FEATURE

Collection of Native Strawberry Germplasm in the Pacific Northwest and Northern Rocky Mountains of the United States

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The cultivated strawberry *(Fragaria* x *ananassa* Duch.) is an interspecific hybrid complex derived from two octoploid (2n = 56) species: *F. chiloensis* (L.) Duch., native to the Pacific coasts of North and South America, the southern Andes Mountains, and Hawaii; and *F. virginiana* Duch., found in North America from Alaska through the Sierra Nevada and Rocky Mountain ranges and throughout the eastern part of the continent (Darrow, 1966; Hancock et al,, 1990; Scott and Lawrence, 1975; Staudt, 1962). Outside of the western hemisphere and Hawaii, octoploid strawberries have been reported only on islands of the western Pacific Ocean. *Frugaria iturupensis* Staudt was described from the Kuril Islands, U.S.S.R. (Staudt, 1973), and an unassigned octoploid plant was collected from Rebun Island, Hokkaido Prefecture, Japan (Oda and Nisitani, 1989).

The evolution of strawberry at the octoploid level thus occurred largely in North America, making this continent an important source of wild germplasm. However, relatively few genotypes of *F. virginiana* have been used in developing the crop. The narrow germplasm base of North American strawberry production has recently been documented. Only 53 founding clones (Sjulin and Dale, 1987) representing 17 cytoplasm sources (Dale and Sjulin, 1990) are represented in the 134 North American cultivars introduced during the last 30 years. Furthermore, the 20 cultivars that account for most of the North American strawberry crop can be traced to 38 founding clones, of which just seven account for ≈ 50% of the genetic contribution (Galletta and Maas, 1990; Luby et al., 1991).

We collected *Fragaria* spp. in 1985 from 20 inland sites in the Pacific Northwest and, in 1989, from 53 sites in the northern Rocky Mountains (Fig. 1). The collection was made to obtain representatives of native *Fragaria* for maintenance at the U.S. Dept. of Agriculture (USDA) National Clonal Germplasm Repository (Corvallis, Ore.) and for distribution to-strawberry breeders and other researchers. Certain accessions may provide new sources of resistance to environmental and biotic stresses and improved fruit quality and productivity. Use of this material in breeding programs would broaden the strawberry germplasm base, reducing genetic vulnerability (Luby et al., 1991). The collections also provided material for specific ongoing research in *Frugaria* systematics, yield efficiency and C exchange capacity, cold hardiness, disease resistance, and fruit quality.

The germplasm collected on these expeditions was deposited at the National Clonal Germplasm Repository in Corvallis, and limited quantities of accessions are available to researchers on request '(Curator, USDA National Clonal Germplasm Repository, Corvallis, OR 97333). An import permit may be necessary for foreign deliveries. USDA phytosanitary certificates are available upon receipt of the import permit.

NATIVE STRAWBERRY GERMPLASM IN MONTANE WESTERN NORTH AMERICA

The wild octoploid strawberries of montane western North America were referred to as two subspecies in the most recent taxonomic revision by Staudt (1962), *F. virginiana* ssp. *glauca* (Wats.) Staudt and ssp. *platypetala* (Rydb.) Staudt. Only six genotypes of western *F. virginiana* (identified as *F. virginiana glauca)* are represented among the 53 founding clones traced by Sjulin and

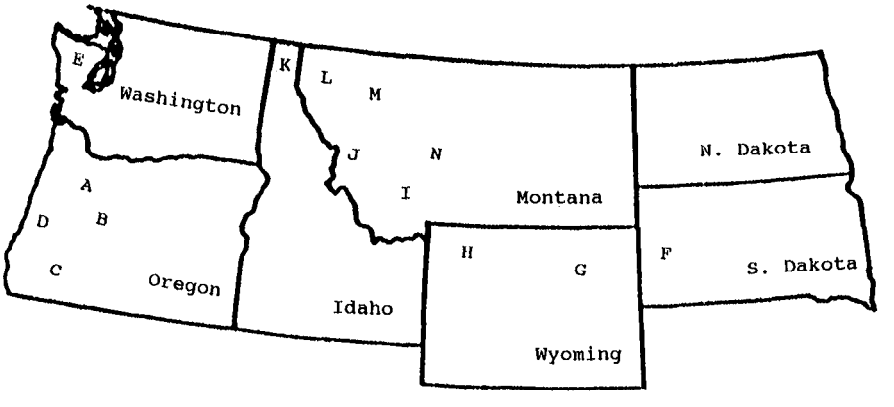

Fig. 1. Map of the western United States showing target regions for *Fragaria* germplasm collections in 1985 and 1989: A, Cascade Mountains (west slope); B, Cascade Mountains (east slope); C, Siskiyou Mountains; D, Coast Range; E, Olympic Mountains; F, Black Hills; G, Bighorn Mountains; H, Absoroka Range and Yellowstone Plateau; I, Madison, Tobacco Root, and Pioneer Mountains; J, Bitteroot Range; K, Cabinet and Selkirk Ranges; L, Flathead and Whitefish Ranges; M, Lewis Range; N, Big Belt, Little Belt, and Crazy Mountains.

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Dale (1987). However, the utility of *F. virginiana* ssp. *glauca* for improvement of several important traits in the cultivated strawberry has been well documented. Hildreth and Powers (1941) and Powers (1944, 1945, 1954) observed that genotypes from the Rocky Mountains contributed considerable winter hardiness, tolerance of blossoms to frost, early maturity, and good fruit quality. Darrow (1966) indicated that it was also a potential source of drought tolerance and resistance to powdery mildew [*Sphaerotheca macularis* (Tul.) Lindau], red-stele root rot *(Phytophthora fragariae* Hickman), and root knot nematode *(Maloidogyne hapla* Chitwood). Newton and Van Adrichem (1958) found that some genotypes were resistant to verticillium wilt *(Verticillium albo-atrum* Reinke and Berth). The important everbearing and day-neutral flowering characteristics were also derived from this species (Ahmadi et al., 1990; Bringhurst and Voth, 1984; Ourecky and Slate, 1968; Powers, 1954; Scott, 1959).

Hildreth and Powers (1941) collected and evaluated some 42,000 genotypes of *F. virginiana* ssp. glauca from 1100 sites in the Rocky Mountains in the 1930s and 1940s. While some of this germplasm was used in further breeding to produce cultivars (Darrow, 1966; Scott and Lawrence, 1975) still grown on a limited basis, this massive collection was lost with the closing of the USDA small fruit research program at Cheyenne, Wyo. More recently, *F. virginiana* ssp. *glauca* germplasm from two sites in the Sierra Nevada in California was collected and evaluated by Hancock and Bringhurst (1979, 1988).

Fragaria vesca L., a diploid, is the only native North American strawberry in addition to the octoploids (Darrow, 1966; Scott and Lawrence, 1975; Staudt, 1962). It is also widespread in Europe and Asia. All other diploid, tetraploid, and hexaploid species occur only in Asia and Europe (Darrow, 1966).

Little is known about the potential germplasm value of Pacific Northwest or Rocky Mountain populations of *F. vesca,* but data from other montane populations suggest they may possess useful genetic variability. Collections from high elevations in California had cold tolerance and earliness, and produced a high flowers : runners ratio (Hancock, 1977; Hancock and Bringhurst, 1978). This germplasm also was frost resistant and had reduced susceptibility to root rot. One population from Hecker Pass, Calif., had an unusually high reproductive effort in terms of flowers per plant and mean fruit weight (Hancock and Bringhurst, 1988). Genes for these traits could be transferred to octoploids through synthetic polyploids (Bringhurst and Voth, 1984).

COLLECTION EXPEDITIONS

A primary objective of the expeditions was to collect seeds, clones, and herbarium specimens of *F. virginiana* and *F. vesca.* Material of other local native fruit species (Rubus, *Vaccinium, Ribes, Vitis, Prunus, Malus, Sorbus,* and *Sambucus)* was also collected where available and as time permitted (Ballington et al., 1988; Luby and Hancock, 1991). In 1985, collections were made between 21 July and 13 Aug. The Coast Range of Oregon, the Siskiyou Mountains (Oregon), the southern Cascade Mountains (Oregon and Washington), and the Olympic Mountains (Washington) were the target areas for the 1985 expedition (Fig. 1). In 1989, collections were made between 31 July and 19 Aug. The Black Hills (South Dakota), and the Bighorn (Wyoming), Absoroka (Wyoming and Montana), Madison (Montana), Tobacco Root (Montana), Pioneer (Montana), Bitteroot (Montana and Idaho), Selkirk (Idaho), Cabinet (Montana), Whitefish (Montana), Crazy (Montana), Big Belt (Montana), and Little Belt (Montana) ranges of the Rocky Mountains were the target areas for the 1989 expedition (Fig. 1). All collection sites were in National Forests except for one site each in Yellowstone and Glacier National Parks. U.S. Forest Service maps were used to locate and identify most sites.

The elevation of collection sites was determined by altimeter and was accurate within 30 m based on calibrations at reference points where the elevation had been determined by the U.S. Geological Survey. Slope and aspect were determined by planeometer and compass, respectively. Associated flora were noted at each site and used to assign the sites to plant communities described by Daubenmire (1943), Munz and Keck (1959), and Peet (1988).

At each site, seed was collected if available. Where seed was not available, we attempted to collect clonal samples from ≈ 20 genotypes. Representative herbarium samples were gathered and pressed at most sites. Fruit and clonal specimens were placed in plastic bags and packed in ice chests while in transit. Fruit samples were sent to the National Clonal Germplasm Repository (Corvallis) for seed extraction. Clonal material was shipped to the Germplasm Repository, Univ. of Minnesota, or Michigan State Univ. for rooting. Seeds were regenerated from *F. virginiana* clonal material in a greenhouse at Michigan State Univ. in Spring 1990 by random pollination among genotypes collected from within each site. This seed was shared with the Germplasm Repository. Herbarium specimens have been deposited at the Germplasm Repository, North Carolina State Univ., and Michigan State Univ.

On the 1989 expedition, a composite soil sample was collected at each site by taking a 2-cm-diameter core to a depth of 20 cm adjacent to each collected *Fragaria* plant. Concentrations of K (ammonium acetate extractable), P (Bray Pl or Olsen test for soils with pH >7.2), pH [l soil : 1 water (w/v)], and organic matter content (wet digestion) were determined for each sample (Rehm et al., 1985).

DESCRIPTION OF COLLECTIONS

Collections and site characteristics are summarized in Tables 1 and 2. In the Pacific Northwest, a total of 23 accessions were collected from 18 sites including 17 seed samples. Fruits were unripe or unavailable at 41 additional locations where species or species hybrids were observed. The Rocky Mountain collections in 1989 included > 800 clonal specimens and nine seed samples from 45 sites. The individual sites and accessions are described in more detail by Ballington et al. (1988) and Luby and Hancock (1991).

Collection sites included several distinct habitats and were widespread in latitude and altitude. *Fragaria virginiana* generally occurred in disturbed or open areas such as roadsides or roadbanks, recent clearcuts, gravelly slopes, open woods, and meadows. Several genera that were nearly always associated in the understory of plant communities containing *F. virginiana were* herbaceous *Potentilla* spp., *Berberis aquifolium* Pursh, *Physocarpus malvaceus* (Greene) Kuntz, *Holodiscus discolor* (Pursh) Maxim., *Symphoricarpus oreophilus* Gray, *Menziesia ferruginea* Smith, *Ribes* spp., *Lonicera* spp., and *Spiraea* spp. In the Pacific Northwest, elevations of collection sites ranged from 800 to 2100 m in Oregon and 400 to 1400 m in Washington. In the eastern Rocky Mountains, *F. virginiana* occurred mainly in the spruce-fir [*Picea englemannii* Parry - *Abies Lasiocarpa* (Hook.) Nutt.] and Douglas fir [*Pseudotsuga menziesii* (Mirb.) France] zones in sites with moderate moisture and limited competition. Collection from high elevation sites (> 1500 m) was emphasized. In western Montana and Idaho, collection sites were often at elevations < 1500 m in the drier Ponderosa pine *(Pinus ponderosa* Dougl.) and Douglas fir zones. Above this elevation, precipitation was high, and tree and shrub growth was so lush that ground cover species such as *Fragaria* were apparently quickly shaded in openings where they might otherwise have become established.

The diversity of habitats where *F. virginiana* was collected, ranging from dry *Pinus ponderosa* forests to wet meadows, suggests that valuable traits in certain accessions could include resistance to drought or to conditions associated with saturated soils (anaerobiosis, low nutrient availability, root rot pathogens). Sites having elevation, aspect, soil texture, and soil profile that might contribute to drought or heat stress include LH 4, LH 10, LH 11, LH 22, LH 28, and LH 38 (Table 1). Sites with conditions promoting prolonged soil saturation included BL 27, BL 30, LH 6, LH 29, LH 34, and LH 35 (Table 1). Several collections (LH 9, LH 15, LH 17, LH 18, LH 45, LH 50) were made near the timberline where the growing season was typically very short (only 6 to 8 weeks, according to local reports) and frost or snow could occur at any time of the year (Table 1). Cold hardiness and blossom frost tolerance may be available from these and other high-altitude sites in the eastern Rocky Mountain ranges.

The sites were quite variable for the soil pH and content of K, P, and organic matter (Table 2). Collections from several sites with alkaline soils may be sources of tolerance to higher pH. Soils at sites LH 2 and LH 40