sistently productive due mainly to later flowering.

Most SHB cultivars and selections could use more plant vigor. Disease resistance is good, but insect resistance is needed, for especially blueberry gall midge (*Dasineura oxycoccana* Johnson) and cranberry fruit worm (*Acrobasis vaccinii* Riley). Marketing windows dictate some of the breeding goals. Since SHB fruit is grown for the early markets, early ripening coupled with late flowering are needed plant characteristics. In other words, a short interval between rather late flowering and fruit ripening would facilitate early ripening and reduce the risks of late spring frosts. Those areas with very low chilling, such as central Florida, need cultivars adapted to that environment. We currently do not have a simple, short test to determine chilling requirements of the blueberry selections. Such a test would facilitate the breeding for low-chilling types.

I believe that all the genes needed to obtain the blueberry cultivars for the differing environments within the southern US are existent. They are in the vast treasure of native *Vaccinium* species and cultivated germplasm. It is up to the breeder to learn what is needed by growers, the markets, and consumers and then systematically search for it.

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Small Fruit Breeding for the Southern United States: Strawberries

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Abstract

This review briefly summarizes the development of the strawberry (*Fragaria x ananassa* Duchesne) industries of the southern United States during the twentieth century, their problems, major cultivars, and breeding programs. The breeding objectives, contributions, and personnel of the several state and federal improvement programs are presented in more detail. Some ideas are offered about the future of the southern strawberry industries, and how the objectives of the fewer remaining breeding programs may have to be altered to accommodate the new and continuing problems of the growing and consuming public.

Historical

While all of the southern United States did and do produce strawberries, major commercial centers during the first half of the twentieth century were Louisiana, Florida, Tennessee, Missouri, Arkansas, Alabama, Kentucky, and Virginia. Maryland, Delaware, Texas, and Mississippi had smaller industries (2). 'Klondike,' Missionary,' 'Aroma,' 'Chesapeake,' 'Parsons,' 'Joe,' and 'Gandy' were the principal southern cultivars of 1900 to 1940, with 'Blakemore' and 'Tennessee Beauty' becoming important in the 1930s and 1940s (1). 'Klonmore' and 'Massey' began to be grown in the 1940s; 'Florida Ninety,' 'Albritton,' 'Armore,' 'Pocahontas,' and 'Dixieland' in the 1950s. 'Blakemore' and 'Tennessee Beauty' continued to be important cultivars into the 1970s. By the 1960s 'Headliner' and 'Dabreak' were commonly grown in Louisiana.

Traditionally, almost all of the strawberries grown in the South have been intended for the fresh fruit shipping trade. The later season crops might be offered to local markets and limited processing outlets in some years. Strawberry culture in the early season and some second early crop districts of the South was annual cul-

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ture and grown as individual "hills." The majority of the strawberries in the Upper South were grown as spring-planted, perennial matted rows until recently.

Problems of strawberry culture in the South were temperature stress, leaf disease (particularly leaf spot (caused by *Mycosphaerella fragariae* (Tul.) Lindau)) and leaf scorch (caused by *Diplocarpon earliana* (Ell & Ev) Wolf), and powdery mildew (caused by *Sphaerotheca macularis* (Wallr. Ex. Fr.) Jacz.f. sp. *fragaria*) to a lesser extent), drought tolerance, root-knot nematodes (*Meloidogyne* spp.), cyclic fruit ripening, and potentially flooding rains during the growing and fruiting seasons. Some regions of the South were also concerned with resistance to the red stele root rot fungus (*Phytophthora fragariae* Hickman). Strawberry breeding programs at several of the southern agricultural experiment stations sought to overcome these problems by producing tolerant hybrid genotypes and balancing these plant characters with fruit of good dessert and shipping quality, high production, fine color, sweetness, and large size.

Strawberry breeding for various parts of the South has been carried on at several U.S. Department of Agriculture Laboratories and by the Florida, Arkansas, Louisiana, Texas, Tennessee, North Carolina, Mississippi, Missouri, and Maryland Agricultural Experiment Stations. Breeding continues presently in Florida, Louisiana, North Carolina, at the Beltsville, Md. and Poplarville, Miss. USDA Laboratories, and selection evaluations from the Arkansas program are being completed.

Review of Southern U.S. Strawberry Breeding Progress

Arkansas. (Information supplied by J. N. Moore) Breeding at the University of Arkansas was begun in 1964 by J. N. Moore. The major cultivars grown at the time were 'Blakemore' (which was too small-fruited and susceptible to leaf spot) and 'Tennessee Beauty' (which ripened too late for the best market prices). Early parents in the program which were used extensively were 'Sunrise,' NC 2655, 'Surecrop,' 'Albritton,' 'Raritan,' 'Earlidawn,' 'Earlibelle,' MD-US 2289, and 'Jerseybelle.' Three cultivars were released from this program, 'Cardinal' (1974), 'Comet' (1975) and 'Arking' (1981). 'Cardinal' became the predominant strawberry grown in Arkansas, and a leading cultivar in several other southern and southeastern states. 'Comet,' although earlier than 'Cardinal,' was not as large or productive, and most growers preferred 'Cardinal.' 'Arking' is late-maturing and resistant to red stele, and growers who have red stele or who wanted to extend their ripening seasons have grown it. In 1993, the University of Arkansas closed the strawberry Substation at Bald Knob, the breeding selections were moved to Fayetteville, and the program was downsized. The last seedlings were fruited at Fayetteville in 1995, and no additional crosses are planned. Remaining selections will be evaluated for varietal potential over the next several years.

The major cultivars grown now in Arkansas are 'Cardinal' and 'Earliglow,' neither of which is resistant to anthracnose (caused by *Colletotrichum* spp.), the major production problem. Strawberries are now a minor fruit crop in Arkansas, with most being marketed as U-pick, at roadside stands, and in local markets.

Florida. (Information supplied in part by C. K. Chandler) Breeding work was started in Florida by A. N. Brooks, plant pathologist at Plant City, in the 1930s. The principal success of the early program was the introduction of 'Florida Ninety' in 1952. By 1960, it was almost the only cultivar grown in Florida, due to its high yields, large size, bright scarlet color, and high flavor. Strawberry yields in Florida were increased by preplant soil fumigation, culture on raised beds mulched with black plastic, more defined fertilization practices, and the use of planting stock from northern nurseries. J. Strobel at the Homestead Station began breeding for Verticillium wilt resistance (caused by *Verticillium albo-atrum*

Reinke & Berth) in 1962, and several of his parent lines were later used by G. J. Galletta of the USDA in breeding for southern adaptation and disease resistance.

Since 1963, strawberry breeding has been centered at the Dover Station east of Tampa, Fla., first under the direction of Charles Howard, and, since 1987, led by Craig Chandler. The 'Flordabelle' and 'Dover' cultivars were produced by Howard as anthracnose resistant, high yielding, shipping types particularly well adapted to Florida. However, the industry started to use a succession of University of California cultivars that were productive, well-colored, had good shipping characteristics, and were well suited to early and late market niches. This trend is being reversed. Chandler's 'Sweet Charlie' released in 1992, is now planted to 38% of the Florida production area. 'Sweet Charlie' is important for its high early season yield, excellent fresh fruit flavor, and resistance to anthracnose fruit rot. 'Rosa Linda,' introduced in 1996, is noted for producing attractive, conically-shaped fruit with a full-bodied and aromatic fresh fruit flavor. Current breeding emphases include: desirable fruit quality (i.e., appearance, size, firmness, flavor, and resistance to water damage); open plant architecture (for improved harvest and spray efficiency); desirable fruiting pattern and high productivity; and disease resistance (principally to anthracnose and Phomopsis fruit rots caused by *Phomopsis obscurans* (Ell. & Ev.) Sutton). Florida has also participated, since 1976, in a cooperative regional project with the USDA to originate anthracnose resistant cultivars for the Southeast. One of the early resistant selections from the cooperative program is a grandparent of 'Sweet Charlie.'

The Florida industry has been steadily growing for the past several years despite active competition from producing areas in southern California and Mexico, and concern for the proposed banning of methyl bromide fumigant. The strawberry is the second most important fruit crop in Florida in terms of dollars generated. Florida is the major supplier of fresh strawberries to the eastern and midwestern U.S. and Canadian cities during December, January, and February.

Louisiana. (Information supplied in part by R. J. Constantin) Strawberry breeding in Louisiana was started in Baton Rouge by Julian Miller and P. L. Hawthorne in 1935 to develop cultivars resistant to leaf spot and leaf scorch with as good shipping qualities as 'Klondike' and less acidity. A notable feature of the early program was the artificial inoculation of seedlings with spore suspensions of the leaf spot and leaf scorch inciting fungi. Six cultivars have been introduced by the Louisiana Agricultural Experiment Station 'Klonmore' (1940), 'Konvoy' (1945), 'Marion Bell' (1948), 'Headliner' ('1957), 'Dabreak' (1961), and 'Tangi' (1973). 'Klonmore' replaced 'Klondike,' and was succeeded in turn by 'Headliner,' 'Dabreak,' and 'Tangi.' When 'Tangi' became susceptible to anthracnose, the industry grew a number of California cultivars, notably 'Chandler.'

Catherine Lundergan directed the program after Professor Hawthorne's retirement, and participated in a regional cooperative breeding project with the USDA, beginning in the late 1970s, to originate cultivars resistant to anthracnose crown rot. The Louisiana breeding program was transferred to Hammond in 1986 and led by T. J. DiVittorio. R. J. Constantin became the project leader in 1992. He is assisted by J. Quebedeaux. The cooperation with the USDA continues, aimed at incorporating plant and fruit quality with the necessary anthracnose crown and fruit rot resistance. A selection made at Hammond from the cooperative program, which is resistant to both anthracnose and red stele, was named 'Pelican' and introduced in 1996. 'Pelican' has yielded as well or better than 'Tangi' in Louisiana, but has varied with respect to 'Chandler,' better in some years, poorer in others, 'Pelican' also seems more susceptible to rain damage than 'Chandler' and 'Tangi.'

In the early 1930s there were 30,000 acres of strawberries grown in Louisiana. In recent years the acreage has remained fairly constant around 1000 acres with an estimated farm value of $10 million, and average yields of 1000 to 1500 flats (12 pints, 10 pounds net weight per flat) per acre.

Maryland. From 1937 to 1986 the University of Maryland cooperated with the USDA at Beltsville to originate strawberry cultivars possessing red stele root rot resistance. W. F. Jeffers, L. O. Weaver, J. Kantzes, I. C. Haut, F. J. Lawrence, G. Stadelbacher, H. D. Stiles and H. J. Swartz all represented the University in this cooperative program at different times and in varying capacities.. Fifteen red stele resistant cultivars were introduced by the USDA and the Maryland Agricultural Experiment Station in the period 1943 to 1994, including the commercially successful 'Earliglow,' 'Allstar,' 'Guardian,' 'Lester,' 'Midway,' 'Redchief, 'Scott,' 'Sunrise,' Surecrop,' 'Temple," Tribute' and' Tristar.' From 1952 until Haut's death, the University had a separate breeding program also to develop cultivars for high elevations, for everbearing sorts and for late Junebearers. The cultivar 'Marlate' was introduced from the separate Maryland program, but was not widely grown because it lacked red stele resistance.

The USDA strawberry breeding in Maryland started at Glen Dale, Md. in 1920 and moved to Beltsville, Md. in 1932, where it is still headquartered. George Darrow was the original project leader, and he was aided by George Waldo, and followed by Donald Scott, Arlen Draper, and Gene Galletta. Though widely known for the 40 cultivars it has produced that were principally adapted to the northeastern and midwestern U.S., the USDA-Maryland program has been very active in breeding strawberries for the southern U.S. It has helped originate and introduce 15 cultivars especially for the South, such as 'Dixieland' and 'Pocahontas.' The USDA has been breeding strawberries cooperatively with North Carolina since 1928 (see the North Carolina discussion), and making the crosses for the cooperative anthracnose program since 1978 (see the Louisiana and Mississippi discussions). Additionally, many of the cultivars originated in the northern portion of the program performed well in many of the piedmont and mountain regions of the South. Examples include 'Blakemore,' 'Earliglow,' 'Surecrop,' 'Scott,' 'Delmarvel,' etc.

Mississippi. J. P. Overcash started a breeding program at Mississippi State College in 1948 to obtain cultivars capable of withstanding hot dry summers. One cultivar, 'Earlimiss,' was named from this program. Since 1976, the USDA's Poplarville, Miss. laboratory has carried on work on anthracnose disease biology and resistance breeding under the direction of pathologist Barbara Smith, aided by geneticists Creighton Gupton and Gene Galletta. The work has been cooperative with the Louisiana, Florida, and North Carolina Agricultural Experiment Stations, and was summarized by Smith, et al. (3). Four anthracnose resistant parent clones, US 70, US 159, US 292, and US 438 were introduced in 1992, and the first cultivar from the cooperative program, 'Pelican,' described in the Louisiana section, was released in 1996.

Missouri. Some early breeding work started in the 1890s did not result in any new cultivars, but did provide some interesting information on the inheritance of sex in strawberries. A later program was started by H. G. Swartout in 1934 and continued by D. D. Hemphill in 1953. The productive, large, and flavorful 'Armore' cultivar was introduced from this program in 1950. Unfortunately, it proved very susceptible to powdery mildew. The later goals of the program included red stele resistance, and many of the resistant cultivars from the USDA proved adapted to Missouri.

North Carolina. Continuous strawberry breeding and selection testing was started cooperatively with the USDA at the former Willard Station of the North Carolina Department of Agriculture

(NCDA) in 1928. Charles Dearing represented the NCDA and George Darrow the USDA in the cooperative effort. One of their first significant products was 'Blakemore,' which proved adapted to a large portion of the south-central region. The objectives of the work have been to secure large, attractive, good shipping, disease resistant, high-flavored, productive cultivars for the Southeast. The North Carolina Agricultural Experiment Station (NCAES) joined in the cooperative work in 1936, with E. B. Morrow representing the NCAES (now the North Carolina Agricultural Research Service-NCARS). Of five cultivars introduced during the period 1936 to 1951, only 'Massey' and the beautiful 'Albritton' were successful commercially. J. W.Sumner succeeded Dearing as Superintendent of the Willard Station. After Morrow's death in 1956, he was succeeded by G. W. Schneider (1956 to 1958), F. E. Correll (1959), and G. J. Galletta (1959 to 1977), J. R. Ballington (1977 to 1984, 1990 to present) and R. Goldy (1980 to 1986). Four superior cultivars released during Galletta's tenure have proved to be durable for matted row culture in the South ('Earlibelle,' 'Apollo,' 'Atlas,' and 'Titan'). 'Earlibelle' was one of the parents of 'Flordabelle' and' Cardinal,' and Atlas' imparted its aroma to the new 'Delmarvel.' Four cultivars released in 1980 ('Sumner,' 'Prelude,' 'Sentinel,' and 'Rosanne'), although possessing many fine qualities, have not been widely grown because the California cultivar 'Chandler' began to be grown as an annual crop in a plasticulture system devised by Barclay Poling and associates. 'Chandler' had a longer fruiting period, fine shipping characteristics, larger fruit size, and good flavor. During Galletta's tenure, selection and seedling testing was extended to a larger number of NCDA research stations. Superintendents associated with the work were Jesse Sumner, Fred Cumbo, John Scott, John Smith, and Harley Blackwell.

Since the anthracnose epiphytotic in portions of North Carolina during 1975, resistance to the disease has become a breeding objective In some parts of the state, red stele resistance has also become necessary. North Carolina has participated in the USDA cooperative anthracnose resistance breeding program since its inception, and was one of the partners introducing the new 'Pelican.'

In recent years the North Carolina program has added the origination of cultivars suitable for plasticulture as an objective, as well as maintaining the matted row objectives. Additionally, Ballington has participated in several domestic and foreign plant explorations which sought to enlarge the strawberry breeding gene pool He is now enhancing the germplasm from several species by introgressing them into the cultivated strawberry.

Tennessee. Breeding work began under the direction of B. D. Drain at Knoxville in 1928. The objectives were to obtain attractive, firm, high-flavored cultivars suitable for processing and shipping, which were also resistant to leaf and root disorders. The work was moved to Jackson in 1935 and later returned to Knoxville. Five cultivars have been released from this program, 'McClintock' (1932), 'Tennessee Supreme' (1940), 'Tennessee Shipper' (1941), 'Tennessee Beauty' (1942) and 'Tennessean' (1950). Of these, 'Tennessee Beauty' has been widely grown, and is still of some importance. 'Tennessee Shipper' proved to be a fine parent for firmness, and is in the ancestry of many of the USDA-Maryland releases. Other workers associated with the Tennessee strawberry breeding program have been E. M. Henry, L. A. Fister, J. P. Overcash, E. H. Hanchey, P. L. Hawthorne, and W. E. Roever.

Texas. A breeding program was initiated in 1933 to obtain cultivars that would produce sufficient runner plants able to survive under high south Texas temperatures. Three cultivars were named from this program, 'Alamo,' 'Ranger,' and 'Riogrande,' all in 1937. Culture of 'Ranger' persisted in south Texas at least until the mid 1960s.

Future Directions of Southern Strawberry Breeding

It is difficult to predict a general direction for the strawberry industries of the South. The shipping trade will continue to be impacted by competition from other growing regions, and by the possible loss of the methyl bromide fumigant in the year 2000. I would expect fresh fruit out-of-region shipment to be the principal sales outlet for much of the fruit produced in Florida, parts of Louisiana and North Carolina, and perhaps Tennessee. The growing population of the South indicates that there may be more intra-regional sales and consumption of local strawberries. There is no evidence that processing will become a major outlet in the region. There are also a number of specialized marketing opportunities that may become of local importance, particularly for the off-season trade. With increased competition from other fruits the strawberry may not have quite the importance which it has had in the South in the past, but the general appeal of the strawberry has not diminished in the U.S. or abroad.

There will be fewer breeding programs in the South, but their major objectives must remain similar to those of the present. General and specific tolerance to major leaf, root and fruit diseases, insect pests, and environmental stresses must be paramount in a diverse region like the South, with its extreme climatic and moisture fluctuations. The disease and insect tolerances are further mandated by increasing pressure from the public to reduce pesticide use. For the annual plasticulture growers, it will be necessary to maximize production in a continuous mode. Selection may have to be in favor of reproductive over vegetative traits. Consistent large fruit size in the 15 to 30 gram per berry range will have to be accompanied by uniform bright red external color and high glossiness of the fruit epidermis, the best combination of sweetness, acidity and aroma, and a tough fruit "skin" that will resist water, wind and temperature damage. For matted row growers the plant health requirements must be balanced by high vigor and good and rapid plant making ability. The fruit requirements remain the same, with special emphasis on fine flavor retention, color and good shelf life. For the pick-your-own and special market situations, the ability to resist weather extremes on the plant assumes increasing importance.

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Morioka Apple Rootstocks

Ten rootstock clones from the crossing of M. prunifolia and M.9 were selected by the high bark/wood ratio and easy propagation of hardwood cuttings in 1984. The rootstocks have various tree size control effects ranging from M.27 to M.7 in size. Most of the candidates have good productivity and result in good fruit quality. Propagation of the series is much better than MM.106. Almost all rootstocks are resistant to crown rot. From Bessho et al. 1994. ISHS Hort Congress Abstract O-1-2 p. 33.