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Autumnberry (*Elaeagnus umbellata*): A Potential Cash Crop

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Abstract

Feral populations of autumn olive (*Elaeagnus umbellata* Thunb) exist throughout the eastern United States. The plants are tolerant of a wide range of environmental conditions and thrive on poor soils. In 2001, researchers published evidence that the red berries of autumn olive have a high carotenoid content, and particularly high levels of lycopene (30-70 mg/100g). Lycopene has powerful antioxidant properties, making it of interest for nutraceutical use, and also provides natural red color for food use. Managed plantings consisting of three cultivars and four wild selections were established in Maryland to evaluate genotypes and management practices for potential commercial fruit production. Annual productivity of autumn olive ranged from 0.5 to 15 kg/plant. Mechanical harvesting was accomplished using a commercial blueberry harvester on plants that had been pruned for mechanical harvest. Berries were high in soluble solids and acidity, similar to blueberries and blackberries, but somewhat astringent. Approximately 10% of the total berry weight is in the seed. Lycopene content differed among genotypes ranging from 33.6 mg/100 g to 55.3 mg/100 g for 'Delightful' and USMD3, respectively. The productivity under low-input management, and the possibility for machine harvest indicate that autumn olive may be a commercially viable crop, especially on low-fertility and sandy soils that may be unsuitable for other agricultural uses. Differences in yield and fruit lycopene content indicate an opportunity for selecting genotypes superior for fruit production.

Introduction

Elaeagnus umbellata Thunb. is a large shrub growing 3.5 to 5 m tall and up to 6 m across. In the eastern United States it is known as autumn olive, but other common names include autumn elaeagnus, asiatic oleaster, umbellate oleaster, aki-gumi and Japanese silverberry (7, 8). Native to China, Korea and Japan, the plant was originally introduced into North America in 1830, and later planted widely as a windbreak and to attract wildlife. The species is relatively fast growing, tolerant of drought, saline soils, and of soil pH ranging from alkaline to acid. The species is also actinorhizal, forming nitrogen-fixing root structures induced by *Frankia* (16). These characteristics make autumn olive particularly adapted to low-fertility loamy and sandy soils (7), and therefore well suited for reclamation of disturbed sites (20) and as a nurse crop for agroforestry establishment (12).

The plants can produce large numbers of fruits, ripening in September and October. Ripe fruit are very attractive to birds that eat

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the fruit and subsequently scatter the seeds. Because the plants were widely planted for conservation purposes and due to seed dispersal by bird feeding, well-established feral populations exist throughout the Eastern U.S., ranging from Maine and Wisconsin in the North to Florida and Louisiana in the South, and as far west as Nebraska (4, 8, 34). The 7 to 10 mm diameter fruit (pseudodrupes) are borne on second-year and older wood, and have a pleasant, unique, sweet-tart flavor. Although the fruit is eaten in Asia (22, 29), references to human consumption in the United States are limited (6, 23). However, several clones with superior flavor and fruit qualities, selected for use in edible landscaping are available as named cultivars (Hidden Springs Nursery, Cookeville, TN).

The red fruit of autumn olive have a carotenoid profile similar to that of tomato, and have exceptionally high levels of lycopene (50 mg/100g compared to 3 mg/100g for tomato) (10). Lycopene is not synthesized in the human body and is available from only a few primarily plant sources. Tomato products are the predominant source of this compound in western diets, but watermelon, guava, papaya, and pink grapefruit have lycopene content similar to tomato (5, 18, 30).

Diets high in lycopene have been associated with a number of health benefits, and a number of epidemiological studies and clinical trials have been carried out to examine the role of lycopene in human health. Increased dietary lycopene has been found to reduce the incidence and severity of prostate cancer (1, 3, 13). Epidemiological studies suggest that increased lycopene intake may reduce the risk of cardiovascular disease (14, 27) and the mortality of those with oral, pharynx, or larynx cancers (19). Additionally, dietary intake of lycopene protects skin from ultraviolet light damage (2). Autumn olive fruit also contains high amounts of a- and b-cryptoxanthin (10). Lutein and b-carotene levels are similar to those of banana and tomato, respectively (30).

With reports of the health benefits of lycopene, and the high lycopene content in autumn olive (10, 11), there has been interest in commercial production of the fruit. However, little is known about plant culture for fruit production, or whether managed fruit production would be commercially feasible. Two plantings have been maintained without pesticides or fertilizer at the Beltsville Agricultural Research Center. Here we present observations from these plantings in order to evaluate the feasibility of, and identify promising genotypes for, commercial fruit production.

Materials and Methods

Two plantings were established at the USDA-ARS Henry A. Wallace Beltsville Agricultural Research Center, in 1998 and 1999 on Downer-Ingleside loamy sand soil (typic hapludult, coarse-loamy, siliceous, mesic). Two-year-old nursery plants of 'Delightful', 'Jewel' and 'Sweet'nTart' were obtained from a commercial nursery (Hidden Springs Nursery, Cookeville, TN) and planted at the Beltsville research site in the spring of 1998. The 1998 planting consisted of 3 to 4 plants of each cultivar spaced at 1.8 m within and between rows. Plants were irrigated during the establishment year, but no supplemental irrigation was provided in subsequent years. Plants were not fertilized or treated with any fungicides or insecticides at any time. Fruit samples were hand harvested annually for chemical analysis, and plants were completely hand harvested in 2000 to determine yield.

Additional plants were obtained in 1999 for a second planting consisting of two-year-old rooted cuttings of 'Delightful', 'Jewel', 'Sweet'nTart' and first-year rooted cuttings of four selections made from feral populations in Howard County, Maryland. Five to 20 plants of each genotype were established in four rows, spaced 3.0 m apart within the row and 3.7 m between rows. Genotypes were randomly assigned to single half-row plots within the planting. As plant genotypes were not replicated within the planting, statistical comparisons are untenable. The field had been planted to tall fescue prior to establishment of autumn olive. Five-foot wide strips were rototilled in the sod, with the remaining grass left to provide cover for the row middles. Nursery plants and cuttings were transplanted into the rototilled strips and trickle lines were installed to provide irrigation during the establishment year. Supplemental irrigation was not provided in subsequent years. As with the first planting, no lime, fertilizer, fungicides or insecticides were applied. Planting maintenance consisted of periodic mowing between rows, and within-row weed management by mowing and occasional application of contact herbicide. Some fruit set occurred in the second planting during the 2001 season, but no attempt was made to quantify yields because of tornado damage.

A commercial blueberry-harvesting machine (Korvan Model 930, Oxbo Intl., Lynden WA.) was used to harvest the planting on 9 October 2002. To facilitate machine harvesting some pruning was carried out in the weeks prior to harvest. Larger horizontal branches extending perpendicular to the rows were cut back to allow shrubs to pass through the harvester, and branches within 0.4 m of the soil were removed to allow proper catch-plate positioning. Machine-harvested yields were not determined in 2002, as adjustments were made to the equipment during the harvest to optimize fruit removal. The machine is equipped with horizontal shaking motion with adjustable amplitude and frequency. Amplitude is determined by the position of counterbalanced weights. With weights set at 85% of the outward maximum position, a shaking frequency of 550 rpm provided a selective harvest, removing approximately 50% percent of the fruit, whereas a shaking frequency of 750 rpm effectively defruited the plant. Machine harvesting was again carried out in both 2003 and 2004, and machine-harvested yields determined for each genotype. After each harvest, winter pruning was carried out to remove branches damaged by the harvester and new growth near the soil line that would interfere with the harvester. A hand-held pneumatic limb shaker (Brewt Power Systems, Merced CA) was tested in 2003 to evaluate the potential for small-scale harvesting, but fruit removal was < 40%.

Fruit analysis - Hand-harvested and machine-harvested samples were collected for analysis. Fruit samples were frozen and held at −80°C until analysis. Two 20 g samples of berries per selection were ground in a blender with water at 1:1 wt/volume. The homogenate was then ground for about one minute with a Polytron homogenizer, then filtered through cheesecloth to remove seeds. A 10-ml aliquots was taken from each sample and diluted in 90 ml deionized water. Sample pH was measured with a pH meter and electrode designed for purees (Orion 8536) then titrated to a final pH of 8.1 to determine titratable acidity as meq citric acid. Soluble solids content was determined by placing an aliquot of undiluted sample on a digital refractometer (Atago Model PR100).

Lycopene was determined from purees on two samples per selection using spectrophotometric methods. Fifteen grams of undiluted puree was homogenized with 15 ml water by polytron (Brinkman, Switzerland). A 10 ml aliquot, with seeds removed, was combined with an additional 20 ml of water. Two 0.4 g samples of this diluted volume were placed in 10 ml ethanol, and 10 ml hexane was added, followed by 5 ml acetone, following the method of Fish et al. (9), and based on the hexane:acetone extraction commonly used for spectrophotometric determination of total lycopene (25). The absorbance of this sample at 503 nm was used to calculate total lycopene, using the extinction coefficient 172,000 (35). Diluted (1:2 wt/vol) puree (0.5 to 1 g) was extracted with 25 ml of a solvent comprised of acetone: methanol:water:formic acid (4:4:2:0.01). Total phenolics were determined by the Folin-Ciocalteau method (28).

Results and Discussion

Cropping In 2000, yields for hand-harvested plants in their third year in the field ranged from 2.7 kg/plant for 'Jewel' to 6.2 kg/plant for 'Sweet 'n Tart' (Table 1). On 24 September 2001, a tornado passed through the research station. It did not directly damage the plants but resulted in excessive fruit drop in both plantings. Consequently, fruit samples were collected for analysis, but no attempt was made to quantify yield. By the 2002 season, the first planting had become overgrown and unmanageable due to the close plant spacing, and the planting was removed in 2003.

In 2002, yield was not determined in the second planting, as machine harvest techniques were being optimized. Yields were again influenced by weather in the 2003 season. High winds and heavy rains from tropical storm Isabel damaged some of the planting on 18 and 19 September 2003. The genotype most severely affected was USMD5 where many plants were partially uprooted and leaning over. Some plants of USMD4 and USMD3 were also leaning and there was fruit drop throughout the planting. Leaning and uprooted plants were propped upright and the planting was again machine harvested on 29 September, 2003. However, USMD5 was not harvested. The harvest was made in two passes, a selective harvest (550 rpm) followed by complete fruit removal (750 rpm). Yields among cultivars and selections ranged from 1.39 kg/plant for 'Jewel' to 7.34 kg/plant for 'Sweet 'n Tart' (Table 1). The selective harvest removed 50% of the total crop for 'Delightful' and USMD4, compared to 62% and 72% of the crop for USMD2 and USMD3, respectively (data not shown).

In addition to winter pruning to facilitate machine harvesting, some additional summer pruning was necessary in the spring of 2003 to remove twigs damaged by 17-year cicada. This insect damage likely had a negative effect on yield, as the damage was concentrated on young wood that would normally set fruit. Fruit sample collection and machine harvesting were carried out during the week of 27 September 2004, with machine harvesting carried out in a single pass. Yields ranged from 0.4 kg/plant for 'Jewel' to 16.8 kg/plant for USMD3.

Other production considerations. Although no fungicides or insecticides were used in the planting, these might become necessary under commercial production systems. In addition to cicada damage, we observed some mid-summer feeding of Japanese beetle in a separate planting. In other small fruit crops, Japanese beetles are of concern both because of direct feeding damage and contamination of the harvested product (15). Due to the ripening season of autumn olive, contamination of the harvested product is not likely, and the threshold level of plant damage is unclear.

We did not observe notable fruit or foliar disease symptoms in either planting, but did see some post-harvest decay on machine-harvested fruit. Disease susceptibility of autumn olive is not well documented. Ruhl and Heimann (24) reviewed diseases commonly found in *Elaeagnus* species, noting that all species are susceptible to *Verticillium*. Other fungal pathogens discussed include cankers and branch dieback caused by *Botryosphaeria, Cytospora, Fusarium, Phoma, Phomopsis, Phytophthora, and Tubercularia*, but documented cases of these

Table 1. Yields, fruit size and seed size of *E. umbellata* genotypes in managed plantings. Results for 2000 are from hand harvest of plants in the third season in the field (1998 planting). Results for 2003 and 2004 are from machine harvest of plants in the fifth and sixth season (1999 planting). Weights of whole fruit and seeds were determined on 100-gram samples collected during the 2004 harvest

Genotype	Yield (kg/plant)			Fresh weight (mg)	
	2000	2003	2004	Fruit	Seed
'Delightful'	4.83	4.25	5.6	431	37.9
'Jewel'	2.70	1.39	0.4	478	41.6
'Sweet 'n Tart'	6.20	7.34	8.0	463	42.6
USMD2	-	6.08	11.9	377	37.0
USMD3	-	4.01	16.8	459	41.7
USMD4	-	1.97	4.4	388	32.2
USMD5	-	-	6.1	450	32.9

Table 2. Fruit quality parameters of *E. umbellata* harvested from managed plantings at the Beltsville Agricultural Research Center. Samples from 2001 are from a planting established in 1998. The remaining samples are from a planting established in 1999. Values are means across years indicated ± standard error.

Genotype	Years sampled	Lycopene (mg/100g)	Soluble[z] solids(%)	Acidity (meq citrate)	pH	Total phenolics[y] (mg/kg)
			mean ± se			
'Delightful'	01, -, 03,04	33.6±1.8	15.4±2.6	2.8±1.2	3.5±.01	1563±166
'Jewel'	01,02,03,04	53.9±8.5	15.4±.09	3.7±1.6	3.4±<.01	1507±281
'Sweet 'n Tart'	01,02,03,04	37.3±3.1	13.0±1.8	4.2±1.8	3.1±<.01	1833±252
USMD2	02,03,04	52.8±7.7	12.7±.06	5.5±1.6	3.1±<.01	1638±374
USMD3	02,03,04	55.3±8.6	12.3±1.1	3.1±.07	3.5±.01	1633±117
USMD4	02,03,04	54.6±9.7	13.0±1.0	1.9±.07	4.0±<.01	1669±355
USMD5	02, -, 04	44.0±7.7	12.6±1.4	1.7	3.8	1399±138

[z]Soluble solids content and titratable acidity were not determined on 2002 samples.
[y]Total phenolics were determined for 2002 and 2004 samples.

are limited to *E. angustifolia* (24). *Verticillium* susceptibility would need to be taken into account during site selection. If autumn olive proves susceptible to canker and branch dieback, these could become a management problem in a commercial planting where other perennial woody crops may act as a source of inoculum, and periodic pruning could provide avenues for infection.

Predation by birds would be an additional production concern. The experimental plantings were not protected by netting or other deterrents and there was significant bird feeding in the upper branches near harvest time. Whether or not deterrents would be cost effective would depend on the end value of the fruit, and the degree to which deterrents would increase harvested yield. Information on long-term productivity and bearing is not available but observations of feral plants have shown yearly variation in productivity, suggesting that more productive selections may have an alternate or biennial bearing cycle. Although autumn olive is relatively drought tolerant and irrigation was only provided during the establishment year, supplemental irrigation would likely increase harvestable yield.

Plants do not spread by root suckering, but can be quite persistent once established, growing back from the roots when cut down or mowed off. Due to this persistent nature, seed dispersal by wildlife, and the ability to thrive in poor soils, autumn olive is listed as an invasive species. However, a number of important crop species are similarly listed. Further, the plant is listed as a noxious weed in West Virginia and as a prohibited invasive species in New Hampshire (34). To prevent further spread of this species, plants should not be grown for commercial fruit production in these states or in areas where feral populations are not already established.

Fruit quality. Fruit size ranged from 478 mg for 'Jewel' to 377 mg for USMD2 (Table 1). Seed weight made up about 10% of the total berry weight. Overall, the soluble solids content (SSC) is high (12-15%) in autumn olive, comparable to the SSC of blueberries (Table 2). Total sugars in autumn olive is 10% (26), indicating that about 70-80% of the SSC is composed of sugars. Fruit pH is similar to that of other small fruits such as blackberry, strawberry, and raspberry. Titratable acidity ranged from 1.7 to 5.5% citric acid. Sakamura and Suga (26) reported % acidity in *E. umbellata* as 1.8%. The total phenolic content of autumn olive is high, comparable to that of blackberry and blueberry. The autumn olive fruit can be astringent due to tannins and other polyphenols that decrease five-fold as color development progresses during ripening (26). We have observed that astringency decreases as ripening continues and after lycopene accumulation is complete.

Genotypes were not replicated within plantings and consequently, statistical comparisons of yield and fruit quality are not possible. However, over multiple harvest seasons and in two separate plantings, trends in yield and fruit quality appeared consistent. 'Jewel' consistently ranked among the highest in soluble solids and lycopene content, but had the lowest yields. By contrast, 'Sweet'n Tart' had lower lycopene and soluble solids, and the highest yield among cultivars. The numbered selections all had higher lycopene content than 'Delightful' and 'Sweet'nTart', and several were comparable in yield. In the 2003 harvest, fruit from the selective harvest did not differ dramatically from the second harvest except in the case of USMD2 and USMD3. For USMD2 the lycopene content and soluble solids for the selective harvest were 72 mg/100g and 14.6%, compared to 40.7 mg/100g and 12.2% for the second harvest, respectively. For USMD3, lycopene and soluble solids content did not differ between harvests, but the selective harvest had higher titratable acidity and lower pH than the second shake (data not shown). This indicates that there may be the potential to selectively harvest the most-ripe fruit using a gentle shake, but at the time that harvesting was carried out most of the genotypes had uniformly ripe fruit.

Genotypic differences in fruit quality parameters and yield likely reflect the conditions under which these genotypes were selected. The named cultivars were selected for edible home landscaping. Under the conditions at the research site, these plants are somewhat more compact and slower growing, with a moderate to low crop load. The USMD series were selected for apparent high yields and high lycopene. These plants tend to grow more vigorously than the named cultivars. These differences also suggest the potential to select genotypes that are better adapted to commercial fruit production, with the traits of high yields, high berry lycopene content, and growth habit conducive to machine harvest.

Production economics. To estimate commercial production costs, management can be compared to other perennial fruit crops. Inputs for the test site included establishment irrigation, mowing, weed control, pruning, and harvesting. Additional management inputs that were not used for the experimental plots but that may be employed in commercial production include: continued irrigation, bird deterrents, and imported beehives for improved pollination. Table 3 provides a simplified budget for autumn olive fruit production including these inputs. Cost estimates for production were adapted from published enterprise budgets for blueberry, bramble, apple and peach (17, 21). Estimates for pruning costs were based on hand pruning. Since the primary objective of pruning was to facilitate machine harvesting, mechanical pruning or hedging might accomplish the same purpose at lower cost. Land charges are based on estimates for other fruit crops. As autumn olive is well suited to marginal soil, these estimates may be high. Machine harvesting and handling costs were based on estimates provided for harvesting blueberry and black current. Machine harvesting costs range from $0.30 to $0.44 per kg depending on productivity and acreage harvested. Cost for post-harvest fruit handling is approximately $0.44 per kg, and includes transportation, preliminary cleaning, boxing and freezing of harvested fruit (S. Erwin, Superb Horticulture Group, Plymouth Ind., personal communication).

Value of product The potential economic value of autumn olive as a commercial crop depends upon a market for the fruit. Since there is not yet an established supply and interest in the fruit is in the developmental stages, it is difficult to estimate value. Two potential markets would be to use the fruit as the basis for processed functional food products such as jam, syrup or preserve, or to extract and purify the lycopene for use as a naturally derived dietary supplement. As a natural source of lycopene, the comparison product would be tomato. With a lycopene content of 3.0 mg/100g (31) and a processing price of $68.42 per metric ton (Ten-year average farm price) (32), the value of unextracted lycopene in tomato would be $2.28 per gram. With an average lycopene content of 50 mg/100g, fresh fruit of autumn olive would have a farm value of $1.14 per kg, assuming equivalent lycopene extraction and purification efficiency.

For using the fruit as a processed food ingredient, prices might be comparable to other processed berry crops that are of interest to the functional food industry. These include: red raspberry, black raspberry, blackberry, boysenberry and blueberry. The six-year average processing price (1998-2003) for these crops as reported for Oregon ranged from $1.13 per kg for blackberry to $2.82 per kg

Table 3. Production cost estimates per hectare for commercial autumn olive fruit production. Additional input costs are for optional inputs not used in the experimental planting that could be used in a commercial planting to increase yields.

Yield (5 kg/plant @ 900 plants/ha)		4500kg	
Income ($1.25/kg)			$5625
Basic inputs[z]		unit cost	
Mowing/machinery		$330	
weeding/spot spraying		$ 60	
pruning		$620	
land		$250	
Additional inputs (optional)			
irrigation	$500		
pollination	$ 90		
bird deterrents	$110		
Preharvest production costs[y]		$1260	
Harvesting[x] harvester $0.37 per kg		$1665	
handling $0.44 per kg		$1980	
Total cost of production and harvest			$4905
Return to management			$720

[z]Input cost estimates were adapted from published enterprise budgets for other fruit crops.
[y]Preharvest production cost total excludes those inputs listed as additional. Only those inputs used in the experimental plantings are included.
[x]Machine harvest and fruit handling cost estimates were based on blueberry and black currant production (Erwin, personal communication)

for black raspberry (33). Excluding black raspberry, the typical processing price among these berry crops was $1.25 per kg. Aronia *(Aronia melanocarpa Michx.)* is another small-acreage fruit crop of interest as a functional food. Processing prices for aronia in the Northwestern United States is $4.40 per kg (Penhallegon, personal communcation). Unlike these berry corps, a large proportion (7 to 9% by weight) of the intact autumn olive fruit is seed. Although the seed does not interfere with lycopene extraction, it would reduce the amount of puree produced from fresh fruit and should be taken into account in estimating value of the fruit. Higher prices for fruit will depend on the development of gourmet or specialty markets. One potential limitation to developing a specialty market for the fruit may arise from a common name that does not connote a sweet fruit. We suggest the name "Autumnberry" as a more palatable alternative.

Whether a market for the fruit is developed around a functional food product, or as a natural source of lycopene, our results indicate that the fruit can be grown and harvested economically. The lack of pest problems seen in our plantings and in wild populations indicate the possibility that Autumnberry could be grown under certified organic practices. Tolerance of poor and disturbed soils would indicate adaptability to sites not suitable for other commercial crops.

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Tree Setting Depth Affects Wind Resistance in Pecan

DARREL SPARKS[1]

Abstract

Hurricanes Frances, Ivan, and Jeanne inflicted widespread damage to pecan [*Carya illinoinensis* (Wangenh.) K. Koch] trees in Georgia during September 2004. Tree damage was either limb breakage, uprooting, or varying degrees of tree tilting without uprooting. The relationship of degree of tree tilt to setting depth at planting was examined. Trees that were set at the same level at which they grew in the nursery did not tilt. Tilting of trees which had been set at a lower depth ranged from a few degrees from upright to total blow over.

Introduction

During September 2004, major wind damage to pecan trees in Georgia occurred during hurricanes Frances (September 5-6), Ivan (September 15-17), and Jeanne (September 26- 27). In south Georgia, maximum sustained winds reached 29-38 knots with peak wind gusts of 37-59 knots (7). Tree damage was either limb breakage, uprooting of the tree, or varying degrees of tree tilting without uprooting. All types were widespread. Limb breakage was especially severe in 'Desirable' and 'Stuart'. Breakage in 'Desirable' was primarily due to poor crotch angles. In 'Stuart' breakage usually occurred on the mid to distal portion of the branch as most of the weight of the foliage and fruit is located on this portion of the branch. Uprooting was more severe on cultivars with dense foliage as in 'Schley' or with a wide-spreading canopy as in 'Cape Fear' than on cultivars with less dense foliage or an upright growth habit as reported for pecan wind damage in general (10, 12). Additionally, and regardless of cultivar, trees with brace roots positioned asymmetrically around the trunk were more likely to uproot than trees with symmetrically positioned brace roots. Tree tilting or blowing over without uprooting occurred regardless of cultivars and was associated with bending or displacement of the taproot and, when the tree blew over, by breakage or cracking of the taproot. Observations indicated the damage was associated with setting the tree deeper than it sat in the nursery. This study examines the relationship of setting depth at planting to the degree of tree tilt caused by the winds.

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