

'Viradoro': A Tospovirus-resistant Processing Tomato Cultivar Adapted to Tropical Environments

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The production of processing tomatoes in Brazil has been dominated over the last decade by open-pollinated cultivars with 'IPA-5' as the leading commercial cultivar. This scenario has changed in recent years with a significant increase in F₁ hybrids, accounting for 12% and 45% of the total acreage in 1997 and 1998, respectively. The estimated area planted to hybrids in 1999 was 80%. 'IPA-5' is still the leading open-pollinated processing cultivar because of its high level of heat tolerance and relatively stable performance across all production regions of the country. In addition, 'IPA-5' has acceptable fruit color and firmness, as well as resistance to verticillium wilt race 1 (*Verticillium dahliae* Kleb.), fusarium wilt race 1 (*Fusarium oxysporum* f.sp. *lycopersici* race 1 sensu Gabe), gray leaf spot [*Stemphylium solani* Weber and *S. lycopersici* (Enjoji) Yamamoto], and root-knot nematodes (*Meloidogyne* sp. Goeldi). However, tospovirus infection has caused severe economic losses in production fields of 'IPA-5' (Fajardo et al., 1997) as well as in all other processing tomato cultivars and hybrids presently grown in Brazil (Giordano et al., 1998).

Severe tospovirus epidemics have been reported as major problems affecting fresh-market tomato crops in Brazil since the 1930s (Azevedo, 1936; Bitancourt, 1936), but is a relatively new problem for the Brazilian processing tomato industry. This disease was first designated as "vira-cabeça" (Portuguese for "upside down") because of the typical downward curling of the plant apex as a consequence of the apical chlorosis and necrosis (Silberschmidt, 1937). Costa and Foster (1941) identified the causal agent as tomato spotted

wilt virus (TSWV). Over the years, TSWV has been placed as the type species within the genus *Tospovirus* in the Bunyaviridae family (Francki et al., 1991). More recently, extensive molecular and biological studies using several isolates of worldwide origin indicated

that the *Tospovirus* genus comprises a complex of at least nine distinct virus species (de Ávila et al., 1993, 1998). Four species were detected infecting processing tomato under natural conditions in Brazil: TSWV, tomato chlorotic spot virus (TCSV), groundnut ring spot virus (GRSV), and chrysanthemum stem necrosis virus (CSNV) (Boiteux and Giordano, 1993; de Ávila et al., 1993; Duarte et al., 1995).

Genetic resistance is one of the few practical strategies to control tomato infection by tospoviruses; chemical and cultural controls are either noneffective or costly (Ullman et al., 1997). A monogenic source of resistance to TSWV was found in the South African tomato cultivar Stevens, and the resistance locus was named *Sw-5* (Stevens et al., 1992). Additional studies indicated that the *Sw-5* locus also confers effective levels of resistance against TCSV and GRSV isolates (Boiteux and Giordano, 1993). These features of the *Sw-5* locus created the possibility of developing new cultivars with resistance to a broad spectrum of tospovirus species, using relatively simple breeding strategies.

Because of the economic damage caused by tospoviruses in virtually all areas of Brazil producing tomato for processing, EMBRAPA-IPA began a breeding program directed to-

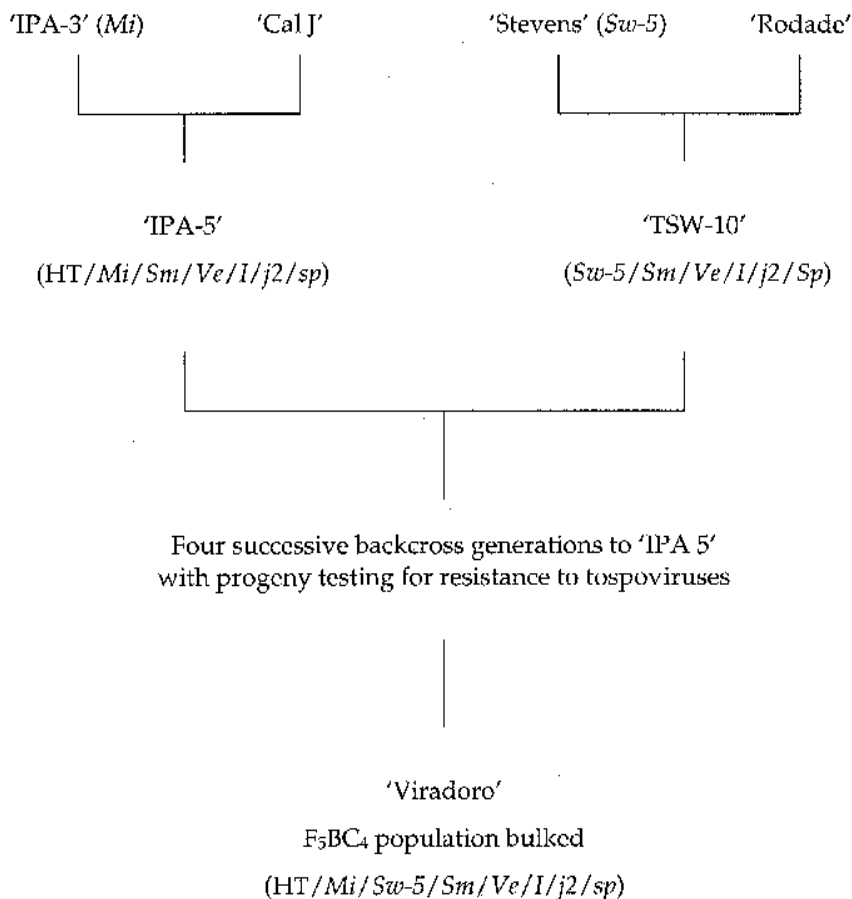


Fig. 1. Pedigree, main attributes, and some of the major loci of the cultivar Viradoro. HT = heat tolerance; Mi = root-knot nematode/potato aphid resistance locus; Sw-5 = tospovirus resistance locus; Sm = gray (*Stemphylium*) leaf spot resistance; Ve = verticillium wilt race 1 resistance; I = resistance to fusarium wilt race 1; sp = self-pruning locus; and j2 = jointless fruit pedicel.

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ward the development of cultivars with the good horticultural characteristics of 'IPA-5' and resistance to tospoviruses. The result of this joint interregional and interinstitutional effort was the development of the multi-resistant, heat-tolerant cultivar Viradoro.

Origin

'Viradoro' is an F_3BC_4 open-pollinated cultivar, which originated from a backcross program using 'IPA-5' (Ferraz et al., 1986) as the recurrent parent (Fig. 1). The nonrecurrent parental line was 'TSW-10', a fresh-market tomato inbred line resistant to Brazilian isolates of TSWV, TCSV, and GRSV (Boiteux et al., 1993a). The resistance to multiple tospovirus species was controlled by the presence of the *Sw-5* locus (chromosome 9) introgressed from *L. peruvianum* Mill. (Brommosschenkel and Tanksley, 1997; Stevens et al., 1992). Tomato lines carrying the *Sw-5* locus were resistant to tospoviruses in both greenhouse and field conditions in Brazil (Boiteux et al., 1993b; Giordano et al., 1994). Both parental lines used for the development of 'Viradoro' were previously selected for homozygosity at three loci controlling resistance to *Fusarium oxysporum* f.sp. *lycopersici* race 1 (locus *I*), *V. dahliae* race 1 (locus *Ve*), and *Stemphyllium solani* and *S. lycopersici* (locus *Sm*). Therefore, subsequent screening and selection cycles were primarily conducted for root-knot nematodes (locus *Mi*) and tospoviruses (locus *Sw-5*). Progeny testing for tospovirus resistance was conducted before each backcross cycle. Seedlings were mechanically inoculated with an assortment of isolates of TSWV, TCSV, and GRSV. Mechanical inoculation was conducted as described (Boiteux and Giordano, 1992). Only symptomless plants were backcrossed to 'IPA-5'. 'Viradoro' and its sister lines (F_3BC_4) were evaluated under greenhouse conditions for resistance to *Meloidogyne javanica* (Treub) Chitwood, *M. incognita* (Kofoid & White) Chitwood (races 1, 2, 3, and 4), and *M. arenaria* (Neal) Chitwood. Inocula were produced on the susceptible tomato cultivar Rutgers and collected from chopped roots shaken for 4 min in a beaker containing 1% NaOCl solution (Hussey and Barker, 1973). Inoculation protocol and evaluation procedures were conducted as described by Boiteux and Charchar (1996) with minor modifications. Plants (at the four-leaf stage) were infested with a suspension of 6000 nematode eggs pipetted into depressions in the soil surface around the root systems. Healthy 'Rutgers' plants were infested with the same nematode suspension and employed as susceptible controls. 'Viradoro' exhibited resistant reaction to all Brazilian populations of *M. javanica*, *M. incognita* (races 1, 2, 3, and 4), and *M. arenaria* tested so far.

Description

'Viradoro' is a processing tomato cultivar developed for warm tropical and subtropical areas where simultaneous infection by tospoviruses and root-knot nematodes

(*Meloidogyne* sp.) are major economic constraints. 'Viradoro' is resistant to all species of the "Vira-cabeça" disease complex (caused by TSWV, TCSV, and GRSV). 'Viradoro' is also resistant to fusarium wilt race 1 (*F. oxysporum* f.sp. *lycopersici* race 1) and verticillium wilt race 1 (*V. dahliae* race 1) as well as gray leaf spot (*S. solani* and *S. lycopersici*). 'Viradoro' is resistant to *M. javanica*, *M. incognita* (races 1, 2, 3, and 4), and *M. arenaria*. In addition, because of the presence of the locus *Mi*, 'Viradoro' is also resistant to some populations of the potato aphid *Macrosiphum euphorbiae* (Thomas) (Rossi et al., 1998). The resistance to *M. euphorbiae* conferred by this locus can indirectly reduce the incidence of some potyviruses transmitted by this aphid (Rossi et al., 1998).

'Viradoro' has indeterminate growth habit (locus *sp*) with vigorous foliage, which provides good fruit protection from sunscald. Ripe fruits of 'Viradoro' are firm, square-shaped (Fig. 2), with an average weight of 75 ± 5 g. The external color is uniform and bright red ($L = 38.0$; $a = 34.0$; $b = 21.0$; $a : b$ ratio = 1.61). The average soluble solids ($^{\circ}\text{Brix}$) of 'Viradoro' is $4.5\% \pm 0.2\%$, which is in the range reported for the recurrent parent 'IPA-5' (Boiteux et al., 1995; Giordano et al., 1997). 'Viradoro' has more uniform fruit ripening and earlier fruit setting than 'IPA-5', allowing mechanical harvesting nearly 100 to 120 d after plant emergence. This cultivar has the jointless phenotype (locus *j2*), which facilitates both manual and machine harvesting. No major negative pleiotropic effects on agronomic and processing attributes have been reported in association with the *j2* gene in this genetic background (Boiteux et al., 1995).

'Viradoro' is also a potential line for F_1 hybrid production because of the dominance at numerous disease resistance loci, as well as acceptable agronomic and processing qualities. Experimental hybrids using 'Viradoro' as parental material are now being tested in Brazil.

Assessment of field performance under low and high tospovirus pressure and heat tolerance

'Viradoro' was evaluated in field trials with 'IPA-5' at two different locations in both semiarid tropical (Belém de São Francisco-PE) and highland subtropical (Brasília-DF) areas of Brazil. In Brasília with late tospovirus field infection (30-d-old plants transplanted to the field), 'Viradoro' significantly ($P \leq 0.05$) outyielded 'IPA-5' with $103.8 \text{ t}\cdot\text{ha}^{-1}$ vs. $94.3 \text{ t}\cdot\text{ha}^{-1}$, respectively. None of the 'Viradoro' plants developed symptoms, whereas 30% of the 'IPA-5' plants showed typical tospovirus symptoms. The heat tolerance of 'Viradoro', as well as the importance of resistance to tospoviruses, was better evaluated in the field trial conducted at Belém do São Francisco (PE) in 1996. Under early tospovirus infection (direct sowing), 'Viradoro' ($98.7 \text{ t}\cdot\text{ha}^{-1}$) outyielded 'IPA-5' ($7.9 \text{ t}\cdot\text{ha}^{-1}$), with the latter cultivar suffering nearly 75% stand reduction (Giordano et al., 1998).

Resistance to root-knot nematodes is especially important in tropical and subtropical areas of the world, where continuous cropping of susceptible host plants may result in permanently infested soils. This scenario has been observed in processing tomato areas of Brazil (Giordano et al., 1997). The resistance of 'Viradoro' to *Meloidogyne* sp. was confirmed under greenhouse and also under naturally infested fields in Belém do São Francisco (PE). Resistance of 'Viradoro' to distinct *Meloidogyne* sp. populations was characterized by almost complete absence of gall and egg-mass formation, which is a similar response to that reported for *Mi* locus-incompatible populations (Roberts et al., 1992).

'Viradoro' has been also evaluated in large plots within production fields at several locations in Goiás and Minas Gerais States (central Brazil). In these commercial fields (conducted under either center-pivot or overhead sprin-



Fig. 2. Plants and fruits of the processing tomato cultivar Viradoro.

kler irrigation), 'Viradoro' had average yields that consistently exceeded 80 t·ha⁻¹ with and without root-knot nematode and tospovirus infection.

Seed availability

Small quantities of seeds are available for farmers, research institutions, and seed companies upon request to EMBRAPA-CNPq and IPA. Both institutions will maintain the genetic seed stocks of 'Viradoro'.

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