The U.S. Department of Agriculture Strawberry Breeding Program[1]

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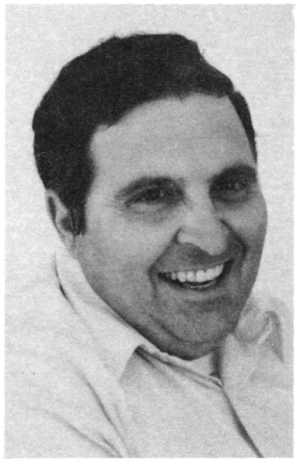
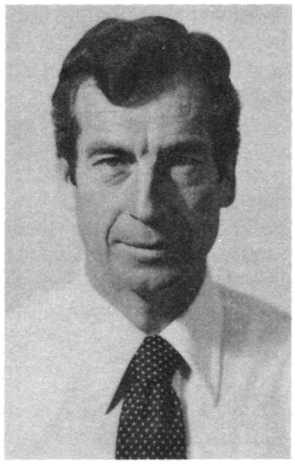
The U.S. Department of Agriculture strawberry breeding program has introduced 61 cultivars from 6 breeding locations in its 61-year history. Fifteen to 20 of these cultivars have been widely grown, and 5 of the recent releases show exceptional promise. From its inception, the program has been aimed at producing high-quality, multipurpose cultivars with disease resistance and broad regional adaptation. Because of disease pressures, genetic resistance has been emphasized, especially for red stele root rot. The USDA has become the principal source of red stele-resistant germplasm for breeding pruposes, and has constantly refined and improved its disease-screening techniques. Red stele and *Verticillium* resistance have now been incorporated into everbearing strawberries adapted to the eastern United States. Investigations concerning virus detection and eradication and the propagation of virus-free stocks have led to state virus-free plant certification programs, which assure the public of production of the cleanest possible strawberry nursery stocks. The work of the USDA and cooperating state stations has played a significant role in the improvement of strawberry cultivars and the development of modern strawberry production in the United States.



Gene J. Galletta



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Although the cultivated strawberry originated by chance species hybridization in Europe about 1750 (9), it is an all-American fruit. Both *F. chiloensis* (from Chile, South America) and *F. virginiana* (from Virginia, North America) are now believed to be its parents (5). Progress in the improvement of the cultivated strawberry proceded slowly for more than 150 years (from 1750 until early 1900). Thereafter progress was rapid as state and federal agencies became involved in the breeding of improved cultivars, providing the refined cultivars that are the basis of an extensive industry today.

Strawberry breeding by the USDA was initiated in 1920 in Maryland by George M. Darrow and has continued uninterrupted to the present time. Darrow directed the program from its inception until his retirement in 1957, at which time D. H. Scott, who has worked with Darrow since 1946, assumed leadership in the program. Scott retired in 1975, and A. D. Draper directed the program until 1977 when G. J. Galletta, formerly in charge of strawberry breeding at North Carolina State University, assumed leadership of the program.

Formal cooperative work was established in 1928 with state experiment stations at Willard, N.C. and Corvallis, Ore.; in 1937 at College Park, Md.; and in 1959 with Southern Illinois University at Carbondale, Ill. The first cooperators were E. B. Morrow in North Carolina, C.E. Schuster in Oregon, and W.F. Jeffers in Maryland. Later cooperators were G. J. Galletta, North Carolina; G. F. Waldo (USDA), Oregon; and I. C. Haut, G. L. Stadelbacher, and H. D. Stiles, Maryland. The cooperative programs with North Carolina, Oregon, and Maryland have continued to the present with J. R. Ballington in North Carolina, F. J. Lawrence (USDA) in Oregon, and Harry Swartz in Maryland as current cooperators. The Illinois program was staffed by R. C. Blake (USDA) from 1959 to its termination in 1972.

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USDA strawberry work at the Cheyenne Horticultural Field Station, Wyoming, was started in 1937 by LeRoy Powers and continued by Gene Howard until the project closed in 1975. The major objective was to combine winter hardiness of *Fragaria virginiana glauca* Staudt (= *F. ovalis* (Lehn) Ryob.) with improved fruit characters from the cultivated strawberry (*F.* X *ananassa* Duch.).

Soon after work began in Maryland, informal cooperation with several state stations was started to test selections. This has continued to the present, notably with New Jersey, Massachusetts, New York, Ohio, Pennsylvania, Indiana, Missouri, and Arkansas.

Early breeding aims

Improvement of fruit characters for specific uses and plant climatic adaptation was emphasized in the early work (4). Darrow was the first strawberry breeder to recognize the importance of fruit firmness, and his 'Blakemore', introduced in 1928 (6), rapidly became a major cultivar because of its firmness and adaptability to the southeastern and the southcentral United States. For 20 years it was the most important strawberry cultivar in the United States, being grown from New Jersey southward to Georgia, Mississippi, and northern Louisiana and westward to Arkansas and eastern Texas. It is still being grown commercially in small areas in Oklahoma and Texas and in home gardens in the southeastern United States. However, improved cultivars with larger fruit size, adaptability to specific regions, and more disease resistance have replaced it in most areas.

Disease resistance

Plant disease resistance has been an important feature of strawberry breeding. In early work in Maryland, resistance to leaf spot [*Mycosphaerella fragariae* (Tul.) Lindens] was emphasized. With the advent of work in North Carolina, leaf scorch [*Diplocarpon earliana* (Ell. & Everh) Wolf], as well as leaf spot, received emphasis. Attention was directed to resistance to powdery mildew [*Spaerotheca macularis* (Wall. ex Fries) W. B. Cooke] at all locations. However, red stele root rot (*Phytophthora fragariae* Hickman) resistance has commanded the largest breeding effort, beginning shortly after the disease was first detected in the United States in 1935. The disease was first noticed about 1920 in the Lanarkshire district of Scotland where it was called the "Lanarkshire disease" and later "red core disease," but not until 1929 was it determined to be incited by a *Phytophthora* species (1). Anderson (2) reported it as being present in Illinois and referred to its as the red stele disease which Bain and Demaree (3) in Maryland found to be the same as red core of Scotland. It remained for Hickman (11) to establish that it was a new species which he named *Phytophthora fragariae*. The disease was prevalent in several states by 1940, and was causing considerable damage, especially in Maryland, Delaware, New Jersey, Illinois, Arkansas, Oregon, and Washington.

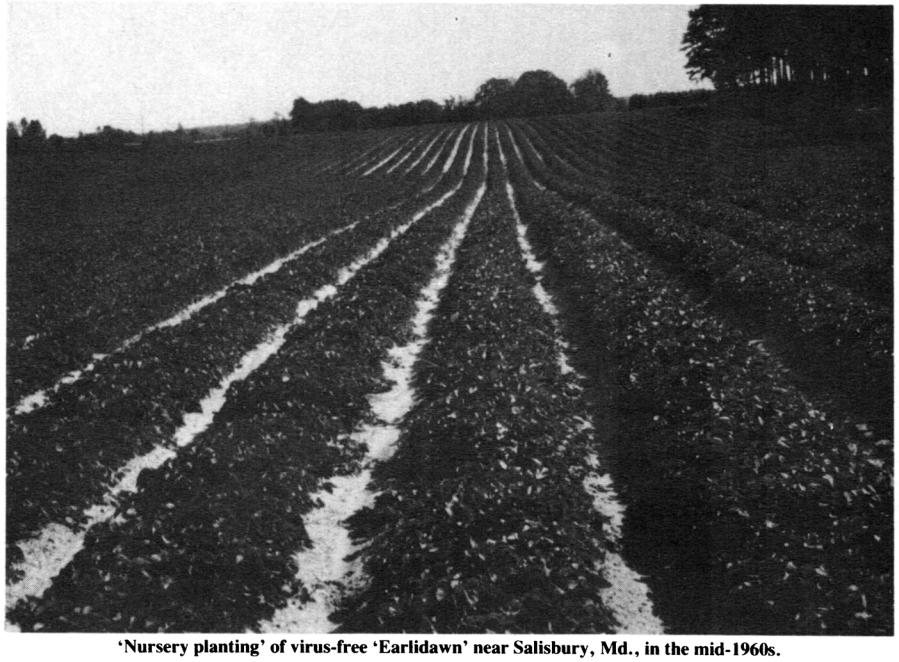
Initially, progenies were screened for resistance by growing them in fields known to be infested with *P. fragariae*, but results were erratic. Waldo was the first to use infested field soils in greenhouse benches as a means of screening seedlings, and the method worked well. However, when it was learned that races of the fungus existed (13), a method was developed to grow seedlings in sand culture in greenhouse benches and flood the sand with zoospores of specific races of the fungus, using fresh cultures each year. Later, Draper et al. (8) refined the technique by dipping the roots of 6- to 8-week-old seedlings in mycelial and spore suspensions of the fungus and planting them in sand in greenhouse benches. A combination of the common eastern U.S. races A-1, A-2, A-3, A-4, and A-6 are currently used at Beltsville in screening seedlings and selections. This method has given consistent infection, with only one selection known to have escaped. Using this method, large numbers of seedlings can be screened in a small area (3600 seedlings per 30.5 m^2 of bench space). Since 1950, 25,000 to 40,000 seedlings have been screened each year at Beltsville and 9,000 to 12,000 at Corvallis for a total of about 1.2 million seedlings in the 30-year period.

Four parental sources of high resistance to red stele have been identified in the United States and used in breeding. These are clones of *F. chiloensis* (L.) Duch. collected by Waldo in Oregon on the shore of the Pacific Ocean, clones of *F. virginiana* Duch. collected by A. F. Yeager in eastern North Dakota, selections from Scotland with 'Frith' parentage obtained from Robert Reid, and 'Aberdeen', an old American cultivar of unknown parentage. Many of the recently introduced cultivars have 'Frith' and 'Aberdeen' parentage in their early lineage.

In 1970, a notable addition to objectives at Beltsville was to originate red stele-resistant everbearing (EB) or day-neutral cultivars. The first crosses had 'Rabunda', 'Ostara', and 'Ozark Beauty' as sources of the everbearing character and did not appear promising. In 1971, California selection 65.65-601 (an everbearing type descended from *F. virginiana glauca*) was obtained from Royce Bringhurst of the University of California, Davis, and was used immediately in crosses with red stele-resistant cultivars adapted to the eastern United States. Results were so satisfactory that further breeding for everbearers has largely dealt with material derived from the CA 65.65-601. The first red stele-resistant everbearing cultivars, 'Tribute' and 'Tristar', were introduced in 1981.

Although genetic studies have been an important part of red stele breeding, the emphasis has focused on origination of cultivars resistant to the disease and adapted to various regions. From the work in Maryland, 15 resistant cultivars have been introduced: 'Allstar', 'Darrow', 'Earliglow', 'Fairland', 'Guardian', 'Midway', 'Redglow', 'Redchief', Scott, 'Stelemaster', 'Sunrise', 'Surecrop', 'Temple', 'Tribute', and 'Tristar'. 'Fairland' and 'Stelemaster' were never grown to any extent. 'Earliglow', 'Guardian', 'Midway', 'Redchief', 'Surecrop', and 'Sunrise' are being grown extensively. 'Scott', 'Allstar', 'Tribute', and 'Tristar' are very recent introductions. In Oregon, 6 cultivars have been introduced: 'Benton', 'Hood', 'Linn', 'Molalla', 'Siletz' and 'Vale'. Of these, 'Molalla' and 'Vale' were not favored, but 'Hood' and 'Siletz' have been grown extensively. The 'Delite' from Carbondale is popular in the central United States for pick-your-own (PYO) plantings.

Virus tolerance is an essential characteristic of cultivars in the Pacific Northwest where large populations of aphid vectors over-



'Nursery planting' of virus-free 'Earlidawn' near Salisbury, Md., in the mid-1960s.

J. R. Magness (left) and George M. Darrow, long-time fruit scientists with the USDA, sample the new 'Scott' strawberry named in honor of D. H. Scott.

winter on wild and cultivated strawberry plants. Screening for virus tolerance has required the testing of selections for several years at several locations. Maintenance of many virtus-indexed stocks in a screenhouse during the screening period has been necessary, but has been an expensive chore. In the eastern United States, virus tolerance has not been so important as in the west, since aphid populations are minimal and the commercial acreage is widely dispersed.

Improvement of fruit characters has included firm flesh, firm skin, bright exterior color, red flesh, good flavor, smooth shape, and uniform large size. Large, uniform fruit size, as exemplified by 'Allstar', 'Guardian', 'Sentinel', 'Titan', and 'Hood', is especially important for rapid and easy picking, whether by PYO harvesting or commercial pickers. The exception has been 'Earliglow' which entices PYO customers because of its pleasant sprightly flavor and fruit rot resistance, despite small berries near the end of harvest.

Recent emphases

Currently, the breeding program, in addition to emphasizing and expanding the red stele resistance work, is focusing on resistance to verticillium wilt (*Verticillium albo-atrum* Reinke & Berth.), anthracnose (*Colletotrichum fragaroae* Brooks), and the everbearing character. First test seedlings that had been screened for resistance to red stele were distributed in 1975 to New Jersey and in 1979 to Wisconsin, New York, and Minnesota for fruiting. The North Carolina station added red stele resistance to its objectives in 1980. Work in Maryland and North Carolina is concerned with combining resistance to red stele, anthracnose, and verticillium wilt with good fruit and plant characteristics. Part of the work on anthracnose resistance is also cooperative with Florida, Louisiana, and the USDA Small Fruit Research Laboratory at Poplarville, Miss. A screening method using young potted seedlings has been developed at Poplarville to identify plants resistant to anthracnose. Prior to 1978, no seedlings were screened for resistance to verticillium wilt, but selections were screened by growing plants in field nursery plots known to be heavily infected with *Verticillium* (15). In 1978 at Beltsville, young seedlings were inoculated by mycelium suspensions of *Verticillium* and grown in sand in greenhouse benches similar to the technique used for red stele resistance screening. During the past 2 years the greenhouse bench technique has been used to evaluate selections and cultivars with uniform results. Micropropagation of selections to obtain plants for extensive testing and introduction is being used as an aid in rapid evaluation and increase of selections. Promising selections are being evaluated for yield in both matted bed and hill systems. Genetic studies on inheritance of economic characters are underway.

Virus investigations and virus-free stocks

Important components of the strawberry breeding work have been virus investigations and maintenance and propagation of virus-free stocks. After Harris and King (10) reported *F. vesca* L. to be a sensitive indicator for viruses in England, Demaree obtained plants of their clone in 1949 and began a study of viruses in the eastern United States. From a survey made of many cultivars from several locations in the eastern United States, Demaree and Marcus (7) reported in 1951 that viruses were widely prevalent in strawberry stocks, including selections and cultivars in the Beltsville breeding plots. Being a pessimistic plant pathologist, Demaree made a wager with Scott that his findings would be ignored and that the breeding would continue

Table 1. Strawberry cultivars originated by the USDA and cooperating state experiment stations, 1928–1981.

Cultivar	Year of introduction	Cooperating agency[z]	Red stele status
Maryland (Beltsville & Glenn Dale)			
Blakemore	*1928*	*None*	*S*[y]
Bellmar	*1931*	*None*	*S*
Redheart	*1931*	*None*	*S*
Southland	*1931*	*None*	*S*
Dorsett	*1933*	*None*	*S*
Fairfax	*1933*	*None*	*S*
Narcissa	*1933*	*None*	*S*
Northstar	*1938*	*None*	*S*
Redstar	*1940*	*None*	*S*
Maytime	*1940*	*None*	*S*
Starbright	*1940*	*None*	*S*
Temple	*1943*	*Md. AES*[z]	*R*
Fairpeake	*1944*	*None*	*S*
Midland	*1944*	*None*	*S*
Suwannee	*1945*	*None*	*S*
Fairland	*1947*	*Md. AES*	*R*
Dixieland	*1953*	*N.C. AES*	*S*
Pocahontas	*1953*	*Va. AES*	*S*
Stelemaster	*1954*	*Md. AES*	*R*
Earlidawn	*1956*	*None*	*S*
Redglow	*1956*	*None*	*R*
Surecrop	*1956*	*Md. AES*	*R*
Midway	*1959*	*Md. AES*	*R*
Sunrise	*1964*	*Md. AES*	*R*
Redchief	*1968*	*Md. AES*	*R*
Guardian	*1969*	*Md. AES*	*R*
Darrow	*1974*	*Md. AES*	*R*
Earliglow	*1975*	*Md. AES*	*R*
Scott	*1979*	*Md. AES*	*R*
Allstar	*1981*	*Md. AES*	*R*
Tribute	*1981*	*Md. AES*	*R*
Tristar	*1981*	*Md. AES*	*R*
North Carolina (Willard)			
Daybreak	1939	AES	S
Eleanor Roosevelt	1939	AES	S
Fairmore	1939	AES	S
Massey	1940	AES	S
Albritton	1951	AES	S
Earlibelle	1964	AES	S
Apollo	1970	AES	S
Atlas	1970	AES	S
Titan	1971	AES	S
Prelude	1980	AES	S
Rosanne	1980	AES	S
Sentinel	1980	AES	S
Sumner	1980	AES	S
Oregon (Corvallis)			
Brightmore	1942	AES	S
Siletz	1955	AES	R
Molalla	1961	AES	R
Hood	1965	AES	R
Vale	1966	AES	R
Benton	1974	AES	R
Linn	1976	AES	R
Wyoming (Cheyenne)			
Early Cheyenne 1	1942	None	S
Cheyenne 2	1942	None	S
Cheyenne 3	1942	None	S
Sioux	1948	None	S
Arapahoe	1954	None	S
Radiance	1954	None	S
Ogalalla	1956	Nebraska AES	S
Fort Laramie	1973	None	S
Illinois (Carbondale)			
Delite	1974	S. Ill. Univ.	R

[z]AES = Agricultural Experiment Station of each state.
[y]R = resistant; S = susceptible.

in its old manner. However, methods were developed to prevent infection and spread of viruses in the Beltsville plots and Demaree lost the wager (but never paid his bet!). From information developed at Beltsville and other locations several state departments of agriculture in the United States initiated state virus certification programs for strawberry nursery stocks, beginning about 1955. The American Pomological Society awarded its esteemed Wilder Medal in 1962 to the Beltsville Small Fruits Unit for its leadership in the protection of strawberries from virus diseases.

Conclusion

The principal thrust in the over-all program has been, and continues to be, origination of disease-resistant cultivars. USDA germplasm has been the source of red stele resistance for a number of American and foreign breeding programs. Since the inception of the program, 61 cultivars have been introduced (Table 1). Many of these cultivars have been grown widely, notably 'Blakemore', 'Earliglow', 'Fairfax', 'Guardian', 'Midway', 'Pocahontas', 'Redchief', 'Sunrise', 'Surecrop', 'Albritton', 'Atlas', 'Apollo', 'Earlibelle', 'Hood', 'Siletz', and 'Delite'. Many of the others have been grown regionally and have been used as parents.

Numerous technical reports have been published during the course of the work. These have dealt with species hybridization, polyploidy, seed germination, inheritance of economic characters, and breeding methods. References to these studies are found in Darrow (4, 5), Scott and Lawrence (14), and most recently in Melville et al. (12).

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Extension Response to a Serious Freeze in Florida[1]

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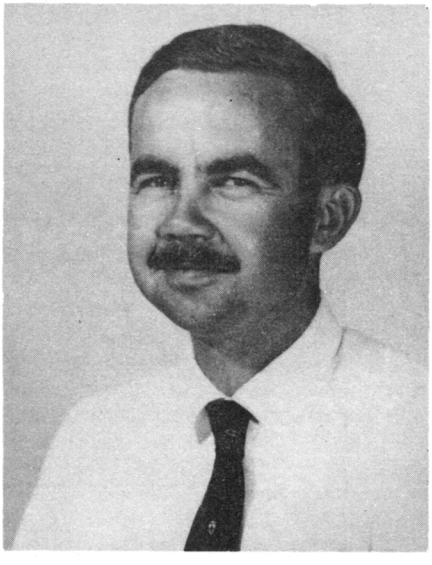
The severe freeze of January 12–14, 1981 gave Florida Fruit Crops Extension faculty some serious challenges and unique opportunities in ensuing months. Record-breaking low temperatures throughout peninsular Florida severely damaged much of Florida's citrus and growers were faced with many problems dealing with rehabilitation and care of frozen fruit and trees. Within 24 hours after the severity of the freeze was apparent, Extension faculty of the University of Florida's Department of Fruit Crops had formulated a massive state-wide effort of intensive Extension to help growers cope with their problems. This paper outlines the procedure used to formulate this educational program.

Severe freezes are infrequent in Florida and rarely cause widespread damage to the entire peninsula. Prior to the 1981 freeze, several lesser freezes (notably in 1971 and 1977) dealt damage to some areas of the state, but a really serious freeze had not occurred in the state since December, 1962. The area devoted to bearing-age citrus in Florida increased from 22,000 ha in 1962 to over 31,000 ha in 1981 (1). Another 3,000 ha of non-bearing trees were in the ground at the time of the freeze. Much of this development was planted by growers who had little or no experience in dealing with freezes of this magnitude. The availability and increased cost of heating devices and the fuel to operate them had also drastically altered cold protection practices since 1962. Therefore, many Florida citrus growers had no cold protection or cold damage experience and, due to the prohibitive cost of cold protection, many areas were damaged in this freeze which had not been seriously hurt in the past.



L. K. Jackson

Fortunately, as the citrus industry expanded, new groves had been planted in warmer areas in south Florida so that the overall damage sustained by the industry was not as serious as it might have been under the same conditions 20 years earlier, when much of the industry was located further north.

Faculty of the Fruit Crops Department were alerted to the potential danger of a massive cold front on January 11, 1981. By the evening of January 12th, it was obvious that critically low temperatures would occur in most of peninsular Florida. Later that eve-

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