Asian Germplasm Influences on American Berry Crops

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Abstract. Asian germplasm has significantly contributed to berry crops in America in several ways. The American wild octoploid species [*Fragaria chiloensis* (L.) Mill. and *F. virginiana* Mill.], and subsequently, the cultivated strawberry (*F. ×ananassa* Duch. ex Rozier), have benefitted from Asian heritage in the evolutionary time scale. Second, breeders have combined Asian germplasm in crosses for improved fruit cultivars. Third, Asian temperate fruit species have been collected from wild stands in their native ranges, imported, and in some cases improved and are now cultivated in the West or throughout the world. The objectives of this article were to 1) describe evolutionary contributions of Asian species to the American strawberry genome; 2) present examples of breeding Asian species (*Rubus* L. subgenus *Idaeobatus*) into cultivated raspberries; and 3) give examples of two Asian fruit species that have been recently introduced and cultivated or that could be developed for cultivation in the United States.

Berries are widely appreciated by the Western palate and have provided highly nutritive components to the human diet for millennia (Hummer and Janick, 2007). Strawberries are a noted American crop, yet they are not without influence from Asian genes. European and American raspberry (*Rubus* L. subgenus *Idaeobatus*) cultivars have benefited greatly from Asian heritage by plant improvement through breeding. In addition, Asian berry species harvested by native peoples from wild stands have potential for cultivation in America. This article summarizes examples of Asian influence in American berry crops.

In the strawberry genus, *Fragaria* L., different ploidy levels are endemic in separate regions or continents (Staudt, 2009). Diploid ($2n = 2x = 14$) species are distributed in the northern hemisphere; tetraploids are found in Asia; hexaploids in Europe; and octoploids in the Americas (Staudt, 1999, 2009). The two known decaploid species

have limited distributions: *F. cascadiensis* Hummer in the Cascade Mountains, OR (Hummer et al., 2012), and *F. iturupensis* Staudt on Atsunupuri Volcano, Iturup Island, Russian Federation (Hummer et al., 2009). The principal strawberry of commerce is *Fragaria ×ananassa*. This species is octoploid and originated as an accidental cross between the white-fruited South American *F. chiloensis* subsp. *chiloensis* f. *chiloensis* and the North American *F. virginiana* subsp. *virginiana* (Hummer et al., 2011; Staudt, 1999).

Scientists have speculated about the evolutionary origins of the American octoploids (Davis et al., 2009). Octoploid taxa have complex genomes, diverse morphologies, and variable, closely related subspecies and forma. Multiple hypotheses concerning the derivation of the octoploids have been proposed, involving allopolyploidy and autopolyploidy (Darrow, 1966; Fedorova, 1946; Folta and Davis, 2006; Senanayake and Bringham 1967). Molecular genomic analyses have provided new insight of relevance to this question.

FRAGARIA GENOMICS

The polyploid *Fragaria* species were derived from diploid ancestors (Staudt, 1999). Species of intermediate ploidy likely played a role in the ascendancy to plants with higher ploidy. Judging from known strawberry species, and the distribution of morphological characteristics, Middle or East Asia was a center of diversity from which diploid and polyploid species spread to the Americas (Staudt, 1999). The present-day Asian tetraploid and European hexaploid species have been discounted as polyploid intermediates in the octoploid ancestry (Staudt, 1999, 2009; Njuguna et al., 2013). However, molecular evidence links the genomes of *F. vesca* L. and the Asian diploids *F. mandshurica* Staudt

and *F. iinumae* Makino with those of the octoploids.

POTENTIAL FRAGARIA DIPLOID ANCESTORS

Staudt (2009) delineates the identities and distributions of 12 diploid species. The most widely distributed diploid is *F. vesca* subsp. *vesca*, which is endemic throughout Europe to Lake Baikal, Russia (Hummer et al., 2011; Staudt, 2009). Red and white-fruited horticultural forms of *F. vesca* subsp. *vesca* were introduced into Asia, the South Pacific Islands, and South America (Hummer et al., 2011), but are not endemic there. This species has disjunct subspecies native in North America. *Fragaria vesca* subsp. *americana* (Porter) Staudt is native in eastern, and *F. vesca* subsp. *bracteata* (A. Heller) Staudt is native in western North America (Staudt, 1999).

Staudt (1999, 2009) lists nine Asian diploid strawberry species. However, judging from morphology, only a few have characters aligned with the American octoploids. Staudt (1999) suggested that *F. iinumae*, a Japanese diploid, might be a genome donor to the octoploids judging by its marked morphological similarity to *F. virginiana* subsp. *glauca*. Staudt (1999) also suggested a possible ancestral role for *F. daltoniana* J. Gay, a diploid from the Himalayan region, based on its morphological similarity to *F. chiloensis* (L.) Mill.

CYTOGENETIC AND MOLECULAR PHYLOGENETIC STUDIES

Authors of three classical cytogenetic studies (Bringham 1990; Fedorova, 1946; Senanayake and Bringham 1967) have implicated *F. vesca* as a likely diploid ancestor to the octoploids. Other molecular phylogenetic studies support this (DiMeglio and Davis, 2004; Folta and Davis, 2006; Rousseau-Gueutin

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et al., 2009), but have also drawn attention to two Asian diploids, *F. mandshurica* and *F. iinumae*. In the two foregoing studies, which used sequences from nuclear, protein-encoding genes, the alleles of *F. mandshurica* clustered with those of *F. vesca* and with a subset from each studied octoploid. Those from *F. iinumae* clustered closely with a second subset of octoploid-derived alleles. No support was found for an ancestral role for *F. daltoniana*.

The octoploid nuclear genomes harbor at least two distinct components: those with affinity to *F. vesca* and *F. mandshurica*, and those similar to *F. iinumae*. Fedorova's (1946) classical octoploid genome composition model is AAAABBCC, with A, B, and C representing distinct subgenome lineages derived from separate diploid ancestors. If this model is correct, a third distinct component of the octoploid nuclear genome, in addition to those contributed by *F. iinumae* and *F. vesca*/*F. mandshurica*, is yet undiscovered. Asia might harbor this hypothetical ancestral diploid, if extant.

Molecular data from the *Fragaria* chloroplast (cpDNA) and mitochondrial (mtDNA) genomes tell complementary, if somewhat contrasting, stories. Phylogenetic analysis of chloroplast genome sequences of 21 *Fragaria* species and subspecies suggest that the octoploid cpDNA may have come from western North American populations of diploid *F. vesca* subsp. *bracteata* (Njuguna, 2010). This study provided broad representation of *F. vesca* germplasm but only one representative of *F. mandshurica*. Additional samples of *F. mandshurica* germplasm are needed before its ancestral role can be adequately assessed. Notably, gene introgression from Asian *F. mandshurica* to western North American *F. vesca* subsp. *bracteata* may have

occurred (Davis and Staudt, personal communication), explaining why *F. mandshurica* and *F. vesca* have not been resolvable through phylogenetic analysis of protein-encoding, nuclear sequence data.

In a comparative study of *Fragaria* mtDNA sequence data, Mahoney et al. (2010) reported that an 8-bp deletion was uniquely shared by *F. iinumae* and octoploid species and was absent in the other taxa examined, including *F. vesca* and *F. mandshurica*. The latter finding was surprising given that only maternal inheritance has been reported for the *Fragaria* chloroplast (Davis et al., 2010) and mitochondrial (Mahoney et al., 2010) genomes. Presumably both organelle genomes would have been transmitted along the same maternal lines from diploids to the octoploids, but existing evidence disagrees.

In summary, molecular phylogenetic analyses of several nuclear protein coding genes and mtDNA implicate *F. iinumae* (or an ancestral form) as a nuclear and mitochondrial genome contributor. The potential role of *F. mandshurica* is suggested but is obscured by the current lack of adequate within-species diversity data and the absence of nuclear, phylogenetic resolution between it and *F. vesca*. *Fragaria mandshurica* may have been a direct genomic contributor to the octoploids or indirect through gene introgression into *F. vesca* subsp. *bracteata*, which then played a direct ancestral role. Another Asian ancestor is possible but is either historical or has not yet been discovered.

ASIAN CONTRIBUTIONS IN RASPBERRY BREEDING

Rubus L. is a diverse genus with species divided into 15 subgenera (GRIN, Germplasm

Resources Information Network, 2013). The two subgenera containing the largest number of economically important species are *Idaeobatus* (raspberries) and *Rubus* (blackberries). *Idaeobatus* includes ≈200 species, which are principally Asian in distribution but also occur in Europe, North America, and east and South Africa (Jennings, 1988). The most economically important subgenus *Idaeobatus* species are *Rubus idaeus* L. (European red raspberry), *R. strigosus* Michx. (North American red raspberry), and *R. occidentalis* L. (eastern North American black raspberry).

Since early in the 20th century, a wide range of Asian subgenus *Idaeobatus* species have been evaluated and used by breeders for developing red raspberry cultivars (Ballington and Fernandez, 2008; Finn et al., 2008; Jennings, 1988; Jennings et al., 1991; Williams, 1950). Some of the Asian raspberry species with useful characteristics for red raspberry improvement are summarized in Table 1. Of these species, *R. parvifolius* and *R. innominatus* var. *kuntzeanus* were incorporated through hybridization into named cultivars in North America (Dale et al., 1993). North American red raspberry cultivars with known Asian heritage are summarized in Table 2.

Asian species have been used in red raspberry improvement (Table 2) to develop tolerance to the warm temperatures and high humidity that prevail at lower latitudes in summer and fluctuating temperatures in winter (Williams, 1950). In this regard, *R. parvifolius* has been useful in interspecific hybridization with red raspberry (Ballington and Fernandez, 2008). This species produces F₁- and backcross-generation seedlings with the high fertility. Fruit of *R. parvifolius* have an unpleasant aftertaste that can be eliminated

Table 1. Characteristics of Asian raspberry (*Rubus*) species useful in red raspberry improvement.

Species	Desirable characteristics
<i>R. biflorus</i> Buch.-Ham ex Sm.	Productivity; vigor; heat tolerance
<i>R. cockburnianus</i> Hemsl.	Increased number of flowers per inflorescence
<i>R. coreanus</i> Miq.	Productivity; vigor; branched canes; tip rooting/stem cutting propagation; good quality; black or yellow fruit; American raspberry aphid (<i>Amphorophora agathonica</i> Hottes) resistance; European raspberry beetle (<i>Byturus tomentosus</i> Degeer) resistance; powdery mildew (caused by <i>Podosphaera aphanis</i> (Wallr.) U. Braun & S. Takam.) resistance; cane anthracnose [caused by <i>Elsinoe veneta</i> (Burkh.) A. E. Jenk] resistance; cane blight and spur blight [caused by <i>Didymella applanata</i> (Niessl.) Sacc.] resistance; midge blight (<i>Resseliella theobaldi</i> Barnes) resistance; cane botrytis (caused by <i>Botrytis cinerea</i>) resistance; leaf and cane spot (caused by <i>Elsinoe veneta</i>) resistance
<i>R. crataegifolius</i> Bunge.	Erect plant habit; bright red fruit; good quality; early and condensed ripening; heat tolerance; mech. harvesting adaptation; European raspberry beetle resistance; raspberry midge resistance; root lesion nematode resistance; cane botrytis resistance; midge blight resistance; spur blight resistance; fruit grey mold resistance
<i>R. ellipticus</i> Sm.	Yellow-fruited; evergreen
<i>R. innominatus</i> var. <i>kuntzeanus</i> (Hemsl.) L. H. Bailey	Vigor; productivity; high fruit number per lateral; erect plant habit; late ripening; tip rooting/stem cutting propagation; high temperature and high humidity tolerance; tolerance to fluctuating winter temperature
<i>R. mesogaeus</i> Focke	Cane blight resistance; dark fruit
<i>R. niveus</i> Thunb. (syn. <i>R. lasiocarpus</i> Sm.; <i>R. albescent</i> Roxb.)	Good fruit quality; excellent fruit firmness; primocane fruiting; mechanical harvesting adaptation; tip rooting/stem cutting propagation; high temperature and high humidity tolerance; low chilling; fruit rot resistance; low chilling; heat-tolerant; black-fruited; spur blight and cane botrytis resistance
<i>R. parvifolius</i> Nutt.	Vigor; productivity; primocane fruiting; tip rooting/stem cutting propagation; high temperature and high humidity tolerance; leaf and cane spot resistance; relatively fertile to fertile F ₁ s with red raspberry
<i>R. phoenicolasius</i> Max.	Good fruit quality; red or yellow fruit; tip rooting/stem cutting propagation; tolerance to fluctuating winter temperatures; powdery mildew resistance; European raspberry beetle resistance
<i>R. pileatus</i> Focke	Powdery mildew resistance
<i>R. pungens</i> Cambess	Fall fruiting, cold-hardiness
<i>R. rosifolius</i> Sm	Vigorous; productive; fruit red or yellow ripening, weakly flavored; ornamental flowers
<i>R. sumatranus</i> Miq.	Root rot resistance

Table 2. North American red raspberry cultivars derived from Asian raspberry (*Rubus*) species.

Cultivar	Yr	Parentage	Origin
Van Fleet	1924	<i>R. innominatus</i> var. <i>kuntzeanus</i> × ‘Cuthbert’	USDA/California
Dixie	1928	<i>R. biflorus</i> × ‘Latham’	North Carolina State University/USDA
Tennessee Luscious	1944	‘Lloyd George’ × (‘Van Fleet’ × ‘Viking’)	University of Tennessee
Tennessee Prolific	1948	‘Lloyd George’ × (‘Van Fleet’ × ‘Viking’)	University of Tennessee
Mandarin	1955	(<i>R. parvifolius</i> × ‘Taylor’) × ‘Newburgh’	North Carolina State University/USDA
Citadel	1966	‘Mandarin’ × (‘Sunrise’ × OSC 420)	University of Maryland
Fallgold	1967	NH-R7 × (‘Taylor’ × <i>R. pungens oldhamii</i>)	University of New Hampshire
Southland	1968	Complex cross (NC 237 × MD 5420-5)	North Carolina State University/Southern Illinois–USDA
Dormanred	1972	<i>R. parvifolius</i> × ‘Dorsett’ (‘Van Fleet’ × <i>R. parvifolius</i>)	Mississippi State University
Prestige	1979	S ₂ (‘Taylor’ × <i>R. pungens oldhamii</i>)	University of New Hampshire
Nova	1981	‘Southland’ × ‘Boyne’	Nova Scotia, Canada
Malahat	1987	Meeker × BC/SCRI 7853/116 (including <i>R. phoenicolasius</i>)	British Columbia, Canada
Kitsilano	1998	Complex pedigree with <i>R. crataegifolius</i>	British Columbia, Canada
Esta	2003	SCRI 8616B6 × ‘Southland’	University of Maryland

with the first backcross to red raspberry. The most successful cultivars have been Southland and Nova (Finn et al., 2008; Jennings, 1988). ‘Nova’ released from Nova Scotia has been successful in California. It is adapted as far south as the Carolina Piedmont Region. ‘Dormanred’, which is largely of *R. parvifolius* parentage, has also been planted for local markets in the southeastern United States. ‘Esta’, a newer release, is a vigorous, early-fruited, summer-bearing red raspberry resistant to rust and diseases. ‘Esta’ may become widely planted in the warmer regions of the United States. Although much of the work with *R. parvifolius* has occurred in the southeastern United States (Widrechner and Rabaler, 1991), the species has not escaped from cultivation there. However, it has escaped in five Midwestern and Western states (Drobney and Widrechner, 2011).

Rubus innominatus is well adapted to warm humid regions with fluctuating winter temperatures (Ballington and Fernandez, 2008). The fruit has a similar unpleasant aftertaste to that of *R. parvifolius*, but the unpleasant flavor is often not present in F₁ crosses with red raspberry. This species has promise as a donor for improving productivity and tolerance to heat, high humidity, and fluctuating winter temperatures.

Five cultivars of *Rubus coreanus* have been released in Korea (Kim et al., 2008). This species shows promise for developing improved black raspberry and red raspberry cultivars (Finn et al., 2008) (also see Table 2). Unexpectedly, the pedigree of Korean ‘Bokbunja’ black raspberry was found to be aligned with *R. occidentalis* rather than *R. coreanus* (Eu et al., 2008, 2010).

Rubus crataegifolius Bunge contributed to the development of ‘Kitsilano’ by Agriculture and Agri-Food Canada and has been used by breeders in Europe for early ripening and resistance to botrytis fruit rot (Daubeny, 2006; Jennings, 1988). In the southeastern United States, it is tolerant to high temperatures and humidity but not to fluctuating winter temperatures. ‘Jinju Jengal’ and ‘Jinju Whangal’ from Korea and ‘Agenuck’ from Russia are pure *R. crataegifolius* cultivars (Jennings, 1988).

Rubus niveus germplasm from Guizhou Province in China has been promising

(Ballington and Fernandez, 2008; Thompson, 1992). Although F₁ hybrids with red raspberry are low in fertility, full fertility is often restored in the first backcross to red raspberry. Fruit size of this black raspberry species is often equal to older cultivars of American black raspberry (*R. occidentalis*). The fruit quality is good and fruit firmness is superior. This species is not winter-hardy or tolerant to fluctuating winter temperatures; however, it has a tendency for primocane fruiting. Accessions of the species often appear worthy of direct release; however, the spines on the canes are numerous and large. Birds are fond of the fruit, so it also has of the potential to become another invasive exotic plant.

The Japanese *R. phoenicolasius* has naturalized throughout much of the Appalachian highlands in eastern North America. It is well adapted to a southern climate. F₁ hybrids with red raspberry are quite low in fertility, although, with effort, East Malling Research developed a selection that Agriculture and Agri-Food Canada used to develop the commercially important ‘Malahat’ (Daubeny, 2006). In addition to introgression into *R. idaeus* germplasm, the fruit quality may be worthy of selection. Native residents of the southern Appalachians who live at the low to mid-elevations typically harvest fruit from *R. phoenicolasius* to make jam.

Further reviews (Finn and Hancock, 2008; Finn et al., 2002; Hall et al., 2009; Jennings et al., 1991; Knight, 1993) go into greater detail of Asian *Rubus* species used in raspberry breeding.

ASIAN BERRY CROPS WITH POTENTIAL FOR AMERICAN CULTIVATION

Although eating fresh-harvested sweet berry crops has not been a long-standing activity in Asian culture, native Asian berry species have been revered, mostly for their stems, leaves, and roots, as components of Chinese traditional medicines (Hsu et al., 1986; Hummer and Janick, 2007; Janick and Hummer, 2012). Fruit consumption for health benefits per se is becoming more widely recognized in Asia as well as globally. Some Asian species have been adopted for cultivation on other continents and in other

cultures. This brief article profiles two Asian berry crops with potential for expanded commercial cultivation in North America. Short descriptions of the Chinese gooseberry, also called hardy kiwifruit [*Actinidia arguta* (Siebold & Zucc.) Planch. Ex Miq.], and the blue honeysuckle, also called honeyberry or haskap (*Lonicera caerulea* L.), are provided.

CHINESE GOOSEBERRY (*ACTINIDIA* LINDL.) FAMILY SECTION

Actinidia, commonly called the Chinese gooseberry or kiwifruit, belongs to the family *Actinidiaceae* (Ferguson et al., 1996). Classical Chinese texts describe how *Actinidia chinensis* Planch, also known as “monkey peach,” was collected in the mountains and brought down by the peasants to be sold in the markets. Historically, fruit were not cultivated but were collected from the wild in China and Japan. Commercial cultivation of *Actinidia* began ≈1930 (Ferguson et al., 1996). New Zealanders devised the common name “kiwifruit” in the 1950s to more easily market this crop. This name has now been accepted in international commerce (Ferguson et al., 1996).

Actinidia species were first introduced to America during the late 1800s by E. H. Wilson, a plant explorer who worked for the U.S. Department of Plant Industry, forerunner of the Department of Agriculture (Fairchild, 1938). His collected *Actinidia* came primarily from Yichang, a town on the Yangtze River. These introductions gave rise to many commercial orchards of the large-fruited species, *Actinidia deliciosa* (A. Chev.) C. F. Liang et A. R. Ferguson. The area of cultivation of this fruit continues to expand annually. In 2012, the Massachusetts Audubon Society published an invasive plant alert for hardy kiwifruit; however, to date, neither state nor U.S. federal regulations restrict *Actinidia* because of invasiveness or noxious weed character.

In 2011, the total world production covered greater than 92,000 ha, which produced greater than 1,438,000 t (FAO, 2013). The main producing countries were Italy, New Zealand, Chile, Greece, France, the United States (California), Japan, Turkey, Australia, and Spain. Acreage is increasing. In 2013, ≈1200 ha of kiwifruit were planted in

southern California (I. Warrington, 2013, personal communication).

The smaller Chinese gooseberry, or kiwifruit, is classified in section *Leiocarpae* family Actinidiaceae. This section includes *Actinidia arguta*, *A. kolomikta*, and *A. polygama* (Siebold & Zucc.) Maxim. These small-fruited species are vining, cold-hardy, polygamodioecious (sometimes having unisexual and bisexual flowers, but tending to be dioecious) plants native to China, Russia, and Japan (Ferguson et al., 1996). Hardy kiwifruit (*A. arguta*) may also be known or marketed under alternate names including “baby kiwifruit,” “grape kiwi,” “wee-kee,” and “cocktail kiwi” or “kiwiberri.”

‘Ananasnaya’ is the most widely grown cultivar of hardy kiwifruit in the world. In 2002, ≈42 ha, equivalent to 100 acres, of commercial ‘Ananasnaya’ were planted in Oregon (Tiyayon and Strik, 2003). Williams et al. (2003) estimated that ≈100 ha of ‘Ananasnaya’ were grown commercially worldwide, in the United States (Oregon, Pennsylvania, New York, and Washington), New Zealand, Canada (British Columbia and Ontario), Chile, Italy, France, Germany, and The Netherlands.

There is interest in this fruit crop as a nutraceutical product. Fruit have 40 to 155 mg/100 g vitamin C, depending on cultivar (Ferguson and Ferguson, 2003; Kabaluk et al., 1997) and are known for their laxative activity, but the active components have not been identified (Ferguson and Ferguson, 2003). Some hardy kiwifruit contain actinidin, a protease that can cause an allergic reaction in 2% to 3% of the population (Ferguson and Ferguson, 2003). Also, fruit can be high in calcium oxalate. In fresh fruit, although these crystals are covered with a gelatinous material and thus are usually not noticeable, they may be evident in some processed products and can be an irritant (Ferguson and Ferguson, 2003).

BLUE HONEYSUCKLE (*LONICERA CAERULEA* L.)

Blue honeysuckle, *Lonicera caerulea* L., family Caprifoliaceae, section *Isika* Rehd., subsection *Caeruleae* Rehd., is a circumpolar boreal species with several forms, species, and subspecies. The plants are deciduous shrubs, to 2 m or more in height, and are not the vine-forming *Lonicera* species that can be invasive. Compared with ornamental *Lonicera* species, flowers are inconspicuous, ≈2 cm long, tubular with flared lobes, and pale yellow to cream-colored. They are essentially self-incompatible and require bees for cross-pollination. Because blooming occurs early in spring, bumble bees are the principal pollinators. Also, blue orchard bees (*Osmia* sp. Panzer) are used for pollination in Japanese plantings. Fruits are dark blue to purple with varying amounts of a white waxy covering. Shapes are variable ranging from oval to long and thin. The berry weight ranges from 0.3 g to rarely over 2.0 g. Flavors are unique and vary considerably from a pleasant mild taste, more sprightly tart-sweet, mildly tart, very

tart, to slightly or very bitter. There is a maximum of 20, but usually fewer, very small seeds in a fruit.

Blue honeysuckle fruit have been harvested from wild plants by Ainu people in the Russian Far East and in Hokkaido, Japan, for hundreds of years. Folklore in both regions has attributed high nutritional and medicinal values to these berries and such findings were documented by phytochemical analyses (Chaovanalikit et al., 2004; Plekhanova et al., 1993; Tanaka and Tanaka, 1998).

Minor efforts to develop this crop in Russia date back to 1913–15, but it was not until the 1950–60s that a serious research program was initiated (Plekhanova, 2000) to cultivate and domesticate this crop. Extensive germplasm explorations were conducted by the Vavilov Institute for Plant Industry in St. Petersburg, and plants were distributed to the Lisavenko Research Institute for Horticulture in Siberia at Barnaul and several other research stations in the former Union of Soviet Socialist Republic for evaluations. From these studies, over 200 cultivars have been named and distributed to farmers and gardeners.

Efforts to domesticate *L. caerulea* from Japan increased in the late-1900s (Hummer et al., 2012). Beginning in the late 1960s and 1970s, the Hokkaido Prefectural Agriculture Experiment Station and a Farmers Co-operative in Chitose began to make selections from the nearby wild populations in the Yufutsu Plains near Tomakomai city. This region was famous for the abundance of fruiting shrubs from which people had long collected wild berries. Selections were evaluated for several years and the best few distributed to farmers, including one named cultivar, ‘Yufutsu’ (Tanaka and Tanaka, 1998). Small-scale commercial production began in the 1970s and increased to 195 ha by 1991. During this initial enthusiasm for “haskap” (the Ainu word used by the Japanese for this berry), a large array of high-quality, high-priced processed products were developed and have become popular as gift items. However, as a result of the high cost of labor and the lack of mechanical harvesting, by 2005, the area under production had decreased to 85 ha with an estimated 200 t of berries, an insufficient amount to satisfy the demand that had been created (Lefol, 2007).

CONCLUSION

This report has summarized three ways Asian genes have influenced American berry crops. First, through evolutionary time, alleles or perhaps whole genomes from Asian diploid ancestors contributed to the complex genomes of the wild octoploids of North America and subsequently to the cultivated *F. ×ananassa*. These determinations are supported by phylogenetic analysis of three nuclear, protein-coding genes as well as mitochondrial and chloroplast genomic sequences. The issue of octoploid strawberry subgenomic composition and ancestral derivation needs further resolution.

Second, the gene pool of raspberry species accessible to small fruit breeders has been expanded greatly through the availability and use of Asian species in *Rubus* subgenus *Idaeobatus*. These Asian parental species have contributed genes for low chilling, heat and drought tolerance, and disease and pest resistance in cultivated red raspberries. More than a dozen red raspberry cultivars with Asian species heritage have been released for Western cultivation during the past century.

Third, Asian berry species have been brought to America and are now being cultivated to increase diversity for small and soft fruit production for small farmers. Other Asian crops are harvested in Asia and sold to North America for diverse nutraceutical or health supplemental foods, some of which provide Asian markets in North America with heritage flavors for recent immigrants. This kind of activity links Asia and North America through cultivation and berries and soft fruit production. From an evolutionary standpoint, and from the effect of human PIs, Asian germplasm has significantly influenced American strawberries, raspberries, and other small fruit crops.

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