In North America Aronia has been promoted as a native replacement for invasive ornamental species because of its adaptability and multiseason interest provided by spring flowers, summer and fall foliage, and orange-red fall foliage (Brand, 2010). Commercial fruit cultivation of Aronia in North America has recently increased significantly since fruits have been found to contain exceptionally high levels of antioxidants and polyphenols (Kakonen et al., 2001; McKay, 2001; Wu et al., 2004; Zheng and Wang, 2003). Furthermore, there is growing evidence that chokeberry consumption can have numerous and varied health benefits (Kokotkiewicz et al., 2010). As a result, there is new interest in conducting research to identify potential avenues for genetic improvement of commercial cultivars of Aronia.

The genus Aronia belongs to the subtribe Pyrinae (formerly subfamily Maloideae) that is rife with taxonomic difficulties (Campbell et al., 2007; Potter et al., 2007). This group includes Sorbus (mountain ash), Malus Mill. (apple), Pyrus L. (pear), Amelanchier Medik. (serviceberry), Crataegus L. (hawthorn), and several other woody plants with pomes or apple-like fruits (Campbell et al., 2007). Hybridization between species within genera is common along with polyploidy and apomony (Campbell et al., 2007; Persson-Hovmalm et al., 2004).

Three species of Aronia are commonly accepted: A. arbutifolia, red chokeberry; A. melanocarpa, black chokeberry, and A. prunifolia, purple chokeberry. The third species, A. prunifolia, is generally considered to be a naturally occurring, interspecific hybrid between A. arbutifolia and A. melanocarpa (Brand, 2010; Dirr, 2009; Rehder, 1920). Most sources distinguish the species by either red or black fruit color (Hardin, 1973) plus the degree of pubescence on leaves, stems, and inflorescences (Krussmann, 1986). Aronia arbutifolia possesses denseomentum on the undersides of leaf blades, stems, and inflorescences compared with nearly glabrous A. melanocarpa.

Despite the phenotypic variation among wild North American Aronia species, none have been described as possessing morphology closely resembling the plant material used in Eurasian commercial orchards. This has led to the proposal by Skvortsov and Maitulina (1982) that this phenotype be designated as a fourth species, Aronia mitschurinii. The A. mitschurinii phenotype is most similar to A. melanocarpa in appearance and often the two are distinguished only by a cultivar designation. Both species have black fruits, relatively glossy, glabrous leaves, stems, and flowers, but A. mitschurinii does possess some unique distinctions from A. melanocarpa. Skvortsov and Maitulina (1982) found that A. mitschurinii fruits are 1.5 to 2 times larger than A. melanocarpa and possess distinct morphology. Fruits are dull, globose, and somewhat depressed at the apex in comparison with wild A. melanocarpa fruits, which are shiny and oval or pyriform in shape. A. mitschurinii was also shown to have larger inflorescences, rounder leaf morphology, and a faster growth rate than A. melanocarpa. Skvortsov et al. (1983) also used ploidy as an identifying characteristic because A. mitschurinii is uniformly tetraploid (2n = 68), although Persson-Hovmalm et al. (2004) identified that polyploidy is common in all Aronia species.

Skvortsov et al. (1983) traced A. mitschurinii’s origins back to early 20th century Russia and the research facility of pomologist Ivan Michurin. Michurin focused his research on developing fruit crops suitable for cultivation in Russia. Michurin’s notes describe successful hybridizations among North American Aronia, originally received from Germany, native European Sorbus aucuparia L., and other members of the subtribe Pyrinae, Rosaceae (Michurin, 1948, 1949). The Pyrinae is a group in which wide hybridizations and allopolyploidy have been important factors in speciation (Campbell and Wright, 1996; Dickinson and Campbell, 1991; Nelson-Jones et al., 2002; Phipps et al., 1991; Robertson et al., 2010).

Although literature sources attribute A. mitschurinii to Ivan Michurin’s research, its genetic relationship to wild North American Aronia and other members of the Pyrinae remains unknown. The goal of this study is to determine if A. mitschurinii is a naturally occurring form of Aronia or is the product of intergeneric hybridization as Skvortsov et al. (1983) theorized and to identify potential avenues for breeding. To study the genetics of Aronia and other members of the Pyrinae, molecular markers including AFLP and cross-priming techniques were used in an attempt to identify potential avenues for breeding. To study the genetics of Aronia and other members of the Pyrinae, molecular markers including AFLP and cross-priming techniques were used in an attempt to identify potential avenues for breeding.
Species from the broader Pyrineae included genera used in Michurin’s research such as *Malus* and *Pyrus*. *Malus* taxa included were *M. baccata* (L.) Borkh., *M. domestica* Borkh., *M. hupehensis* (Pamp.) Rehder, and *M. platycarpa* Rehder. *Pyrus communis* L. and *P. calleryana* Deune were included to represent potential parentage. *Aronia* and *Photinia* Lindl. are genera with taxonomic links to *Aronia* but not included in Michurin’s experiments. The East Asian genera *Chaenomeles* Bartl. and *Cydonia* Mill. were selected as outgroups and are not known to hybridize with *Aronia*.

DNA isolation. DNA was isolated from ≈0.5 g of newly emerged fresh or frozen (–80 °C) leaf tissue using a modified CTAB procedure (Holm, 1995). Leaf tissue was ground in liquid nitrogen and then transferred to 15-mL conical polypropylene Falcon® tubes (BD Falcon, Franklin Lakes, NJ). Frozen tissue was suspended in 3 mL DNA extraction buffer containing 1 mg·mL−1 RNase and 2.1 μL β-mercaptoethanol. Tubes were mixed vigorously for 1 min and incubated for 1 h in a 60 °C water bath during which time samples were mixed by inversion at 15-min intervals. Samples were then centrifuged for 5 min at 2500 × g and the supernatant was transferred to new 15-mL tubes. Equal volume of 24:1 (v/v) chloroform:isoamyl alcohol was added to the supernatant and shaken for 1 min. Tubes were centrifuged for 10 min at 2500 × g and the aqueous phase was transferred to a new tube. This process was repeated until little to no interphase was visible. DNA was precipitated using 2:1 (v/v) ice cold 100% ethanol (EtOH) and samples were centrifuged for 5 min at 2500 × g. DNA pellets were dissolved in TE 0.1 buffer (pH 8.0) to achieve a concentration of ≈300 ng·μL−1. All centrifugation was done at 4 °C. Quality of extracted DNA was assessed by gel electrophoresis and a NanoDrop ND-100 spectrophotometer (Thermo Fisher Scientific, Waltham, MA). Only non-degraded and high-quality DNA samples were used for AFLP analysis. Extracted DNA samples were stored at –80 °C until needed for the AFLP procedure.

### Table 1. Germplasm information for material used in amplified fragment length polymorphism analysis.

| Species                      | Accession/cultivar | Germplasm source                          | Germplasm origin |
|------------------------------|--------------------|-------------------------------------------|------------------|
| *Amelanchier arborea*        | None               | Blue Ridge Hills Reservation, Milton, MA  | Massachusetts    |
| *Aronia arbutifolia*         | ‘Brilliantissima’  | Spring Meadow Nursery, Grand Haven, MI    | Unknown          |
| *Aronia arbutifolia*         | P1578096           | USDA, Ames, IA                            | Virginia         |
| *Aronia melanocarpa*         | AMES27010          | USDA, Ames, IA                            | Michigan         |
| *Aronia melanocarpa*         | P1545687           | USDA, Ames, IA                            | Michigan         |
| *Aronia melanocarpa*         | P1953106           | USDA, Ames, IA                            | Tennessee        |
| *Aronia melanocarpa*         | P1953106           | USDA, Ames, IA                            | Massachusetts    |
| *Aronia melanocarpa*         | P1951684           | USDA, Ames, IA                            | Wisconsin        |
| *Aronia melanocarpa*         | UC007              | University of Connecticut, Stors, CT      | Connecticut      |
| *Aronia melanocarpa*         | UC009              | University of Connecticut, Stors, CT      | Maine            |
| *Aronia melanocarpa*         | UC010              | University of Connecticut, Stors, CT      | Maine            |
| *Aronia melanocarpa*         | UC031              | University of Connecticut, Stors, CT      | Connecticut      |
| *Aronia mitschurinii*        | ‘Nero’             | Spring Meadow Nursery, Grand Haven, MI    | Cultivated origin|
| *Aronia mitschurinii*        | ‘Viking’            | Spring Meadow Nursery, Grand Haven, MI    | Cultivated origin|
| *Aronia prunifolia*          | Pt603107           | USDA, Ames, IA                            | Virginia         |
| *Chaenomeles japonica*       | 750-82-A           | Arnold Arboretum, Boston, MA              | Unknown          |
| *Chaenomeles prunifolia*     | None               | University of Connecticut, Stors, CT      | Unknown          |
| *Cydonia oblonga*            | 829-84-A           | Arnold Arboretum, Boston, MA              | France           |
| *Malus baccata*              | 1843-80-A          | Arnold Arboretum, Boston, MA              | China            |
| *Malus domestica*            | ‘Cameo’            | Wright Orchard, Willington, CT            | Cultivation      |
| *Malus domestica*            | ‘Macoun’           | Wright Orchard, Willington, CT            | Cultivation      |
| *Malus hupehensis*           | 21-96-C            | Arnold Arboretum, Boston, MA              | Unknown          |
| *Malus platycarpa*           | 134-2004-A         | Arnold Arboretum, Boston, MA              | North Carolina   |
| *Photinia beaverdiana*       | 1733-80-A          | Arnold Arboretum, Boston, MA              | Unknown          |
| *Photinia villosa*           | None               | University of Connecticut, Stors, CT      | Unknown          |
| *Pyrus calleryana*           | ‘Bartlet’          | Private residence                         | Unknown          |
| *Pyrus communis*             | None               | University of Connecticut, Stors, CT      | Unknown          |
| *Sorbus alnifolia*           | 1497-52-B          | Arnold Arboretum, Boston, MA              | England          |
| *Sorbus aucuparia*           | 1733-80-A          | Arnold Arboretum, Boston, MA              | Scotland         |
| *Sorbus aria*                | 222-27-A           | Arnold Arboretum, Boston, MA              | Scotland         |
| *Sorbus aria*                | 260-27-A           | Arnold Arboretum, Boston, MA              | Scotland         |
| *Sorbus aucuparia*           | 180-57-A           | Arnold Arboretum, Boston, MA              | Scotland         |
| *Sorbus montana*             | 18462-B            | Arnold Arboretum, Boston, MA              | France           |
| *Sorbus montana*             | 183-2002-C         | USDA, Ames, IA                            | Unknown          |
| *Sorbus reducta*             | 994-84-A           | Arnold Arboretum, Boston, MA              | England          |
| *Sorbaronia dippelii* 1      | 759–78             | Arnold Arboretum, Boston, MA              | Germany          |
| *Sorbaronia dippelii* 2      | None               | UC007 × *S. aria* 222-27-A               | Connecticut      |
| *Sorbaronia fallax*          | None               | University of Connecticut, Stors, CT      | Massachusetts    |
| *Sorbaronia fallax*          | ‘Ivan’s Beauty’    | University of Connecticut, Stors, CT      | Cultivation      |
| *Sorbaronia sorbifolia* BC1 | UC120              | UC007 × *S. sorbifolia* 1239-85-A         | Connecticut      |

*×Sorbaronia alpina* is a cross between *Sorbus aria* and *Aronia arbutifolia*.

*×Sorbaronia dippelii* is a cross between *Sorbus aria* and *Aronia melanocarpa*.

*×Sorbaronia fallax* is a cross between *Sorbus aucuparia* and *Aronia melanocarpa*.

*×Sorbaronia sorbifolia* is a cross between *Sorbus americana* and *Aronia melanocarpa*.

*×Sorbaronia sorbifolia* 1239-85-A is in the living collections of the Arnold Arboretum, Boston, MA. Accession was collected as a feral hybrid in Nova Scotia, Canada.
Amplified fragment length polymorphism procedure. The AFLP steps including restriction digestion, adaptor ligation, and preselective and selective amplification reactions were carried out as outlined in the AFLP plant mapping protocol (Anonymous, 2007). Restriction-ligation enzymes were purchased from New England Biolabs (Ipswich, MA). Adaptor sequences, AFLP preselective primers, and polymerase chain reaction (PCR) amplification core mix were purchased from Applied Biosystems (Foster City, CA). Preselective primers had one selective nucleotide (Eco RI-A + Mse I-C). Seven primer combinations were chosen for selective amplification (Eco RI-ACT + Mse I-CAC, Eco RI-ACT + Mse I-CTA, Eco RI-AGG + Mse I-CTC, Eco RI-AGG + Mse I-CTA, Eco RI-AGG + Mse I-CAT, Eco RI-AGG + Mse I-CAC). Fluorescently labeled Eco RI and unlabeled Mse I primers were purchased from Applied Biosystems. The DNA fragments from selective PCR were visualized by capillary electrophoresis on an ABI3730x1 analyzer (Applied Biosystems) using GeneScan™ 500 LIZ® size standard. To ensure reproducibility, DNA for all individuals was isolated in duplicate and final AFLP fragment products were compared.

Amplified fragment length polymorphism data analysis. Fragments between 60 and 500 bp long generated by each primer pair were scored using GeneMarker® Version 1.95 software (SoftGenetics, State College, PA). Peaks were first binary scored (1 for peak present and 0 for peak absent) using automatic settings followed by visual inspection and manual adjustment of each peak to ensure accurate scoring. Similarity matrices were constructed using the SIMQUAL function in NTSYSpc 2.21 software (Exeter Software, Setauket, NY) (Rohlf, 2005). Phenograms were constructed in NTSYSpc using an UPGMA cluster analysis. Bootstrapping was performed using PAUP*4.0 (Swofford, 2002) and Nei-Li genetic distances (Nei and Li, 1979) with 2000 replicates. Cophenetic correlation coefficients were calculated to test the goodness of fit using a two-way Mantel test in the MXCOMP module of NTSYSpc. The DCENTER and EIGEN functions were used to perform the original principal coordinates analysis, which served as inputs for the nMDS using MDSCALE (Kruskal, 1964a, 1964b). To test the goodness of fit between the original distances and fitted values, the Stress1 coefficient was used.

Results

Amplified fragment length polymorphism analysis. The seven primer combinations produced 769 useable markers, 761 of which were polymorphic. Aronia samples UC007 and PI578096 produced non-reproducible profiles for primer combinations Eco RI-ACT + Mse I-CTA and Eco RI-AGG + Mse I-CTC, respectively, and were treated as missing data (0.7% of the entire data set). Aronia mitschurinii cultivars Viking and Nero produced identical AFLP marker profiles. Of the 761 markers that were polymorphic across all included taxa, 36 were polymorphic between A. mitschurinii and the aggregate of wild North American Aronia accessions. Within that group of 36 markers, 32 were monomorphic with one or
more ×Sorbaronia species, the most of any genera tested. ×Sorbaronia ‘Ivan’s Beauty’ shared 29 markers with A. mitschurinii, ×S. fallax shared 28, and ×S. sorbifolia BC₁ shared nine. Among hybrids between Aronia sp. and S. aria (×S. alpina and ×S. dippelii), seven of the 36 markers were monomorphic with A. mitschurinii. Sorbus also shared a large number (24) of the 36 markers that were polymorphic between A. mitschurinii and wild Aronia accessions. Of the four Sorbus subgenera, Sorbus had 24 monomorphic bands with A. mitschurinii, Torniaria had eight, and Aria and Micromeles each shared six markers. S. aucuparia (subgenus Sorbus) shared 22 markers with A. mitschurinii and S. americana shared 21. Malus (12 markers), Amelanchier (nine markers), Photinia (nine markers), Pyrus (nine markers), Chaenomeles (six markers), and Cydonia (four markers) had relatively small numbers of monomorphic markers from the group of 36 A. mitschurinii markers that were polymorphic with wild Aronia accessions.

Genetic similarity matrix and cluster analysis. Cophenetic correlation values for Jaccard’s and Dice similarity coefficients were compared with Jaccard’s producing the highest value (0.93). Pairwise similarities ranged from 0.149 to 0.876 for non-identical taxa with a mean of 0.322. Pairwise cophenetic correlation coefficients observed for A. mitschurinii were highest among ×S. ‘Ivan’s Beauty’ (0.675), ×S. fallax (0.612), and ×S. sorbifolia BC₁ (0.608). Intergeneric hybrids involving S. aria, including ×S. alpina and ×S. dippelii, had lower cophenetic correlation coefficients with A. mitschurinii (0.471 and 0.502, respectively).

A. mitschurinii also had relatively high similarity values with S. aucuparia (0.459) and S. americana (0.411), which were significantly higher than for other Sorbus including S. aria (0.236), S. yuana (0.256), and S. torminalis (0.245). In comparing A. mitschurinii with other Aronia species, mean similarity values for A. melanocarpa (0.535) and A. prunifolia (0.537) were higher than for A. arbutifolia (0.461). Among Aronia accessions tested, A. melanocarpa UC010 was observed to have the highest coefficient at 0.597.

The phenogram (Fig. 1) resolved five groups with greater than 50% bootstrap support. Cydonia clustered with Chaenomeles forming an outgroup (#1). Amelanchier formed a group (#2), Photinia formed a group (#3), and Malus/Pyrus formed a group (#4). The fifth large cluster consisted of Sorbus, ×Sorbaronia, and Aronia, and was supported with 65% bootstrap support. Within this cluster, a branch consisting of ×S. fallax, ×S. ‘Ivan’s Beauty’, and A. mitschurinii was resolved between Sorbus and Aronia with a bootstrap support of 66%. Within the large Sorbus, ×Sorbaronia, and Aronia group, A. mitschurinii was more closely aligned with S. aucuparia and S. americana than the Asian Sorbus species, simple-leaved European Sorbus, or ×Sorbaronia species derived from these Sorbus.

Non-metric multidimensional scaling (nMDS) was applied to the group of Aronia, ×Sorbaronia, and Sorbus from Table 1. The nMDS ordination was run on up to five dimensions with the fifth (0.05) considered an excellent fit of the data based on Kruskal (1964a, 1964b). Additional simulations produced insignificant changes in stress values. Because more than two dimensions were chosen, a principal components analysis was performed on the nMDS ordination to line up trends of variation in the configuration space with the coordinate axes. The first three dimensions explained 85.2% of the observed variation; however, for ease of viewing, this analysis focused on two dimensions, explaining 71.5% of the observed variation.

In Figure 2, accessions of wild North American Aronia species formed a well-defined cluster (A) and the genus Sorbus formed two distinct groups. The European simple-leaved species S. aria and S. latifolia grouped with the East Asian simple-leaved species S. alnifolia, S. torminalis, and S. yuana to form a cluster (E). The North American compound-leaved S. americana grouped with the European compound-leaved species, S. aucuparia, to form the second Sorbus cluster (D). Two individuals of ×Sorbaronia dippelii (A. melanocarpa × S. aria) formed a cluster (F) with ×Sorbaronia alpina (A. arbutifolia × S. aria), which fell halfway between the Aronia cluster (A) and the simple-leaved Sorbus cluster (E) as would be expected given the parentage of the two ×Sorbaronia taxa. ×Sorbaronia fallax (A. melanocarpa × S. aucuparia) and ×Sorbaronia ‘Ivan’s Beauty’ (reported to be a triploid ×S. fallax plant) formed cluster (C), halfway between the compound-leaved Sorbus cluster (D) and the Aronia cluster (A), as would be expected based on parentage. Aronia mitschurinii ‘Viking’ and ‘Nero’ clustered together with

![Fig. 2. Principal components analysis (PCA) scatterplot derived from nonmetric multidimensional scaling (nMDS) of Jaccard’s similarity data. Displayed are dimensions one and two accounting for 51.4% and 20.1% of the variation, respectively. For visual clarity, taxa are limited to species of Aronia, ×Sorbaronia, and Sorbus. Aronia mitschurinii ‘Viking’ and ‘Nero’ overlap in the scatterplot.](image-url)
Discussion

We found AFLP to be very useful in resolving closely related members of the Pyrinae subtribe of the Rosaceae. Genera and species were clearly identified with high levels of certainty. In addition, subgenera of Sorbus were easily differentiated. AFLP also reliably identified and confirmed intergeneric hybrids between Sorbus and Aronia as well as backcrosses.

Our genetic analysis could not differentiate between the two common large-fruited commercial cultivars, Viking and Nero. Persson-Hovmalm et al. (2004) was also unable to distinguish between ‘Viking’ and ‘Nero’ using random amplified polymorphic DNA (RAPD) markers. Using both RAPDs and intersimple sequence repeats, Smolik et al. (2011) found that among European black chokeberry cultivars, only ‘Hugin’ differed significantly from several very similar cultivars, including ‘Viking’ and ‘Nero.’ It is likely that the majority, if not all, of the commonly grown, large-fruited black chokeberry cultivars are apomictic seedlings derived from an initial progenitor.

Results of this study demonstrate the use of the AFLP technique for identifying hybridity in closely related species. Generic × Sorbaronia were resolved, as expected, between Aronia and their respective Sorbus ancestors. The clustering of A. mitschurini with a known [Aronia × Sorbus] Aronia hybrid provides strong evidence that it has hybrid origins and is not a unique strain of wild North American Aronia. The study also identified 36 polymorphic bands that can be used to identify A. mitschurini, 24 of which are shared by one or more Sorbus species. Furthermore, a clear genetic progression is also identified in the nMDS scatterplot between Aronia, Sorbaronia and their respective Sorbus parents. Michurin (1948, 1949) does not mention crossing Aronia with S. americana or receiving any wild × Sorbaronia hybrids from North America. This historic documentation and the relative ease with which S. aucuparia hybridizes with Aronia leads us to believe that S. aucuparia is the source of Sorbus genetic material observed in A. mitschurini. Furthermore, we believe A. mitschurini is the product of × S. fallax backcrossed to a black-fruited Aronia species.

The belief that Michurin received a large-fruited form of A. melanocarpa that subsequently was rebranded as A. mitschurini is not supported by our data. The large-fruited accessions UC031 and P603106 produced lower conphenic correlation coefficients with A. mitschurini than did Aronia accessions with average-sized fruits. It does seem likely that the Aronia parent was either A. melanocarpa or a dark-fruited form of A. prunifolia as indicated by Michurin’s notes specifying a “black-fruited” Aronia (Skvortsov et al., 1983). Our data support this, showing higher pairwise similarities between A. mitschurini and dark-fruited A. melanocarpa and A. prunifolia than between A. arbutifolia. Although we present A. mitschurini as an intergeneric hybrid, we do not propose nomenclatural changes to express Sorbus genetics. The large-fruited forms of Aronia, such as ‘Viking’ and ‘Nero,’ are largely Aronia, with lesser amounts of a Sorbus genome included; therefore, we support Skvortsov and Maitulina’s (1982) treatment of these plants as Aronia A. K. Skvortsov & Maitul.

Understanding the intergeneric hybrid composition of commercial A. mitschurini as well as the genetic uniformity of all A. mitschurini cultivars is useful in developing strategies to breed improved forms of Aronia. Persson-Hovmalm et al. (2004) identified wild North American Aronia as one potential source of novel genetic material to expand A. mitschurini’s limited genetic base. Based on our study, intergeneric hybridization of A. mitschurini with Sorbus is another approach that will likely yield novel and improved Aronia for the nutraceutical fruit industry.

Literature Cited

Anonymous. 2007. AFLP plant mapping protocol. Applied Biosystems, Foster City, CA p. 16–26.
Brand, M.H. 2010. Aronia: Native shrubs with untapped potential. Arnoldia 67:14–25.
Campbell, C.S., R.C. Evans, D.R. Morgan, T.A. Dickinson, and M.P. Arsenault. 2007. Phylogeny of the subtribe Pyrinae (formerly the Maloideae, Rosaceae): Limited resolution of a complex evolutionary history. Plant Syst. Evol. 266:119–145.
Campbell, C.S. and W.A. Wright. 1996. Apomixis, hybridization, and taxonomic complexity in eastern North American Amelanchier (Rosaceae). Folia Geobot. Phytotaxon. 31:345–354.
Dickinson, T.A., A., and C.S. Campbell. 1991. Population structure and reproductive ecology in the Maloideae (Rosaceae). Syst. Bot. 16:350–362.
Dirr, M.A. 2009. Manual of woody landscape plants. 6th Ed. Stipes Pub., Champaign, IL.
Hardin, J.W. 1973. The enigmatic chokeberries (Aronia, Rosaceae). Torreya 100:175–184.
Holm, S. 1995. Unexpectedly high levels of genetic variation in Potentilla argentea L. (S. 1.) in southern Sweden. Hereditas 123:127–139.
Jones, C.J., K.J. Edwards, S. Castaglione, M.O. Winfield, F. Sala, C. Van de Wiel, G. Bredemeijer, B. Vossman, M. Matthes, A. Daly, R. Brestzchina, G. Bortini, L. Biazzetti, E. Malvechis, N. Marmolli, R. Aert, G. Volckaert, J. Rueda, R. Linacer, A. Vazquez, and A. Karp. 1997. Reproduceability testing of RAPD, AFLP and SSR markers in plants by a network of European laboratories. Mol. Breed. 3:381–390.
Kahlkonen, M.P., A.I. Hojpa, and M. Heinonen. 2001. Berry phenolics and their antioxidant activity. J. Agr. Food Chem. 49:4076-4082.
Kokotkiewicz, A., Z. Jaremicz, and M. Luczkiewicz. 2010. Aronia plants: A review of traditional use, biological activities, and perspectives for modern medicine. J. Med. Food 13:255–269.
Kruskal, J.B. 1964b. Multidimensional scaling: A numerical method. Psychometrika 29:28–42.
Krusmann, G. 1986. Cultivated broad-leaved trees and shrubs, 3 volumes. B. T. Batsford Ltd., London, UK.
McKay, S.A. 2001. Demand increasing for Aronia and elderberry in North America. New York Fruit Quarterly 9:2–3.
Michurin, I.V. 1948. Sochineniya [in Russian]. 4th Vol., 2nd Ed. OGIz, Moscow, Russia.
Michurin, I.V. 1949. Selected works. Foreign Languages Pub. House, Moscow, Russia.
Nei, M. and W. Li. 1979. Mathematical model for studying genetic variation in terms of restriction endonucleases. Proc. Natl. Acad. Sci. USA 76:5256–5273.
Nelson-Jones, E.B., D. Briggs, and A.G. Smith. 2002. The origin of intermediate species of the genus Sorbus. Theor. Appl. Genet. 105:953–963.
Persson-Hovmalm, H.A., N. Jeppsson, and L.V. Barthist. 2004. RAPD analysis of diploid and tetraploid populations of Aronia points to different reproductive strategies within the genus. Hereditas 141:301–312.
Phelps, J.B., K.R. Robertson, M. Rohrer, and P.G. Smith. 1991. Origins and evolution of subfam. Maloideae (Rosaceae). Syst. Bot. 16:303–332.
Potter, D., T. Eriksson, R.C. Evans, S. Oh, J.E.E. Smedmark, D.R. Morgan, M. Kerr, K.R. Robertson, M. Arsenault, T.A. Dickinson, and C.S. Campbell. 2007. Phylogeny and classification of Rosaceae. Plant Syst. Evol. 266:5–43.
Rehder, A. 1920. New species, varieties and combinations from the herbarium and collections of the Arnold Arboretum. J. Arnold Arbor. 2:42–62.
Robertson, A., T.C.G. Rich, A.M. Allen, L. Houston, C. Roberts, J.R. Bridle, S.A. Harris, and S.J. Hiscock. 2010. Hybridization and polyploidy as drivers of continuing evolution and speciation in Sorbus. Mol. Ecol. 19:1675–1690.
Rohlf, J.F. 2005. NT SYSSp. Applied Biostatistics, Port Jefferson, NY.
Skvortsov, A.K. and Y.K. Maitulina. 1982. On distinctions of cultivated black-fruited Aronia from its wild ancestors [in Russian]. Bull. GBS AN SSSR 126:35–40.
Skvortsov, A.K., Y.K. Maitulina, and Y.N. Gorbanov. 1983. Cultivated black-fruited Aronia: Place, time and probable mechanism of formation [in Russian]. Bull. MOIP. Otd. Biol. 88:85–96.
Smolik, M., I. Ochimian, and B. Smolik. 2011. RAPD and ISSR methods used for fingerprinting selected, closely related cultivars of Aronia melanocarpa. Not. Bot. Horti. Agrobo. 39:276–284.
Swofford, D.L. 2002. PAUP*: Phylogenetic analysis using parsimony (*and other methods). Version 4. Sinauer Associates, Sunderland, MA.
Vos, P.R., R. Rogers, M. Bleeker, M. Reijans, T. van de Lee, M. Hornes, A. Fijters, J. Pot, M. Kuiper, and M. Zabeau. 1995. AFLP: A new technique for DNA fingerprinting. Nucleic Acids Res. 23:4407–4414.
Wu, X., L.G. Xu, R.L. Prior, and S. McKay. 2004. Characterization of anthocyanins and proanthocyanidins in some cultivars of Ribes, Aro- nia, and Sambucus and their antioxidant capacity. J. Agr. Food Chem. 52:7846–7856.
Zheng, W. and S.Y. Wang. 2003. Oxygen radical absorbing capacity of cranberries, chokeberries, and lingonberries. J. Agr. Food Chem. 51:502–509.