Nematode Resistance: A Useful Tool for Root-Knot Nematode (RKN) Management in Tomato[1]

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Tomatoes are a major commodity in Florida, with an estimated production value of $453 million and accounting for 18% of Florida's fresh market vegetable acreage, and 35% of the fresh market tomato acreage in the US (USDA/NASS, 2021). Among the many pests and diseases that affect tomatoes, nematodes are one of the major problems. Since the ban on methyl bromide, these ubiquitous soil pests have become much more difficult to manage. This article will discuss the use of nematode-resistant tomato cultivars as a tool to help manage root-knot nematodes in Florida.

Root-knot disease in tomato is a serious and growing problem in Florida and is mainly due to three major tropical root-knot nematode (RKN) species, i.e., *Meloidogyne javanica*, *M. incognita* and *M. arenaria*. RKNs (*Meloidogyne* spp.) are broadly distributed and are generally considered to be the most important plant-parasitic nematodes worldwide. RKNs are sedentary, obligate parasites and are particularly difficult to control due to wide host ranges, short generation times, and high reproductive rates. Among a range of vegetable crops affected by RKNs, tomato is a very good host for all three major tropical root-knot nematode species in Florida. Common symptoms exhibited by tomato plants due to severe RKN infection can be categorized as:

- Above-ground symptoms

Symptoms resemble nutrient deficiencies such as yellowing of leaves and stunted growth.

Figure 1a. Typical above-ground symptoms of root-knot-nematode-infected tomato plants (left) next to nematode-free plants (right).
Credits: J. Desaeger, UF/IFAS

- Below-ground symptoms

Galled roots are the typical symptom caused by root-knot nematode.

Fortunately, tomato is one of the few vegetable commodities in which host resistance against root-knot nematode is well established. Resistance in tomato against root knot nematode is generally governed by a single dominant gene *Mi*, which confers resistance to *M. incognita*, *M. arenaria*, and *M. javanica* (Gilbert and McGuire 1956). The *Mi* gene

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was identified during the 1940s in a wild relative of tomato *Solanum peruvianum* and was later introgressed into cultivated tomato (Smith 1944).

Figure 1b. Typical below-ground symptoms of root-knot-nematode-infected tomato roots.
Credits: J. Desaeger, UF/IFAS

Tomato varieties carrying the *Mi* gene are effective in controlling *Meloidogyne* spp. and can be cultivated in RKN-infested fields without significant yield loss (Figure 2).

Figure 2. Roots from Tasti-Lee, which lacks the *Mi* gene and is susceptible to RKN (b), and a Tasti-Lee isoline, which has *Mi* and is resistant to RKN (a) (developed by S.F. Hutton at the UF/IFAS Gulf Coast Research and Education Center).

Mi resistance against RKNs is characterized by a hypersensitive response of the plant causing localized cell death of host tissue near the invading nematodes (Williamson and Kumar 2006). A typical root-knot nematode life cycle (Figure 3) involves root invasion by the second-stage juvenile (J2), and formation of giant cells (specialized feeding cells within the root galls) that allow the nematodes to develop to adult females with eggs. Newly emerging juveniles then move through the soil to invade more roots. In roots of *Mi* tomato cultivars, the formation of giant cells required by the invading nematode, is largely prevented. Root-knot nematode juveniles may still penetrate and migrate through roots of nematode-resistant cultivars (although in lower numbers), but most of them will not be able to feed and reproduce. They either leave or starve within the root.

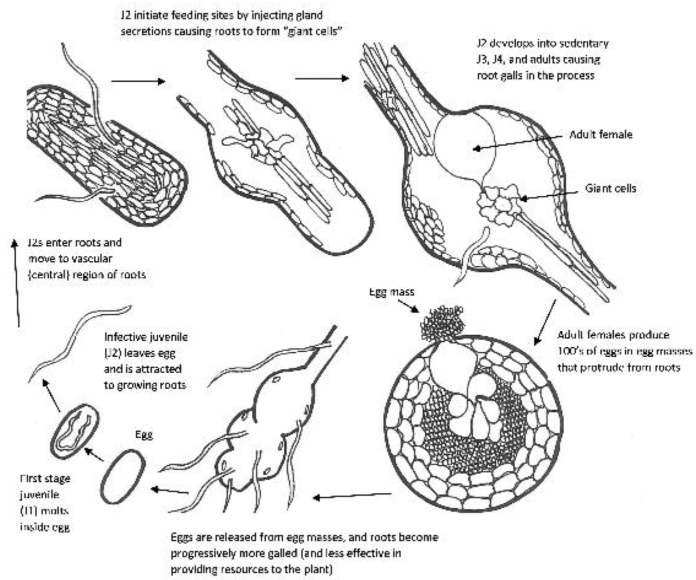

Figure 3. Life cycle of the root-knot nematode *Meloidogyne* spp.
Credits: H. Regier, adapted from G. Abawi and V. Brewster

Mi gene in tomato has also induced resistance to some piercing and sucking insects such as aphids and whiteflies (Kaloshian et.al. 1995; Nombela et.al. 2003), although this effect is generally insufficient for providing field-level resistance against such pests.

The level of RKN resistance in *Mi*-gene-bearing tomatoes can vary from good to intermediate among cultivars. For example, Sanibel, Daytona, and Mariana exhibit good resistance to RKNs while Skyway 687, Southern Ripes, SV 7631TD, and Felicity possess intermediate resistance against the same nematodes.

Although *Mi*-nematode-resistant tomato cultivars may be valuable to Florida tomato growers, there are certain risks associated with these:

- To date, *Mi* is the only nematode resistance gene that has been introgressed into tomato. Although several other genes have been reported, none of these have been successfully incorporated in commercial tomato cultivars.
- **Resistance breakdown—**There is always a chance that RKNs become insensitive to the *Mi* gene. This is more likely when RKNs are continuously exposed to root-knot-resistant cultivars, especially in monoculture systems. Resistance-breaking populations of *M. incognita* have been reported since the 1990s, and these have become very widespread in California.
- **Heat instability—**Although the *Mi* gene is highly effective, resistance is compromised at high soil temperatures (=32°C or 90°F). Some researchers have reported a complete loss of function of *Mi* at high soil temperatures of (Dropkin 1969; Williamson 1998), while others have found that the gene regains function once the soil temperature lowers (de Carvalho 2015). In Florida, trials conducted by D. W. Dickson (personal communication) in Citra, FL, and by ourselves in Wimauma, FL, showed no breakdown of resistance in *Mi* tomato cultivars—neither in spring- nor fall-planted tomatoes—suggesting that soil temperatures may not often exceed the limits for maintaining *Mi*-based resistance.
- **Target specificity—**The *Mi* gene is effective against the three major tropical and sub-tropical RKNs, but it does not work against another tropical RKN, *M. enterolobii*. *M. enterolobii*, the guava root-knot nematode, was first reported in the United States in Florida (Brito *et al.* 2007), but has now been found in several other southeastern states. *Mi* is also ineffective against *M. hapla*, the northern root-knot nematode, which is common in the northern United States and Canada. This species has been reported in several strawberry farms in Florida where the seedlings are imported from Canada and more northern parts of United States, but the nematode does not appear to be common in Florida tomato fields.

Final note: The *Mi* gene in tomato provides reasonable protection against major tropical and sub-tropical root-knot nematodes, but soil fumigation may still be needed for management of other pests. Besides nematodes, soilborne pathogens are endemic to Florida tomato fields, and major disease challenges include fusarium wilt, caused by *Fusarium oxysporum* f. sp. *lycopersici*; fusarium crown androot rot, caused by *Fusarium oxysporum* f. sp. *radicus-lycopersici*; *Pythium, Phytophthora*; southern blight caused by *Sclerotium rolfsii*; and bacterial wilt caused by *Ralstonia solanacearum*. Additionally, there are many weeds in tomato fields that can compete with the crop, and not all of these can be controlled through the use of herbicides. Soil fumigation may therefore be needed to simultaneously manage all these different soilborne pests and diseases. Thus, although tomato cultivars with the *Mi* gene may not be a replacement for soil fumigants in Florida, they may be a valuable tool for those tomato growers who choose not to fumigate, or for growers to use in combination with soil fumigation for fields with high root-knot-nematode pressure.

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Table 1. List of tomato cultivars available in Florida having resistance to root-knot nematode and other diseases.

Tomato Type and cv.	Disease Resistance (*)										
	ASC	BSK	CLS	F-R1,2,3	FCR	N	GLS	TMV	TSW	TYCLV	V(1)
Large and beefsteak											
Amelia				R		R	R				
Crista	R			R		R	R			R	R
Red Bounty				R (1,2)		R	R		R		R
Sanibel	R			R (1,2)		R	R				R
Skyway 687				R (1,2)		IR			IR	IR	
Southern Ripe				R	R	IR			R		
SV 7631TD	R			R (1,2)		IR			R		R
Plum											
Daytona	R			R (1,2)		R	IR			IR	R
Mariana	R			R (1,2)		R	IR				R
Supremo		R		R		R			IR		R
Tachi	R			R (1,2)		R			IR		R
Cherry											
Shiren				R (1,2)		IR			R		
Grape											
Amai			R	R (1)		IR	IR		R		
Brixmore						R			R		R

(*) ASC – Alternaria stem canker = *Alternaria alternata* f.sp. *lycopersici*; BSK – Bacterial speck - *Pseudomonas syringae* pv *tomato*; CLS - Cladosporium leaf mold = *Cladosporium fulvum*; F-R 1, 2, 3 - Fusarium wilt race 1, 2, 3 = *Fusarium oxysporum* f.sp. *lycopersici* races 1, 2, 3; FCR – Fusarium crown rot = *Fusarium oxysporum* f.sp. *radicis-lycopersici*; N – Root knot nematode = *Meloidogyne arenaria, M. incognita,* and *M.javanica*; GLS – Gray leaf spot = *Sylium solani*; TMV = Tomato mosaic virus; TSW = Tomato spotted wilt; TYLCV – Tomato yellow leaf curl virus; V (1) - Verticillium wilt - *Verticillium albo-atrum* and *Verticillium dahliae* race 1; R = Resistant; IR = Intermediate Resistance; T = Tolerant.