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The United States Department of Agriculture Strawberry Breeding Program

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Abstract

The comprehensive USDA strawberry breeding program was started by George Darrow In Maryland In 1919-20. It continues today at three of six former federal locations: Beltsville, Maryland; Corvallis, Oregon; and Poplarville, Mississippi (breeding has been discontinued at Glenn Dale MD, Carbondale, IL, and Cheyenne, WY). Cooperating scientists, growers and nurseries are presently located in 24 states, three Canadian provinces and five countries. The Beltsville portion of the program originates strawberry cultivars intended for one or more of five broad eastern U.S. regions. Its emphasis is on combining disease and stress resistance with superior fruit quality and productivity for the market outlets of each region. The Corvallis emphasis is on breeding productive, well-colored and fine-flavored procewsing cultivars for the Pacific Northwest. The Poplarville program concentrates on producing shipping cultivars highly resistant to anthracnose crown and fruit rots and adapted to winter and early spring production areas. Seventy-four cultivars and four anthracnose-resistant parent germplasm clones have been Introduced by the USDA and its cooperators. The program has freely shared cultivar and parental germplasm and/or seed progenies worldwide during its entire history.

History

The noted physician, horticulturist, plant hybridist, and renowned rose specialist, Dr. Walter Van Fleet, introduced four strawberries from his private breeding efforts prior to and just after becoming associated with the United States Department of Agriculture (11, 16). Van Fleet also produced an interspecific raspberry hybrid later named for him (1) while stationed at the Chico, California Plant Introduction Garden in 1910. Van Fleet's four strawberry introductions (16), 'Early Jersey Giant,' 'Late Jersey Giant' 'Edmund Wilson,' and 'John H. Cook' are described by Hedrick (12). Van Fleet also acted as advisor to the early USDA strawberry breeding work from 1920 until his death in early 1922 (5).

The present strawberry breeding effort was preceded by a comprehensive series of small fruit industry surveys throughout the United States conducted by George Darrow prior to America's entry into

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World War I. Initial crosses were made at Glenn Dale, Maryland in 1920. The aims and progress of the early work were ably summarized by Darrow et al. (4, 5). The extensive list of desirable selection characteristics for cultivar breeding given in Table 1 of Darrow et al. (4) is still generally valid. Emphasis was and continues to be placed on: 1) the use of broadly divergent parent germplasm [in the first 12 years, for example, "In all, over 130 varieties and 20 selections of species have actually been used in the breeding." (Darrow et al., 5)]; 2) broad U.S. regional cooperative breeding efforts; and 3) free exchange of germplasm with other programs. By 1933, seven cultivars had been name, and cooperative work established with Oregon State University and the North Carolina Department of Agriculture.

By the mid 1930's Darrow's extensive correspondence and travel and his pioneering strawberry breeding, morphology, and physiology work had made him a world authority, as evidenced by his "Strawberry Improvement" chapter in the 1937 U.S.D.A. Yearbook of Agriculture (2). Waldo moved to Oregon to lead the breeding program there in 1932, and the Maryland work moved from Glenn Dale to Beltsville in the same year. Red stele root rot (caused by the water mold *Phytophthora fragariae* Hickman) became a recognized strawberry problem in the 1930's and led to the establishment of formal cooperative work with the University of Maryland in 1937. This cooperative effort to better understand the disease and to select and breed berries resistant to it lasted 50 years, and red stele resistance became and continues to be a primary USDA breeding aim for the northern U.S.

Cooperative breeding work has taken to general forms; formal, conducted under written agreement for specific purposes, and informal, usually for the testing of selections for regional adaptation. Much of the present cooperative work is informal, carried on under broad general agreement terms between the USDA and each State Agricultural Experiment Station, although there is now considerable work performed with grants from outside sources. The rich history of the USDA strawberry breeding and related research has been well documented by a succession of federal workers, each stressing different aspects of the programs (2-10, 13-15, 17-20).

Regional Problem Approach and Impact

The USDA Horticultural Field Station at Cheyenne, Wyoming carried on an interesting series of strawberry studies in the period 1937-1975 under the leadership of Leroy Powers, Donald Scott and Gene Howard. The work centered around the collection, evaluation and enhancement of selections of the very hardy Rocky Mountain strawberry species [*Fragaria cuneifolia* Nutt. = *F. ovalis* (Lehm.) Rydb. = *F. virginiana* var. *glauca* Staudt]. A number of studies involved the inheritance of sex expression and of the everbearer habit. The primary emphasis of the program was the transfer of the drought and cold tolerance of the Rocky Mountain strawberry to cultivated types. Eight cultivars were named from this locality (Table 1).

Leaf spot [caused by *Mycosphaerella fragariae* (Tul.) Lindau] and leaf scorch [caused by *Diplocarpon earlianum* (Ellis & Everh.) F. A. Wolf] can be very destructive diseases in the eastern U.S. They are particularly destructive in the Midwest, as is the red stele root rotting fungus. A contract with Southern Illinois University to breed strawberries for the Midwest resistant to these diseases led to the establishment of a federal field station at Carbondale, Illinois in 1959. The breeding work was led by Roland Blake and the disease studies by Stanley Nemec. Dr. Nemec demonstrated racial divergence in the leaf spot inciting fungus. Dr. Blake introduced the very disease resistant and productive cultivar 'Delite' (Table 1). The station was closed in an economy move in 1972. The Beltsville location reinitiated breeding for the Midwest in 1978.

A serious epiphytotic of the anthracnose crown rot disease (caused by *Colletotrichum* spp.) in North Carolina in 1975 demonstrated that the disease formerly thought to be sporadic and confined to the Gulf Coast, was becoming more widespread. In 1976 cooperative studies of the disease and possible sources of resistance were initiated by the North Carolina, Florida, and Louisiana Agricultural Experiment Stations and two federal locations, the Fruit Lab of the Beltsville Agricultural Research Center in Maryland (Gene Galletta and Arlen Draper–breeding, John Maas–disease), and the USDA Small Fruit Research Station at Poplarville, Mississippi (Barbara Smith–disease and breeding, Creighton Gupton-genetics and breeding). The ensuing work on disease screening procedures, pathogen species and races, genetics of resistance inheritance, pathogen host ranges, disease epidemiology and cultural and chemical management of the diseases are summarized by Smith et al. (20). Four anthracnose resistant parent clones were introduced in 1992, and the first anthracnose and red stele resistant cultivar from the program was introduced In 1996 (Table 1)

The breeding work at Corvallis has been led by C. E. Schuster, George Darrow, George Waldo, Frances Lawrence, Margaret Stahler, and Chad Finn (present), and the disease work by Richard Converse and Robert Martin (present). This program has always cooperated very closely with Washington State University, Oregon State University, and Agriculture Canada in British Columbia. Most of the cultivars grown in the region have selections from 2 or 3 of the programs in their ancestry. The Corvallis program has served the Pacific Northwest's small fruit processing industry, initially seeking berries for canning and then for freezing. In processing crop areas, varietal succession and adoption is slow. Important traits include high sugar, high acids, a well-colored fruit (solid, medium dark red), maintenance of fruit integrity during processing, productivity over several harvest seasons, easy cap removal and tolerance to cold, red stele and viruses. The Corvallis location has introduced ten cultivars (Table 1), and pioneered in the collection and enhancement of native beach strawberry [*Fragaria chiloensis* (L.) Duch.] clones. It has performed important work in bench screening for red stele resistance, field screening for virus tolerance, and also breeding for machine harvesting. Since the establishment of the National Clonal Germ Plasm Repository at Corvallis, the breeding team has had added opportunity to participate in small fruit plant exploration trips, germplasm evaluation and enhancement.

The breeding work begun at Glenn Dale and later moved to Beltsville has been led by George Darrow, George Waldo, Donald Scott, Arlen Draper and Gene Galletta (present); the disease work by H. F. Bain, J. B. Demaree, Richard Converse, John McGrew, and John Maas (present). The regions served by, and the objectives of this program are so diverse that it has required the greatest financial and personnel support. During its long tenure, the Maryland portion of the USDA program had a hand in the origination of four anthracnose-resistant parent clones and one cultivar for the South, 13 cultivars for the mid-South, and 40 cultivars for the Northeast and Midwest (Table 1).

The cooperative work with North Carolina has evolved from originating berries for spring-planted matted-row culture that had resistance to the prevalent leaf diseases and temperature stresses and firm, light-colored fruit of good quality for the shipping trade and local market to more multi-purpose cultivars. Strawberries for this region now must combine red stele and anthracnose resistance with resistance to fungal foliar pathogens. They must be suitable for shipping or for the local market. They must be capable of outperforming the 'Chandler' or 'Sweet Charlie' cultivars following fall planting on raised beds mulched with black plastic, or the 'Apollo' or 'Atlas' cultivars when spring planted and permitted to form matted rows.

Table 1. U.S. Department of Agriculture Strawberry Cultivars and Parent Clones.

Clone	Year introduced	Origin/USDA location	Cooperator location
FROM ILLINOIS			
Delite	1974	Carbondale	So. Ill. Univ.
FROM MARYLAND			
Albritton	1951	Beltsville	NC
Allstar	1981	Beltsville	MD
Apollo	1970	Beltsville	NC
Atlas	1970	Beltsville	NC
Bellmar	1932	Glenn Dale	—
Blakemore	1930	Glenn Dale	—
Darrow	1974	Beltsville	MD
Daybreak	1939	Beltsville	NC
Delmarvel	1994	Beltsville	OH, NJ
Dixieland	1953	Beltsville	NC
Dorsett	1933	Glenn Dale	—
Earlibelle	1964	Beltsville	NC
Earlidawn	1956	Beltsville	—
Earliglow	1975	Beltsville	MD
Early Midway	≈1964	Beltsville	Private Nursery
Eleanor Roosevelt	1939	Beltsville	NC
Fairfax	1933	Glenn Dale	—
Fairland	1947	Beltsville	—
Fairmore	1939	Beltsville	NC
Fairpeake	1944	Beltsville	—
Guardian	1969	Beltsville	MD
Joan	1933	Glenn Dale	Private Nursery
Lateglow	1987	Beltsville	—
Latestar	1995	Beltsville	—
Lester	1984	Beltsville	MD
Massey	1940	Beltsville	NC
Maytime	1941	Beltsville	—
Midland	1944	Beltsville	—
Midway	1959	Beltsville	MD
Mohawk	1994	Beltsville	ONT; MD
Narcissa	1933	Glenn Dale	—
Northeaster	1994	Beltsville	NJ, OH
Northstar	1939	Beltsville	—
Pocahontas	1953	Beltsville	VA
Prelude	1980	Beltsville	NC
Primetime	1995	Beltsville	—
Redchief	1968	Beltsville	MD
Redglow	1956	Beltsville	—
Redhead	1932	Glenn Dale	—
Redstar	1940	Beltsville	—
Rosanne	1980	Beltsville	NC
Scott	1979	Beltsville	MD
Sentinel	1980	Beltsville	NC
Southland	1932	Glenn Dale	—
Starbright	1940	Beltsville	—
Stelemaster	1954	Beltsville	MD

Table 1. Continued.

Clone	Year introduced	Origin/USDA location	Cooperator location
FROM MARYLAND			
Sumner	1980	Beltsville	NC
Sunrise	1964	Beltsville	MD
Surecrop	1956	Beltsville	MD
Suwanee	1945	Beltsville	—
Temple	1943	Beltsville	MD
Titan	1971	Beltsville	NC
Tribute	1981	Beltsville	MD
Tristar	1981	Beltsville~	MD
Winona	1996	Beltsville	MN
FROM MARYLAND AND MISSISSIPPI			
Pelican	1996	Beltsville, Poplarville	LA, NC
US 70	1992	Beltsville, Poplarville	—
US 159	1992	Beltsville, Poplarville	—
US 292	1992	Beltsville, Poplarville	—
US 438	1992	Beltsville, Poplarville	—
FROM OREGON			
Benton	1975	Corvallis	OR, WA
Bountiful	1993	Corvallis	OR, WA
Brightmore	1942	Corvallis	
Hood	1965	Corvallis	OR
Linn	1976	Corvallis	OR, WA
Mollala	1961	Corvallis	OR
Redcrest	1990	Corvallis	OR, WA
Redgem	1993	Corvallis	OR, WA
Siletz	1955	Corvallis	OR
Vale	1966	Corvallis	OR
FROM WYOMING			
Alaska Pioneer	1968	Cheyenne?	AK
Arapahoe	1954	Cheyenne	—
Cheyenne2	1942	Cheyenne	—
Cheyenne3	1942	Cheyenne	—
Early Cheyenne 1	1942	Cheyenne	—
Fort Laramie	1973	Cheyenne	—
Ogallala	1958	Cheyenne	NB
Radiance	1954	Cheyenne	—
Sioux	1948	Cheyenne	NB

The strawberries developed at Beltsville are usually adapted from lower New England to the Middle Atlantic region, south in the mountains to North Carolina and west to Missouri, and west in the North to all but the coldest locations of the Midwest and North Central regions. The matted-row system is still the predominant cultural method of the regions served by the Beltsville work, but there is considerable interest in raised bed culture. Consequently, promising selections must be tested for suitability to different planting times, training systems and planting bed contours and mulches. With the impending loss of methyl bromide, seedling selection and selection evaluation is being carried out again at Beltsville on unfumigated soils. There has been considerable recent experimentation with various sus-

tainable organic and inorganic mulches, cover crops, intercrops and killed sod planting treatments of a variety of genotypes to complement the breeding work.

While red stele resistance has been the principal disease breeding aim for both the Junebearing and the everbearing portions of the Beltsville program, other diseases have not been neglected. Epidemiology, breeding for resistance, and identification of resistant parents has been carried on for angular leaf spot, black root rot, leaf scorch, leaf spot, leaf blight, powdery mildew, anthracnose crown and fruit rots, Verticillium wilt, leather rot, and gray mold fruit rot. The Beltsville group was one of the pioneers in the identification and eradication of viruses from strawberry cultivars and encouraged the ewtablishment of certification programs for the maintenance of virus-negative plant stocks. All highly promising selections from our own and cooperative programs are virus-indexed and only virus-negative stocks are used for advanced testing and for introduction.

The current active cooperative breeding projects for the northern U.S. are combining red stele resistance with: tarnished plant bug resistance (Maine); early ripening and fall-planted types (New Jersey); hardiness and black root rot resistance (New york); hardiness, heat tolerance and leaf spot resistance (Minnesota and Wisconsin); and high flavor components (Ohio and Beltsville). Of course within each project, the best possible combination of plant health, vigor, disease resistance, productivity and fruit quality for the desired market outlet is continually sought. The Beltsville group is also involved in a number of cooperative genetic studies, both traditional and molecular.

Parent and Germplasm Impact

USDA strawberry cultivar and selection clones have been distributed freely for testing and for parent use to most of the breeding programs in North America, western Europe and Asia. Three of the Corvallis selections were apparently named in Chile (OSC 2074, a 1947 selection, was named 'Quillan,' OSC 2127 and 2130, both 1948 selections, were named 'Maullin' and 'Ancud,' respectively). In many instances seed of elite progenies also has been distributed on request for either special studies or for selection. An unconfirmed report indicated that several clones were selected and named from seed sent to China from Beltsville in the early 1980's.

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