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Adaptive Zones and Ancestry of the Most Important North American Strawberry Cultivars

JIM HANCOCK[1] AND JIM LUBY[2]

Abstract

The most popular strawberry cultivars grown in North America are contained in 7 cluster groups based on coefficients of relationship. They can be assorted into six major climatic/geographical regions: 1) California, 2) Florida, 3) Pacific Northwest, 4) Southern U.S., 5) Lower Mid-western and Eastern U.S. and 6) Eastern Canada and Upper Mid-western U.S. There are key horticultural traits associated with the founding clones of each cluster group, but in many instances cultivars are grown in areas quite distant from the origin of their ancestors. This suggests that germplasm from very broad geographical/climatic zones can be successfully incorporated in regional breeding programs.

Introduction

Strawberries are cultivated in most arable regions of the world. They are grown in all types of environments from the arctic to the tropics. Much of this broad adaptability can be attributed to breeders who have used a variety of gene pools to develop regionally adapted types. Sjulin and Dale (19) demonstrated that North American cultivars can be clustered into 9 groups based on their coefficients of relationship (19), but they did not describe the climatic adaptations of the various genetic backgrounds or compare the geographical origins of their founding clones. In this study, we examine where representatives of the various cluster groups are grown in North America and list their apparent environmental adaptations. We also describe the site of origin and horticultural characteristics of the predominant founding clones of each gene pool. This information should be useful to breeders interested in incorporating new germplasm into their genetic improvement programs, and producers who want to select new cultivars for trial.

Materials and Methods

Several recent publications were consulted for regional patterns of popularity over the last 10 years (1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18). Cultivars mentioned as "important," "leading" or "major" were assorted by states or province and then overall patterns of distribution were identified. A cultivar had to be mentioned by at least three independent sources to be included in a state or province. The USDA Yearbook of Agriculture, Climate and Man (21) and The Old Farmers Almanac (20) were then consulted for climatic information on the resulting broad geographical ranges.

Results and Discussion

Climatic zones. Cultivars can be assorted into six major geographical regions in the United States and Canada: 1) California, 2) Florida, 3) the Pacific Northwest, 4) Southern US, 5) Lower Mid-western and Eastern US, and 6) Upper mid-western US and Eastern Canada (Table 1). Other studies have grouped cultivars in eastern North America into finer grids (4, 9, 18), but we decided to lump these into only two regions, as the same cultivars are grown in both the lower-midwest and eastern US, and the upper mid-west and eastern Canada. California, Florida and the Southern US also share selected cultivars, but each of these regions also has its own unique types.

[1]Department of Horticulture, Michigan State University, East Lansing, MI 48824.
[2]Department of Horticultural Science and Landscape Architecture, University of Minnesota, St. Paul, Minnesota 55108.

Table 1. The most popular North American cultivars of the last decade assorted by their region of popularity and their coefficient of relationship (19).

Cultivar	Cluster group	Region of Popularity					
		Coastal California	Central Florida	Pacific NW[1]	Southern US[2]	Lower Midwest[3] Eastern US[4]	Upper Midwest[5] Eastern Canada[6]
Chandler	1	X	X		X		
Oso Grande	1	X	X				
Pajaro	1	X	X				
Selva	1	X	X		X		
Dover	2		X				
Benton	4			X			
Hood	4			X			
Olympus	4			X			
Rainier	4			X			
Shuksan	4			X			
Totem	4			X			
Apollo	6				X		
Tangi	6				X		
Atlas	7				X		
Cardinal	7				X		
Titan	7				X		
Delite	7				X	X	
Earliglow	8				X	X	
Allstar	8					X	
Guardian	8					X	
Jewel	8					X	
Lester	8					X	
Raritan	8					X	
Redchief	8					X	
Tribute/Tristar	8					X	
Honeoye	8					X	X
Kent	8					X	X
Annapolis	8						X
Blomidon	8						X
Gov. Simcoe	8						X
Bounty	9						X
Glooscap	9						X
Veestar	9						X

[1]BC, WA, OR
[2]TX, OK, AR, LA, MS, TN, AL, GA, SC, NC, VA
[3]NE, southern ID, IO, IL, IN, MI, OH, KY
[4]WV, MD, DE, PA, NJ, NY, CN, RI, MA, VT, NH, ME
[5]ND, SD, MN, northern IO, WI, northern MI
[6]ONT, QUE, maritime provinces

The most important North American cultivars are contained in 7 of Sjulin and Dale's cluster groups (CG) based on coefficient of relationship (Table 1). Only cultivars from CG1 are grown to any extent in California, while Florida has types from both Clusters 1 and 2. The Pacific Northwest is made up of cultivars solely from CG4. Representatives of clusters 6 and 7 are found in the southern US. Cultivars in CG8 are grown primarily in the lower midwestern and eastern US, while representatives of both CG8 and 9 are found in the upper midwestern US and eastern Canada.

Table 2. Climatic zones of major strawberry production regions.

Parameter	Coastal California	Central Florida	Pacific NW	Southern US	Lower Midwest Eastern US	Upper Midwest Eastern Canada
Hardiness zone	10	9 & 10	8 & 9	7 & 8	5 & 6	3-6
Minimum winter temperature (C)	>0	5-10	0-(-10)	-10-(-20)	-20-(-30)	-20-(-40)
Mean January temperature (C)	10	10-15	5-10	0-10	0-5	-5-(-20)
Maximum summer temperature (C)	20-25	30-35	25-30	35-40	30-35	30-40
Mean July temperature (C)	15-20	25-30	15-20	25-30	25-30	20-25
First short day (<14 hrs)	mid-July	all year	mid-August	mid-July	late July	mid-August
Frost free days	>250	>280	180-280	180-280	160-180	120-160
Annual rainfall (cm)	50-75	125-140	200-250	100-125	75-100	75-100

In most cases, cultivars are restricted to a single region, with a few notable exceptions. 'Chandler' and 'Selva' from CG1 are grown in California, Florida and the Southern US, and they are making inroads into the Pacific Northwest and the lower midwestern US. 'Delite' (CG7) and 'Earliglow' (CG8) are planted in the southern US and the lower midwestern/eastern US. 'Honeoye' and 'Kent' (CG8) are grown in both the lower midwestern/eastern US, and upper midwestern US/eastern Canada.

There are some key differences between the climates of the various gene pools (Table 2). Cultivars in CG1 (California) are grown predominantly in regions having mild winters and long, cool summers. 'Dover' in CG2 (Florida) is grown in an area having mild winters and long, hot summers. Representatives of CG4 (Pacific Northwest) are found in areas with moderate winters and long, cool summers. Individuals of CG6 and 7 (southern US) are planted in areas with moderate winters, but the summers are long and hot. Those in CG8 (lower midwestern and eastern US) are found in areas with cold winters and short, cool summers. Cultivars of CG9 (upper midwestern and eastern Canada) are located in areas characterized by cold winters and very short, cool summers. The winter lows and summer highs in Nova Scotia are much more moderate than those of the upper midwest (-30 vs -40 C; 32 vs. 38 C); however, both these locations have very short frost free periods (120-140 days) and late floral induction periods of < 14 hours of daylength (August 18).

Ancestry. Key horticultural attributes can often be identified among the founding clones that predominate in each gene pool, but their contributions to regional climatic adaptations are frequently less clear. In several instances, cultivars are grown in areas distant from the origin of their founding clones (Table 3). Eastern material was used liberally in western breeding programs, and a limited amount of California germplasm found its way east.

The pedigrees of the CG1 (California) cultivars contain large contributions (> 10%) from 'Nich Ohmer' and 'Marshall' (19). 'Nich Ohmer' was originated in Ohio, but had important adaptation features for the north coast California production area around Watsonville, where it fruited all summer and had better flavor than in the east. 'Nich Ohmer's berries were large,

Table 3. Ancestry of the cluster groups (CG) of Sjulin and Dale (19) grown in different geographical regions of the US and Canada. Only those contributing > 10% of the genetic background of a gene pool are listed.

		CG1	CG2	CG4	CG6 & 7	CG8	CG9
Founding Clone	Origin	California	Florida	Pacific NW	Southern US	Lower Midwest Eastern US	Upper Midwest Eastern Canada
Aberdeen	New Jersey			X		X	X
Ettersburg 121	California			X			
Ettersburg 450	California			X		X	X
Marshall	Massachusetts	X		X			
Missionary	Virginia	X	X		X	X	
New Jersey Scarlet	New Jersey	X		X	X	X	
Nich Ohmer	Ohio	X	X				

firm and glossy crimson (6). 'Marshall' was discovered as a chance seedling in Massachusetts (12) but became widely grown in the west due to its excellent flavor, large size and freezing quality. It was relatively large-fruited, soft, irregular shaped and deep red in color (6). Drought resistance was considered its main adaptational feature.

The CG2 cultivar 'Dover' (Florida) also contains large contributions from 'Nich Ohmer.' In addition, the old southern cultivar 'Missionary,' features prominently in its pedigree. 'Missionary' was originally found in Virginia and probably provided adaptation to southern climates through its low chilling requirement and adaptation to relatively short summer photoperiods (6). It also had high virus tolerance and high acid levels in the fruit, a desirable feature in a climate that can be hot during the fruiting period. The fruit of 'Missionary' was soft, deep red in color and was pointed with a pronounced shoulder (6).

The cultivars of CG6 and 7, grown in the southern US, are also characterized by large contributions from 'Missionary' whose climatic adaptation for warm seasons adaptations has already been described above. Also important, was 'New Jersey Scarlet,' perhaps selected for its high vigor and earliness (12). It had medium-sized, conic, necked, light scarlet berries with whitesh medium-firm fruit and was early ripening (6).

The CG4 cultivars grown in the Pacific Northwest have founding clones which in many cases owe their prominence to their processing quality. 'Marshall' from Massachusetts was an important parent due largely to its high processed quality. It's drought resistance may also have been important during the warm, dry periods of several weeks that occur in the late summer in the Pacific Northwest. Other important founding clones in this group are 'Aberdeen' from New Jersey whose resistance to *Phytophthora fragariae* (red stele) was probably important in the seasonally wet cool soils of the region. It produced large, medium red, soft, mildly subacid fruit and was a vigorous plant maker (6).

'Ettersburg 121' and '450' from California are also important in the CG4 background. 'Ettersburg 121' was widely grown in the wet heavy soils of the Willamette Valley during the 1920s and 1930s where it was prized for canning due to its firm flesh, high flavor, persistent color and easy capping ability (6). 'Ettersburg 450' apparently had many of the same canning qualities of 'Ettersburg 121' and contributed to many modern varieties through the intermediate parent, 'Fairfax.' 'Ettersburg 450' was noted for its large, firm, attractive berries and ex-

cellent flavor (22). 'New Jersey Scarlet' was also an important founding clone, probably contributing high flavor for processing. CG8 and 9, grown in the lower and upper mid-west, are very similar to each other in having large contributions from eastern 'Aberdeen,' and western 'Ettersburg 450.' However, CG8 also incorporates high percentages of Virginian 'Missionary' and 'New Jersey Scarlet.' The characteristics of these clones have already been mentioned.

Conclusions

In their classic study, Sjulin and Dale (19) suggested that the germplasm base of North American cultivars was relatively narrow and should be expanded for continued breeding success. Our studies confirm this conclusion as we found only 7 founding clones to predominate in the major cultivars grown in North America, and in many cases the same progenitors are important in more than one geographical region. For example, 'New Jersey Scarlet' is a critical component of the genetic background of cultivars grown in California, the Pacific Northwest, Southern US, and Lower midwestern US/Eastern Canada. 'Aberdeen' and 'Ettersburg 450' are important in the genetic background of cultivars grown in the Pacific Northwest, lower midwestern US/eastern US and upper midwestern US/eastern Canada.

While the germplasm base of the North American cultivars is narrow, it is interesting to note that founding clones originating from very diverse regions were successfully incorporated into regional breeding programs. Eastern clones like 'Nich Ohmer,' and 'Marshall' played an important role in the development of California and Florida cultivars. Likewise, eastern 'Aberdeen' and 'New Jersey Scarlet' contributed heavily to the ancestry of cultivars in the Pacific Northwest. 'Ettersburg 450' from California played an important role in the development of midwestern and eastern cultivars.

At numerous locations, an expansion of the germplasm base apparently outweighed the negative attributes of specific climatic adaptations. Of particular note is 'Nich Ohmer' which flourished in coastal California with high flavor, firm-large fruit and high productivity, but did not succeed in the eastern United States due to poor flavor, small size, susceptibility to leaf spot, and high cultural demands (6). Likewise, 'Marshall' was not hardy enough to be widely planted in the east, but flourished in the milder climates like California and the Pacific Northwest. The far reaching success of California 'Chandler' and 'Selva' across the southern US and into the east coast and Europe further demonstrates that the geographical origin of strawberry germplasm does not necessarily restrict its utility in regional breeding programs.

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Effects of Simazine on the Mycorrhizal Population in Soil Beneath an Apple Tree Canopy[1]

RAYMOND L. GRANGER,[2] SHAHROKH KHANIZADEH,[3] MICHAEL MEHERIUK,[4] LUCE S. BÉRARD[5] AND YOLANDE DALPÉ[6]

Abstract

Simazine treatments were applied during four consecutive years to the soil beneath the trees of a young apple orchard in southern Quebec. Following a one-year interruption in treatments, the population of mycorrhizal propagules (spores and sporocarps) in the soil under the tree canopy was quantified. Simazine diminished the population of mycorrhizae. The effect of simazine was linear and only Glomus species were found in the soil.

Key Words: *Malus domestica* Borkh., VAM fungi, 'Spartan'/M.7 EMLA, *Glomus calospora, Glomus constrictum, Glomus aggregatum, Glomus rubiformis.*

Introduction

Inoculation of apple tree roots with certain vesicular-arbuscular mycorrhizal (VAM) species has been shown to stimulate growth (Covey et al., 1981; Koch et al., 1982; Hoepfner et al., 1983). It could also promote phosphorus and zinc uptake in apple seedlings (Geddeda et al., 1984; Benson and Covey, 1976). The response to such a treatment was dependent on the rootstock or the species of mycorrhizal fungi used (Granger et al., 1983; Covey

[1]Agriculture Canada Contribution No.335/91.10.08
[2,5]Research Scientists, Agriculture Canada Research Station, St. Jean-sur-Richelieu, Quebec, Canada J3B 3E6.
[3]Research Scientist and Assistant Professor, Agriculture Canada Research Station, St. Jean-sur-Richelieu, Quebec, Canada J3B 3E6 and McGill University, Macdonald Campus, 21,111 Lakeshore rd Ste-Anne-de-Bellevue, Quebec, Canada H9X 3V9.
[4]Research Scientist, Agriculture Canada Research Station, Summerland, British Columbia, Canada V0H 1Z0.
[6]Research Scientist, Biosystematics Research Institute, William Saunders Building, Central Experimental Farm, Agriculture Canada, Ottawa, Ontario, Canada K1A 0C6.