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University of Florida Tomato Breeding Accomplishments and Future Directions

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ABSTRACT

Fresh market tomato (*Lycopersicon esculentum* Mill.) breeding began at the Univ. of Florida in 1922. Contributions from the program have been a key reason why tomato is the most valuable vegetable in Florida, and that Florida is by far the leading state in fresh market tomato production in the USA. At present, 44 cultivars/breeding lines have been released, of which 41 are open-pollinated and three are hybrids. Five additional releases are planned for 1999. Seed companies did not have significant involvement in tomato breeding for Florida until the 1970's, when hybrids began to take over the market. Thus, much of the germplasm used in present-day Florida varieties and elsewhere in the world traces to improvements derived from the UF program. There have been nine scientists at the Univ. of Florida with a primary responsibility to breed tomatoes, although numerous cooperators have also made significant contributions. Some of the significant advancements were: the eradication of nailhead rust (*Alternaria tomato* (Cke.) Weber) in the 1930's by the use of resistant cultivars; the combination of more than five disease resistances in 'Manalucie' in 1953; the first Fusarium wilt [*Fusarium oxysporum* Schlecht. f. sp. *lycopersici* (Sacc.) Snyder & Hansen] race 2 resistant (*I-2* gene) cultivar 'Walter' in 1969; the development of cultivars with high levels of fruit firmness and jointless pedicels in the 1970's; the development of commercially acceptable heat-tolerance with the release of 'Solar Set' in 1989; the discovery of resistance to Fusarium wilt race 3 (*I-3* gene) in the 1980's; and the release of breeding lines with *I-3* in 1994. The release of the miniature dwarf 'Micro-Tom' in 1989 provided a model system for modern mutagenesis techniques for plants with fleshy fruit. Of possible importance in the future are the development of: high lycopene (*og* gene) hybrid cultivars with superior internal color and flavor; germplasm with resistance to the three races of bacterial spot (*Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye) that infect tomato; and the development of improved germplasm with resistance to the geminiviruses tomato mottle virus (ToMoV) and, especially, tomato yellow leaf curl virus (TYLCV). The impact of the Univ. of Florida tomato breeding program has been important not only to the livelihood of Florida growers but also to tomato breeding programs around the world.

EARLY RESEARCH/CULTIVARS

The Gulf Coast Res. & Educ. Center originated as the Tomato Disease Laboratory in 1925. One of the early areas of research was the evaluation and selection of experimental tomato breeding lines for adaptation to local conditions and resistance to diseases. The breeding work actually started in 1922 when a local grower, J. P. Harlee Sr., donated ≈ 2 ha for tomato breeding (Crill et al.,1977b). The early work was largely pathology-related and resulted in the release of several cultivars before a full-fledged tomato breeding position was established in 1942. The primary scientists who have developed tomato cultivars at the Univ. of Florida are listed in Table 1. Several of the scientists were not trained specifically as plant breeders. G. F. Weber was a plant pathologist from the Gainesville campus who traveled to Manatee county to evaluate tomato breeding lines, identify disease problems, and select for resistances. Drs. Harrison, Walter, Crill, Villalon and Volin also were trained primarily as plant pathologists. Many others have been involved as cooperators in the breeding program. A chronological list of tomato releases with their year of release is given in Table 2, along with the last name of most of the authors for each release. For a complete listing of authors see Jones et al. (1995).

The attributes of many of the variety releases have been one of the major reasons why tomato production has been commercially successful in Florida. Over 2 630 ha (6 500 acres) of tomatoes were grown in Florida in 1900. The area increased to 11 736 ha (29 000 acres) in 1930, reached a peak of 26 710 ha (66 000 acres) in 1957, fell to 18 454 ha (45 600 acres) in 1990 and had dropped to about 14 165 ha (35 000 acres) by 1997. The recent decrease in area is due, in large part, to Mexican competition. The crop value has been as high as $800 million per year. The value in 1996-1997 was $462 million (Florida Agric. Stat. Serv., 1998), making tomato the most valuable vegetable crop grown in the state. Florida has the highest fresh market tomato crop value in the United States.

Some of the early contributions were resistance to the fungal pathogen nailhead rust, which was eradicated as a result of the resistant cultivars released from 1925-1940 (Table 2). The single dominant *I* gene conferring resistance to Fusarium wilt race 1 was discovered elsewhere, but introduced into Florida cultivars in the 1940's. Another major disease resistance gene (*Sm*) conferred resistance to the foliar fungus causing gray leafspot (*Stemphyllium solani* Weber), with *Sm* being introduced in the 1950's. 'Manalucie' (Walter and Kelbert, 1953) was an important release combining *I*, *Sm*, gray mold (*Cladosporium fulvum* Cke.) resistance, plus field tolerance to early blight (*Alternaria solani* (Ell. & Mart.) L. R. Jones & Grout, and some other diseases. 'Homestead', or derivatives of it, was widely grown in Florida for much of the 1950's and 1960's. This was a de-

Table 1. Univ. of Florida tomato breeders.

Breeder	Location	Tomato Breeding Assignment
G. F. Weber	Gainesville	1922-1941
A. L. Harrison	Bradenton	1942-1944
J. M. Walter	Bradenton	1947-1967
J. W. Strobel	Homestead†	1959-1968
B. Villalon	Homestead	1969-1971
J. P. Crill	Bradenton	1968-1974
R. B. Volin	Homestead	1971-1984
J. J. Augustine	Bradenton	1975-1980
J. W. Scott	Bradenton	1981-present

†Moved to Bradenton as Center Director 1968-1971.

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Table 2. Chronological listing of Univ. of Florida tomato variety and breeding line releases and their developers.

Variety	Date Released	Author(s)†
Marglobe (Coop. USDA)	1925	Weber, Prichard, Porte
Glovel (Coop. USDA)	1935	Weber, Prichard, Porte
Newell	1940	Weber, Kelbert
Cardinal King	1940	Weber, Kelbert
Ruby Queen	1940	Weber, Kelbert
Manasota	1949	Walter, Beckenbach, Kelbert
Manahill	1949	Walter, Beckenbach, Kelbert
Manalucie	1953	Walter, Kelbert
Homestead (Coop. USDA)	1953	Andrus, USDA & Florida AES
Manalee	1954	Kelbert, Walter
Indian River	1958	Hayslip, Walter, Kelbert
Manapal	1960	Walter, Kelbert, Hayslip
Floralou	1962	Whitner, Walter, Kelbert, Hayslip
Floradel	1965	Hayslip, Walter, Kelbert, Everett
Immokalee	1966	Everett, Kelbert, Hayslip, Walter et al.
Tropi-Red	1967	Strobel, Walter, Hayslip
Tropi-Gro	1967	Strobel
Tropic	1969	Strobel, Walter
Walter	1969	Strobel, Hayslip, Burgis, Everett
Florida MH-1	1971	Crill, Strobel, Burgis, Bryan, John
Florida 556	1972	Strobel, Crill, Burgis, John
Flora-Dade	1976	Volin, Bryan, Burgis, Everett, Hayslip
Floramerica	1977	Crill, Bryan, Everett, Bartz et al.
Florida 1011	1977	Volin, Augustine, Bryan, Strobel et al.
Walter PF	1977	Burgis, Crill, Hayslip, Everett et al.
Calypso (co-op. Caribbean Agric Res. & Dev. Inst.)	1977	Phelps, Crill, Bryan, Everett et al.
Burgis	1981	Augustine, Volin, Everett, Bryan et al.
Hayslip	1981	Augustine, Volin, Bryan, Everett et al.
Florida 2432	1981	Augustine, Volin, Bryan, Everett et al.
Florida 1A, 1B, 1C	1981	Augustine, Volin, Burgis, Everett et al.
Florida Petite	1981	Augustine, Harbaugh, Crill
Florida Lanai	1981	Augustine, Harbaugh, Crill
Florida Basket	1981	Augustine, Harbaugh, Crill
Horizon	1985	Scott, Bartz, Bryan, Everett et al.
Suncoast	1985	Scott, Everett, Bryan, Gull et al.
Floragold Basket	1987	Scott, Harbaugh
Micro-Tom	1989	Scott, Harbaugh
Solar Set	1989	Scott, Olson, Bryan, Howe et al.
Equinox	1994	Scott, Olson, Howe, Stoffella et al.
Florida 7547, 7481	1994	Scott, J. P. Jones
Micro-Gold	1994	Scott, Harbaugh
Neptune	1994	Scott, J. B. Jones, Somodi, Chellemi et al.

†For complete listing see Jones et al., 1995.

terminate cultivar due to the *sp* gene, whereas previous Univ. of Florida releases and several others released in the 1960's had indeterminate growth habits.

In the 1960's, race 2 of Fusarium wilt was causing major losses to the Florida tomato industry. The release of 'Walter' (Strobel et al., 1969) marked the world's first cultivar with the *I-2* gene which conferred resistance to this pathogen. The *I-2* gene was discovered by Univ. of Florida scientists (Stall and Walter, 1965) in a Plant Introduction (PI 126915) identified by Alexander (1959) prior to the discovery of race 2 in Florida. The *I-2* gene is one of the most widely used genes in tomato cultivars the world over. 'Walter' was the second determinate cultivar released by the Univ. of Florida. All the cultivars released subsequent to it are also determinate (Table 2). A cooperative project between the Univ. of Florida and the H. J. Heinz Company resulted in the development of tomatoes with improved fruit firmness that was the primary source of firmness for breeding programs around the world (Scott, 1983). This project led to 'Florida MH-1' (Crill et al., 1971), a cultivar that could be machine-harvested because it combined firm fruit, concentrated fruit setting, and jointless pedicels. Jointless pedicels remain on the plants, allowing for stemless fruit to be harvested and thus eliminating fruit punctures. Unfortunately, 'Florida MH-1' caused a major stir in the public press as it was the target of the report "Hard tomatoes, hard times . . .," a critical analysis of research in the Land Grant university system (Hightower, 1973). Another jointless pedicel cultivar 'Flora-Dade' (Volin et al., 1976) proved highly adaptable, and was grown commercially throughout the southeastern U.S. and in many regions around the world including Africa and Australia. In the 1970's, private seed companies began to breed tomatoes for Florida and their hybrids began to take major market share in the state for the first time. The hybrid 'Sunny' was released by Asgrow Seed Co. and became the major cultivar grown in Florida and parts of the Southeast during the 1980's. To date it has been one of the most successful fresh market tomato hybrids grown in the world. One of the parents in 'Sunny' was Flora-Dade. 'Floramerica' (Crill et al., 1977a) was the first hybrid released by the Univ. of Florida and won a bronze medal in the 1974 All America Vegetable trials. It has been widely grown in home gardens throughout North America.

'Florida Petite', 'Florida Lanai', and 'Florida Basket' were the first dwarf (*d* gene) cultivars released by the Univ. of Florida (Augustine et al., 1981a,b,c). They were intended for use in the nursery industry and in the bedding plant trade. 'Micro-Tom' (Scott and Harbaugh, 1989) is a miniature dwarf cultivar dubbed "the world's smallest tomato", again released primarily for the nursery industry. This cultivar recently has been used for mutagenesis work including modern techniques such as transposon tagging. A picture of 'Micro-Tom' was featured on the cover of the "Plant Journal" along with Arabidopsis, and it was proposed that 'Micro-Tom' be used as a model system for fleshy fruited crops in such work (Meissner et al., 1997). 'Solar Set' was the second hybrid released by the Univ. of Florida and the first to have heat-tolerant fruit setting ability (Scott et al., 1989). It has been an important fall tomato in Florida throughout the 1990's, especially in North Florida. Also, it is superior in flavor to many varieties and has been part of numerous taste panel studies (Baldwin et al., 1996). 'Florida 7481' and 'Florida 7547' were released as breeding lines with the *I-3* gene conferring resistance to Fusarium wilt race 3 (Scott and Jones, 1995). The hybrid 'Floralina', presently available from Petoseed Co., uses Florida 7547 as a parent to provide Fusarium wilt race 3 resistance. The *I-3* gene was discovered in research conducted by scientists associated with the Univ. of Florida breeding program (Scott and Jones, 1989) and *I-3* is now widely used in tomato breeding programs around the world. 'Neptune' was the first bacterial wilt [*Ralstonia solanacearum* (Smith) Yabuuchi et al.] tolerant cultivar released from the Univ. of Florida (Scott et al., 1995). It is being used primarily in North Florida home gardens that are infested with the bacterial wilt pathogen.

CURRENT CULTIVARS

Three breeding-line releases are planned for next year (Scott, 1998, Table 3). 'Florida 7771' is a heat-tolerant, jointless pedicel inbred that has performed well in spring and summer trials over the past 2 yr. It has been difficult to develop large fruited, jointless, heat-tolerant inbreds without major fruit defects. Florida 7771 has resulted from a long-term breeding effort and should be useful to breeders in developing heat-tolerant, jointless hybrids. 'Florida 7775' and 'Florida 7781' have jointless and jointed pedicels, respectively, and are resistant to Fusarium crown and root rot (*Fusarium oxysporum* Schlect. f.sp. *radicus-lycopersici* W. R. Jarvis & Shoemaker), a disease that has caused problems in southwest Florida. Florida 7775 and Florida 7781 should be useful to tomato breeders who are developing hybrid cultivars with resistance to this disease. Also planned for release are red fruited 'Micro-Tina' and yellow fruited 'Micro-Gemma', miniature dwarf tomatoes that have sweeter flavor than their respective predecessors, 'Micro-Tom' and 'Micro-Gold'.

Table 3. Proposed tomato releases during 1999.

Cultivar†	Major Characteristics
Florida 7771	heat-tolerant, medium-large fruit, jointless pedicel
Florida 7775	Fusarium crown-rot resistant, very firm, jointless pedicel, crimson (*og*)
Florida 7781	Fusarium crown-rot resistant, jointed pedicel, crimson (*og*)
Micro-Tina	miniature dwarf, red fruited, sweet-balanced flavor
Micro-Gemma	miniature dwarf, yellow (gold) fruited, sweet balanced flavor

†First three are breeding lines.

FUTURE DIRECTIONS

Future breeding efforts will focus on three major areas; premium fruit quality cultivars, resistance to bacterial spot, and resistance to geminiviruses.

PREMIUM FRUIT QUALITY CULTIVARS

The chemistry of tomato flavor is currently being studied under a USDA-NRI grant. Cooperators are Rob Shewfelt from the Univ. of Georgia, Elizabeth Baldwin of the USDA at Winter Haven, and Harry Klee and Jay Scott at the Univ. of Florida. This is a major effort, with a large time commitment. It is hoped that information obtained will aid the development of cultivars with improved flavor that are well-adapted to Florida conditions. A major goal will be to develop high lycopene cultivars with superior flavor (Scott, 1998). The crimson (*og*) gene increases lycopene by about 50% while reducing β carotene by the same amount. These tomatoes are a beautiful red due to increased lycopene, the red pigment in tomato. Recent medical literature indicated that lycopene was a potent antioxidant linked to reduced risk of cancers of the prostate (Giovannucci et al., 1995) and digestive tract including colon and rectal cancers (Franceschi et al., 1994). Several crimson hybrids were tested in a replicated trial during 1998 and performed very well compared with presently grown commercial cultivars (Scott, 1998). More testing is required before release, but possibly a premium crimson hybrid could be released in the near future. Such a cultivar could be marketed as a more healthful product which has good color and good taste.

BACTERIAL SPOT RESISTANCE

Bacterial spot is still the most ubiquitous disease problem of tomato in Florida. There are three races of the bacterial spot pathogen which infect tomato and two of these races, T1 and T3, are in Florida. Work with T1 resistance derived from 'Hawaii 7998' has been ongoing since 1983. In 1991, T3 was discovered in Florida and now has become the predominant race. Resistance to T3 was found in 'Hawaii 7981' and this resistance has been backcrossed into T1-resistant recurrent parents. Hybrids heterozygous for resistance to these two races have intermediate resistance and are presently being tested for commercial acceptability. Meanwhile, PI 114490 was discovered to be resistant to race T2 in Ohio experiments (Scott et al., 1997). This accession also has resistance to races T1 and T3, and recent work indicates that the same genes confer resistance to all three races. Thus, selection for resistance to one race, such as T3 in Florida, should provide resistance to the other races as well. This simplifies the breeding approach, and major emphasis will be placed on incorporation of this general resistance into advanced lines.

GEMINIVIRUS RESISTANCE

Tomato mottle geminivirus (ToMoV), a silverleaf whitefly (*Bemisia argentifolii*, Bellows & Perring) transmitted virus, was discovered in Florida in 1989 and caused significant losses to the tomato crop in 1991. Accessions were inoculated with ToMoV in 1990 and the best resistance was found in accessions of the wild species *Lycopersicon chilense* Dunal (Scott et al.,1996). High levels of resistance have been obtained from accessions LA 1932, LA 1938 and LA 2779. Several lines have been sent to scientists around the world and many lines have had resistance to the more devastating tomato yellow leaf curl virus (TYLCV). TYLCV was discovered in Florida in 1997 and appears to be the predominant geminivirus in the state at present, probably due to its wider host range than ToMoV. We are now testing our more advanced ToMoV-resistant lines for TYLCV resistance. Molecular markers linked to at least three regions in the tomato genome confer resistance to ToMoV (Griffiths, 1998). With further work it is hoped that molecular markers can be used to accelerate future breeding efforts. At present an insecticide drench is controlling the whitefly and the viruses to a large extent, but resistance will provide a better long-term solution to the problem.

LITERATURE CITED

Alexander, L. J. 1959. Progress report of national Screening Committee for Disease Resistance in tomato for 1954-1957. Plant Dis. Rep. 43:55-65.

Augustine, J. J., B. K. Harbaugh, and J. P. Crill. 1981a. Florida Basket, a dwarf tomato for hanging baskets. Florida Agric. Exp. Sta. Circ. S-283. Univ. of Florida, Gainesville.

Augustine, J. J., B. K. Harbaugh, and J. P. Crill. 1981b. Florida Lanai, a dwarf tomato for the patio. Florida Agric. Exp. Sta. Circ. S-284. Univ. of Florida, Gainesville.

Augustine, J. J., B. K. Harbaugh, and J. P. Crill. 1981c. Florida Petite, an extremely dwarf tomato for window sill gardens. Florida Agric. Exp. Sta. Circ. S-285. Univ. of Florida, Gainesville.

Baldwin, E. A., J. W. Scott, and R. L. Shewfelt. 1996. Quality of ripened mutant and transgenic tomato cultigens. p. 47-62. *In* Proc. Tomato Quality Workshop, Sept. 12, 1995, Davis, CA.

Crill, P., H. H. Bryan, P. H. Everett, J. A. Bartz, J. P. Jones, and R. F. Matthews. 1977a. Floramerica, a widely adapted, multiple disease resistant, fresh market tomato. Florida Agric. Exp. Sta. Circ. S-248. Univ. of Florida, Gainesville.

Crill, P., D. S. Burgis, J. P. Jones, and J. Augustine. 1977b. Tomato variety development and multiple disease control with host resistance. Florida Agric. Exp. Sta. Monograph Series #10. Univ. of Florida, Gainesville.

Crill, P., J. W. Strobel, D. S. Burgis, H. H. Bryan, C. A. John, P. H. Everett, J. A. Bartz, N. C. Hayslip, and W. W. Dean. 1971. Florida MH-1, Florida's first machine harvest fresh market tomato. Florida Agric. Exp. Sta. Circ. S-212. Univ. of Florida, Gainesville.

Florida Agric. Statistics Service. 1998. Vegetables: Acreage, production and value. Florida Agric. Stat. Serv., Orlando.

Franceschi, S., E. Bidoli, C. La Veccia, R. Talamini, B. D'Avanzo, and E. Negri. 1994. Tomatoes and risk of digestive-tract cancers. Int. J. Cancer 59:181-184.

Giovannucci, E., A. Ascherio, E. B. Rimon, M. J. Stampfer, G. A. Colditz, and W. C. Willett. 1995. Intake of carotenoids and retinol in relation to risk of prostate cancer. J. Natl. Cancer Inst. 87:1767-1776.

Griffiths, P. D. 1998. Inheritance and linkage of geminivirus resistance genes derived from *Lycopersicon chilense* (Dunal) in tomato (*Lycopersicon esculentum* Mill) Ph.D. diss., Univ. of Florida, Gainesville. 170 p.

Hightower, J. 1973. Hard tomatoes, hard times; a report of the Agribusiness Accountability Project on the failure of America's land grant college complex. Schankman Publ. Co., Cambridge, MA.

Jones, J. P., W. E. Waters, and C. K. Chandler. 1995. Cultivar development at GCREC-Bradenton and GCREC-Dover 1925-1995. GCREC Res. Rep. BRA-1995-19. Bradenton, FL.

Meissner, R., Y. Jacobson, S. Melamed, S. Levyatuv, G. Shalev, A. Ashri, Y. Elkind and A. Levy. 1997. A new model system for tomato genetics. The Plant J. 12:1465-1472.

Scott, J. W. 1983. Genetic sources of tomato firmness. p. 60-67 *In* Proc. Fourth Tomato Quality Workshop. Mar. 7, 1983. Miami, FL. Veg. Crops Res. Rep. VEC-83-1.

Scott, J. W. 1998. Prospective releases from the University of Florida tomato breeding program. p. 45-48. *In* C. S. Vavrina and P. R. Gilreath (eds.). 1998 Florida Tomato Institute Proc. 111:45-48.

Scott, J. W., and B. K. Harbaugh. 1989. Micro-Tom, a miniature dwarf tomato. Florida Agric. Exp. Sta. Circ. S-370. Univ. of Florida, Gainesville.

Scott, J. W., J. B. Jones, G. C. Somodi, D. O. Chellemi, and S. M. Olson. 1995. 'Neptune', a heat-tolerant, bacterial wilt-tolerant tomato. HortScience 30:641-642.

Scott, J. W., and J. P. Jones. 1989. Monogenic resistance in tomato to *Fusarium oxysporum* f.sp. *lycopersici* race 3. Euphytica 40:49-53.

Scott, J. W., and J. P. Jones. 1995. Fla. 7547 and Fla. 7481 tomato breeding lines resistant to *Fusarium oxysporum* f.sp. *lycopersici* races 1, 2, and 3. HortScience 30:645-646.

Scott, J. W., S. A. Miller, R. E. Stall, J. B. Jones, G. C. Somodi, V. Barbosa, D. L. Francis, and F. Sahin. 1997. Resistance to race T2 of the bacterial spot pathogen in tomato. HortScience 32:724-727.

Scott, J. W., S. M. Olson, H. H. Bryan, T. K. Howe, P. J. Stoffella, and J. A. Bartz. 1989. Solar Set, a heat-tolerant, fresh market tomato hybrid. Florida Agric. Exp. Sta. Circ. S-359. Univ. of Florida, Gainesville.

Scott, J. W., M. R. Stevens, J. H. M. Barten, C. R. Thome, J. E. Polston, D. J. Schuster, and C. A. Serra. 1996. Introgression of resistance to whitefly-transmitted geminiviruses from *Lycopersicon chilense* to tomato. p. 357-367. *In* D. Gerling and R. T. Mayer (eds.). Bemisia 1995 Taxonomy, Biology, Damage, Control and Management. Intercept Press, Andover, UK.

Stall, R. E., and J. M. Walter. 1965. Selection and inheritance of resistance in tomato to isolates of races 1 and 2 of the Fusarium wilt organism. Phytopathology 55:1213-1215.

Strobel, J. W., N. C. Hayslip, D. S. Burgis, and P. H. Everett. 1969. Walter, a determinate tomato resistant to races 1 and 2 of the Fusarium wilt pathogen. Florida Agric. Exp. Sta. Circ. S-202. Univ. of Florida, Gainesville.

Volin, R. B., H. H. Bryan, D. S. Burgis, P. H. Everett, and N. C. Hayslip. 1976. Flora-Dade, a fresh market tomato with resistance to verticillium wilt. Florida Agric. Exp. Sta. Circ. S-246. Univ. of Florida, Gainesville.

Walter, J. M., and D. G. A. Kelbert. 1953. Manalucie, a tomato with distinctive new features. Florida Agric. Exp. Sta. Circ. S-59. Univ. of Florida, Gainesville.