Productivity and Characteristics of American Elderberry in Response to Various Pruning Methods

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Abstract. American elderberry [*Sambucus canadensis* L.; *Sambucus nigra* ssp. *canadensis* (L.) Bolli] is being increasingly cultivated in North America for its edible fruit and flowers, yet it remains largely undeveloped as a horticultural crop. Elderberry is a shrub that produces fruit on both new and old wood, thereby offering unique pruning management opportunities and challenges. The objective of this study was to document the response of American elderberry to various pruning methods in terms of flowering, fruit yield, phenology, plant growth, and incidence of disease and arthropod pests and to consider the impact of various pruning methods on horticultural management. Four pruning treatments (annual removal of all shoots, biannual removal of all shoots, annual selective pruning, and no pruning) were studied among three cultivars at two Missouri sites over 5 years. Although significant interactions among experimental effects made interpretation challenging, several trends were evident. Annual selective pruning was an excellent way to manage elderberries with mean yields of 1086 g/plant across all experimental parameters; however, pruning to the ground annually or biannually also resulted in satisfactory yields (855 and 1085 g/plant, respectively) with a fraction of pruning labor involved. Pruning plants to the ground consistently resulted in fewer, but larger, fruiting cymes compared with selectively pruned or unpruned plants, which may be important in terms of harvest efficiency. Pruning treatment generally affected the time of flowering and fruit ripening; plants that flowered only on new stems (after removal of all shoots) ripened fruit 14 to 21 days later than plants that fruited on old wood. Although annually pruned plants generally yielded lower, the plants remained vigorous and productive, and this pruning management technique may have numerous advantages over other pruning methods.

The American elderberry [*Sambucus canadensis* L.; *Sambucus nigra* ssp. *canadensis* (L.) Bolli] is a common shrub native to eastern and midwestern North America that produces edible flowers and berries. The fruit is used to make jam, jelly, syrup, food coloring, beverages, and wine, whereas the flowers are consumed cooked, in beverages, wine, or as an infusion. The medicinal attributes of elderberry are becoming well known (e.g., Charlebois et al., 2010; Thomas et al., 2008; Zakay-Rones et al., 1995, 2004), and demand for nonfermented elderberry juice concentrates taken as a nutraceutical or dietary supplement is increasing (J. Brewer, Wyldewood Cellars, Mulvane, KS, pers. comm.). Many U.S. elderberry processors rely on

juice concentrates imported from Europe or on local harvest of wild fruit; however, the quality of wild-harvested fruit is often poor and inconsistent compared with what could be raised commercially. We are aware of numerous new elderberry orchards being established in eastern and midwestern North America; however, producers establishing elderberry are taking risks as a result of the substantial lack of scientifically based horticultural recommendations for this crop.

Horticultural production of American elderberry has been studied only marginally. A few improved cultivars were introduced from southeast Canada and New York many decades ago (American Society for Horticultural Science, 1997). Only a handful of minor, dated reports (Craig, 1978; Hill, 1969, 1970; Ritter, 1958; Ritter and McKee, 1964; Skirvin and Otterbacher, 1977; Way, 1957, 1967, 1981) presently provide growers with limited information on cultivating this species. A recent review of elderberry horticul-

ture and botany (Charlebois et al., 2010) has provided an updated and comprehensive summary of current elderberry knowledge. Some guidance on cultivating American elderberry may be gleaned from studies on the European elder [*Sambucus nigra* L.; *Sambucus nigra* ssp. *nigra* (L.) Bolli]; however, the two species are morphologically different, and such information is also limited (e.g., Kaack, 1988, 1990; Ważbińska et al., 2004). No literature is available on the effect of pruning either species of elderberry in terms of productivity, phenology, or pest management.

The American elderberry is a large, vigorous, multistemmed shrub that produces fruit on the current season's growth as well as older wood. For simplicity, we use the terms "primary" and "secondary" to refer to new flowering shoots that emerge annually from the soil and flowering stems that arise from older woody shoots, respectively. In general, American elderberry primary shoots emerge each spring from rhizomes that spread aggressively from the original growing point or to replace secondary shoots that are damaged, killed, or removed. Primary shoots end in a single large inflorescence that opens a few to several days later than inflorescences on secondary stems, which tend to be smaller and more numerous. The very different morphology of these two types of fruiting stems in elderberry has important management implications in terms of productivity, uniformity of ripening, potential for mechanical harvest, harvest efficiency, pruning labor, and pest management. The European elder is taller and tends to spread less aggressively from rhizomes compared with *S. canadensis*; this characteristic permits pruning *S. nigra* into a single-trunked plant that can be coppiced to the same point at 1 to 2 m annually. We do not believe that *S. canadensis* could be grown successfully in this manner, but this concept certainly merits research.

Given the potential productivity of primary shoot fruiting in American elderberry, the simplest and least costly pruning management technique might be to prune the plants to the ground each spring, perhaps most efficiently with a motorized or tractor-mounted sickle bar cutter. Well-established plants managed in this manner should produce good yields annually while maintaining long-term vigor and productivity, but yield may be somewhat compromised compared with a much more labor-intensive selective pruning system in which only old, unproductive wood is removed each winter. The objectives of this study were to evaluate that hypothesis and to ascertain the characteristics and productivity of elderberry in response to four pruning methods in terms of fruit yield, phenology, plant growth, and arthropod pest and disease incidence.

Materials and Methods

This elderberry pruning management study was conducted over 5 years after a

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2-year establishment period (2000 to 2006) at two locations in Missouri. The sites were at the University of Missouri's Southwest Research Center in southwest Missouri near Mt. Vernon (lat. 37°4' N, long. 93°53' W, alt. 378 m) and Missouri State University's State Fruit Experiment Station in south-central Missouri near Mountain Grove (lat. 37°13' N, long. 92°26' W, alt. 434 m). The two sites are 140 km apart. Annual precipitation averages 1117 mm at Mt. Vernon and 1148 mm at Mountain Grove. 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 13.5 mEq/100 g, low levels of phosphorus (P), and adequate levels of potassium (K), calcium (Ca), and magnesium (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%, cation exchange capacity 9.1 mEq/100 g, low levels of P, and high levels of K, Ca, and Mg. The chief difference between the two soils is that the Hoberg generally has a darker, thicker, softer surface horizon with more organic matter compared with the Viraton. At Mountain Grove, the soil was moved into 20-cm raised soil ridges before planting, whereas flat, undisturbed ground was used at Mt. Vernon. Worth noting is that the Mountain Grove site was ≈50 m downhill from a large (2-ha) irrigation lake, which likely influenced subsurface hydrology there. Both planting sites were prepared by killing existing vegetation in the planting rows with glyphosate herbicide before planting. Alleyways of tall fescue grass (*Festuca arundinacea* Schreb.) were maintained and mowed at both locations.

The three elderberry cultivars used in the study included one long-established cultivar

(Adams II) and two new wild selections from Missouri that were under evaluation for their promising horticultural potential ('Bob Gordon' and 'Netzer'). The origin and morphology of these two elderberry selections were initially described in Thomas and Byers (2000), in which 'Bob Gordon' was tested as 'Gordon B'. This cultivar was also called 'Gordon B' in Finn et al. (2008) and elsewhere. The original source for our 'Adams II' material was Pense Nursery (Mountainburg, AR).

Hardwood and softwood cuttings were collected from our own mother plants in Spring 2000, rooted in a greenhouse, and then transplanted to both sites in June 2000. Experimental plots contained three plants each, planted 1.2 m apart. Plots were separated by 2.4 m within and 3.1 m between rows. The total number of plants per site was 144 with each planting covering ≈0.10 ha. The three cultivars and four pruning treatments were assigned to plots in a completely randomized experimental design with four replications of each cultivar-pruning treatment combination. The four pruning treatments included 1) pruning plants to the ground annually in early spring; 2) pruning to the ground every other spring (biannually); 3) annual selective pruning, defined as removal of old unproductive or poor-quality wood and tipping back to strong stems at ≈1 m; and 4) unpruned. Both plantings were fertilized each spring with 56 kg·ha⁻¹ N (as NH₄NO₃). When rainfall was lacking during the growing seasons, plants were irrigated by drip lines to provide 2.5 to 4.0 cm water per week. Weeds were managed with mulch, hand-weeding, and glyphosate herbicide, and no insecticides or fungicides were used. All plants were allowed to grow normally without pruning in 2000 and 2001, except that inflorescences were removed to encourage root and structural growth. After this 2-year establishment period, all plants in all plots were pruned to the ground in early Spring 2002 to initiate the study. Thereafter, the biannual pruning treatments were ap-

plied in Spring 2004 and 2006. Data were collected over 5 years from 2002 to 2006. Data included fruit yield, cyme number and size, individual berry weight, arthropod pest and disease incidence, plant height, and phenological characteristics such as bloom time, fruit ripening, and harvest date. Individual berry weights were determined by counting and weighing, in bulk, 50 random ripe berries (fresh weight) per treatment plot. Eriophyid mites (Eriophyidae) and bacterial leafspot [tentatively identified as *Pseudomonas viridiflava* Burkholder (Dowson)] were assessed multiple times throughout the growing seasons in 2004 to 2006 using a subjective scale of 1 to 5, in which 1 = severe damage and 5 = no occurrence.

Statistical analyses were conducted using split plots in time and fixed locations. The experimental unit was the entire three-plant plot; however, for simplicity and practicality, all production data are presented on a single-plant basis. Data were analyzed using the "Mixed" procedure (Proc Mixed; SAS Institute, Cary, NC), with means separated by Fisher's protected least significant difference at the $P \leq 0.05$ level. Least significant differences were calculated using the SE of the differences of least square means and the appropriate t level for the degree of freedom for each variable ($P \leq 0.05$).

Results and Discussion

The elderberry plantings at both locations survived and performed well for the duration of the study, except that part of the 'Netzer' fruit crop at Mountain Grove was destroyed by birds in 2003. Table 1 displays broad and generalized mean results across the entire study. Significant differences in fruit production, cyme number and size, berry weight, plant height, and eriophyid mite and bacterial leafspot incidence were detected in varying degrees between the two sites and among the three cultivars, the four pruning treatments, and the 5 years. Across all experimental parameters, mean fruit yields generally increased

Table 1. Mean yield, cyme production, plant height, and pest response from American elderberry pruning study at Mountain Grove (MG) and Mt. Vernon (MV), MO.

		Mean fruit yield per plant (g)	Mean no. of cymes per plant	Mean wt per cyme (g)	Single berry wt (mg)	Plant ht (cm)	Eriophyid mites ^y	Bacterial leafspot ^y
Site	MG	1,400 a ^z	36.6 a	51 b	67.4 b	184 a	3.8 b	3.5 b
	MV	606 b	13.6 b	67 a	90.0 a	152 b	4.4 a	4.8 a
Cultivar	Bob Gordon	1,856 a	37.1 a	87 a	86.0 a	175 a	4.3 a	4.1 a
	Adams II	647 b	21.6 b	36 c	63.2 c	145 b	3.6 b	3.8 b
	Netzer	414 c	14.5 c	53 b	80.2 b	175 a	4.2 a	4.1 a
Pruning treatment	Annual	855 b	10.4 c	86 a	77.5 a	159 b	4.0 a	4.1 a
	Biannual	1,085 a	26.7 b	61 b	75.1 a	158 b	4.0 a	4.1 a
	Selective	1,086 a	31.6 a	48 c	76.9 a	169 a	4.1 a	3.9 a
	Unpruned	940 b	30.1 ab	42 c	76.1 a	174 a	4.1 a	3.9 a
Year	2002	423 d	5.9 d	95 a	—	—	—	—
	2003	1,034 b	33.2 b	41 c	—	—	—	—
	2004	1,369 a	22.6 c	68 b	76.5 b	175 a	4.8 a	3.9 b
	2005	1,307 a	39.0 a	41 c	79.8 a	146 c	4.2 b	4.3 a
	2006	822 c	24.2 c	49 c	72.8 c	164 b	3.6 c	3.8 b

^zValues within subcolumns having similar letters are not statistically different ($P \leq 0.05$).

^yScale 1 to 5: 1 = severe damage; 5 = no damage.

from 2002 and 2003 to maximum yields in 2004 and 2005 (overall mean maximum yield 1369 g/plant) and then declined in 2006. We do not know if this eventual decline was an anomaly or, if indeed, an elderberry orchard's highest productivity may be short-lived. Overall mean yields were significantly higher at Mountain Grove (1400 g/plant) compared with Mt. Vernon (606 g/plant). This substantial yield difference between sites is consistent with another elderberry study conducted at these two sites (Finn et al., 2008) but is difficult to understand. The climate, management, and soils were generally similar at both locations, but the plants at Mountain Grove were established on raised soil ridges very near a large irrigation lake. The ridges may have improved soil aeration, whereas the lake may have increased subsurface water availability to the plants; both of these factors may have contributed to the higher yields at Mountain Grove. With an overall mean yield of 1856 g/plant, the experimental cultivar Bob Gordon yielded nearly triple that of 'Adams II' and over four times that of 'Netzer' across all experimental parameters. Overall, annually pruned plants and unpruned plants yielded significantly less than selectively pruned or biannually pruned plants.

During the first year's (2002) harvest, mean number of cymes per plant (5.9) was lowest and individual cyme weight (95 g) the greatest (Table 1). This was certainly because all plants had been pruned to the ground that spring to initiate the study and that all growth and flowering among all plants occurred on primary shoots that ended in single, large inflorescences. When considering cyme number and size in subsequent years, the annually pruned plants consistently produced fewer, larger cymes compared with biannually pruned, selectively pruned, or unpruned plants. In Table 1, the data for cyme number and size in biannually pruned plants are, of course, means across years when plants were pruned and not pruned and clearly reflect an intermediate result between annually pruned and selectively pruned or unpruned plants. Berry size was unaffected by pruning but did

vary by cultivar, location, and year. 'Bob Gordon' produced the largest mean berry weight overall at 86.0 mg. Mt. Vernon, which had lower overall fruit yields, produced larger berries (90.0 mg) compared with Mountain Grove (67.4 mg). Plant height was also generally influenced by the various experimental parameters. Plants were taller at Mountain Grove; the cultivars Bob Gordon and Netzer were taller than 'Adams II'; and plants were taller in 2004 compared with 2005 and 2006. Over multiple parameters, annually pruned and biannually pruned plants were slightly but significantly shorter (159 and 158 cm, respectively) compared with selectively pruned and unpruned plants (169 and 174 cm).

Eriophyid mite occurrence was generally unaffected by pruning but varied among locations (greater infestation at Mountain Grove), cultivars ('Bob Gordon' and 'Netzer' less affected than 'Adams II'), and years (generally increased incidence as years progressed). Eriophyid mites are a common and important pest of elderberry, but little is known about their taxonomy, life cycles, or management. Vaněčková-Skuhravá (1996) reported that the eriophyid mite *Epitrimerus trilobus* Nalepa overwinters within and beneath leaf buds of *S. nigra* in the Czech Republic. The same mite species has been documented as occurring on *S. canadensis* in North America (Davis et al., 1982). Eriophyid mites are generally known to overwinter in cracks and crevices of stems and bud scales. This led to a hypothesis that annual removal and destruction of overwintered stems might remove a significant source of mite proliferation, but this was not evident in our study. Many eriophyid mite species are spread by wind and it is possible that reinfestation occurred from neighboring unpruned plots within our study or from other sources. Two important insect pests that might also be managed through annual removal of stems are the elder shoot borer (*Achatodes zeae* Harris), which overwinters as eggs on stems (Buriff and Still, 1972; Silver, 1933; Solomon, 1995), and the elder borer beetle (*Desmocerus palliatus* Forester), which overwinters as

pupae in the crown and lower stem areas of the plant (Solomon, 1995). We did not address these two pests in this study, but because elderberry flowers and fruit can be reliably produced with annual removal of stems, this approach to elderberry pest management should be studied further. Although pruning treatment did not affect bacterial leafspot incidence in this study, the effect of various pruning regimens on plant structure and air circulation within the plant canopy may be important considerations with this disease and potentially with various fungal pathogens that attack elderberry.

Significant interactions among experimental effects were detected across most production and phenological factors and are detailed in Table 2. Many of these interactions are profound and difficult to understand or explain and were no doubt exacerbated by the substantial differences in experimental results between the two sites and among the three cultivars. These significantly differing results and the high degree of interaction among experimental effects suggest that elderberry is highly responsive to environment and management and that genetic development and improvement of elderberry is a realistic goal. Finn et al. (2008) observed similar substantial variability in experimental effects, including genotype-by-environment interactions, in a separate elderberry study at these same two sites.

Because of the substantial variability and interactions among sites and cultivars, and because of the need to specifically examine long-term year-to-year responses of the elderberry plants to our pruning treatments, we present detailed experimental results in three tables (Tables 3–5) sorted by the cultivars Adams II, Bob Gordon, and Netzer, respectively. The least significant difference (LSD) for each of the two sites per table was calculated separately.

'Bob Gordon' plants (Table 4) that received biannual pruning treatments produced significantly higher yields the year after pruning (2003 and 2005) compared with annual pruning at both sites. Similar yield differences were evident with 'Netzer' at

Table 2. Statistical interactions among site, cultivar, pruning treatment, and year for production and phenological characteristics.

Effect	Mean yield per plant	Mean no. of cymes per plant	Mean wt per cyme	Single berry wt	First bloom	Full bloom	First ripe	Full ripe	Plant ht
Site (S)	*** ²	***	***	***	NS	***	***	***	***
Cultivar (C)	***	***	***	***	***	***	***	***	***
S × C	***	***	***	***	*	***	***	NS	***
Pruning treatment (P)	*	***	***	NS	***	***	***	***	***
S × P	NS	***	NS	**	***	**	NS	NS	***
C × P	NS	***	***	*	NS	***	**	***	***
S × C × P	NS	*	NS	**	NS	*	**	***	*
Year (Y)	***	***	***	***	**	NS	***	***	***
S × Y	***	***	***	***	***	NS	NS	***	NS
C × Y	***	***	***	NS	**	**	***	***	NS
S × C × Y	***	***	***	NS	NS	*	*	*	NS
P × Y	***	***	***	***	***	***	***	***	***
S × P × Y	***	***	NS	NS	**	**	**	NS	***
C × P × Y	***	***	NS	*	NS	NS	**	**	NS
S × C × P × Y	**	*	*	*	NS	NS	*	**	NS

²NS, *, **, *** = nonsignificant, significant at $P < 0.05$, $P < 0.01$, $P < 0.001$, respectively.

Table 3. Yield, cyme production, phenology, and plant height of American elderberry 'Adams II' at Mt. Vernon and Mountain Grove, MO, from 2003 to 2006 in response to four pruning regimens.

Year	Pruning treatment	Mean yield per plant (g)	Mean no. of cymes per plant	Mean wt per cyme (g)	Single berry wt (mg)	First bloom ^z	Full bloom ^z	First ripe ^z	Full ripe ^z	Plant ht (cm)
Site: Mt. Vernon										
2003	Annual ^y	331	11.2	28.3	—	—	—	225	230	—
	Biannual	205	17.8	13.4	—	—	—	225	230	—
	Selective	309	23.1	14.1	—	—	—	223	230	—
	Unpruned	258	14.9	16.5	—	—	—	223	228	—
2004	Annual	399	11.4	35.6	—	—	—	223	224	150
	Biannual	400	13.7	29.2	—	—	—	221	228	130
	Selective	247	9.7	25.3	—	—	—	223	223	159
	Unpruned	221	8.0	29.1	—	—	—	221	228	148
2005	Annual	217	5.7	39.8	93.5	165	171	220	228	121
	Biannual	379	26.7	14.6	73.3	156	161	216	226	129
	Selective	322	11.1	29.1	89.7	156	164	216	234	123
	Unpruned	387	21.6	19.7	75.8	155	160	216	234	148
2006	Annual	545	14.4	34.4	57.4	—	167	224	235	131
	Biannual	635	19.1	34.3	58.5	164	168	219	234	139
	Selective	235	7.7	30.7	62.8	143	166	217	226	129
	Unpruned	292	14.3	22.8	63.1	143	164	213	233	134
	Overall mean	307	12.6	28.6	71.7	2 June	14 June	8 Aug.	17 Aug.	136.8
	Least significant difference (0.05)	225	9.6	16.0	21.4	4.2	5.7	5.8	10.4	16.1
Site: Mountain Grove										
2003	Annual	946	13.0	146.0	—	158	165	223	227	—
	Biannual	920	34.1	28.0	—	157	165	211	225	—
	Selective	695	24.1	31.9	—	145	158	211	223	—
	Unpruned	1,058	50.7	24.0	—	145	159	211	225	—
2004	Annual	1,712	22.0	80.6	58.9	159	166	215	229	147
	Biannual	1,941	26.5	79.5	64.0	158	166	215	224	163
	Selective	2,061	34.6	59.0	69.0	146	159	215	227	166
	Unpruned	1,624	36.7	44.0	68.9	146	160	213	229	170
2005	Annual	1,144	27.4	38.1	52.3	161	169	219	228	—
	Biannual	1,308	54.0	25.0	49.8	153	161	205	219	—
	Selective	698	28.9	22.9	57.0	153	159	508	210	—
	Unpruned	823	32.2	25.1	49.0	152	162	208	219	—
2006	Annual	804	21.3	38.0	65.0	170	175	216	225	125
	Biannual	842	28.1	29.9	53.9	156	156	212	225	134
	Selective	548	72.5	7.3	53.9	169	169	205	214	171
	Unpruned	867	61.1	13.9	48.5	168	169	200	216	184
	Overall mean	979	30.4	42.8	57.5	5 June	12 June	2 Aug.	12 Aug.	157.5
	Least significant difference (0.05)	777	30.2	66.4	11.6	8.4	7.9	5.3	6.7	27.4

^zNumerical day of year beginning with 1 Jan.

^yAfter establishment, all plants in all plots were cut to the ground in 2002 to initiate the study. Thereafter, plants with biannual pruning treatments were cut to the ground in Spring 2004 and 2006.

both sites (Table 5). 'Adams II', however, did not appear to respond favorably (or unfavorably) to the biannual pruning treatment during the year after pruning (Table 3). Annually pruned plants generally produced good and reliable yields in our study. They tended to yield less than plants with other pruning treatments, but this was not consistent across sites and cultivars, and in a few cases (e.g., 'Bob Gordon' at Mountain Grove in 2004; Table 4), they actually yielded more than plants pruned otherwise. In only a few cases did selectively pruned plants yield significantly more than other treatments, and likewise, in only a few cases did unpruned plants yield less, as might have been expected. We expect that plants left unpruned for durations longer than this study would eventually begin to decline as a result of accumulation of old, unproductive wood and pathogenic organisms. The high amount of variability (and high LSDs) among fruit yields across this study does not permit us to definitively conclude that one elderberry

pruning methodology is consistently superior across site and genetic parameters for yield. The profound and inconsistent differences in yield response to pruning by these three elderberry genotypes underscore the need to study and develop management recommendations tailored to specific cultivars and specific sites (Finn et al., 2008).

Cyme number and size were more clearly and consistently affected by pruning treatments than were yields. Annual pruning generally resulted in the production of fewer, larger cymes across both locations and all three cultivars. This same response is evident on plants that were pruned to the ground biannually; during the year of pruning, fewer larger cymes were produced, with cyme number increasing and cyme size decreasing the subsequent year. For example, with 'Bob Gordon' at Mountain Grove (Table 4), the biannually pruned plots that were pruned in 2004 produced similar number and size of cymes (24.0 and 132.4 g, respectively) compared with annually pruned plants (27.5

and 174.3 g), and both of these treatments produced significantly fewer, larger cymes compared with other treatments. The next year, 2005, the biannually pruned plants behaved similarly to the selectively pruned and unpruned plants in terms of cyme size and number (129.4 and 38.1 g, respectively). These results suggest that cyme number and size are directly affected and can be precisely manipulated by pruning. Indeed, this aspect of elderberry pruning management may be more important than yield effects. In most cases, producers would prefer harvesting fewer, larger cymes rather than more numerous, smaller cymes in terms of harvest efficiency and postharvest handling. Individual berry weights were largely unaffected in a consistent manner by pruning treatment.

Phenological characteristics of elderberry were, in many cases, significantly affected by the pruning treatments in this study. The predominant trend agreed with our observations and hypothesis that pruning plants to the ground delays anthesis and fruit ripening by

Table 4. Yield, cyme production, phenology, and plant height of American elderberry 'Bob Gordon' at Mt. Vernon and Mountain Grove, MO, from 2003 to 2006 in response to four pruning regimens.

Year	Pruning treatment	Mean yield per plant (g)	Mean no. of cymes per plant	Mean wt per cyme (g)	Single berry wt (mg)	First bloom ^z	Full bloom ^z	First ripe ^z	Full ripe ^z	Plant ht (cm)
Site: Mt. Vernon										
2003	Annual ^y	434	3.2	134	—	—	—	227	230	—
	Biannual	1,239	45.8	25	—	—	—	225	227	—
	Selective	1,894	65.4	29	—	—	—	223	223	—
	Unpruned	795	23.8	30	—	—	—	227	227	—
2004	Annual	1,042	7.3	162	—	—	—	224	236	193
	Biannual	1,187	19.3	99	—	—	—	223	227	163
	Selective	1,113	18.8	57	—	—	—	218	220	168
	Unpruned	656	26.6	29	—	—	—	220	225	166
2005	Annual	1,051	10.8	92	134.6	176	183	225	231	158
	Biannual	2,485	51.3	49	90.1	155	160	214	219	155
	Selective	1,698	24.4	71	109.0	158	164	214	223	149
	Unpruned	925	24.4	41	111.2	155	161	214	216	158
2006	Annual	2,577	16.2	160	101.5	164	171	223	230	163
	Biannual	1,955	12.3	156	95.9	164	176	223	233	163
	Selective	1,918	26.8	72	80.1	144	164	209	227	163
	Unpruned	952	16.4	59	93.9	142	166	207	224	142
	Overall mean	1,219	20.2	104.2	102.0	8 June	17 June	8 Aug.	14 Aug.	161.8
	Least significant difference (0.05)	754	15.8	49.2	16.2	9.3	6.3	4.5	11.1	20.0
Site: Mountain Grove										
2003	Annual	1,080	15.6	77.0	—	168	176	227	232	—
	Biannual	2,543	79.4	33.2	—	168	176	211	214	—
	Selective	3,083	87.6	35.7	—	145	160	211	212	—
	Unpruned	3,120	96.1	36.9	—	144	159	211	218	—
2004	Annual	4,653	27.5	174.3	86.2	169	177	215	229	210
	Biannual	3,148	24.0	132.4	81.3	169	177	215	229	188
	Selective	3,622	66.8	54.9	84.9	146	161	209	212	184
	Unpruned	3,719	70.9	54.9	87.9	145	160	209	215	194
2005	Annual	2,223	18.6	124.7	65.9	167	180	214	227	—
	Biannual	4,950	129.4	38.1	60.5	151	159	201	208	—
	Selective	3,783	127.4	31.0	67.9	152	159	201	211	—
	Unpruned	3,740	111.6	33.0	63.7	151	159	201	209	—
2006	Annual	1,223	14.4	88.7	66.5	166	166	219	227	197
	Biannual	665	9.7	74.4	83.6	166	166	219	227	164
	Selective	2,029	89.6	24.1	78.0	166	166	200	206	208
	Unpruned	1,906	75.2	26.9	77.4	161	168	201	206	208
	Overall mean	2,493	54.1	70.6	75.3	7 June	16 June	2 Aug.	8 Aug.	194.1
	Least significant difference (0.05)	1,110	29.0	23.7	12.5	10.4	9.7	3.9	6.4	24.1

^yNumerical day of year beginning with 1 Jan.

^zAfter establishment, all plants in all plots were cut to the ground in 2002 to initiate the study. Thereafter, plants with biannual pruning treatments were cut to the ground in Spring 2004 and 2006.

several days. For example, with 'Bob Gordon' at Mountain Grove (Table 4), both annually pruned plants and biannually pruned plants during the years of pruning (2004 and 2006) ripened their fruit 14 to 17 d later in 2004 and 21 d later in 2006 compared with selectively pruned or unpruned plants. During 2005, when only the annually pruned plants were pruned to the ground, those plants ripened their fruit 16 to 19 d later than all other pruning treatments, which were not different from each other. However, such differences were not always consistent or significant. Our phenological results for the three pruning regimens other than annual pruning may have been somewhat "averaged" because we collected anthesis and fruit ripening data across the entire plot, which likely included both primary and secondary stems. Because pruning plants to the ground generally delayed ripening, it also tended to reduce the number of harvests and therefore focused the harvest window into a narrower timeframe as the growing season concluded in August (data not shown). Fur-

thermore, because all growth on such plants is primary shoots, greater uniformity of flowering, fruiting, and ripening is achieved. For most producers, this system of pruning management would likely increase harvest and postharvest efficiency depending on their goals and resources. Such producers may consider a potentially lower overall yield a reasonable tradeoff for the greatly simplified pruning and harvest. Other producers, for example, those with limited labor or resources for harvest and postharvest handling, may prefer a longer, more gradual harvest that could likewise be manipulated by pruning. The harvest window may be more uniform and predictable with a given pruning regimen. Such uniformity of ripening and plant architecture would be especially important toward the development of mechanical harvest of elderberries.

Experimental differences in plant height at this level of detail were, again, quite variable. In a few cases [e.g., 'Adams II' and 'Netzer' at Mountain Grove (Tables 3 and 5)], annually and biannually pruned plants

were shorter than plants pruned otherwise, but in general, differences in end-of-season plant height resulting from various pruning methods were inconsistent and insignificant. Pruning plants to the ground seems to have little consequence on ultimate plant height.

Other aspects of yield management and crop protection such as bird predation may also be directly affected by pruning. For example, in our experience, birds tend to favor fruit borne on stiff, upright stems rather than on procumbent branches. Primary elderberry stems that are less woody and rigid than secondary branches and that bear single, large, heavy fruit-laden cymes tend to bend toward the ground where birds are less inclined to dwell. The potential impact of a longer exposure of ripening fruit to birds, insects, diseases, and weather (hail, for example) caused by pruning-induced delayed fruit ripening should also be considered.

Although this study provides new information on potential pruning strategies for manipulating elderberry production, questions remain concerning the long-term implica-

Table 5. Yield, cyme production, phenology, and plant height of American elderberry 'Netzer' at Mt. Vernon and Mountain Grove, MO, from 2003 to 2006 in response to four pruning regimens.

Year	Pruning treatment	Mean yield per plant (g)	Mean no. of cymes per plant	Mean wt per cyme (g)	Single berry wt (mg)	First bloom ^z	Full bloom ^z	First ripe ^z	Full ripe ^z	Plant ht (cm)
Site: Mt. Vernon										
2003	Annual ^y	9	0.3	30.0	—	—	—	223	223	—
	Biannual	673	25.3	26.6	—	—	—	225	228	—
	Selective	582	22.2	25.4	—	—	—	223	230	—
	Unpruned	596	25.3	23.7	—	—	—	225	230	—
2004	Annual	179	2.2	85.0	—	—	—	240	240	156
	Biannual	172	2.5	74.6	—	—	—	240	240	153
	Selective	413	9.3	43.1	—	—	—	224	224	161
	Unpruned	504	24.2	19.6	—	—	—	221	223	191
2005	Annual	17	0.3	46.7	108.7	183	191	257	257	123
	Biannual	593	11.7	48.7	102.6	165	171	228	234	161
	Selective	342	6.5	48.6	108.2	163	173	231	234	142
	Unpruned	488	10.0	57.4	109.0	163	168	222	231	183
2006	Annual	143	2.8	52.0	89.4	169	190	235	237	151
	Biannual	283	3.8	68.8	100.4	176	186	243	252	149
	Selective	213	4.6	47.0	81.8	164	169	228	244	161
	Unpruned	137	3.8	34.5	75.6	—	169	226	230	156
	Overall mean	284	7.9	66.6	96.8	18 June	26 June	18 Aug.	23 Aug.	157.3
	Least significant difference (0.05)	249	5.5	56.0	15.9	13.3	8.7	12.9	9.2	20.4
Site: Mountain Grove										
2003	Annual	—	—	—	—	167	179	—	—	—
	Biannual	—	—	—	—	170	178	—	—	—
	Selective	—	—	—	—	156	164	—	—	—
	Unpruned	665	16.9	39.4	—	156	163	225	—	—
2004	Annual	1,024	10.9	93.0	80.3	168	180	215	236	201
	Biannual	1,099	11.5	105.3	80.9	171	179	215	236	211
	Selective	1,207	38.2	38.3	80.7	157	165	215	231	224
	Unpruned	502	18.8	26.4	75.6	157	164	215	232	211
2005	Annual	146	5.3	25.8	62.0	174	181	229	229	—
	Biannual	1,567	89.5	17.8	60.3	154	165	213	225	—
	Selective	1,063	47.9	22.8	62.6	159	169	210	225	—
	Unpruned	1,017	59.4	17.4	67.0	161	167	215	223	—
2006	Annual	96	2.8	34.1	52.0	159	159	227	227	154
	Biannual	113	3.4	33.5	67.5	166	166	225	227	167
	Selective	363	30.7	12.9	68.0	169	169	208	221	226
	Unpruned	388	29.4	13.6	75.3	154	163	212	221	216
	Overall mean	575	22.8	36.8	69.4	11 June	18 June	11 Aug.	19 Aug.	201.3
	Least significant difference (0.05)	363	14.6	25.4	9.7	10.8	10	3.9	6	28.5

^zNumerical day of year beginning with 1 Jan.

^yAfter establishment, all plants in all plots were cut to the ground in 2002 to initiate the study. Thereafter, plants with biannual pruning treatments were cut to the ground in Spring 2004 and 2006.

tions of pruning. Although we seem to be espousing the multiple benefits of pruning elderberry to the ground annually, we know little about the long-term implications of such a pruning regimen. For example, a quantity of stored carbohydrates is removed as a consequence of annual shoot removal, which may over time reduce vigor and productivity. Additional research on the short- and long-term implications of various pruning strategies and, in fact, on the productive longevity of elderberry plantings is needed.

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