeding of the acorn delicate hybrid:

> The way we came up with Harlequin, which is an acorn delicate hybrid, was we made the initial cross to get powdery mildew resistance into delicata—and the hybrid was absolutely beautiful. We wanted to develop an OP that looked like that hybrid, but our problem was everything segregated back to one type or the other; you couldn't stabilize something that looked like that hybrid in an open-pollinated.
>
> Ruth: Why not?
>
> We didn't get the color combination that we wanted. We either had dark delicatas or light colored acorns, or we didn't get that beautiful dark green-white mix that we were looking for. So, and one of the offshoots of that was a bush delicate with powdery mildew, and we said, well, hey, why don't we try that hybrid again, and we tried it again between our newly developed bush delicate and our powdery mildew resistant bush acorn, and the hybrid was gorgeous. . . the offshoot of that was a powdery mildew tolerant bush delicata, and we got an All American Award.

The research project Joe is describing began with a specific goal, to create an open pollinated acorn delicata squash that was powdery mildew resistant, a goal which was not achieved. It happens that the second generation, the so-called F-2, re-segregates such that one cannot produce the desired color combination and the disease resistance at the same time. However, as this breeder was acutely aware, failure to achieve one's goal is relative in plant breeding. A prize-winning hybrid did result from knowledge gained from watching the failure of the initial project. The key here is that it is the skill and curiosity of the breeder interacting with the limitations set by the plants that create new entities. When I suggested to Joe that plants participate in the breeding process, he responded affirmatively:

> Oh yeah. . . you have to keep an eye open, and a lot of times what is going to catch your eye is the oddball, that always happens. If you've got one oddball plant, and every time you go out to the field, you keep gravitating back towards that oddball plant, you're wondering, what in the world is this, why did it do that. Well, I myself would keep seed of it just because it's an oddball and we're going to find a use for it.

The oddballs produced by breeding activities over a period of years form a unique and valuable resource for future breeding. In other conversations Joe described how one year's oddball might be next year's salvation as needs and desires change. It is also the case that the unexpected products of a given breeding experiment may give the breeder ideas for a new project. He gave the following example:

> We've got these note cards, we've got summaries, who knows, we can go back and say, hmm, years ago, we had a little tiny dwarf pumpkin plant, it only made one fruit, and finally you get somebody that says, hey, I'm looking for a bush pumpkin, just an ornamental so somebody can grow a pumpkin in a five-gallon bucket. Guess what I have? . . . we thought it was ugly at the time, but somebody else may come along and say I want to grow pumpkins in bucket, as ridiculous as that sounds.

This particular breeder was unusually creative about marketing uses for strange offshoots of breeding projects but his point was shared by all of the breeders, on-farm and off, that the breeding process is anything but formulaic. Moreover, because plant genetics are complex and not entirely understood, every breeding program produces volumes of plant feedback in the form of a variety of results other than one's specific breeding goal. On the one hand, this messiness, the lack of precision and predictiveness, makes traditional plant breeding slow, a bit more costly, and sometimes frustrating, breeders admitted. On the other, the process creates a plethora of results that are useful in their own right, given time and opportunity. Plant breeding is not efficient from a human industrial perspective, but it is a means by which plants can influence human activities by throwing up unexpected options. Plant breeding functions as a location for joint brainstorming between humans and plants, assuming that the humans involved have the patience to participate, such as the examples Joe shared.

Large plant breeding programs, according to my informants at the university, face a real challenge because they do not have sufficient physical space to save all the seed that might be useful. One supplement to long-term seed storage is written notes but those must be both preserved and comprehensible to future users. At stake is time. Because the process of breeding is necessarily time intensive, records of past projects can be crucial, especially in a grant-funded environment.

> ...you may come up with another grant program that's looking for something different, and you can look back in your records and say, we've already got a good start on that because we have these segregating populations or we have this oddball thing stabilized; it may not necessarily be the type that you're looking for, but you've got whatever disease resistance or something stabilized in a plant habit that you're looking for, and you can go right back and there's several years' worth of work already invested in that project... you've already got a three year head start. Joe

It was clear from this conversation that both the choice to save materials and the process of finding it once it had been stored demanded considerable judgment, training, and creativity. This means that experimental agrobiodiversity is uniquely fragile. It resides in the memories of plant breeders, on handwritten notes written in the fields, and sometimes in computer files which are subject to all of the limitations of electronic preservation, and in seed storage facilities around the universities. As my breeder friend explained: "The biggest problem with it (experimental information) is it's a memory-based system. Not all of this information gets onto a computer; it's not available to the public, it's only available to people in the program". If a plant breeder retires or leaves and is not replaced, those files may survive or they may not. Technical staff with long years of experience also retire or leave taking with them the ability to read the handwritten notes and the memories of the plants that are signified by the notes. Even if the seed survives, it is only useful if its characteristics and provenance are preserved as well. Without those it will take a full season to grow out seed, potentially mitigating its usefulness. In my earlier chapters I have discussed the current crisis of plant breeding programs at US land grant institutions. Suffice it to say here that as traditional plant breeding programs have been shut down or downsized in favor of molecular or biotech programs, countless plant resources have potentially been lost. Expert staff lose their jobs, notes get archived, memories fade, seeds grow infertile. The interested public cannot step in as they have done with seeds preserved by farmers and gardeners because these materials are retained by the institutions where breeders once worked.

Breeders working in seed companies or on-farm probably may stand a better chance of having their materials survive them. Companies keep careful track of the germplasm they develop although they also have physical and temporal restraints on storage. They may also have less capacity to save oddballs for their own sake given the pressures of their business environment. Farmer/breeders run the risk that their experimental work may be discarded by uncomprehending heirs. This is why the distribution of unfinished varieties, heirlooms, and less than perfect varieties through networks like Seed Savers Exchange is so important in my view. On-farm experimental agrobiodiversity from farmer/breeders can thus be transferred during the breeder's lifetime to others who will care for it and make use of it. Ironically and perhaps uniquely, the greatest producers of experimental materials, university-based breeders, are at greatest risk for losing their work when institutional priorities change.

4.8 Conclusion

The purpose of this chapter has been to demonstrate the use of agrobiodiversity as revealed by participants in the Seed Project. The distinctions I have drawn based on the interviews I conducted showed that while the main goal of the project was expanding varietal resilience, both farmers and breeders were concerned about the underlying availability of plant germplasm for breeding and farming purposes. The difference between molecular and phenotypical methods of measuring agrobiodiversity were never directly addressed in conversations I observed between participants, yet the fact that these two kinds of measurements exist may need to be more explicitly addressed in future projects since failing to do so can lead to significant miscommunication and misunderstanding. Equally important is the problem of commercial and experimental agrobiodiversity both of which are issues of access at the level of the seed system rather than the individual plant. Without commercial outlets for a broad selection of varieties, the particular needs of the farmers I interviewed were constrained. Moreover, the university-based breeders knew that they were losing valuable materials because of institutional lack of support for conventional plant breeding. These several issues raise the prospect that improving the world's crop varieties may be less a matter of scientific innovation than the need for fuller use of those materials and varieties already in existence.

Chapter 5

Circulation of Scientific Knowledge

> My message is that *research priorities—in breeding and improvement not less than in any other field—are too important to be left to research directors, management types, or scientists.* (emphasis original)
>
> Jack Kloppenburg, *First the Seed*, 2004

> Plant Breeding is a fascinating science because it's very complex; it requires tremendous knowledge of related disciplines, including real sociology, and we have to use a lot of almost instinct to figure out how to breed better crops...
>
> Jake, academic plant breeder

5.1 Overview

Participatory plant breeding for organic systems straddles the intersection between academia, business, farming, gardening, and government policy. Breeders can be academic faculty, research associates, or technical staff inhabiting various locations within a defined institutional hierarchy. They can also be organic farmers who breed either for their own purposes or as a part of collaborations with seed companies, experiment station researchers, or university-based faculty and staff. Seed companies also employ breeders and work collaboratively with university-based breeders. Breeding knowledge rests with a variety of agents enmeshed in several kinds of institutions.

From this study of the Seed Project emerged a picture of plant breeding as a system that is incomplete and chaotic. It is the purpose of this chapter to describe how the Seed Project uniquely negotiated existing disjunctures between actors and institutions with an emphasis on the manner in which bridges were built and the results that emerged. I pay particular attention to the tempered expertise of the various participant and the expanded skill set demanded of participants, especially the two women who functioned as the leaders of the project. Also important is nature of the technoscientific artifacts that emerged from this method of collaborative, grassroots-friendly, but expert-driven breeding process. I begin with a brief description of the context within which the Seed Project was conceived, that is, plant breeding as it is now practiced in several spheres and by several different kinds of practitioners. I will then describe the particular interventions that the Seed Project initiated and the impact it had from the diverging perspectives of various participants. Finally I show the critiques leveled at the project in its final meeting and contextualize those remarks as expressions of differing plant breeding worldviews.

5.2 Plant breeding as a human science

5.2.1 Experimental plant breeding's inherent vulnerabilities

Plant breeding is generally classified as an applied biological science. In chapter two, Plant Breeding as Technoscience, I outlined the necessity to adopt a more inclusive approach acknowledging the social construction integral to the practice of all science. This chapter is focused upon the human or social elements of scientific breeding practice and the resulting fragility of the underappreciated human networks essential to varietal improvement and how the Seed Project addressed some of those issues.

Plant breeders themselves are aware of the the hybridity and interdisciplinarity of their technoscientific practice as the comment from Jake above demonstrates. A hybrid science, as defined by Jake and the science studies literature on technoscientific innovation, is a public practice that melds the material and human organisms using standardized organizing principles of investigation. As we should recall from Longino's framework discussed earlier, a meaningfully democratic or public science allows for open venues, fair uptake or engagement with opposing views, and development and use of reasonable and transparent standards (Longino, 2002). Jake's remarks indicate that part of the fascination for him with plant breeding is that "breeding better crops" requires broad data collection that fuels an instinct for what humans and plants need from each other. Susan Ashworth's seed saving bible puts it this way:

> The seeds that gardeners hold in their hands at planting time are living links in an unbroken chain reaching back into antiquity. Today's gardeners cannot possibly comprehend the amount of history contained in their seeds, both what has come before and what may potentially come after their brief involvement (Ashworth, 1991).

While Ashworth emphasizes the seed as a vessel of previous generations of selection and development, my data calls attention to the relationships of generations of humans who have created the seed in an image that they desire, a phenomenon that has been described by Stephen Brush as well (Brush, 1991, 1992, 1995, 2000b). Joe, for example, gave the following description of the process necessary to produce a new open pollinated variety:

> Ruth: So how do you develop a new open-pollinated variety?
>
> Joe: Well, it depends on what traits you're looking for. You do the initial crosses, selecting the F-2 for whatever disease; if it's a recessive gene, you have to wait 'til the F-2—if it's a dominant gene, you can select any F-1 and do a back-cross program,. . . you just continue back-crossing and selecting and it'll take ten, 12, 15 years to get enough back-crosses and enough selection so that you've got things stabilized so that you have what you are looking for.

Joe, a habitually modest man, casually mentions that development of an open-pollinated variety can easily take 10 to 15 years to stabilize in a form that can be used commercially. Other plant breeders in industry and academia agreed with this time frame. One mentioned that he had begun his work in fruits but abandoned that because the time it would take to achieve a viable variety could be so long that his career would be almost over.

Presuming a decade of time as a standard unit of success puts plant breeding into a very specific temporal framework at odds with either quarterly business performance, yearly planting seasons, the tenure process for professors, or grant cycles. It implies years of carefully collected information preserved and passed along from person to person. Institutions with highly stable funding streams and long-term employment horizons can be a significant asset in such endeavors. This is a fact that has been clear from the beginning of the agricultural experiment station system in the late 19th century when the decision was made that to be competitive, American farmers and agricultural businesses needed research support (Rosenberg, 1961; Pistorius and van Wijk, 1999). In the next chapter I will illustrate how valuable each plantings' results may be to both a current project and as a step towards building a catalog of incremental trait expression that can be helpful in the future. Joe will describe a hypothetical "runty" pumpkin that could prove attractive to container gardens as an example but explained that memory-based systems or even those on computers whose users have moved on, lower the chances that important advances will be saved and used.

Worse than shortcomings in preservation systems or human memory, is the danger that when a research program is shut down, the knowledge and seed produced by that program becomes utterly inaccessible, a threat to what I will describe as "experimental agrobiodiversity". Joe gives an example:

> Ruth: What happens if a breeder leaves or retires, what happens to all of that material?
>
> Joe: It sits in seed storage looking for somebody to rediscover it. A particular plant breeder for the experiment station retired, he was among other things, a lettuce breeder, had incredible lettuce varieties, perfect for the Northeast, and they are sitting in seed storage. I tried to get a USDA lettuce breeder interested in them, but they were in the process of thinking about changing jobs, as well, so that didn't happen.

Chance can break the chain of epistemic, scientific and personal relationships that link useful plant materials with people who can breed them or eventually farm with them. In the lettuce case Joe knew that the seeds were well cared for, but nationally the circumstances were not so rosy.

> Ruth: Potentially there are these resources all over the United States where plant breeders used to be and aren't anymore?

> Joe: Yes. Whether or not their seed has been boxed up and thrown in the basement of a building someplace or put in adequate seed storage depends on the university and whether or not folks are around who think that that material has value. . . . It's different material than the seed companies have, it's different material than the Seed Savers Exchange has, its different material than the experiment stations. I mean, everybody has their own stuff.

The concern that Joe so eloquently voiced paints a picture of loss and wasted time and energy. Because the materials in question are the property of the research entity, because they can only be passed along to other designated researchers, it is the chain of relationships that makes those seed lots meaningful that are at risk. Even if the seed itself is revived, the individual memories that could explain the virtues of each breeding line are gone. Even if the notes are complete, they are handwritten and not cross referenced because many pre-date the computer. With the work loads such as they are, Joe himself can't always ensure that all of the most important data points are preserved. This is a significant part of the fragility of plant breeding as a human science in that it is the actual sharing or circulation of knowledge in a usable form with other interested interlocutors which make plant breeding possible. The most compelling parallel I see is to works of art. Like art works, seeds are unique artifacts that are best understood if their provenance is understood. Without the narrative of their development and characteristics, individual plant materials are far less useful. They must be grown out, re-tested, re-trialed under varying conditions, and then integrated into their proper place in the breeding world. Time is lost. Potential is lost. Knowledge is lost. If enough of all of these factors are missing, the materials may simply never reemerge out of storage and a set of breeding problems may seem far less possible to solve.

5.2.2 Farmers' networks are insufficient to preserve germplasm

Loss of experimental material is only one example of holes in the seed production system. The seed saving literature documents many other seed and knowledge networks that once existed and no longer do. Among farmers around the world the shift from subsistence or local market agriculture to global food chains has resulted in drastic consolidations of germplasm (Busch et al., 1991; Howard, 2003; Kloppenburg, 2004; Fowler and Mooney, 1990; Pistorius and van Wijk, 1999; Nazarea, 1999, 2005). In the case of the organic farmers that I interviewed in this study, another break in the chain was evident. With two exceptions, all of the farmers I interviewed came to farming from some other occupation. They brought no germplasm with them to their new profession. Even the two farmers who had been conventional farmers first and then converted to organic approaches, had been dependent on purchased commercial seed for their production. One of the Seed Project's key farmer liaisons offered this comment in reference to existing on-farm germplasm, ". . . we tend to think about this as being the 19th century. . . it seems to be World War II that's the big dividing line for so much of this stuff."

In this regard my farmer informants were very much like their peers, conventional and organic, many of whom do not save their own seed. From scholarly studies of the seed system it is clear that since World War II the majority of American farmers in the vegetable sector have purchased their seed (Kloppenburg, 2004; Pistorius and van Wijk, 1999). They did and do so for rational economic and cultural reasons according to this literature: the emergence of hybrid seed which can't be saved and reused; the expansion of the land-grant and experiment station based breeding infrastructure; and, the expansion of a thriving commercial seed sector which could provide farmers with the quantity of seed they desired (Fitzgerald, 1990). By the time the organic farm movement emerged in the United States in the early 1970's the infrastructure in this country was thoroughly commercialized. There were still farmers and gardeners who were saving seed but their numbers were declining and much of the know-how associated with on-farm seed improvement had vanished (Whealy and Adelmann, 1986).

5.2.3 The Seed Project shares experimental seed stocks with farmers

For all of these reasons, the organic farmers who participated in my study who wanted to breed or save their own seeds were working from a germplasm base that consisted primarily of commercially available seed. In cases where the commercial seed was relatively stabilized, farmer/breeders had to recreate diversity within their breeding populations by crossing commercial varieties out in the field for several years to create enough variation to begin resegregating toward specific goals. One of the five farmer/breeders in the project described his parsnip project as follows:

> I wanted to breed for crown rot [resistance]so I started by crossing three varieties for a couple of years.
> Johan, farmer/breeder

The Seed Project offered those individuals access to less stabilized, more varying seed then they could have achieved on their own. That is, because the university engages in breeding, it has in its storage facilities breeding lines that produce plants that vary rather significantly from each other from which a breeder can then select. Finished varieties on the market should not vary that much because farmers and gardeners want and need consistent and dependable results when they plant a given variety. Indeed the whole point of using a particular variety is that one can predict with some certainty the vegetable that seed will produce. If a variety contains so called "off types", that is plants that don't produce the specific results they are bred to produce, the outcome may be unusable or unsalable. For example, if an edible pod pea seed produces some plants with edible pods and others without, a farmer may be confronted with dissatisfied customers who bite into a few fibrous pods and subsequently vow never to buy from that farmer again.

5.2.4 The thirst for knowledge: other sources of traits and seeds

There do exist other sources of variable vegetable germplasm that could be used by farmers: grassroots sources like the Seed Savers Exchange and the national genebank system run by the US government and connected to the international genebank network. The Plant Germplasm Repository Unit [PGRU] of the USDA does allow the public to request germplasm from their holdings. The hitch is that the system is difficult to use. Few of my farmer/informants considered these sources to be effective links to existing germplasm for reasons that their representative explained:

> . . . it's a very complicated system, and frankly it's pretty terrifying given that it's our major genebank, the viability of the seed is often horrible. So, for example, for an onion demonstration and replicated trial that I'm doing, this is the second year I went through their [site]–I personally experienced what somebody is up against, and, I'm a researcher, so to go through accession after accession and to try to–if one technique of finding something

> doesn't work, find another. But I found the descriptions horrible, out-of-date, and then they sent me 16 varieties, and of those six had no viability at all.
> Ann, farmer, breeder and farmer's representative

I did not have the opportunity to confirm this experience with other farmers. To achieve some sense of how the system works I accessed the system on the web myself. The site itself is clear and easy to navigate but when one drills down to the level of individual accession listings, an accession being a particular variety or breeding line, a user accustomed to buying from seed catalogs might be put off. The listings are by taxa and then accessions. More importantly, Ann related a conversation she had held with the head of the PGRU unit in which that individual had said that his collection was far from complete.

> So he was saying to me that they [Seed Savers Exchange] are serving a purpose, a real purpose. When I was looking for onions, I was saying, well, shall I just assume that you have everything that Seed Savers does? He said, oh, no, do not make that assumption. And the more I looked at the list of materials, the clearer it became that Seed Savers is out there doing some stuff that nobody else is doing. So there should be ways of linking national efforts of seed conservancy with that nonprofit sector better. Ann, farmer/breeder/farmer's representative.

The importance of the Seed Project therefore was its ability to bring together already existing resources that had been previously inaccessible to farmers. Participation in this sense meant that by affiliating with a university-based breeding program, farmers had a mechanism by which they could either use germplasm controlled by the university or owned by the Federal government. The latter source was and is technically available to anyone but its means of storage and distribution is so user-unfriendly that without mediation from trained staff, the materials would be essentially unavailable. In this regard the USDA's failure to provide appropriate access to germplasm resources demonstrates an addition to Longino's standards for inclusive science that are particular to plant breeding. If the seed from the repository is non-viable or too hard to access by farmers and grassroots breeders because of the way it is cataloged, the interaction between artifact and those communities is constrained. This means that as a technoscientific practice where the interaction between seeds and humans produces knowledge feedback is limited to those experts who can utilize the PGRU database. Given the small number of trained plant breeders in the US, (Brush, 2000b; Duvick, 2004; Frey, 2000; Bliss, 2006, 2007; Gepts, 2006a,b; Gepts and Hancock, 2006), by some accounts as few as 2200 in the US in both the private and public sectors for all crops (Bliss, 2007, p.S-255), the lack of access Ann articulated points to a severely reduced number of possible participants in the plant improvement process. This is a direct example of the feminist contention that when issues of access limit who can participate in a technoscientific discourse, the quality of the inquiry and the resulting innovations are unavoidably compromised (Longino, 2002; Harding, 1986, 1991, 2004; Hartstock, 1987; Haraway, 1999). Fewer unique traits in circulation means less opportunity for those traits to be transferred into useful varieties. If the old saying is true, many hands make light work, the reverse is clearly also the case in the situation Ann is describing.

From the literature we know that there are a number of possible approaches by which participatory plant breeding projects have facilitated germplasm sharing together with other aspects of plant breeding and crop improvement (Ceccarelli et al., 1996, 2000, 2001). It is to the mechanisms that the Seed Project utilized that we now turn our attention.

5.3 The Seed Project: A model of distributed varietal development

5.3.1 The network's point-of-origin

In its first iteration, the Seed Project sought to connect four distinct classes of agents into a multi-directional network. Figure 5.1 on page 110 below shows the parties between whom information flowed. It is important to understand the institutional point of origin for the Seed Project. Although the PI said that she got the idea from others who had pioneered the concept of on-farm cooperative breeding, it was she and her team who translated those ideas into a funded, viable network. Figure 5.1 on page 110shows the basic organization of the project in its initial three-year iteration. There were five groups involved: the host university, a group of small seed companies, the USDA experiment station for the region, the regional farmers' association, and the individual farmers themselves. The figure shows just those relationships and flows of information that were initiated by the Project. Preexisting contacts, such between farmers and the seed companies from whom they buy seed, are not shown. Reading from left to right, we see that the host university shared breeding materials, techniques, support capacity (greenhouse space, etc.) and data support with farmers and the farmers' association. Some of the seed filtered through the project had come from seed companies originally but was passed through the project in order that the trialing results could be tracked by the university staff. The farmers responded to the university's initiatives with information about NE 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 although as the project entered a second phase and a third phase was considered, the representatives of that group also explained the perspectives and opinions of their membership to the professional breeders. The experiment station's primary role in the project was to house the seed cleaning machinery and train growers in its use. Again, as with the seed companies and the growers, there were pre-existing relationships between the university breeders and the experiment station breeders and staff but those are not shown.

While it is tempting in the science studies literature to talk about the generation of networks as a decentralized, co-constitutive process (Latour, 2005), in this instance, the network that emerged in this case was deliberately initiated and organized by a well-placed and experienced academic. This is not to say that the idea was imposed upon the farmer 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 impact the project would have on farmers. Even more impressive was the collection of letters gathered for the first grant when the project was at its inception shown in Table 5.1 on page 112.

Figure 5.2 on page 111 illustrates the formal structure of the project within the lead university.

There exist two tracks: the academic and the management/staff track. The PI is ultimately responsible for people working in both tracks although the nature of her relationship to them differs in type. The academic track is in theory governed by the system designed to educate students who in turn can become eligible for tenure-track jobs.

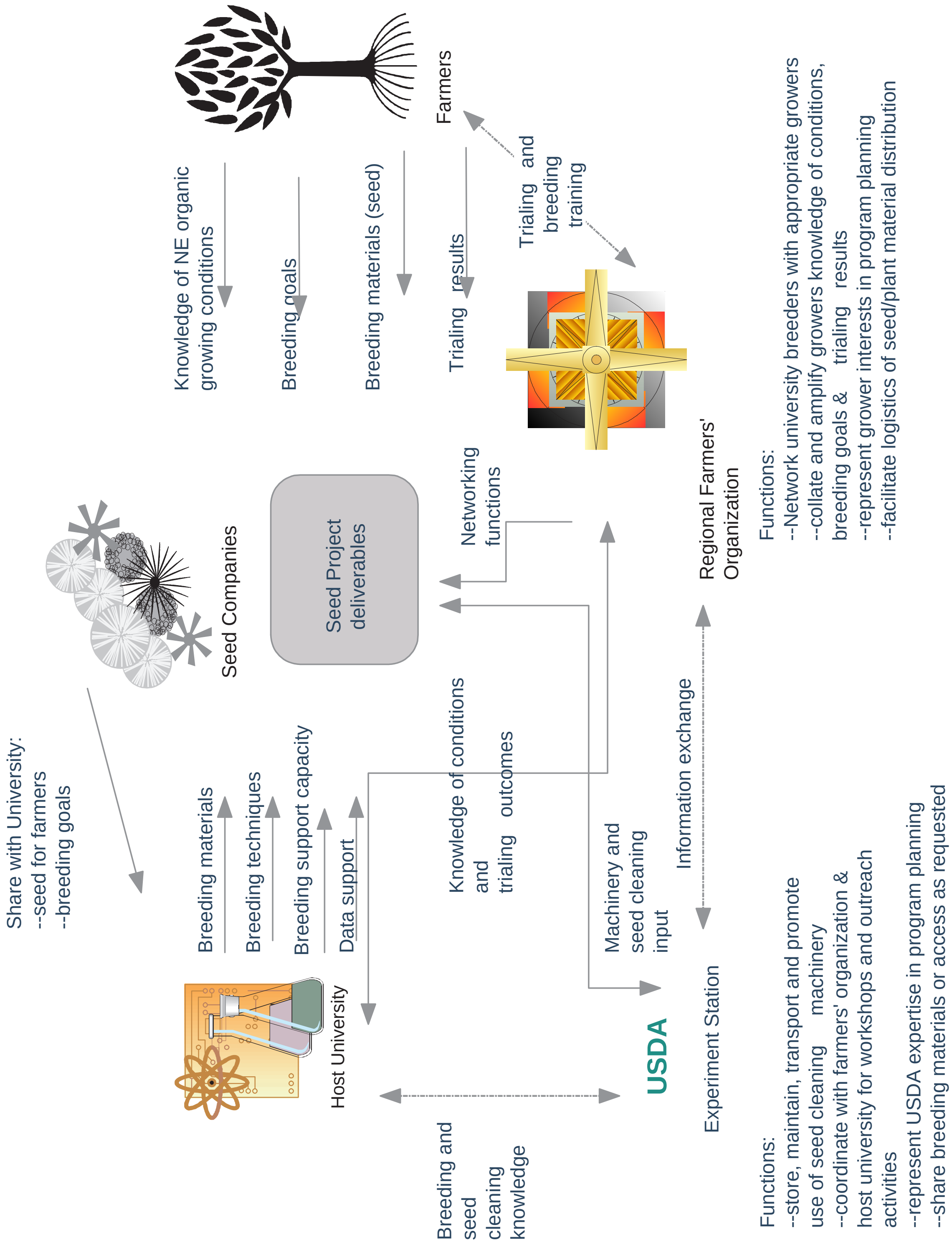

Figure 5.1. Institutional Relationships

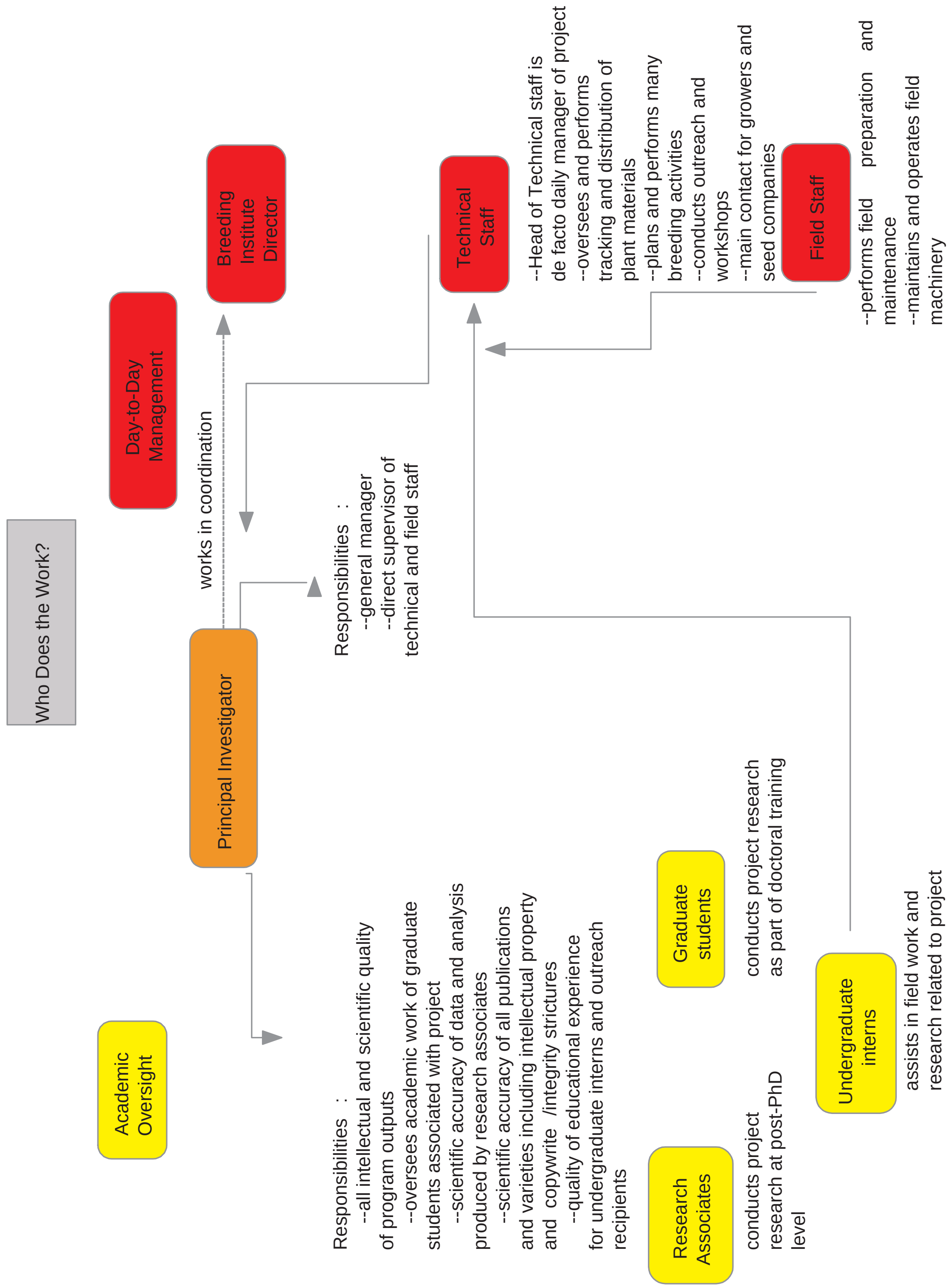

Figure 5.2. Division of labor

Institutional Affiliation of Correspondent	
Government organization	8
University-based faculty	10
Seed Company	3
Organic Farmer	35
Farmer Representative	3
Technical Staff	8

Table 5.1. Letters of Collaboration and Support

Thus a professor in this model has responsibility to ensure that both the work on her projects proceeds and at the same time students and research associates are able to gain the experience and credentials to move on in their careers. The other major academic responsibility is that of generating research outcomes. This second responsibility, in the case of disciplines that require extensive lab and or field data collection, can be further subdivided between the generation of research goals, determination of methods, data analysis and day-to-day management. It is this last category, the managerial responsibilities, that I have segmented off in Figure 5.2 on page 111 for separate consideration. I have done so to highlight the fact that while the technical staff did engage in intellectual/academic research work on this project, the course of their careers and the type of relationship the PI could have towards them was fundamentally different from those on the academic track. The distinction I am drawing is at some level artificial, as both groups overlap in terms of their contribution to scientific outcomes. On the other hand, the individual rewards and recognition for those who fall into the academic half of the project are different from those who do not.

The actual viability of the current academic system has come under significant attack in recent years with critics documenting that in fact tenured jobs are disappearing and being replaced by adjunct hires (Bousquet, 2008). As yet insufficient research has been done in applied agricultural sciences at land-grants to ascertain if this critique applies to this type of institution or not. However effective the academic track may or may not be in terms of producing tenured professors, the management track has much more circumscribed goals. Those who report to the PI in that hierarchy have limited, "as needed" prospects for advancement. Their education is ancillary to their roles as employees. This particular PI worked hard both to secure fair working conditions for her employee reports and to obtain for them access to education-based advancement, but in this regard her leadership was different from many individuals in her position.

There are also a third group of people who had considerable influence on the project: the intellectual property office and the director of a university-wide breeding institute who do not report to to the PI but who must be worked with or influenced in order for crucial aspects of the project to go forward. It is important to note that although the PI's responsibilities are broad, the project's success is linked to her ability to persuade those outside of her direct reports to work on behalf of the project's needs. An easy example of this phenomenon has to do with the relationship to the intellectual property matrix.

Even before the Seed Project was initiated, the materials transfer agreements (MTAs) that governed plant materials was nineteen pages long, according to one informant who became responsible for the licensing part of the program.

> The licensing activity is a means of generating revenue for vegetable breeders and is something I really didn't go looking for, it came looking for me. I had one faculty member who was frustrated with the process that was in place at the time here relative to licensing materials, and she felt that there was a less intrusive mechanism that could be developed. And so we ended up taking what had been a 19-page licensing agreement and compressing that down to two pages and essentially memorializing on a piece of paper what the understandings were between the faculty member here and their counterpart and any private seed company without all of the boilerplate, and it's working beautifully.
> Mark, plant breeding administrator

Technically, it is not part of the responsibility of a plant breeder to concern herself with the form of the MTAs. The PI on this project did so personally because she knew that the original document would not contribute to the climate of openness and accessibility that she felt needed to happen. As in the case of facilitating access to germplasm, the simplification of the legal documentation facilitated the participation of a diverse group of participants and smoothed the way for amicable exchange of information and ideas. Again her colleague explains:

> . . . [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.

According to her staff, who had to use these documents, taking a less legalistic approach to controlling germplasm helped ease the tensions that exist between a large university that wants to keep some kind of control over their germplasm property and farmers who may not approve of the concept of germplasm ownership. What was interesting was is that the initial motivation for shortening the MTAs was a desire to avoid offending seed companies, not alternative farmers. Mark, the administrator quoted above who ended up leading the simplification process explains,

> It had been a difficult job to get seed companies to sign these agreements because they were offended by them. There were so many clauses and phrases in these documents that implied that something illicit would happen or something illegal would happen, and so we simply wrote an agreement that is based on an honorable relationships between two people , and the basic preface for the agreement was, in the case that either one of them died, there'd be some paper record of what their understandings were.

In Figure 5.3 on page 115, we can see the array of relationships that exist within the university and the PI's central role as mediation point between all parties including the farmer's representatives who were employed by the university as part of the project. The pressure that comes to rest with a PI in such circumstances is visible in this diagram especially, since this particular individual had other grants and other, much larger research projects running concurrently. The managerial and personal skills involved in managing a life with such disparate responsibilities is important to keep in mind when we ask the question why senior researchers may shy away from holistic, multi-party outreach efforts.

5.3.1.1 The second iteration: national expansion

The second funding cycle required that the Seed Project re-frame itself as a national project at the end of the first three year period. Each grant application had to provide

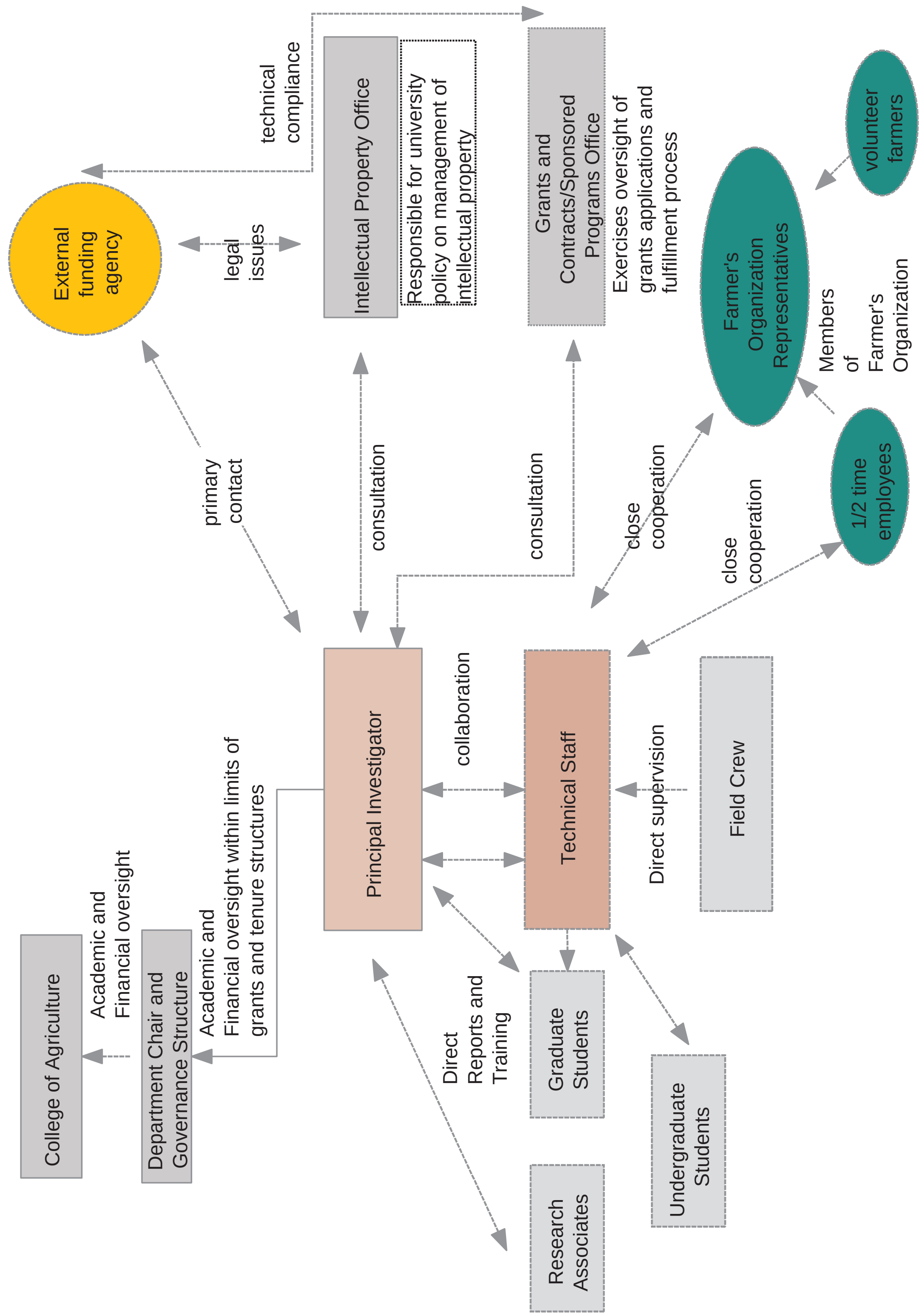

Figure 5.3. Central role of the principal investigator

evidence of its status as a new and innovative idea. This was a problem in the thire round but it was clearly a challenge in the second round as well. In order to meet the innovation requirement the original university reached out to a number of institutions around the country.

Figure 5.4 on page 117 illustrates how other universities in a diversity of geographic locations were included into the project. The changes in the function of the project were essentially an expansion of what had been done before. Although several skilled plant breeders were added to the team, a number of them worked at locations that were underfunded or where the organic farming community was underdeveloped. Part of the reason for that reflected a direct strategic decision on the part of the project leadership. One key criterion for selecting the new universities for the project, according to the PI and others involved in the project, was a desire to include minority and underrepresented groups. To that end, a historically black institution in the South was selected, as was a state university that served a mostly Appalachian population and a southwestern institution that, it was hoped, would have connections to the Hispanic, Native American, and immigrant farming communities. The second grant documentation also points to collaboration with such national non-profit seed saving and breeding organizations such as Restoring Our Seed and Saving Our Seed. The non-profit contribution was primarily in the form of seeds and some limited collaborative activities.

The viability of the nationwide expansion proved somewhat difficult to assess by the time I began my research. The number of requests for materials from outside of the northeast did seem to increase slowly over the life of the project but the majority of requests from farmers were still concentrated in the Northeast. From the final meeting it seemed that different hubs had been able to participate to differing degrees. One participant assessed the project in this way:

> I think to do any of this we need to set up the hubs to be really strong. And some of them have strengthened over the years, some never went anywhere. I mean we have seen the six year relationship with the farmers' organization has worked out really well and I guess in Wisconsin there are probably those connections . . . and I would think a lot of it is actually funding. Our growers' organization has a 3/4 – 1/2 funded person and that makes a big difference. These other hubs, they don't have that funding. We are not going to be able to put a full-time person at every hub. But maybe we could

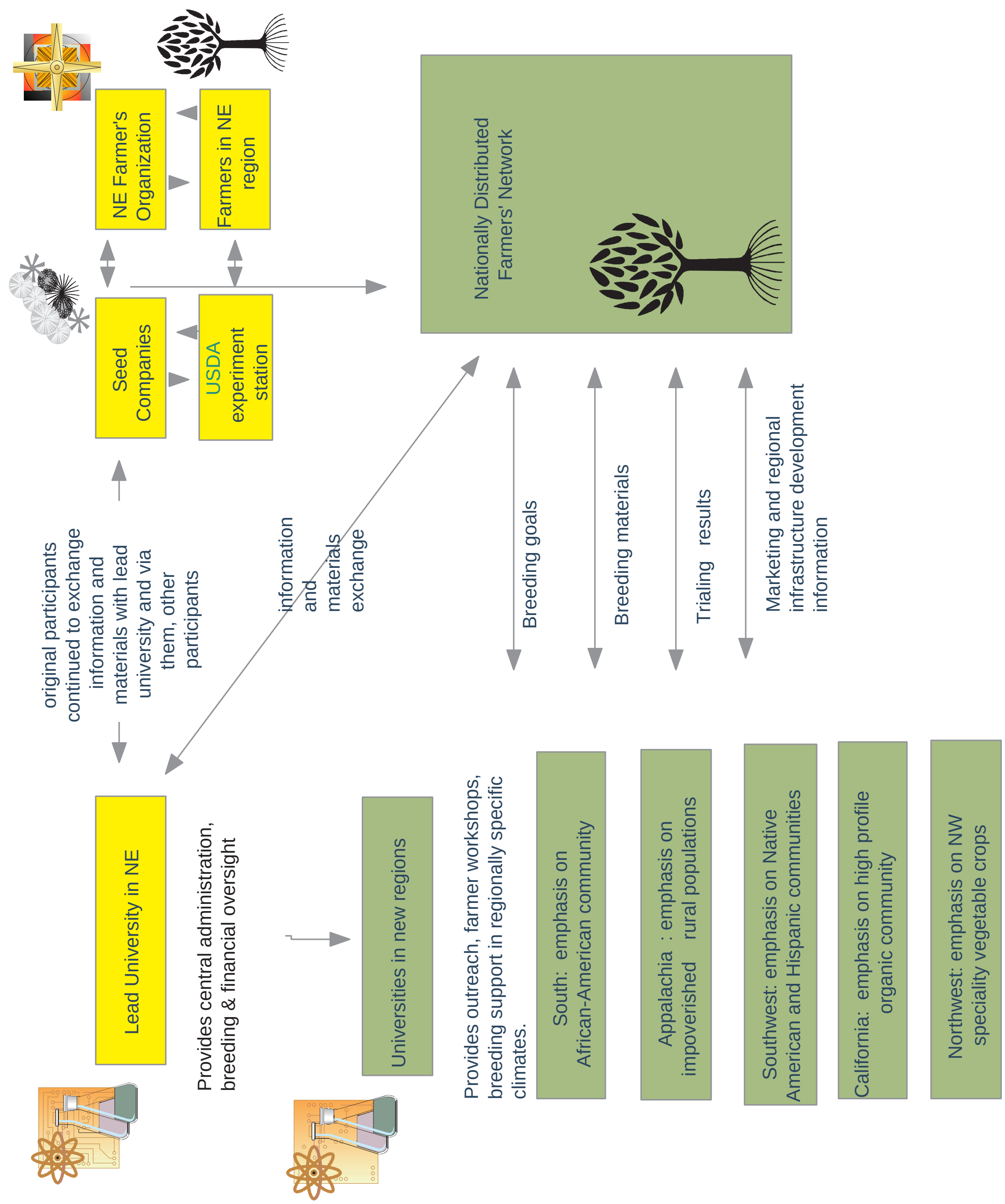

Figure 5.4. National expansion of the project

> try to focus on one of the other hubs.

As discussed earlier in this chapter, the lack of an organized organic farming sector was one considerable barrier. Another was lack of money and personnel. One breeder working in a hub location described her frustrations this way:

> Actually, at least at my place, having another person is not actually helpful. Because, no, seriously I couldn't attract somebody to come and live in Charleston, West Virginia to do what I do or to do any of the stuff, because the technicians I just hired, I hired because of his lab abilities and I'm training him in horticulture. Even though I did a nationwide search. I couldn't find anybody that would come.

In the end it seemed that the effort to nationalize had stumbled over the limits of funding and the difficulty of finding and paying people to do the basic outreach work. When I asked Joe and John who had given workshops and traveled nationally to farmer's conferences what it would have taken to increase the number of participants, Joe's answer was immediate:

> Time and personnel. If we could visit all these growers and do a quick pollination demonstration, or even walk through the field with them to do selections and do a couple of pollinations and leave them there to watch this mature through out the rest of the season, and just give them the little bit of information they're going to need to, you know, to harvest that fruit and save the seed that would be absolutely wonderful. But. . . I think people are afraid that they're going to make mistakes or they're not going to do it right. I mean it is very easy to do, and that's what we need is more time talking to these folks. . .

Joe's point is one which future projects would do well to heed, namely that there is no substitute for hands-on direct contact between farmers and a project like this one. Although the Seed Project had an extensive website with detailed information about how to pollinate or how to save seeds, Joe felt that many farmers were still too intimidated by the process to engage in breeding without some direct reassurance. "We need more time talking to these folks. . .", highlights the fact that encouraging the enhancement of grassroots farmer-based breeding skills benefits primarily from person-to-person discussions. Indeed when I spoke to a several farmers who were considering taking up on-farm breeding, they all said that they had only begun considering the prospect because the Seed Project had demystified the process at workshops or in other personal contact.

5.3.2 Garnering support: seed companies and farmers speak up

Once the idea of the Seed Project had been conceived, it received strong support from small seed companies and farmers. Both private sector partners wanted increased public breeding and said so in their eloquent letters of support. The list of seed company supporters in the first grant proposal included some of the world's largest producers as well as six letters from small seed companies that serve the Northeastern organic market. Those letters (written in 2000) outline the dire need those smaller companies felt for access to plant germplasm for organic farmers. One letter said:

> Ten years ago we at —– 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 distribution entity, buying seed from producers in bulk, repackaging and selling smaller quantities to gardeners and farmers mostly in the Northeastern US. However, in time, 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 that they owned themselves.

Here we see Erwin Baur's concern about genetic erosion and Sir Albert Howard's organic movement intersecting. Small scale and organic farmers are pushing the limits of what the conventional plant breeding and distributing sectors can provide. Although in earlier days organic farmers could use the varieties in commercial circulation, by the mid-1990s, according to this seed company founder, genetic erosion had proceeded so far apace 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 themselves. Instead they searched through the seed resources of the Seed Savers Exchange, a free-standing network of seed savers and other related groups for varieties that could be transformed into usable commercial varieties. Unfortunately those sources fall short of the resource base necessary to serve the organic farming market. The same letter continues:

> 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 author of this letter alludes to a problem I will discuss separately, the demise of classical breeding as an academic discipline. What is important here is the testimony offered that the sustainable farming community and the small seed companies that serve it have been cut off from the germplasm and the accompanying expertise that reside in academic breeding programs. In the earlier quote this seed company representative had made clear that while this particular company had jumped into the breach and begun bringing older varieties back onto the market, they were handicapped by limitations in expertise and access to disease resistance.

Another plant breeder from a different company pointed to two additional barriers that keep plant breeding knowledge and germplasm resources from reaching the organic community specifically: the tendency of large commercial entities to breed for optimal conditions 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.

Market dynamics push large seed companies to work only on problems facing large farmers. For vegetable plants that means that varietal development is being directed exclusively towards the California market. Since 2001 when this letter was written the organic market in California has expanded and there may be some breeding directed towards those needs however, the two other distinctive characteristics of the California market: climate and mechanization, have not changed (Guthman, 2004). The farmers I interviewed often harvested and processed their crops by hand or had members of their CSAs do that work. Because all but one were under 200 acres, half under 50, the key to 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 some of the shipping characteristics that California organic enterprises would need. The key is that a particular kind of knowledge, how to create workhorse varieties that will thrive in diverse conditions, is no longer circulating. As a result, 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 letter cited above continues with a discussion of the germplasm that small companies and organic farmer/breeders can access and the shortcomings of that body of material.

> 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.

Again we see confirmation of the problem that Joe, an academic breeder, cited at the beginning of the chapter. The existence of the germplasm itself is only half 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 corroded leaving farmers, seed companies, and public breeders isolated from each other and unmotivated or unable to bridge those gaps, plant breeding knowledge evaporates or fails to emerge.

A handwritten letter from an individual farmer confirms the problem of time and resources stretched too thin:

> It has been difficult finding organic seed of food products that my customers are interested in, all 159 of them. Unfortunately, my search has been long, arduous, and unfruitful. . . . I am sure that not everyone has time to write you to tell you this and I am sure that for every letter like mine there are a thousand farmers elsewhere who do not have the time and who do not know who to write to. . .

Another significant player in the organic seed industry, a well respected breeder who heads another company that focuses on organic vegetable seed agreed that time was of the essence:

> Our company is one of the smaller companies active in plant breeding. Those of us who do the breeding here have a lot of other work to do in the company as well. The years just seem to go by with less than we would like of contact with colleagues–also less with those of you in the public sector who are bridging the basic-to-applied research gap in both classic and biotech plant improvement techniques.

In the absence of the kind of work that the Seed Project was proposing to do, the quality of the organic seed bank was decreasing. Outside of the university breeding programs, technical expertise was hard to come by. Again according to the breeder quoted earlier:

> There is also a large increase in interest among these specialty and organic vegetable growers to acquire seeds of many of the older standard open-pollinated vegetables by growing them "on-farm" or by procuring them from small independent seed companies which are springing up to meet their demands. A number of these seed growers were coming to me for advice on how to best select and maintain these varieties, realizing that just "saving" the seed was leaving them open to the vagaries of genetic drift and inbreeding depression.

Without robust connections between the university breeders and the other parties to the seed system, the actual quality of the varietal selection decreases according to these accounts. Farmers and farmer/breeders need access to disease resistance and other features that can be found in research collections exclusively. Relying on the adaptations crafted by earlier generations without skilled intervention and broad access to genetic material puts organic farmers at risk. They will have difficulty collecting the material they need as the handwritten letter from the farmer attests. The commercial large scale seed companies who do have deep research capacity, only breed for optimal conditions in California. Small regional companies lack the time and money to breed enough to fill the increasing demands. On-farm breeders face the same economic challenges plus all but the most sophisticated need additional training to ensure that they maintain varietal integrity, not to mention that as new farmers enter the profession, they too need training.

One final aspect of seed production has been neglected: cleaning, processing and storing seed for sale, collectively referred to as post-harvest processing. Several farmer/breeders who did not participate in the Seed Project because their major crops were not vegetables, told me that seed cleaning, separation, and harvesting machines were being deliberately destroyed by larger seed companies as they bought up smaller entities. One such informant had tried to buy old seed cleaning equipment from a scrap dealer only to be told that the dealer was sworn to destroy and not resell those machines. "If I sell them to you, the company will never speak to me again," the dealer was quoted as saying. The farmer who had tried to access the scrapped machines explained that even 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. This was the last farmer that I interviewed so I was unable to confirm with anyone else if they had heard of such destruction of machinery. In only one other interview had a farmer mentioned cleaning machinery and in that case that individual seemed to think that one could buy old machines at auction although he had not attempted to do so. Because these two individuals were not in the same location nor did they plant the same crops, it would be difficult to assess what may be actually happening to old machinery at various locations.

In the letters of support for the first Seed Project grant, a seed company head mentioned the processing difficulties his seed producers encountered:

> In our experience, the greatest technical gap and biggest problem for our seed growers lies in the area of seed conditioning. Our growers need better techniques and access to better equipment.

A second small seed company mentioned in their support letter that:

> As we get involved in more research and development, and as the quality and variety of seed we distribute increases, there is need for expanded and more sophisticated processing and handling of seeds.

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. I attended one workshop, held on-farm and 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 and 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 rich, diverse, technoscientific infrastructure that takes a seed from germination to replanting has withered leaving behind underserved farmers, overburdened small seed companies, and a 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 must include the post-harvest processing and storage issues as well as the actual breeding itself.

5.3.3 The Seed Project: A Model for PPB in the US for the benefit of the organic sector

> You better be changing or you're dead. You've got to be up-to-speed on the latest technologies, the latest science, and you have to be willing to change not just your opinion, but your science; you have to change your program to take advantage of the new knowledge and technologies, and that's–that's something that is very challenging for some people. But in plant breeding, you have to be very, very cognizant of changes, because new knowledge is developed on a daily basis. Just like out here, you're learning all about new diseases, new sources of resistance, and it you're a plant breeder and you're

> not taking advantage of this information, your company or your breeding program will fall behind.
> Jake, academic plant breeder

> Participatory research in general, defined as that type of research in which users are involved in the implementation and in the design–and not merely in the final testing–of a new technology,is now seen by many as a way to address these problems. PPB in particular, is defined as a form of plant breeding in which farmers, as well as other partners, such as extension staff, seed producers, trader, NGOs, etc, participant in the development of a new variety. The objective is to produce varieties, which are adapted not only to the physical but also to the socio-economic environment in which they are utilized (Ceccarelli and Grando, 2007, p. 350).

The research that this dissertation describes 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 major Northeastern land grant university. As such it clearly fell into the formal-led model described by Sperling *et al.*, and it could also be understood as an expansion of an already extent client-based conventional research agenda advocated by Morris and Bellon and Witcombe *et al.* which I discussed in the previous chapter. It was the opinion of several people involved in the project, both staff and a now former graduate student, that the reputation the principal investigator of the initial project enjoys in the profession and the fact that she was already tenured, helped convince the funding agency that the Seed Project could be successful. Certainly the larger project to which it was attached was of the scale and type that only an established breeder could win. The project was refunded as an expanded, national stand alone project with the intended goal of expanding developing vegetable varieties for organic growers in all relevant regions. My study of the project came in the last year of its existence at the request of the PI who was interested in a social science assessment of the project's outcomes and methods.

5.3.4 Rationale and program structure

The Seed Project consisted of a holistic package of PPB activities that included the four stages outlined byWitcombe *et al.* (Witcombe et al., 2005): product design, product development, product testing and product marketing. 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. In addition, the project generated considerable data and training materials which were placed on the website where that material is available to the general public. This last contribution is an area which has not been discussed in any of the current literature and yet it is an important contribution especially in cases like this one where the project ended with its funding stream but the site continues to provide ongoing and useful information. The Web is a major repository for sharing of information between the formal and informal participatory plant breeding communities to the extent that there is communication between those two groups, since many organic farmers lack access to academic libraries and the professional literature they contain. The Seeds and Breeds conferences, the annual Organic Seed Alliance conferences, and European conferences such as the ECO-PB Workshop held in France in 2006 are invaluable archives and loci of exchange between breeders and growers in the organic sector and the Seed Project's site contributes to that body of materials.

5.3.5 Program goals

The Seed Project took place in two iterations, one regional and an expanded version that was intended to be national in scope. The initial 3-year phase outlined three primary goals in the grant application: providing workshops for growers, facilitating on-farm trialing of germplasm available from the originating university, and providing seed processing machinery. These activities map onto the second stage of Witcombe *et* a*l's* sequence of PPB activities the product development stage, specifically the first segment of the second phase, generating diversity. It is also the case that some of the on-farm trialing that took place was of commercial finished varieties from small seed companies and thus would fall into the 4th category of the Witcombe schema, product testing.

The second grant application cited four specific objectives which I paraphrase: to provide a wide array of improved crop varieties through the formal seed distribution mechanisms; to enhance organic farmers' selection and breeding capacity; to expand trialing, variety evaluation and selection activities; and to create curricula in support of organic research objectives. More significantly, the project's leaders had come to articulate five roles for project partners involved in the breeding process: objective setters, germplasm providers/breeders, germplasm evaluators, seed growers, and variety distributors. Of those five, farmers were projected to be significant contributors to all but the final stage, variety distribution. This model mirrors the Witcombe model that I have discussed, demonstrating that the Seed Project had determined to be more inclusive and to offer a greater menu of involvement options to farmers over time rather than making strategic decisions to limit them to one portion of the breeding process.

5.3.6 Program functioning and mechanisms

Because the Seed Project was so comprehensive in its aims, at any one time individuals might be working towards multiple goals. The heart of the program was dominated by 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, (cross) bred, and then the seed from the resulting fruits grown out in turn. For some crops this process can take a full year, for biennials, two. A big greenhouse facility can help shave off some 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, tomatoes and within those each breeding project would have specific goals towards which the team would be working. For example, they might be trying to develop a squash with a shape like a conventional zucchini but with better flavor and disease resistance of specific kinds. Furthermore, as Tracy indicated earlier, plant breeders work with populations not individuals. Work has been done to strategically reduce the number of crosses (Witcombe and Virk, 2001), that is the number of plants that need to be used for breeding in each generation, but the number of plants required is still in the thousands for a wide ranging program that addresses multiple vegetable types like the Seed Project. On one memorable day an improvised team that included this participatory sociologist, a field of 2000 pepper plants was planted in a single morning.

Over the winter, the Seed Project distributed to participating farmers lists of varieties that had been divided into A, B, and C categories. 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 might contain less developed materials and the C list was explicitly experimental seed. Farmers could request seed from the A list but only from the B and C lists if they were willing to commit to planting and reviewing a set number of A list materials. For each packet of seed the farmer 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. They did, however, request that if the material they had been sent was integrated into a new variety that was successful, a small royalty be paid. Not all companies were entirely vigilant in paying their remittances. One of Joe's responsibilities was to review seed catalogs to ensure that if a new variety emerged from a company where parent seed had been sent some time back, the company in question could be called and gently reminded of their responsibilities.

Although the grant application accurately described a two year consultation process that had occurred prior to the official start of the Seed Project, it was clear even in the final year of the program that consultation with farmers and with the farmers' organization representatives remained an important regular function of the Seed Project. Phase I, product design, never entirely ends in plant breeding; indeed one experienced and successful grower I interviewed said that in his opinion 20% of his job consisted of on-going innovation and rethinking his production approaches, including variety selection. The ICARDA team in Syria had coined the term demand driven breeding to describe PPB (Ceccarelli and Grando, 2007) and it would seem that the demanding fresh market consumers of the US East Coast combined with climate challenges kept Northeastern organic farmers and their breeders in constant consultation. Contributing to the need for regular interaction in the form of workshops, meetings and informal conversations was the fact that the Seed Project was working to overcome 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 and that demanded time. Beyond establishing contact, the workshops held by the Seed Project addressed a number of specific skill areas. They included using seed cleaning machinery and saving seed, breeding one's own varieties, taste testing popular vegetables like tomatoes, potatoes or melons, or plant selection and trialing. Many of these workshops were held on farms or on 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 and some larger conventional seed companies that were not actual participants in the Seed Project inspected the organic fields. The purpose of field days is for seed company representatives to see potential new varieties, perhaps even before they reach the finished stage, as they actually grow under agricultural conditions.

5.3.6.1 Funding: The point of origin

The Seed Project's existence was tied directly to its funding source and as such enjoyed two phases defined by the duration of two grants. 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 discipline 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. Rather they are the directed sharing of the fruits of the working group's core research, an activity sometimes referred to as outreach.

To make matters more complex, plant breeders and geneticists do rely on the state and national extension systems to feed them information about the needs of farmers. Jake, a plant breeder who works on conventional crops explained the importance of working closely with extension agents in determining plant breeding goals.

> The extension service is extremely important for transmitting knowledge back to the researcher. Without that extension component, you're flying in the dark sometimes. So you need to have that on-farm exploration and

connection, and extension does a good job of that.

What Jake is describing is the model of extension–plant breeding division of labor that was devised over time to distribute new plant varieties to farmers. Jake is clear that his breeding goals need to align with farmer's needs but that is information that can be transmitted third-hand through extension agents working in local communities and does not require direct contact with farmers.

The fact that the Seed Project fulfilled an extension role rather than a research role *per se* from the perspective of the initiating academic and her unit is extremely important. According to the Carnegie Classification of Institutions of Higher Education developed by the Carnegie Foundation for the Advancement of Teaching and Learning, doctorate-granting universities are divided into three subcategories with the distinguishing quality being the level of research activity (Carnegie Foundation for the Advancement of Teaching, 2009). While this is only one measure of distinction in higher education it is without question one of the most significant. The Carnegie Classification scheme uses indices such as number of research staff, research and development expenditures, and number of doctoral degrees conferred (Carnegie Foundation for the Advancement of Teaching, 2009). These numbers are then divided by the number of faculty who were categorized by their primary responsibility the choices being: primarily research, primarily instruction, or a combination of both. Extension or outreach activities are not captured by this measure.

A new and voluntary category, community engagement, is described as, "The collaboration between institutions of higher education and their larger communities. . . (Carnegie Foundation for the Advancement of Teaching, 2009)." Of the three subclassifications, the Seed Project falls most clearly into the category of outreach and partnerships (Carnegie Foundation for the Advancement of Teaching, 2009). What this means is that the kind of work and the monies designated to projects like the Seed Project do not contribute to the university's ranking as a research institution. The benefits are delineated instead in a voluntary category of community engagement which is not taken into account in the primary ranking that determines institutional worth. One might argue that high performing institutions can afford and may desire the additional status conferred by a high community engagement ranking. In the absence of any evidence to that effect, however, it is reasonable to presume that most institutions will place greater emphasis on evidence of research productivity than optional community service. The National

Science Foundation provides an alternative means of assessing Colleges of Agriculture but their ranking is based exclusively upon designated federal research funds received by the College at a given institution and thus also places outreach and extension activities outside of the category of research (National Science Foundation, 2009a). It is also the case that Extension activities are valued as an entity of their own in Colleges of Agriculture but the resources to support those services have been stressed by budget cutting in most states and at the federal level. Extension may well not have the time to respond to every faculty initiative especially those on topics like organic agriculture which may or may not be perceived as important weighed against other priorities.

The second grant was exclusively designed to support the Seed Project but as such it had to make the case that the group would be doing something new. That is, competitive grants are not designed to fund on-going projects. They are designed to get projects started, provide seed money and otherwise provide impetus for innovation which then is supposed to either be funded further by the funds of the recipient organization or by transformation of the research outcomes into salable products. This latter effect, the pressure universities feel to accept private monies to support research activities has altered the dynamics of the life sciences including plant breeding (Slaughter and Rhoades, 2004; Kloppenburg, 2004). Rural sociologist Frederick Buttel coined the term the "biotechnalization of agricultural R & D" to designate the ways in which private support pushes universities in directions that are unacceptable and unnecessary to the organic farming community. Although germplasm can be treated as property, and methods of breeding subject to patenting, the time necessary to breed new varieties dilutes the positive impact of pushing the research process towards marketable ends. In the case of the Seed Project this issue emerged in a meeting held to consider a possible third renewal. At that meeting, the academics wanted to ask the question, how can the group frame a project that will fly with the same funding agency. One put the question this way:

> I think as we are thinking in the discussion in the next hour or so it is really important to think of some of our broader goals on how to fit this and how to re-sell this in terms of the new priorities.

Another member of the team was even more blunt concluding that the language of the call was written to exclude having the currently funded project reframe themselves successfully.

> 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 speaker is alluding to is the nature of the grants process, one which this person even endorses, "I would have done exactly the same thing", namely, that the purpose of a new call for proposals is to elicit new ideas. In this case, the speaker is implying that because the Seed Project had been so successful and because the funding agency knew that the group would be willing to reapply for extended funds. The agency wrote the call for proposals such that plant breeding was not a stated priority. Because the speakers quoted above are seasoned grant applicants, they express no surprise or even discomfort that their success has potentially led the agency to attempt to preclude them. Instead, the second speaker sees the interaction with the agency through the mechanism of its funding calls as a means of communication. "We have to focus on . . . what will not go away when [the Seed Project] terminates. . ." this speaker says; "I'm hearing and seeing a lot of not only social but economic pulls . . ." Having had the Seed Project's breeding activities directly excluded is interpreted as a signal that there are social and economic needs that the agency perceives to be emergent and urgent. The Seed Project can morph in that direction if the members of the group respond to the call as a kind of guidance about what needs to happen next on a global scale. If the breeding project is going so well, the time has now come to move into the social and economic realms, would be the message that the second speaker claims to read between the lines of the proposal call. The academics of whom there were eleven in the room proceeded to discuss the possibility of proposing mechanisms that would link marketing to breeding when one of the farmer's representatives spoke up:

> 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. Um in particular perhaps in the —-West Virginia, if you don't have that infrastructure to try and put that infrastructure in place from on top from a national grant, it is not going to happen.

This moment in the meeting was followed by a significant pause in the conversation. The farmers' representative's point was informed by a very different perspective than that of the academics. For him, branching into a significantly new approach in the new grant application ran the risk of "veering way off from the [Seed Project] activities". He didn't object to the content of the new approach, indeed he embraced it as relevant but he feared that, "join[ing] all of those things together" would make the project unworkable. His assumption is that the refunded project would continue to do everything that the first two iterations had, plus take on new responsibilities. From a farmer point-of-view this is entirely reasonable. After all, each year farmers engage in fairly similar activities. They choose seed, plant, harvest, and sell vegetables. Of course a skilled organic farmer is always rethinking and restructuring her choice of seed, her marketing approach, her use of machines and all other aspects of her business. One farmer said that farming is, "equal parts innovation, management, and grunt work." That said, the creativity of commercial vegetable growing occurs within structures that don't change radically. Change is best pursued incrementally so as to avoid exposing a small business to undo risk.

With that in mind, the farmers' representative's concern about unwieldiness betrays his lack of understanding of the grants project. Grants are intended to support academic production in the form of innovative ideas. They are not designed to implement and sustain regular collaborations with farmers or anyone else. The purpose of grants is not to create and maintain an important plant breeding service for organic farmers, it is to encourage researchers to try out new ideas which someone else will then be able to use.

From a farmer's perspective this unstated fact is terribly frustrating. Why would you walk away from an approach that you have just spent the last six years learning how to operate? In this particular meeting, this individual and the other farmer/representatives were too polite to be so blunt, yet in other circumstances they did express considerable bitterness that the land-grant university system didn't serve their needs. It is perhaps tempting to dismiss their critique as simply the complaints of an underserved population, but I would argue that this exchange demonstrates a far deeper rift between academia and the organic farming community. The farmers are not just upset that academics undervalue their work (although that is also an issue). When they were given the opportunity to work with a group of academics, people they liked and respected, breeders who had shown themselves to be skilled and flexible, the end result was disappointing. Just as the project was beginning to bear fruit from a farmer point-of-view, the money was running out and the discussions about how to continue were pushing forward into new terrain at the risk of abandoning work that had just started to prove itself. In the meeting itself this issue was never addressed directly. Perhaps to do so would have been too painful given the strong personal ties that brought these people together.

The last sentence of the farmer's remarks points to another related difference in perspective between farmers and academics. The second phase of the project had won its funding by claiming that it would expand its network from a regional base to a larger national scale. This proved much harder to do then perhaps had been realized at the beginning. There were funding level differences between the regional hubs and the original university. Although the staff at the home university traveled extensively they were not able to compensate for the lack of designated staff at hub institutions. In the case of West Virginia, mentioned above, the lack of infrastructure on the university side was paralleled by a lack of a farmer organization with whom the academics could interact. From the farmer point-of-view working to reach farmers in locations without a grassroots support system meant that time and energy needed to be expended on those issues in order to consider the project a success. As one representative said:

> How do you take what you already have and build on it? It seems logical to continue with some of the successful things that you have already done. Maybe you include new varieties for different regions or that sort of thing. But then how can we move what works so successfully in the Northeast and some places in the Northwest. How can we transfer that information

> to places like West Virginia, and Mississippi and Alabama who are just starting, like we don't want to have people to have to reinvent the wheel. And so, here is the program that we used. It worked really well, let's not lose that knowledge.

In response a senior plant breeder reminded the group of the limitations of putting together a viable grant application.

> I'm seeing two things that we really have to do which is we really can't, I think the hub and spoke thing. We can't kind of present it that way. We're going to have to do it some other way. They want on-farm but I think . . . but more as models for how to do it. Um maybe then, emphasizes observation up, innovation and all of that. We may want to present ourselves as a method and then implement the method as opposed to we want better vegetable varieties for the world. . . . In other words focus on the process more, then the particular outcomes? Breeding outcomes? Nothing in here says they want breeding. . .

The difficulty of this exchange should not be underestimated. This academic at least understands that the structure of the funding mechanism actively prevents the group from doing what they all would like to do, create a working version of the original Seed Project at a number of regionally important institutions around the country. The money involved would be bigger than even the prospect of a new grant could provide, and in any case, the granting agency has no interest in replicating a project regardless of its success. The driver that made the Seed Project possible, the competitive grants system, also sealed its fate at the end of the funding stream. Left behind were unhappy farmers. Even the academics who are considerably more accustomed to the realities of grant funding and are themselves inhabitants of the university where innovation is the key requirement for success, even they do feel restricted by the limitations this approach to funding imposes. In a one-on-one interview I had with the PI she talked about her desire to connect plant breeding to socially important outcomes, to ensure that the varieties produced and the methods uncovered actually assisted all stakeholders. In a sense her plea parallels the intentions of the early 80s Reaganites who wanted to move research "off the shelf" with the important difference that the PI has a much more inclusive definition of the public good as demonstrated by her leadership on the Seed Project. She understands that the limited time frames and the structure of the competitive grants program can preclude effective transfer of knowledge.

5.4 The farmers' perspective

So far this description of the project and its structure has focused upon the university-based components because the project came to life there. At the same time, as an outreach project, the success of the project was dependent on the farmers' experiences of the project. Both farmers and academics agreed that historically plant breeders had neglected the organic farming sector. One experienced farmer put it this way:

> Ruth: Where would farmers like yourself find the kind of seed breeding and access to breeding that the project has facilitated?
>
> Lisa: No there is no other place to go. There's no other place to go. The organic movement has made increasing federal funding for organic research one of our major demands. We're saying that we should get a percentage of the federal research budget that matches the percentage of organic in the marketplace. So we're hoping that at least over the five years, there will be five millions dollars a year. It should be way more; it should be, like two billion dollars a year.

Lisa is referring to the macro issue of access to federal research funds. Other farmers who were asked the same question responded with a more specific analysis of the kind of research the Seed Project engaged in.

5.4.1 The benefits of the Seed Project to farmers

Leah, for example, was another experienced farmer who explained that while she had the contacts both within the farming community and with her local land-grant, she still benefited from participation in the Seed Project. She was able to access certain seeds more easily and she said, "I think that they are bringing some publicity to the issue." This particular farmer went on to highlight what for her was a unique benefit to participatory breeding research:

> They [the Seed Project] are getting responses from multiple farmers on one set of stock in any given year at varying locations, and they're coordinating those responses, whereas otherwise, while you had to conceivably have six people who decided to trial Liz's peppers she was talking about, unless all of –unless those six people decided to get together in some sort of group to do it, you would only know your results, you wouldn't know the other people's results, and so you might, since the–had something go wrong or right on your specific place, it might have been useful to know that while it was really dry over here and this did great and it was really wet here and this did terrible–and therefore maybe the reasons it did terribly for me or great for me is because maybe it does better in dry years than wet.

Leah's point is that it is difficult to sort out environmental attributes from fundamental varietal performance issues if one is only planting and trialing at one location. It may take a number of years to determine why a variety is doing well or not, especially when weather conditions vary as they do in the Northeast. On a small farm which grows a wide variety of vegetables like Leah's, tracking and determining the best possible variety selection can be challenging. The Seed Project helped in this regard as she explained:

> I mean you can get some idea of that [varietal characteristics as opposed to environmental influences] by a multi-year growing on your property. But you can get it faster if you've got different people doing it in the same year. And it could also help to have different people–if there are six different people growing it and they're all in a drenching wet year, and some of them said it did great and some of them did poorly, and they all said they had a whole lot of water, then the reason it did well or poorly on your place probably isn't because it was a wet year, it's probably something else about your place and not what the weather was that year.

In other words, networking with other organic farmers and having the data from their results to compare to one's own provided information that could not be replicated by an isolated individual or even by a set of commercial field trials. Another newer grower with a Masters degree in biology, Kathryn, liked the access to varieties and the connection that the project gave her to other like-minded farmers:

> The varieties really are an interest of mine, and that's the reason the Seed Project is sort of cool, because it gave me access to more varieties, and also its like I was able to share what I was finding out with somebody.

At the same time she was somewhat critical of a vegetable variety website sponsored by the same university as the Seed Project which collected random input from farmers and gardeners because she worried that individual assessments would lack context.

> I think people get away with being unscientific. . . . one university has a vegetable variety website . . . and I rated some stuff for them, and I haven't looked at it in a couple of years. I did not find that very useful. . . . the situation is that they're sort of inviting people to come in and rate varieties, but you never knew what their comparison varieties are. So somebody comes in and they say, wow, Brandywine's the best tomato; . . . and it's like, okay, but what other tomatoes do you grow?
>
> If you say that you've tried, like, five big red heirloom tomatoes and you think that Brandywine is the best, that's one thing. But if you've just grown Jet Stars and Celebrities your whole life and then you try Brandywine and you like it, well, that's nice, but. . . it doesn't really tell you about the variety.

Unlike the public website that this grower had used and disliked, the Seed Project provided a more controlled framework within which on-site trialing was combined with analysis from the research plots at the university. Although Jane, the technical staff member mentioned above had felt she needed more stringent benchmarks as she tested melons for flavor, she was engaged in systematic comparisons between a wide number of melons grown under similar conditions. Kathryn expressed doubt that even the quality of her contributions to the Seed Project were of the same value:

> I told you that a bunch of varieties that I had chosen turned out to be Seed Project varieties. Well, I feel like with this white eggplant, I feel like we've got five different white eggplants, I feel like maybe I can contribute something useful; on the other hand, I decided to grow a buttercup squash, and then it turned out it was a Seed Project variety, so I figure I'll tell them what

> I find out. But I'm not growing any other buttercup squash, so I'm not feeling like, . . . I can compare it to butternut and sweet dumpling and some other stuff, so that's not going to be–it's not going to be super useful.

I should explain here that some of the varieties distributed by the Seed Project were commercial varieties that participating farmers could buy from seed companies. Because the Seed Project's seed lists tended to come out in April and farmers tend to order seeds in January, it was usually the case that farmers would scan the Seed Project lists and realize that they had already committed to growing a variety about which the Seed Project wanted information. Several informants mentioned that when this happened they would try and respond with comments even if they hadn't gotten the seed for free from the Seed Project. Kathryn was the only one to express this concern about data quality under those circumstances in exactly this manner although the Seed Project staff did express some discomfort with feedback comments that they felt were too critical.

Kathryn gave another pertinent example of the kinds of flaws that can afflict unmonitored varietal assessments:

> I find with pole beans, I'm pretty fussy about pole beans, and I've tried a lot of varieties that get very good ratings, and I don't think they're very good. I think pole beans are inherently a lot better than bush beans, and people try a pole bean and they think, wow, this is amazing, this is what a bean's supposed to taste like. Well, that's great. . . but I think there are superior pole beans and I guess we're real lucky that we stumbled onto some of those first. . .

Kathryn's fussiness was not unique. Marisol conducted extensive testing of her own above and beyond anything the Seed Project demanded.

> I do a lot more testing on my own besides the Seed Project. So you know, I'll sit there and the squashes are all ready and I'll cut them all up and cook them, and we'll sit there and I'll make my kids all taste them, and we say, oh, this is really good, or . . . I don't like this texture. . .

The tests Marisol is describing are taste and texture tests. In addition to those variables, this relatively new farmer who had just been in business for four years, had begun her own tomato breeding project the genesis of which was when a tomato she liked disappeared from the market.

> Last year, there was a tomato that I grew that I really like for me. Being that it's just my husband and myself that do the work, we have to have this give-and-take, and one of the things that he hates to do is he hates to pull out staking in the fall–all the trellises, all of the fencing, all of that.
>
> So we grow a determinant red tomato, because the market, everybody wants a standard red tomato, and so we like this determinant variety instead of the indeterminate because it grows low and we don't need to stake it.
>
> And I had bought the seed from Turtle Tree last year and it did really well. I had actually tried probably, six different varieties of tomato. We were also looking for one that would hold up to blight, because we'd had a lot of trouble with blight tomatoes. We had decided on this one particular variety that did better than the one that we had been using before, and I was all set to order it this year. . .and they didn't offer it.
>
> I talked to them on the phone, I really wanted those tomatoes, and they're like well, you know, we're not doing it, do you want to try these. And I'm like, yeah, but I wanted this low kind of bush variety, that's the way I wanted to grow them. And so they were very nice about it, they sent me ten seeds and I just happened to have six seeds from last year. So I have 16 plants in the ground, and I intend to save the seeds so that next year I'll be able to put in a whole 150 row foot of the same tomato.

In the upcoming chapter on agrobiodiversity I discuss the concept of "commercial agrobiodiversity", which captures the need of farmers to be able to purchase seed from desired and varied varieties consistently. In this case, Marisol improvises and is working to create her own seed bank with the help of a small seed company that no longer carries the variety that she wants. From a network analysis point-of-view what surprised me about this exchange and others like it was that farmers often worked cooperatively with small seed companies but not with either the extension service or plant breeders in the university systems. The missing role of extension is a question that arose from my study but which requires further investigation. Ann, the farmer who also worked for the farmers' organization and had been an academic in an earlier period of her life had a clear explanation for the isolation of organic farmers from plant breeding. Her position mirrored Lisa's observation at the beginning of this section.

> Ruth: What is the relationship between organic farmers and breeders?
>
> Ann: I think there hasn't been one. You know, because organic farming in this country started to develop in 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.

Leah was even more direct in her criticisms of the land-grant university system other than the Seed Project:

> Including people actually doing the farming on relatively small scales as well as on large scales, which is what they [land grants] were originally a very good idea, and I think that they were intended to do [this] . . . If they would yank the subsidies from those making millions of dollars and living in Manhattan and put them into the land grant colleges for them to do the work they were originally designed to do, I think this would be a very good idea, ... working with farmers to find out what works on the actual farms and distributing that information and distributing the resources needed to help the farmers continue to develop that information in seed as well as other areas.

Leah's reference to the people who earn millions of dollars in subsidies while living in Manhattan was a reference to a map that circulated on the Web showing the home addresses of some high agricultural subsidy recipients were in fact in cities like Manhattan and San Francisco because commodity subsidies accrue to landowners who are not themselves working as growers.

5.4.2 Barriers to the circulation of knowledge

When asked directly if the land-grant system met their needs, farmers were bewildered, hurt, and resentful that they had been neglected. Leah's claim that farm subsidies should be redirected to help smaller farmers was typical of a number of complaints that farmers had about the lack of support they felt they deserved. The farmers tended to presume that the commercial seed industry and conventional agriculture had bought out the academic system for their own private good. While the influence of industry on applied agricultural sciences cannot be denied (Welsch and Glenna, 2006; Glenna and Jussaume, 2007; Bliss, 2006; Baenziger, 2006; Morris and Bellon, 2004; Gepts and Hancock, 2006), plant breeders working for large companies and senior plant breeders working at universities mentioned another phenomena affecting traditional public plant breeding specifically and which the organic farmers could not see.

5.4.2.1 The Crisis of Traditional Plant Breeding

The connection between the seed industry and plant breeding as an academic discipline has traditionally been close (Bliss, 2006; Lindner, 2004; Morris et al., 2006; Rausser and Ameden, 2004; Terpstra et al., 2006). The industry recruits graduates of top PhD programs to fill their ranks. The most outspoken representative of the farmers' groups spoke for many when she contended that that relationship between industry and academia had taken a turn for the worse in terms of traditional plant breeding:

> I think the other thing that's happened is that most public sector breeders are retiring and now they're not being rehired because the industry has taken over the research because they want direct lines to the bucks.
> Ann

Ann's contention here is that the large scale commercial seed companies have pushed universities out of plant breeding in order to exercise fairly direct and far-sighted control over the direction of plant research. This interview with Ann was the first indication I had had that there was a problem with traditional plant breeding at land grant universities other than the failure to respond to organic farmers. Indeed when I recorded this first interview with Ann I was only just learning why plant breeding mattered at all to farmers, much less the distinctions between traditional plant breeding for conventional farming systems, biotechnologically based breeding, traditional plant breeding for organic systems and participatory plant breeding that actively involved farmers in the decision-making process. Therefore, over the course of my study I specifically interviewed some plant breeders who were not active participants in the Seed Project, indeed a number were employed by large commercial seed companies, precisely the source of the problem in the mind of my farmer informants. It also happened that in the middle of my study, the Department of Plant Breeding at Cornell University celebrated its Centennial with a conference to which graduates of the program were invited to speak. Many did, and the resulting papers, some of which are publicly posted on the Cornell website (http://www.ctl1.com/publicaccess/calscentennial/presentationlist.cfm), present a unique opportunity to hear a wide range of plant breeders reflect on their profession, the role it has played in agriculture, and its possible future. These videos with the accompanying slides offer a rare opportunity to hear applied scientists reflect upon their profession outside of the usual venues and scientific conventions.

As I put together the data from these various sources I discovered a curious convergence between the radical politics of Ann the farmers' representative and plant breeders working in both industry and academia. Both groups would agree with her that public sector plant breeding is suffering from a dramatic decline and that decline has to do with short-sighted transfers of resources away from traditional plant breeding towards other kinds of research, specifically molecular genetics (Gepts, 2006a; Bliss, 2006, 2007; Weebadde and Messah, 2006; Ransom et al., 2006; Terpstra et al., 2006; Baenziger, 2006; Rausser and Ameden, 2004; Knight, 2003). Where Ann might find some disagreement is the question, why did this transfer happen?

A 2000 study by Iowa State noted that:

> From 1980 to the mid-1990s, 30 plant breeding positions (6% of the total) associated with graduate programs were eliminated (Frey, 2000).

A year earlier, in 1999, K. Frey had published a national strategy for plant breeding based on empirical research that indicated 60% of the national investment in plant breeding in 1994 had been in the private sector and had been in "hybrid crops and near market cultivars" (Frey, 2000). In 2007 Bliss estimated that only 70 to 80 breeders were being produced each year and that this would not be sufficient for either private or public sector needs (Bliss, 2007, p. S-255).

By 2007 at the Centennial celebration for the Department of Plant Breeding at Cornell University, several of the speakers publicly called for a reinvigoration of the public plant breeding sector including Bob Heisey of United Genetics in Hollister, CA who described the current industry needs this way:

> We need a continuing supply of new young breeders with experience in applied breeding, with a good knowledge of the real world and practical side of plant breeding. We need strong public breeding programs in our major crops. Private programs are increasingly interested only in projects that have a quick payback and long-term IP protection.

At the same event, Ronnie Coffman, who had presented to the Corn and Sorghum Research Conference of the American Seed Trade Association about the future of plant breeding in public institutions in 1998, contended that a big part of the challenge for plant breeders was to explain the importance of their work to the general public. He suggested an adapted quotation from Carl Sagan who had effectively explained the space sciences to the general public:

> If you want to explain plant breeding from scratch, you must first create the universe.

The plant breeders that I interviewed in industry seemed to agree with the public statements and the literature. James, a plant breeder for a major commercial company that I interviewed explains the impact of these reductions on industry:

> We've seen a decrease in funding at the academic level plant breeding and a shift in many universities from classical plant breeding and applied plant biologies or applied plant science to a shift more to molecular biology at the expense of the traditional. There are only so many positions, indeed universities only have so much money when a new position is needed and someone retires they don't fill it.
>
> Ruth: What is the impact on industry?
>
> It affects the industry in really two ways. The first way is, there's no training with new plant breeders and horticulturalists, each of the positions of the

> industry is going to need. Just because there are staff now, there won't be staff, ten, 20, 30 years down the road and that's a real problem.
>
> The other problem is, that academics is the place to search for disease resistance, to tackle the long-term projects that take many, many years, take 12, 15, 20 years to tackle, a problem like insect resistance, for example or a new disease resistance. That private industry may or many not have the resources or wherewithal to invest in, and so the collection, evaluation of germplasm from natural sources or exotic sources isn't going on as it should be.
>
> Plus when you are talking about minor crops, which many vegetable crops are, there's no one to do the work. There are only a handful of plant breeders that serve these crops and without the support of the university system and university plant breeding in different locations, you run the risk of having a break in the wheel sometime down the road.

Another well known plant breeder in industry, Abe, described in an interview with me how biotechnology became an attractive well-funded prospect for universities only to become a financial sink after a number of years:

> The dollars for biotechnology were originally disbursed in three year grants to build new facilities but after that initial period the money to sustain them came out of conventional or traditional plant breeding programs. When the initial grants were received the claim was made by College of Agriculture administrators nationally that this wouldn't happened but in the long run it did.

Abe also claimed that industry fell into the same trap.

> Seed company managers were also convinced that biotechnology was necessary to keep up with everyone else. The long term result is that seed companies spend too much money on biotechnology rather than conventional breeding.

Abe had himself done significant work with biotech methods but at this point he said that:

> Biotechnology as a basic science has outpaced applied science. What that means is that the explanations for why things happen doesn't translate into better varieties for the farmer. We probably have enough basic knowledge to keep us busy for the next 20 years.

James drew a parallel between the biotech craze of the '90s and the photosynthesis fad of the '60s neither of which lived up fully to their initial promise:

> Ruth: You were mentioning earlier that within institutions there has been a trade-off. . .
>
> James: Well, when bio tech–this is mirrored, actually in the '60s, when we first started to figure out photosynthesis, it was touted as being the premier seed method: if we only knew everything there was to know about photosynthesis, we can increase crop yields. . . And so at that time, there was an influx of money and position into plant physiology in the United States. Fortunately, there was enough money floating around in the '60s when this happened that it wasn't at the detriment of other disciplines.
>
> When biotechnology first appeared on the scene and the molecular genetics started to come into play in the late '70s through the '80s, the universities across the United States were suffering from decreasing federal and state funding because of recession problems and all sorts of things beyond our control.
>
> And every university saw this as the cutting edge, need to be done, and there were grants available, national and federal grants, state grants, to fund molecular research, and so the pool of money was going in one direction, and so the positions go into that direction, as well.
>
> And some of the larger state universities that were well-endowed and well-insulated did maintain programs or where there was someone with their brain on top of their head says yes, molecular genetics is very important, a lot of new tools here, but you know, in the grand scope of things, you need all these disciplines for crop improvement, not just one.

James' analysis confirms what Buttel had argued in the late 1990s (Buttel, 1999) and others both in plant breeding and the sociology of plant breeding see as a negative trend

(Kloppenburg, 2004; Gepts, 2006a; Bliss, 2006, 2007; Knight, 2003). Jake who heads one such plant breeding program that still supports both traditional breeding and molecular approaches had this to say about the institutional viability of public plant breeding:

> Ruth: What is your assessment of the state of public plant breeding in the United States right now?
>
> Jake: Still in danger. Even though there's more and more visibility because of the sudden realization that plant breeding is important, it's still a discipline in danger of going away and being reduced–and we're already at such low levels in public institutions that companies are flocking to those institutions that still have real plant breeding programs going on and asking if they can contribute to their graduate program–at least some of the companies are.
>
> . . . right now there's a huge deficiency in trained plant breeders and it's because we've let our capability to train plant breeders decline drastically in the last ten to twenty years. There's been a shift to, in public institutions, towards hiring faculty that can bring in grant money. And it's never been easy to support plant breeding *per se*. It's an applied science, very limited resources. . .

Jake, Abe and James all worked with biotechnological methods and should not be understood as opponents of molecular genetics nor uncritical supporters of organic agriculture. Indeed none of the three engaged in any breeding for organic conditions *per se*. Yet all three and others like them agreed that the headlong shift towards supporting one kind of technological development and the failure of universities to maintain traditional public plant breeding programs threatens the development of new plant varieties upon which all agriculture depends. Against this background it is easy to understand why the kinds of research that organic farmers need would be increasingly difficult for the land grants to provide simply because the faculty who could choose to initiate organic oriented breeding programs are themselves being phased out.

At the same time, Bill Tracy, a senior sweet corn breeder and Head of the Department of Agronomy at the University of Wisconsin-Madison, raised an interesting alternative issue at the 2003 Seeds and Breeds Summit held in Washington, DC. Tracy, who has done participatory plant breeding projects with small scale farmers and who champions selection-based breeding as a source of creativity in plant development, had this to say about the future of plant breeding as a discipline in the public sector:

> In any discussion of the impact of plant genomic engineering on plant improvement, it will be asserted that plant breeding will continue to be extremely important and that without plant breeding genomic engineering cannot be successful. Unfortunately I disagree. The world will not come to an end if traditional plant breeders disappear and it is clear the disappearance is well underway. Don't misunderstand, the planet will be poorer for the loss of plant breeders, but it will keep on spinning.
>
> To explain my belief, a definition of plant breeder is required. I could use Darwin's description, but I will be more concise. Based on the discussion above I define a plant breeder as one who develops and implements phenotype selection programs and spends enough time with the plants so as to gain a feeling for the organism. Scientists with the title "plant breeder" may continue to exist but, unless trends change, professionals who meet this definition will continue to disappear (Tracy, 2003, p. 25).

Tracy goes on to describe the triumph of an engineering paradigm of plant variety creation which, if allowed to become the dominant paradigm, relegates selectionist or traditional plant breeding to a very secondary role. As he explains:

> The reigning engineering paradigm is in direct opposition to the selectionist paradigm. Engineering suggests that we can find out what all the genes do and then put them together in the optimal way. Selectionists apply selection and let nature and the organism create an array solutions, any number of which will be useful, some in unique and unexpected ways (Tracy, 2003, p. 25).

The danger for traditional plant breeders may be that they are relegated to a mere supporting role, serving to transfer the products of engineered manipulations, a defacto disciplinary organization somewhat similar to the position that PhD holders in foreign languages find themselves when they are reduced to service units that provide mere language instruction. In Tracy's words:

> Plant improvement can and will occur following the engineering paradigm. Gains may not be as rapid, cost efficient, successful, or to my mind interesting as those made via selection, but gains will be made. Plant breeders will exist as technicians for engineering programs (Tracy, 2003, p. 29).

At the 2007 Cornell Centennial Tracy's remarks focused on the power and creativity of selection but he did challenge the audience members to support those passages of the farm bill that specifically earmarked research funding in the Farm Bill for classical plant breeding. At the same time a colleague of Tracy's, James Coors, argued that the engineering and selectionist paradigms were essentially complementary but that they appealed to different types of scientists (Cornell University Transnational Learning, 2006). Coors contended that the selection paradigm appealed to scientists who could tolerate randomness and diversity as a part of the scientific process.

From a sociological point-of-view, it is fascinating that both my informants and several well-respected plant breeders nationally seem to agree that traditional plant breeding is not failing on either scientific nor on economic grounds even from an industry-based perspective. Most of the speakers at the Cornell conference, graduates of the program who had scattered to all corners of the world and all sectors of the discipline, praised the multi-disciplinary training they received with a specific emphasis on both basic and applied science. Bob Heisy, the United Genetics breeder, said that his remarks might be somewhat controversial but he was willing to say in public that even on economic grounds, conventional breeding was usually more cost efficient. He mentioned for example that,

> Asgrow had spent $25 million on a biotech virus resistant squash. With 1/10 of that we could have funded a conventional program for 5 years using resistance from conventional sources.

In other words traditional plant breeding has not run its course, even if we are measuring the usefulness of the practice for conventional crop improvement or as a means to advance basic scientific knowledge. What we may be seeing here is a case in which a powerful industry is trying to create path dependence in favor of molecular genetics to the exclusion of traditional plant breeding despite the widely held view that those two aspects of plant science can both coexist and serve all involved well. Some breeders have even argued that molecular techniques make traditional plant breeding all the more effective (Goodman, 2004; Moose and Mumm, 2008). Judy Wajcman explains the phenomenon that Heisy cited in the Asgrow case:

> The usual economic explanation, which assumes that firms simply choose technologies that offer the maximum possible rate of profit, has also been the subject of much criticism. In response, some economists utilize the notions of technological trajectory, path dependence and lock-in to capture the mechanisms through which the evolution of a technology becomes more and more irreversible (Wajcman, 2004).

The question may well be, what happens when lock-in mechanisms resist the desire of powerful actors to change technological trajectories? Could this be a case in which path dependence combined with the high economic costs of certain favored technologies makes those cutting edge approaches untenable? Clearly Bill Tracy at Wisconsin thought in 2003 that the survival of selectionist plant breeding was potentially open to being co-opted and gradually eliminated. Heisy and Peter Gepts, an emeritus plant breeder from UC Davis who has written on the possible positive convergences between molecular genetics and plant breeding, would seem to be more optimistic (Cornell University Transnational Learning, 2006; Gepts, 2006a).

What none of these experts at the various plant breeding conferences mention directly is the additional benefit of traditional breeding, namely that traditional plant breeders using the selectionist paradigm are the only option for organic farmers and probably for much of the world's subsistence and local market/low income farmers. Such farmers either reject engineered varieties *a priori* or are unable to pay for them. If Heisy is correct and the engineering paradigm is in fact more expensive as well as less creative, as Tracy contends, it may well be that traditional plant breeding is the best return on investment for all but the most industrialized crops and farmers. The hitch is that the current seed system is not designed to produce inexpensive seed for use by the farmers, it is designed to maximize profits for the life sciences corporations that run the seed business as an ancillary profit center (Kloppenburg, 2004). It is at this juncture that the function of the land grant university system as a provider of the public good, broadly, defined needs to be raised.

5.4.2.2 Intellectual property

Since the early 1980s it has been possible to establish ownership of both specific germplasm and certain genetic mechanisms used in plant improvement (Mascarenhas and Busch, 2006; Runge and Defrancesco, 2006; Kloppenburg, 2004). This area is extremely controversial and complex, pitting those who favor open source free exchange vs. those who believe that ownership rights will increase profit margins and therefore provide incentives for enriched plant breeding. Kloppenburg's 1988 study, expanded in 2004, and Pistorius and Van Wijk's 1999 book, traced the consolidation of the seed industry in which intellectual property regulation has played a role (Kloppenburg, 2004; Pistorius and van Wijk, 1999). Given the general anti-corporate discourse that is a part of the organic movement, I therefore expected to find resistance among farmers to the intellectual property requirements that the study required they agree to respect. The actual response in my interviews was more diverse.

In order to understand the context in which intellectual property issues played out within the study it is important to remember three factors: first, that the intellectual property agreements, called materials transfer agreements (MTAs), were managed by the lead university and not by a corporate entity even in cases where the intellectual property rights being protected might belong to a commercial seed company. Secondly, the seed companies participating in the project were small, farmer-friendly, organic and untreated seed providers, the same companies from which the farmers routinely bought their seed anyway and this fact was public knowledge. Thirdly, organic farmers are themselves small business people who believe that breeders should be compensated for the work that they do. Even when they were uncertain that the mechanisms of intellectual property as currently defined and enforced in the US are the best approach, farmers saw the fairness of paying breeders, commercial and university-based, for their efforts, just as farmers want to be paid for their labor.

Earlier in this chapter I outlined how the Seed Project took advantage of an improved and streamlined MTA process and made the process of obtaining farmer consent much easier. Mark, the technical administrator who oversaw the simplification of the documents mentioned, as quoted above, explained how seed companies had been offended by the language and the legalistic or oppositional relationship that the original type of documentation implied. By the time the Seed Project was up and running, 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, monies which were used to pay for summer field help.

When I asked farmers how they felt about germplasm as property many responded as Jane did with very divided feelings:

> Ruth: How do you feel about the Supreme Court ruling that says that you can own plant germplasm, and about the idea that you can patent varieties?
>
> Jane: I don't know. I mean, that's a tough one because, I mean–no, owning plant varieties and owning germplasm seems inherently wrong, 'cause everyone–I mean, I do believe that everyone should be able to breed vegetables on their own and save their own seeds at all times. On the other hand, there's got to be an initiative for plant breeders to produce varieties. There's not always going to be grant money that pays for breeders to produce new varieties, or just for the good of the people. There should be that too but. . . So I can see why paying royalties guarantees that a plant breeder will have an initiative, some sort of initiative to want to do it because they could make money off of it.

The desire for fairness and recompense for work done seems to justify some kind of property scheme in Jane's mind, although in fact ownership of germplasm, like ownership of any other kind of intellectual property, does not require that the owner be the creator of that property. Yet the fact that intellectual property restrictions could limit seed saving for one's own use, was less acceptable even though "personal use" in her case might mean producing vegetables for sale.

> I can remember John [her partner] pointing out a variety that I was growing and saying, now, whatever you do, don't save seed from that. And I said, what? That does seem a little insane to me that one couldn't save seed. I'm not going to do it on a commercial scale; you've going to save seed for your own farm. So I suppose I believe that if you're going to save seed for your own production, you should be able to save anything you want . But if you're going to save seed and sell it to make a profit, then it would sort of only make sense that whoever originally developed that variety might be in

> on it in some way, because they have probably laid out the time and labor and expense to produce that variety, like anything you produce. You want to read a book by yourself, perfect, wonderful, share it within your family. But if you're going to copy it and sell it, then whoever produced it in the first place—

The parallel with the publishing industry that Jane draws is interesting in light of the fact that she is a commercial farmer. Clearly for her, saving seed, growing that seed out, and finally selling the fruit of that seed is equivalent to reading a book within the family. I should be clear here, when Jane references saving seed for "your own production" she means production of vegetables for sale not for home consumption. When she says, "you're going to save seed and sell it to make a profit", she is referring to replicating seed for sale as *seed*. These distinctions were obvious from the volume of each crop that she grew and a much longer conversation that we had had off tape about the fact that her small family could eat well from that portion of her commercial produce that couldn't be sold for some reason. Jane's position is a judgment about the source of the value-added produced by farmers, namely, that farmers are paid for the work that they do in transforming seed into usable food. Inputs, like seed, should be paid for in her view, but once that original fee is paid the inherent capacity of the seed to reproduce its particular qualities in subsequent generations belongs to the common domain. As she said in the first quote above, germplasm itself is fundamentally non-fungible. What can be reimbursed is the effort breeders expend to combine certain traits in certain varieties. That power of recombination is valid reimbursable work but the underlying capability of the plant to express itself, remains unassigned to any human entity.

In a sense, Jane is outlining a kind of temporary and shifting property rights that accrue for a while to a person or entity in compensation for work on a given variety but which will pass along to the next user who invests of their own time and effort. Thus if a farmer were to engage in commercial seed production without compensating the breeder that would be unfair because the farmer would be capitalizing on the improvement work of the breeder at her expense. If, however, a farmer is willing to invest her own labor into saving and using the seed to produce vegetables which then are sold, she has earned the right to profit from whatever residual benefit the improved plant stock may bring because she has invested so much of her own effort in the production process. Jane's analysis ties ownership to human labor expressed in the seed. As such, no one individual owns germplasm, each individual owns their contribution to that germplasm for a distinct period and under certain strictures imposed by the willingness of others to labor with that same germplasm.

Jane's model displays a greater flexibility than the model which currently exists. It also explains why she rejects out-of-hand terminator technology and has reservations about hybrids, a common position among my farmer/informants:

> Terminator genes make me furious, of course. The thought that people would become basically hooked on seed varieties that they couldn't grow themselves, and that's happening more and more in third world countries where they can't save their own seed because it's a hybrid or it has a terminator gene or they'll be sued. That starts to get a little out of control. I don't know where the fine line is, honestly.

Terminator genes or Genetic Use Restricted Technologies (GURTS) as they are formally known, render the seed of plants sterile (van Doorn, 2008) thus preventing unwanted geneflow from one field to another. A farmer planting a GURT would find that any seed saved from her crop would not germinate the following year. In fact, terminator genes were not in commercial production or authorized for sale at the time of this interview. It was, however, the case that hybrids and some genetically modified seeds with highly restrictive use contracts were and are being sold with controversial impacts on farmer autonomy. It is also arguably the case that terminator technology would have been promulgated if it had not been for sustained public outcry when companies attempted to introduce the seed.

Like Ann, Jane worries that industry funding is becoming the only funding for plant breeding and that means that the organic farmers will be shut out of the breeding agendas of universities because organic seed doesn't produce high profit margins:

> I would love it if [host] university had endless amounts of fabulous funding to do plant breeding but who is going to fund that? Monsanto is not going to fund organic plant breeding so it's obvious that revenue has to come from somewhere to fund such breeding, unless the universities take it upon themselves to find money from elsewhere. But nobody really makes money from developing organic varieties unless there's some incentive there.

Within the context of a market economy in which the public sector is perceived as supplementary to private entities, rather than a potential parallel system with its own goals, Jane sees property regulation as a mechanism for rewarding labor albeit one that does not currently function very effectively, especially for small farmers.

Allen, a new grower running a small operation in its second year, had also signed an MTA as part of the Seed Project but shared Jane's misgivings:

> I signed one [an MTA]–I'm doing the purple fruited tomato for [the Seed Project] so I had to sign that. And it's a little weird to think they're gonna come chasing me down if I save seed from that, or if that seed, crosses with tomatoes I do save, then I guess I'm in trouble, you know? But I don't really worry about it too much. The reality is I'm such a small fish, and nobody knows I'm in the pond so I'm not too worried about it. But if I was a real vegetable grower and really kind of saving my own seed and grew 50 acres of tomatoes or something, then I would be a little put out by that and especially because it's a publicly funded university that is doing it; it's kind of like, just don't worry about it 'cause they try and make out–they say, oh, it's to make sure that nobody takes this and patents it and then tries to not let other people use it, and, yeah, there's some–that makes some kind of sense, but the reality is most universities are run like big corporations and they want the patent because it will bring them money. I mean, that's the primary motivation, I think. I don't think it's as altruistic as they make it out to be but what are you gonna do?

Allen's position shifts over the course of his discussion touching on several themes that emerged from conversations with farmers about the MTAs. As with Jane's comments, Allen is uncomfortable with the fact that MTAs restrict farmers from saving seed from plants that they grow on their land, as if some portion of the plant that they own isn't entirely theirs. Jane had suggested a solution to that conundrum by attributing value to the labor of the breeder but not to the structure of the germplasm itself. Allen did not question the constitutive justification for the current intellectual property scheme, focusing instead on the impact it has on seed saving. Like Jane he chafes at the prospect that seed saving is restricted as a condition for participation in the Seed Project even as he agrees to do so. He points out the possibility that on a small operation like his, his site was only 2 acres total, a protected variety could outcross, leaving him technically in violation. Because of his small scale, he figures that if that happens it won't matter, he's "too small a fish" and "nobody even know I'm in the pond" but clearly at a conceptual level being subject to rules that he might inadvertently violate makes him uneasy. Moreover the prospect that the intellectual property system might be disadvantageous to "real," i.e. larger farmers, leaves Allen speculating that he would feel "a little put out", if he were large enough to get caught in a violation.

At that point his attention shifts to the question of how universities are run and the parallels between university funding structures and those of big corporations. Jane mentioned that universities lacked grant money and therefore profits derived from licenses might be the only way to fund plant breeding programs at land grants. Allen, by contrast, picks up a theme that Ann had sounded namely that universities, in particular, land grant universities, deviate from serving the public good when they imitate or cooperate too closely with corporate interests. Allen's position, unlike Jane's, implies that pecuniary motivations may not be optimal for universities, even as universities may try to claim to be in his words, "altruistic". It seems fair to say that Allen and Ann trust the university system less than Jane seemed to although all three worked within the Seed Project's necessary promulgation of university intellectual property regulations.

Rachel, who considered becoming an academic plant breeder but decided to teach science and farm instead, reflected the same kind of uncertainty as Allen and Jane:

> I think if I were getting ready to embark on some kind of breeding program, I would–and there was a variety I was interested in working–I would probably think closely about whether I wanted to sign that. But as you said, some of the stuff I'm interested in is so weird anyway, I don't know if I would be getting it from them [mainstream seed sources or the university]. I'd really have to explore that further. I have some issues with it [ownership of germplasm] but I also recognize that a lot of work can go into developing and preserving varieties, and people need some compensation for that, but you know, I suspect there's a lot of gray area there, and I'd have to figure out exactly where the line is for me.

Howard, who has run a CSA on a land trust for many years, was more trusting of the process and the institutions involved:

> Ruth: have you ever signed a materials transfer agreement?
>
> Howard: yes.
>
> Ruth: How do you feel about signing such an agreement?
>
> Howard: I'm fine. I trust the–I sort of believe in the process so I'm happy to do so.
>
> Ruth: You think it is reasonable for [name of host institution] or seed companies to be able to own germplasm?
>
> Howard: I think it is reasonable. I'd like to see an expansion of how all that is controlled, but it's reasonable.
>
> Ruth: What do you mean by an expansion of how it's controlled?
>
> Howard: Well, . . . this gets into a much broader issue, really here of whether–which leads to corporate control of seed varieties, and that I don't know enough about the stages leading to that; that, I'm entirely against. So, you know, that's what I mean, is that I'm–anything that has to do with large corporations buying out smaller seed companies and for ownership for purposes, I'm totally against that. . .
>
> Ruth: But you see paying [host institution] plant breeders a royalty in support of their breeding program as being substantively different than that other process?
>
> Howard: Yeah. Well, since we've–we're cooperating with one another, yes.

Howard's remarks are notable because he had said in another part of the interview that he had no contact with the host institution until the Seed Project initiated working together. In his case, the trust in the process seems to have emerged from his cordial working relationship with Seed Project personnel which was obvious during our visit there in the summer of 2006. Joe and his assistant had worked hard to build personal contacts with farmers like Howard. Together they were responsible for recruiting participants, assisting farmers in the program, but also for ensuring compliance with the intellectual property requirements. From the conversations with the farmers cited above it seems clear that for many participants, the intellectual property area was fraught with uncertainty. In the absence of a consensus about the proper policy, even when individuals like

Allen might harbor suspicions about the trustworthiness of the land grant system as a whole, the reasonableness of the Seed Project and its personnel helped to soften what might otherwise have been a difficult issue. It did not take much probing on my part to reveal deeply held animosities towards the corporate seed sector even by relatively trusting individuals like Howard. The Seed Project, with its endorsement by the farmers' organization and seed companies that serve the organic sector, as well as staff who cultivated a low key, personable, non-legalistic approach to intellectual property management that was already in place, managed to massage a working arrangement with many participating farmers that they could live with even if they withheld judgment on the underpinnings of the property regulation system as a whole. There were however a select number of individuals who felt more strongly about the issue.

Ann, the farmers' representative explained that there are a number of members in her organization who will not use hybrids seed because they feel that to do so would be to participate in a process that leads to in appropriate patterns of seed ownership. Ann herself feels that using hybrids should be determined by relative degrees of vigor and type of crop in question but others do not agree:

> There are crops where hybrids make very little sense–lettuce, peas–those are in-breeding, not cross-breeders, and there's really no reason to do it unless you want to keep people from saving seed, which some companies really want to do. And farmers are aware of these–the experienced growers are certainly aware of which varieties, but a lot of core organic growers, for example, [Alice] in New York will not grow any hybrids and she's not alone.
>
> Ruth: Because?
>
> Ann: She just doesn't–she believes that it's a way of taking seeds out of the hands of farmers and it's an ownership thing. And that's a very strong attitude in the organic community.
>
> Ruth: Meaning the sense is that they want to own their own seed or. . ?
>
> Ann: Nobody should own the seed. It should be open for anyone to use and to use–I mean it's one thinking if somebody's gone to the trouble of raising the seed for sale, you pay them for it. But that is a large thing behind the

> GMO thing, too. I mean, there are many reasons why organic growers don't want to have anything to do with GMO's but the issue is right up there.

Ann herself seemed comfortable planting hybrids but her vision for plant germplasm ownership had an even more radical twist.

> Growers want to get their hands on these variable populations. Now, the problem is that–this is where the land grant problem comes into play–most land grants will not make those kinds of populations available to growers without saying that we still control this; if you come up with a product from this, we get a royalty, it's ours. And you'll find that it is a terribly ironic thing, because the only people in our community that are interested in breeding happen to be those people that–it is anathema to them. And I don't know if I told you this but if you look at our seed list, you'll see on list C, which is all experimental material with the exception of ——- at the —unit of the USDA—, they don't have to sign an MTA for any of the stuff you get from them. So that's one area that farmers can go to get variable populations. You can go to Seed Savers Exchange. But Joe and Regina [the PI on the project] have wonderful breeding populations that have some disease resistance and stuff from South American or Central America, and they're all protected. They'll give them to farmers, but they will not give them freely, and this is a real issue. And there is no resolution at the moment, I don't think there is going to be one, so the question is how you get more of these variable populations back out there, how do you recreate landraces, landrace availability to the people.

Ann speaks here on behalf of those farmers who are already engaged in breeding and who are actively seeking germplasm with specific characteristics or with sufficient variation to potentially generate certain characteristics in the breeding process. Unlike the farmers quoted earlier Ann and others like her want the raw material with which to craft their own seed made available without any property designations. Farmer/breeders understand that intellectual property as it is currently defined is not a function of work expended but rather is assigned to whomever is able to make an initial claim to a given population. Thus the lead breeders on the Seed Project control populations from South and Central America which are not their creation although someone at that university collected those accessions. Because the university is a collection point for materials, breeders working in a large institution or for a seed company can access genetic resources that farmers can't. Ann contends that the university won't share the materials freely which the university personnel would dispute. The difference in perception lies in the fact that from the university point-of-view, most users can receive the materials for free and never pay for the privilege because they will never incorporate proprietary material into their own varieties. Indeed no one pays for the access up front. Ann, and the farmer/breeders for whom she speaks, see the MTA agreement as a kind of after-the-fact reimbursement system that is no less disliked because it is contingent on success. Given that the amounts of money involved are generally very small, I find Ann's last sentence most revealing. There she muses about the need to recreate and re-release landraces. When she used the term landrace in this way, that is as a modern deliberately created variable population, I was a little taken aback. I had only heard the term used that way once before by a well-known farmer/breeder from Maryland who has created and released through Fedco, what he calls modern landraces. Over the course of my study I asked many people if they were familiar with this usage and most were not, but it is clear that among a small group of farmer/breeders or gardener/breeders, the idea that one can create a genepool or variable population that others can use as a basis for further selection down to the level of a finished variety enjoys some currency. It remains unclear to me how many farmer/breeders share Ann's policy views on intellectual property regulation. Several with whom I spoke were uncomfortable expressing criticism of the existing system in general terms, preferring to redirect the conversation towards positive contributions they could make improving particular genepools. Fedco Seed Company does sell both genepools and modern landraces which farmer/breeders place in the marketplace as a *de facto* alternative to mainstream varietal releases. A further exploration of this topic would benefit from in-depth interviews with farmer/breeders nationally to examine their beliefs about intellectual property regimes and their conceptions of seeds as property, individually or jointly owned.

5.5 Conclusion

The circulation of knowledge between farmers, breeders and commercial entities of various kinds was a process framed by numerous competing discourses, that of the university, the generally accepted norms of private enterprise, and the somewhat marginalized status of the organic farming movement. Figure 5.3 on page 115 shows the larger relationships between the principal investigator and her technical staff and the external and internal entities with which they cooperated in order to achieve the project goals. The project received its impetus from a grant-funded opportunity but the money alone was probably not responsible for its successes. From the many interview excerpts I have quoted here at some length I hope the reader has gained a sense of the good will and pragmatism that infused the Seed Project from all sides. Despite sometimes deeply held differences about key issues like the role of intellectual property or the purpose of land grant agricultural research, participants did seem willing to work together towards certain well defined goals such as evaluation of vegetable varieties, and learning new pollination techniques. In the process the project demonstrated increased need for participatory plant breeding and traditional plant breeding training that is necessary if the organic community is to be served.

Chapter 6

Conclusion

Agriculture faces a collection of potentially irreconcilable challenges in the 21st century: feeding a growing world's population that demands a more affluent diet, providing better nutrition for the poor and a more balanced nutrition for the rich, adapting to a changing climate, and reducing its impact on the environment. Food consumption and agricultural production are interdependent, and new tools are needed to understand how one influences the other (Peters et al., 2006).

. . . Science as a problem-solving method has failed to make a distinction between contributions that are simply edited summaries of a sequence of isolated research activities, and contributions which provide genuine integration through collaborative working and common methodological frameworks (Jeffrey, 2003).

Effective agricultural research needs to be a cornerstone of food production increases and sustainable ecological systems. Nevertheless, it has become increasingly apparent that the diversity within farming systems in the margins should no longer be discounted simply for small, short-term productivity increases (Bardsley, 2006).

6.1 Feminism, science studies, and the discursive space of plant breeding for organic farmers

6.1.1 Science studies and the innovations inherent in participatory plant breeding

In Chapter two of this dissertation I have traced the ways in which science studies has allowed scholars to abandon overly simplified models of technological determinism to embrace a more nuanced understanding of how scientific and technological innovation are interwoven with social reality. Historians within this tradition have tried to answer the question, What other paths might human innovation have taken beyond that which in fact occurred? This study has looked at a situation in which one plant breeding laboratory made the conscious choice to redirect some of their energies toward one of the paths not taken in the early 1970s. At that time, when the organic food movement was young, university plant breeders and the seed establishment chose not to investigate how organic plant varieties might be improved, or for that matter how the research infrastructure might interact with the new kind of farmer then emerging. Thirty years later, what might have seemed at inception to have been a minor back-to-the-land movement offshoot, has proven itself to be a vital and profitable part of the vegetable growing landscape. Organic farming now matters in the US economy. The Seed Project embarked upon a concrete effort to examine the possibilities left unused by breeders of an earlier era, and find new methods to work with organic growers.

I have argued that in order to understand the full theoretical impact of the Seed Project's inclusion of the organic sector's breeding needs, it is necessary to rethink the dominant metaphors used to characterize agricultural plant breeding. To that end it is useful to understand domesticated plant varieties as technoscientific human/non-human hybrids that combine plant agency and human intentions into unstable but highly useful packages. Technoscience not only resists the separation of scientific abstraction from technical application, it points to the fact that domesticated plants are not natural objects, they are objects which have emerged under the attention and material intervening of humans, together with the limitations and innovations that arise from non-humans. Creating technoscientific plants demands new skills on the part of researchers. Whereas conventional plant breeding uses a technology transfer model in which breeding decisions are made by scientists in light of what they know or perceive are the needs of farmers, participatory plant breeding for the organic sector benefits from a new set of skills on the part of breeders and their technical staffs. This new approach demands increased managerial attention, a willingness to think comprehensively about easing interactions between the university and alternative farmers, and a desire to capture farmer input at all stages of the plant breeding process.

6.1.2 Stewardship trumps naturalism among organic farmers

One part of the organic and alternative foods movement has been attracted to the discourse of naturalness particularly in regard to plant breeding in part as a means to resist genetic engineering technology. More usefully I suggest that the idea of stewardship offers a model of human/material world interaction that takes into account the changed nature of plants and humans in an agricultural context. Proponents of genetic engineering, especially the Monsanto corporation, equate all significant scientific plant improvement with GMO technology. Those who question or reject this position have drawn into endless debates about the virtues and problems of GMOs while the rest of plant breeding, including the strengths of selectionist plant breeding receive virtually no public attention. Moreover, within the framework of the GMO debate, the organic and sustainable agriculture movements are reduced to positioning themselves as natural or possibly even anti-scientific in ways that clearly are at odds with any idea of plant improvement or indeed domestication at all. As the Seed Project demonstrated, a responsive public sector plant breeding program that rigorously incorporates farmer and consumer needs can be created at modern land-grant universities along the lines of the tempered expertise model espoused by Helen Longino. Given sufficient leadership and funding it is possible to bring together farmers, seed companies and university personnel to produce genuinely improved seed, that is seed that meets farmers' needs, the product of which satisfies consumers, and which supports small and medium seed companies. From this perspective, plant breeding outputs need to be assessed for how thoroughly the process of their creation reflected a social consensus among end-users. Selectionist bred organic open pollinated tatsoi, for example, requires sophisticated manipulation of targeted populations in ways that are technoscientific, but also respectful of diverse biological and social constraints. Working within constraints in order to attain ecosystem balance is a better way to characterize the work of organic agricultural plants.

Unfortunately, we are not yet at that point in our public discourse. Given the alienation that I have just outlined between the agricultural research establishment and my specific example of plant breeders and the organic farm movement, it might be hard to imagine why organic farmers would be attracted to terminology like that of technoscience. This term would seem to remove plant breeding from realm of grassroots practitioners and into the laboratory. As I have pointed out in my early analysis, however, those terms do not have to be used in that way. Technoscience honors the practical side of scientifically created artifacts and the knowledge gained by watching a technical artifact perform in the field and responding with necessary corrections and improvements. This mode of understanding innovation, as a trial and error process, in which multiple kinds of participants bring their differing kinds of expertise to bear on a problem seems most consistent with the idea of public, democratic science practice.

Articulating public democratic practice particularly with attention paid to the feminist concern for including those excluded from positions of social power requires overcoming an historical gap between scientists and farmers. The farmers in my study expressed considerable skepticism that university-based breeders outside of the Seed Project were interested in classical plant breeding for the organic sector particularly if doing so would require using participatory methods. Thus plant technology and plant science have become discursively stranded within the greenhouses and laboratories of industry and the universities, exactly the locations from which science studies theorists have worked so hard to free them. A case can be made that the phenomenon I observed among growers in my study, the distrust they felt about research in general, yet their willingness to work across party lines with scientists and technical staff who would treat them with respect in personal interactions, indicates possible wiggle room for an anti-traditionalist vision of organic farming.

To imagine how such an agenda might work it is important to remember the ANT injunction that what we study as sociologists is the emergence of social coherence. That was certainly empirically the case in this instance. The Seed Project's most revolutionary act was to apply participatory plant breeding principles on a wide scale to any organic farmer who desired to participate, offering a variety of modes of participation, and allowing for a variety of start dates. This programmatic openness created a discursive space in which is was possible to begin dialog about the rapprochement between

Table 6.1. Key Findings

1	University-based breeders and organic farmers are profoundly isolated from each other.
2	This isolation has diminished biodiversity and a lead to a lack of robust varieties adapted to Northeastern growing conditions.
3	The two key reasons for this isolation are the relative distrust that organic farmers feel for the university establishment and a very real crisis within plant breeding as a discipline.
4	The disciplinary crisis in plant breeding results from the fact that universities and funding agencies have been shifting resources away from traditional plant breeding and towards biotechnology/life sciences programs.
5	The seed industry, organic and conventional, is concerned that the dearth of US-trained traditional plant breeders will undermine the industry's ability to produce needed varieties for all kinds of farming systems.
6	Farmers, breeders, and company representatives have strongly held and contradictory views about the validity and value of current intellectual property regulations.
7	The Seed Project successfully negotiated some of the barriers in ways that should be replicated, producing a unique breeding network and a number of successful varieties including an All-American Award winner.

breeders and farmers up to and including my recruitment as a social scientist who would interview participants and document those interactions. In the process farmers had the opportunity to shift their conceptions of themselves and their needs in light of possible assistance from the university breeders.

6.2 Key insights into the circulation of scientific knowledge

Table 6.1 on page 167 shows the key outcomes from my study in terms of the interactions between the essential parties to the project and the impact of barriers to the circulation of knowledge between them on the overall well-being of the organic farmers and the small and medium seed companies that serve them.

Most importantly, university-based breeders and organic farmers are profoundly isolated from one another because of lack of financial and structural infrastructures as well as cultural differences. On the university side, breeders have been forced to seek funding from either large seed companies that can fund proprietary research or, more frequently, grant funds for life-science or molecular work. The desire to do molecular work is not merely a matter of money, at stake are also the scientist's sense of self, the tendency to identify molecular laboratory work with cutting edge technology, in contrast to field-based selectionist work which has always struggled to differentiate itself from serving as merely on-call advisers to farmers. Farmers, for their part, feel considerable bitterness at the university system and the scientific establishment in general for the lack of respect and service they have received. The degree of resentment felt by my informants depended on their particular experiences, but many expressed strong distaste for the close relationship they observed between conventional agriculture and the land-grant system.

6.2.1 Redefining progress

This distaste can be understood as a kind of conceptual mistrust of the idea of progress itself as a linear, temporally one-way system, precisely the critique supported by feminist science studies theorists and historians. It seems that the farmers I spoke with defined their kind of innovation in farming as a process of reviving, rediscovering, refurbishing, reinventing and reapplying a mixture of lost, neglected and possibly some new information, into a systematic approach that is sustainable ecologically and economically. "Newness" in this model and all of its synonyms such as "innovative", "cutting-edge", "technologically advanced" and related terms which often signal a rhetorical alliance with mainstream conceptualizations of progress, are met with great skepticism or at least are not embraced as *a priori* public goods. What I am arguing here goes beyond the tendency to be conservative about ecological risk. This group of farmers is engaged in a shifting process where, with the assistance of each other, larger farmer networks, and publications dating back many years, farmers collect expertise about how to farm organically in this region of the country. These activities happen during the winter and are then supplemented in the summer by extensive experimentation both in terms of trialing varieties, checking out formally or informally what other farmers do, assessing customer feedback, conversations with seed companies, and, occasionally speaking with extension staff at the county level. Although they have little time and work 60-80 hours per week during the growing season, it is fair to say that this group of farmers did engage in regular independent research and assessment of plant varieties as well as related farming methods without much interaction with plant breeders or university scientists of any kind prior to the Seed Project.

Farmer/breeders, of course, engaged in even more research type activities as they actively sought to breed new varieties as well as, of necessity as all plant breeders must, collect new germplasm. It is perhaps easy to see how farmers deeply enmeshed in their own subculture, which is constantly creating, sharing, rediscovering, and reapplying knowledge, might wonder what exactly they stand to gain from connecting with the university-based scientific establishment which operates using a much more conventional and linear definition of plant breeding and indeed general farming progress. Land-grant universities and researchers have not made the process any smoother by asserting their own methodological superiority. At the 2008 annual conference of the Pennsylvania Association for Sustainable Agriculture, the President of the Association openly criticized the tendency of university scientists to use the term “sound science” to dismiss sustainable agriculture concerns. While some within the sustainable and organic movements may have mixed feelings on this point, the farmers I spoke with harbored long standing pain at the unwillingness of the scientific establishment, including plant breeding as a discipline, to understand and respect alternative agriculture’s willingness to investigate the past as well as the latest methods for improving agriculture.

For the Seed Project then the challenge arose how to bring cutting edge, genuinely new and innovative plant breeding resources to the attention of the organic farming sector without setting off alarm bells either by asserting institutional superiority, or by presuming that the methods of formal science would inherently trump farmer-based knowledge.

6.2.2 Overcoming mistrust: building a better participatory plant breeding model

The Seed Project succeeded in bridging the cultural and institutional barriers that separate the generation of knowledge between plant breeding scientists and organic farmers by taking a number of important steps in program design. As a participatory plant breeding project, the breeders included farmers in project activities at a number of points of entry. That is, for the most sophisticated farmer/breeders the Seed Project was happy to co-develop varieties including one which was eventually named after the farm of the farmer/breeder who had been involved in its selection from the initial stages. Other farmer/breeders exchanged experimental populations and participated in setting initial goals as well as receiving germplasm and other kinds of support from the project. At the same time, farmers who were not yet ready for this level of participation were given other kinds of opportunities. The bulk of participants, for example, trialed experimental and seed company varieties on their farms and shared their results with the project which then collated that information and posted it on the web. Still other farmers were able to attend pollination workshops where they learned how to pollinate varieties, an important field skill for those who want to eventually breed their own varieties. Workshops were also held to demonstrate seed cleaning machinery and taste test varieties at the end of the summer. Finally, the seed cleaning machinery that the project purchased was available for farmers to park on their farms and use to process their own and their neighbors' seed more quickly and efficiently. All of these different points of entry into the project gave it greater flexibility and made it easy for farmers to enter into participation on their own time and in a manner that they felt was commensurate with their level of expertise and interest. It was also useful that farmers could join the project at any time, they did not have to have been on board from the beginning which allowed the project to preserve its dynamic nature up until the very end of its financial life.

From the beginning the farmers' association was intimately involved in the project. Several farmers' association members were hired by the project either to manage part of the distribution of materials and run workshops or to farm the organic plots at the lead university. At the final meeting of the project which I attended, plant breeders from cooperating universities around the US were very clear that the well-developed sustainable agriculture infrastructure in the Northeast, both in terms of farmers' associations and also in terms of marketing outlets like farmers' markets, were missing links that do not exist in other parts of the country. I observed a tremendous dedication on the part of the farmers' association representatives for the Seed Project even as they were from time to time critical of its achievements. The representative who worked on the lead university's organic farm was particularly eloquent about the need for different kinds of individuals with different kinds of training to be in dialog with each other and how much he had benefited from the process of learning to work with the other university staff and academics. Another representative insisted that her participation had been only what anyone would have done but according to other informants her help included going to member farms to do chores so that the member could take the time to participate in Seed Project activities. The relative expense of hiring members of the farmer community to function as outreach and project management participants was not significant but those modest sums allowed those individuals the time to act as social translators and pragmatic facilitators for their membership. Their regular input also insured that the project enjoyed legitimacy among farmers who still felt free to make suggestions for improvement but who said that they considered the Seed Project to be an exception to the general neglect that they felt from the university and plant breeding establishment.

Farmers and farmers' representatives specifically cited the involvement of the technical staff at the university as an important group who helped to establish trust and who did the vast majority of the actual outreach work that I observed. As I have said in earlier chapters, a portion of the agrobiodiversity resources that are under threat as universities cut their traditional breeding programs is the knowledge of technical staff who are generally let go or transferred to other projects when a tenured breeder retires. In this instance, the technical staff interfaced particularly well with the farmers and built trust and mitigated some of the hard feelings farmers had about land-grant universities. To some extent this was simply a matter of personality and personal dedication on the part of the individuals involved. On the other hand, technical staff are generally not PhD holders, their lives have followed trajectories more similar to those of farmers (although a surprising number of farmers where themselves PhD holders, generally not in agricultural subjects). Most importantly, the technical staff were not involved in academic publishing activities. They did in fact informally teach and mentor both undergraduate and graduate students as well as every participant in the Seed Project workshops including me, but they were not the faculty of record for any official course. In this way, their focus was on the pragmatic work of producing varieties and running the project which gave them solidarity with the farmers. They also happened to be particularly creative about marketing ideas for new varieties, especially Joe, the most senior project manager. Joe's ideas about how to sell everything from multi-colored cherry tomatoes to miniature broccoli shoots filled pages of my notebook on one memorable car trip. This kind of intellectual connection to the work that farmers do and the contribution that plant varieties can make made Joe a significant asset to the Seed Project. Recruiting, training, and retaining expertise like Joe's within the land-grant university system is a challenge that the Seed Project raised in stark relief. Just as experimental breeding lines can be lost if an institution depends too heavily on temporary grant monies, personnel like Joe are not well served by the current grant-funded system. When projects like the Seed Project end they leave behind them the potential for even greater disillusionment among growers when key contact people leave or are reassigned.

6.2.3 Agrobiodiversity consumers vs. agrobiodiversity conservators: which role do commercial farmers play?

Because of the common philosophical commitments to respectful land use which both my pool of growers and the larger organic, sustainable agriculture movement and seed savers share, it is easy to elide the subtle differences in viewpoint that each group holds in regard to agrobiodiversity. Organic farmers can contribute to agrobiodiversity by consistently purchasing bulk seed and by providing feedback to seed companies and plant breeders about the relative performance of given varieties. They can also participate, as they did in the Seed Project, in joint breeding projects, and some will become master breeders on their own. They are, however, not sufficient as the exclusive or even the primary conservators of diverse vegetables varieties. Indeed when I spoke to farmers who had been in the business for relatively longer periods of time, it became clear that longevity and size made them if any thing more dependent on a wider seed system including breeders and a vibrant network of small seed companies. I do not think it is unreasonable to project from the evidence given by the farmers in this study, that the small-scale organic farm sector may be less productive both in terms of nutrition produced and economic well-being of the farm sector because farmers are currently forced to be too self-reliant in terms of their seed use. The tendency of varieties to vanish from catalogs without warning, the propensity of companies to be bought out by others and their inventories to be severely trimmed in the merger and other factors hurt the productivity of the organic sector in ways which such farmers cannot compensate for by seed saving or other agrobiodiversity schemes alone. Instead, preserving agrobiodiversity for Northeastern organic farmers must be seen as a social, public or common good. That is, the diversity of cultivated vegetable crops used by organic farmers is a project too large, and too at odds with the constraints of farming, for farmers to achieve on their own.

The Seed Project provided one partial solution to this challenge in that it integrated organic farmers into preexisting institutional structures that have been used for the last forty years by conventional farmers, namely, a government funded plant breeding project based at a university and connected to the appropriate industry sector. Such an approach could be more broadly successful and would answer the need for seed conservation to be shared in a larger venue than simply at the level of the individual farmer. However, as the analysis and discussion in the chapter on agrobiodiversity attests, central to the success of any such broad based social networking approach would have to be a long-term commitment and the financial support to a project and a careful discussion of program goals. The simple term "biodiversity" or even "agrobiodiversity" means very different things to molecular geneticists than to farmers. Both molecular and phenotypical modes of assessment have their place in a participatory breeding project but it is essential that the differences and uses of both be explored as part of a larger process of knowledge exchange.

6.2.4 Farmers as businesspeople

If farmers are not conservators of agrobiodiversity and organic farms are not genebanks, they do have a role for which they are not well known in the public discourse about local, sustainable, or ethical food consumption. I refer to the fact that organic farms in the Northeastern United States must operate as businesses. My informants were very clear that although ethical and lifestyle commitments governed their decisions to become farmers, maintaining financial profitability allowed them to remain in the fields. While not all the farmers with whom I spoke earned a full-time living from their growing endeavors, all said that they had to constantly assess the financial success of each crop each year and ruthlessly eliminate those which did not meet certain benchmarks. The degree to which this analysis was carried out in detail varied but all of the farmers indicated that at the end of the day, they had to make the financial situation work such that they could justify remaining in business. None of the farmers I interviewed were financially independent enough to be able to run their farms as hobbies. While at some level this observation seems to be a matter of common sense, the public discourse about local, organic or sustainable agriculture tends not to emphasize this fact although it is a constant topic of discussion at farmers' conferences.

The degree of sophistication in tracking systems varied between farms but most who had been in business more than a year evaluated each crop and frequently each variety in terms of its marketability and relative labor inputs. Sometimes breeding goals were directly shaped by labor requirements such as the couple who were looking for a bush tomato because the work of staking tomatoes was too time intensive and tended to burden the member of the couple who worked off farm too much. Thus labor shortages, the cost of labor relative to the profitability of fresh vegetables, and the relative attractiveness to local consumers of a given variety or crop, all exercise compelling, perhaps even decisive, influence on farmers' varietal choices. To the extent that growing many varieties of different crops enhances the goal of enhanced agrobiodiversity, organic farmers in the northeastern US can be fairly said to contribute significantly to enhancement and preservation of agrobiodiversity. However, to the extent that those business necessities conflict with the component parts of agrobiodiversity, when for example, it might be essential to continue growing varieties that are more labor intensive to pick, or which have thorns, or which grow so erratically as to be unreliable for commercial purposes, farmers are unlikely to be able to afford to act as reservoirs.

Furthermore, because they are specialized businesses, although seed saving of open pollinated varieties is something many of them feel compelled to do in light of an unstable seed market where favored varieties can disappear without notice, my sense was that the farmers I interviewed would prefer a robust small scale commercial seed sector. The relationships between existing organic seed companies and farmers are, from the farmers' side, perceived as a very positive contribution to the organic farming movement. In an earlier chapter I did cite one farmer who distinguished between a seed company owned by a large conglomerate and those which are not. However, to the extent that for the moment the farmers in my study can access their seed from small to medium sized independent seed companies they do so with a sense that their purchasing dollars are contributing to maintaining another commercial sector which is philosophically in line with their own. They do worry about the cost, particularly of certified organic seed, sometimes choosing to buy untreated seed instead because the cost differential can be so high. In this regard I thought the comment of the one farm manager who ran a CSA was particularly telling when he said that he felt he had a responsibility to his members who pay a set fee for the season not to overspend on organic potato sets because the difference in cost would mean that his members who receive less for their share than if he used the untreated seed.

6.2.5 Farmers and intellectual property

One final and fascinating outcome of the farmers' position as businesspeople was their deeply ambiguous feelings about intellectual property regulation. I had expected that farmers would reject the current legal provisions which allow plant varieties to be patented and which under certain circumstances allow certain breeding approaches to be restricted as well. In fact, only one farmer rejected patenting and plant variety protection out-of-hand. Most farmers felt that their needed to be some way of compensating plant breeders for the work that they do. While patenting was an imperfect solution, most of the farmers said they didn't understand the exact regulations and the true policy impacts of legal protections vs. the lack thereof. Indeed I didn't understand the issue myself until I spoke with a plant breeder who explained that the the Plant Variety Protection Act allows other breeders to use the germplasm for breeding purposes and compensate the owner if the resulting new variety is commercialized, whereas patents preclude access of any kind except for those who are doing proprietary work at the behest of the patent owner. This nuance is not well known in the farming community.

More fundamentally, farmers as businesspeople are attached to the idea that their purchases of seed would be the mechanism by which good plant breeding could be rewarded. It allowed them to vote with their seed buying dollars, giving them consumer input into the plant breeding system and circumvented the necessity of lobbying for research dollars from the Federal government or other research entities, a prospect that felt well nigh impossible to those who mentioned it. The one outspoken critic of intellectual property rules as they currently existed on the farmer side was a farmer/representative who had a PhD in sustainable agriculture and was well versed in the political and policy side of the issue. She felt, and I have heard her position at farmer conferences from others in the sustainable agriculture movement who are enmeshed in policy issues, that the ability to own germplasm in any form was resulting in reduced circulation of germplasm among breeders and farmers. Interestingly, the same concern was voiced by plant breeders at the university who were unhappy that some private corporations had bought and taken off the market so many patented varieties that certain traits were getting hard to find. The farmer/representative's solution was to contemplate a radical break with the current market driven system of plant breeding and to revert to a farmer-based extra-market circulation of genepools that could then be custom bred on each farm or for each region.

My view is that this is probably not the ideal approach for pragmatic reasons. As I have said before, farmers in general seemed most interested in a stable and robust seed system into which they could have input at various levels but which did not require them to become jacks-of-all-trades. However, the existence of farmer/breeders who are willing to produce and circulate genepools through organizations like Seed Saver's Exchange and companies like Fedco, does, in my view, provide a useful supplement and source of diversity for those farmers who are interested in becoming more involved in varietal production. I would also agree with this farmer/representative that the broad circulation of diverse genepools among the general population, including gardeners, could be the key to preserving and enhancing agrobiodiversity. Gardeners do not have the same time and financial constraints that farmers do and they could be fruitfully engaged as varietal conservators, a task that farmers can't afford to do. I do agree with her that the current patent system allows hording of germplasm and should be radically revised. This study does not extend beyond the farming community but it seems to me that from an advocacy and further research perspective it would be worthwhile to contemplate the role that a well organized master gardener community could play as a supplement to the organic farming community. Unburdened by the need to produce for market, gardeners working with plant breeders and growers could enrich the breeding possibilities in developed countries like the US where many people garden passionately and well.

6.2.6 Varietal insecurity is unnecessary

The level of varietal insecurity with which these farmers lived was unnecessary. When I asked some of my informants about their vision for a better seed system, especially when I asked them about the role of intellectual property, it became more and more clear that what many might really want was not an wholly autonomous organic subculture, but a more integrated organic seed system that had a mutually beneficial cooperative relationship with the necessary institutions. The problem is, in asking for that kind of access, the organic community in the Northeast, which is still small-scale and very independent, may well fear it will be subject to rampant invasion by well-financed, large scale concerns. The advent of organic monoculture in California, the consolidation in the organic dairy sector, even some aspects of the USDA organic certification process, leave small scale Northeastern growers deeply wary that to engage in a discourse of modernity is the equivalent of capitulating to industrialization and consolidation. However, as the Seed Project demonstrated, there are very real and perhaps vital benefits to be gained from imagining and experimenting with multi-scale, farmer-inclusive, highly modern, perhaps even technoscientific organic production. The inclusiveness of the organic knowledge system, the willingness to weigh old ideas alongside new ones that characterized my farmer informants' information gathering and use, is a powerful antidote to technological utopianism. At the same time, the tendency of some agriarianists within the movement to use a language of naturalism and tradition brings with it politically repressive implications. Feminist science studies models such as the one put forward by Donna Haraway, Helen Longino, and Evelyn Fox Keller speak to the emancipatory potential of the biological ethos, which if applied to organic farming, could harness the power of plant breeding innovation without sacrificing the caution that distinguishes the organic movement.

6.3 Improving on compromises

The delicate peace which the project maintained to its end demonstrates that diplomacy and a strict focus on concrete, mutually beneficial goals can enable the organic and plant breeding communities to work together. At a more theoretical level however, I believe that the tensions that the Seed Project managed so well do need to be dissected and the underlying ideological fissures exposed in the hope that perhaps a more thoroughgoing dialog can be advanced. Longino's model of public science with its emphasis on public venues and debate about standards and methods yielding tempered expertise fits well into the needs of participatory plant breeding science in this regard. The benefits of such a conversation would be the creation of new varieties that are urgently needed in the organic community. The potential for the ecologically responsible farming sector to succeed are so clearly enhanced by improving and increasing participatory plant breeding that this justifies in my mind a broad commitment to increasing support for selectionist plant breeding in support of organic food systems within the land-grant university system and in other research venues. There have been a number of studies that attempt to measure the ability of organic systems to feed the world's current population (Cassman, 2007; Sligh and Christman, 2007). Without a robust suite of varieties across all major and minor crops, something which clearly does not exist for the organic community right now, such measurements are undoubtedly inaccurate. In essence, scholars are forced to measure organic production methods using varieties from early in the last century vs. industrial production methods using specifically adapted varieties that capitalize on the strengths of that input intensive approach.

That broad committment will require political support among organic food consumers, most of whom are now unaware of the crisis of plant breeding and the underserved nature of the organic plant breeding sector. Secondly, the current food crisis has lead to a call for greater agricultural research of the high-tech variety. A coalition of agri-business transnationals has launched a new lobbying campaign to increase support for agricultural research (http://www.foodandenergy.org/). Not only is there a risk that this will exacerbate the already existing tendency to build certain kinds of high-tech capacity at the expense of less expensive and frequently more effective selectionist methods of plant breeding, there is also the risk that those segments of the public including the organic and sustainable farming communities will be even further alienated from the research community. The idea that agricultural research is inherently antithetical to the interests of small and alternative farmers and to those consumers who care about issues such as food safety, environmental degradation and pesticide use, has negative repercussions for the entire research community and potentially for the land-grand system as a whole. I feel strongly that the land-grant system, particularly Colleges of Agriculture, need to become honest brokers, a venue where all agricultural producers can have their needs served by the best research and most empowered outreach and extension money can provide. In order for that to happen, however, there must be a conversation about the nature of agriculture research and organic farming that shifts the parameters of each into closer proximity.

Bibliography

Adelmann, Arllys and Steph Hughes. 2007. "Seed Savers 2007 Harvest Edition." Seed Savers Exchange.

Adelmann, Arllys, Steph Hughes, and Kent Whealy. 2006. "Seed Savers 2006 Summer Edition." Seed Savers Exchange.

Adelmann, Arllys, Steph Hughes, and Kent Whealy. 2007. "Seed Savers 2007 Summer Edition." Seed Savers Exchange.

Almekinders, C.J.M. and A. Elings. 2001. "Collaboration of farmers and breeders: Participatory crop improvement in perspective." *Euphytica* 122:425–438.

Almekinders, C., L. O. Fresco, and P. Struik. 1995. "The need to study and manage variation in agro-ecosystems." *Netherlands Journal of Agricultural Science* 36:127–142.

Alston, Julian M. 2004. "Horticultural biotechnology faces significant economic and market barriers." *California Agriculture* 58:80–83.

Ammann, Klaus. 2008. "Integrated farming: why organic farmers should use transgenic crops." *New Biotechnology* 25:101–107.

Anderson, Warwick and Vincanne Adams. 2008. *The Handbook of Science and Technology Studies*, chapter Pramoedya's Chickens: Postcolonial Studies of Technoscience, pp. 181–204. Cambridge, MA: MIT Press, third edition.

Ashby, Jacqueline A, Teresa Garcia, Maria del Pilar, Guerrero Carlos, Arturo Quiros, Jose Ignacio Roa, and Jorge Alonso Beltran. 1996. "Innovation in the organization of participatory plant breeding." In *Participatory plant breeding. Proceedings of a workshop on participatory plant breeding 26-29 July 1995, Wageningen, The Netherlands*, edited by P Eyzaruirre and M. Iwanaga, pp. 77–97, Rome, Italy. IPGRI.

Ashworth, Suzanne. 1991. *Seed To Seed*. Decorah, IA: Seed Savers Publications.

Atlin, G.N., M. Cooper, and A. Bjornstad. 2001. "A Comparison Of Formal And Participatory Breeding Approaches Using Selection Theory." *Euphytica* 122:463–475.

Baenziger, Marianne and Mark Cooper. 2001. "Breeding for Low Input Conditions and Consequences for Participatory Plant Breeding: Examples from Tropical Maize and Wheat." *Euphytica* 122:503–519.

Baenziger, P. Stephen. 2006. "Plant Breeding Training in the US." *Horticultural Science* 41:40–44.

Bardsley, Douglas. 2006. "Valuing Diversity for Sustainable Futures: A Response to Wood and Lenne." *Land Use Policy* 23:643–644.

Baur, Erwin. 1914. "Die Bedeutung der primativen Kulturrassen und der wilden Verwanten unserer Kulturpflanzen für die Pflanzenzüchtung." *Jahrbuch der Deutschen Landwirtshafts-Gesellschaft* pp. 104–109.

Beinart, William and Karen Middleton. 2004. "Plant Transfers in Historical Perspective: A Review Article." *Environment and History* 10:3–29.

Biagioli, Mario (ed.). 1999. *The Science Studies Reader*. New York: Routledge.

Biggs, S. and D. Gauchan. 2001. "The broader institutional context of participatory plant breeding in the changing agricultural and natural resources R and D system in Nepal." In *An Exchange of Experiences from South and Southeast Asia: Proceedings of the International Symposium on Participatory Plant Breeding and Participatory Plant Genetic Resource Enhancement, Pokhara, Nepal 1-5 May 2000*, pp. 61–74, Cali, Columbia. Participatory Research and Gender Analysis Program, Coordination Office, International Center for Tropical Agriculture.

Bijker, Wiebe. 1992. *Shaping Technology/Building Society*, chapter The Social Construction of Fluorescent Lighting–Or How an Artifact Was Invented in its Diffusion Stage. Cambridge, MA: MIT Press.

Bijker, Wiebe E. 1995. *Of Bicycles, Bakelites and Bulbs: Toward a Theory of Sociotechnical Change*. Cambridge, MA: MIT Press.

Bijker, Wiebe E., Thomas P. Hughes, and Trevor Pinch (eds.). 1987. *The Social Construction of Technological Systems*. Cambridge, MA: MIT Press.

Bijker, Wiebe E. and John Law (eds.). 1992a. *Shaping technology/building society*. Cambridge, UK: Cambridge University Press.

Bijker, Wiebe E. and John Law (eds.). 1992b. *Shaping Technology/Building Society: Studies in Sociotechnical Change*. Cambridge, MA: MIT Press.

Bishaw, Zewdie and Michael Turner. 2007. "Linking Participatory Plant Breeding To The Seed Supply System." *Euphytica* .

Bliss, Frederick A. 2006. "Plant breeding in the private sector of North America." *Horticultural Science* 41:45–47.

Bliss, Frederick A. 2007. "Education and Preparation of Plant Breeders for Careers in Global Crop Improvement." *Crop Science* 47:S250–S261.

Bousquet, Marc. 2008. *How the University Works: Higher Education and the Low-Wage Nation*. New York: New York University Press.

Bowker, Geoffrey C. and Susan Leigh Star. 2002. *Sorting Things Out: Classification and Its Consequences*. Cambridge, MA: The MIT Press.

Brookfield, H. and C. Padoch. 1994. "Appreciating agrodiversity: a look at the dynamism and diversity of indigenous farming practices." *Environment* 36:6–11, 37–45.

Brookfield, Harold, Christine Padoch, Helen Parsons, and Michael Stocking (eds.). 2002. *Cultivating Biodiversity: Understanding, Analysing & Using Agricultural Diversity*. London: ITDG Publishing.

Brown, Anthony H. D. 2000. *Genes in the Field*, chapter The genetic structure of crop landraces and the challenge to conserve them in situ on farms, pp. 29–48. Lewis Publishers.

Brown, Cheryl, Stacy M. Miller, Deborah A. Boone, Harry N. Boone, Jr., Stacy A. Gartin, and Thomas R. McConnell. 2006. "The Importance Of Farmers' Markets For West Virginia Direct Marketers." *Renewable Agriculture and Food Systems* 22:20–29.

Brush, S.B. 1992. "Ethnoecology, Biodiversity, And Modernization In Andean Potato Agriculture." *Journal of Ethnobiology* 12:161–85.

Brush, S. B. 1991. "A Farmer-Based Approach To Conserving Crop Germplasm." *Economic Botany* 45:153–161.

Brush, S. B. 1995. "In Situ Conservation Of Landraces In Centers Of Crop Diversity." *Crop Science* 35:346–354.

Brush, S. B. 1996. "Valuing Crop Genetic Resources." *Journal of Environment and Development* 5:418–435.

Brush, Stephen B. (ed.). 2000a. *Genes in the Field: On-Farm Conservation of Crop Diversity*. Boca Raton, FL: Lewis Publishers.

Brush, Stephen B. 2000b. *Genes In The Field: On-Farm Conservation Of Crop Diversity*, chapter The Issues Of In Situ Conservation Of Crop Genetic Resources, pp. 3–28. Lewis Publishers International Development Research Centre International Plant Genetic Resources Institute.

Brush, S. B., H. J. Carney, and Z. Hauman. 1981. "Dynamics Of Andean Potato Agriculture." *Economic Botany* 35:70–88.

Brush, S. B. and E. Meng. 1998. "Farmers' Valuation And Conservation Of Crop Genetic Resources." *Genetic Resources and Crop Evolution* 45:139–150.

Brush, Stephen B. and Doreen Stabinsky (eds.). 1996. *Valuing Local Knowledge: Indigenous People and Intellectual Property Rights*. Washington DC: Island Press.

Brush, S. B., J. E. Taylor, and M. R. Bellon. 1992. "Biological Diversity And Technology Adoption In Andean Potato Agriculture." *Journal of Development Economics* 39:365–387.

Busch, Lawrence, William B. Lacy, Jeffrey Burkhardt, and Laura R. Lacy. 1991. *Plants, Power, and Profit: Social, Economic, and Ethical Consequences of the New Biotechnologies*. Cambridge, MA: Basil Blackwell.

Butler, Judith. 1993. *Bodies That Matter*. New York: Routledge.

Butler, Judith. 2004. *Undoing Gender*. New York: Routledge.

Buttel, Frederick. 1999. "Agricultural biotechnology: its recent evolution and implications for agro-food political economy." *Sociological Research Online* 1995-1.

Callon, Michael. 1999. *The Science Studies Reader*, chapter Some elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieuc Bay, pp. 67–83. New York: Routledge.

Campbell, Kirsten. 2004. "The Promise of Feminist Reflexivities: Developing Donna Haraway's Project for Feminist Science Studies." *Hypatia* 19:162–182.

Carlson, Allan. 2008. "Agrarianism Reborn: On the Curious Return of the Small Family Farm." *The Intercollegiate Review* pp. 13–23.

Carlson, Elof Axel. 2004. *Mendel's legacy: the origin of classical genetics*. Cold Spring Harbor Laboratory Press.

Carnegie Foundation for the Advancement of Teaching. 2009. http://www.carnegiefoundation.org/.

Carolan, Michael S. 2006a. "Do You See What I See? Examining the Epistemic Barriers to Sustainable Agriculture." *Rural Sociology* 71:232–260.

Carolan, Michael S. 2006b. "Social change and the adoption and adaptation of knowledge claims: Whose truth do you trust in regard to sustainable agriculture?" *Agriculture and Human Values* 23:325–339.

Carolan, Michael S. 2007. “Saving Seeds, Saving Culture: A Case Study of a Heritage Seed Bank.” *Society and Natural Resources* 20:739–750.

Cassman, Kenneth. 2007. “Editorial Response by Kenneth Cassman: Can Organic Agriculture feed the world?–Science to the rescue?” *Renewable Agriculture and Food Systems* 20:83–84. filed with original article: by Catherine Badgley and Ivette Perfecto.

Ceccarelli, S., S. Granco, E. Bialey, A. Amri, M. El-Felah, F. Nassif, S. Ezgui, and A. Yahyaoui. 2001. “Farmer Participation in Barley Breeding in Syria, Morocco and Tunisia.” *Euphytica* 122:521–536.

Ceccarelli, Salvatore and Stefania Grando. 2007. “Decentralized-participatory plant breeding: an example of demand driven research.” *Euphytica* 155:349–360.

Ceccarelli, Salvatore, S. Grando, and R. H. Booth. 1996. “Farmers and Crop Breeders as Partners.” In *Participatory plant breeding. Proceedings of a workshop on participatory plant breeding, 26-29 July 1995 Wageningen, The Netherlands.*, edited by P. Eyzaruirre and M. Iwanaga, pp. 99–116, Rome, Italy. IPGRI.

Ceccarelli, S., S. Grando, M. Singh, M. Michael, A. Shikho, M. Al Issa, A. Al Saleh, G. Kaleonjy, S. M. Al Ghanem, A. L. Al Hasan, H. Dalla, S. Basha, and T. Basha. 2003. “A Methodological Study on Participatory Barley Breeding II. Response to Selection.” *Euphytica* 133:185–200.

Ceccarelli, S., S.Grando, R. Tutwiler, J. Baha, A. M. Martini, H. Salahieh, A. Goodchild, and M. Michael. 2000. “A Methodological Study on Participatory Barley Breeding I. Selection Phase.” *Euphytica* 111:91–104.

Cleveland, David A. 2001. “Is Plant Breeding Science Objective Truth or Social Construction? The Case of Yield Stability.” *Agriculture and Human Values* 18:251–270.

Cleveland, David A. and Daniela Soleri (eds.). 2002. *Farmers, Scientists and Plant Breeding: Integrating Knowledge and Practice*. Wallingford, UK and New York: CABI Publishing.

Cleveland, David A., Daniela Soleri, and Steven E. Smith. 2000. “A Biological Framework for Understanding Farmers’ Plant Breeding.” *Economic Botany* 54:377–394.

Connolly, Bryan. 2004. *Wisdom of Plant Heritage: Organic Seed Production and Saving*. Organic Principles and Practices Handbook Series. Northeast Organic Farming Association. Contributing Editor: C.R. Lawn.

Cooper, Mark, Oscar Smith, Geoff Graham, Lane Arthur, Lizhi Feng, and Dean W. Podlich. 2004. "Genomics, Genetics, and Plant Breeding: A Private Sector Perspective." *Crop Science* 44:1907–1913.

Cornell University Transnational Learning. 2006. "CALS Centennial Presentations." http://www.ctl1.com/publicaccess/calscentennial/presentationlist.cfm.

Courtois, B., R.K. Singh, S. Pandey, C. Piggin, T. Paris, S. Sarkarung, V. P. Singh, H. N. Singh, A. Singh, O.N. Singh, B.V.S. Sisodia, C. H. Mishra, J. K. Roy, D. Choudhary, K Parasad, R. K. Singh, P.K. Sinha, and N. P. Mandal. 2000. "Breeding better rainfed rice varieties through farmer participation: some early lessons from eastern India." In *Proceedings of the 2nd International Seminar of the CGIAR SWP on Participatory Research and Gender Analysis in Quito, Ecuador*, CIAT, Cali, Columbia.

Cowen, Ruth Schwartz. 1983. *More work for mother*. Basic Books.

Creswell, John W. 1998. *Qualitative Inquiry and Research Design: Choosing Among Five Traditions*. Thousand Oaks, CA: Sage Publications.

Crosby, A. 1972. *Columbian Exchange: Biological and Cultural Consequences of 1492*. Westport, CT: Greenwood.

Culler, Jonathan. 1986. *Ferdinand de Saussure*. Ithaca, NY: Cornell University Press.

Dale, Virginia and Stephen Polasky. 2007. "Measures of the effects of agricultural practices on ecosystem services." *Ecological Economics* 64:286–296.

Daniel, Daniel, Jan Parlevliet, Conny Almekinders, and Graham Thiele. 2007. "Farmers' participation and breeding for durable disease resistance in the Andean region." *Euphytica* 153:385–396.

David, Sonia. 2004. "Farmer seed enterprises: A sustainable approach to seed delivery?" *Agriculture and Human Values* 21:387–397.

Dawson, Julie C., Kevin M. Murphy, and Stephen S. Jones. 2008. "Decentralized selection and participatory approaches in plant breeding for low-input systems." *Euphytica* 160:143–154.

DeGregori, Thomas R. 2004. *Origins of the Organic Agriculture Debate*. Ames, IA: Iowa State Press.

del Rio, Carlos Martinez. 2008. "Metabolic theory or metabolic models?" *Trends in Ecology and Evolution* 23:256–260.

Desclaux, D. and M. Hedont (eds.). 2006. *Proceedings of the ECO-PB Workshop: "Participatory Plant Breeding: Relevance for Organic Agriculture?"*, Paris, France. Biocivam11, INRA, ITAB, Reseau Semences Paysannes, ONIC, Conseil General de l'Aude, ITAB (Institut Technique de l'Agriculture Biologique).

Desclaux, D., J. M. Nolot, Y. Chiffoleau, E. Goze, and C. Leclerc. 2008. "Changes in the concept of genotype x environment interactions to fit agricultural diversification and decentralized participatory plant breeding: pluridisciplinary point of view." *Euphytica* 163:533–546.

Dillon, Matt. 2008. "Moving Organic Seeds Forward." In *5th Organic Seed Growers Conference Proceedings February 14-15, 2008, Salem, OR*, edited by C. Miles, M. Colley, and J. King, pp. 2–5, Port Townsend, WA. Organic Seed Alliance.

Douglas, Mary and Baron Isherwood. 1979. *The World of Goods: Towards an Anthropology of Consumption*. New York: Routledge.

DuPuis, E. Melanie and Sean Gillon. 2009. "Alternative modes of governance: organic as civic engagement:." *Agriculture and Human Values* 26:43–56.

Duram, Leslie A. and Kelli L. Larson. 2001. "Agricultural Research and Alternative Farmers' Information Needs." *Professional Geographer* 53:84–96.

Duvick, Donald N. 2004. "The Current State of Plant Breeding: How did we get here?" In *Summit Proceeding: Seeds and Breeds for 21st Century Agriculture, September 6-8, 2003 Washington D.C.*, edited by Michael Sligh and Laura Lauffer, pp. 71–84, Pittsboro, North Carolina. Rural Advancement Foundation International.

Elings, Anne. 2001. "Introduction: Why focus the thinking on participatory plant breeding?" *Euphytica* 122.

Evans, L. T. 1993. *Crop evolution, adaptation and yield*. Cambridge, UK: Cambridge University Press.

Feldman, Shelley and Rich Welsh. 1995. "Feminist Knowledge Claims, Local Knowledge, and Gender Divisions of Agricultural Labor: Constructing a Successor Science." *Rural Sociology* 60:23–43.

Finckh, M. R. 2007. "Erhaltung und Gene genetischer Ressourcen durch die Entwicklung moderner Landrassen unserer Kulturpflanzen: Wozu wir die Ko-Evolution im Feld brauchen." In *9. Wissenschaftstagung Oekologischer Landbau*. FG Oekologischer Pflanzenschutz, FB Oekologische Agrarwissehschaften, Uni Kassel.

Fitzgerald, Deborah. 1990. *The Business of Breeding: Hybrid Corn in Illinois, 1890-1940*. Ithaca, NY: Cornell University Press.

Flitner, Michael. 1995. *Sammler, Raeuber und Gelehrte: die politischen Interessen an pflanzengenetischen Ressourcen 1895-1995*. Frankfurt/New York: Campus Verlag.

Fowler, Cary and Pat Mooney. 1990. *The Threatened Gene: Food, Politics, and the Loss of Genetic Diversity*. Cambridge: The Lutterworth Press.

Fox Keller, Evelyn. 1983. *A Feeling for the Organism: The Life and Work of Barbara McClintock*. New York: W.H.Freeman and Co.

Fox Keller, Evelyn. 2007. "A clash of two cultures." *Nature* 445:603.

Frankel, O.H. and E. Bennett (eds.). 1970. *Genetic Resources in Plants–Their Exploration and Conservation*. London: Blackwell Scientific Publications.

Frey, Kenneth J. 2000. "National Plant Breeding Study–IV: Future Priorities for Plant Breeding." Special Report 102, Iowa State University.

Freyfogle, Eric T. (ed.). 2001. *The New Agrarianism: Land, Culture, and the Community of Life*. Washington: Island Press.

Fromartz, Samuel. 2006. *Organic, Inc.: Natural Foods and How They Grew*. New York: Harcourt Inc.

Fussell, Betty. 1992. *The Story of Corn*. New York: North Point Press.

Gane, Nicholas. 2006. "When We have never Been Human, What Is to Be Done? Interview with Donna Haraway." *Theory, Culture & Society* 23:135–158.

Gepts, Paul. 2006a. "Plant Genetic Resources Conservation and Utilization: The Accomplishment and Future of a Societal Insurance Policy." *Crop Science* 46:2278–2292.

Gepts, Paul. 2006b. "Plant Genetic Resources Conservation and Utilization: The Accomplishments and Future of a Societal Insurance Policy." *Crop Science* 46:2278–2292.

Gepts, Paul and Jim Hancock. 2006. "The Future of Plant Breeding." *Crop Science* 46:1630–1634.

Ghaouti, Lamiae, Werner Vogt-Kaute, and Wolfgang Link. 2008. "Development of locally-adapted faba bean cultivars for organic conditions in Germany through a participatory breeding approach." *Euphytica* 162:257–268.

Gibson, R. H., S. Pearce, R. J. Morris, W.O.C. Symondson, and J. Memmott. 2007. "Plant diversity and land use under organic and conventional agriculture: a whole-farm approach." *Journal of Applied Ecology* 44:792–803.

Gibson, Richard W., Emmanuel Byamukama, Issac Mpembe, James Kayongo, and Robert O. M. Mwanga. 2008. "Working with farmer groups in Uganda to develop new sweet potato cultivars: decentralisation and building on traditional approaches." *Euphytica* 159:217–228.

Glacken, Clarence J. 1967. *Traces on the Rhodian Shore*. Berkeley, CA: University of California Press.

Glenna, Leland L. and Raymond A. Jussaume. 2007. "Organic and conventional Washington State farmers' opinions on GM crops and marketing strategies." *Renewable Agriculture and Food Systems* 22:118–124.

Gomiero, T., M. G. Paoletti, and D. Pimentel. 2008. "Energy and Environmental Issues in Organic and Conventional Agriculture." *Critical Reviews in Plant Science* 27:239–254.

Goodman, Major M. 2004. "Plant Breeding Requirements for Applied Molecular Biology." *Crop Science* 44:1913–1914.

Griffin, Mathew R. and Edward A Frongillo. 2003. "Experiences and perspectives of farmers from Upstate New York farmers' markets." *Agriculture and Human Values* 20:189–203.

Grundens-Schuck, Nancy. 2000. "Conflict and engagement: An empirical study of a farmer-extension partnership in a sustainable agriculture program." *Journal of Agricultural and Environmental Ethics* 13:79–100.

Guthman, Julie. 2004. *Agrarian Dreams: The Paradox of Organic Farming in California*. Berkeley, CA: University of California Press.

Hackett, Edward J, Olga Amsterdamska, Michael Lynch, and Judy Wajcman (eds.). 2008. *The Handbook of Science and Technology Studies*. Cambridge, MA: MIT Press.

Hajjar, Reem and Toby Hodgkin. 2007. "The use of wild relatives in crop improvement: A survey of developments over the last 20 years." *Euphytica* 156:1–13.

Hall, Clare, Alistair McVittie, and Dominic Moran. 2004. "What does the public want from agriculture and the countryside? A review of the evidence and methods." *Journal of Rural Studies* 20:211–225.

Hammer, K. and Y. Teklu. 2008. "Plant Genetic Resources: Selected Issues from Genetic Erosion to Genetic Engineering." *Journal of Agriculture and Rural Development in the Tropics and Subtropics* 109:15–50.

Haraway, Donna. 1991. *Simians, Cyborgs and Women: The Reinvention of Nature*, chapter A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century. London: Free Association Books.

Haraway, Donna. 1999. *The Science Studies Reader*, chapter Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective, pp. 172–201. New York: Routledge.

Haraway, Donna J. 1997. *Modest Witness@Second Millennium. FemaleMan Meets OncoMouse: Feminism and Technoscience*. New York: Routledge.

Harding, Sandra. 1986. *The Science Question in Feminism*. Ithaca, NY: Cornell University Press.

Harding, Sandra (ed.). 1987. *Feminism and Methodology: Social Science Issues*. Bloomington, IN: Indiana University Press.

Harding, Sandra. 1991. *Whose Science? Whose Knowledge?* Ithaca, NY: Cornell University Press.

Harding, Sandra (ed.). 2004. *The Feminist Standpoint Theory Reader: Intellectual and Political Controversies*. New York: Routledge.

Harding, Sandra and Kathryn Norberg. 2005. "New Feminist Approaches to Social Science Methodologies: An Introduction." *Signs* 30:2009–2017.

Harlan, H. V. and M.L. Martini. 1936. "Problems and results in barley breeding." Technical report, USDA.

Harlan, J. R. 1971. "Genetics of disaster." *Journal of Environmental Quality* 1:212–215.

Harlan, J. R. and J.M.J de Wet. 1971. "Towards a rational classification of cultivated plants." *Taxon* 20:509–517.

Hartstock, Nancy. 1987. *Feminism and Methodology: Social Science Issues*, chapter The Feminist Standpoint: Developing the Ground for a Specifically Feminist Historical Materialism. Indiana University Press.

Hassanein, Neva. 1997. "Networking Knowledge in the Sustainable Agriculture Movement: Some Implications of the Gender Dimension." *Society and Natural Resources* 10:251–257.

Hassanein, Neva. 2003. “Practicing food democracy: a pragmatic politics of transformation.” *Journal of Rural Studies* 19:77–86.

Hawkes, J. G., N. Maxted, and B. V. Ford-Lloyd. 2000. *The Ex Situ Conservation of Plant Genetic Resources*. Kluwer Academic Publishers.

Henderson, Elizabeth and Karl North. 2004. *Whole Farm Planning: Ecological Imperatives, Personal Values and Economics*. Organic Principles and Practices Handbook Series. Barre, MA: Northeast Organic Farming Association.

Henke, Christopher R. 2006. *The New Political Sociology of Science: Institutions, Networks, and Power*, chapter Changing Ecologies: Science and Environmental Politics in Agriculture, pp. 215–243. Madison, WI: The University of Wisconsin Press.

Hesse-Biber, Sharlene Nagy and Patricia Lina Leavy (eds.). 2007. *Feminist Research Practice*. Sage Publications.

Hobhouse, Henry. 1985. *Seeds of Change*. New York: Harper and Row.

Hole, D. G., A.J. Perkins, J. D. Wilson, I. H. Alexander, P.V. Grice, and A.D. Evans. 2004. “Does organic farming benefit biodiversity?” *Biological Conservation* 122:113–130.

Howard, Patricia (ed.). 2003. *Women and Plants: Gender Relations in Biodiversity Management and Conservation*. London and New York: Zed Books Ltd.

Howard, Sir Albert. 2006 (original publication date 1947). *The Soil and Health: A Study of Agriculture*. The University Press of Kentucky.

Hunt, Alan R. 2007. “Consumer interactions and influences on farmers’ market vendors.” *Renewable Agriculture and Food Systems* 22:54–66.

Irwin, Alan. 1995. *Citizen Science: A Study of People, Expertise and Sustainable Development*. London and New York: Routledge.

Jain, H. K. and M. C. Kharkwal (eds.). 2004. *Plant Breeding: Mendelian to Molecular Approaches*. Boston/Dordrecht/London: Kluwer Academic Publishers and Narosa Publishing House.

Jeffrey, Paul. 2003. “Smoothing the Waters: Observations on the Process of Cross-Disciplinary Research Collaboration.” *Social Studies of Science* 33:539–562.

J.G.Hawkes, N. Maxted, and B.V.Ford-Lloyd (eds.). 2000. *The Ex Situ Conservation of Plant Genetic Resources*. Dordrecht/Boston/London: Kluwer Academic Publishers.

Jones, Stephen and Kevin Murphy. 2008. “Strategies for Plant Breeding in the Public Interest.” In *5th Organic Seed Growers Conference Proceedings*, edited by C. Miles, M. Colley, and J. King, p. 107, Port Townsend, WA. Organic Seed Alliance.

Jordan, Jennifer A. 2007. “The Heirloom Tomato as Cultural Object: Investigating Taste and Space.” *Sociologia Ruralis* 47:20–41.

Joshi, K. D., B. R. Sthapit, and J. R. Witcombe. 2001. “How narrowly adapted are the products of decentralised breeding? The spread of rice varieties from a participatory plant breeding programme in Nepal.” *Euphytica* 122:589–597.

Kass, Lee B. 2003. “Records and Recollections: A new Look at Barbara McClintock, Nobel-Prize-Winning Geneticist.” *Genetics* 164:1251–1260.

Katz, Sandor Ellix. 2006. *The Revolution Will Not be Microwaved: Inside America’s Underground Food Movements*. White River Junction, VT: Chelsea Green Publishing.

Kelkar, Meghana. 2007. “Local Knowledge and Natural Resource Management: A Gender Perspective.” *Indian Journal of Gender Studies* 14:295–306.

Khlestkina, E. K., X. Q. Huang, F. J.B. Quenum, S. Chebotar, M. S. Roeder, and A. Boerner. 2004. “Genetic Diversity in cultivated plants–loss or stability?” *Theoretical Applications of Genetics* 108:1466–1472.

Kleinman, Daniel Lee. 2003. *Impure Culture: University Biology and the World of Commerce*. Madison, WI: The University of Wisconsin Press.

Kloppenburg, Jack. 1991. “Social theory and the De/Reconstruction of Agricultural Science: Local Knowledge for an Alternative Agriculture.” *Rural Sociology* 56:519–548.

Kloppenburg, Jack. 2004. *First the Seed: The Political Economy of Plant Biotechnology*. Madison, WI: The University of Wisconsin Press, second edition.

Kloppenburg, Jack and Neva Hassanein. 2006. “From old school to reform school?” *Agriculture Food and Human Values* 23:417–421.

Knight, Jonathan. 2003. “A Dying Breed.” *Nature* 421:568–570.

Kotschi, Johannes. 2008. “Transgenic Crops and Their Impact on Biodiversity.” *GAIA* 17:36–36–41.

Latour, Bruno. 1999a. *Pandora’s Hope: Essays on the Reality of Science Studies*. Boston: Harvard University Press.

Latour, Bruno. 1999b. *The Science Studies Reader*, chapter Give me a Laboratory and I Will Raise the World, pp. 258–275. New York: Routledge.

Latour, Bruno. 2005. *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford and New York: Oxford University Press.

Law, John (ed.). 1991. *A Sociology of Monsters: Essays on Power, Technology and Domination*. New York: Routledge.

Law, John. 2002. *Aircraft Stories: Decentering the Object in Technoscience*. Durham, NC: Duke University Press.

Lawrence, George H. M. 1955. *An Introduction to Plant Taxonomy*. The Macmillan Company.

Levkoe, Charles Z. 2006. “Learning democracy through food justice movements.” *Agriculture and Human Values* 23:89–98.

Lien, Gudbrand, J. Brian Hardaker, and Ola Flaten. 2007. “Risk and economic sustainability of crop farming systems.” *Agricultural Systems* 94:541–552.

Lindner, Bob. 2004. “Privatised provision of essential plant breeding infrastructure.” *The Australian Journal of Agricultural and Resource Economics* 48:301–321.

Longino, Helen E. 2002. *The Fate of Knowledge*. Princeton, NJ: Princeton University Press.

Lumsden, Karen. 2009. “’Don’t Ask a Woman to do Another Woman’s Job’: Gendered Interactions and the Emotional Ethnographer.” *Sociology* 4:497–513.

Mahoney, James. 2000. "Path dependence in historical sociology." *Theory and Society* 29:507–548.

Mangione, D., S. Senni, M. Puccioni, S. Grando, and S. Ceccarelli. 2006. "The cost of participatory barley breeding." *Euphytica* 150:289–306.

Marshall, D. R. 1977a. "The Advantages and Hazards of Genetic Homogeneity." *Annals of the New York Academy of Sciences* 287:1–20.

Marshall, D. R. 1977b. "The Advantages and Hazards of Genetic Homogeneity." *Annals of the New York Academy of Sciences* pp. 1–18.

Martin, Deborah L. and Grace Gershuny (eds.). 1992. *The Rodale Book of Composting*. Emmaus, PA: Rodale Press.

Mascarenhas, Michael and Lawrence Busch. 2006. "Seeds of Change: Intellectual Property Rights, Gene Modified Soybeans and Seed Saving in the United States." *Sociologia Ruralis* 45:122–138.

Mayo, Oliver. 1987. *The Theory of Plant Breeding*. Oxford, UK: Clarendon Press.

Mayr, Ernst. 1982. *The growth of biological thought: diversity, evolution, and inheritance*. Belknap Press.

McGrayne, S. B. 1993. *Nobel Prize Women in Science: Their lives, Struggles, and Momentous Discoveries*. Carol Publishing Group.

McNeely, Jeffrey A. and Sara J. Scherr. 2003. *Ecoagriculture: Strategies to Feed the World and Save Wild Biodiversity*. Washington: Island Press.

Miles, C., M. Colley, and J. King (eds.). 2008. *5th Organic Seed Growers Conference Proceedings*, Organic Seed Alliance PO Box 772 Port Townsend, WA 98368. Organic Seed Alliance Oregon State University Washington State University.

Mintz, Sidney. 1986. *Sweetness and Power: The place of sugar in the modern world*. Penguin Books.

Montmarquet, James A. 1989. *The Idea of Agrarianism from Hunter-Gatherer to Agrarian Radical in Western Culture*. Moscow, IA: University of Idaho Press.

Moose, Stephen P. and Rita H. Mumm. 2008. "Molecular Plant Breeding as the Foundation for 21st Century Crop Improvement." *Plant Physiology* 147:969–977.

Morgan, Kevin and Jonathan Murdoch. 2000. "Organic vs. conventional agriculture: knowledge, power and innovation in the food chain." *Geoforum* 31:159–173.

Morris, Michael, Greg Edmeades, and Eija Pebu. 2006. "The Global Need for Plant Breeding Capacity: What Roles for the Public and Private Sector." *Horticultural Science* 41:30–39.

Morris, Michael L. and Mauricio R. Bellon. 2004. "Plant breeding research: Opportunities and challenges for the international crop improvement system." *Euphytica* 136:21–35.

Morris, M. L. and P. W. Heisey. 2003. "Estimating the benefits of plant breeding research: methodological issues and practical challenges." *Agricultural Economics* 29:241–252.

Murphey, Kevin, Doug Lammer, Steve Lyon, Brady Carter, and Stephan S. Jones. 2004. "Breeding for organic and low-input farming systems: An evolutionary–participatory breeding method for inbred cereal grains." *Renewable Agriculture and Food Systems* 20:48–55.

N. I. Vavilov Research Institute for Plant Industry. 2009. "Official website of the N. I. Vavilov Research Institute for Plant Industry." http://www.vir.nw.ru/.

Nabhan, Gary Paul. 1989. *Enduring Seeds: Native American Agriculture and Wild Plant Conservation*. Tucson, AZ: The University of Arizona Press.

National Science Foundation. 2009a. http://www.nsf.gov/.

National Science Foundation. 2009b. "National Science Foundation Website." http://www.nsf.gov/pubs/2008/nsf08070/nsf08070.jsp.

Navazio, John P. 2008. "Participatory Approaches to Breeding Organic Crop Varieties for Genetic Resiliency." In *Proceedings of the 2008 Organic Seed Grower's Conference*, edited by Micaela Colley, pp. 86–93, Port Townsend, WA.

Nazarea, Virginia D. (ed.). 1999. *Ethnoecology: situated Knowledge/located lives*. Tucson, AZ: University of Arizona Press.

Nazarea, Virginia D. 2005. *Heirloom Seeds Their Keepers: Marginality and Memory in the Conservation of Biological Diversity*. Tucson, AZ: University of Arizona Press.

Nazrea, Virginia D. 1998. *Cultural Memory and Biodiversity*. Tucson: University of Arizona Press.

Nerbonne, Julia Frost and Ralph Lentz. 2003. "Rooted in grass: Challenging patterns of knowledge exchange as a means of fostering social change in a southeast Minnesota farm community." *Agriculture and Human Values* 20:65–78.

Nestle, Marion. 2002. *Food Politics*. Berkeley, CA: University of California Press.

Nobel Prize Foundation. 2009. "The Nobel Prize in Physiology or Medicine 1983." http://nobelprize.org/nobel_prizes/medicine/laureates/1983/index.html.

Norton, Lisa, Paul Johnson, Andrew Joys, Rick Stuart, Dan Chamberlain, Ruth Feber, Les Firbank, Will Manley, Martin Wolfe, Barbara Hart, Fiona Mathews, David Macdonald, and Robert J. Fuller. 2009. "Consequences of organic and non-organic farming for field, farm and landscape complexity." *Agriculture Ecosystems & Environment* 129:221–227.

O.H.Frankel. 1974. "Genetic Conservation: Our Evolutionary Responsibility." *Genetics* 78:53–65.

Penley, Constance and Andrew Ross (eds.). 1991. *Technoculture*. Minneapolis: University of Minnesota Press.

Peters, Christian J., Jennifer L. Wilkins, and Gary W. Fick. 2006. "Testing a complete-diet model for estimating the land resource requirements of food consumption and agricultural carrying capacity: The New York State example." *Renewable Agriculture and Food Systems* 22:145–153.

Pistorius, Robin and Joeren van Wijk. 1999. *The Exploitation of Plant Genetic Information: Political Strategies in Crop Development*. New York: CABI Publishing.

Pollan, Michael. 2001. *The Botany of Desire: A Plant's-Eye View of the World*. New York: Random House.

Purdue, Derrick A. 2000. "Backyard Biodiversity: Seed Tribes in the West of England." *Science as Culture* 9:141–166.

Ransom, Callista, Chrislyn Paticka, Kaori Ando, and Jim Olmstead. 2006. "Report of Breakout Group 1. What Kind of Training do Plant Breeders Need, and How Can We Most Effectively Provide that Training?" *Horticultural Science* 41:53–54.

Rausser, Gordon and Holly Ameden. 2004. "Public-private partnerships needed in horticultural research and development." *California Agriculture* 58:116–119.

Reese, J. David and Ejnavarzala Haribabu. 2007. "Genes to feed the world: The weakest link?" *Food Policy* 32:459–479.

Reinstaller, Andreas and Werner Holzl. 2009. "Big causes and small events: QWERTY and the mechanization of office work." *Industrial and Corporate Change* pp. 1–33.

Ronald, Pamela C. and Raoul W. Adamchak. 2008. *Tomorrow's Table: Organic Farming, Genetics, and the Future of Food*. Oxford University Press.

Rose, Hilary. 1983. "Hand, Brain, and Heart: A feminist Epistemology for the Natural Sciences." *Signs* 9:73–90.

Rosenberg, Charles E. 1961. *No Other Gods: On Science & American Social Thought*. Baltimore and London: The Johns Hopkins University Press.

Rowe, Gene and Lynn J. Frewer. 2000. "Public Participation Methods: A Framework for Evaluation." *Science, Technology and Human Values* 25:3–29.

Runge, C. Ford and Edi Defrancesco. 2006. "Exclusion, Inclusion, and Enclosure: Historical Commons and Modern Intellectual Property." *World Development* 34:1713–1727.

Scherr, Sara J. and Jefferey A. McNeely. 2008. "Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'ecoagriculture' landscapes." *Philosophical Transactions of the Royal Society of Biological Sciences* 363:477–494.

Serageldin, I. and G.J. Persley (eds.). 2003. *Biotechnology and Sustainable Development: Voices of the South and North*. Oxford and New York: CABI Publishing.

Shiva, Vandana. 1993. *Monocultures of the Mind: Perspectives on Biodiversity and Biotechnology*. London: Zed Books Ltd.

Shiva, Vandana. 2007. *Manifestos on the Future of Food and Seed*. Cambridge, MA: South End Press.

Shiva, Vandana and Ingunn Moser (eds.). 1995. *Biopolitics: A Feminist and Ecological Reader in Biotechnology*. London and New Jersey: Zed Books Ltd.

Slaughter, Sheila and Gary Rhoades. 2004. *Academic Capitalism and the New Economy: Markets, State, and Higher Education*. Baltimore: The Johns Hopkins University Press.

Sligh, Michael and Carolyn Christman. 2007. "Issues Paper: Organic Agriculture and Access to Food." Rural Advancement Foundation International, FAO Inter-Departmental Working Group on Organic Agriculture.

Smale, Melinda. 1997. "The Green Revolution and Wheat Genetic Diversity: Some Unfounded Assumptions." *World Development* 25:1257–1269.

Smale, M. (ed.). 2006. *Valuing Crop Biodiversity: On-farm Genetic Resources and Economic Change*. Cambridge, MA: CABI Publishing.

Smale, M., M. P. Reynolds, M. Warburton, B. Skovmand, R. Trethowan, R.P. Singh, I. Ortiz-Monasterio, and J. Crossa. 2002. "Dimensions of Diversity in Modern Spring Bread Wheat in Developing Countries from 1965." *Crop Science* 42:1766–1779.

Smith, Bruce D. 1995. *The Emergence of Agriculture*. New York: Scientific American Library.

Smith, Dorothy E. 1987. *The Everyday World as Problematic: A Feminist Sociology*. Boston: Northeastern University Press.

Smith, Dorothy E. 2005. *Institutional Ethnography: A Sociology for People*. New York: AltaMira Press.

Smith, Miranda and Elizabeth Henderson (eds.). 1998. *The Real Dirt: Farmers Tell About Organic and Low-Input Practices in the Northeast*. Burlington, VT: Northeast Organic Farming Association.

Sperling, L., J.A. Ashby, M. E. Smith, E. Weltzien, and S. McGuire. 2001. "A framework for analyzing participatory plant breeding approaches and results." *Euphytica* 122:439–450.

Stock, Paul V. 2007. "'Good Farmers' as Reflexive Producers: an Examination of Family Organic Farmers in the US Midwest." *Sociologia Ruralis* 47:83–102.

Stoskopf, Neal C., Dwight T. Tomes, and B.R. Christie. 1993. *Plant Breeding: Theory and Practice*. Boulder, CO: Westview Press.

Straub, Cory S., Deborah L. Finke, and William E. Snyder. 2008. "Are the conservation of natural enemy biodiversity and biological control compatible goals?" *Biological Control* 45:225–237.

Taylor, Michele E. and Michael D. Morecroft. 2009. "Effects of agri-environment schemes in a long-term ecological time series." *Agriculture Ecosystems and Environment* 130:9–15.

Terpstra, Karolyn, Hesham Oraby, and Veronica Vallejo. 2006. "Report of Breakout Group 3: How can Public and Private Sectors Most Effectively Partner to Train new Generations of Plant Breeders?" *Horticultural Science* 41:58.

Thro, Ann Marie, Wayne Parrott, Joshua A. Udall, and William D. Bevis (eds.). 2004. *Genomics and Plant Breeding: The Experience of the Initiative for Future Agricultural and Food Systems*, volume 44. Crop Science.

Tracy, William F. 2003. "What is Plant Breeding?" In *Summit Proceedings: Seeds and Breeds for 21st Century Agriculture*, edited by Michael Sligh and Laura Lauffer, pp. 23–30, Pittsboro, NC. Rural Advancement Foundation International.

Tscharntke, Teja, Alexandra M. Klein, Andreas Kruess, Ingolf Steffan-Dewenter, and Carsten Thies. 2005. "landscape perspectives on agricultural intensification and biodiversity–ecosystem service management:." *Ecology Letters* 8:857–874.

van Bueren, Edith Lammert. 2008. "Concepts and Values in Organic Breeding." In *5th Annual Organic Seed Growers Conference Proceedings. February 14-15, 2008, Salem, OR*, edited by C. Miles, M. Colley, and J. King, pp. 7–13, Port Townsend, WA. Organic Seed Alliance.

van Doorn, Thom. 2008. "Terminated Seed: Death, Proprietary Kinship and the Production of (Bio)Wealth." *Science as Culture* 16:71–94.

van Eeuwijk, F. A., M. Cooper, L. H. DeLacy, S. Ceccarelli, and S. Grando. 2001. "Some vocabulary and grammar for the analysis of multi-environment trials, as applied to the analysis of FPB and PPB trials." *Euphytica* 122:477–490.

van Wijk, Jeroen. 1998. "Plant Patenting Provision Reviewed in WTO." *Biotechnology and Development Monitor* pp. 6–9.

Vavilov, N. I. 1992. *Origin and Geography of Cultivated Plants*. Cambridge, UK: Cambridge University Press, translated by doris loeve edition.

Vernooy, Roonie. 2003. *Seeds that Give: Participatory Plant Breeding*. in focus. Ottowa, Canada: International Development Research Centre.

Wajcman, Judy. 2004. *TechnoFeminism*. Cambridge, UK and Malden, MA: Polity Press.

Warner, Keith Douglass. 2005. "Extending agroecology: Grower participation in partnerships is key to social learning." *Renewable Agriculture and Food Systems* 21:84–94.

Warner, Keith Douglass. 2008. "Agroecology as Participatory Science: Emerging Alternatives to Technology Transfer Extension Practice." *Science, Technology and Human Values* 33:754–777.

Weebadde, Cholani and Clarice Messah. 2006. "Report of Breakout Group 2. How Will We Provide Improved Varieties of Specialty Minor and Subsistence Crops in the Future?" *Horticultural Science* 41:55.

Welsch, Rich and Leland Glenna. 2006. "Considering the Role of the University in Conducting Research on Agri-biotechnologies." *Social Studies of Science* 36:929–942.

Whealy, Kent and Arllys Adelmann (eds.). 1986. *Seed Savers Exchange: The First Ten Years 1975-1985*. Decorah, IA: Seed Savers Publications.

Whelan, Emma. 2001. "Politics by Other Means: Feminism and Mainstream Science Studies." *Canadian Journal of Sociology* 26:535–581.

Wieland, Thomas. 2006. "Scientific Theory and Agricultural Practice: Plant Breeding in Germany from the Late 19th to the Early 20th Century." *Journal of the History of Biology* 39:309–343.

Wilson, E.O. 1992. *The Diversity of Life*. London: Penguin Press.

Witcombe, John and Arun Joshi. 1996. "Farmer participatory approaches for varietal breeding and selection and linkages to the formal seed sector." In *Participatory plant breeding. Proceedings of a workshop on participatory plant breeding.*, edited by P. Eyzaguire and M. Iwanaga, pp. 57–65, Rome, Italy. IPGRI.

Witcombe, J. R., K. D. Joshi, S. Gyawali, A. M. Musa, C. Johansen, D.S. Virk, and B. R. Sthapit. 2005. "Participatory Plant Breeding is Better Described As Highly Client-Oriented Plant Breeding. Four Indicators of Client-Orientation in Plant Breeding." *Experimental Agriculture* 41:299–319.

Witcombe, J. R. and D. S. Virk. 2001. "Number of crosses and population size for participatory and classical plant breeding." *Euphytica* 122:451–462.

Wood, David and Jillian M. Lenne. 1997. "The conservation of agrobiodiversity on-farm: questioning the emerging paradigm." *Biodiversity and Conservation* 6:109–129.

Wyatt, Sally. 2008. *The Handbook of Science and Technology Studies*, chapter Technological Determinism Is Dead; Long Live Technological Determinism, pp. 165–180. Cambridge, MA: MIT Press, third edition.

Wynne, Brian. 2002. "Risk and Environment as Legitimatory Discourses of Technology: Reflexivity Inside Out?" *Current Sociology* 50:459–477.

Zeven, A. C. 1998. "Landraces: A review of definitions and classifications." *Euphytica* 104:127–138.

Zeven, A. C. 1999. "The traditional inexplicable replacement of seed and seed ware of landraces and cultivars: A review." *Euphytica* 110.

Zimmerer, Karl S. 1996. *Changing Fortunes: Biodiversity and Peasant Livelihood in the Peruvian Andes*. Berkeley: University of California Press.

Vita: Ruth M. Mendum

Education

August 2009	PhD Rural Sociology and Women's Studies, The Pennsylvania State University Defense : March 27, 2009
1988	MA German Literature, European History and Women's Studies emphasis, Cornell University
1986-1987	Graduate Exchange Student, Free University of Berlin
1984	BA with honors, German Languages and Literatures, University of Virginia

Academic Awards

- Gamma Sigma Delta, The Honor Society of Agriculture, 2009
- Public Scholarship Fellow, Penn State University, 2008 Participated in a year-long colloquium on the topic: A Capacity to Sustain Democracy
- Women's Studies Graduate Student Award, Penn State College of the Liberal Arts, 2008 Awarded in recognition of outstanding teaching and research in Women's Studies.
- Tag-Along Fund Travel Grant, Penn State College of Agricultural Sciences, 2005 Granted in support of research in Mexico in coordination with the state of Chihuahua and the Tarahumara people.
- National Endowment for the Humanities Summer Institute, Summer 1999 The Writing of African American Identity: Self, Race, and Gender

Administrative Experience

- August 2008—present, Director, University Fellowships Office, Penn State University
- Faculty Liaison, University Office of International Programs, The Pennsylvania State University, 2000-2008.
- Marketing and Public Relations, Scientific American Magazine, New York, NY, January 1994–January 1998