Begomoviruses vectored by the sweetpotato whitefly (Bemisia tabaci) are a major threat to tomato (Solanum lycopersicum) production in many regions around the world. Of the many begomoviruses, the strains that cause Tomato yellow leaf curl virus (TYLCV) are the most widespread and well known. TYLCV resistant cultivars are commercially available in production regions, and most of these use the dominant Ty-1 gene that was introgressed from S. chilense accession LA1969. Producers in Florida often prefer to grow susceptible cultivars because of linkage drag effects that lower marketable yield and increase foliar disease infections. The Fla. 8923 x Fla. 8879 F1 was highly resistant but wild in appearance. Seed was sent to Judith Milo at the Hebrew University in Rehovot, Israel, who crossed the F1 with a begomovirus-susceptible greenhouse tomato inbred and returned F2 seed from that cross. An F2 ToMoV-resistant selection without wild species characteristics was made and advanced to the F3 generation. The F3 was fixed for ToMoV resistance and crossed to Fla. 7833; selections were thereafter tested in separate trials for both ToMoV and Tomato yellow leaf curl virus (TYLCV). In 2002 the F2 Fla. 8680 was crossed to Fla. 7833 (Scott and Jones, 2000) and F2 seed were screened for molecular markers flanking the S. chilense introgression (Ji et al., 2007). Of 719 F2 plants, 30 recombinants were identified and genotyped for markers between 5 and 32 cM on chromosome 6, and recombinant inbred lines (RILs) were evaluated in the field for resistance to TYLCV. All RILs having intragenes that spanned 18–25 cM showed some resistance. Two of the resistant F3 RILs, each containing this region, were selected and used to develop fine-mapping populations; the intragenes in RIL 554 spanned from 5 to 25 cM, and the intragenes in RIL 157 spanned from 18 to 32 cM. These RILs were crossed to Fla. 7776 (Scott et al., 2006), and F2 populations were developed. Of nearly 11,000 plants genotyped with flanking markers, 299 recombinants were obtained, and 114 of these had crossovers between 18 and 25 cM. Phenotyping of cuttings from these recombinants in 2009 and genotyping with newly available single nucleotide polymorphism markers developed from sequences available through the tomato genome project mapped the Ty-3 gene to a 2.5 cM region. Further testing of informative RILs in 2010 located the gene within a 0.3 cM region (Verlaan et al., 2013). Two resistant RILs (i.e., E942-482 and E948-725), each resulting from a crossover within this 0.3 cM interval and immediately on either side of Ty-3, were intercrossed to develop a Ty-3 recombinant population (Verlaan et al., 2013, Table S3). More than 2000 F2 plants from this cross were grown in 2010 and tested with flanking markers to identify recombinants; three plants were found to have resulted from crossovers within this region and were heterozygous for a Ty-3 introgression less than 70 kb in size. Progeny were grown and markers were used to select for homozygosity of the reduced region; one of these plants became Fla. 8879.

Fla. 8879 was crossed to Fla 8111B (Scott, 2013), a globe-shaped tomato with large fruit size derived from Fla. 7777 (Scott et al., 2004). Fla. 8111B has a large vine and a number of good horticultural characteristics, but it is very susceptible to bacterial spot. The Fla. 8879 x Fla. 8111B F1 was crossed to Fla. 8626, another large-fruited globe-shaped tomato inbred that also had Fla. 8111B in its

**Origin**

The pedigree of Fla. 8923 is shown in Fig. 1. Resistance was derived from S. chilense accession LA2779 that was crossed with Campbell 28 (C28) in 1990. Two interspecific F1s were obtained from the 66 fruit that set from this cross. The F1s were backcrossed to Fla. 7409 and a fair amount of seed was produced, but germination was less than 2%. The backcross to Fla. 7409 was advanced to the F2 generation in the field after inoculation with Tomato mottle virus (ToMoV) and selection for resistant plants each generation.
pedigree. Scott et al. (2009) reported that Fla. 8626 had resistance to bacterial wilt (Ralstonia solanacearum), but further testing showed this not to be the case (Scott, unpublished data). Marker assisted selection was used at the seedling stage in the F1 and subsequent generations to identify and select plants containing Ty-3. In Spring 2012, an F2 plant was selected that was heterozygous for Ty-3. A homozygous F3 line was obtained with a good yield of very large fruit. Yield data were taken on more advanced selections in 2013. Seed was increased in the F6 generation in Spring 2014 for release.

Description

Fla. 8923 has a determinant, open vine with intermediate vigor typical of most tomato vines with globe-shaped fruit. Fruit cover is fair. The deep round-(-globe-) shaped fruit have jointed pedicels, shoulders are uniform green, and blossom scars are stellate cover is fair. The deep round- (globe-) shaped tomato vines with globe-shaped fruit. Fruit have jointed pedicels, shoulders are uniform green, and blossom scars are stellate.

Disease Resistance

Fla. 8923 had intermediate resistance to both TYLCV and ToMoV under the heavy disease pressure that resulted when seedlings were inoculated for 2 weeks (Table 4). On grower farms in Florida, the resistance of the cultivar Tygress, heterozygous for Ty-1, would be rated very close to 0 on our severity scale. Observations for genotypes with Ty-3 have shown that when young plants are

Table 1. Marketable yield, extra-large yield and fruit size for tomato inbreds and control hybrids at the Gulf Coast Research and Education Center, Balm, FL, Spring 2013.

| Genotype      | Marketable yield (11.4 kg box/ha) | Extra large | Fruit size (g) |
|---------------|-----------------------------------|-------------|---------------|
|               | Total                             | Extra large|               |
| Fla. 8872B    | 2,132 a                          | 1,846 a     | 230 a         |
| Fla. 7781     | 2,110 a                          | 540 d       | 139 e         |
| ‘Solar Fire’  | 1,836 ab                         | 681 cd      | 150 e         |
| Fla. 8923     | 1,653 ab                         | 1,265 b     | 206 b         |
| Fla. 8925     | 1,649 ab                         | 1,250 bc    | 193 bc        |
| ‘Sanibel’     | 1,530 ab                         | 1,099 bc    | 184 b–d       |
| ‘Sebring’     | 1,184 b                          | 744 cd      | 176 c–e       |
| ‘Florida 47’  | 1,151 b                          | 690 d       | 162 de        |

*Mean separation in columns by Duncan’s multiple range test at P ≤ 0.05. The experiment was a completely randomized block design with two blocks and eight plant plots.

Table 2. Total and extra-large marketable yield and fruit size for tomato inbreds and control hybrids at the Gulf Coast Research and Education Center, Balm, FL, Fall 2013.

| Genotype      | Marketable yield (11.4 kg box/ha) | Extra large | Fruit size (g) |
|---------------|-----------------------------------|-------------|---------------|
|               | Total                             | Extra large|               |
| Fla. 8925     | 2,174 a                          | 1,746 a     | 206 b         |
| ‘Solar Fire’  | 1,947 ab                         | 967 b       | 166 c         |
| Tasti-Lee     | 1,608 a–c                        | 758 b       | 163 c         |
| Fla. 8857     | 1,485 a–c                        | 943 b       | 182 bc        |
| ‘Florida 47’  | 1,151 b                          | 1,062 b     | 213 b         |
| Fla. 8923     | 1,235 bc                         | 1,150 ab    | 260 a         |
| Fla. 8124C    | 1,148 c                          | 754 b       | 188 bc        |

*Mean separation in columns by Duncan’s multiple range test at P ≤ 0.05. The experiment was a completely randomized block design with two blocks and 10 plant plots.

Table 3. External color, internal color, and firmness for fruit of Fla. 8923 and comparison of tomato cultivars over two seasons at the Gulf Coast Research and Education Center, Balm, FL, 2013.

| Genotype      | External L | Hue angle L | Internal L | Hue angle L | Firmnessa (mm deformation) |
|---------------|------------|-------------|------------|-------------|----------------------------|
|               |            |             |            |             |                            |
| Spring 2013   |            |             |            |             |                            |
| Fla. 8923     | 47.2 a     | 69.7 a      | 34.8 a     | 55.6 a      | 4.2                        |
| ‘Solar Fire’  | 42.4 b     | 53.1 b      | 30.6 b     | 44.5 b      | 4.1                        |
| ‘Florida 47’  | 44.4 b     | 54.8 b      | 35.1 a     | 55.8 a      | 3.9                        |
| ‘Sebring’     | 47.6 a     | 61.0 a      | 31.0 b     | 44.5 b      | 3.6                        |
| Fall 2013     |            |             |            |             |                            |
| ‘Solar Fire’  | 40.9 b     | 47.7 b      | 36.3 ab    | 40.5 b      | 3.9                        |
| ‘Florida 47’  | 44.6 a     | 52.1 a      | 38.3 a     | 44.7 a      | 3.7                        |
| ‘Sebring’     | 39.6 b     | 45.6 b      | 36.2 b     | 37.7 c      | 3.3                        |

*Data taken with a Minolta CR-300 chromameter; higher ‘L’ numbers indicate lighter color (value), lower hue angles indicate more red color (hue). 
*Determined with an Institute of Food and Agricultural Sciences pressure tester using a 1-kg weight for 5 s with a fruit contact plate 1.5 cm in diameter. Pressure applied over a locule in equatorial plane. Lower values indicate greater firmness.
*Mean separation in columns by Duncan’s multiple range test at P ≤ 0.05. The experiments were completely randomized block designs with two blocks and 8 and 10 plant plots for spring and fall, respectively. Ten fruit per plot were harvested at the breaker stage and ripened in a laboratory at 24 °C until table ripe for color and firmness measurements.

Table 4. Tomato yellow leaf curl virus (TYLCV) and Tomato mottle virus (ToMoV) disease severitya for tomato genotypes inoculated at the seedling stage at the Gulf Coast Research and Education Center, Balm, FL, Spring 2014.

| Genotype      | Begomovirus resistance gene | TYLCV | ToMoV |
|---------------|-----------------------------|-------|-------|
| Horizon       | Ty-3/4                       | 3.9 a | 3.3 b |
| HMX 1823      | Ty-1/4                       | 2.5 b | 3.0 bc|
| Tygress       | 1.8 c                       | 3.0 bc|
| (Fla. 8624 × Fla. 8923) | Ty-3/4, Ty-6/6 | | |
| Fla. 8923     | Ty-3                         | 1.7 c | —     |
| Fla. 8608     | Ty-3, Ty-6                  | 2.0 c | 2.7 c |
| TAMU 5        | Ty-2                         | 0.3 d | 0.1 d |
|               |                              | 0.0 e | 3.9 a |

*Rated at 66 d after inoculation began on a 0–4 scale where lower value indicated less disease; for scale and inoculation information see Hutton et al. (2012).
inoculated they show some disease symptoms, but often gradually improve as the plants continue to grow in the field. The inheritance is additive, so plants heterozygous for Ty-3 alone show more disease symptoms than plants homozygous for Ty-3 alone (Verlaan et al., 2013). When Ty-3 is combined heterozygously with other TYLCV resistance genes, a good level of resistance is often obtained which is evidenced in the (Fla. 8624 × Fla. 8923) hybrid (Table 4). Fla. 8923 is resistant to Fusarium wilt races 1 and 2 (Fusarium oxysporum f. sp. lycopersici), gray leaf spot (Stemphyllium sp.), and Verticillium wilt race 1 (Verticillium dahliae). It is more sensitive to bacterial spot race T4 (Xanthomonas perforans) than many susceptible genotypes and it is similar to Fla. 8111B in that regard. However, hybrids of Fla. 8923 crossed with other bacterial spot susceptible parents do not show extreme susceptibility as is the case for crosses among many other very susceptible inbreds (Hutton and Scott, unpublished observations). The primary disorder has been zippering. It has a high level of resistance to graywall.

**Availability**

Fla. 8923 is an inbred breeding line release. Seed distribution is controlled by Florida Foundation Seed Producers, P.O. Box 309, Greenwood, FL 32443. Initial seed requests should be made to S.F. Hutton.

**Literature Cited**

Ji, Y., D.J. Schuster, and J.W. Scott. 2007. Ty-3, a begomovirus resistance locus near the Tomato yellow leaf curl virus resistance locus Ty-1 on chromosome 6 of tomato. Mol. Breed. 20:271–284.

Hutton, S.F., J.W. Scott, and D.J. Schuster. 2012. Recessive resistance to Tomato yellow leaf curl virus from the tomato cultivar Tyking is located in the same region as Ty-5 on chromosome 4. HortScience 47:324–327.

Scott, J.W. 2013. Fla. 8111B a large-fruited, globe shaped tomato breeding line. Rpt. Tomato Genet. Coop. 63:31.

Scott, J.W. and J.P. Jones. 2000. Fla. 7775 and Fla. 7781: Tomato breeding lines resistant to Fusarium crown and root rot. HortScience 35:1183–1184.

Scott, J.W., S.M. Olson, J.A. Bartz, D.N. Maynard, and P.S. Stofella. 2004. Fla. 7964 hybrid tomato resistant to spotted wilt virus. Rpt. Tomato Genet. Coop 54:51.

Scott, J.W., S.M. Olson, H.H. Bryan, J.A. Bartz, D.N. Maynard, and P.J. Stoffella. 2006. ‘Solar Fire’ hybrid tomato: Fla. 7776 tomato breeding line. HortScience 41:1504–1505.

Scott, J.W., G.E. Vallad, and J.B. Jones. 2009. High level of resistance to bacterial wilt (Ralstonia solanacearum) obtained in large-fruited tomato breeding lines derived from Hawaii 7997. Acta Hort. 808:269–274.

Verlaan, M.G., S.F. Hutton, R.M. Ibrahim, R. Kormelink, R.G.F. Visser, J.W. Scott, J.D. Edwards, and Y. Bai. 2013. The tomato yellow leaf curl virus resistance genes Ty-1 and Ty-3 are allelic and code for DFDGD-class RNA-dependent RNA polymerases. PLoS Genet. 9(3):e1003399.