Project Title: Evaluation of Day-Neutral Strawberries in Organic Systems in Washington

Final Report

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Project Summary

The main objective of this project was to evaluate day-neutral strawberry cultivars for organic production in the Pacific Northwest (PNW), including their second year of production. When this project commenced, little data was available for day-neutral cultivars under organic management, and no organic evaluations had taken place in the PNW. We hoped to generate cultivar information that farmers could use to choose cultivars for their production scheme. Among ten cultivars evaluated on research and organic farm sites, 'Aromas' and 'Seascape' were the highest yielding and durable under organic management in both the first and second production years. However, flavor of 'Aromas' was rated low, and 'Seascape' was susceptible to verticillium wilt. 'Albion' was not as robust a cultivar as 'Aromas', but was rated very highly for flavor.

An additional objective of this project was to identify evaluation criteria that describe cultivars likely to perform well in organic systems. New breeding efforts for this strawberry type in this region will rely on evaluation criteria identified in this cultivar trial. Vigor estimates at various stages of growth appear to be correlated with yield and durability. Plant diameter and foliage color show promise as selection criteria for organic breeding. Traits of fruit quality, such as size, firmness, and flavor will also be essential, as they are in all fruit breeding. This project afforded the opportunity to become more familiar with the diversity of management practices for organic strawberry in our area, and observe cultivars across these different conditions.

Introduction to Topic

Day-neutral cultivars allow the production of strawberries throughout an extended season ranging from May to October, and even longer under protected culture. For organic growers, who often rely on direct-to-consumer marketing, day-neutral strawberries can be an important crop. Appropriate cultivar selection is critical for organic producers, who use system approaches to optimize yield, overall vigor and durability, pest resistance, and fruit quality.

Generally, producers select strawberry cultivars that have been developed and evaluated specifically for their region. However, this is not possible for currently available day-neutral cultivars, which all originated from breeding programs in California, the Eastern United States, or the United Kingdom, where climates, production methods, and fruit quality objectives differ substantially from those common in the PNW.

Organic farmers are particularly disadvantaged because their soils and management practices differ greatly from the conventional systems for which almost all available day-neutral cultivars were developed and tested. Cultivars bred and tested under organic regimes are not available to Pacific Northwest farmers, and results from organic evaluations of conventionally bred strawberry cultivars are scarce. Three day-neutral cultivars, Aromas, Seascape, and Pacific were consistently high-yielding under organic management in Central California (Bull et al., 2005). In New York state, two day-neutral cultivars, 'Tribute' and 'Tristar', were evaluated under both conventional and organic management, but neither was highly rated for organic production (Rhainds et al., 2002). Private companies have begun to evaluate their proprietary cultivars in organic conditions, such as California Giant, Inc.'s tests of 'Cal Giant 3' and 'Cal Giant 4' on non-fumigated soil (Small, 2002a, 2002b). However, neither the data nor the proprietary cultivars are available to Pacific Northwest growers.

Cultivar performance is strongly affected by climatic and geographical factors, including timing and type of precipitation, temperature means and extremes, frost dates, disease and insect pressure, intensity of solar radiation, and day length. The temperate maritime climate of western Washington has wet, mild, and cloudy winters, and temperatures rarely drop below 10ºF (Hancock and Luby, 1995). Average yearly rainfall is 875 to 1270 mm, mostly falling in the winter. Our trial location, at 47º13' N latitude, has relatively dry summers with maximum temperatures averaging 72-78ºF from June to August, but cool night-time temperatures averaging 50-52ºF.

There are many cultivar traits important for organic growers in the Pacific Northwest. Cultivars must be robust against root, foliar, and fruit diseases such as red stele root rot *(Phytophthora fragariae* var. *fragariae),* fruit gray mold (*Botrytis cinerea*), powdery mildew (*Sphaerotheca macularis*), and anthracnose (*Colletotrichum acutatum*). Other criteria are overall vigor and yield, which are both good indicators of a cultivar's adaptation to the whole system and ability to absorb plant nutrients from organically managed soils. Durability, or sustained plant health, over two seasons is important in this region, where annual planting systems are less common than in California, the origin of most available day-neutral cultivars. Finally, intense flavor and sweetness are extremely important for growers in direct or fresh markets to earn repeat sales among a discriminating public. Flavor is influenced by growing conditions (Watson et al., 2002), and a cultivar grown in the unique geographic, climatic, and management conditions of an organic farm in the Pacific Northwest may have a different flavor compared to its flavor where the cultivar was originally evaluated. Our goal was to identify these important qualities among the tested cultivars.

3. Objectives Statement

The objectives of this project were to 1) evaluate day-neutral strawberry cultivars for organic production in the Pacific Northwest, 2) improve selection strategies for organic production, and 3) evaluate the feasibility of growing day-neutral strawberries on a two-year production cycle in the Pacific Northwest.

4. Materials and Methods

Research and Extension Center study. Experimental plots of 10 cultivars were established in a randomized complete block design with three replicates at the WSU Puyallup Research and Extension center (47°11'N, 122°18'W) on land certified organic under WSDA #1290.
The field was solarized prior to planting. On-farm compost was spread on the field at the rate of 8.3 dry tons/acre on 15 Apr. 2009. Raised beds were formed 25 cm high and 60 cm wide on 1.3 m centers. A single drip tape with emitters spaced at 8-in was laid down the center of each row, and the beds were covered with 1-ml black plastic mulch. Bare-root or plug plants of six cultivars were planted on 23 Apr. 2009 in staggered double rows spaced 30 cm in the row and 25 cm between rows. Plots were 3 m long and contained 20 plants. Plug plants of 'Malling Pearl' were planted 21 May with 10 plants per plot due to limited quantity from the nursery. Bare-root plants of cultivars San Andreas, Monterey, and Portola were planted 5 Aug. 'Malling Pearl' plugs and 'Evie 2' bare root plants were obtained from Nourse Farms (Deerfield, MA). 'Whitney' bare root stock was supplied by Crown Nursery (Red Bluff, CA). Bare root plants of the cultivars Aromas, Albion, Seascape, Monterey, San Andreas, and Portola were obtained from Norcal Nursery (Red Bluff, CA). The plugs and bare root plants were not certified organic. Non-organic 'Sarian' seeds were purchased from Johnny's Selected Seeds (Winslow, ME) and sown in an organic soil-less mix. Plugs were produced using organic greenhouse practices. High-quality planting stock was not available from organic sources for the desired cultivars, as determined from inquiries made to three organic nurseries in Feb. 2009. Curtis Gaines, Plant Licensing Field Representative for UCDavis, stated that he would not authorize a testing agreement for several UCDavis cultivars if we used the poor quality plants available from organic suppliers.

Row alleys were seeded with rapeseed in May and mowed as needed to control weeds. Further fertilization (.01 lb N/100 linear bed feet) was supplied by a soluble liquid organic fertilizer via the drip lines once a month in July, August, September, and October. Weeds in the row were controlled by hand on three occasions in August and September; alleys were mowed as needed. Runners were removed by hand from plants periodically between May and September; flowers were removed from plants for the first six weeks after planting. A field vacuum was used on plots and alleys once a week between 1 Aug. and 18 Sept. to reduce lygus bug populations.

The strawberries were harvested twice weekly between 15 July and 31 Oct. 2009. Yield was classified as marketable or unmarketable because of botrytis fruit rot, powdery mildew, anthracnose fruit rot, and other damage. "Other damage" included malformations due to poor pollination or injury by lygus bugs (*Lygus* spp.), birds, spotted wing drosophila (*Drosophila suzukii*, SWD), or slugs. The total yield in each plot was divided by the number of healthy plants in the plot to obtain the yield per plant. Yield data was analyzed for the entire harvest season

(15 July-31 Oct.) and the late harvest season (17 Aug-31 Oct.) to account for the delay in planting 'Malling Pearl'. Five marketable berries from each plot were tested for firmness on each harvest date. Firmness was recorded by a Chatillon Force Gauge (Model 516-500) and measured as puncture force, the force (g) necessary for a 3.5-mm diameter flat rod to penetrate fruit to a depth of 2 mm. Fruit size was calculated as the weighted mean of marketable berries over the entire harvest season.

Data were analyzed using the general linear model of SAS (SAS Insitute, Cary, NC). Least significant differences between means were determined at $P<0.05$ with Fisher's protected LSD.

Organic farm study. Experimental plots of five cultivars were established on four organic farms in randomized complete blocks with 3 or 4 replicates. The four farms hold current organic certification by the Washington State Department of Agriculture. Farms 1 and 2 are located in Chimacum, Jefferson County, WA (latitude 48°0', longitude -122°46') where annual precipitation is 710 mm. Farm 1 plots were on a Belfast silt loam with organic matter of about 7%; Farm 2 was on a Semiahoo muck soil with 35% organic matter. Farm 3 is located near Tacoma, Pierce County, WA (latitude 47°13', longitude -122°22'), with annual precipitation of about 1000 mm on a Puyallup fine sandy loam with 3% organic matter. Farm 4 is located near Orting, Pierce County, WA (latitude 47°3', longitude -122°11'), on an Orting loam with 7.7% organic matter, with annual precipitation of 1000 mm.

Prior to planting, soil samples were obtained for nutrient analysis. Bare-root plants of cultivars Albion, Aromas, Monterey, San Andreas, and Seascape were planted in staggered double rows with 25-cm spacing between double rows, and in-row spacing of 30 cm. Individual plot length ranged from 4.9 m to 6.7 m depending on field layout. Farm 1 and Farm 2 were planted 1 April 2010, Farm 3 was planted 22 April 2010, Farm 4 was planted 26 March 2010. Plots were maintained according to organic farmers' individual practices for fertility, mulch, and runner and weed control. Farm 1 applied Nutri-Rich organic fertilizer (derived from dried poultry manure) 4-3-3 to plots in March and July 2010, and March and August 2011. Farm 3 applied compost prior to planting, but applied no further soil amendment. Farms 2 and 4 used no soil amendment or fertilizer during the trial. All four farms used black plastic mulch or landscape fabric to control weeds; raised beds of 7.5 to 25 cm in height were used on Farms 1, 2, and 3.

Plots were harvested weekly or bi-weekly according to farmer schedule during production seasons of 2010 and 2011. Yield, fruit weight, fruit firmness, and losses due to insects or disease were recorded four times during each season at two to three week intervals representing early, mid, and late season harvests. Total yield in each plot was divided by the number of healthy plants in the plot to obtain the yield per plant. Fruit firmness was measured on each harvest date using the method described above. Fruit size was calculated as the weighted mean of marketable berries over the entire harvest season. Early and mid-season vigor was also recorded at some of the locations. Flavor of available cultivars was rated by farm consumers in each harvest season.

Analysis of variance was performed using the general linear model of SAS 9.2 (SAS Institute, Cary, NC). Where assumptions of normality or homogeneity of variance were violated, data were transformed prior to analysis. Arithmetic means are displayed in tables. Data were

analyzed as a multiple-location RCB and as individual experiments. Least significant differences between means were determined at $P<0.05$ with Fisher's protected LSD. A nursery error prevented 'Monterey' from being planted in 2010. It was planted in early Spring 2011 at all on-farm locations. Harvest data was excluded from statistical analysis but included in tables and graphs.

5. Project Results

Research and Extension Center study. 'Seascape' was included in this research trial as an industry standard, as it has been the most widely grown day-neutral cultivar in Washington for the past 10 years. However, its performance in 2009 and 2010 was uncharacteristic of a day-neutral type. The plants did not flower at all in the establishment year 2009, and then gave a concentrated crop in June and early July 2010, after which it ceased to flower further. We submitted samples for genotype verification to California Plant and Seed Laboratories (Elverta, CA), and found that the 'Seascape' plants were actually 'Jewel', a short-day cultivar originating from New York. Further inquiries revealed that the nursery had mislabeled and mis-shipped our original plant order. Thus, no comparisons with 'Seascape' are possible in our study at Puyallup.

'Aromas' , 'Evie 2', and 'Malling Pearl' had high combined total yields over the two harvest seasons, and had higher yields in 2010 than in the establishment year 2009 (Fig. 1). The cultivars Monterey, Portola, and San Andreas were planted late in 2009 due to nursery delays, and thus their yields cannot be meaningfully compared with that of the other cultivars planted in April 2009.

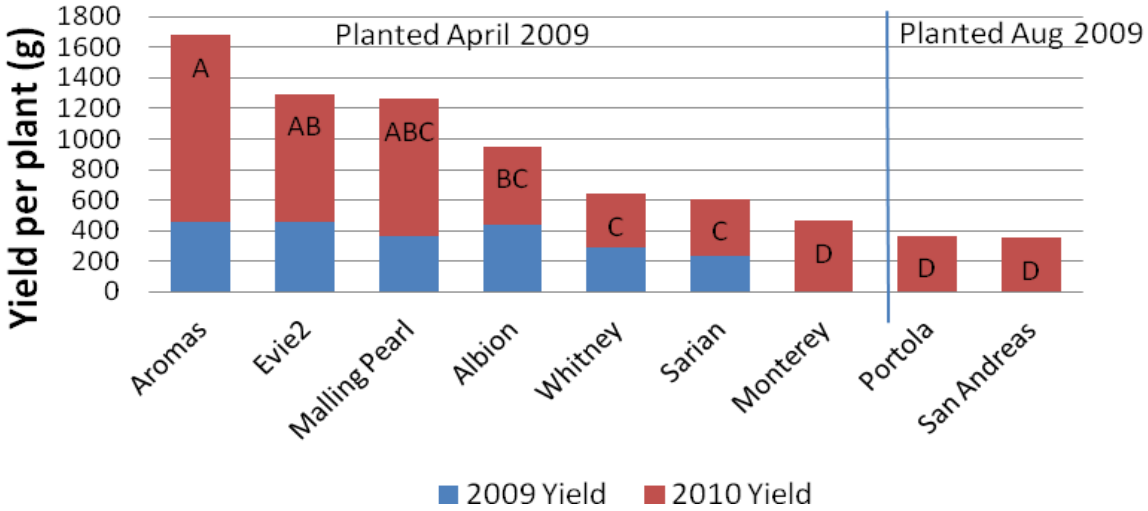

Figure 1. Combined total yield per plant in 2009 and 2010 of cultivars evaluated under organic management. Within a planting date, means followed by the same letters are not significantly different at $p < 0.05$.

Marketable yields ranged from 28 to 56 % in 2009 and from 23 to 60% in 2010 (data not shown). 'Aromas' had the highest marketable percentage in 2009, and 'Albion' and 'Monterey'

had the highest percentages in 2010. 'Sarian' had the lowest marketable percentage in both years, indicating consistently poor quality.

Organic farmers in Washington often expect to crop strawberries for two years before removing the planting. Thus the importance for a durable cultivar is greater for most of the state's organic farmers than for farmers cropping their strawberries on an annual basis. 'Aromas' was by far the most vigorous and long-lived cultivar in our field trial. In addition to being the highest yielding in both production years, 'Aromas' had the lowest mortality, highest average vigor (data not shown) , and the greatest percentage of plants exhibiting a vigor rating of 3 or higher, on a scale of 1-4 (Fig. 2).

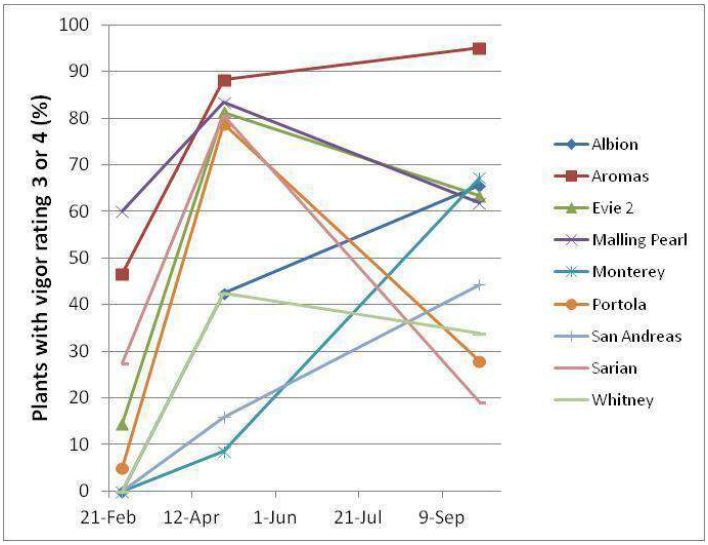

Fig. 2. Percentage of plants rated 3 or 4 on a scale of 1 to 4 of nine day-neutral cultivars on three dates in 2010, the second year of evaluation.

Although 'Albion' was only moderately productive in 2009 and 2010, it continued to show very low damage from botrytis fruit rot in 2010 (Table 1).

Table 1. Botrytis symptoms of fruit harvested during August 2010 from cultivars managed organically.

Cultivar	% Damage	
San Andreas[z]	6	c
Monterey	7	c
Albion	8	bc
Whitney	13	abc
Portola	14	abc
Aromas	14	abc
Sarian	20	abc
Evie 2	21	ab
Malling Pearl	28	a

[z]Means followed by the same letter are not significantly different at $p<0.05$.

In 2009 and 2010, 'Malling Pearl' and 'Evie 2' had among the highest rates of botrytis damage. Overall, damage from anthracnose was higher in 2010 than in 2009. 'Whitney' was significantly more susceptible to anthracnose injury than the other cultivars in both years (data not shown).Losses to spotted wing drosophila (SWD), a new pest in 2009, ranged from 1-5% in 2010, and little difference among the cultivars was seen (data not shown). Similarly, powdery mildew was not as much of a problem in 2010, affecting less than 1% of fruit (data not shown).

Culls, representing all non-disease damage, including lygus feeding, poor pollination, rain damage, and rough fruit, were less in 2010 than in 2009, and ranged from 22 to 45%. 'Sarian', 'San Andreas', and 'Whitney' had the highest percentage of culled fruit, whereas 'Aromas', 'Albion', 'Monterey', and 'Malling Pearl' had the lowest percentage of culled fruit.

Fruit quality was assessed through measurements of fruit firmness, fruit size, and flavor. Berry firmness is a good indicator of suitability for fresh market, as firmer berries tend to stand up better to the picking, packing, and moving necessary to bring fruit to market; especially when the fruit needs continue to look glossy and attractive for a few days. 'Monterey', 'Portola', 'San Andreas', and 'Albion' tended to be the firmest berries in our study (Table 2).

Table 2. Firmness and berry size of strawberries harvested from organically managed day-neutral cultivars during August 2010.

Cultivar	Firmness (g)		Berry weight (g)	
Monterey	300	a[z]	11.8	ab
Portola	266	ab	10.6	b
San Andreas	251	abc	15.4	ab
Albion	216	bcd	15.2	ab
Aromas	204	cd	13.6	ab
Whitney	190	d	11.9	ab
Evie2	185	d	12.3	ab
Malling Pearl	183	d	15.9	a
Sarian	178	d	5.0	c

[z]Means followed by the same letter within a column are not significantly different at $p<0.05$.

Organic farm study. 'Aromas' and 'Seascape' gave significantly higher harvested yields than 'Albion and 'San Andreas' in 2010 and 2011 (Table 1). Cumulative harvest over two seasons for 'Aromas' and 'Seascape' were similar across the locations, and significantly higher than 'Albion' and 'San Andreas'. Low yields for 'Seascape' affected by verticillium wilt were recorded at Farm 4, giving rise to a significant location x cultivar interaction. 'Albion' and 'San Andreas' yielded on average 60% of 'Aromas's yield.

Table 3. Mean harvested yield of five day-neutral cultivars on four organic Washington farms.

	2010			2011			2010-2011
Cultivar	Farms	Harvests	Yield per plant (g)	Farms	Harvests	Yield per plant (g)	Yield per plant (g)
Aromas	4	4	96	3	4	139	217
Seascape	4	4	101	3	4	96	172
Albion	4	4	77	3	4	70	131
San Andreas	4	4	73	3	4	85	129
Monterey	4	4	-	3	4	38	62
loc			<.0001			<.0001	<.0001
cultivar			0.0003			<.0001	<.0001
loc*cultivar			0.0202			0.1974	0.01

Fruit of ‘Albion’ and ‘San Andreas’ were significantly more firm than from ‘Aromas’. Seascape was the least firm cultivar over 2 harvest seasons (Table 4). ‘Seascape’ was significantly smaller in size than ‘Aromas’, ‘Albion’, and ‘San Andreas’ (Table 4). There was no effect of cultivar on anthracnose fruit rot, powdery mildew, or damage from spotted wing drosophila at any location. Vigor ratings were recorded in May and August 2011 at Farm 1; no significant effect of cultivar was detected, though the trend generally had ‘Aromas’ at the higher end of the vigor range and ‘Albion’ at the lower end (data not shown).

Table 4. Berry weight and firmness of five day-neutral strawberry cultivars evaluated over two years on four Washington organic farms.

	Berry mass (g)		Berry firmness (g)	
Cultivar	2010	2011	2010	2011
Albion	15.3	13.9	255	256
Aromas	13.1	14.0	236	225
Monterey	-	12.0	-	290
San Andreas	16.4	15.0	249	264
Seascape	12.6	11.8	208	200
loc	<.0001	<.0001	<.0001	<.0001
rep(loc)	0.0119	0.1064	0.0381	0.7176
cultivar	<.0001	0.0337	0.0028	<.0001
loc*cultivar	0.0235	0.4739	0.0383	0.1304

Location had a very pronounced effect on botrytis, probably due to both climate effects and management practice. In the first year, Farm 2 had very vigorous growth of plants, leading to a crowded canopy, which was exacerbated by infrequent runner removal by the farmer. As a result, botrytis fruit rot on all the cultivars was high. The other farms had less vigorous growth

than Farm 2, and better runner maintenance, thus making conditions less favorable to botrytis fruit rot. There was no significant effect of cultivar on botrytis fruit rot at any location.

There was a significant difference in the percentage of marketable fruit among the cultivars. 'Seascape' had the highest marketable percentage, 69%, and 'Albion', 'Aromas', and 'San Andreas' were lower, between 56 and 61%. The two main reasons for fruit being categorized as unmarketable were extremely small size (<3g) and misshapenness, due to lygus or poor pollination. 'Seascape' showed less damage overall in these areas. However, 'Aromas' marketable yield was significantly higher than that of 'Seascape'.

'Albion' was the most highly rated for flavor in 2010 and 2011 (Table 5). 'Albion' had significantly higher ratings than 'Aromas' ($p < 0.0001$), 'San Andreas ($p = .02$), and 'Seascape' ($p = 0.002$) in 2011. 'Aromas' was the lowest rated for flavor in both years.

Table 5. Flavor ratings of five day-neutral strawberry cultivars by organic farm consumers.

	2010			2011	
Cultivar	N	Rating[z] (1-5)		N	Rating[y] (1-4)
Albion	26	4.0	a[x]	38	3.6
Aromas	26	3.3	b	39	2.9
Monterey	-	-		5	3.0
San Andreas	26	3.5	ab	39	3.3
Seascape	26	3.8	a	40	3.1

[z]Flavor was rated from 1-5, where 1 = poor, 2 = fair, 3 = somewhat good , 4 = very good, 5 = excellent.

[y]Flavor was rated from 1-4, where 1 = poor flavor, 2 = fair, 3 = good, 4 = excellent.

[x]Means followed by the same letters within a column are not significantly different with Fisher's protected LSD test, $p<0.05$.

'Monterey' was planted in the spring of the harvest season and never produced well. Spring 2011 was unusually cold and wet, and even when plants established, they were not kept weeded as necessary because the farmers were not able to maintain the three plots separately from the main trial and the other plots didn't need much weeding.

6. Conclusions and Discussion

This study provided valuable information for farmers making cultivar choices. A summary sheet of cultivar traits has been made available to participants at various organic farm extension events, and will be included in an extension bulletin on day-neutral strawberries forthcoming from WSU. 'Aromas' and 'Seascape' appear to be the best available day-neutral cultivars for organic production in the state in terms of yield potential, plant health, and durability. Both are University of California (UC) cultivars, but neither are currently important in conventional or organic production in CA, having been supplanted by newer cultivars Albion,

San Andreas, and several proprietary cultivars. This contrast highlights the idea that merely importing day-neutral cultivars from California will not result in a cultivar well adapted to organic management in the PNW. On the contrary, as elite UC germplasm has advanced, its suitability for organic in the PNW seems to have decreased, as evidenced by the comparative performance in our organic evaluations of 1990s releases 'Seascape' and 'Aromas' relative to 'Albion' and 'San Andreas, released in 2004 and 2008, respectively (Bringhurst and Voth, 1990; Shaw, 1998; Shaw and Shaw, 2008).

Evaluations in California in conventional fumigated production revealed that 'Albion' had lower yields, greater size and firmness, and better flavor relative to 'Aromas' (Shaw and Larson, 2003). A previous organic evaluation identified 'Aromas' and 'Seascape' as well adapted to organic management in central California, which corresponds well to our findings, despite the introduction of 'Albion', 'San Andreas', and 'Monterey' after the completion of that study (Bull et al., 2005). For the last six years, 'Seascape' and 'Albion' have been the dominant day-neutral cultivars in Washington, comprising about 90% of the total day-neutral sales (Fig. 3). Since its release in 2006, 'Albion' plant sales have encroached on 'Seascape's market share, possibly because of its consistently good flavor. For organic growers, however, 'Albion's lower yields compared to 'Seascape' bears consideration. Although 'Aromas' is very high yielding, durable over two harvest seasons, and vigorous under organic management, its low flavor ratings make it undesirable for the fresh market, on which organic farmers rely heavily. The results of this trial indicate there may be a need for a flavorful, vigorous day-neutral cultivar adapted to Washington growing conditions and that yields better than 'Albion' under organic management.

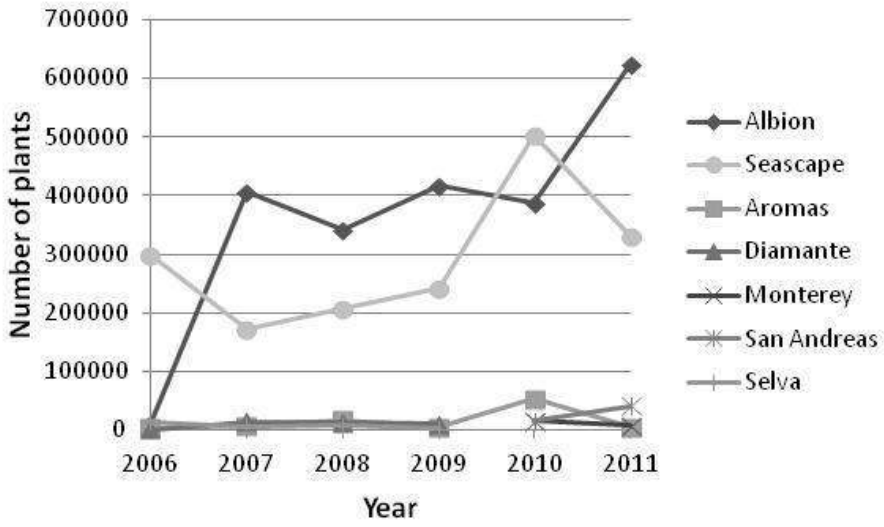

Fig. 3. Plant sales of commercially important day-neutral cultivars between 2006 and 2011 in WA.

Evaluation of cultivar establishment, development, yield, fruit quality, and longevity in the field is instructive in identifying crucial traits of cultivars likely to perform well in organic systems. Some traits became important over the first fruiting season of the day-neutral planting. Lygus bugs were a very serious pest in our system, and lygus resistance may be an

important trait for a potential breeding effort. Significant variation exists among strawberry genotypes to resist lygus bug damage to fruit (Dale et al., 2008). Lygus resistance may be an effective management tool combined with other control measures against the insect, like trap cropping, barriers, and field vacuuming.

Similarly, the new pest, spotted wing drosophila (SWD), has the potential to be a serious problem for organic strawberry growers with few effective organic control options. It is unknown at this time whether strawberry genotypes vary in their susceptibility to SWD damage and thus, whether breeding is likely to produce a resistant cultivar. However, it may be worthwhile to screen strawberry genotypes for their reaction to SWD.

'Sarian' and 'Whitney' showed significant susceptibility to two diseases affecting fruit quality, powdery mildew and anthracnose fruit rot, respectively. It is important that a day-neutral cultivar for organic management show resistance nearer the levels of 'Aromas' for both diseases.

Organic day-neutral plantings are not likely to remain productive for longer than 2 years because of viruses and soil-borne root and crown diseases (Pritts, 2003). Additionally, ensuring adequate nutrition may become problematic if farmers try to harvest their day-neutral plantings over 2 years. Conventional day-neutral production typically utilizes 20 to 30 lbs N per acre per month of production. Even with soluble organic fertilizers, most organic producers on small farms will not apply those N levels. A second year of evaluation at our research site and the first year of on-farm trials were helpful in continuing to identify cultivar traits important for organic plasticulture production in Washington, namely, durability over two cropping seasons, open plant habit, excellent flavor, consistent but not overly large size, low susceptibility to lygus, low susceptibility to SWD, low susceptibility to botrytis. Variability exists among strawberry genotypes for many of these traits that could be exploited in an organic breeding effort. We found strong positive correlations in both evaluation years with average vigor ratings and yield in our organic system (2009, $r = .73$, $p = 0.0006$; 2010, $r = 0.78$, $p < 0.0001$). Although a previous study found a positive correlation between plant nutrient status and organic yield (Bull et al., 2005), little else is known about specific strawberry plant traits that contribute to good vigor in organic production. Reeve et al. (2008) found that strawberry species vary in their ability to take up organic N and hypothesized that cultivars specially adapted for organic management could be selected based on that trait. However, other breeders maintain that plant diameter, though only weakly correlated with various other root traits, such as root rating or total root mass, is the single best predictor of yield in both fumigated and nonfumigated environments (Fort and Shaw, 2000). Since our ratings of vigor assess plant diameter as well as foliage appearance, they may be an important selection tool for genotypes suitable for organic management.

7. Outreach. Results of these evaluations and extension information on organic day-neutral strawberries were directly shared between researchers and farmers and interested members of the public in the following formats:

- Oral presentation and printed booklet, Tilth Producers of WA Farmwalk, WSU Puyallup, 3 August 2009, Puyallup, WA, ~75 attendees.

- Workshop presentation at annual Tilth Producer's Conference, 14 November 2010, Port Townsend, WA, ~20 attendees.
- Poster presentation at annual Tilth Producer's Conference, 11 November 2011, Yakima, WA.
- Oral presentation and printed booklet, Tilth Producers of WA Farmwalk, Red Dog Farm, 23 May 2011, Chimacum, WA, 50 attendees.

Additionally, extension information resulting from this study contributed to two additional outreach events:

- Day-neutral field day, Cloud Mountain Farm, 9 October 2011, Everson, WA
- Season extension presentation, NW Washington Sustainable Agriculture Conference, 19 March 2012, Lynden, WA.

Efforts to compile information on growing day-neutral strawberries for a WSU Extension bulletin are underway.

8. References

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9. Addenda

Marketable fruit harvested on 7 Sept 2011 from Red Dog Farm, from left to right, top, Aromas, Seascape, Albion; bottom, Monterey, and San Andreas.

On-farm collaborator John Bellows of SpringRain Farm uses the spacing tool on plastic mulch.

Terry Carkner (right) of Terry's Berries organic farm stands next to the on-farm evaluation within her farm's strawberry planting.

Karyn Williams of Red Dog Farm, speaks to participants of a May 23, 2011 Tilth Farmwalk about strawberry production on her farm and collaborating in research with WSU.