USDA 02L1058 and 02L1059: Cherry Tomato Breeding Lines with High Fruit β -Carotene Content

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More than 20 genes have been characterized from tomato (*Lycopersicon esculentum* Mill.) that influence the type, amount, or distribution of carotenoids in fruit and/or foliage (Stommel, 1992). Orange-fruited tomato genotypes containing high levels of β -carotene were first identified among segregants from a cross of a red-fruited tomato genotype and the green-fruited wild tomato species *L. hirsutum* Dunal (Lincoln et al., 1943). High β -carotene levels are conditioned by a single dominant gene, *Beta*, and subject to influence by a modifier gene, *Mo_B* (Tomes et al., 1954). Recent studies demonstrated that *Beta* and *Mo_B* are linked on chromosome 6 and do not segregate independently as originally proposed (Zhang and Stommel, 2000). In the presence of the homozygous recessive *Mo_B*, *Mo_B* β -carotene accounts for >90% of colored carotenenes. With the dominant *Mo_B⁺* allele, β -carotene to lycopene ratios are reduced, resulting in red-orange pigmented fruit.

Tomato fruit with high β -carotene content are suitable for specialty applications and provide a rich dietary source of provitamin A. Many studies have examined the relationship between vegetables, fruit, and human health (e.g., Steinmetz and Potter, 1996). Horticultural crops represent about one-third of the U.S. diet and are the main source of dietary carotenoids. β -carotene is an essential nutrient due to its retinoid activity and like other carotenoids, is an antioxidant and may protect against free radical damage. The role that β -carotene and vitamin A play in growth, reproduction, mortality and morbidity from infectious diseases has been reviewed (e.g., Ross, 1998; Tee, 1992).

The Agricultural Research Service of the United States Department of Agriculture announces the release of two new cherry tomato breeding lines designated 02L1058 and 02L1059. These lines produce fruit with high

β -carotene content and are intended for use as breeding material in the development of new specialty cherry tomato cultivars.

Origin

Breeding lines 02L1058 and 02L1059 were developed from an initial cross between the fresh-market tomato cultivar Flora-Dade and *L. cheesmanii* f. *minor* (Hook f.) C.H. Mull, accession LA317 (Fig. 1). The interspecific hybrid was sequentially backcrossed three times to 'Flora-Dade' and once to the processing cultivar Spectrum 579. Lines 02L1058 and 02L1059 are small-fruited F₇ selections from a subsequent backcross to the North Carolina State University cherry tomato breeding line NC 1C (Gardner, 1993). Early generation selections focused on plant habit and fruit carotenoid content, followed by selection in later generations for horticultural quality.

Fig. 1. Pedigree of USDA 02L1058 and 02L1059.

Breeding lines 02L1058 and 02L1059 were selected for their determinate (*sp* gene) growth habit and concentrated set of cherry-size fruit with high β -carotene content. Plant growth is compact and less vigorous than the red-fruited check cultivars 'Mountain Belle' and 'Castlette'. Fruit of 02L1058 and 02L1059 contain two to three locules, ripen uniformly (*u* gene) and have jointless pedicels (*j-2* gene). Fruit quality of 02L1058 and 02L1059 was compared to 'Mountain Belle' and 'Castlette'. 'Mountain Belle' is a cherry tomato hybrid developed at North Carolina State University from the cross of breeding lines NC 1C and NC 2C (Gardner, 1993). 'Castlette' was a parental line in the development of NC 1C and NC 2C. Fruit shape of 02L1058 is round with average fruit fresh weight of 22.3 ± 0.9 g. Fruit of 02L1059 are slightly elongated to round and average 23.5 ± 0.9 g fresh weight. Fruit of 'Castlette' are comparable in size (21.7 ± 0.5 g fresh weight) to 02L1058 and 02L1059, while fruit of 'Mountain Belle' are smaller (17.0 ± 0.6 g fresh weight). Fruit of 02L1058 and 02L1059 mature about 7 d later than 'Mountain Belle'.

High fruit β -carotene content in these breeding lines is attributed to introgression of the dominant *Beta* gene from the wild tomato species *L. cheesmanii*, accession LA317. Lines 02L1058 and 02L1059 are homozygous *BB Mo_B Mo_B*, and hence fruit accumulate predominantly β -carotene and are orange-pigmented. In 2003 trials at Beltsville, Md., β -carotene content averaged 46.5 and 41.8 $\mu\text{g}\cdot\text{g}^{-1}$ tissue fresh weight in 02L1058 and 02L1059 (94.6% of total colored carotenoids), respectively, about 13-fold higher than the two red-pigmented cultivars (Table 1). Fruit of the red-pigmented cultivars, Mountain Belle and Castlette, contained lycopene as the major colored carotenoid and relatively

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Table 1. Fruit quality attributes of cherry tomato breeding lines USDA 02L1058 and 02L1059, and commercial cultivars in 2003 trials at Beltsville, Maryland.^a

Genotype	β -Carotene ($\mu\text{g}\cdot\text{g}^{-1}$ fresh wt)	Lycopene	Fructose	Glucose	Sucrose	Total sugars ($\text{mg}\cdot\text{g}^{-1}$ fresh wt)	Soluble solids (%)	Titrateable acidity (% citric acid)	Sugar to acid ratio (% total sugar/ % citric acid)
02L1058	46.5 a ^b	2.7 b	19.07 a	15.75 b	0.13 b	34.95 a	7.7 a	0.46 a	7.6 c
02L1059	41.8 a	2.3 b	18.74 a	17.76 ab	0.07 b	36.56 a	7.5 a	0.41 b	8.9 b
Mountain Belle	3.2 b	31.1 a	14.65 b	19.41 a	0.58 a	34.64 a	6.8 b	0.35 c	9.9 a
Castlette	3.7 b	54.2 a	10.57 c	10.96 c	0.10 b	21.63 b	5.7 c	0.44 ab	4.9 d

^aAdapted from Stommel et al. (2005). Data for sugars, soluble solids and titrateable acidity represent the mean of 14 bulked samples of 10 to 15 fruit per bulked sample for each genotype. Data for β -carotene and lycopene represent the mean of ten sets of bulked fruit.

^bMean comparisons in columns by Tukey's HSD test at $P \leq 0.05$.

little β -carotene. Laboratory evaluation of carotenoid content conducted on fruit from 2002 trials did not differ significantly from 2003 trials (data not shown).

Average fruit soluble solids content of 02L1058 and 02L1059 was 10.5% and 25.0% higher than that measured in 'Mountain Belle' and 'Castlette', respectively (Table 1), likely due to the transfer of favorable genes for soluble solids content from the wild donor parent *L. cheesmanii* (Garvey and Hewitt, 1984; Stommel, 2001; Stommel and Haynes, 1994). Similar observations for soluble solids content were noted in 2002 trials (data not shown). Total sugar content of 02L1058 and 02L1059 was 39.5% greater than 'Castlette' and equivalent to 'Mountain Belle' (Table 1). Because fructose has a higher sweetness score than glucose (1.8 vs. 0.7; Sikorski, 1997), higher fructose levels in lines 02L1058 and 02L1059 resulted in favorably lower (32.6% less) glucose to fructose ratios for 02L1058 (0.83) and 02L1059 (0.96). Relative sweetness scores [$1.8 (\text{mg}\cdot\text{g}^{-1}$ fresh weight fructose) + $0.7 (\text{mg}\cdot\text{g}^{-1}$ fresh weight glucose) + $1.0 (\text{mg}\cdot\text{g}^{-1}$ fresh weight sucrose)] of 02L1058 (45.5) and 02L1059 (46.2) were comparable to 'Mountain Belle' (40.5) and significantly greater than 'Castlette' (26.8).

Titrateable acidity of 02L1058 and 02L1059 fruit was 19.5% higher, relative to 'Mountain Belle' and comparable to 'Castlette' (Table 1). Sugar to acid ratios of 02L1058 and 02L1059 were intermediate to 'Mountain Belle' and 'Castlette'. The relatively high sugar to acid ratios of 'Mountain Belle' likely influenced that cultivars superior subjective sweetness rating by sensory panels (Stommel et al., 2005). Total volatile levels did not differ among genotypes. However, several individual volatiles differed significantly in high β -carotene genotypes vs. lycopene-rich cultivars (data not shown). Hexanal (green, grassy aroma), the predominant volatile in tomatoes and considered to be important for tomato flavor (Petro-Turza, 1987), was 1.5-fold higher in 'Mountain Belle' and 'Castlette' in comparison to 02L1058 and 02L1059. Breakdown products of β -carotene, *trans*-2-heptenal (green aroma) and geranyl-acetone (floral or fruity aroma) were 2.3 and 1.5-fold higher, respectively, in 02L1058 and 02L1059 in comparison to 'Mountain Belle' and 'Castlette'.

Use

Lines 02L1058 and 02L1059 are intended for use as breeding lines in the development of specialty cherry tomato cultivars. Their combination of desirable plant and fruit characteristics make them a good source of the *Beta* gene in cultivar development. The dominant nature of high fruit β -carotene content permits ready use of these lines for hybrid production in combination with elite disease resistant red-fruited breeding material. Fruit are orange-pigmented, making this material a specialty product for use where additional variety, flavor, or retinoid activity is desired. Our recent study (Stommel et al., 2005) demonstrated the importance of color on consumer perceptions of fruit quality. In this study, panelists preferred the appearance of the red-pigmented cultivars when viewed under white light, but scored many of the other fruit quality attributes of red and orange-pigmented genotypes similarly under white light and under masked lighting conditions where differences in fruit color could not be discerned.

Premium quality tomatoes and specialty products attract a loyal consumer following (Goldman, 1988). Specialty products in today's marketplace include cluster tomatoes sold on the vine, vine-ripened greenhouse-grown tomatoes, and specialty cherry and grape tomato cultivars, all of which command premium prices. The diversity of tomato products currently found in the marketplace demonstrates the opportunities for added product variety.

Availability

USDA 02L1058 and 02L1059 are breeding line releases. Seed of these lines will be deposited in the National Plant Germplasm System where it will be available for research purposes, including development and commercialization of new cultivars. Small samples of seed are available for professional trial and breeding purposes upon written request to the corresponding author. It is requested that appropriate recognition be made if this germplasm contributes to the development of a new breeding line or cultivar.

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