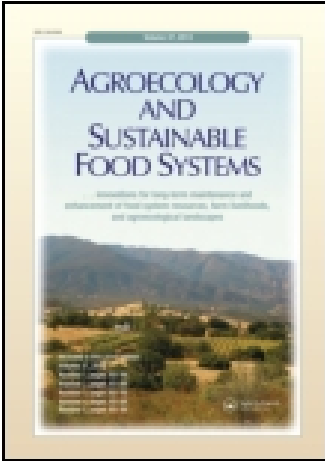


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Seed and Plant Breeding for Wisconsin's Organic Vegetable Sector: Understanding Farmers' Needs

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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: a) general characteristics and farm practices; b) challenges in accessing organic seed; c) plant breeding priorities; and d) 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.

KEYWORDS *organic seed, vegetable seed, participatory plant breeding, on-farm research, Wisconsin*

INTRODUCTION

Issues of plant breeding and seed access have become increasingly important to the organic farming community in recent years. In the United States,

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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 (Quaday et al. 2011; Martens 2004; Sooby et al. 2007). This article 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 (Howard 2009; Hubbard 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; 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 2014:48). As the majority of organic vegetables in the United States 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, Maine) and High Mowing Organic Seeds (Wolcott, Vermont), as well as smaller, regionally focused seed companies such as Wild Garden Seeds (Philomath, Oregon) and Prairie Road Organic Seeds (Fullerton, North Dakota).

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). 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). 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; 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 statewide 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 article, 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° and 47°N and 86° and 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 et al. 2012).

Survey Implementation

Our goal 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 (see supplemental material) with input from the University of Wisconsin Survey Center and OSA staff. Prior to distribution, the questionnaire was pretested 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: a) demographics and farm characteristics; b) access to and use of organic seed; c) plant-breeding priorities including crops, traits, and open-pollinated (OP) versus hybrid seed; and d) 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 the percentage of cultivars grown rather than volume of seed or percentage 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 five 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 toward OP 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 (Serpalay et al. 2011). 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, although 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 5–12 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.

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 = 160).

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 11% 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 1 Acres of vegetables planted by respondents in a 2012 survey of Wisconsin organic vegetable growers (85 responses)^a

Acres of vegetables planted	%	Cumulative %
<5	48.2	48.2
5–12	27.1	75.3
12–25	10.6	85.9
>25	14.1	100.0

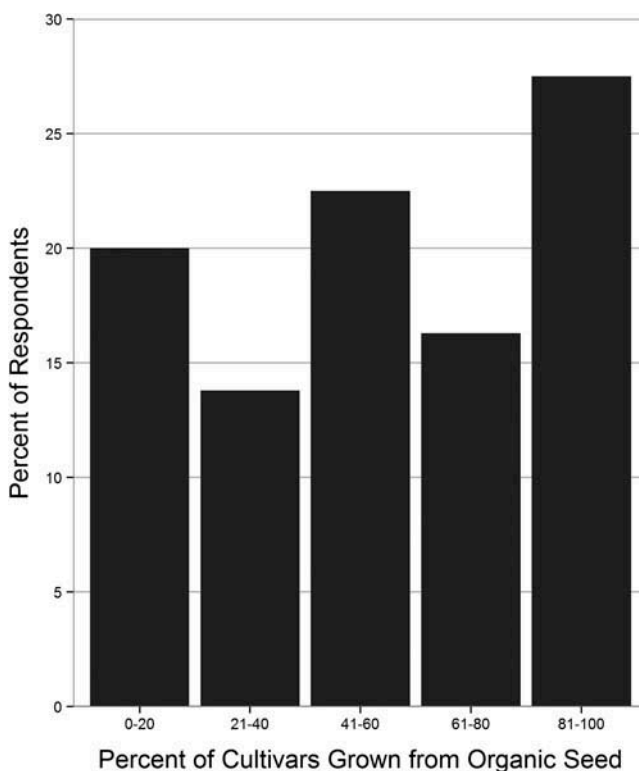
^aAcres of vegetable production was reported for the year prior to the survey, for example, 2011.

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

Market venue	Frequency	Proportion
Wholesale: direct/local	43	0.51
Wholesale: fresh market Distributor	38	0.45
Wholesale: processor	9	0.11
Farmers market	38	0.45
CSA	29	0.34
Restaurant	26	0.31
Farm stand	21	0.25
Other	16	0.19

Organic Seed Use and Access

Over one quarter of respondents (27.5%) reported using organic seed for 80–100% 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

**FIGURE 1** Reported percentage of cultivars grown from organic seed in a 2012 survey of Wisconsin organic vegetable growers (83 respondents).

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 three 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 4). 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."

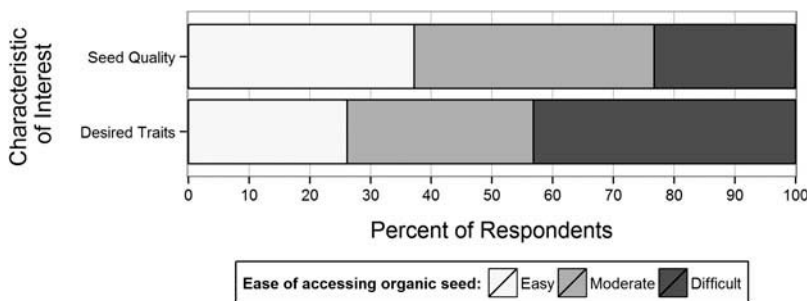


FIGURE 2 Reported ease of access to organic seed of satisfactory quality and with desired traits in a 2012 survey of Wisconsin organic vegetable growers (80 respondents).

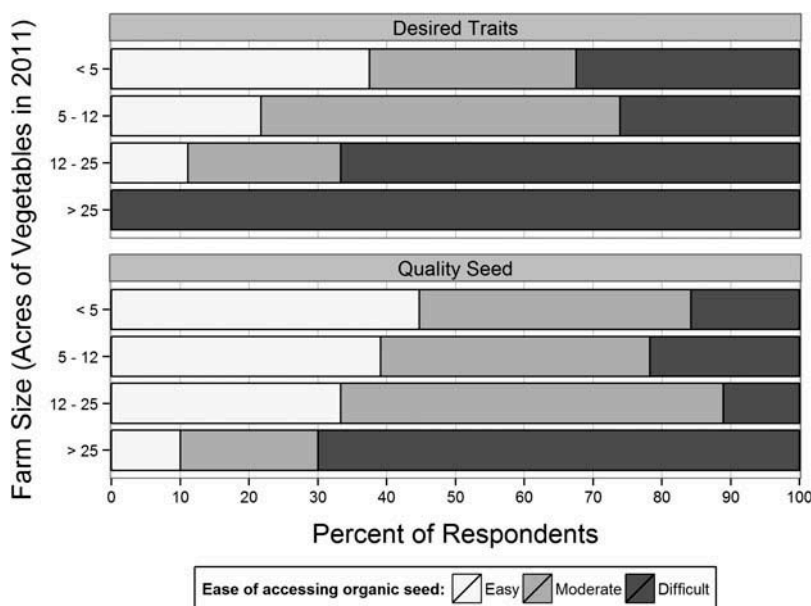


FIGURE 3 Reported ease of access to organic seed of satisfactory quality and with desired traits, by farm size in a 2012 survey of Wisconsin organic vegetable growers (80 respondents).

TABLE 3 Relationship between acres of vegetable production, pressure from organic certifiers, and selected demographic variables with access to organic seed and satisfactory quality and variety traits, in a 2012 survey of Wisconsin organic vegetable growers (85 responses)^a

Independent variable	Access to quality seed		Access to satisfactory traits	
	R^2	p	R^2	p
Acres of vegetable production in 2011	0.096	0.005*	0.188	0.000*
Pressure from organic certifiers	0.009	0.407	0.000	0.871
Respondent education level	0.002	0.680	0.000	0.959
Respondent age	0.002	0.738	0.017	0.242
Respondent gender	0.010	0.393	0.000	0.887

^a R^2 and p values obtained through univariate regression.

* $p < 0.05$.

Plant-Breeding Priorities

For both CSA and non-CSA categories, tomatoes ranked highest as an economically valuable crop (Tables 5A and 5B). 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

TABLE 4 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)^a

Market Venue	Frequency	Relationship with					
		Use of alternative seed sources		Access to good quality seed		Access to satisfactory traits	
		<i>p</i>	<i>R</i> ²	<i>p</i>	<i>R</i> ²	<i>p</i>	
Wholesale: direct/local	43	0.360	0.000	0.855	0.004	0.577	
Wholesale: fresh market distributor	38	0.818	0.010	0.380	0.000	0.987	
Wholesale: processor	9	0.718	0.076	0.013	0.012	0.332	
Farmers market	38	0.251	0.016	0.260	0.000	0.931	
CSA	29	0.815	0.012	0.344	0.011	0.341	
Restaurant	26	0.811	0.070	0.018	0.001	0.772	
Farm stand	21	0.797	0.002	0.680	0.019	0.214	
Other	16	0.043*	0.002	0.668	0.000	0.977	

^aFrequencies 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.

**p* < 0.05.

TABLE 5A Most economically valuable crops for non-CSA market venues according to Wisconsin organic vegetable growers in a 2012 survey (81 responses, multiple answers allowed)

Rank	Crop	Frequency	%
1	Tomatoes	43	53.1
2	Other	34	42.0
3	Winter squash	23	28.4
4	Beets	20	24.7
5	Potatoes	19	23.5
5	Garlic	19	23.5
6	Kale	18	22.2
7	Carrots	17	21.0
8	Lettuce	16	19.8
8	Cucumbers	16	19.8
8	Peppers	16	19.8
9	Summer squash	13	16.0
10	Peas	11	13.6
10	Onions	11	13.6
11	Spinach	10	12.3
11	Cabbage	10	12.3
12	Beans	9	11.1
12	Melon	9	11.1
13	Radish	8	9.9
14	Broccoli	7	8.6
15	Leeks	4	4.9

TABLE 5B Most economically valuable crops for CSA market venues according to Wisconsin organic vegetable growers in a 2012 survey (62 responses, multiple answers allowed)^a

Rank	Crop	Frequency	%
1	Tomatoes	43	69.4
2	Carrots	22	35.5
3	Other	21	33.9
4	Lettuce	20	32.3
5	Beans	19	30.6
6	Potatoes	17	27.4
7	Cucumbers	15	24.2
8	Peppers	13	21.0
9	Peas	11	17.7
9	Winter squash	11	17.7
9	Garlic	11	17.7
10	Beets	10	16.1
10	Broccoli	10	16.1
10	Onions	10	16.
10	Melon	10	16.1
11	Spinach	8	12.9
12	Radish	6	9.7
12	Kale	6	9.7
13	Cabbage	5	8.1
14	Summer squash	4	6.5
14	Leeks	4	6.5

^aOnly a subset of respondents practiced CSA, therefore, the question about CSA market venues received fewer responses.

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.

Due to an uneven response rate for the three questions about plant breeding priorities, 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.

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

TABLE 6 Vegetable crops most in need of plant breeding, according to respondents in a 2012 survey of Wisconsin organic vegetable growers (66 responses)^a

Rank	Crop	Frequency
1	Winter squash	18
2	Tomatoes	16
2	Potatoes	16
2	Melon	16
3	Peppers	12
4	Carrots	9
4	Peas	9
4	Cucumbers	9
5	Summer squash	7
5	Onions	7
5	Sweet corn	7
6	Beets	6
6	Cabbage	6
7	Beans	5
7	Broccoli	5
8	Lettuce	4
8	Spinach	4
9	Kale	3
10	Radish	2
10	Leeks	2
10	Garlic	2

^aFrequencies 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, 66 is the maximum possible response rate for a given subquestion. See supplemental material for question wording.

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)

Rank	Trait	Frequency
1	Disease tolerance	89
2	Insect tolerance	59
3	Yield	50
4	Germination	46
5	Season extension	42
6	Weeds	36
7	Other	35
8	Flavor	30
9	Appearance	29
10	Nutrient use	21
11	Ease of harvest	11

squash, tomatoes, potatoes, and melon) (Tables 8A–8D). 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

TABLE 8A Most important traits for first priority crop (winter squash), from a 2012 survey of Wisconsin organic vegetable growers (66 responses, multiple answers allowed)

Rank	Trait	Frequency
1	Yield	8
1	Disease tolerance	8
2	Insect tolerance	7
3	Weeds	5
4	Flavor	4
5	Appearance	3
5	Season extension	3
5	Germination	3
6	Other	2
7	Nutrient use	1
7	Ease of harvest	1

TABLE 8B Most important traits for second priority crop (tomato), from a 2012 survey of Wisconsin organic vegetable growers (66 responses, multiple answers allowed)

Rank	Trait	Frequency
1	Disease tolerance	15
2	Season extension	7
3	Appearance	6
4	Nutrient use	4
4	Flavor	4
5	Other	3
6	Insect Tolerance	2
7	Yield	1
7	Germination	1
7	Ease of harvest	1
8	Weeds	0

TABLE 8C Most important traits for third priority crop (potato), from a 2012 survey of Wisconsin organic vegetable growers (66 responses, multiple answers allowed)

Rank	Trait	Frequency
1	Insect tolerance	12
2	Disease tolerance	9
3	Yield	7
4	Appearance	5
5	Nutrient use	2
5	Weeds	2
6	Flavor	1
6	Germination	1
6	Other	1
7	Season extension	0
7	Ease of harvest	0

TABLE 8D Most important traits for fourth priority crop (melon), from a 2012 survey of Wisconsin organic vegetable growers (66 responses, multiple answers allowed)

Rank	Trait	Frequency
1	Flavor	9
2	Disease tolerance	7
3	Season extension	6
4	Insect tolerance	5
4	Germination	5
4	Other	5
5	Weeds	3
6	Ease of harvest	2
7	Appearance	1
8	Nutrient use	0
8	Yield	0

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 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 3). 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 ($p = 1.00$).

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 9).

TABLE 9 On-farm research activities reported by respondents in a 2012 survey of Wisconsin organic vegetable growers (86 responses, multiple selections allowed)

Research type	Research partner	Frequency	Proportion of 86 responses
Variety trials	On my own	58	0.67
	University/extension	9	0.11
	Private company	6	0.07
	Total	73	0.85
Plant breeding	On my own	7	0.08
	University/extension	2	0.02
	Private company	2	0.02
	Total	11	0.13
Other agronomic	On my own	15	0.17
	University/extension	14	0.16
	Private company	1	0.01
	Total	30	0.35

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 Nationwide Surveys

Most of the demographic differences between our respondents and those in nationwide surveys were slight, although 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); survey research typically experiences higher return rates from women. The National Organic Farmers' Survey conducted by OFRF found that 45% of respondents had been farming for 21 years or more (Walz 2004); 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), 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 toward 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 toward 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 1995). 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 (Almekinders and Louwaars 2002; Bishaw and Turner 2008).

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 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 OP 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 OP 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 a 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, farmers are adding value by specializing in unique crops and varieties. This is similar to a trend observed among wheat growers in Washington (Glenna et al. 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. Although 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 produced 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 (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 (Almekinders et al. 2006; Bishaw and Turner 2008; Tin et al. 2011).

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 grant 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.

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SUPPLEMENTAL DATA

Supplemental data for this article can be accessed on the [publisher's website](#).

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