Evaluating for Resilience: Participatory variety trials and seed systems for Wisconsin's organic farms

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Evaluating for Resilience:
Participatory Variety Trials and Seed Systems
for Wisconsin’s Organic Vegetable Farms

By
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ABSTRACT

Crop varieties that are well-adapted to the environmental and social specifications of organic agriculture are key to improving sustainability and resilience in these farming systems. Variety trials are an important way to evaluate the suitability of existing commercial varieties for organic agriculture, and are a necessary step in plant breeding. However, observation on research stations, even on certified organic ground, is not sufficient to accurately assess variety performance because histories of management result in different environmental pressures on research stations than on organic farms, and because farmers’ experiential knowledge is an essential part of organic cropping systems. On-farm trials and farmer collaboration are therefore highly sought in organic plant breeding and variety trialing projects, but the physiology of fresh vegetable crops complicates evaluation at multiple farm sites. In order to effectively focus research efforts, more information is needed not only about participatory trailing designs, but also about farmers’ priorities and perceived challenges with respect to organic seed systems.

This dissertation addresses these issues in the context of Wisconsin, through three distinct research projects using different methodological approaches. This research arose in part from on-farm variety trials with researchers and organic farmers in four states, in a variety trialing network known as the Northern Organic Vegetable Improvement Collaborative (NOVIC). First, we conducted a state-wide survey of organic vegetable growers, soliciting their opinions about organic seed and plant breeding. We found that growers had more difficulty accessing satisfactory genetics than seed quality, and that seed access was more problematic for growers with larger farming operations. Diverse plant breeding priorities, combined with prevalent variety trialing and seed saving, suggest a good fit with participatory plant breeding. Second, we use adaptability analysis to characterize the
response of varieties in the NOVIC trials to a range of environments. A promising tool for participatory trials, adaptability analysis showed that some varieties were broadly adapted while others were specifically adapted to low- or high-yielding environments. Better methods are still needed, though, for evaluating non-yield traits such as flavor and appearance, key for organic markets. Third, we use a qualitative case study approach based on farmer interviews to contextualize survey findings about farmers’ seed decisions and draw out their opinions about variety adaptation. Taken together, these multi-disciplinary research projects suggest ways to resolve some of the challenges inherent in on-farm trialing of organic vegetable crops and provide insights into the ways that organic farmers are responding to challenges in the seed system.
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Introduction

In the Annual Proceedings of the Wisconsin State Horticultural Society, 1919, an article entitled “Truck Farming on Ten Acres” offers encouraging advice for any “young man” considering a future in commercial fresh vegetable production. The author, J.W. Roe of Oshkosh, writes that “Wisconsin offers as great inducements to the truck gardeners and small fruit grower as any of the states,” with nearby markets that “will take anything from a dozen eggs to a bunch of green onions.” He goes on to advise prospective truck farmers to grow a wide selection of vegetables in order to minimize the risk of losses due to any particular seasonal threat, to plant nitrogenous cover crops such as clover and alfalfa, and “to trust Wisconsin soil” (1919, 23). With roots in the French *troquer* (to exchange or barter), “truck” has been used in American English to refer to fruits and vegetables grown for commercial sale since long before the motorized vehicle of the same name became a fixture of rural life (Robinson and Davidson 2001). Throughout the 19th century, truck farms developed on the outskirts of metropolitan areas, where farmers could transport fresh goods to urban markets. With the advent of refrigerated shipping, truck farms began marketing produce further and further away, until current trends such as the local foods movement began to create new opportunities for market gardens and farms that serve local metropolitan areas (Ingerson-Maher 2004).

Though Wisconsin’s organic vegetable farmers in the 21st century utilize new agronomic science and respond to different cultural and economic forces, in many ways they still follow the advice given to the ten-acre truck farm: building soil fertility through agronomic management, diversifying their assortment of cash crops, and depending on direct
marketing to urban and suburban consumers. Wisconsin is now one of the top states in the United States for organic farming, including organic vegetable production. It has the second-highest number of organic farms of any state with 1,180 farms and $121,527,000 in sales according to the 2012 Census of Agriculture, and the fourth-highest number of organic vegetable and melon farms, with 161 farms (USDA-NASS 2012). Wisconsin’s organic sector is growing, with the number of certified organic farms increasing by 77% between 2005 and 2015 (Carusi et al. 2015). Organic farms in general are much more likely than conventional farms to sell directly to customers through farmers’ markets, farm stands, or membership shares, or to market products to regional retail and grocery outlets, as opposed to national distributors. Wisconsin’s organic sector follows this national trend (Carusi et al. 2015). Many organic vegetable farms in Wisconsin are also comparable in size to the farm Roe describes, with 75% of organic vegetable farms planting less than 12 acres in 2012. As was the goal of the ten acre truck farm, organic vegetable farms in Wisconsin have a high level of financial self-sufficiency, and 40% of them provide the sole source of income for the farmers who operate them (Silva et al. 2012, 19–20). Farmers on Wisconsin’s organic vegetable farms tend to be young compared to other farmers, and to have been farming for fewer years. In other ways, many things have changed—not least that women are now the primary farm operators on 10.6% of Wisconsin’s organic farms (Carusi et al. 2015, 9).

In order to understand today’s organic vegetable sector in Wisconsin, it is helpful to examine some of the developments that have contributed to its growth. Organic agriculture in this region benefits from a northern, temperate climate in which cold winters disrupt the lifecycles of pests that can trouble organic production in warmer climates. Wisconsin soils also include some of the rich mollisols responsible for the unprecedented agricultural productivity found throughout the Midwestern United States. Differentiating Wisconsin from the Corn Belt, though, is the unique geography which has made the state a haven for organic
and small scale production. In Wisconsin, organic agriculture is most heavily distributed in hill-and-valley terrain of the unglaciated Driftless Area, which stretches along both sides of the Mississippi River from Dubuque, Iowa in the south to Lacrosse, Wisconsin, in the north, also including parts of Illinois, Iowa, and Minnesota. Though this area includes areas fertile savannah soil, its steep hillsides and coulees have impeded the agricultural intensification and monoculture production that dominates the rest of the Midwest. Lower land prices resulting from these constraints attracted farmers interested in alternative approaches and a smaller scale, including counterculture-inspired homesteaders in the 1960s and 70s and Amish families in the 1970s through 1990s (Lyons 2015; Cross 2004). Though organic agriculture can now be found throughout Wisconsin, the geology and culture of the Driftless Area must be recognized in its early growth and its strength today.

Some the organic sector’s strength in Wisconsin can also be attributed to the contributions of farmers, scientists, and organizers who began making connections between agriculture and conservation as early as Roe’s article on truck farming in 1919. At that time, Franklin Hiram King, Professor of Agricultural Physics at the University of Wisconsin-Madison, was already working on his treatise on “permanent agriculture,” describing traditional farming practices to renew soil fertility through crop rotations and manure applications (King 1911). His writings informed the early pioneers of the organic movement including Lady Eve Balfour, and later inspired the term “permaculture” (Paull 2011).

Meanwhile, from the 1920s through the 1940s, UW-Madison professor Aldo Leopold began making the case for farmers’ roles in the conservation of natural landscapes, and the role of conservation in farmers’ quality of life (Meine 1987). The writings of both Leopold and F. H. King became more influential after the authors’ deaths, when they were embraced by the environmental movement of the 1960s. A key Wisconsin contribution to that movement was Senator Gaylord Nelson’s successful campaign to ban DDT in the United States (Blobaum
1966), though Leopold’s ideas are reflected even more clearly in Nelson’s work for farm conservation payments (Congressional Record 1965).

Organic farming as a widespread farmer and consumer movement emerged in the early 1970s, drawing on some of the writings above and strongly influenced by J.I. Rodale’s work in Pennsylvania, developing “non-chemical” farming methods that would become the foundation of modern organic practices (Rodale 1945). Many of the first organic farmers in the Upper Midwest came from farming families and grew corn, soybeans, and small grains (Blobaum 2015), contrary to the back-to-the land image of early organic farming. At the same time, natural foods buying clubs and cooperatives in Madison, Milwaukee, and Minneapolis began to bring organic products to urban consumers, including beef and other goods produced by farmers in the region (Blobaum 2015; Wedge Community Co-op 2015; Willy Street Co-op 2013). The Dane County Farmers’ Market, still the largest producers-only farmers’ market in the U.S., opened in 1974 and provided another market venue of local organic vegetable producers (Dane County Farmers’ Market 2015).

The late 1980s and 1990s saw further organization of the organic movement in the Upper Midwest, including the entrance of three organizations that remain central to organic vegetable production in the region: the Madison Area Community Supported Agriculture Coalition (MACSAC), the Midwest Organic and Sustainable Education Service (MOSES), and the Coulee Region Organic Produce Pool (CROPP). The concept of Community Supported Agriculture (CSA) was brought to the United States from Germany in the mid-1980s by two farms in New England, who offered customers the opportunity to invest in the farm through a membership fee (and sometimes shared labor) in return for produce (McFadden 2004). In 1993, eight CSA farms were launched in the Madison area with support from a group of local foods advocates who would go on to found MACSAC, a grassroots organization that provided training, extension outreach, and marketing support to organic
CSA farms, almost entirely vegetable producers (Hendrickson 2015). This organization
(which changed its name to FairShare CSA Coalition in 2012) presently serves 50 farms and
over 25,000 CSA customers throughout Wisconsin and is a strong force for promoting
organic vegetable production in the state. Another influential organization in the development
of organic vegetable production in Wisconsin has been MOSES, which provides further
training, outreach, and field days, and is best known for its annual Organic Farming
Conference held in Lacrosse, WI. This conference provides farmer-to-farmer education and
builds community among organic farmers across the country, and it has been instrumental in
training many organic vegetable producers in the region. Starting in 1990 with 90 farmer
participants, the conference now regularly draws over 3,000 attendees and is the largest
organic farming conference in the U.S. Additionally, in 1988 a group of small-scale farmers
in the Wisconsin section of the Driftless Area formed a cooperative to market organic
vegetables, the Coulee Region Organic Produce Pool (CROPP). In 2001, reflecting its growth
and expanded geographical reach, the group changed its name to Cooperative Regions of
Organic Producer Pools. Best known today for its dairy label, Organic Valley, CROPP is now
the largest organic dairy cooperative in the country, with over 1,800 member farms in 34
states, Canada, and Australia. Though focused primarily on meat and dairy, CROPP also
serves as a wholesale distributor for organic produce, buying 50 varieties of vegetables from
producers in Wisconsin and other states (Trussoni and McGeorge 2013). In addition to
providing an important wholesale market for organic vegetables in the region, the cooperative
has had a substantial impact in raising the visibility of organic agriculture throughout
Wisconsin and providing financial support for research and conferences.

Though initially met by resistance from the United States Department of Agriculture
(USDA) and from land-grant universities, organic agriculture is now the subject of a growing
body of formal research (Sooby, Landneck, and Lipson 2007). One essential area of research
and development in which organic agriculture is notably underserved is plant breeding. Research increasingly demonstrates that organic farms represent distinct growing environments from conventional farms and can benefit from crop varieties that are bred for adaptation to the conditions of organic rather than conventional farming (Lammerts van Bueren and Myers 2012). Because organic farmers do not use conventional methods that offer more immediate control over the environment, such as chemical fertilizers and pesticides, organic systems tend to experience more environmental variation, both among farms and from year-to-year on the same farm (Przystalski et al. 2008; Drinkwater et al. 1995). Unpredictable year-to-year variation certainly characterizes Wisconsin climate patterns—as J.W. Roe put it, “Owing to the perversity of our growing season, no man can figure on a sure thing” (1919, 42). Moreover, due to climate change, farmers can expect weather to become increasingly unpredictable in the future. Under such conditions, adaptation to variability will be an important tool for withstanding production challenges of all kinds (Smit et al. 2000).

For well-adapted varieties to become more available to organic farmers, a number of prerequisites must be addressed. First, plant breeding programs in both the public and private sectors must be employed to improve crop varieties with the traits most needed by organic farmers. Plant breeding for organic agriculture benefits from on-farm research, including not only on-farm selection, but variety testing in both the early and late stages of breeding (Haussmann et al. 2012). Farmers also need information about the performance of existing varieties in organic environments. This leads to two specific needs:

1. Improved methods to evaluate the performance of new and existing varieties on organic farms, including ways of involving organic farmers’ knowledge and experience in scientific research.
2. Improved understanding of the strengths and weaknesses of the seed system from farmers’ points of view, as well as their priorities for plant breeding.

In this dissertation, I address these issues using an interdisciplinary, mixed-methods approach. I conducted this research as a doctoral student in a collaborative research initiative to evaluate and improve vegetable varieties for organic farms across the northern U.S., called the Northern Organic Vegetable Improvement Collaborative (NOVIC). Involving a group of researchers and organic farmers in Wisconsin, New York, Oregon and Washington and funded by a grant from the USDA Organic Research and Education Initiative (OREI), NOVIC consisted of three initial seasons of variety trials on research stations and organic farms from 2010 to 2013, with a second phase beginning in 2015 with renewed OREI funding. NOVIC trials included existing commercial varieties, heirloom and open-pollinated varieties, and advanced lines from associated organic breeding programs. My involvement allowed me to conduct research about the varieties included in the trials and their adaptation to organic environments, as well as broader social research about organic farmers’ plant breeding priorities, their perceptions of the seed industry, and the experiences and contexts behind those opinions.

In Chapter 1, I examine Wisconsin organic vegetable farmers’ needs, priorities, and practices as they relate to seed and plant breeding, based on a state-wide survey conducted in 2012. While farmers’ use of organically-grown seed varied, nearly half of respondents reported growing some of their own seed. Finding satisfactory varieties offered as organic seed was a greater challenge than finding organic seed of good quality; however, large-scale growers struggled to find sufficient quantity of seed for their preferred varieties. Characteristic of Wisconsin’s diverse organic vegetable sector, growers had a wide range of crops that they considered economically important. Priorities for plant breeding were
similarly diverse and varied by crop, though disease tolerance received considerably more mentions than other traits. Though few farmers had participated in on-farm plant breeding, I argue that the prevalence of farmer-led variety trials and seed saving indicate the potential for further engagement.

In Chapter 2, I look more closely at the performance of some of the varieties in the NOVIC trials, using an approach called adaptability analysis to make graphics that help identify adaptation to low- or high-yielding environments. Adaptability analysis is a straightforward and flexible tool that may be useful for handling challenges such as missing data and unbalanced trial designs, typical of on-farm trials. However, while useful methods for data analysis in participatory research have been developed in grain and dry bean crops, fresh vegetables present considerable challenges for timely data collection on multiple farm sites. Better methods are still needed to evaluate these crops, especially with regard to non-yield traits such as appearance and flavor.

In Chapter 3, I return to the social aspects of organic seed for Wisconsin vegetable growers through a series of qualitative interviews, contextualizing the survey findings in Chapter 1 and observations about adaptation in Chapter 2. Organic farmers’ decisions related to seed are influenced by overlapping agroecological, social, and economic contexts. Farmers value resilient varieties that can tolerate unpredictable year-to-year variation in growing conditions, but also look for varieties that can help them enter profitable market niches. Concerned about losing access to important varieties, farmers took a number of practical steps and leveraged their relationships to gain personal agency in relation to an opaque seed industry.

Finally, in my conclusion, I synthesize my key research findings and reflect on ways to resolve some of the inherent challenges of on-farm trialing of organic vegetable crops. I draw lessons from recent participatory plant breeding projects in organic vegetable crops and
ask how the strengths of those projects might be applied to variety trialing. I suggest the
model of “core farms” as a way to enhance farmer engagement in variety trials while
improving data quality.
References


Chapter 1

Seed and Plant Breeding for Wisconsin’s Organic Vegetable Sector: Understanding Farmers’ Needs

This is an Accepted Manuscript of an article published by Taylor & Francis in Agroecology and Sustainable Food Systems on April 30, 2015, available online at http://www.tandfonline.com/doi/full/10.1080/21683565.2015.1017786.

ABSTRACT

Plant breeding and seed issues are of growing importance in organic farming, but more regionally-specific information is needed. In 2012, we surveyed Wisconsin organic vegetable growers regarding: 1) general characteristics and farm practices; 2) challenges in accessing organic seed; 3) plant breeding priorities; and 4) improving access to appropriate plant breeding and seed systems. Results suggest that growers had more difficulty accessing satisfactory genetics than seed quality, and that seed access was more problematic for growers with larger farming operations. Diverse plant breeding priorities, combined with prevalent variety trialing and seed saving, suggest a good fit with participatory plant breeding.

Introduction

Issues of plant breeding and seed access have become increasingly important to the organic farming community in recent years. In the United States, advocacy and research groups such as the Rodale Institute and the Organic Farming and Research Foundation (OFRF) describe a healthy seed supply as one of the most critical conditions for the
continued success of organic agriculture (Sooby, Landneck, and Lipson 2007; Martens 2004; Quaday et al. 2011). This paper addresses two types of obstacles to a healthy seed supply for organic farmers. One is the availability of seed that is produced in accordance with organic standards (“organic seed”). The second is the availability of varieties that are well-suited to organic cultivation and markets, including varieties that have been bred specifically for organic agriculture.

Regulations from the U.S. Department of Agriculture’s National Organic Program (USDA-NOP) require organic farmers to use organic seed, seedlings, and planting stock, turning to conventionally-produced seed only “when an equivalent organically produced variety is not commercially available” (USDA-NOP 2000, §205.204). Even then, the seed must be free of prohibited seed treatments, such as fungicidal coatings that are frequently applied to conventionally-produced seed. Certifying agencies are responsible for making sure that the exception is not abused, and generally require growers to search for organic seed of a given variety in at least three seed sources, such as catalogs, before resorting to untreated conventional seed (USDA-NOP 2013). The cost of seed production varies by crop and variety, playing an important role in seed companies’ decisions to offer varieties as untreated or organic seed. In addition, an ongoing trend of seed industry consolidation has led to important varieties becoming unavailable in any form (Hubbard 2009; Howard 2009).

Most modern varieties, even those available as organically produced seed, were developed through plant breeding under exclusively conventional cultivation practices. Such breeding may not produce the traits needed to optimize organic cultivation (Lammerts van Bueren et al. 2011; K. M. Murphy et al. 2007; Singh et al. 2011). Furthermore, plant breeders express concern that seed industry consolidation continues to result in less prominent geographic areas being dropped from the focus of private breeding programs, or “abandonment of the margins” (Tracy and Sligh 2014). As the majority of organic vegetables
in the U.S. are grown in California (Guthman 2004), farmers in regions with more varied and seasonal growing conditions may have difficulty finding varieties that are well-adapted to their specific challenges.

Despite setbacks, though, recent years have seen increased interest in organic and regional plant breeding and seed systems. In 2005, the National Center for Appropriate Technology found no commercially available varieties bred specifically for organic production, although some breeding programs were underway (Adam 2005). By 2011, the Organic Seed Alliance (OSA) identified 57 projects funded through public or foundation grants that were “directly related to organic breeding or organic seed” (Dillon and Hubbard 2011, 39). Examples of private plant breeding for organic agriculture now can be found at established companies specializing in organic seed such as Johnny’s Selected Seeds (Fairfield, ME) and High Mowing Organic Seeds (Wolcott, VT), as well as smaller, regionally-focused seed companies such as Wild Garden Seeds (Philomath, OR) and Prairie Road Organic Seeds (Fullerton, ND).

As efforts expand to improve organic seed and plant breeding, they draw attention to the need for more information about organic farmers’ needs and practices. Findings from three previous surveys help provide an overview, but more information is needed at the regional level. First, reports from the Organic Production Survey by the United States Department of Agriculture (USDA) show the size of the organic vegetable market and the importance of seed as a farm expenditure. In 2008, the average annual farm expenditure on seed and planting stock was $11,919 for U.S. farms and $4,868 for Wisconsin farms (USDA-NASS 2008, 83-91). Vegetables from U.S. farms sold as certified organic accounted for over one billion dollars in gross sales in 2011, and over nine million dollars in Wisconsin (USDA-NASS 2012, 19-21). A second set of findings comes from the National Organic Farmers’ Surveys conducted by OFRF 1993 and 2001 (Walz 2004). Without focusing on seed

Specifically, these surveys identified pest- and disease-resistance as top research priorities and documented farmers’ concerns about genetically engineered crops. The 2001 OFRF survey identified that farmers’ greatest perceived challenge in maintaining compliance with the newly-implemented USDA-NOP was meeting the requirements of the use of organic seed, in part due to insufficient availability of such seed. Finally, the Organic Farmer Seed Survey conducted by OSA is the only quantitative survey to date specifically designed to investigate seed and plant breeding issues among organic farmers. This survey found that organic farmers who grew vegetables used less organic seed than those who grew field, forage, or cover crops and were more likely to report insufficient varietal availability. It also demonstrated the wide array of crops and traits that are seen as breeding priorities by organic vegetable farmers (Dillon and Hubbard 2011).

Given the diversity of the organic vegetable sector, more detailed information about breeding needs at state and regional scales and within specific crop types would provide important guidance for local efforts at plant breeding and seed system development. Plant breeders who have developed varieties for organic agriculture emphasize the importance of a local, decentralized approach to plant breeding due to the heterogeneity among organic farms (Dawson et al. 2011; K. M. Murphy et al. 2005), with differences in environmental conditions presenting region-specific challenges for organic seed production (Navazio 2012). Qualitative and quantitative studies have addressed questions about organic seed and plant breeding in some regions of the United States (Northeast Organic Farming Association of New York 2004; Organic Seed Alliance 2012), but in other regions data is lacking.

In response to this need, in 2012 we conducted a state-wide survey of Wisconsin organic vegetable growers, covering questions about plant breeding as well as seed availability. Our goal was to use quantitative data to create a picture of the practices, needs, and opinions of Wisconsin organic vegetable growers in order to guide future efforts to
improve their access to appropriate, high-quality seeds and varieties. In this paper, we present the results of our survey, focusing on four central questions:

1.) What are the general characteristics and farm practices of Wisconsin organic vegetable growers?

2.) What challenges do these farmers face in accessing appropriate, high-quality, certified organic seed?

3.) What are the greatest plant-breeding priorities for this group of growers?

4.) How can their access to appropriate plant breeding and seed systems be improved?

Methods

Study area

Our study area was bounded by the state borders of Wisconsin, approximately between 42°-47°N and 86° to 93° W. Frost-free season length varies by latitude, with last killing frost occurring on average between April 26 and May 13, and the first killing frost between September 18 and October 24 (USDA Plant Hardiness Zones 3b-5b). Wisconsin soils vary regionally, with less-fertile spodosols in the forest-dominated north, clay-heavy alfisols and loamy mollisols covering the productive agriculture areas in the west, south, and east, and a Central Sands area composed of entisols, where cranberry and potato are dominant vegetable crops (Hartemink, Lowery, and Wacker 2012).

Survey implementation

Our goals was to survey all organic vegetable growers in the state. We did not include farmers who follow organic methods but are not certified, because they represent a more loosely-defined category than certified growers and may have different motivations in their variety and seed selection since they are not influenced by inspection and certification.
We designed a survey questionnaire (Appendix A) with input from the University of Wisconsin Survey Center and OSA staff. Prior to distribution, the questionnaire was pre-tested by four organic vegetable farmers and revised accordingly. Our mailing list consisted of 208 farm addresses obtained from the USDA-NOP. By comparison, Wisconsin had 254 organic vegetable farms in 2008 according to farm census statistics compiled by USDA National Agricultural Statistics Service (Silva et al. 2012). We used a paper survey sent by mail to facilitate representation of farmers who do not regularly use email, particularly Wisconsin’s Amish farming population. To ensure a high response rate, a notification postcard was sent on January 4, 2012, preceding the first mailing of the questionnaire on January 28. A follow-up postcard was sent on February 24 to those recipients who had not yet responded. On March 2, those who had not yet responded were sent a second questionnaire.

Topics covered by the questionnaire included: 1) demographics and farm characteristics; 2) access to and use of organic seed; 3) plant-breeding priorities including crops, traits, and open-pollinated versus hybrid seed; and 4) possibilities for improving regional seed systems in the Midwest, including farmer participation in on-farm research. Because it is a metric that most organic farmers record, we asked about organic seed use in terms of percent of cultivars grown rather than volume of seed or percent of seed purchases. To determine crops of economic significance, we asked respondents to name their top five income-earning crops for community supported agriculture (CSA) and non-CSA (e.g. farmers market, wholesale, etc.) market venues. In CSA, consumers pay for a subscription or “share” consisting of a regularly-delivered market box that includes a selection of vegetables available that week. Therefore, the income-earning value of any vegetable is related to how essential the farmer deems it to be in creating an attractive market box. Respondents were
asked to indicate the 5 most important crops from a list of 20 crops commonly grown in Wisconsin, with space to write in other crops if desired.

To determine breeding priorities, we asked respondents to select the crops they thought were most in need of crop improvement, from the list described above. Respondents were asked to name their first, second, and third priority crops, and to check the three traits they thought most in need of improvement for each. We also asked several questions to ascertain respondents’ attitudes towards open-pollinated and hybrid varieties as plant breeding priorities. Hybrid varieties result from a cross between inbred parent lines, making them genetically uniform and heterozygous. This heterozygosity makes their seed unsuitable for saving and replanting. In contrast, OP varieties consist of more diverse genetic populations and can be resown (Serpolay et al. 2011). Commonly cited advantages of OP varieties often stem from their potential for adaptation to local conditions, and the possibility for farmers to produce their own seed (J. R. Kloppenburg 1990). Advantages of hybrid varieties include the potential for improved crop uniformity and performance and for faster variety stabilization and release.

Regarding seed sources and the potential for regional seed systems, we asked respondents to indicate, from a list of six options, all sources of seed that they used. We considered two of these—growing one’s own seed and acquiring seed directly from other farmers—as “alternative” seed sources, with positive implications for farmers’ capacity for and interest in local or regional seed production. We also asked what kinds of on-farm research farmers had done that might relate to seed and plant breeding, either on their own or in collaboration with private or public partners.

Analysis

Survey analysis was performed using Stata 13 (StataCorp 2013). In accordance with our objectives and due to the limitations of our survey design, we confined most of our
analysis to descriptive statistics. We tested for relationships to gain further insight into two areas: seed access and use of alternative seed sources. In each of these areas, we wanted to know whether responses were influenced by farm scale and structure, as indicated by acres farmed and market venues used. For seed access, our interest was based on the OSA finding that vegetable growers operating at a larger scale reported using less organic seed, with lack of available varieties reported as the primary reason (Dillon and Hubbard 2011). Regarding alternative seed sources, our interest was based on the perception that seed saving is more feasible for home gardeners than for mid- to large-scale vegetable growers, an idea we encountered at field days and conferences. In both areas, we were also interested in whether answers were influenced by organic certifiers exerting pressure on farmers to search for more sources of organic seed. In addition, we tested for relationships with a set of demographic variables including respondents’ education level, age, and gender. For the two seed access variables (access to seed of good quality and access to seed with satisfactory traits), we tested for relationships using univariate regression. For use of alternative seed sources, we tested for association with our independent variables using Fisher’s exact test.

**Results**

We received 134 surveys, a return rate of 64%. Of the returned surveys, 43 were unusable because the respondents returned a blank survey or indicated that they were no longer farming in Wisconsin or farming at all. This left 91 surveys, for a useable rate of 43%. Of these 91 surveys, 84 were from certified organic farms, 2 were from farms in transition, and 5 were from farms that practiced organic methods but were not certified, and were thus eliminated from further analysis. Thus, for the purpose of our analysis, the highest possible number of respondents for any question is 86, though not all respondents answered every question.
Demographics and farm characteristics

Six percent of our survey respondents were under 30 years old, 21.7% were 30-39 years old, 22.9% were 40-49 years old, 33.7% were 50-59 years old, and 15.7% were over 60. Roughly one quarter (25.6%) of survey respondents were female. Many were highly-educated, with 79% having attended post-secondary education including vocational school, university, or graduate school. Nearly half (48%) of respondents had planted less than 5 acres of vegetables in 2011, with roughly one-quarter (27%) planting five to twelve acres and one-quarter planting more than 12 acres (Table 1). The number of crops grown ranged from 1 to 150 with a mean of 23.1 crops and a median of 14.0 crops. Years of farming experience ranged from 2 to 40 years, with mean 16.6 and median 15. The distribution of time in certification (excluding farms in transition) had a heavy positive skew, with a range from 2 to 27 years, a mean of 8.8 years, and a median of 7.0 years.

Table 1. Acres of vegetables planted by respondents in a 2012 survey of Wisconsin organic vegetable growers (85 responses). Acreage of vegetable production was reported for 2011.

<table>
<thead>
<tr>
<th>Acres of vegetables planted</th>
<th>Percent</th>
<th>Cumulative percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 5</td>
<td>48.2</td>
<td>48.2</td>
</tr>
<tr>
<td>5 to 12</td>
<td>27.1</td>
<td>75.3</td>
</tr>
<tr>
<td>12 to 25</td>
<td>10.6</td>
<td>85.9</td>
</tr>
<tr>
<td>More than 25</td>
<td>14.1</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Seventy-four percent of respondents had paid employees on their farm and 40% had volunteers, including 33% who had both. The distribution of hired labor among survey respondents was also heavily skewed, with most farms employing very little hired labor outside of the family and a few farms employing a large amount of outside labor. Among farms that had employees, the median number of worker hours per year was 1,010, or roughly the equivalent of one half-time employee (i.e. 20 hours per week) for a year. The median absolute deviation (MAD) was 810, reflecting the high variation in these responses. Among farms that had volunteers, the median number of volunteer hours per year was 240 (MAD =
The leading market venue, used by half of survey respondents, was direct or local wholesale, followed by farmers’ market and fresh market distributors (tie), CSA, restaurants, and farm stands, respectively. Only 10.6% of respondents reported using wholesale processing markets (Table 2). Responses indicate that many growers are combining direct marketing with local and fresh market wholesale venues.

Table 2. Market venues used by respondents in a 2012 survey of Wisconsin organic vegetable growers (85 responses).

<table>
<thead>
<tr>
<th>Market Venue</th>
<th>Freq.</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wholesale: Direct/Local</td>
<td>43</td>
<td>0.51</td>
</tr>
<tr>
<td>Wholesale: Fresh Market Distributor</td>
<td>38</td>
<td>0.45</td>
</tr>
<tr>
<td>Wholesale: Processor</td>
<td>9</td>
<td>0.11</td>
</tr>
<tr>
<td>Farmers Market</td>
<td>38</td>
<td>0.45</td>
</tr>
<tr>
<td>CSA</td>
<td>29</td>
<td>0.34</td>
</tr>
<tr>
<td>Restaurant</td>
<td>26</td>
<td>0.31</td>
</tr>
<tr>
<td>Farm Stand</td>
<td>21</td>
<td>0.25</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Organic seed use and access

Over a quarter of respondents (27.5%) reported using organic seed for 80 to 100% of their cultivars (Figure 1). Half (50%), reported that, during the previous 3 years, their organic certifier had requested that they take greater steps to source organic seed, and such requests were most common among growers who reported using organic seed for 20% or less of their cultivars. Among this latter group, 66% had been asked to take greater steps to source organic seed. Of respondents who had received such requests, 31% said they had been asked to trial available organic varieties, 11% said they had been asked to search the Organic Materials Review Institute (OMRI) database, and 56% said they had been asked to search more than 3 seed catalogs. Finally, 24% reported other requested steps, including choosing alternative varieties, growing one’s own seeds, placing earlier seed orders, and searching for other seed growers. One respondent reported that their wholesale buyer, a vegetable processing plant,
required them to grow a variety that was not available as organic seed. In response, the
grower’s certifier had asked the plant to switch to a variety that was available organically.
With regard to organic seed availability, respondents reported more difficulty accessing
organic seed with satisfactory varietal traits than with satisfactory seed quality. Organic seed
with satisfactory traits was described as “somewhat difficult” or “very difficult” to find by
43.2% of respondents, while only 23.3% said the same about satisfactory seed quality (Figure
2). Univariate regression demonstrated a significant negative relationship between acreage of
vegetable production and farmers’ reported ease of access to organic seed, in terms of both
satisfactory variety traits ($R^2 = 0.188$, $p = 0.000$) and satisfactory seed quality ($R^2 = 0.096$, $p =
0.005$). All growers who produced over 25 acres of vegetables in 2011 found it difficult to
access seed with good traits (Figure 3). None of the other potentially explanatory variables
(market venues, certifier pressure, education, age, and gender) demonstrated a significant
relationship with seed access, for either satisfactory seed quality or satisfactory variety traits
(Tables 3 and 8). Written comments indicated that the difficulty of finding organic seed for
good varieties may be crop specific. One farmer wrote, “Tomatoes are easy, carrots are hard.”
Others described variety availability as highly variable: “some [varieties are] very easy and
some impossible.”
Figure 1. Percentage of cultivars grown using organic seed, based on a survey of WI organic farmers in 2012 (80 responses).

Figure 2. Ease of accessing organic seed with satisfactory traits and seed quality, based on a survey of WI organic farmers in 2012.
Figure 3. Ease of accessing organic seed with satisfactory traits and seed quality, by farm size, based on a survey of WI organic farmers in 2012.

Table 3. Relationship of acres of vegetable production, pressure from organic certifiers, and selected demographic variables with access to organic seed with satisfactory quality and variety traits, in a 2012 survey of Wisconsin organic vegetable growers (85 responses). R² and p-values obtained through univariate regression. Asterisks mark significance at p <0.05.

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Access to quality seed</th>
<th>Access to satisfactory traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acres of vegetable production in 2011</td>
<td>0.096  0.005*</td>
<td>0.188  0.000*</td>
</tr>
<tr>
<td>Pressure from organic certifiers</td>
<td>0.009  0.407</td>
<td>0.000  0.871</td>
</tr>
<tr>
<td>Respondent education level</td>
<td>0.002  0.680</td>
<td>0.000  0.959</td>
</tr>
<tr>
<td>Respondent age</td>
<td>0.002  0.738</td>
<td>0.017  0.242</td>
</tr>
<tr>
<td>Respondent gender</td>
<td>0.010  0.393</td>
<td>0.000  0.887</td>
</tr>
</tbody>
</table>
Plant-breeding priorities

For both CSA and non-CSA categories, tomatoes ranked highest as an economically valuable crop (Tables 4 and 5). Other crops listed among the ten most valuable in both categories included winter squash, potatoes, carrots, lettuce, and cucumbers. Write-in responses for “Other” displayed substantial diversity, with many crops listed by only one farmer. Write-in crops which received more than three mentions were asparagus (7 mentions), sweet corn (5 mentions), and Brussels sprouts (4 mentions) for non-CSA venues, and sweet corn (6 mentions) for CSA venues. One point of contrast between CSA and non-CSA venues was that many of the top-ranked crops for non-CSA venues can be classified as storage crops. These include winter squash, beets, potatoes, garlic, and carrots—all listed in the top 8 crops. For CSA venues, in contrast, carrots are the only one of those crops that made the top 8.
<table>
<thead>
<tr>
<th>Rank</th>
<th>Crop</th>
<th>Freq.</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tomatoes</td>
<td>43</td>
<td>53.1</td>
</tr>
<tr>
<td>2</td>
<td>Other</td>
<td>34</td>
<td>42.0</td>
</tr>
<tr>
<td>3</td>
<td>Winter Squash</td>
<td>23</td>
<td>28.4</td>
</tr>
<tr>
<td>4</td>
<td>Beets</td>
<td>20</td>
<td>24.7</td>
</tr>
<tr>
<td>5</td>
<td>Potatoes</td>
<td>19</td>
<td>23.5</td>
</tr>
<tr>
<td>5</td>
<td>Garlic</td>
<td>19</td>
<td>23.5</td>
</tr>
<tr>
<td>6</td>
<td>Kale</td>
<td>18</td>
<td>22.2</td>
</tr>
<tr>
<td>7</td>
<td>Carrots</td>
<td>17</td>
<td>21.0</td>
</tr>
<tr>
<td>8</td>
<td>Lettuce</td>
<td>16</td>
<td>19.8</td>
</tr>
<tr>
<td>8</td>
<td>Cucumbers</td>
<td>16</td>
<td>19.8</td>
</tr>
<tr>
<td>8</td>
<td>Peppers</td>
<td>16</td>
<td>19.8</td>
</tr>
<tr>
<td>9</td>
<td>Summer Squash</td>
<td>13</td>
<td>16.0</td>
</tr>
<tr>
<td>10</td>
<td>Peas</td>
<td>11</td>
<td>13.6</td>
</tr>
<tr>
<td>10</td>
<td>Onions</td>
<td>11</td>
<td>13.6</td>
</tr>
<tr>
<td>11</td>
<td>Spinach</td>
<td>10</td>
<td>12.3</td>
</tr>
<tr>
<td>11</td>
<td>Cabbage</td>
<td>10</td>
<td>12.3</td>
</tr>
<tr>
<td>12</td>
<td>Beans</td>
<td>9</td>
<td>11.1</td>
</tr>
<tr>
<td>12</td>
<td>Melon</td>
<td>9</td>
<td>11.1</td>
</tr>
<tr>
<td>13</td>
<td>Radish</td>
<td>8</td>
<td>9.9</td>
</tr>
<tr>
<td>14</td>
<td>Broccoli</td>
<td>7</td>
<td>8.6</td>
</tr>
<tr>
<td>15</td>
<td>Leeks</td>
<td>4</td>
<td>4.9</td>
</tr>
</tbody>
</table>
Table 5. Most economically valuable crops for CSA market venues according to Wisconsin organic vegetable growers in a 2012 survey (62 responses, multiple answers allowed). Only a subset of respondents practiced Community Supported Agriculture (CSA), therefore the question about CSA market venues received fewer responses.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Crop</th>
<th>Freq.</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tomatoes</td>
<td>43</td>
<td>69.4</td>
</tr>
<tr>
<td>2</td>
<td>Carrots</td>
<td>22</td>
<td>35.5</td>
</tr>
<tr>
<td>3</td>
<td>Other</td>
<td>21</td>
<td>33.9</td>
</tr>
<tr>
<td>4</td>
<td>Lettuce</td>
<td>20</td>
<td>32.3</td>
</tr>
<tr>
<td>5</td>
<td>Beans</td>
<td>19</td>
<td>30.6</td>
</tr>
<tr>
<td>6</td>
<td>Potatoes</td>
<td>17</td>
<td>27.4</td>
</tr>
<tr>
<td>7</td>
<td>Cucumbers</td>
<td>15</td>
<td>24.2</td>
</tr>
<tr>
<td>8</td>
<td>Peppers</td>
<td>13</td>
<td>21.0</td>
</tr>
<tr>
<td>9</td>
<td>Peas</td>
<td>11</td>
<td>17.7</td>
</tr>
<tr>
<td>9</td>
<td>Winter Squash</td>
<td>11</td>
<td>17.7</td>
</tr>
<tr>
<td>9</td>
<td>Garlic</td>
<td>11</td>
<td>17.7</td>
</tr>
<tr>
<td>10</td>
<td>Beets</td>
<td>10</td>
<td>16.1</td>
</tr>
<tr>
<td>10</td>
<td>Broccoli</td>
<td>10</td>
<td>16.1</td>
</tr>
<tr>
<td>10</td>
<td>Onions</td>
<td>10</td>
<td>16.1</td>
</tr>
<tr>
<td>10</td>
<td>Melon</td>
<td>10</td>
<td>16.1</td>
</tr>
<tr>
<td>11</td>
<td>Spinach</td>
<td>8</td>
<td>12.9</td>
</tr>
<tr>
<td>12</td>
<td>Radish</td>
<td>6</td>
<td>9.7</td>
</tr>
<tr>
<td>12</td>
<td>Kale</td>
<td>6</td>
<td>9.7</td>
</tr>
<tr>
<td>13</td>
<td>Cabbage</td>
<td>5</td>
<td>8.1</td>
</tr>
<tr>
<td>14</td>
<td>Summer Squash</td>
<td>4</td>
<td>6.5</td>
</tr>
<tr>
<td>14</td>
<td>Leeks</td>
<td>4</td>
<td>6.5</td>
</tr>
</tbody>
</table>

The survey questions about crop and trait priorities for plant breeding received different numbers of answers per questions, with more respondents listing their second- and third-priority crops than their first-priority crop. Because of this, we ranked crops based on the cumulative number of times each crop was selected as a first, second, or third priority (Table 6). Tomato breeding ranked first when looking at the first-priority crop alone, but came in second when summing answers across first, second, and third priority crops. The top three crops in Table 6—winter squash, tomatoes, and potatoes—were in the ten highest-value crops for CSA and non-CSA venues. In contrast, melon ranked equally with potatoes in terms of plant breeding priority but was low on the list of economically valuable crops for both CSA and non-CSA venues.
Table 6. Vegetable crops most in need of plant breeding, according to respondents in a 2012 survey of Wisconsin organic vegetable growers (66 responses). Frequencies reflect the cumulative number of times a crop was selected when respondents were asked to name their first, second, and third priority crops. Response rates varied for first, second, and third priority crops, therefore for Tables 4 and 5, sixty-six is the maximum possible response rate for a given sub-question. See Appendix A for question wording.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Crop</th>
<th>Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Winter Squash</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td>Tomatoes</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Potatoes</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Melon</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>Peppers</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>Carrots</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>Peas</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>Cucumbers</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>Summer Squash</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>Onions</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>Sweet Corn</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>Beets</td>
<td>6</td>
</tr>
<tr>
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<td>Cabbage</td>
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<tr>
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<td>Kale</td>
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</tr>
<tr>
<td>10</td>
<td>Radish</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Leeks</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Garlic</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 7. Most important traits for plant breeding in organic vegetable crops, according to respondents in a 2012 survey of Wisconsin organic vegetable growers (66 responses, multiple answers allowed).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Trait</th>
<th>Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Disease Tolerance</td>
<td>89</td>
</tr>
<tr>
<td>2</td>
<td>Insect Tolerance</td>
<td>59</td>
</tr>
<tr>
<td>3</td>
<td>Yield</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Germination</td>
<td>46</td>
</tr>
<tr>
<td>5</td>
<td>Season Extension</td>
<td>42</td>
</tr>
<tr>
<td>6</td>
<td>Weeds</td>
<td>36</td>
</tr>
<tr>
<td>7</td>
<td>Other</td>
<td>35</td>
</tr>
<tr>
<td>8</td>
<td>Flavor</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>Appearance</td>
<td>29</td>
</tr>
<tr>
<td>10</td>
<td>Nutrient Use</td>
<td>21</td>
</tr>
<tr>
<td>11</td>
<td>Ease of Harvest</td>
<td>11</td>
</tr>
</tbody>
</table>
With regard to priority traits for plant breeding, the three highest-ranked traits when averaging across all crops were disease tolerance, insect tolerance, and yield, respectively (Table 7). Disease tolerance was also ranked first or second for each of the four highest-priority crops listed above (winter squash, tomatoes, potatoes, and melon) (Table 8a-d). Beyond this commonality, though, the highest-ranked traits varied by crop. For instance, yield improvement was an important priority for potatoes and winter squash, but a low priority for tomatoes and melon. Breeding varieties with improved flavor was the top priority for melon but ranked somewhere in the middle for winter squash, tomatoes, and potatoes.

In general, respondents were well-informed about the meaning of “open-pollinated,” with only 15.5% saying they were confused about the term. Slightly more respondents agreed (46.4%) than disagreed (36.9%) with the statement, “I prefer to use open-pollinated varieties rather than hybrids when possible.” A majority of respondents (54.8%) agreed that “developing open-pollinated varieties should be a priority for plant breeding for organic agriculture.” However, a strong majority of respondents were not willing to use OP varieties

Table 8a-d. Most important traits for the top four priority crops for plant breeding, from a 2012 survey of Wisconsin organic vegetable growers (66 responses, multiple answers allowed).

8a. First priority crop: Winter squash.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Trait</th>
<th>Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yield</td>
<td>8</td>
</tr>
<tr>
<td>1</td>
<td>Disease Tolerance</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Insect Tolerance</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>Weeds</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Flavor</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Appearance</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Season Extension</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Germination</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Other</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Nutrient Use</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Ease of Harvest</td>
<td>1</td>
</tr>
</tbody>
</table>
8b. Second priority crop: Tomato.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Trait</th>
<th>Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Disease Tolerance</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>Season Extension</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>Appearance</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Nutrient Use</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Flavor</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Other</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Insect Tolerance</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Yield</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Germination</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Ease of Harvest</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Weeds</td>
<td>0</td>
</tr>
</tbody>
</table>

8c. Third priority crop: Potato.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Trait</th>
<th>Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Insect Tolerance</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>Disease Tolerance</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>Yield</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>Appearance</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Nutrient Use</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Weeds</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Flavor</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Germination</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Other</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Season Extension</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>Ease of Harvest</td>
<td>0</td>
</tr>
</tbody>
</table>

8d. Fourth priority crop: Melon.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Trait</th>
<th>Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Flavor</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>Disease Tolerance</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>Season Extension</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Insect Tolerance</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Germination</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Other</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Weeds</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Ease of Harvest</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Appearance</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Nutrient Use</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Yield</td>
<td>0</td>
</tr>
</tbody>
</table>
at the expense of quality, with only 25% agreeing with the statement, “I would choose an open-pollinated variety over a hybrid variety even if the quality of the open-pollinated variety was slightly lower.”

These questions sparked a number of unsolicited write-in comments. Some highlighted problems with OP varieties: “I have more disappointments when trialing OP varieties, more successes with hybrids,” and “You want quality and yield, but OP can leave you open to cross-pollination, which is hard on smaller farms.” Another expressed a sense of a trade-off, which was also reflected in farmer interviews: “The reason I don't go for OP varieties is because the marketability is usually lower because of poorer uniformity of fruit sizes, but for the sake of keeping seeds available in a possible time of seed crisis, I think OP varieties should be available.” Finally, some comments emphasized the importance of taking the crop into account. One comment, referring to the question of breeding priorities, said, “It depends on the crop.” Another respondent specified liking OP’s because, “[I] can save [my] own seed and breed varieties for my own micro-climate,” but added that, “hybrid vigor is a plus for some crops.”

*Seed systems and on-farm research*

Printed and online catalogs were by far the most common seed sources, with 81.7% of respondents using them. “Produce my own,” was the second most frequently indicated seed source (54.9% of respondents), followed by other farmers (24.4%), “Other” (24.4%), seed brokers (20.7%) and garden centers (14.6%). Altogether, 52 respondents (63%) had used what we considered “alternative” seed sources, including growing one’s own seed and acquiring seed directly from other farmers. There was a significant ($p = 0.043$) relationship between use of alternative seed sources and use of “Other” markets, but with only 16 respondents indicating markets in this category, we hesitate to draw conclusions. There were no other significant associations between use of alternative seed sources and market venues.
used (Table 9). Nor did use of alternative seed sources appear to be related to acres of vegetable production ($p = 0.956$), certifier pressure ($p = 1.00$), education ($p = 0.142$), age ($p = 0.156$), or gender ($p = 1.00$).

Table 9. Relationship of market venues used by respondents with use of alternative seed sources and access to organic seed with satisfactory quality and variety traits, in a 2012 survey of Wisconsin organic vegetable growers (85 responses). Frequencies represent the total number of respondents who indicated using the respective market venues, with respondents allowed to select multiple venues. Associations between market venues and use of alternative seed sources were evaluated using Fisher’s exact test. Relationships between market venues and seed access variables were evaluated using univariate regression. Asterisks mark significance at $p < 0.05$.

<table>
<thead>
<tr>
<th>Market Venue</th>
<th>Freq.</th>
<th>Use of alternative seed sources</th>
<th>Access to good quality seed</th>
<th>Access to satisfactory traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wholesale: Direct/Local</td>
<td>43</td>
<td>0.360</td>
<td>0.000</td>
<td>0.855</td>
</tr>
<tr>
<td>Wholesale: Fresh Market Distributor</td>
<td>38</td>
<td>0.818</td>
<td>0.010</td>
<td>0.380</td>
</tr>
<tr>
<td>Wholesale: Processor</td>
<td>9</td>
<td>0.718</td>
<td>0.076</td>
<td>0.013</td>
</tr>
<tr>
<td>Farmers Market</td>
<td>38</td>
<td>0.251</td>
<td>0.016</td>
<td>0.260</td>
</tr>
<tr>
<td>CSA</td>
<td>29</td>
<td>0.815</td>
<td>0.012</td>
<td>0.344</td>
</tr>
<tr>
<td>Restaurant</td>
<td>26</td>
<td>0.811</td>
<td>0.070</td>
<td>0.018</td>
</tr>
<tr>
<td>Farm Stand</td>
<td>21</td>
<td>0.797</td>
<td>0.002</td>
<td>0.680</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
<td>0.043*</td>
<td>0.002</td>
<td>0.668</td>
</tr>
</tbody>
</table>

Of the types of on-farm research named in the survey (variety trials, plant breeding, and other agronomic research), variety trials were by far the most common. Overall, a higher proportion of respondents had conducted more on-farm research on their own (0.92) than with either private (0.35) or public (0.10) research partners; proportions are out of 86 responses to the question. Looking at the individual research types, this overall trend was reflected in the categories of variety trials and plant breeding but not in the category of other agronomic research. In that category, partnering with university or extension researchers was as common as doing research on one’s own, and partnering with a private company was quite uncommon (Table 10).
Table 10. On-farm research activities reported by respondents in a 2012 survey of Wisconsin organic vegetable growers (86 responses, multiple selections allowed).

<table>
<thead>
<tr>
<th>Research Type</th>
<th>Research Partner</th>
<th>Freq.</th>
<th>Proportion of 86 responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety Trials</td>
<td>On my own</td>
<td>58</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>University/extension</td>
<td>9</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>Private Company</td>
<td>6</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>73</td>
<td>0.85</td>
</tr>
<tr>
<td>Plant Breeding</td>
<td>On my own</td>
<td>7</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>University/extension</td>
<td>2</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Private Company</td>
<td>2</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>11</td>
<td>0.13</td>
</tr>
<tr>
<td>Other Agronomic</td>
<td>On my own</td>
<td>15</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>University/extension</td>
<td>14</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>Private Company</td>
<td>1</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>30</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Discussion

Our survey was designed around four lines of inquiry about Wisconsin’s organic vegetable growers: their general demographics and farm practices, the challenges they face in accessing organic seed, their plant breeding priorities, and ways to improve their access to effective plant breeding and seed systems. We now discuss our results with respect to each of these questions.

Comparison of farmer characteristics with nation-wide surveys

Most of the demographic differences between our respondents and those in nation-wide surveys were slight, though direct comparison was not always possible. In the 2007 Census of Agriculture, 44.2% of organic farmers fell into the under-50 category, compared to 50.6% in our survey. In the 2007 Census, 17% of organic farmers were female, compared with 26% in our survey. This difference should be viewed with skepticism, however, considering that the Census asked for the gender of the primary farm operator while we asked for that of the survey respondent (USDA-NASS 2009, 53); survey research typically
experiences higher return rates from women. While it is likely that women are
overrepresented in our study compared to the Census data, it may also be argued that Census
methods underrepresent women’s involvement in farm management by requiring that only
one person identify as the primary farm operator. The National Organic Farmers’ Survey
conducted by OFRF found that 45% of respondents had been farming for 21 years or more
(Walz 2004, 92); by comparison, the median in our survey was 15 years. The Organic Farmer
Seed Survey by OSA found that over 50% of respondents had been certified for 5 years or
less (Dillon and Hubbard 2011, 52), while the median length of time in certification in our
survey was 7 years. Like ours, the OSA survey found that organic vegetable production was
heavily distributed towards smaller-scale production.

Seed use and access

Our results suggest wide variation between farms in the proportion of cultivars grown
from organic seed, with a trend towards higher rates of organic seed use. Responses about
pressure from certifiers suggest that many farmers comply voluntarily with USDA-NOP seed
guidelines, while those using less organic seed receive more pressure from their certifiers.
The prevalence of variety trials as a step requested by certifiers to meet the criteria of the
NOP regulations points to an influential role for certifiers in encouraging on-farm trialing and
raising awareness of organically available varieties.

Our finding that farmers had greater difficulty with variety availability than organic
seed quality concurs with the OSA survey, in which 79% of respondents indicated “specific
variety not available” as a factor in not purchasing organic seed, while only 20% indicated
“distrust of organic seed quality” (Dillon and Hubbard 2011). Farmers’ difficulty finding
satisfactory varieties might be due to seed companies shifting varieties out of organic
production or ceasing to offer them altogether (Raeburn 1996, 77). Lack of plant breeding
might also contribute to this problem, especially in specialty vegetable crops that are less
likely to be the focus of any breeding program, conventional or organic (Weebadde and Mensah 2006). The negative relationship between acres of vegetable production and ease of accessing organic seed is similar to the findings of the OSA survey, that larger scale vegetable farmers were more likely to report a lack of available varieties. This may indicate that farmers who produce organic vegetables at a larger scale have different needs with respect to traits and seed quality. Another interpretation is that larger-scale producers need to buy seed in greater quantity, and their difficulty is due to shortages of organic seed for many varieties on the market, a problem documented by Hanson et al (2004). This would suggest that for larger farms the scale of organic seed production is just as important as relevant plant breeding. We do not believe that this interpretation should detract from the importance of breeding new varieties, but rather add to the existing discussion of the importance of seed supply systems (Bishaw and Turner 2008; Almekinders and Louwaars 2002).

**Plant breeding**

The heterogeneity among farms with regard to crop economic value and plant breeding priorities renders general recommendations elusive. However, a few specific points stand out. One is the importance of tomatoes to both CSA and non-CSA growers, and another is the consistent emphasis on disease tolerance, a finding reflected in the both the OSA and OFRF surveys (Dillon and Hubbard 2011; Walz 2004). In addition, the apparent inconsistency of melons ranking low in terms of economic value but high in terms of plant breeding priority might suggest that farmers see a potentially high value market for melons if better varieties were available for production in Wisconsin’s environmental conditions.

Respondents’ familiarity with the term “open-pollinated” was high, perhaps not surprisingly given their high levels of education. It is possible that some respondents who said they were not confused about the term “open-pollinated” are nonetheless misinformed about its definition. This qualification aside, survey results indicate a good deal of interest in
OP varieties, driven especially by a desire to preserve and increase seed access. Results suggest that OP varieties must have comparable quality to hybrid varieties if they are to be adopted more widely. Moreover, these findings do not preclude a role for hybrid varieties in some cases. Self-pollinating crops and open-pollinated varieties of cross-pollinating crops lend themselves more easily to participatory plant breeding than hybrids because of the relative ease with which farmers can produce and select seed (Duvick 2009). Nonetheless, our findings support taking farmers’ practical considerations into account and using a context-dependent approach to decisions about breeding open-pollinated or hybrid varieties.

Overall, our results show that the organic vegetable sector in Wisconsin is characterized by diverse needs and priorities. This was reflected in the wide range of responses about crops and traits that should be the focus of variety improvement efforts, also of the OSA survey. The differences in economically valuable crops between CSA and non-CSA growers suggest that market strategies may play a role in driving this diversity of needs. In the results for crop economic value, the close ranking of crops and the large number of farmers who selected “Other” (a crop that was not in the top 20 most frequently grown), might indicate that rather than competing directly with each other in producing the same crops, the farmers are adding value by specializing in unique crops and varieties. This is similar to a trend observed among wheat growers in Washington (Glenna, Jussaume, and Dawson 2010). The perpetual search for novel vegetables would logically lead to an increasing diversity of crops that growers consider important, creating disparate priorities for breeding and other research. That is, one of the very processes that drives diversification on and among organic farms also complicates research and development efforts to benefit this group of farmers.
Capacity for improving regional seed systems

Our findings lead us to believe that while regional plant breeding and seed production are not yet commonplace in the Upper Midwest, farmer capacity and interest in related areas such as on-farm research, seed saving, and variety trials provide a promising foundation on which to build future efforts. The high incidence of on-farm variety trials indicates that farmers are willing to invest effort and field space to identify better varieties for their growing conditions and markets. We do not know how respondents defined “variety trials,” but farmers commonly plant a small amount of seed for a new variety and make informal observations. Though such trials are often the only practical option for farmers, the results may be unreliable because they are dependent on the idiosyncrasies of a particular growing season and field location (Colley and Myers 2007). Efforts to build on farmers’ existing practices should therefore include not only education about variety trialing methods but also efforts to develop experimental designs that provide relevant and reliable information while working within farmers’ practical constraints.

The percentage of growers who either produce some of their own seed or got some seed from other farmers suggests more widespread familiarity with seed production techniques than we expected. Moreover, the lack of a significant relationship between farm scale and use of alternative seed sources suggests, at least preliminarily, that farmers operating at larger and smaller scales may be equally likely to be involved in growing seed for personal use or local exchange. These findings merit further investigation about which seed crops farmers are producing for themselves, their motivations, and how their capacity for local seed production might be improved.

Although on-farm plant breeding was uncommon among survey respondents, variety trialing and on-farm seed production both represent important skills needed to carry out plant breeding projects (White and Connolly 2011). Respondents’ significant involvement in
alternative seed systems and various kinds of on-farm research have positive implications for the feasibility of participatory plant breeding (PPB), which can be farmer-led or a collaboration between farmers and professional plant breeders (Vernooy 2003). Because it facilitates farmer involvement at every step of the selection process, PPB can provide better opportunities to respond to farmers’ place-specific needs, particularly in heterogeneous agroecosystems (Ceccarelli and Grando 2006; Desclaux et al. 2008). The high number of vegetable breeders at the University of Wisconsin-Madison (with breeding programs covering sweet corn, carrots, beets, onions, beans, peppers, and potatoes) provides important opportunities to develop PPB by connecting interested farmers with public plant breeders, as exemplified by the recent release of the OP sweet corn variety ‘Who Gets Kissed?’, a product of farmer-plant breeder collaboration (A. C. Shelton 2014). Additionally, the prevalence of on-farm seed saving suggests a basic capacity for regional seed production, such as farmer seed clubs or exchanges, that could help make the results of PPB more widely available (Tin et al. 2011; Almekinders, Thiele, and Danial 2006; Bishaw and Turner 2008).

Conclusion

Finding high-quality varieties in the form of organic seed was a real concern for the growers in this survey. Insufficient variety availability, felt especially keenly by larger-scale growers, reveals the need for more variety development focused on organic agriculture as well as increased organic seed production for existing varieties favored by organic farmers. Addressing these needs, though, is complicated by the diversity and regional specificity of farmers’ crop priorities and trait requirements—driven in part by specialization and diversification within the sector. Given the challenges of diverse farmer needs and limited university resources, a decentralized, participatory approach variety to trialing could be an effective way to serve farmers’ interests, particularly if small farmer groups work together to trial crops that might not be addressed by formal research programs. Important further
research in this area would include determining what type of support, such as trainings or coordination, university and extension researchers can provide that would enable farmers to gather useful information about varieties of interest. Currently, the Northern Organic Vegetable Improvement Collaborative (NOVIC), a collaborative variety trialing network involving land grand universities and nonprofit partners, provides a test case for this kind of research (Oregon State University 2014).

Although few Wisconsin growers are currently doing their own breeding, the incidence of on-farm variety trialing and seed saving documented in this survey make it possible to imagine greater farmer participation in plant breeding and seed production in the Upper Midwest. Such participation might involve farmers doing their own variety selection, collaborating with public plant breeders, and producing greater quantities of organic seed for regional distribution and use. Given the diversity of practices and needs, we believe that supporting such activities should be a key focus of efforts to improve seed access for growers in Wisconsin and other regions with similarly specialized and diversified organic farming.
References


StataCorp. 2013. *Stata Statistical Software: Release 2013*. College Station, TX: StataCorp LP.


Chapter 2

Characterizing Response to Environmental Variation in a Participatory Variety Trial of Organic Vegetable Crops

ABSTRACT

Organic farming requires crop varieties that are resilient to predictable and unpredictable environmental variation. Assessing variety performance on working farms is vital to developing such varieties, but participatory trials are often subject to constraints such as inherent variability and challenges to implementing trial designs. We examined the response of squash, broccoli, and carrot varieties to diverse environments in participatory trials in Oregon, Washington, Wisconsin, and New York, using adaptability analysis (regression of variety means on environmental index). Patterns of adaptation varied, with some varieties demonstrating broad adaptation and others showing specific adaptation to low- or high-yielding environments. Selection of varieties with broad versus specific adaptation should be guided by farmers’ risk tolerance and on-farm environmental variation. Adaptability analysis was effective for continuous variables and yield traits, but less so for ordinal variables and quality traits such as flavor and appearance. Much work in participatory plant breeding, including development of statistical analyses, has focused on grain crops. As evidenced in our research, vegetable crops present unique challenges and require novel approaches to facilitating farmer participation.
Background

Organic farming is an approach to agricultural production based on ecological principles, particularly the enhancement of soil biological function through the management of carbon-containing (i.e. organic) materials (Lotter 2003). In the United States, the definition of organic agriculture was codified in 2002 with the implementation of the USDA National Organic Program, which specified standards for organic production, processing, and handling (USDA-NOP 2002, §205). Consistent with an ecological approach to plant nutrition, organic farmers do not use chemical sources of nitrogen, phosphorous, and potassium, relying instead on organic sources such as manures, compost, and cover crops to build soil health and fertility. Organic standards also restrict pesticides to a limited list of naturally-derived alternatives and encourage preventive approaches to insect and disease management, such as lengthening crop rotations, increasing on-farm biodiversity, and enhancing habitat for beneficial insects (Delahaut, Silva, and Behar 2007). Because organic farming relies on long-term, preventive measures and seeks to minimize curative measures based on chemical inputs, farmers have less immediate control over environmental conditions during the growing season (Lammerts van Bueren and Myers 2012). This circumstance, along with the high diversity of agronomic practices and socio-economic contexts in the organic sector may explain researchers’ observations of higher farm-to-farm variation in organic than in conventional agriculture (Wolfe et al. 2008; Drinkwater et al. 1995; Przystalski et al. 2008). Under such conditions, well-adapted cultivars are a crucial tool for withstanding production challenges of all kinds, from disease problems to extreme weather.

Recent efforts to breed for adaptation to organic agriculture in Europe and the United States (examples include Mazourek et al. 2009; Myers, McKenzie, and Voorrips 2012; OSA
have drawn on decades of work in participatory plant breeding (PPB) with resource-poor farmers in the developing world. Researchers and farmers have found that PPB, which involves farmers as research partners and emphasizes testing and selection of varieties in farmers’ fields, is more effective than traditional top-down approaches in terms of producing varieties that meet local needs (Ceccarelli, Grando, and Hamblin 1992; Ceccarelli 1994). The effectiveness of PPB can be explained by its incorporation of both farmers’ experiential knowledge and the environmental conditions of farmers’ fields into the variety selection process (Frossard 2002; Soleri and Cleveland 2002). This approach is particularly important for agroecosystems in which research stations tend not to reflect on-farm environments very well, frequently the case in organic agriculture because of the considerable farmer expertise required to manage complex organic systems. For example, Singh et al. (2011) observed higher correlation in dry bean yields between conventionally-managed research station plots and conventional farms than between organically-managed research station plots and organic farms, evidence of the disconnect between organic farms and research stations.

Experiences applying PPB to organic agriculture show the importance of on-farm testing and trialing in developing better organic varieties. Even in situations where breeding for organic farms can reasonably be carried out under conventional management, trialing on organic farms is still important for assessing finished varieties (Burger et al. 2008). However, while a number of research designs and analytical methods have been elaborated by practitioners of PPB, most research using these methods has been conducted with grain or dry bean crops (such as Snapp 2002; Ceccarelli et al. 2003; Bellon et al. 2003; K. M. Murphy et al. 2005; Dawson et al. 2011 to name a few). In comparison to fresh vegetables, these edible seed crops provide more flexibility for on-farm trialing because the harvested crop can be more easily transported or stored until
Vegetable crops often have narrower temporal windows in which evaluation must take place, and the timing of these with farmers’ seasonal workloads, particularly on diversified farms, can hinder farmers’ ability to participate. In instances when participatory research has been conducted with organic vegetable crops, it has largely been related to breeding and selection rather than strictly variety evaluation (Myers, McKenzie, and Voorrips 2012; Shelton and Tracy 2015), or has involved a limited number of sites (Renaud et al. 2014). Variety trials are important for farmers who need reliable information about the performance of existing varieties, as well as for plant breeders who employ variety trials to identify promising material for future breeding programs and to evaluate varieties in advanced stages of the breeding process (Haussmann et al. 2012). Developing better methods for on-farm variety trials in fresh vegetable crops is therefore an important step towards identifying and developing well-adapted varieties for organic farms.

Stability and adaptation

An important reason for coordinated, multi-farm, variety trials is to determine how varieties respond to different environments. Genotype by environment (G × E) interactions in which crop varieties perform better in some environments than others can justify breeding for specific adaptation to defined environments, but only if environmental variation is relatively predictable; in other words, when G × E interactions consist mainly of genotype × location or genotype × management interactions. Unpredictable environmental variation, resulting in large genotype × year interactions, can warrant broad adaptation (Allard and Bradshaw 1964).

The response of varieties to environmental variation can be characterized further in terms of stability and adaptation, both of which are also commonly evaluated in variety trials (Abidin et al. 2005). Plant breeders have recognized the importance of stability and adaptation since at
least the 1960s, and have been debating how to define and measure these concepts for just as long. Two early, influential, and conflicting frameworks—by Finlay and Wilkinson (1963) and by Eberhart and Russell (1966)—both involve linear regression of variety yields on the mean yields of all varieties in each environment, termed environmental index (EI) by the latter authors. Eberhart and Russell define a stable variety as one with “a high mean ($x_i$), unit regression coefficient ($b_i = 1.0$), and the deviations from regression as small as possible ($s^2d_i = 0$).” By contrast, in Finlay and Wilkinson’s framing, such a variety has only average stability; for them a stable variety is one with $b_i < 1$, because it shows less sensitivity to changes in environment. In this understanding of stability, greater stability is associated with specific adaptation to low-yielding environments, while in Eberhart and Russell’s definition a stable variety is broadly adapted to all environments.

Subsequent authors have further classified concepts of stability, proposing static/biological stability as that characterized by similar performance across all environments and dynamic/agronomic stability as that characterized by increasing yields in more optimal environments (Becker and Leon 1988). Lin et al. (1986) classify these as Type 1 and Type 2, respectively, and include Type 3 stability characterized by little deviation from regression, also a component of Eberhart and Russell’s definition. In elaborating a “stability variance” parameter, Shukla (1972) favors this Type 3 concept of a stable variety as one with little variation around its mean performance. In a comparable approach, Francis and Kannenberg (1978) propose the coefficient of variation as “a measure of consistency that will account for yield (p. 1032).” Yan and Kang’s (2003) GGE biplot provides a further method for simultaneously considering both stability and performance, and for identifying varieties specifically adapted to certain environments. A comparison of these four methods of stability analysis (Finlay-Wilkinson
regression coefficient, Shukla’s stability variance, Francis and Kannenberg’s covariance, and GGE biplot) found the results generally to be in agreement when analyzing soy isoflavone content (S. E. Murphy et al. 2009).

Observing this history, Hildebrand and Russell (1996) contend that the widespread use of stability parameters to identify varieties with broad adaptation (agronomic stability), to the exclusion of varieties better-adapted to poor environments, is motivated by an assumption that farmers will use conventional agronomic practices that suppress variability. For many of the world’s resource-limited farmers, though, “risk avoidance and above-average yields in poor environments (and seasons) are far more important than above-average yields in all environments.” The authors go on to predict that the necessity of sustainability will increasingly require all farmers, not just those in resource-limited situations, to “farm within the capabilities of their environments and not modify the environments to suit the technology” (1996, 23). This approach of working with innate variability applies to many aspects of agroecological farming (Bell et al. 2008), including organic agriculture.

Adaptability Analysis

As an alternative to stability analysis, Hildebrand and Russell propose a modification of regression analysis methods that they call “adaptability analysis.” Though it employs similar graphical methods as those used in standard regression analysis, adaptability analysis shifts from evaluating agronomic stability of varieties or agricultural technologies to identifying those that are well-adapted to specific environments. In other words, rather than prioritizing varieties with regression coefficients closest to 1, adaptability analysis helps identify varieties that are specifically adapted to high- or low-yielding environments. Decisions about which kind of
adaptation is preferable then rest on farmers’ tolerance of risk and an evaluation of the farm environment (Figure 1).

This approach seems well-suited to participatory research for a number of reasons. Participatory plant breeding and variety trials are often conducted specifically to address agroecosystems that tend to experience more variation, from organic farming to marginal environments (Ceccarelli et al. 1994; Haussmann et al. 2012). Because on-farm trials are often subject to unbalanced data, high inherent variability, and challenges to implementing trial designs, meeting the requirements of stability analyses can be extremely difficult when working with data from participatory projects (Raman et al. 2011). Snapp (2002) uses adaptability analysis to handle these complexities in the mother-baby trial design, which our trails also

Figure 1. Three example of varieties plotted against Environmental Index. Variety A is specifically-adapted to high-yielding environments, while C is specifically adapted to low-yielding environments. Variety B, with imagined slope $b_i = 0$, is broadly adapted. Adapted from Hildebrand and Russell (1996, 6).
employed. Finally, compared to many stability parameters, adaptability analysis is simple to execute and produces relatively straightforward graphical representations of trial results.

**Objectives**

Beginning in 2010, a group of researchers and organic farmers in Washington, Oregon, Wisconsin, and New York conducted participatory trials of vegetable varieties in five crops as part of the Northern Organic Vegetable Improvement Collaborative (NOVIC). In each region, trials were conducted under certified organic conditions at research stations and on working organic farms, and linked with organic breeding programs in each of the five core crops. The goals of NOVIC included “partnering with organic farmers to breed new varieties, identify the best-performing existing varieties for organic agriculture, and educate farmers on organic seed production and plant variety improvement (eOrganic 2014a).” In this paper, we analyze selected data from the NOVIC trials in order to:

1.) Assess differential responses of varieties in the NOVIC trials to high- and low-yield environments.

2.) Assess the feasibility of simple graphic methods to analyze adaptation and performance in a participatory variety trialing project.

3.) Use this experience to make recommendations on participatory trialing methods.

**Methods**

The NOVIC variety trials were administered by researchers at the four participating institutions, including professors, research staff, and graduate students. Crops and varieties to be trialed were selected by researchers at an annual winter meeting, after gathering comments from
farmers in each region. Traits to be evaluated were also determined through a combination of farmers’ comments and the advice of participating plant breeders. Trial design was adapted from the mother-baby design, which pairs multiple replications on research stations with on-farm trials that each consist of a single replication (Snapp 2002). An advantage of this design is that it provides replicated data and allows evaluation under on-farm conditions while minimizing field space and time commitments for farmers. From 2010 to 2013, variety trials were conducted on research stations in Ithaca, NY; Madison, WI; Corvallis, OR; and Sequim, WA; as well as at 5 farm sites in New York, 10 in Wisconsin (including one in Minnesota), 7 in Oregon, and 14 in Washington. Of the 36 total participating farms, some grew variety trials every year of the project, while others participated for only some growing seasons. Likewise, while the five core crops were grown on all research stations, farmers chose which crops they would trial each season.

Research station trials were managed by staff from each participating institution. On-farm trials were co-managed by farmers and research staff, with farmers responsible for planting and growing the crop as well as carrying out selected mid-season and harvest evaluations as their time and ability permitted. Researchers ordered and distributed seed and/or seedlings to farmers and assisted with some mid-season evaluations, the majority of harvest evaluations, and all storage evaluations. Data from the four participating regions were compiled each year by OSA staff to create a multi-site, multi-year data set. Researchers in each region also created reports and presentations to communicate results to farmers.

For the analysis presented here, we reviewed the available NOVIC data to identify the crops and variables with the most complete data. Our goal was to identify a set of variables for adaptability analysis that would be of interest to farmers and provide a range of examples to
evaluate the utility of this method. We used two continuous variables for squash: marketable number of fruit per plant and marketable fruit weight per plant. For broccoli, we used one continuous variable (head diameter), and one ratio (uniformity of maturation). For squash, we used two variables measured as 1-5 scores: root smoothness and sweetness.

*Table 1. Variables evaluated in adaptability analysis of squash, broccoli, and carrot varieties in participatory organic trials in NY, WI, OR, and WA, 2010-2013.*

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variable</th>
<th>Measurement</th>
<th>Varieties</th>
<th>Sites</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squash</td>
<td>Marketable Fruit per Plant</td>
<td>number of fruit</td>
<td>7</td>
<td>11</td>
<td>Average number of squash per plant that were judged marketable at harvest</td>
</tr>
<tr>
<td>Squash</td>
<td>Marketable Weight per Plant</td>
<td>kg</td>
<td>7</td>
<td>11</td>
<td>Average weight of squash per plant judged marketable at harvest</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Head Diameter</td>
<td>cm</td>
<td>7</td>
<td>23</td>
<td>Width of widest part of broccoli head at harvest (average of 5 heads per rep)</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Uniformity of maturation</td>
<td>percent</td>
<td>7</td>
<td>20</td>
<td>Percent of total heads judged prime (v. over- or under mature) on the day of harvest</td>
</tr>
<tr>
<td>Carrots</td>
<td>Root Smoothness</td>
<td>1 - 5</td>
<td>6</td>
<td>22</td>
<td>Score of root smoothness, which can be influenced by stress and disease, where 1 = least smooth and 5 = smoothest</td>
</tr>
<tr>
<td>Carrots</td>
<td>Sweetness</td>
<td>1 - 5</td>
<td>6</td>
<td>22</td>
<td>Score of sweetness determined by field tasting at harvest, where 1 = least sweet and 5 = sweetest</td>
</tr>
</tbody>
</table>

Table 1 provides an explanation of how variables were measured. Data were collected in each state by researchers at the research stations and researcher-farmer teams at the farm sites, with some variation by state. For the qualitative scores used to evaluate the carrot root smoothness and sweetness, evaluators were given an explanation of the trait and then asked to view or taste every plot and establish the extremes of the scale (1 and 5). In general, the same individual researchers were present for all evaluations within each of the four states, but different farmers were also part of the evaluation team on each farm site.
Because the varieties in the trials rotated from year to year, and because farms did not always grow trials for multiple years, we did not have sufficient data to consider the influence of years and locations separately. Rather, we treated each year-by-location combination as a distinct environment. For each trait of interest, we used R software to conduct a search process that identified the varieties with available data in the most environments (R Core Team 2014). See Table 2 for a description of the varieties included. Given that a trade-off existed between including more varieties and evaluating them in more environments, we chose the combination that balanced both, also performing the analysis with fewer and more environments to see if the results were affected. As described later, notable changes in results with different inclusion of sites were only observed with the carrot variables, for which two iterations of the analysis are presented.
Table 2. Squash, broccoli, and carrot varieties included in adaptability analysis of participatory organic trials in NY, WI, OR and WA, 2010-2013.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squash</td>
<td>Early F1</td>
<td></td>
</tr>
<tr>
<td>Squash</td>
<td>Pilgrim F1</td>
<td></td>
</tr>
<tr>
<td>Squash</td>
<td>Bugle OP</td>
<td></td>
</tr>
<tr>
<td>Squash</td>
<td>Waltham OP</td>
<td></td>
</tr>
<tr>
<td>Squash</td>
<td>JWS 6823 F1</td>
<td></td>
</tr>
<tr>
<td>Squash</td>
<td>Tiana F1</td>
<td></td>
</tr>
<tr>
<td>Squash</td>
<td>Metro F1</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>Common Ground Population OP Breeding Stock</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>Solstice OP</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>Oregon State University (OSU) Population OP Breeding Stock</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>Windsor F1</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>Arcadia F1</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>Belstar F1</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>Gypsy F1</td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>Rumba OP</td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>Bolero F1</td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>Spring Market OP</td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>Scarlet Nantes OP</td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>Yaya F1</td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>Nelson F1</td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>Jeanette F1</td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>Hilmar OP</td>
<td></td>
</tr>
</tbody>
</table>

Different degrees of relatedness existed within the varieties included in the analysis, which could contribute to similarities in performance. The three OP broccoli varieties were closely related as ‘Solstice’ and ‘Common Ground Population’ were each the result of on-farm selection of the Oregon State (OSU) Population, which plant breeder James Myers created through a series of initial crosses. Except for ‘Spring Market,’ all carrot varieties Nantes types, a market class characterized by cylindrical shape and blunt, rounded tips. In contrast, ‘Spring Market’ is as a “New Zealand overwintering carrot,” being used in by OSA in participatory breeding work to develop varieties with improved season extension (eOrganic 2014b). The
Nantes-type varieties in this analysis therefore likely share more common genetic background with each other than with ‘Spring Market.’

For each crop trait, we created three graphs: 1) a bar chart showing the performance of varieties within each environment, 2) a box plot of variety performance averaged over all sites, and 3) for each variety under consideration, a separate linear regression (scatterplot) of variety performance on EI. Because only the means were reported for each site, rather than individual plant or fruit measurements, we lacked a measurement of variation of traits within sites. For this reason, bar charts do not include indications of error or significance for variety performance within sites. In addition, because there was only one replication of each variety in the on-farm trials, insufficient degrees of freedom prevented the inclusion of G × E interactions in ANOVA. The IE for each environment was calculated as the mean value of the trait of interest of all varieties under consideration in that environment. We also calculated the regression coefficient ($\beta$) and coefficient of determination ($R^2$) for each variety, and tested whether regression coefficients were significantly different from one. To assess the contributions of variety and environment as sources of variation, analysis of variance (ANOVA) was calculated on environment (location × year) means using the PROC GLM procedure in SAS® 9.1.3 (SAS Institute, Inc. 2000). All effects were treated as fixed. We decided to fit linear models because the relationships appeared to be relatively linear and we did not have big enough samples size to justify non-linear models.
**Results**

*Squash*

Analysis of squash variables included 7 varieties in 11 environments. Considering overall variety averages, ‘Metro,’ and ‘Tiana’ were the top-performing varieties in terms of average number of marketable squash fruit per plant. ‘JWS 6823,’ ‘Waltham,’ and ‘Bugle’ and were average performers, and ‘Early’ and ‘Pilgrim,’ were below-average performers (Figure 2). Rank-order of varieties varied by environment, with differences between nearly all environments in rank-order of varieties (Figure 3). The highest-yielding site had an average of just over five squash per plant, while the lowest-yielding site had an average of less than one squash per plant. Linear regression against EI suggested that ‘Metro’ was specifically adapted to high-yielding environments, with a regression coefficient greater than and significantly different from one ($\beta = 1.4, p = 0.034$) and relatively little deviation from the regression ($R^2 = 0.9$) (Figure 4). ‘Tiana,’ which had similar overall average fruit numbers, was more broadly adapted with somewhat less consistent performance ($\beta = 0.99, p = 0.96, R^2 = 0.61$). Comparing the two varieties with average overall performance, ‘JWS 6823’ was very broadly adapted ($\beta = 1.0, p = 0.87, R^2 = 0.70$) while ‘Waltham’ displayed more specific adaptation towards low-yielding environments ($\beta = 0.66, p = 0.071, R^2 = 0.64$). ‘Bugle’ ($\beta = 1.2, p = 0.27, R^2 = 0.82$) and ‘Pilgrim’ ($\beta = 0.98, p = 0.92, R^2 = 0.77$) appeared to be more responsive to improvements in environment than ‘Early’ ($\beta = 0.7, p = 0.0015, R^2 = 0.92$). A caveat is that the Oregon research station in 2011 (OR1-11) had very high numbers of fruit in all varieties, so with only 11 environments this site may have an oversized influence on the results.
In terms of marketable squash weight per plant, ‘Tiana,’ ‘Waltham,’ and ‘Metro’ were the highest performers overall, while the median performances of the other varieties all fell below the trial average (Figure 5). Rank-order differences existed between most environments, and average marketable weight ranged from about 1 kg per plant in the lowest-yielding environment to around 5 kg per plant at the highest-yielding environments (Figure 6). Though we analyzed the same environments for marketable weight per plant as for marketable fruit number per plant, the ranking of environments and varieties was somewhat different for each variable. For instance, OR1-11 was only an average environment in terms of squash weight. ‘Waltham’ was the 4th highest performer in terms of fruit number but was 2nd highest in terms of weight. For both yield metrics, the higher-performing varieties displayed greater variation than lower-yielding varieties. Linear regression revealed different patterns of adaptation for the two yield metrics (Figure 7). Where ‘Tiana’ showed broad adaptation in terms of fruit number, in terms of weight it was more specifically adapted to high-yielding sites (β = 1.6, p = 0.088, R² = 0.74). ‘Waltham’ displayed the opposite, with broad adaptation in terms of marketable weight (β = 1.1, p = 0.75, R² = 0.7). Among the lower-yielding varieties, ‘Pilgrim’ (β = 0.96, p = 0.83) and ‘Bugle’ (β = 0.76, p = 0.094) appeared to be more responsive to improved environments while ‘Early’ (β = 0.67, p = 0.0015) and ‘JWS 6823’ (β = 0.51, p = 0.039) appeared to be less responsive.
Figure 2. Marketable fruit numbers of 7 squash varieties, averaged over 11 environments from participatory organic vegetable trials in NY, WI, OR, and WA, 2010-2013.
Figure 3. Marketable fruit numbers of 7 squash varieties in 11 environments from participatory organic vegetable trials in NY, WI, OR, and WA, 2010-2013.
Figure 4. Linear regression of mean marketable fruit numbers of 7 squash varieties on an environmental index (IE) composed of the mean of all varieties in each environment. From participatory organic vegetable trials in NY, WI, OR, and WA, 2010-2013.
Figure 5. Marketable fruit weight of 7 squash varieties, averaged over 11 environments from participatory organic vegetable trials in NY, WI, OR, and WA, 2010-2013.
Figure 6. Marketable fruit weight of 7 squash varieties in 11 environments from participatory organic vegetable trials in NY, WI, OR, and WA, 2010-2013.
Figure 7. Linear regression of mean marketable weight of 7 squash varieties on an index of 11 environments, from participatory organic vegetable trials in NY, WI, OR, and WA, 2010-2013.
Broccoli

Analysis of broccoli variables included 7 varieties in 23 environments. The broccoli varieties ‘Belstar’ and ‘Gypsy’ had the largest head diameters, while ‘Windsor’ and ‘Arcadia’ had closer to average performance. The three open-pollinated entries—‘OSU Composite,’ ‘Solstice,’ and ‘Common Ground Population,’ had the smallest heads (Figure 8). As with the squash variables, numerous rank-order differences existed among environments (Figure 9). ‘Gypsy’ ($\beta = 1, p = 0.93$) and ‘Belstar’ ($\beta = 0.85, p = 0.53$) were broadly adapted, with regression coefficients equal to or very close to one, though ‘Gypsy’ had head sizes more consistently above site averages (Figure 10). ‘Arcadia’ and ‘Windsor’ also displayed broad adaptation. The three open-pollinated entries, though genetically related, displayed markedly different patterns of adaptation. The cultivar ‘Solstice’ showed specific adaptation to higher-quality environments ($\beta = 1.4, p = 0.013$), while ‘Common Ground Population’ showed broad adaptation across environments ($\beta = 1, p = 0.86$) and ‘OSU Composite’ seemed to display better adaptation to more challenging environments ($\beta = 0.5, p = 0.028$).

Analysis of maturation uniformity in broccoli was less informative than analyses for the preceding variables. Variation within varieties was high, and average performance across all sites was not significantly different among varieties (Figure 11). Environmental means were strongly grouped between 0.25 and 0.75, characteristic of a variable measured as a proportion (Figure 12). By muting the variation between environments, this metric may have violated a requirement of adaptability analysis, that EI represent a wide range of average performance. Results of regression on EI were highly influenced by which sites were included (Figure 13).
Figure 8. Head diameter of 7 broccoli varieties, averaged over 23 environments from participatory organic vegetable trials in NY, WI, OR, and WA, 2010-2013.
Figure 9. Head diameter of 7 broccoli varieties in 23 environments from participatory organic vegetable trials in NY, WI, OR, and WA, 2010-2013.
Figure 10. Linear regression of mean head diameter of 7 broccoli varieties on an index of 23 environments, from participatory organic trials in NY, WI, OR, and WA, 2010-2013.
Figure 11. Maturation uniformity of 7 broccoli varieties, averaged over 20 environments from participatory organic vegetable trials in NY, WI, OR, and WA, 2010-2013.
Figure 12. Maturation uniformity in 7 broccoli varieties in 20 environments from participatory organic vegetable trials in NY, WI, OR, and WA, 2010-2013.
Figure 13. Linear regression of maturation uniformity of 7 broccoli varieties on an index of 20 environments, from participatory organic trials in NY, WI, OR, and WA, 2010-2013.
Carrot

Analysis of carrot variables was initially conducted with 6 varieties in 22 environments. As with broccoli maturation, there was little separation among carrot varieties for root smoothness, with the exception of the notably poorer performance of though ‘Spring Market,’ the only non-Nantes type in this analysis (Figure 14). This pattern was even more striking for carrot sweetness, where ‘Spring Market’ was rated much lower than all other entries, with little significant difference between the Nantes types (Figure 15). These traits were evaluated using rankings of one to five, and the data was highly grouped between two and four, resulting in similar violation of the requirements of adaptability analysis as was apparent with broccoli maturation. Regression analysis yielded inconclusive results, and analysis of 8 varieties in 14 environments yielded markedly different results, demonstrating that results for both traits were highly influenced by the sites included in the analysis (Figures 16-19).
Figure 14. Root smoothness of 6 carrot varieties, averaged over 22 environments from participatory organic vegetable trials in NY, WI, OR, and WA, 2010-2013.
Figure 15. Sweetness of 6 carrot varieties, averaged over 22 environments from participatory organic vegetable trials in NY, WI, OR, and WA, 2010-2013.
Figure 16. Linear regression of root smoothness of 6 carrot varieties on an index of 22 environments, from participatory organic trials in NY, WI, OR, and WA, 2010-2013.
Figure 17. Linear regression of root smoothness of 8 carrot varieties on an index of 14 environments, from participatory organic trials in NY, WI, OR, and WA, 2010-2013.
Figure 18. Linear regression of sweetness of 6 carrot varieties in 22 environments.
Figure 19. Linear regression of sweetness of 8 carrot varieties in 14 environments.
Analysis of Variance

The ANOVA model was significant \((p < 0.0001)\) for both squash yield variables, marketable fruit per plant, and marketable weight per plant. In each case, far more variation was explained by environment than by genetics (Table ). The model was also significant \((p < 0.0001)\) for both head diameter and uniformity of maturity in broccoli. Contrary to the squash yield variables, variety was more important than environment in explaining variation in both broccoli variables. The ANOVA model was significant for carrot sweetness \((p = 0.044)\) but not root smoothness \((p = 0.356)\). For both these variables as well, variety explained more variation than environment.

Table 3. ANOVA of 6 variables in organic trials of squash, broccoli, and carrot varieties in NY, WI, OR and WA, 2010-2013.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F Value</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQUASH MARKETABLE NUMBER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>16</td>
<td>117.654</td>
<td>7.353</td>
<td>10.790</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Environment</td>
<td>10</td>
<td>109.958</td>
<td>10.996</td>
<td>16.130</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Variety</td>
<td>6</td>
<td>7.696</td>
<td>1.283</td>
<td>1.880</td>
<td>0.099</td>
</tr>
<tr>
<td>Residuals</td>
<td>60</td>
<td>40.890</td>
<td>0.681</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>76</td>
<td>158.544</td>
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### Discussion

Our results provide a number of specific insights regarding the response of varieties to environment in the NOVIC trials, as well as some of the advantages and limitations of adaptability analysis as an analysis tool in participatory variety trials. When considering
quantitative data and continuous variables, as we did for yield characteristics in squash and broccoli, adaptability analysis proved to be a useful method for presenting straightforward representations of adaptation patterns. As suggested by Hildebrand and Russell (1996), we believe that graphs of performance regressed on EI have the potential to allow farmers to visualize variety performance in a clear way, which could help them to make decisions based on the type of adaptation they prioritize. A community-based approach could be used to assess farmers’ ability to utilize variety trial results presenting in this fashion. Adaptability analysis proved less informative when working with ratio variables and qualitative rankings because these types of variables tended to be highly clustered on the x-axis, leading to a scattershot pattern. Problematically for adaptability analysis, qualitative rankings are often used to evaluate traits related to vegetable quality, in our case flavor, appearance, and harvest (maturation) uniformity. Participatory research would benefit from improved methods to evaluate these characteristics, while taking into account the logistical challenges associated with collecting data from multiple field sites at peak maturity for fresh vegetable crops. This is particularly important in breeding for the organic market, where culinary characteristics are of great importance.

*Adaptation of NOVIC varieties*

Regarding the performance of varieties in the NOVIC trials, the contrast between ‘Tiana,’ ‘Metro,’ and ‘Waltham’ in terms of marketable squash fruit per plant illustrates the utility of regression on EI for demonstrating differences in adaptation. These varieties show the importance of considering multiple variables to characterize adaptation, as results differed depending on whether yield was measured as marketable weight or marketable fruit number. The desirability of these two yield metrics can depend on marketing practices, as farmers growing for wholesale and processing may benefit from increased net weight per plant, while CSA growers...
often prioritize having more individual fruit to put in customer boxes and tend to prefer medium-
to-small sized winter squash. However, a tradeoff exists in squash between the size of individual
fruit and the number of fruit per plant (Michael Mazourek, personal communication, June 4,
2015).

For broccoli head diameter, the broad adaptation and high average performance of
‘Belstar’ and ‘Gypsy’ confirmed farmers’ observations based on experience with these widely-
used hybrids. While this trial was not designed to compare adaptation of hybrids and OP
varieties, it is worth noting that the only broccoli entries that deviated from the pattern of wide
adaptation were OP entries, with ‘Solstice’ and ‘OSU Composite’ showing specific adaptation to
high- and low-yielding environments, respectively. ‘Solstice’ is the result of participatory
breeding undertaken by Jonathan Spero of Lupine Knoll farm in southwestern Oregon in
collaboration with Prof. James Myers of Oregon State University, using the ‘OSU Composite’
breeding stock (for more details see Myers, McKenzie, and Voorrips 2012). Though we hesitate
to draw conclusions based on the low number of environments included, our analysis raises the
question of whether ‘Solstice’ is better adapted to relatively high-yielding environments due to
the conditions of the farm and region in which it was selected. The lack of conclusive results for
adaptability analysis of broccoli maturation may have resulted from the low number of
environments with available data. The data may also have been highly influenced by harvest
date, as it was nearly impossible for research staff to reach all farm sites on the peak harvest day
for each variety. This may have produced a bias towards the varieties that were at peak maturity
on the day of the farm visit, and towards research stations where staff could easily evaluate each
variety on the optimal harvest day.
The results for the two carrot variables may demonstrate the limits of qualitative ranking (i.e. 1 – 5 scores) as an evaluation method in multi-farm variety trials. Because evaluation teams varied from state to state, with different farmers participating at each farm site, evaluator effects are impossible to separate from environment effects for the carrot variables. Multiple evaluators with varying taste perceptions may have resulted in too much variation in the scores given to each variety to observe significant separation between varieties. However, the difference between ‘Spring Market,’ the non-Nantes type, and the other Nantes-type varieties shows that evaluators were in agreement about the clear difference in tastes between these variety types.

Utility of adaptability analysis

Regression of variety yields on EI can serve as a simple, visual method for interpreting how varieties respond to higher- and lower-quality growing environments and identifying patterns of adaptation. Statistical analysis is straightforward to execute, and could be accomplished using a spreadsheet program such as Microsoft Excel, an advantage for farmer-led groups who may not have access to, or experience with, statistical software. This method can be used even when varieties were not grown in the same place in consecutive years, an advantage for participatory trials. Characterizing adaptation as demonstrated by these analyses can provide a better basis for choosing varieties that suit specific purposes, environmental conditions, and farming strategies. The question of whether narrow adaptation to specific environments (as demonstrated by varieties like ‘Metro’) is preferable to broad adaptation across environments (as demonstrated by varieties like ‘Gypsy’) rests in part on the type of environmental variation that farms experience. Varieties with specific adaptation to high-yielding environments are appropriate when farmers place a high priority on maximizing yield, can reasonably assure optimal growing conditions for the crop in question (e.g. access to irrigation and high levels of
fertility), and can tolerate a higher risk of crop loss in the case of unexpected environmental challenges. On the other hand, varieties with specific adaptation to low-yielding environments are preferable for farmers with lower risk tolerance and who prioritize having some yield in challenging circumstances over maximizing yields in optimal circumstances (Ceccarelli 1994). This leaves unresolved the debate discussed at the beginning of this paper, regarding the advantage of broad adaptation versus specific adaptation to low-yielding environments in regions with high temporal variation. It is possible that varieties developed for regions with less predictable weather may need to be more broadly adapted, while regions with more predictable weather, such as California and the Pacific Northwest, may benefit from narrower adaptation. However, since vegetable crops have varied agronomic requirements, diversified vegetable production inherently means that some crops are likely to be cultivated in suboptimal conditions for that particular crop, meaning that farms of this sort are likely to benefit from varieties that can tolerate lower-quality environments.

Challenges for measuring quality-related traits

The usefulness of adaptability analysis was severely limited when considering non-continuous variables which included all of our non-yield traits. In our study these included flavor, appearance, and maturation uniformity, but other traits named as priorities by organic farmers, such as disease tolerance, insect tolerance, and season extension, present similar challenges for evaluation. First, the use of a proportion to measure maturation uniformity in broccoli (head at peak maturity/total heads) may have led to data being artificially centered on 0.5, producing an EI with an insufficient range of values for meaningful evaluation of adaptation. In addition, adaptability analysis was also limited when analyzing qualitative variables evaluated as one-to-five scores, in our case carrot sweetness and root smoothness.
Although scoring is a common method for evaluating entries in plant breeding programs, researchers have long been aware that evaluators tend to disproportionately assign values of two through four, and avoid values of one or five, effectively limiting in the range of the scale (Coe 2002). Moreover, in a project with multiple evaluators, such as NOVIC, an extra layer of variability is added when evaluators interpret the scale differently. If the same evaluator assesses these traits for all varieties at a given site and year, the environmental index should account for the preferences of the evaluator, but it is not possible to separate these preferences from actual environmental influence. On the other hand, quantitative measurement of these traits can be much more expensive and laborious than the scoring approach. Establishing specific descriptors for each level of the scale may help make this data more reliable. Alternative methods of evaluating quality traits may also be equally effective, including systematic approaches to recording farmers’ written or verbal observations (Ashby 1990 provides a number of promising approaches). Efficient but precise and reliable methods for evaluating quality-related traits would allow researchers to assess stability and adaptation with regard to a wider variety of traits, an advantage in breeding and trialing varieties for the organic sector.

Implications for participatory research

Our experience with on-farm trials in the NOVIC project showed the potential of a participatory trialing network to provide insights into variety performance on working organic farms across a wide geographic area. Innovative organic farmers are interested in new crops and varieties, and university-supported trials have the potential to shield them from some of the risk involved in planting an unknown variety. Some NOVIC varieties became new favorites with several Wisconsin growers, particularly ‘Honeynut’ butternut because, as a small “single-
serving” butternut with outstanding flavor, it stood out as novel offering and fit a niche for CSA growers.

However, working with the NOVIC dataset also demonstrated the difficulties of gathering on-farm data for research involving vegetable crops due to the unique issues of harvest time and workflow discussed at the outset of this paper. These challenges call for rethinking trial designs and statistical analyses, as well as the roles of farmers and researchers in research collaborations. For vegetable variety trials specifically, we can imagine two possible directions. One would be a more decentralized approach, with farmers receiving seed, trial design suggestions, and evaluation worksheets, and being largely responsible for data collection. Evaluations would need to be very simple to execute. Researchers might receive data from farmers and be responsible for analysis and distribution of the findings. The opposite direction would be a more centralized approach, with data collection happening largely on research stations and farmers involved in other ways, but not through on-farm trials. After several years of mother-daughter trials, this more centralized approach has been adopted for sweet corn trials in the current iteration of NOVIC.

Other possibilities might come from creative combinations of these approaches. For instance, centralized trials on research stations could be paired with on-farm trials in which the only evaluation is the farmer’s written comments. These qualitative on-farm trials could be organized as simply as sending seed and feedback worksheets to farmers, with little involvement from researchers during the course of the growing season. Though this would preclude statistical analysis of on-farm trials, a great depth of information might nevertheless be captured through such “anecdotal” evaluations. Alternately, on-farm trials could be limited to a few, highly-involved farms, with feedback and guidance from a wider circle of farmers who do not grow the
trials. The potential of key relationships between individual, highly-motivated farmers and trained plant breeders has already been demonstrated in the release of several participatory-bred varieties, such as ‘Who Gets Kissed?’ sweet corn the University of Wisconsin-Madison (Shelton and Tracy 2015) and recent releases from Organic Seed Alliance (OSA 2001). This kind of relationship may serve as a better framework for vegetable trials than attempting to gather data from many farms, as has been possible with grain crops.

Resilient and well-adapted varieties are widely recognized as priorities for organic agriculture, in vegetables as well as other crops. Developing effective ways to identify and evaluate varieties with these characteristics, particularly in terms of quality traits, will benefit both organic breeding and farmers’ ability to judge the performance of existing varieties. Whatever the arrangement, approaches to variety trialing that facilitate collaboration between trained researchers and organic farmers will ensure that research for the organic sector truly reflects the environmental and cultural conditions of organic farms. Adaptability analysis may be a useful tool towards both these ends, to be combined with others in improving the productivity and sustainability of organic vegetable production.
References


Coe, Richard. 2002. “Analyzing Ranking and Rating Data from Participatory On-Farm Trials.” In *Quantitative Analysis of Data from Participatory Methods in Plant Breeding*, CIMMYT.


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Chapter 3

Adaptation and Resistance: Responses of Upper Midwest organic vegetable growers to a changing seed industry

ABSTRACT

Breeding well-adapted crop varieties is key to strengthening the sustainability and productivity of organic systems and meeting consumer interest in organic products. Addressing this goal requires plant breeders and other researchers, who are often more familiar with conventional cropping systems, to better understand organic growers’ needs and practices. In this paper, I seek to complement and contextualize current knowledge about organic farmers’ priorities and responses to seed- and plant breeding-related challenges through case studies of 16 Wisconsin and Minnesota organic vegetable growers spanning a range of farm structures and sizes. I investigate the socioeconomic and agroecological factors affecting these farmers’ choices about seed and how farmers are coping with problems in the seed system. I find that, though caught between pressures from consumer market pressures and seed industry consolidation, organic vegetable growers in the Upper Midwest are adapting to some challenges, resisting others, and working to create new spaces in the seed system. I use these findings to make recommendations about how plant breeding and extension programs can better address growers’ needs.
Introduction

A sudden downpour announced the first thunderstorm of spring in Wisconsin’s hilly Driftless region. It was well after dark but I was still sitting at a large wooden table talking to two farmers whom I’d come to interview, and beginning to doubt the wisdom of having pitched my tent at a nearby county park. Across the table, unconcerned by the hour or the storm, a middle-aged farmer was pulling seed catalogs out of a basket and emphatically tossing them into piles on the table. His friend—another middle-aged, male farmer—looked on and nodded quietly. The first farmer raised up a handful of catalogs that seemed largely to be printed on newsprint or thin office paper.

“These are just really Mom-and-Pop, small, seed growers. Making some of their own, but then distributing them,” he said. He was aware that many seed companies, large and small, redistribute varieties produced by other companies.

The next stack was more brightly colored, printed on glossy pages. “And then I’d throw in Johnny’s, Abundant”—he rattled off more seed company names—“that are really mission-driven, around organics. They are, you know, organic organic.”

After a bit more conversation, he moved on to the next stack. “Then, commercial—Harris, Rupp, and Seedway. Those are just like, your real commercial growers.”

This was not the only interaction involving seed catalogs that occurred during my research about Wisconsin organic vegetable growers’ access to seed and varieties. For many farmers, these catalogs were an entry point to the world of seed production and plant breeding, a sector of agriculture on which they vitally depended yet about whose inner workings they often felt mystified and powerless. As salesmen and saleswomen themselves, they were wary of the
marketing involved in the glossy illustrations, yet like their customers at the Saturday market, they enjoyed browsing. Moreover, some farmers were far less excited about new offerings than they were anxious about not being able to find their favorite tried-and-trues in those pages.

**Background**

I began this research as a doctoral student involved in a collaborative project to identify and breed high-quality vegetable varieties for organic cropping systems, the Northern Organic Vegetable Improvement Collaborative (NOVIC). This project sought participatory involvement from organic vegetable growers in Wisconsin and three other states in planning and implementing variety trials on working farms and university research stations (Oregon State University 2014). The NOVIC project was inspired by a growing understanding that breeding crop varieties in organic agricultural conditions can produce different results than breeding under conventional conditions, and that varieties bred for conventional farming—as most are—are not necessarily the best performers in organic conditions (Singh et al. 2011; K. M. Murphy et al. 2007). As a result, organic farmers are often making do with varieties that are not optimally adapted to their cultivation systems (Lammerts van Bueren et al. 2011). In addition to well-adapted varieties, certified organic seed is important to organic farmers for both ideological and practical reasons. Because seed crops require a long growing season and must be kept free of diseases that could be transferred to farmers’ fields, they often involve intensive pesticide use and high environmental impact (Navazio 2010). The USDA National Organic Program stipulates that organic crops must be grown using organic seed or planting stock, which is defined as seed produced on organic ground using organic cultivation practices (USDA-NOP 2000 §205.204). If organic seed is not available for a desired variety, and no equivalent substitute can be found,
farmers may use conventionally-grown seed, as long as it is free of prohibited fungicidal seed treatments (“untreated seed”).

Aside from lack of plant breeding specifically for organic systems, the availability of certified organic seed suffers from insufficient production, due in part to technical challenges (Lammerts van Bueren, Struik, and Jacobsen 2003) and unclear regulatory frameworks that do not encourage companies to invest in increased organic seed production (Renaud, Bueren, and Jiggins 2014). In addition, organic farmers and advocates express concern that seed industry concentration is leading to higher seed prices and varieties being dropped from seed production (Quaday et al. 2011, 17; Howard 2009; Hubbard 2009), and intellectual property rights held by increasingly fewer companies hampers the introduction of new varieties that might benefit organic growers (Kloppenburg 2014; Tracy and Sligh 2014; Luby et al. 2015). At the same time, recent years have seen growth in the organic seed sector, including increased interest in organic breeding at public universities (Luby, Lyon, and Shelton 2013), and the growth of seed companies that serve the organic market. In 2004, a meeting of stakeholders from 57 countries at First World Conference on Organic Seed identified two faces to the organic seed sector: “community-based seed production systems” led by farmers who save seed for reasons of self-reliance, variety conservation, and production for local communities; and “conventional seed companies who also produce organic seed,” providing hybrids and modern varieties to larger-scale farmers who require the performance characteristics of these varieties (Lammerts van Bueren, Ranganathan, and Sorensen 2004, 2). Arguably, a third category has emerged consisting of mid-scale seed companies focusing specifically on the organic market either through plant breeding or seed production and distribution (Renaud 2014, 221). These constitute the “organic organic” category described by the farmer above.
In the midst of this rapidly changing situation, the research team leading the NOVIC trials in Wisconsin sought to understand how organic vegetable producers in this state experienced and responded to challenges related to seed, as well as their priorities in relation to plant breeding, adopting a mixed-methods approach including interviews and a state-wide survey (Lyon et al. 2015). For those seeking to understand the needs and practices of U.S. organic vegetable growers with regards to seed, the primary source of information on organic farmers’ seed use and needs is a nation-wide survey conducted by the Organic Seed Alliance (OSA). In 2011, this survey found that organic farmers who grew vegetables used less organic seed than those who grew field, forage, or cover crops and were more likely to report insufficient varietal availability, that that the problem was especially pronounced for larger-scale growers (Dillon and Hubbard 2011). The OSA survey has been conducted again in 2015, and results are expected soon. In addition, a study of organic seed use in Canada focused on the volume and value of vegetable seed purchases and identified ways to strengthen seed availability (Levert 2014).

In addition to these surveys, a substantial body of literature describes methods of participatory plant breeding (PPB) developed primarily with resource-poor farmers in the global South (e.g. Morris and Bellon 2004; Ceccarelli and Grando 2009). More recent contributions involve farmer-plant breeder collaborations in Europe (Dawson et al. 2011) and the United States (Myers, McKenzie, and Voorrips 2012; A. Shelton and Tracy 2015). Much of this literature has been written for the purpose of describing the process and results of specific PPB projects and field methods for participatory variety selection. In other instances, researchers have employed ethnographic approaches to investigate farmers’ choices around seed and varieties, demonstrating how farmers’ variety selections are shaped by local knowledge, cultural practices, and political regimes (Temudo 2011; Frossard 2002), in addition to farmers’ empirical
observations of environmental variation and genetic inheritance (Soleri and Cleveland 2001). In the U.S., Renaud et al. (2014) employed a case study approach to understanding entrenched interests in the debate around establishing organic seed regulation. Mendum and Glenna (2009) elaborated some of the obstacles to collaboration between plant breeders, organic farmers, and small seed companies in a case study of a PPB project in the Northeastern United States, while McKenzie documented the benefits and challenges experienced by participants in a PPB project in Oregon (2013, 76–84).

A qualitative case study of Wisconsin organic vegetable growers offered the opportunity both to contextualize the picture of organic farmers’ needs and opinions provided by national and state-wide surveys and to extend upon the insights provided by other qualitative case studies about the motivations and broad contexts shaping organic farmers interactions with the seed system. Given the strength and diversity of its organic vegetable sector, Wisconsin presents a unique case in which to conduct this research. Wisconsin is one of the top states in the United States for organic farming, including organic vegetable production. It has the second-highest number of organic farms of any state with 1,180 farms and $121,527 in sales, according to the 2012 Census of Agriculture, and the fourth-highest number of organic vegetable and melon farms, with 161 farms. Wisconsin’s organic sector is also experiencing remarkable growth, with the number of certified organic farms increasing by 77% between 2005 and 2015 (Carusi et al. 2015). Direct markets and value-added marketing are an important part of organic important part of Wisconsin’s organic vegetable sector (ibid, 6), and Wisconsin has a strong history of cooperatives, farmers markets, and Community Supported Agriculture which has benefited the organic farming community (for examples, see Blobaum 2015; Hendrickson 2015).
The farmer’s typology of companies in the opening vignette provides an example of how organic growers were trying to understand the seed system in order to claim some amount of agency in relation to a seemingly vast, global industry. Many of the farmers I interviewed felt that by acting on such understandings, they could begin to shape the seed industry to serve their needs. This paper will investigate what those needs are, the challenges farmers perceived based on trends in the seed industry, and the ways in which farmers responded to these circumstances. It addresses four central questions:

1. What socioeconomic and agroecological contexts are affecting organic farmers’ choices around seed and varieties?
2. What constraints do organic vegetable growers in Wisconsin experience in accessing seeds and varieties?
3. How are organic farmers coping with problems they experience in the seed system?
4. How can plant breeding and extension programs better address these farmers’ needs?

Methods

As a coordinator of on-farm trials for NOVIC in Wisconsin from 2010 through 2013, I had the opportunity to engage with organic vegetable growers across southern and southwestern Wisconsin and eastern Minnesota about their opinions on seed. Together with my observations at organic conferences and conversations with research collaborators in the NOVIC project—including plant breeders, organic seed advocates, and farmers in other states—these exchanges formed my first understanding of the world of organic seed and plant breeding. Though I do not use these experiences directly in the following analysis, they served as a reference point for planning this study and interpreting the data.
I employed the concept of theoretical sampling, selecting cases that represent the multiplicity of the study population and provide a range of relevant examples in relation to research questions and theory (Orne and Bell 2015, 69). Flyjberg describes this approach as “information-oriented selection” as opposed to “random selection,” (2006, 230). The driving questions in this research related to how farmers in Wisconsin experience and conceptualize challenges in the seed system. In order to contextualize and better understand findings from our state-wide survey, I sought to interview farmers who expressed an interest in seed systems, seed saving, and/or plant breeding, with the idea that these farmers would be best positioned to provide explanatory insights. Because the OSA survey suggested that farm size may have some bearing on the problems that farmers’ report in accessing seed and varieties (Dillon and Hubbard 2011), I included farmers from a range of farm sizes as well as farmers selling to an array of direct and wholesale venues. An unexpected finding in our survey was that over half of Wisconsin organic vegetable growers reported producing some of their own seed or acquiring seed directly from other farmers, while researchers in the NOVIC project often presumed a low occurrence of seed saving in the region due to difficult climatic conditions for seed production. To follow up on this finding, I sought out respondents who produced significant amounts of seed for their own use or for sale or trade.

Farmer respondents were recruited in three ways: 1) requesting interviews with a subset of participants in the NOVIC trials, 2) soliciting volunteers at a presentation about NOVIC at the Organic Farming Conference organized by the Midwest Organic and Sustainable Education Service (MOSES) in Lacrosse, WI, in 2012, and 3) asking respondents to refer other farmers who were particularly involved in vegetable seed production. Respondents included a total of 18 farmers, representing farms in northern, central, and southwestern Wisconsin, and eastern
Minnesota. The Wisconsin farms were located in Vernon, Marathon, Columbia, Polk, Bayfield, Dane, Jefferson, and Sauk Counties. Although in a different state, the Minnesota farmers shared soil types, climate, and markets in the Twin Cities metro area with several of the farms from western Wisconsin. Farm sizes ranged from about one quarter of an acre to 140 acres of vegetable production, though most farms fell between 5 and 20 acres. Most farms had multiple market venues, although many focused on a primary venues such as CSA and used other venues as secondary, flexible income streams. Of the 15 farms, 10 marketed through CSA and 11 through farmers markets, while 4 sold to wholesale distributors and 6 to local grocery chains or co-ops. Of the respondents, ten were male and eight were female, though only three of the farms were solely owned and operated by women. Many of the farms were jointly managed by couples, though only three of these couples were available to interview together. Famers ranged in age from mid-thirties to mid-sixties, and had from 10 to 40 years of experience managing their own farms. All farmers were Caucasian, reflecting the wide racial disparity in Wisconsin farming population (Carusi et al. 2015).

Interviews were semi-structured and followed a standardized interview guide that included a subset of questions to be added for growers who produced seed for sale. The first round of eight interviews took place in the spring through fall of 2012, and the rest took place in the spring through summer of 2013. In interview guide was modified slightly during the second round to reflect ongoing analysis (See Appendices B and C). All interviews were conducted in person with the exception of one phone interview with a grower in far northern Wisconsin whom I had previously met in person. Interviews lasted 60 to 90 minutes on average. I took field notes immediately after interviews to recall additional details. To protect farmers’ privacy, the names in this article are pseudonyms.
Data analysis followed grounded theory, a systematic approach to qualitative research that emphasizes allowing theory to emerge from the data, rather than fitting the data into existing theory (Glaser and Strauss 1967; Strauss and Corbin 1990; Glaser 1992). Grounded theory is an iterative process involving assigning codes of meaning to transcribed text, using regular memo writing to organize those codes into theoretical categories, and returning to the data to test emerging ideas and theories. I was informed by Charmaz’s constructivist interpretation of grounded theory, which acknowledges the subjectivity of the researcher (Charmaz 2003; Charmaz 2006).

Findings

1.0 Seed choices in context

Farmers choose crop varieties to serve a purpose. On diversified organic vegetable farms those purposes are heterogeneous and multi-layered, creating many different demands. When describing how they chose varieties, farmers in this study spoke of considerations that reached far beyond the annual task of cross-referencing seed catalogs to compare varieties and prices. Contexts that came to influence seed decisions spanned from the ecological to the economic, and were embedded in farmers’ personal and social values.

1.1 Environmental contexts

On a practical level, varieties had to be well-adapted to environmental conditions of the farms on which they were to be grown. These environmental conditions were created by the interactions of agronomic practices with weather, seasonality, soil types, and a range of diseases and insect pests, all of which affected each farm differently and could vary from one year to another. Given the diversity of agroecological influences, clear priorities in terms of traits for
organic plant breeding have proven elusive (Lyon et al. 2015; Dillon and Hubbard 2011).

Nevertheless, these interviews presented a consistent, if broader, theme: the need for resilient and reliable varieties under a wide range of environmental conditions. Alice, a relatively new farmer who operated a small CSA and market farm in far northern Wisconsin, described this quality in an heirloom flour corn called ‘Mandan Bride’:

Last year it pretty much proved itself. It survived drought, flood, it got planted in July, cut worms—it was just the whole array of catastrophes, and I still got a crop out of it. And I thought, well, this is the corn for me!

April, who ran a mid-size CSA and market farm and had a longer farming career than Alice, portrayed resilient varieties as a safeguard against unforeseen problems.

In the heat of the summer some things would do just fine, but not reliably fine. So if we’re going to have a whole string of 90 or 95 [degrees Fahrenheit] days, I don’t want to lose my lettuce crop. And so we always plant, through the hottest time of the year, all ‘Batavian’ lettuces…and they just do very well in those conditions.

Many growers had similarly crucial varieties, whether they were disease-resistant salad greens or tomatoes that didn’t develop cracks. James, who specialized in sweet corn for local wholesale, called such varieties “workhorses” and had identified several over his decades of farming, but perhaps none as invincible as a hybrid called ‘Temptation.’ With its large, sugary seeds, sweet corn is vulnerable to rotting in wet soils if temperatures are too cold to promote quick germination, which is particularly problematic in early spring in the Upper Midwest. Conventional sweet corn seeds are treated with fungicides to prevent rotting, but germination is a major issue for organic sweet corn. James described a spring when he thought the seed wouldn’t germinate at all:

The ‘Temptation’ thing, you know, it was 21, 22 days under the ground when we had a very wet, cold spring. I had the experience of three weeks under the soil, and they wanted to disc the ground up. [But]…it came through! I couldn’t believe it! So, it certainly earned its keep, and our belief in it.
Growers’ preferences for strong performance despite unexpected environmental setbacks speaks to a question of plant-breeding strategy. Plant breeders involved in participatory breeding for marginal environments have long argued the importance of local adaptation to the “target environment”—the combination of place and farmers’ management that determines the conditions of plant growth (Simmonds 1991; Ceccarelli 1996). Ceccarelli (1994) frames this as specific adaptation to on-farm conditions, in opposition to wide adaptation resulting from testing varieties in many locations and selecting the one that performs best on average. Farmers are less interested in the variety that performs best in a large geographic area, than in varieties that are “specifically adapted to their conditions, needs and uses, and which have a high degree of stability over time (1994, 213).” Somewhat confusingly, circumstances requiring “stability over time,” e.g. environments with unpredictable environmental variation, justify breeding for wide adaptation in Allard and Bradshaw’s conception (1964). This contradiction suggests, as Ceccarelli concedes, that wide adaptation can be understood both geographically and temporally. Farmers’ identification of workhorse varieties through years of personal observation on their farms reflects the value they placed on wide temporal adaptation, or stability over time.

1.2 Market contexts

In addition to varieties that were well-adapted to environmental conditions, farmers needed varieties that worked within their economic contexts, including market structures, customer tastes, and price competition. James’s enthusiasm for ‘Temptation’ shows how market structures and cropping systems shaped farmers’ use of varieties. Sweet corn derives its sweetness from a genetic mutation that prevents the normal conversion of sugar into starch as kernels develop. Though older sweet corn varieties carried a mutation named sugary1 (sh1), sweet corn breeders have introduced other variants, including sugary enhancer1 (se1) and shrunken2 (sh2),
often called super-sweet (Tracy and Marshall 2003). Varieties with the \textit{sel} mutation, which include ‘Temptation’ tend to have strong germination but short-lasting flavor. These varieties are best when harvested and eaten within a few days of maturity. This was not a problem for James, because on his farm all the sweet corn could be harvested at once and promptly delivered to grocery stores or sold at his farm stand. In contrast, most CSA growers in Southern Wisconsin needed a more flexible harvest window in order to accommodate weekly delivery of market boxes to their members. If \textit{sel} varieties matured out of synch with the weekly harvest and delivery schedule, ears would lose their flavor before customers received them. Instead, many CSA farmers grew super-sweet \textit{sh2} varieties, which held their flavor better but had much poorer germination. As a result, growers had learned to transplant their corn in order to circumvent germination problems. Here, the logistics of certain market structures required a harvest schedule that influenced farmers’ variety preferences, and farmers altered their cropping practices to accommodate those varieties.

Consumer tastes, and farmers’ perceptions of them, added another layer to the economic considerations around variety choices. Even within market venue categories, farmers sometimes perceived different demands from their customers. Chuck and Miranda discussed how their CSA model allowed them to use open-pollinated (OP) broccoli varieties, which matured unevenly, because “if we have a little variation that’s okay…we want it over a couple weeks.” In contrast, Beth, who was generally committed to growing OP varieties, said the variability present in OP broccoli didn’t work for her markets because of the same quality Chuck and Miranda saw as an advantage. “It all comes ready at different times,” she said, making it necessary to harvest the side shoots that broccoli plants produce after the main head is harvested. This didn’t work for their CSA: “That’s not the type of broccoli that people are familiar with, especially around here.”
Other growers found that customer preferences were not completely fixed. By marketing through a CSA and farmers’ market, April said, “You can put things right into people’s hands and educate them at the same time. And so we have the ability to grow and distribute things that we otherwise wouldn’t.” While some wholesale growers tried to shape consumer preferences by introducing new or unusual vegetables, direct markets generally allowed for more give-and-take between farmers’ needs and their customers’ tastes, allowing farmers to choose from a wider array of varieties.

Finally, economic pressure from price competition with other farmers played into decisions about seed. Marsha, who had been farming for 25 years and had seen the number of CSA’s in her area increase dramatically, was aware of both the positive and negative effects of this growth.

It’s really good for the environment when we have more and more farmers doing organic farming. It’s good when we have more and more customers aware of what organic means. [But] it means that we as individual farmers probably have to work harder to get our CSA members and to sell our stuff at the farmers market.

Competition played out differently depending on market venues and location. For one CSA grower, a sense of price competition with CSA’s who were not certified organic—and therefore did not need to follow the requirement to use organically-grown seed—led to a reluctance to pay higher prices for organic seed.

We can’t reflect those same costs in our CSA because we’re competing with the non-organic CSA’s, because that’s who’s in our neighborhood. And I don’t think that there’s a market for people to pay more for a CSA because it’s organic…We probably couldn’t charge ten percent more for our CSA than everybody else, just to have that label.
For James, economic competition for local grocery and co-op markets increased the need to produce a consistent crop over a longer harvest window. Identifying the right varieties was a crucial step to capturing limited markets.

Staying power was everything. The fact that you could say you were going to grow a crop, deliver it, and have a product with shelf life and quality…that you could get in the window and stay there until no one else had it. So those varieties then had to have those qualities, whether it was in the broccolis or the peppers or the corns or whatever.

Economic structures seemed to drive seed and plant breeding priorities in a different, though not always conflicting direction from environmental contexts. Rather than selling at low prices and competing on volume, organic vegetable growers tried to find niches where competition was lower and they could command a higher price. Thus where environmental contexts seemed to favor varieties that were stable over time, the drive to exploit new economic niches resulted in an ever-increasing number of specific trait priorities. James’s recollection of marketing produce to local grocery venues demonstrates these variety needs:

In the early days, everybody grew the same thing. And in marketing, what it came down to was that in produce you either were the first in, you had early crops, or on the other side you had the last of them, so you were late. Or you had ornate, so you might have something novel—you know, strawberry popcorn, or a new squash. And then you worked that one. And so, I kind of had that criteria going on: how do I fit in?

Other respondents gave further examples of “ornate” varieties that helped them market to niches. The history and vivid colors of ‘Mandan Bride,’ a variety of flour corn traced to the Mandan people of North Dakota and Minnesota, fit well with Alice’s strategy of differentiating her market stand by focusing on heirloom varieties. Ray excelled at marketing uniquely appealing vegetables to his CSA, farmers market, and wholesale venues, such as a small “snack-size” sweet pepper. Others specialized further by processing their crops into goods like sauces,
bread, and even vitamins and supplements, resulting in yet more specific needs from their varieties. Some growers went so far as to protect their market niches by maintaining secrecy around their variety names in order to prevent other farmers from entering the same niche. One grower said that his preferred varieties were a “trade secret,” and claimed that growers at farmers markets in the Twin Cities area would purposefully misidentify varieties if asked by other farmers. The common theme for these growers was that identifying good varieties required time and risk, and they did not to share the resulting knowledge with direct competitors. Other growers scoffed at this idea, seeing it as contrary to the spirit of information sharing in the organic community.

The role of niche markets as part the development of alternative food systems has been documented in multiple agricultural sectors, including wheat (Glenna, Jussaume, and Dawson 2010), pork (Wheatley 2003; Honeyman et al. 2006), and vegetables (Carey 2009). We interpreted the results of our state-wide survey on seed and plant breeding, which showed a marked lack of consensus about which crops were most economically important, as evidence of niche-seeking in the organic vegetable sector in Wisconsin (Lyon et al. 2015). Sociologists have employed several frameworks to understand the socioeconomic implications of niche markets in food, including Fordism (Friedland 1994, 219), actor network theory (Ilbery and Kneafsey 1999), social ecology (Dimara, Petrou, and Skuras 2003), and food regimes (Giménez and Shattuck 2011). Perhaps most relevant here is literature that questions whether niche markets provide long-lasting alternatives to the dominant food regime (Wheatley 2003; Smith 2006), or in fact represent a continuation of advanced capitalist accumulation, as Friedland argues (1994). The tensions that were apparent in these interviews between some growers’ sense of protectiveness and competition in regard to niche varieties, versus social values of knowledge-
sharing and cooperation within the organic community indicate a rich area for further inquiry about these questions.

1.3 Social values

Mediating the influences of economic pressures were farmers’ values in relation to the way they farmed. These values were part of farmers’ personal identities and were strongly shaped by the ideas of the organic community, reflecting farmers’ identification with that community. Bell (2010) describes similar interplays of identity, community, and values as cultivated knowledge. Social values shaped how farmers interacted with both economic and agroecological contexts, adding another layer to seed decisions. First, values were an important motivation for seeking and maintaining organic certification, which in turn informed all seed decisions. Though economic motivations like selling to organic distributors played a role in certification decisions, the farmers I interviewed identified other reasons that had to do with their values and how they saw the world. An Amish farmer objected to pesticides on moral grounds because of potential effects on human health, saying, “I can’t in good conscience use things that are going to hurt other people.” Marsha said that, “probably the reason that most of us became organic farmers was we came out of an environmental perspective,” and many other farmers echoed perspectives from the environmental and sustainable food movements. Others spoke of organic farming as a source of pride and personal satisfaction, as April demonstrated:

I think of myself as a student of this farm. I don’t ever think I’ll know everything about what’s going on here, but I love learning about the natural processes that happen on a farm…I think just about any farmer that you talk to loves their land, and feels they have a strong connection to their land…but I think there’s something about organic farming systems that kind of force you into this relationship of observation and paying attention.
For April, organic farming was an important part of how she thought of herself, and she talked about how her seed choices fit into her vision of organic agriculture. For example, choosing varieties with strong disease resistance helped her use fewer inputs.

I know for myself, even organically-approved insecticides I don’t want to use. I do on occasion, but on a very limited basis. I’d much rather have strong, vigorous plants that can resist those things…versus use a product that is certainly a milder form, but is still an insecticide that has impacts that go beyond targeting your pests.

Implied in April’s avoidance of “even organically-approved insecticides” was a sense that she did not think these insecticides were really consistent with organic values, even if they might be acceptable for certification. This kind of policing of the social values cultivated by the organic community came up in the way farmers talked about using organic seed. Beth expressed concern that not everyone was following the spirit of the NOP regulation requiring farmers to use organic seed whenever an equivalent variety was available.

There’s some places where you don’t have a lot of choice. But, like bok choy—you shouldn’t be planting non-organic bok choy, that’s a joke! I mean, I can buy cheaper seed…and say it’s because of the variety, but it’s not because of the variety.

She could not imagine any market for bok choy that would be so specific as to require a variety not available as organic seed. Ray demonstrated similar policing of social values around seed, arguing that the NOP seed regulations should be more strictly enforced. For both these growers, with very different farm sizes and market structures, using and talking about using organic seed was, among other things, a sign of commitment to the values of the organic movement. For many of the growers in these interviews, such commitments were an important part of how they organized their thoughts around seed, and had even greater influence on their opinions about which seed companies to support, as I will discuss.
2.0 Seed access and farmer concerns

Considering the amount of effort involved in identifying workhorse and niche varieties, farmers were understandably concerned about being able to find seed for them consistently. Nearly all farmers I interviewed had at least one example of an important variety for which they had trouble finding seed. Some farmers spontaneously began talking about varieties they could no longer find; others responded affirmatively to an interview question asking if they had ever had difficulty accessing seed of the varieties they wanted. Not only was losing access to a variety a common experience, farmers had similar ways of talking about these occurrences. They frequently named the specific varieties, explained the traits the made them valuable, expressed confusion about why the variety had disappeared, talked about their search for replacements varieties or described their efforts to maintain access.

Andy and his partner Sina ran a very small CSA with an emphasis on permaculture practices, and saved a relatively large number of crops compared to other growers I interviewed. Like other growers’ accounts, Andy’s story of a lost variety was particular to his interests, but exhibited all the common themes:

There was a red onion variety called ‘Southport Red Globe.’ You ever heard of it? It hasn’t been in seed catalogs that I’ve seen for about five, six years now. And it was an open-pollinated variety, a real long-lasting, good storage, red onion, pretty big. And I was growing it back to seed several years in a row in the late 90’s, early 2000’s and then for whatever reason I stopped and tried some other varieties and I didn’t save the seed. And then I went back and looked for it and it disappeared! I don’t understand why. I don’t understand what happened to it. But I’m frustrated that we can’t find a good—it seems like it’s mostly hybrid onions out there now.

While Andy had been taken by surprise by this disappearance, other farmers acted on rumors or hints to try to maintain access to varieties they thought might be threatened. When Ray
got wind that one of his favorite hybrid melon varieties might be dropped, he took multiple steps
to try to maintain access.

    We had this melon that we’re in danger of losing that I tried but failed to grow. It’s
a hybrid, but I thought maybe we could…select out an open-pollinated melon out
of it, but I just got weird stuff. Just weird. I lost my patience because it was just, it
looked impossible.

    Instead of dropping the variety altogether, the seed company moved it to a separate home
gardening catalog and offered it only in smaller amounts. Still fearing the variety would
disappear, Ray spent “several thousand dollars” on a pound of melon seed to store away. “We’re
planting seed that’s five years old,” he said, “but we still have it!”

    When varieties disappeared, farmers looked for replacements that would fill the same
niche, but sometimes found that varieties that were advertised as replacements did not work as
well for the same purposes. April lamented the loss of a hybrid tomato called ‘Cascade,’ which
she described as particularly productive and reliable, producing fruit over a long period of time.
Most uniquely, its meaty texture made it suitable as a sauce or canning tomato as well as a fresh-
eating tomato, or “slicer.” Unable to find a replacement with the same versatility, April had
altered her approach to tomato production.

    We ended up just doing away with that category of tomato, and saying, well, we’ll
grow our sauce tomatoes, we’ll grow our slicing tomatoes, and not expect anything
to be a cross-over.

    Sometimes varieties disappeared completely, either permanently or for a few years. In
other cases farmers couldn’t obtain seed in the quantity they needed or found that the quality of
the variety had deteriorated. After years of growing the same OP leek variety, Beth had begun to
notice problems. “I feel like I’m planting a different variety half of the time. I don’t feel like it’s
the same.” For the largest-scale growers, variety access was limited by the quantity of seed they
could find. Lauren managed a very large farm, growing vegetables for on-farm processing. She wished she had “the luxury” of choosing varieties based on their characteristics, but said the decision usually came down to whichever varieties she could find in sufficient quantity of organically-grown seed. Comments like this were in line with our survey findings, which found that growers with larger farms were much more likely to report seed quantity as a problem.

Losing access to important workhorse and niche varieties not only presented immediate practical problems, but also drew attention to the opacity of the seed system and growers’ resulting sense of vulnerability. Marsha described how abrupt variety disappearances left farmers scrambling and often unable to make credible comparisons with potential replacement varieties.

I understand that there’s going to be constant development, but it would be nice if there was—like we still have this variety so that we can grow it too and we can compare and say, ‘Oh yeah this one really is better.’ But when it just disappears it’s like, wow, you know...what happened? Why did that one suddenly fall out of favor and stop being produced?

In the absence of a clear understanding of how and why seed companies made these decisions, growers wondered and speculated. A farmer who specialized in bedding plants worried about losing access to ‘Sun Sugar,’ a cherry tomato variety that was very popular with his customers:

Well, there was a rumor a couple years ago that Monsanto bought out the company that had the rights to ‘Sun Sugar.’ And there was a rumor that Monsanto was eliminating some varieties. And I’d heard that, and this is maybe just through the grapevine—you don’t really know if there’s anything to it, but I’d heard that they were going to eliminate the ‘Sun Sugar’ variety. But, I don’t know.

Farmers were especially concerned about potential changes in availability of workhorse varieties. Because the seed company that owned ‘Temptation’ had recently introduced a version with genetically engineered resistance to corn root borer and other insects (Bt), James feared that
non-GMO and untreated ‘Temptation’ seed would soon be eliminated from their offerings in order to drive sales towards the new product.

They’ve already tightened up the availability of untreated seed. So now the suspicion is that when they do the Bt…it’s a great corn, and it’s a product that everybody wants, and so…well, they would [only] produce the Bt because they’ve got the money into that.

Frustrations like this led to skepticism about whose interests were represented in the seed industry. Many farmers sensed that variety offerings were based on the needs of very large-scale production. Even Ray, who ran one of the largest organic vegetable farms in the Midwest, remarked that his seed orders were “small change” compared to the wholesale vegetable production operations in California. For April, this was the best explanation for seed companies dropping varieties that seemed so popular among the growers she knew:

It might just be my interpretation, but I kind of feel that happening when I look at the seed catalogs. Seeds that I have been buying for years and love, and think they perform really well, and other people are saying the same thing, and then they disappear. And I don’t know...my assumption has been that this variety’s been dropped from the market because it’s unappealing, or unpopular with a certain sector of growers that doesn’t—that’s not me.

3.0 Coping with seed system challenges

As they described the contexts surrounding their seed decisions and their troubles in accessing seed, farmers seemed to be caught between the agroecological contexts of their farms, the pressures of their markets, and the idiosyncrasies of the seed industry. They responded to the challenges presented by this squeeze in a variety of ways, from the practical to the political. On a practical level, they were concerned with maintaining access to their most valued varieties, but they also developed political critiques of the seed system and found ways to resist the concentration of power they observed. Finally, a few were working to create alternatives in the form of local seed production.
3.1 Adaptation

Farmers adapted to the challenges of the seed system by employing practical actions and relying on social relationships. Some practical steps included maintaining variety access through seed storage and seed production, and ongoing trials of replacement varieties. Several farmers described buying and storing extra seed in anticipation of a variety going out of production, as Ray did with the melon seeds. This kind of stockpiling of seed was not a long-term solution, as the seeds could lose their viability over time, and would eventually run out. Still, this strategy bought farmers a few more seasons during which to look for replacements for their workhorse varieties or see if the seed would appear on the market again.

Producing one’s own seed was a longer-term adaptation to inconsistent variety access. It could also save farmers money, though the economics varied by crop depending on seed prices and the revenue farmers could expect from selling the crop as fresh produce. Farmers tended to choose crops that were less challenging for seed production; tomatoes, peppers, legumes, corn, and herbs were all common. They also tended to have specific reasons for the crops they saved, either related to seed price or concerns about variety availability. Beth’s attitude reflected what many other growers said:

We don’t save that much seed. We do when we feel worried about something. Like, sometimes we save tomato varieties. There are some tomato varieties—‘Cherokee Purple’ is not going anywhere, but ‘Striped German’? I get worried, because [only one company] really has the one that we like.

Informal variety trials were another adaptation to uncertain variety access. By keeping up an ongoing search for replacement varieties, growers tried to avoid being caught shorthanded. The farmer who specialized in bedding plants talked about this strategy:

We try to grow more than one variety and the see what’s a suitable alternative. Broccoli is an example, you know, like we’re doing two varieties of broccoli this
year. And we’re very pleased with one variety, but if it’s not available, why then, what do you do, you know? You’ve got to figure something else out.

Finally, farmers used social relationships to help compensate for the opacity of the seed industry. Steps to maintain variety access were often taken based on a tip from someone with insider knowledge. Farmers valued seed-related “gossip,” in James’s words, even when it seemed tangential, because it helped them to understand and picture the inner workings of the seed industry and the world of plant breeding. Other times, the benefits from information obtained through these relationships was quite concrete. James credited his “spies” with receiving a heads-up on the cancellation of ‘Cascade,’ the same tomato variety April missed, and being able to order enough seed to last several years.

One of the most common contacts that farmers had with seed companies were seed sales representatives. Farmers measured the value of these relationships, and indeed their regard for the seed companies they represented, by the seeming trustworthiness of the information that seed reps passed on to them. Beth said, about one seed company:

I feel really good about working with them, because I feel like, they hire farmers. So it’s not just a rep. And, they’ve been really honest...they didn’t have ‘Napoli’ [carrot seed] a few years ago, and [the seed rep] was like, ‘I wouldn’t replace Napoli.’ You know, even if there’s no organic seed, because that variety is way better than the comparables.

Other farmers related similar stories of reps advising against varieties in their own catalog, regarding this as an ultimate mark of trustworthiness. Ray spoke highly of a trials manager for one of the seed companies catering to vegetable growers. “I remember ordering a melon that I thought we should try because it sounded good in the seed catalog. She said, ‘Don’t buy it!’”
The information Ray had gained from this contact went beyond variety recommendations. “She clues me into like different varieties, who they’re from, and so I learned that Bejo is a producer of all the seeded shallots.” Bejo Zaden, a multi-national vegetable seed company based in the Netherlands, is one of a handful of companies that breeds and produces seed but sells only to other seed distributors rather than retailing directly to farmers. Ray had learned that his favorite hybrid shallot came from this company, even if he had purchased it elsewhere. Through conversations with the trails manager, Ray had gained insight into areas of the seed supply chain that remained hidden to many farmers.

Not all growers had the same sorts of connections, and not all were able to access the same information. Marsha pointed out how farmers’ ability to access information from seed companies was uneven, and likely influenced by farm size:

I used to work for a guy that now works for [a seed company], so I’ll call him up periodically and talk to him. But not really the seed reps as much. I’ve talked to them at conferences, but I’m not really big enough for them to spend a lot of time with, because I don’t necessarily buy the volume that they get from, you know, those farms that are hundreds of acres.

Nonetheless, Marsha had her own sources of information, one of which was close relationships with university researchers and frequent participation in university research and trials. Other farmers also mentioned knowledge gleaned from relationships with public and private plant breeders, university extension agents, and researchers from nonprofit organizations such as Organic Seed Alliance, Michael Fields Agricultural Institute, and Seed Savers’ Exchange. Some farmers tested whether I might be a source of information, turning the interview around to ask me about the reasons behind which varieties were available as organic seed or how on-farm variety improvement might work. Through connections and word of mouth, farmers
attempted to piece together a picture of the seed system in order to adapt to changes and stay a step ahead problems with variety access.

3.2 Resistance

While farmers took practical steps to cope with the problems they faced related to seed and variety access, many of them also presented political explanations for their actions. Farmers’ framing suggested that they saw some of their actions not simply as adapting to the problems in the seed system, but as resisting and creating new alternatives. Practices that farmers frequently framed in terms of resistance included aspects of seed purchasing, using OP varieties, and, in a few cases, building local seed systems by producing seed for sale or exchange. Often, the difference between practical and political acts was one of framing: it was possible, and common, to do both at once.

Many farmers saw a way to alter the seed industry by choosing to support companies that were trying to offer more organic varieties. Marsha identified this kind of selective seed purchasing as the primary way to improve the representation of organic agriculture in seed companies’ priorities:

I think it starts with us as farmers. Buying from these smaller companies and keeping them in business. We need to keep them in business or else we’re going to be stuck with those other varieties, and, and some of those names are not going to be people that are interested in making any organic seeds. They’re not even interested in making any untreated seeds. So that’s where it starts.

Choices about which seed companies to support were another way in which farmers expressed their identification with the social and political values of the organic movement. Beth, who was upfront about her family’s progressive values, said that they looked for varieties first from a company with a cooperative ownership structure even though she had had bad experiences with their seed quality. “I ideologically like them,” she said.
In the piles of seed catalogs sorted on the kitchen table that rainy night, Keith had sorted companies into “Mom-and-Pop,” “mission-driven organic,” and “commercial” categories. Though this classification initially seemed to be based on company size, further questioning revealed that it had even more to do with what kind of farmers those seed companies served. When I asked about the distinction between what he called “mission-driven” and “commercial” seed companies, Keith said that the commercial companies sold to “all kinds of commercial growers all across the country.”

“So these catalogs are for large growers,” said his friend Peter, clarifying for my benefit.

“Right, huge growers,” Keith agreed. Of the “mission-driven” stack, he said, “I bet it’s CSA’s, organic, small…”

Furthermore, the “commercial” companies were likely to have the fewest offerings of organic seed. This typology helped Keith explain how seed companies operated and how to position himself in relation to them. Specifically, as Peter went on to point out, it provided a framework with which to act on Marsha’s admonition to support organically-oriented companies.

Not represented on the table was a category of even larger, multi-national companies, such as DuPont/Pioneer, Syngenta, and Monsanto. Respondents criticized these companies frequently, particularly Monsanto, as emblematic of corporate control and monopoly of seed. Avoiding purchasing their varieties, however, was easier said than done. Farmers were aware that several of their most widely-used hybrid varieties were owned and produced by Seminis, one of the largest vegetable seed companies in the world, which was acquired by Monsanto in 2005 (Kaskey 2005). Some farmers mentioned these varieties sheepishly, immediately giving explanations of why they used them. In addition to ‘Temptation’ sweet corn, these included ‘Sun
Gold’ and ‘Sun Sugar’ cherry tomato, varieties that were widely popular with customers because of their flavor. Beth tried, without success, to identify replacements.

We’re trying to get away from varieties that are owned by Seminis. And so for the last few years we’ve been trialing, next to ‘Big Beef’ [tomato], which is a Seminis variety, we’ve been trialing other varieties side-by-side with ‘Big Beef’. We really haven’t found anything that’s as good.

In addition selective purchasing from specific seed companies, some farmers framed their use of OP varieties as an expression of resistance to corporate control in the seed industry. For these growers, hybrid varieties represented dependence on a global seed industry—or as Keith put it, “a string with a hook on it.” Because they offered the possibility of seed saving, OP varieties seemed to promise more farmer control. For Alice, OP seed carried this meaning whether or not she saved the seed herself.

I’m basically thumbing my nose at this massive global consolidation in the seed world, and this huge…push to corner the world seed supply. It’s fairly terrifying to me. And so, any way that the seed can remain in the hands of the farmers, where it’s been for thousands and thousands of years, the better. And so even though I may not save an open-pollinated seed variety, I want to buy open-pollinated seed to, sort of, claim my stance in the world.

From the smallest farms to the largest farms, the growers I interviewed thought that farmers’ ability to save seed was important to organic agriculture, and drew connections between this and the maintenance of existing OP varieties and development of new ones. Nevertheless, many took a more pragmatic approach than Alice. As Vance put it in discussed the bedding plants he sold, “I prefer to grow the varieties that do the best for our customers. And if it’s hybrid versus open-pollinated, well, so be it.” April said her use of OP’s or hybrids depended largely on the crop.

Some things like broccoli, we rely pretty heavily on hybrids. And then, in tomatoes it’s probably two-thirds heirloom or open-pollinated. And then other things like,
well, pea seeds and bean seeds, it’s a whole mix… I know some people feel very strongly about one or the other but I don’t really have that preference.

Instead, April talked about importance of seed companies who were focused on developing and producing seed specifically for organic farmers, including both OP’s and hybrids. For her, a stronger and more manageable way to enact change in the seed system was to support these companies.

3.3 Alternatives

In addition to growers who were selectively choosing seed companies and using OP seed as forms of resistance, I met a few growers who were actively creating alternative local seed systems by producing, selling, and exchanging seed. One of these was an Amish farmer who had begun ordering seeds for other farmers in his community after they decided as a group to pursue organic certification in order to sell produce to an organic distributor. This experience had given him the idea of starting his own seed retail business. Eventually, some of the Amish farmers began producing their own seeds for sale, which were offered in the catalog alongside seed that was purchased wholesale and redistributed from other companies. The coulee geography of the Driftless region, home to most of Wisconsin’s Amish communities, facilitated easier isolation of seed crops to prevent unwanted cross-pollination. In addition, their long experience of working as a community made it easy to distribute seed crops to different farms, further helping with isolation and production planning. Though his company did not do online or phone sales, their paper catalog was distributed throughout the region and beyond, and was one of the catalogs in Keith’s “Mom-and-Pop” pile.

In the same region, Jan had begun marketing seeds in local stores, grown by network of home gardeners. He mailed seed envelopes to these amateur seed growers, who packeted their
seed and sent it back to him. Most seed sales were within the local region, including a seed rack at a nearby natural foods co-op, and Jan described most of his customers as home gardeners as well. Jan saw his company primarily as a way to enable small-scale seed savers to market seed to small-scale farmers and gardeners. A corn grower for many years, Jan had some of the most critical views of the conventional seed industry of any of the farmers I interviewed, as well as a large amount of skepticism about the influence of private industry on university research. He was also highly critical of the widespread adoption of hybrid varieties, which he associated with unsustainable monocultures.

When you’re thinking about hybrids, you’re balancing the sustainability of an agricultural system, if it becomes the dominant plant in an agricultural system, versus profit. And that’s as simple as it is.

In starting his seed company, he hoped to promote the use of OP and heirloom varieties, which he called “traditional” varieties.

Meanwhile, Alice was working on plans to develop a seed-growing group with two other farmers in Wisconsin and Minnesota. Rather than selling seed, these growers were primarily interested in producing seed for their own use, but they recognized the time and labor challenges of growing seed for multiple varieties and crops on one farm.

It’s in its very, very early stages, but the thought is that it would be a collaborative, like a commercial collaborative. So, for example, I might be maintaining ‘Mandan Bride’ corn and other people would have different things, and we would be putting this up on a website somewhere, and say, you know, ‘I’ve got this for sale’. And all of us would focus on [our] bioregion, so we’re maintaining a variety that’s really tuned to our climate, and soils.

Though they were aware that the Seed Savers’ Exchange yearbook offered a similar platform for seed producers to find each other and exchange seed, April’s group of farmers hoped that by saving, exchanging, and possibly breeding seeds in a more targeted region, they
could improve the local adaptation of their varieties. Seeking more information and training about how to do this, some of them attended a workshop at the MOSES Organic Farming Conference about growing seed crops. April came away from that workshop with seeds from two OP kale populations grown by an organic farmer in Washington, and she was excited to start selecting them on her farm. “I planted both of those in huge quantities this year, to see what comes out of it and see if I can start to focus those varieties a little bit more.”

4.0 Recommendations to support organic seed systems

Farmers’ accounts from this study contribute a number of insights about the support that public plant breeders, agricultural researchers, and other Extension personnel can provide for organic vegetable growers. Particularly instructive are the constraints that prevented some farmers from taking steps they wanted to take, that would help them secure access to seed or create alternatives in the seed system. These constraints lead to three specific recommendations. Undoubtedly, many of the challenges that growers faced must be addressed through broader organizing for organic seed systems, work that is already underway by farmers and nonprofit advocates in these areas. The following list provides examples of ways that universities could support organic seed systems, arising from specific constraints mentioned in these interviews.

4.1 Facilitate variety trials of vegetable crops in organic environments.

Farmers’ accounts of losing access to varieties and seeking replacement varieties underscored the value of variety trials that accurately capture the performance of commercially-available varieties in a range of organic environments. Making the results of such trials available in a timely fashion could help farmers judge potential replacements when a key variety is not available. However, as documented in Chapter 2, the time- and labor-related barriers to on-farm trialing of vegetable crops are high. Narrow harvest windows for many vegetables make it
difficult for researchers to visit on-farm plots, yet conflicts with the labor-flow of harvest on a diversified vegetable farm make data collection burdensome for farmers. Innovative and simple methods for evaluating important traits in fresh vegetables might facilitate more farmer participation. One farmer in these interviews said that it would be helpful for researchers to provide evaluation forms for farmers to use in their own trials. Such resources have been developed by Organic Seed Alliance, and should be further publicized to vegetable growers in the Midwest. Another route might be to rethink the structure of collaborative variety trials by conducting them in fewer locations but building in stronger farmer leadership, such as involving experienced organic farmers as semi-formal project advisors.

4.2 Identify and document farmers’ workhorse varieties.

Surveys and farmers’ accounts demonstrate that organic vegetable growers in the Upper Midwest grow and prioritize a diverse range of crops, and that diversity may continue to expand as farmers more into more economic niches. Nevertheless, farmers also had identified reliable, workhorse varieties within important crop types, and several of these were mentioned by more than one farmer even within the small sample represented in these interviews. ‘Temptation’ was certainly an example for sweet corn, as were ‘Big Beef’ and ‘Cascade’ for tomato. These varieties serve an important role as “checks” in variety trials, providing a known quantity with which to compare the performance of other varieties across environments. Working with farmers to document workhorse varieties in important crops could aid future variety trialing and breeding efforts.

4.3 Tailor trainings in seed production to account for the logistics of market farms.

While farmers talked about saving seed to preserve variety access and trying out new varieties that replace varieties with uncertain access, they also talked about the practical
challenges to carrying out both these activities. Many of the farmers I interviewed were already aware of some seed saving resources: some were members of Seed Savers Exchange in Iowa, some had read books on the subject, and a few had attended workshops in Wisconsin or Minnesota with Organic Seed Alliance. Still, many had difficulty working out the logistics of saving vegetable seeds while simultaneously bringing fresh crops to market. April summed it up:

I feel overwhelmed enough with the demands of a crop rotation and the diversity of things that we have going on here, that I have a hard time wrapping my head around seed saving, too. Even though I also have this bottom-of-my-gut feeling that it’s really important.

Providing training or enabling information-sharing between farmers on this topic could help many growers follow through with their ambitions to save seed from some of their varieties. This might involve research about the feasibility of seed saving on CSA and other fresh vegetable farms.

4.4 Assist beginning seed producer groups.

Though the seed production I encountered was mostly small-scale and for personal use, I did encounter three farmer-led enterprises who were attempting to grow seed on a somewhat larger scale. In addition, many farmers voiced support for the idea of regional seed systems and wanted to find seed that was adapted to regional conditions. Farmers’ preference for seed from companies that aligned with their values, particularly the goals of the sustainable agriculture movement, speaks favorably of their interest in buying seed from local seed producers or companies, if they existed. Compared with farmers in major seed-producing regions of the Pacific Northwest, vegetable growers in the Upper Midwest are largely unfamiliar with the practicalities of commercial-scale vegetable seed production, making training and support all the more important. Opportunities exist to support farmers groups who are interested in collaborative
seed production, following models such as Farm Breeding Club initiated by the Northern Plains Sustainable Agriculture Society (NPSAS 2015). Potential contributions from university personnel might including helping grower groups identify seed crops and varieties with the best chance of success, helping them access grants to build coordination infrastructure and buy equipment, and researching economic feasibility.

Discussion

Interviews with Wisconsin organic vegetable growers provided insight into the agroecological and socioeconomic contexts that played into farmers’ decisions about seed and varieties, the challenges they perceived in accessing seed that met their needs, the actions they undertook in relation to the seed industry, and the opportunities for university and extension personnel to provide support and outreach. Farmers’ strategies of seeking and developing economic niches for new crops and varieties with unique stories and characteristics may help explain the wide array of crops listed as economically important in our state-wide survey. Farmers’ pursuit of new market niches further emphasizes the importance of quality traits such as flavor, appearance, culinary uses, and novelty in plant breeding for the organic market. While the diversity of crops prioritized by Wisconsin growers may make plant breeding priorities difficult to pinpoint, it should also inspire breeders interested in unique specialty crops with the knowledge that a subset of organic growers is likely to be interested in new, high-quality varieties in nearly any crop.

In addition to niche varieties, workhorse varieties may be a useful vernacular for summarizing the kind of resilience and reliability that organic farmers valued. Further consideration is warranted regarding whether these qualities are best achieved by breeding for
narrow or wide adaptation. While specific adaption to local environments is widely held to be important for agroecosystems with high farm-to-farm variability, arguably including organic agriculture, regions with high year-to-year variability may require more widely-adapted varieties. Farmers’ comments about workhorse varieties bear out the idea, discussed in Chapter 2, that organic growers would prefer varieties that perform reliably during challenging years over varieties that perform outstandingly in good years.

In general, as suggested by our survey results, farmers’ attitudes towards organic seed was positive, and they drew strong connections between strengthening the organic seed system and the success of organic agriculture as a whole. Identification with the social values of the organic movement was prevalent among growers of a range of sizes, leading them to express support for seed companies that they perceived as devoted to the organic “mission” and responsive to growers’ needs. Social relationships and informal modes of information-sharing, particularly with contacts in the seed industry, were an important factor in growers’ understandings of the global seed industry, which influenced their seed purchasing practices and their choices of seed companies. Finally, the challenges that farmers related about finding seed and accessing varieties highlight the urgency of further plant breeding and variety release for organic systems, and their critiques of the concentration of power concentration in the seed industry call attention to the value of developing more diverse, democratic seed systems. Achieving these goals will doubtless require collaboration between multiple actors and stakeholders, as well as active public involvement. The value farmers placed on seed companies that aligned with their values, and their willingness to take actions to create alternatives, shows the importance of farmers as partners in the movement for broader seed system change.
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Conclusion

This dissertation provides a view of Wisconsin organic farmers’ needs and experiences with regard to seed and plant breeding for vegetable crops, as well lessons from evaluating vegetable varieties in on-farm trials. A goal of this research was to help inform efforts to improve seed availability and plant breeding for organic vegetable growers in the Upper Midwest. To this end, I offer a few insights on the broader implications of my findings.

The farmer survey gives an overview of strengths, weaknesses, and opportunities in the organic seed system from the perspective of organic vegetable growers in Wisconsin. Farmers’ valuations of vegetable crops in terms of economic value as well as their assessments of crops most in need of plant breeding can help plant breeders make decisions about where to focus their resources. However, while a few top-priority crops emerged, an overarching theme from the survey and qualitative interviews was that the diversity of strategies and economic niches used by direct-market vegetable growers results in high valuation of a wide array of crops and traits. While perhaps a positive note for the agrobiodiversity of organic systems, these findings have the potential to leave plant breeders and others working on organic seed systems feeling overwhelmed. Where should we begin, and how can we ever address such varied needs?

The lessons of the NOVIC project in conducting participatory variety trials for fresh vegetable crops do not provide immediate reassurance. While the importance of on-farm research and farmer involvement in evaluating varieties for organic conditions is clear, the logistical challenges of visiting a network of field sites in order to evaluate multiple vegetable
varieties at peak maturity can compromise the quality of data, and the timing of variety trial evaluations with the harvest of commercial crops can hinder farmers’ participation. Some of these challenges can be addressed by designing participatory trials to facilitate the use of statistical methods that can handle unbalanced trial designs and missing data. As my research shows, adaptability analysis can be a useful tool in this regard because it is simple to execute and provides graphical representations that are fairly easy to explain to a lay audience. However, better methods are still needed for incorporating analysis of non-yield traits such as those related to eating quality, which are essential for the organic market.

While these challenges might seem daunting, motivation for addressing them should be strong. Growers’ comments in qualitative interviews show the challenges they face in finding reliable access to their most important varieties, a situation which can be ameliorated in part by introducing more varieties that are bred for organic agriculture and by better understanding the performance of existing varieties in organic conditions. The interviews also highlight the importance of resilient varieties that can stand up to a wide range of environmental stresses, particularly important in places with unpredictable environmental variation such as the Upper Midwest. While organic farms can be more vulnerable to some kinds of environmental variation because farmers abstain from chemical inputs such as pesticides and fertilizers, it stands to reason that all vegetable growers could benefit from varieties that provide reliable performance with fewer fertilizers, pesticides, and chemical seed treatments. This becomes especially clear when considering a future of increasingly unpredictable weather, and recognizing that “adaptation to climate change necessarily includes adaptation to variability” (Smit et al. 2000, 227).
So, the stakes are high for developing vegetable crops that are well-adapted to organic systems and can tolerate a wide range of environmental challenges. Decades of research in breeding for marginal and low-input systems show the effectiveness of participatory approaches when working in complex agroecosystems, and successful participatory work in organic plant breeding, particularly in grain crops, shows the importance of employing farmers’ expertise. Again the questions arise of how to apply these methods to variety trialing in fresh vegetable crops, and what needs to address out of a diverse set of farmer priorities. Where to start and how to proceed?

To address these questions, may be useful to study examples which we now have of participatory plant breeding of organic vegetable varieties in the United States. Recent instructive cases include: 1) the release of ‘Who Gets Kissed?’, an open-pollinated sweet corn bred by plant breeder Bill Tracy and graduate student Adrienne Shelton of University of Wisconsin-Madison, plant breeder John Navazio of Organic Seed Alliance (OSA), and farmer Martin Diffley in Minnesota; 2) the release of ‘Solstice,’ an open-pollinated broccoli bred by plant breeder Jim Myers and graduate student Laurie McKenzie of Oregon State University with farmers Jonathan Spero in Oregon and Julie Puhich in Washington; and 3) the release of ‘Dark Star,’ an open-pollinated zucchini bred by John Navazio and a team of OSA staff with famers Bill Reynolds and Donna Ferguson of California. A common feature in all of these projects is that they were led by a fairly small research team, anchored on a strong relationship between one to three researchers and one or two farmers. Qualitative accounts by McKenzie (2013) and Shelton (2014) of their involvement in the participatory breeding process, as well as the OSA (2015) description of ‘Dark Star’ zucchini reveal that the farmer collaborators were highly interested in the respective crop, and stood to gain personally from the development of a variety
that would perform better on their farms. In addition, because of the small size of the research team, projects could be tailored to the specific interests and insights of the farmers involved. And motivations for collaboration went beyond personal gain; in all of these cases, it is readily apparent that the collaborators simply liked spending time together. They had, as Michael Bell (1998) has described it, a solidarity of both interests and sentiments.

On-farm variety trials involve a different set of objectives that make the work of collaborative research distinct from that in plant breeding. The final product is, at best, a research report with insights about which varieties might suited to different locations—useful, but probably not as satisfying as brand new variety to name. On the other hand, breeding is less predictable and may have more potential to lead to frustrating outcomes. In addition, variety trials generally involve more farm sites in order to understand how varieties perform in different environments. Because more farmers need to be involved, there is less flexibility for any one farmer’s opinions to shape the project strongly, and this is especially true when working across states in a project like NOVIC. When Wisconsin farmers suggest varieties and traits that they would like to see evaluated, and then find that the final variety list and trailing plan reflects a compromise between their interests and the interests of farmers in three other states, they sometimes decide that the trials do not justify their investment of time and field space. The solidarity of interests begins to fray. Sometimes farmers’ positive feelings towards university researchers help to overcome these hesitations, since many organic vegetable growers are grateful that the university is doing any organic research. Yet, with larger groups of farmers, time commitments on both sides make it more difficult to build the kinds of relationships that have held smaller teams together in the examples of participatory plant breeding in vegetable crops.
It may be possible, though, to use some of the lessons from breeding projects to think differently about how to make variety trials “participatory.” One way forward, both in terms of designing variety trials and in terms of choosing directions for organic plant breeding is to follow the example of these small farmer-plant breeder teams and allow strong relationships to guide research directions. While this may seem to exclude a larger community of farmers, examples from community development offer compelling reasons to believe that conversations that are limited to smaller groups may end up being more effective in building wider community involvement than starting with the entire community (Lee 2007). While involving fewer farmers might also seem contrary to the objective of testing variety performance in many environments, this could potentially be addressed by choosing farms that represent “mega-environments,” or environmental regions in which the same varieties tend to do well (Gauch and Zobel 1997). Identification of mega-environments for organic vegetable crops would be an important step towards more efficient use of variety trialing resources.

One possible model for variety trials led by closer farmer-research teams is the Discovery Farms program administrated by University of Wisconsin Extension, particularly the group of nine “Core Farms” that commit to five- to seven-year water quality monitoring projects guided by a farmer-research steering committee (UW Extension 2015). Crawford et al. (2007) provide an analysis of how the involvement of such commercial farms can facilitate public learning about complex agroecological issues. Establishing core farms for variety trialing in organic vegetable crops, connected with land grand universities or nonprofits in several states, might allow for more extensive farmer training in variety trialing techniques and facilitate easier comparison of data across farms. In addition, field days and outreach activities involving core farms could allow more farmers to be learn from and contribute to the variety trials without having to grow the
trials themselves. A steering committee comprised of farmers, researchers, and organic industry stakeholders could provide further opportunities for involved beyond the core farmers. The idea of core farms is just one proposal for participatory variety trialing in organic vegetable crops, and most certainly involves challenges and setbacks which would need to be considered further, particularly regarding funding. It is an example, however, of the kind of rethinking of trialing systems that is needed in order to effectively address the need for vegetable varieties that are proven in organic systems.

On a final note, as plant breeders, graduate students, and other researchers continue to improve methods for participatory research in organic cropping systems, their qualitative accounts of their own work are invaluable for allowing others to learn from their experiences. My dissertation is unusual in its span of quantitative and qualitative methods in both natural and social sciences. Developing enough familiarity with this wide an array of methodological approaches to produce research at the doctoral level necessarily means compromising on the depth of expertise one can gain in any one discipline, and this compromise should not be taken lightly. However, qualitative social science methods have an important, and easily overlooked, role to play in the development of participatory research in quantitative science. In research collaborations with farmers, qualitative writing can shed light on dynamics of the research process that typical natural science writing obfuscates. Furthermore, because organic plant breeding is a small and emerging field, each new breeding program and collaboration currently represents an illustrative case that can aid other researchers. Graduate students engaged in this discipline could benefit from training in qualitative methods such as comparative case studies, ethnography, and other tools for reflexive interrogation of one’s own involvement in the research process. In my observation, plant breeders, graduate students, and farmers who work together
have many important insights about the process. Documenting and sharing these experiences can improve the responsiveness of plant breeding, variety trialing, and a wide range of research to the evolving needs of sustainable agriculture.
References


Appendix A

WISCONSIN ORGANIC VEGETABLE SEED AND PLANT BREEDING SURVEY

Please fill out only one survey per farm. Please complete and return by Friday, February 10.

1. Are you a vegetable farmer?
   - ☐ Yes, I farm in Wisconsin
   - ☐ Yes, I farm elsewhere (specify state)
   - ☐ No, I do not grow vegetables. Thank you; please return the survey in the envelope provided.

Farm Characteristics

2. Is your farm Certified Organic? (Check one)
   - ☐ Yes
   - ☐ No
   - ☐ Transitioning to organic certification
   - ☐ I follow organic practices but am not certified
   - ☐ Other_________________________

3. If you answered “Yes” in the above question, how many years has your farm been organically certified? ________________ years

4. How many acres of vegetables did you plant in 2011?
   - ☐ Less than 5
   - ☐ 5 -12
   - ☐ 12 - 25
   - ☐ Over 25

5. In the last 3 years, how have you marketed your vegetables? (Check all that apply, and circle your primary marketing outlet)
   - ☐ Wholesale – mainly to a fresh market distributor
   - ☐ Wholesale – mainly processing
   - ☐ Direct/local wholesale (e.g. direct to grocery store or grocery co-op)
   - ☐ Restaurant
   - ☐ Community Supported Agriculture (CSA)
   - ☐ Farmers’ market
   - ☐ Farm stand
   - ☐ Other _____________________

6. In 2011, how many different vegetable crops did you grow? (Write a number)________
7. This question is about the crops you market through venues other than CSA. From the following list of crop groups, please put a check next to your 5 top income-earning crops for market venues other than CSA. If one of them is not on this list, please write it in space provided.

- Tomatoes
- Cucumbers
- Peppers
- Cabbage
- Lettuce
- Winter Squash
- Radish
- Garlic
- Carrots
- Summer Squash
- Spinach
- Other
- Potatoes
- Beets
- Kale
- Other
- Beans
- Broccoli
- Leeks
- Other
- Peas
- Onions
- Melon
- Other

8. Some farmers who market through CSA, farmers market, and other direct venues find that certain crops are very important for customer appeal, and yet are not the highest income earners. Please put a check next to the 5 crops which you consider “most important” on your farm, regardless of cash value. If your main marketing venue is CSA, these might be crops you feel have to be in the CSA box.

- Tomatoes
- Cucumbers
- Peppers
- Cabbage
- Lettuce
- Winter Squash
- Radish
- Garlic
- Carrots
- Summer Squash
- Spinach
- Other
- Potatoes
- Beets
- Kale
- Other
- Beans
- Broccoli
- Leeks
- Other
- Peas
- Onions
- Melon
- Other

Perspectives on plant breeding for organic agriculture

Please choose the three crops from the following list that you think are most in need of crop improvement and plant breeding. For each of the three crops, you will be asked about the traits you think are most in need of improvement. You may also write in a crop which is not on the list.

- Tomatoes
- Squash, summer
- Spinach
- Lettuce
- Squash, winter
- Kale
- Carrots
- Beets
- Leeks
- Potatoes
- Broccoli
- Melon
- Beans
- Onions
- Cabbage
- Peas
- Peppers
- Garlic
- Cucumbers
- Radish
- Other (Specify)

9. For the first crop, (write in crop) __________________________, please check the top 3 traits in need of improvement from the list below.

☐ Nutrient use efficiency
☐ Flavor
☐ Appearance
☐ Cold hardiness/season extension
☐ Yield
☐ Disease resistance/tolerance
☐ Insect resistance/tolerance
☐ Germination/seedling vigor
☐ Ease of harvest
☐ Competitiveness with weeds
☐ Other __________________________
10. For the second crop, (write in crop) ________________, please check the top 3 traits in need of improvement from the list below.

- [ ] Nutrient use efficiency
- [ ] Insect resistance/tolerance
- [ ] Flavor
- [ ] (Specify) __________________________
- [ ] Appearance
- [ ] Germination/seedling vigor
- [ ] Cold hardiness/season extension
- [ ] Ease of harvest
- [ ] Yield
- [ ] Competitiveness with weeds
- [ ] Disease resistance/tolerance
- [ ] Other ___________________________
- [ ] (Specify)
- [ ] Other ___________________________

11. For the third crop, (write in crop) ________________, please check the top 3 traits in need of improvement from the list below.

- [ ] Nutrient use efficiency
- [ ] Insect resistance/tolerance
- [ ] Flavor
- [ ] (Specify) __________________________
- [ ] Appearance
- [ ] Germination/seedling vigor
- [ ] Cold hardiness/season extension
- [ ] Ease of harvest
- [ ] Yield
- [ ] Competitiveness with weeds
- [ ] Disease resistance/tolerance
- [ ] Other ___________________________
- [ ] (Specify)
- [ ] Other ___________________________

12. Below is a list of 7 potential research priorities for organic agriculture. Please rank them from 1 to 7, in order of importance to you, where 1 is the most important. Use each number only once.

- ____ Plant breeding for organic production
- ____ Variety trialing for organic production
- ____ Weed management
- ____ Insect management
- ____ Disease management
- ____ Fertility management/soil health
- ____ Season extension/high tunnels
- ____ Post harvest handling and storage
- ____ Economics/profitability
Perspectives on availability and quality of organic seed

13. In 2011, what percent of your seed did you get from the following sources? Fill in your best estimate below based on percentage of seed used on the farm. Your answers should add up to 100%.

- % Produce your own
- % Seed broker
- % Printed or online catalogs
- % Garden centers
- % Other farmers
- % Other

14. Of the cultivars (varieties) you planted in 2011, approximately what percent were in the form of certified organic seed?

- None
- Some, but less than 2% of cultivars
- 3-5% of cultivars
- 6-10% of cultivars
- 11-20% of cultivars
- 21-40% of cultivars
- 41-60% of cultivars
- 61-80% of cultivars
- Over 80% of cultivars

15. For the crops you grow, how easy or difficult is it to find certified organic seed for varieties with satisfactory traits?

- Very easy
- Somewhat easy
- Moderate
- Somewhat difficult
- Very Difficult

16. For the crops you grow, how easy or difficult is it to find certified organic seed with satisfactory seed quality?

- Very easy
- Somewhat easy
- Moderate
- Somewhat difficult
- Very Difficult

17. Over the last three years, has your organic certifier requested that you take greater steps to source organic seed?

- Yes
- No

18. If you answered yes to the above question, check which additional steps your certifier has requested (Select all that apply.)

- Trialing of available organic varieties
- Searching OMRI database
- Researching more than three seed catalogs
- Other(s)
19. Please indicate how much you agree or disagree with the following statements:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Somewhat Disagree</th>
<th>No Opinion</th>
<th>Somewhat Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I'm confused about what &quot;open-pollinated&quot; means.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>I prefer to use open-pollinated varieties rather than hybrid varieties</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<td>☐</td>
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<tr>
<td>when possible.</td>
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</tr>
<tr>
<td>I would choose an open-pollinated variety over a hybrid variety even if</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>the quality of the open-pollinated variety was slightly lower.</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Developing open-pollinated varieties should be a priority for plant</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>breeding for organic agriculture.</td>
<td></td>
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</tr>
</tbody>
</table>
Participatory and on-farm research

In participatory research, farmers and scientists share decision-making and responsibilities through some or all parts of the research process. Ideally, this approach produces better scientific results and research that is more useful for farmers. Because everyone’s time is limited, participants may want to be less or more involved with different parts of the research. The following questions relate to making participatory research efforts in plant breeding easier and more rewarding for farmers.

20. Which of the following have you done while operating this farm? (Check all that apply.)

☐ My own variety trials
☐ Other plant breeding activities on my own
☐ Other agronomic research on my own (please elaborate) ____________________________

☐ Variety trials in collaboration with a private company
☐ Other plant breeding activities in collaboration with a private company
☐ Other agronomic research or product evaluation in collaboration with a private company (please elaborate) ____________________________

☐ Variety trials in collaboration with university or extension personnel
☐ Other plant breeding activities in collaboration with university or extension personnel
☐ Other agronomic research in collaboration with university or extension personnel (please elaborate) ____________________________

☐ Other ____________________________

21. If you participated in research with university or extension personnel, what did you hope to gain from your involvement?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

22. Which of the following would increase your interest or ability to participate in collaborative research with university/extension personnel? Please check all that apply.

☐ None—I’m just not interested
☐ Better communication during the project
☐ More opportunities/better advertisement of opportunities
☐ If I had more space on my farm
☐ If I already knew the researchers involved
☐ If I had more time
☐ Other farmers I know were participating
☐ Financial compensation
☐ Clearer expectations
☐ Project relevance to my interests
☐ Better communication of project result
23. Figuring out how to share responsibility is a common challenge in participatory research. Please indicate how you would like responsibility, (including decision-making and management), to be allocated for the following common agronomic research tasks. Place each on a scale where (1) is totally researcher-led, (5) is totally farmer-led, and (3) is equally shared between farmers and scientists. Circle a number, 1 through 5, for each item.

<table>
<thead>
<tr>
<th>Research planning and design</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applying for grants/funding</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Planting research plots on my farm</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Crop management during the growing season, incl. managing weeds, pests, etc.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Harvest</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Data collection during the growing season, such as germination rate, plant height, disease assessment, etc.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Data collection at harvest, such as yield, weight, appearance, flavor, etc.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Data interpretation and application</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Communication of results</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

**Demographic Questions**

24. How many years have you been managing your own farm, including this and any other farms you have managed? ________________

25. Approximately how many hours of help do you hire per year? (For example, one employee working 40 hours per week for 52 weeks would be 2080 hours.) _______ hours

26. Approximately how many worker-share and/or volunteer hours are worked on your farm per year? _______ hours

27. Gender (please check one)
   - Male
   - Female

28. Age (please check one)
   - < 30
   - 30 – 40
   - 41 – 50
   - 51 – 60
   - > 60

29. What is the highest level of formal education you have attended?
   - High School/GED Program
   - College/University
   - Vocational/Technical Training Program
   - Graduate School
Appendix B

INTERVIEW GUIDE I

May 1, 2012

1. Describe your farm
   -primary crops, primary markets, size/acreage, farm history

2. Why do you practice (or not practice) organic (or biodynamic) methods?
   -Why do you choose to be certified (or not certified)?

3. Do you save seed for yourself or grow seed to sell?
   -If they save seed → Question 4; If they sell seed → Question 5
   -If no, why not? What would make you consider starting?

4. Questions about seed saving
   -What crops/varieties do you save and why?
   -When did you start doing this/how did you learn?
   -How do you save seed—do you practice selection?
   -Have you seen changes in the varieties you save?

5. Questions about commercial seed production
   -What crops/varieties do you produce?
   -When did you start doing this?
   -How much do you produce?
   -What are your markets?
   -What advice would you give to someone else in WI who wants to do this?

6. Seed purchasing decisions
   -How do you decide which varieties to add or drop?
   -How do you decide which seed companies to order from?
   -What problems have you encountered with accessing varieties?
   -How important is it that seed be certified organic?
   -Has your approach changed over time? Why?

7. Hybrids and OP’s
   -Do you prefer one over the other? Why? Can they coexist?
   -If you prefer hybrids, what about the argument for OP’s?
   -If you prefer OP’s, what about the advantages of hybrids?
   -Has your attitude about this changed over time? Why?
8. **Competition and capitalism**
   - In an ideal world, what would the role of seed companies play? What about public breeders? What about farmers?
   - Do you think some seed companies have “sold out”? How did that affect you?
   - Is “selling out/being bought” inevitable or could it be prevented somehow?
   - Do you see the identity of the varieties you grow as a trade secret? Did you always feel this way? What changed?
Appendix C

INTERVIEW GUIDE II
April 10, 2013

1. Describe this farm
   - primary crops, primary markets, size/acreage, farm history

2. Is this farm certified organic?
   - How long has the farm been certified?
   - Why do you choose to be certified (or not certified)?
   - (If biodynamic) Why do you practice biodynamic farming?

3. Tell me about your seed ordering process…
   - How do you decide which varieties to add or drop?
   - How do you decide which seed companies to order from?
   - What problems have you encountered with accessing varieties?
   - How important is it that seed be certified organic?
   - Has your approach changed over time? Why?

4. I have a few questions about hybrid and open-pollinated varieties…
   - Do you prefer one over the other? Why? Can they coexist?
   - (If they prefer hybrids) What about the argument for OP’s?
   - (If they prefer OP’s) What about the advantages of hybrids?
   - Has your attitude about this changed over time? Why?

5. Do you save seed for yourself or grow seed to sell?
   - If they save seed → Question 4; If they sell seed → Question 5
   - If no, why not? What would make you consider starting?

6. Questions about seed saving
   - What crops/varieties do you save and why?
   - When did you start doing this/how did you learn/what resources did you use?
   - How do you save seed—do you practice selection?
   - Have you seen changes in the varieties you save?
   - Have you considered selling seed?

7. Questions about commercial seed production
   - What crops/varieties do you produce?
   - When did you start doing this?
   - How much do you produce?
   - What are you markets?
   - What advice would you give to someone else in WI who wants to do this?
8. Competition and capitalism

-Ideally, what would role would seed companies play? Public breeders? Farmers?
-Do you think some seed companies have “sold out”? How did that affect you?
-Is “selling out/being bought” inevitable or could it be prevented somehow?
-Do you see the identity of the varieties you grow as a trade secret? Did you always feel this way? What changed?