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Horticultural Performance of Eight American Elderberry Genotypes at Three Missouri Locations

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Abstract

American elderberry (*Sambucus nigra* subsp. *canadensis*) is being increasingly cultivated in North America for its edible and medicinal fruit and flowers, yet remains largely undeveloped as a horticultural crop. Productive genotypes with desirable horticultural attributes, including disease and insect resistance, precocity, uniform fruit ripening, and large berry size are needed in order to advance the commercial production of elderberries. A four-year study of eight elderberry genotypes was established in 2008 at three diverse Missouri (USA) locations. Phenology, plant morphology, pest susceptibility, productivity, and fruit characteristics data were collected over three growing seasons, 2009–2011. Significant differences for most phenological, horticultural, and fruit juice characteristics were observed among the three sites, three years, and eight genotypes. The genotype ‘Ozark’ was the earliest to break bud, produced fruit with high levels of soluble solids, and out-yielded most other genotypes at the three sites over the three-year study. None of the new genotypes produced berries as large as or larger than the standard ‘York’ which is known for its large fruit. Some of the genotypes tested, especially ‘Ozark’ show promise as potential cultivars and as breeding stock for further development of elderberry as a commercially-viable horticultural crop.

Keywords

Sambucus; fruit; yield; cultivar; management; phenology

INTRODUCTION

American elderberry [*Sambucus nigra* L. subsp. *canadensis* (L.) Bolli; syn. *S. canadensis* L.] is native to eastern and midwestern North America. The fruit and flowers have been traditionally used in wines, jams, jellies, juices, colorants, and other products such as dietary supplements. A renewed interest in the medicinal attributes of elderberry has sparked an increase in its cultivation (Charlebois et al., 2010; Mohebalian et al., 2012). While European elderberry (*Sambucus nigra* L. subsp. *nigra*; syn. *S. nigra* L.) is relatively well developed as a horticultural and processing crop, the North American subspecies remains underdeveloped (Finn et al., 2008; Thomas et al., 2013; Byers et al., 2015).

Most cultivation of American elderberry is based on a handful of standard cultivars developed in New York and southeast Canada from a very narrow gene pool many decades ago (Brooks and Olmo, 1997). Until recently, very few of these cultivars were evaluated or grown commercially in other regions of the USA. In general, these cultivars have not performed as well as regionally-selected unimproved germplasm in the midwestern USA (Finn et al., 2008). In order to advance the development of American elderberry as a viable horticultural crop, germplasm screening under varying environmental conditions and new cultivar development is necessary.

To that end, our program has amassed and tested a large number of wild elderberry selections at multiple locations (Thomas and Byers, 2000; Finn et al., 2008), resulting in the release of two cultivars adapted to Midwestern conditions: ‘Wyldewood’ (Byers et al., 2010) and ‘Bob Gordon’ (Byers and Thomas, 2011). To continue this development, five additional genotypes that had shown promise in non-replicated evaluation plots were selected for further evaluation in this study. The objective was to compare these five genotypes to three standard cultivars at multiple Missouri locations in terms of phenology, morphology, pest resistance, fruit yields, and fruit characteristics. Such information is needed to identify and develop potential new elderberry cultivars for the region while also adding important data to the general knowledge base of elderberry horticulture.

MATERIALS AND METHODS

This field study was conducted over three years (2009–2011) after a one-year establishment period at three locations in Missouri, USA. The sites were the University of Missouri’s Southwest Research Center near Mt. Vernon (37.0710°N, 93.8795°W, 378 m alt.), Missouri State University’s State Fruit Experiment Station near Mountain Grove (37.1559°N, 92.2644°W, 434 m alt.), and Lincoln University’s Carver Farm at Jefferson City (38.5299°N, 92.1383°W, 175 m alt.). The three sites are a minimum of 140 km apart. Annual precipitation averages 1,117 mm at Mt. Vernon, 1,148 mm at Mountain Grove, and 1,093 mm at Jefferson City. The soil at Mt. Vernon was a Hoberg silt loam (fine-loamy, siliceous, mesic Mollic Fragiudalfs) that is upland, deep, gently sloping, and moderately well-drained with a fragipan at 40 to 90 cm (Hughes, 1982). Soil tests at Mt. Vernon indicated pH 5.7, organic matter 3.6%, cation exchange capacity (CEC) 13.5 meq/100 g, low levels of P, and adequate levels of K, Ca, and Mg based on recommendations for blackberry (*Rubus* sp.) production. The soil at Mountain Grove was a Viraton silt loam (fine-loamy, siliceous, mesic Typic Fragiudalfs) with very similar properties (Robertson, 1981). A soil test indicated pH 6.3, organic matter 2.4%, CEC 9.1 meq/100 g, low levels of P, and high levels of K, Ca, and Mg. The soil at Jefferson City was a Freeburg silt loam (fine-silty, mixed, superactive, mesic Aquic Hapludalfs) that is fertile, very deep, somewhat poorly-drained, and situated on alluvial footslopes (Davis, 2005). Soil test indicated pH 6.4, organic matter 1.4%, CEC 8.8 meq/100 g, and high levels of P, K, Ca, and Mg. The soils at Mt. Vernon and Mountain Grove are more similar than the soil at Jefferson City, which does not have a fragipan and may be more suitable for elderberry production if organic matter and CEC were improved. At Mountain Grove, the soil was moved into 20-cm raised soil ridges prior to planting; whereas flat, undisturbed ground was used at Mt. Vernon and Jefferson City. All planting sites were prepared by killing existing vegetation in the planting rows with glyphosate herbicide prior to planting, and alleyways of mixed grasses were maintained and mowed during the study.

Hardwood cuttings of eight selected genotypes were collected from our own mother plants in spring 2008, rooted in a greenhouse, and then transplanted July 2008 at all three sites. Experimental plots contained four plants of the same genotype, planted 1.2 m apart. Plots were separated by 2.4 m within and 3.1 m between rows at all three sites. The eight genotypes were assigned to 32 plots in a completely randomized manner at each site, with four replications per genotype. The total number of plants per site was 128, with each planting covering about 0.10 ha. All plantings were fertilized each spring with 56 kg ha^{-1} N (as NH_4NO_3). Plants were irrigated via drip lines to provide 2.5 to 4.0 cm water per week when rainfall was lacking. Weeds were managed with mulch, hand weeding, and herbicides (glyphosate, clethodim); no insecticides or fungicides were used. All plants were allowed to grow normally during the establishment year, except that inflorescences were removed to encourage root and structural growth.

Eight elderberry genotypes were studied. Five of these had shown promise in earlier non-replicated multi-location trials, and were selected for further evaluation: ‘Dallas’, ‘Ocoee’, ‘Ozark’, ‘Ozone’, and ‘Sperandio’. Table 1 provides collection and provenance information for these genotypes. These five genotypes were compared with three standard, commercially-available cultivars: ‘Bob Gordon’ (Byers and Thomas, 2011), ‘Wyldewood’ (Byers et al., 2010), and ‘York’.

Horticultural data were collected over three years, 2009–2011. These data included bud break, bloom time, harvest date, plant height, arthropod pest incidence, berry weight, fruit yield, cyme number and size, and fruit juice characteristics. Individual berry weights were determined by counting and weighing, in bulk, 50 random ripe berries (fresh weight) per treatment plot. Eriophyid mites [most likely *Phyllocoptes wisconsinensis* Keifer (Warmund and Amrine, 2015)] and Japanese beetle (*Popillia japonica* Newman) were assessed multiple times throughout the growing seasons using a scale of 1–5, where 1 = no occurrence and 5 = severe damage.

The experiment was established and analyzed as a completely randomized design at each of the three locations, with data sampled as a repeated measure over time. The experimental unit was the entire four-plant plot; however, for simplicity and practicality, all production data are presented on a single-plant basis. Data were analyzed using the general linear model procedure (SAS Institute, Cary, N.C.), with means separated by the least significant difference method at $P \leq 0.05$.

RESULTS AND DISCUSSION

The elderberry plantings performed well at all three sites for the duration of the study. Significant differences for most phenological, horticultural, and fruit juice characteristics were observed among the three sites, three years, and eight genotypes (Table 2). The Jefferson City site is about 150 km north of the other two sites, and is in a different USDA Hardiness Zone (6A) compared with the other two sites (7B). Budbreak at Jefferson City was a few days later but harvest 10 days earlier on average. Plants at Jefferson City were slightly (but significantly) taller compared with plants at other locations. Eriophyid mite damage was lowest at Jefferson City and highest at Mountain Grove. Japanese beetle incidence was highest at Mt. Vernon but beetles were not observed on any elderberry plants at Mountain Grove (while Japanese beetles have been trapped at Mountain Grove, they are not yet a significant problem in the region). Yields were numerically higher at Jefferson City, but not significantly higher than at Mt. Vernon; meanwhile, Mt. Vernon consistently produced larger berries. Assuming that a lower pH and higher soluble solids content is more desirable in elderberry fruit juice, Mountain Grove produced the best fruit quality for processing, despite lower overall yields. We might have expected the Jefferson City site to be more favorable for elderberry cultivation based on soil type (a deeper, more alluvial site with no fragipan). However, except for high levels of P, the soil test from that site indicated a superficially-poorer soil with lower organic matter and CEC. Management was generally similar at all three sites. These results do not clearly favor one site over another for elderberry production; for example, while Mountain Grove produced the lowest yields, it produced the highest quality fruit while Mt. Vernon produced the largest (and presumably juiciest) berries. In an earlier study (Finn et al., 2008), elderberry plots at Mountain Grove out-yielded similar plots at Mt. Vernon, while berry size was similarly larger at Mt. Vernon.

Phenologically, 'Ozark' was the earliest to break bud, averaging eight days earlier than 'York', which was the last genotype to break bud. Early bud break in elderberry is not usually a concern in Missouri; however a later bud break may be desirable to avoid damage from erratic spring freezes. 'York' was the first genotype to bloom, compared with 'Wyldewood' which achieved full bloom an average of 15 days later. Bloom time in elderberry occurs well after danger of freezing temperatures in Missouri; therefore an early bloom may be desirable if that leads to an earlier harvest or improved fruit quality based on a longer fruit development season. Following this trend, 'York' berries were harvested significantly (6 to 26 days) earlier compared with all other genotypes. This early harvest, combined with the very large berry size of 'York' (mean 139 mg), may make 'York' a desirable cultivar for Midwestern producers, especially in terms of harvest labor management. While there were some differences in plant height among genotypes, those differences were not profound, varying only as much as 6 cm. For pest incidence, 'Dallas' and 'Ocoee' were most resistant to Eriophyid mites; whereas 'Bob Gordon', 'Dallas', and 'York' were most resistant to Japanese beetles. 'Sperandio' was most affected by mites, and 'Wyldewood' and 'Ocoee' by beetles.

When evaluated across sites and years, the genotype 'Ozark' produced the highest fruit yields overall (0.60 kg/plant), but not significantly higher than 'Ocoee' (0.48 kg/plant). Genotypes 'Ozark', 'Bob Gordon', and 'York' produced the largest number of fruiting cymes, but the average individual cyme weight was greater in 'Ocoee' which tended to produce fewer but larger cymes. In an earlier elderberry genotype evaluation based at the same Mt. Vernon and Mountain Grove sites (Finn et al., 2008), 12 genotypes, including 'Bob Gordon' and 'Wyldewood', produced mean fruit yields that were substantially higher at Mountain Grove (exceeding 3 kg/plant in one year) but relatively similar at Mt. Vernon (averaging 0.39–0.64 kg/plant). The very significant reduction in productivity at the Mountain Grove site from study to study is difficult to explain. Fruit quality (based here on preferred low pH and high soluble solids concentration) was best for 'Ozark' and 'Bob Gordon', while 'Sperandio' consistently produced fruit of poorer quality. We noted that 'Sperandio' fruit from all three sites tended to turn brown very soon after harvest even while frozen, and especially after thawing and additional handling. We do not know the cause of this browning, but assume it must be genetically based; browning and poor quality of 'Sperandio' fruit was also observed in Thomas et al. (2013).

Significant variations were also found among most experimental factors across the three production years. Phenological differences across years are most likely due to simple year-to-year climate differences; because elderberry breaks bud early in spring, it may be more susceptible to year-to-year climate vagaries compared with crops that break bud later in spring. Arthropod pest incidence may similarly fluctuate naturally from year to year depending on a variety of environmental and ecological factors. Overall fruit yields in 2009 were low because of a limited fruit set at Mountain Grove and Jefferson City that year; however Mt. Vernon experienced a full harvest that year. In our experience, elderberry will usually produce a moderate to full crop the year following planting, but in this case, a full crop was not produced at two sites until two years after planting.

Experimental interactions among genotype, site, and year were often significant but patterns were inconsistent across the study. Interactions among study parameters were especially significant for fruit yields, indicating that elderberry genotypes may be highly responsive to environmental conditions from site to site and season to season, and that high-yielding genotypes might be selected for specific growing conditions. These variable interactions are similar to results in earlier studies in which consistent patterns were difficult to discern (Finn et al., 2008; Thomas et al., 2009). These results suggest that more study is needed in order to determine the best environmental conditions for high-quality elderberry production.

Few elderberry production studies are available to assess the economic viability of elderberry production in Missouri compared with other locations. The present study used previously un-evaluated genotypes or relatively new cultivars, except 'York', for which some other production data are available. In a trial in Illinois, Skirvin and Otterbacher (1977) reported yields for 'York' as high as 7 kg/plant, which was significantly less than yields produced by 'Adams 2' and 'Nova' in that study. Mathieu (2009) and D. Charlebois (2005 unpublished data) reported yields for 'York' at a site south of Montreal, Quebec increasing from 3.1 kg/plant in the second growing season to 9.3 kg/plant in the fourth season. 'York' plants in that study reached mature heights of 137 cm, more than three times the average height of plants in our study, and 'York' berries averaged 203 mg. Interestingly, while 'York' is a very early-ripening genotype in Missouri, it was one of the last to ripen among several cultivars studied in Quebec. Finn et al. (2008) compared elderberry yields in Oregon and Missouri, and reported yields for 'York' grown in Oregon. Elderberry plants were more productive in Oregon (mean 4.0–6.5 kg/plant) compared with many of the same genotypes in Missouri (0.5–2.3 kg/plant). In that study, 'York' produced mean yields of 6.2 kg/plant in Oregon, exceeded only by 'Johns' (9.5 kg/plant), which performed very poorly in Missouri. These data from other studies suggest that the soil and climatic conditions in Missouri may not favor high productivity of elderberry fruit. Additional research is needed in order for

Missouri producers to be able to realize the true productive potential of elderberry in the region.

None of the new genotypes being evaluated produced berries as large as or larger than the standard 'York' which is known for its early and large fruit. While it was not a top producer in this study, its size and earliness suggest that it may be a good cultivar choice for the Midwest. This study also suggests that 'Ozark' may be a promising elderberry genotype for midwestern producers based on its high yields and excellent fruit quality. Concurrent research (Thomas et al., 2015) also indicates that 'Ozark' produces fruit high in desirable polyphenols for potential use in dietary supplements. In addition to cultivars for Midwest production, the combination of desirable traits in some of these genotypes suggest that they would be excellent candidates for a breeding program to further advance the development of elderberry as a viable North American fruit crop.

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Table 1

Provenance and description of five wild-collected American elderberry genotypes evaluated at three Missouri sites from 2009–2011

Genotype	Where collected	Lat. / Long.	When collected	Who collected	Characterstics at collection
Dallas	Mtn. Grove, MO	37.165, −92.263	2002	Dallas Dawson	Large and vigorous plant, productive
Ocoee	Ducktown, TN	35.035, −84.427	11 June 2004	Patrick Byers	Healthy plant, large cymes, upland site
Ozark	Deer, AR	35.822, −93.214	18 June 2003	Patrick Byers	Healthy plant, vigorous growth, extremely large cymes
Ozone	Ozone, AR	35.672, −93.451	18 June 2003	Patrick Byers	Healthy plant, vigorous growth, large cymes
Sperandio	Monett, MO	38.8511, −93.9620	21 Sept 1999	David Sperandio	Very large and tall plant, large cymes, good quality berries, dry site

Table 2

Phenology, morphology, pest, yield, and juice characteristics from eight American elderberry genotypes grown at three Missouri (USA) sites, 2009–2011.

Variable	Bud break[z]	Full bloom[z]	Peak harvest[z]	Average height (cm)	Eriophyid mites[y]	Japanese beetles[y]	Berry wt. (mg)	Yield per plant (kg)	Cymes per plant	Cyme wt. (g)	pH	Soluble solids (°Brix)
Site (S)												
Mt. Vernon	61 ^{cx}	170 ^{a}	234 ^{a}	44.3 ^{b}	2.74 ^{a}	2.53 ^{a}	100 ^{a}	0.44 ^{a}	17 ^{a}	39 ^{a}	4.85 ^{a}	8.7 ^{c}
Mtn. Grove	65 ^{b}	169 ^{a}	234 ^{a}	46.3 ^{b}	2.90 ^{a}	1.00 ^{c}	88 ^{b}	0.25 ^{b}	12 ^{b}	43 ^{a}	4.55 ^{b}	11.2 ^{a}
Jeff. City	69 ^{a}	--	224 ^{b}	48.5 ^{a}	2.49 ^{b}	1.89 ^{b}	85 ^{b}	0.52 ^{a}	--	--	4.88 ^{a}	10.1 ^{b}
Genotype (G)												
Bob Gordon	63 ^{cd}	170 ^{c}	223 ^{d}	47.5 ^{ab}	2.50 ^{c}	1.21 ^{d}	88 ^{bc}	0.38 ^{bc}	21.0 ^{a}	37 ^{b}	4.68 ^{de}	10.4 ^{ab}
Dallas	65 ^{b}	169 ^{c}	230 ^{c}	46.9 ^{ab}	1.89 ^{d}	1.33 ^{d}	95 ^{b}	0.40 ^{bc}	11.3 ^{b}	43 ^{ab}	4.86 ^{bc}	9.8 ^{b}
Ocoee	65 ^{b}	172 ^{b}	243 ^{a}	44.7 ^{bc}	1.97 ^{d}	2.71 ^{ab}	84 ^{c}	0.48 ^{ab}	12.0 ^{b}	55 ^{a}	4.63 ^{e}	10.0 ^{b}
Ozark	61 ^{e}	169 ^{c}	230 ^{c}	47.3 ^{ab}	2.78 ^{bc}	2.21 ^{c}	86 ^{c}	0.60 ^{a}	20.5 ^{a}	43 ^{ab}	4.71 ^{de}	11.3 ^{a}
Ozone	64 ^{bc}	170 ^{bc}	233 ^{bc}	49.3 ^{a}	3.11 ^{b}	2.21 ^{c}	76 ^{d}	0.28 ^{c}	13.0 ^{b}	35 ^{b}	4.78 ^{cd}	10.1 ^{b}
Sperandio	64 ^{bc}	170 ^{bc}	234 ^{bc}	43.3 ^{c}	3.50 ^{a}	2.58 ^{b}	86 ^{c}	0.31 ^{c}	6.8 ^{b}	41 ^{ab}	5.04 ^{a}	7.9 ^{c}
Wyldewood	62 ^{de}	176 ^{a}	236 ^{b}	45.5 ^{bc}	3.08 ^{b}	3.00 ^{a}	83 ^{c}	0.28 ^{c}	11.0 ^{b}	32 ^{b}	4.92 ^{ab}	8.3 ^{c}
York	69 ^{a}	161 ^{d}	217 ^{e}	46.5 ^{abc}	2.83 ^{bc}	1.25 ^{d}	139 ^{a}	0.37 ^{bc}	20.5 ^{a}	37 ^{b}	4.75 ^{cde}	7.9 ^{c}
Year (Y)												
2009	55 ^{c}	175 ^{a}	235 ^{a}	--	2.15 ^{c}	2.50 ^{a}	97 ^{a}	0.15 ^{b}	2.5 ^{c}	62 ^{a}	4.59 ^{c}	8.3 ^{b}
2010	67 ^{b}	168 ^{b}	222 ^{b}	43.8 ^{b}	3.26 ^{a}	2.06 ^{b}	91 ^{a}	0.50 ^{a}	10.0 ^{b}	51 ^{b}	4.94 ^{a}	8.2 ^{b}
2011	68 ^{a}	167 ^{b}	234 ^{a}	49.0 ^{a}	2.72 ^{b}	1.92 ^{c}	90 ^{a}	0.44 ^{a}	29.8 ^{a}	17 ^{c}	4.81 ^{b}	10.2 ^{a}
Overall mean	64	170	231	46.4	2.71	2.06	92	0.39	14.5	41	4.79	9.5
Interactions[w]												
S × G	***	NS	***	***	NS	***	***	***	***	***	*	*
S × Y	***	***	NS	NS	***	**	***	***	NS	***	--	--
G × Y	***	***	*	NS	***	*	***	***	***	***	**	***
S × G × Y	***	**	NS	NS	NS	NS	*	***	**	***	--	--

[z]Days from 1 January.

[y] Based on 1–5 scale, where 1 = no incidence and 5 = severe incidence.

[x] Means within sub-columns with the same letters are not significantly different according to the least significant difference test ($P \leq 0.05$)

[w] NS, *, **, ***: Interactions nonsignificant, or significant at $P \leq 0.05$, 0.01, and 0.001, respectively.