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Evaluation of some processing tomato lines with resistance to *Tomato spotted wilt virus* for agricultural and processing characters

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Abstract

Nowadays, *Tomato spotted wilt virus* (TSWV) is one of the most limiting factors for tomato culture in Spain. Some breeding programs have been recently developed to obtain cultivars with resistance to TSWV. The evaluation of six lines of processing tomato obtained from one of these breeding programs and carrying the *Sw-5* gene that confers resistance to TSWV, has shown that all these lines have both agronomic (yield, vigor, etc.) and quality characters better or similar to those of control cultivars. The lines tested here could be very useful in regions where TSWV is an endemic disease and to get hybrids that would express heterosis and more stability in different environmental conditions.

Key words: *Lycopersicon esculentum* Mill., *Meloidogyne* spp., *Fusarium oxysporum* f. sp. *lycopersici*, yield, breeding programs, genetic resistance.

Resumen

Evaluación de caracteres agronómicos y de calidad industrial en líneas de tomate de industria resistentes al virus de las manchas bronceadas del tomate

El virus de las manchas bronceadas del tomate (TSWV) constituye en la actualidad uno de los factores limitantes más importantes del cultivo del tomate en nuestro país. En los últimos años se han desarrollado programas de mejora para obtener variedades comerciales de tomate resistentes a esta virosis. La evaluación de seis líneas de tomate de industria que incorporan el gen *Sw-5* de resistencia al TSWV, obtenidas mediante uno de estos programas, puso de manifiesto que estas líneas presentan vigor adecuado, buena cobertura foliar de los frutos, producción comercial elevada, agrupación óptima de la maduración y características de calidad externa e interna adecuadas para el procesado industrial. Estas líneas podrán utilizarse directamente en áreas con una elevada incidencia de la enfermedad causada por el TSWV, y para construir híbridos que expresen heterosis y tengan mayor estabilidad frente a variadas condiciones ambientales.

Palabras clave: *Lycopersicon esculentum* Mill., *Meloidogyne* spp., *Fusarium oxysporum* f. sp. *lycopersici*, producción, programas de mejora, resistencia genética.

Introduction

Tomato spotted wilt virus (TSWV) is among the ten most important plant viruses and annual losses attributed to this virus have been estimated to be around 1,000 million dollars (Goldbach and Peters, 1994). The disease was first detected in Spain in 1989 (Cuadrado *et al.*, 1991). In our country, damage to tomato crops is especially important along the coast of Catalonia where the proportion of infected plants in commercial crops can exceed 50% (Aramburu *et al.*, 1994). In the Valencia and Murcia communities, and in the Almeria province (Jordá, 1996; Roselló *et al.*, 1996, 1999; Ro-

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selló and Nuez, 1999), in 1991 the total damage suffered in all the horticultural crops was between 120 and 240 million euros according to estimations of the National Plant Health Department. In 1992, the presence of TSWV was detected in Vegas del Guadiana (Santiago *et al*., 1997), an Extremadura territory where most Spanish processing tomato production takes place (AMITOM, 2000). The damage caused by TSWV in this community is so far of little importance, producing economically important damage to around 2% of the processing tomato crop.

TSWV-infected plants do not recover from sickness and often die resulting in a reduced total yield (Soler *et al*., 1998). In the case of tomato grown for fresh market, the development of varieties that incorporate the dominant *Sw-5* gene proceeding from *L. peruvianum* (Stevens *et al*., 1992), have greatly reduced the repercussions of TSWV. To date, most breeding programs to obtain TSWV resistant material have focused on tomato cultivars for fresh consumption. However, breeding programs aimed at obtaining varieties of processing tomato resistant to TSWV have been slow to develop, mainly for financial reasons since the unit value of tomato production for fresh consumption is much higher than the unit value of processing tomato. Owing to the possible spread of the disease by TSWV in Extremadura, in 1994 a breeding program was started in which processing tomato lines resistant to TSWV were obtained. This work presents the results obtained in the evaluation of agronomical and industrial quality characters for six of these lines.

Material and Methods

Plant material

The following TSWV resistant lines were used: D-2-1-12-6, D-2-1-12-15, E-2-5-1-8, E-2-5-1-14, F-11-7-2-8 and F-11-7-2-16. Line D-2-1-12-6 is also resistant to *Meloidogyne* spp. and *Fusarium oxysporum* f. sp. *lycopersici* races 0 and 1.

These lines were obtained by a backcrossing program in which the gene for TSWV resistance *Sw-5* was introduced (Roselló and Nuez, 1999). As recurrent parents, the following open pollination cultivars were used: FM-6203 [substituted from the third backcrossing with an isogenic line called Gévora, resistant to nematodes of the genus *Meloidogyne* and to *Fusarium oxysporum* f. sp. *lycopersici* races 0 and 1 (Fernández-Muñoz *et al*., 1999)] in the case of lines D-2-1-12-6 and D-2-1-12-15, H-324-1 in the case of E-2-5-1-8 and E-2-5-1-14, and Peelmech in the case of F-11-7-2-8 and F-11-7-2-16. As a parental donor of the *Sw-5* gene, a homozygotic F_7 was used for this descendent gene from a crossing between the cultivars Stevens and Rodade (Stevens *et al*., 1991). In each of the backcrossing cycles, genotypes were selected that did not produce symptoms of TSWV or positive results with the ELISA test after mechanical inoculation with isolate HA-931100, and confirmed the same results after a second inoculation (Roselló *et al*., 1999). Between the genotypes selected in this way in each backcrossing cycle, the ones with the best agronomical and industrial quality characters were chosen. In order to study simultaneously resistance to TSWV, agronomical characters and quality characters, clonal replicas of each genotype were obtained in each backcrossing cycle (George, 1996). Some of these replicas were used to study TSWV resistance and the rest were used to study agronomical and industrial quality characters in similar conditions as with a commercial crop. After the fourth backcrossing, four cycles of self-fertilization were performed to fix the resistance to TSWV, nematodes and *Fusarium* (Espárrago *et al*., 1994; Rodríguez-Molina *et al*., 1995; Roselló *et al*., 1999). The crop from the first self-fertilization together with sensitive materials (cultivars FM-6203, H-324-1, Peelmech and Gévora) in Campo de Cartagena (Murcia) in 1999, revealed the resistance of the materials obtained in field conditions against 100% attack on sensitive materials. As expected, only 25% of the self-fertilized crops presented symptoms of TSWV and were positive for the ELISA test.

The recurrent parental cultivars, the open pollination processing tomato cultivar Guadajira and the hybrid cultivars Early Nemapride, Centurión, Ercole, Heinz-9661 and Soprano were used as controls. Although all the controls are commercial cultivars which are or have been registered in the National Greenhouse Plants and Seeds Institute as processing tomato crops, the hybrid cultivars are the only ones currently widely grown (Rubio, personal communication), although all of them present good agronomical and industrial quality characters (Rodríguez *et al*., 1992, 1995; Fernández-Muñoz *et al*., 1999; López, 2001). All controls were not used in all the experiments.

Experimental design

The experiments were carried out in 2000 and 2001. To determine the behavior of commercial crop lines, in addition to the trials carried out on the experimental farm La Orden, other experiments were carried out in commercial crops by independent farmers.

2000

In this year, three trials were carried out: two in the Guadajira locality (Vegas Bajas del Guadiana, Badajoz), being one of them in the experimental farm La Orden (from hereon referred to as La Orden) and the other in a commercial crop plot; the third was carried out in Medellín (Vegas Altas del Guadiana, Badajoz). In this last locality, severe attacks of TSWV had been detected previously, although in the present work symptoms of this disease were not detected.

The experimental design for La Orden trial consisted in 3 randomized blocks, with elemental plots 15 m^2, arranged in beds 1 m wide and set 0.5 m apart. The crop was sown at the end of May with a sowing density of 25,000 plants ha^{-1}. The crop was managed by cultivation techniques typical for the area. The crop was harvested in the last week of September.

In the other two experiments, elemental plots 300 m^2 were cultivated with each of the materials to be tested interspersed with a commercial crop of Centurión, Ercole and Early Nemapride. The crop was planted by direct drilling in March for Medellín and by transplantation in the commercial plot of Guadajira in April. The crop density was 25,000 plants ha^{-1} in Guadajira and 40,000 plants ha^{-1} in Medellín. The crop was managed by cultivation techniques typical for the area. The harvest in both experiments was collected in the first fortnight of August.

2001

Two experiments were carried out, one again in La Orden, and another in the plot of Arroyo de San Serván (Vegas Bajas del Guadiana, Badajoz).

The experiment of La Orden presented a similar design to the one of the previous year except that it included four blocks instead of three. The crop density and cultivation techniques were the same as for the previous year. The harvest was collected in the last week of September.

The experiment in Arroyo de San Serván had the same design as those carried out with Medellín and the commercial plot Guadajira of the previous year, and elemental plots were interspersed with a commercial crop of Early Nemapride. The harvest was collected at the end of August.

Characters controlled and their analysis

Agronomical study

An agronomical evaluation was carried out before the harvest in all experiments (Rodríguez *et al.*, 1995) and the following factors were assessed: plant foliar cover, size of plants at the end of the crop cycle, uniformity of fruit size, setting capacity, cluster maturation, precocity, total yield, commercial yield and mean weight of fruit.

Evaluation of external and industrial quality characters

These characters were evaluated for the fruit collected on an area of 7.5 m^2 in the center of each elemental plot in the experiments of La Orden and four areas of 3 m^2 chosen at random in each elemental plot of 300 m^2 in the experiments using Guadajira, Medellín and Arroyo de San Serván. The following external characters were studied in the fruit: shape, firmness, parthenocarpy, hollowness and breaking off of the peduncle.

After the harvest, between 2 and 6 samples of 3 kg of fruit were taken from each elemental plot. For these samples, the following internal quality characters were determined: pH, Brix degree, color according to Hunter's scale («L» luminosity coordinates, «a» from the red-green axis and «b» from the yellow-blue axis). In experiments carried out in La Orden the consistency was also measured by the Bostwick potential (Wolcott, 1987).

The data obtained were studied by two-way analysis of variance (crop line and block) in La Orden experiments and a single factor analysis of variance (line-cultivar) in the remaining experiments. Also, a separation of means was carried out by the Student-Newman-Keuls test.

Results

Agronomical description of the lines

In general, the lines studied exceeded controls in agronomical aspects such as better fruit cover and smaller percentage of ruined fruit but better values were recorded for most of the controls in setting, which was quite irregular in the lines in the first or first two racimes and hardness of fruit.

Lines D-2-1-12-6 and D-2-1-12-15 presented a similar aspect to that of FM-6203 and that of Gévora, characterized by a better leaf foliage, good setting, oval-roundish fruit and good firmness, that was generally greater in the case of D-2-1-12-6, with fruit a little more rounded than the other line. There was some incidence of parthenocarpic fruit and it was more difficult to break the fruit off the stem than in FM-6203.

Also, lines E-2-5-1-8 and E-2-5-1-14 were very similar to their recurrent parent line, presenting large sized plants, of late maturation, with a very tupid intense green foliage, and a pear shaped form, flexible skin and jointless fruit.

Lines F-11-7-2-8 and F-11-7-2-16 are characterized by presenting medium or large-sized plants with abundant foliage that gave good shade to the fruit. These two lines were earlier to mature than many of the control cultivars tested and the rest of the lines obtained. They presented very good setting and rounded-oval fruit with a medium firmness. The F-11-7-2-8 line was noteworthy for the strong fruit color obtained.

Commercial production

In general, the largest commercial yields were obtained in the experiment carried out in La Orden, probably due to the different crop management in smaller plots. In some cases, in the Arroyo de San Serván experiment, very low yields were obtained due to local failure of the crop's irrigation system.

The lines D-2-1-12-6 and D-2-1-12-15 reached very similar levels of production ranging from 53 ± 4 to 99 ± 5 t ha^{-1} and a significantly lower commercial production to that of the most productive cultivar or line was observed in Guadajira and Arroyo de San Serván (Table 1).

In the case of lines E-2-5-1-8 and E-2-5-1-14, greater differences were observed between the yields obtained in the different experiments (Table 1). Also, in this case the yields of these lines were significantly lower than those of the most productive cultivars only in experiments carried out in Guadajira and Arroyo de San Serván (Table 1).

Finally, lines F-11-7-2-8 and F-11-7-2-16 showed yields comparable to FM-6203 and to the group of controls used, except for the Guadajira experiment, where the Centurión hybrid reached yields significantly higher than the remaining lines and controls. This could be because the cultivation methods (irrigation and fertilizer dose) were applied at the optimum time for development of the hybrid Centurión, the predominant variety in the commercial plot.

Maturation factor

With the exception of E-2-5-1-14 in the experiments of Medellín, Arroyo de San Serván and La Orden in 2001, E-2-5-1-8 in the San Serván experiment and D-2-1-12-15 in the experiment of La Orden of 2001, the commercial yield at the time of harvest of the lines studied was equal to or higher than 75% of the total yield and some lines reached higher percentages than those observed in the control cultivars (Table 1).

Lines E-2-5-1-8 and E-2-5-1-14 were the latest to mature and line F-11-7-2-16 was the earliest.

Weight of fruit

All the lines except E-2-5-1-8 and E-2-5-1-14 (which had fruit weighing around 50 g), always reached a fruit weight between 63 ± 1 g and 90 ± 4 g (Table 2), suitable for mechanical harvest.

Estimation of the soluble solid contents (ºBrix)

In general, the lines studied reached a level of soluble solids equal and in many cases higher than that of control cultivars (Table 2). The highest ºBrix values were observed in the least productive experiments while the lowest values were observed in the experiment of La Orden in 2001, which had an earlier harvest.

Lines E-2-5-1-8 and E-2-5-1-14 were noteworthy for their higher ºBrix values, significantly higher on several occasions than most control cultivars and 5.4

ºBrix, which is the level at which the industry will supplement the contracted fresh tomato price.

pH value

In general, the values of pH observed both in the lines and in the control cultivars were quite high, often exceeding a pH of 4.4, the value above which sterilization of the manufactured tomato concentrate becomes more expensive (Table 3).

Lines D-2-1-12-6 and D-2-1-12-15 presented pH values of around 4.4. E-2-5-1-8 and E-2-5-1-14 were those with the highest pH values. Both F-11-7-2-8 and F-11-7-2-16 were noteworthy for being the lines with the lowest pH values, which were sometimes significantly lower than control values.

Bostwick potential

The Bostwick values obtained range from 8.0 cm (corresponding to juices with less consistency), a value only significantly exceeded by two lines and a control, and 2.0 cm (indicating juice with a greater consistency). Juices with the greatest consistency

Table 1. Commercial yield and percentage of commercial yield compared to the total in processing tomato lines studied

Lines	2000			2001	
	La Orden	Guadajira	Medellín	La Orden	A. de S. Serván
*Commercial yield (t ha^{-1})**					
D-2-1-12-6	99 ± 5	84 ± 9 b**	70 ± 12	71 ± 5 bc**	53 ± 4 cd**
D-2-1-12-15	99 ± 9	75 ± 6 b	71 ± 8	75 ± 11 abc	64 ± 7 bc
E-2-5-1-8	117 ± 11	84 ± 6 b	74 ± 1	77 ± 9 abc	34 ± 3 d
E-2-5-1-14	110 ± 8	81 ± 4 b	62 ± 5	62 ± 12 bc	45 ± 7 cd
F-11-7-2-8	92 ± 3	62 ± 2 b	64 ± 9	83 ± 4 ab	82 ± 6 ab
F-11-7-2-16	80 ± 8	61 ± 4 b	78 ± 6	82 ± 5 ab	101 ± 4 a
FM-6203	83 ± 9	74 ± 3 b	75 ± 4	68 ± 7 abc	78 ± 11 ab
Gévora	98 ± 8	—	—	—	—
H-324-1	119 ± 8	—	—	53 ± 6 c	—
Peelmech	87 ± 12	—	—	68 ± 12 abc	—
Centurión	—	111 ± 11 a	—	—	—
Ercole	—	81 ± 2 b	—	—	—
Early Nemapride	—	—	82 ± 9	81 ± 9 ab	85 ± 3 ab
Guadajira	82 ± 6	—	—	—	—
Heinz-9661	—	—	—	92 ± 4 a	—
Soprano	—	—	—	87 ± 6 ab	—
*% Commercial yield over total yield**					
D-2-1-12-6	77 ± 1 ab**	88 ± 3 ab**	81 ± 5 ab**	78 ± 1	80 ± 2 a**
D-2-1-12-15	79 ± 1 ab	86 ± 3 ab	82 ± 3 ab	71 ± 5	83 ± 2 a
E-2-5-1-8	85 ± 3 a	81 ± 2 b	82 ± 2 ab	80 ± 4	59 ± 5 b
E-2-5-1-14	77 ± 4 ab	87 ± 1 ab	71 ± 6 b	69 ± 4	61 ± 4 b
F-11-7-2-8	76 ± 0 ab	90 ± 1 ab	83 ± 4 ab	79 ± 4	83 ± 2 a
F-11-7-2-16	74 ± 5 ab	94 ± 1 a	91 ± 1 a	75 ± 4	82 ± 1 a
FM-6203	69 ± 4 b	90 ± 2 ab	89 ± 1 a	75 ± 3	77 ± 3 a
Gévora	78 ± 2 ab	—	—	—	—
H-324-1	85 ± 3 a	—	—	67 ± 3	—
Peelmech	76 ± 1 ab	—	—	66 ± 8	—
Centurión	—	92 ± 1 a	—	—	—
Ercole	—	82 ± 4 b	—	—	—
Early Nemapride	—	—	89 ± 2 a	79 ± 2	76 ± 3 a
Guadajira	74 ± 6 ab	—	—	—	—
Heinz-9661	—	—	—	79 ± 2	—
Soprano	—	—	—	75 ± 6	—

* Mean ± standard error. ** Separation of means in a column by the Student-Newman-Keuls test with $p > 0.95$.

were those of lines D-2-1-12-6 and F-11-7-2-8 (Table 3).

Colour

In all the lines, the juice tone measured by the a/b index was higher than 2.3, a suitable value for the production of tomato concentrate (Table 4), and lines E-2-5-1-8 and E-2-5-1-14 presented the lowest values. The intensity of the juice colour (L) reached acceptable values in all the lines, although significant differences were observed in all of these. Lines E-2-5-1-8, E-2-5-1-14 and F-11-7-2-16 were noteworthy for their higher L values.

Discussion

From the agronomical evaluation carried out in this work it can be concluded that the six lines studied present an adequate vigour and a plant morphology that provides enough shade for fruits. All the lines showed the capacity to reach a high commercial yield comparable to that of the control cultivars used. These lines present an optimum cluster maturation that makes it possible to

Table 2. Weight of fruit and Brix degrees of the processing tomato lines studied

Lines	2000			2001	
	La Orden	Guadajira	Medellín	La Orden	A. de S. Serván
*Mean weight of fruit (g)**					
D-2-1-12-6	74 ± 2 a**	70 ± 1 c**	68 ± 1 c**	63 ± 1 c**	64 ± 2 cd**
D-2-1-12-15	79 ± 3 a	75 ± 1 bc	71 ± 3 bc	68 ± 1 bc	73 ± 2 bc
E-2-5-1-8	40 ± 2 b	47 ± 2 d	46 ± 1 e	47 ± 2 de	52 ± 4 d
E-2-5-1-14	50 ± 5 b	44 ± 0 d	52 ± 2 d	50 ± 1 d	55 ± 2 d
F-11-7-2-8	87 ± 4 a	77 ± 2 b	75 ± 1 ab	71 ± 2 abc	90 ± 4 a
F-11-7-2-16	79 ± 2 a	70 ± 2 c	74 ± 1 ab	81 ± 2 a	74 ± 1 bc
FM-6203	85 ± 5 a	86 ± 2 a	78 ± 2 a	76 ± 1 ab	91 ± 4 a
Gévora	72 ± 8 a	—	—	—	—
H-324-1	44 ± 3 b	—	—	41 ± 2 e	—
Peelmech	79 ± 3 a	—	—	80 ± 1 a	—
Centurión	—	68 ± 2 c	—	—	—
Ercole	—	74 ± 1 bc	—	—	—
Early Nemapride	—	—	76 ± 2 ab	81 ± 3 a	82 ± 7 ab
Guadajira	79 ± 3 a	—	—	—	—
Heinz-9661	—	—	—	71 ± 7 abc	—
Soprano	—	—	—	80 ± 3 a	—
*°Brix**					
D-2-1-12-6	4,8 ± 0,4	4,7 ± 0,1 cd**	5,2 ± 0,1 b**	4,4 ± 0,1 bcd**	5,0 ± 0,1 bc**
D-2-1-12-15	5,0 ± 0,3	5,1 ± 0,0 ab	5,2 ± 0,1 b	4,4 ± 0,1 bc	5,1 ± 0,1 b
E-2-5-1-8	5,1 ± 0,0	5,0 ± 0,1 abc	5,6 ± 0,1 a	4,2 ± 0,1 cde	5,9 ± 0,1 a
E-2-5-1-14	4,6 ± 0,2	5,2 ± 0,0 a	5,7 ± 0,1 a	4,6 ± 0,1 b	5,7 ± 0,1 a
F-11-7-2-8	5,0 ± 0,1	4,6 ± 0,1 d	5,6 ± 0,2 a	4,1 ± 0,1 de	5,2 ± 0,1 b
F-11-7-2-16	4,8 ± 0,2	4,9 ± 0,1 bcd	5,4 ± 0,1 ab	3,9 ± 0,02 e	4,5 ± 0,1 d
FM-6203	4,9 ± 0,2	4,7 ± 0,1 cd	5,4 ± 0,1 ab	4,0 ± 0,1 e	5,0 ± 0,0 bc
Gévora	5,0 ± 0,2	—	—	—	—
H-324-1	5,4 ± 0,3	—	—	4,9 ± 0,1 a	—
Peelmech	4,8 ± 0,2	—	—	4,1 ± 0,1 e	—
Centurión	—	5,0 ± 0,1 abc	—	—	—
Ercole	—	4,6 ± 0,0 d	—	—	—
Early Nemapride	—	—	4,9 ± 0,1 c	3,8 ± 0,0 e	4,8 ± 0,0 c
Guadajira	5,0 ± ,2	—	—	—	—
Heinz-9661	—	—	—	4,0 ± 0,1 e	—
Soprano	—	—	—	4,0 ± 0,2 e	—

* Mean ± standard error. ** Separation of means within the column by the Student-Newman-Keuls test with $p > 0.95$.

Table 3. pH value and Bostwick estimated in the processing tomato lines

Lines	2000			2001	
	La Orden	**Guadajira**	**Medellín**	**La Orden**	**A. de S. Serván**
*pH**					
D-2-1-12-6	4.31 ± 0.01 b**	4.42 ± 0.02 c**	4.41 ± 0.01 bc**	4.46 ± 0.02 f**	4.37 ± 0.02 ab**
D-2-1-12-15	4.39 ± 0.01 d	4.43 ± 0.01 c	4.40 ± 0.01 bc	4.23 ± 0.02 c	4.36 ± 0.01 a
E-2-5-1-8	4.37 ± 0.02 cd	4.38 ± 0.01 abc	4.47 ± 0.01 c	4.46 ± 0.00 f	4.47 ± 0.01 c
E-2-5-1-14	4.32 ± 0.01 bc	4.39 ± 0.01 abc	4.41 ± 0.04 bc	4.42 ± 0.02 e	4.46 ± 0.00 c
F-11-7-2-8	4.33 ± 0.02 bc	4.36 ± 0.02 ab	4.31 ± 0.02 a	4.27 ± 0.02 d	4.34 ± 0.02 a
F-11-7-2-16	4.21 ± 0.01 a	4.40 ± 0.02 bc	4.38 ± 0.01 b	4.18 ± 0.02 b	4.37 ± 0.01 ab
FM-6203	4.31 ± 0.01 b	4.38 ± 0.01 abc	4.40 ± 0.01 bc	4.10 ± 0.01 a	4.42 ± 0.01 b
Gévora	4.34 ± 0.01 bc	—	—	—	—
H-324-1	4.32 ± 0.01 bc	—	—	4.30 ± 0.02 d	—
Peelmech	4.23 ± 0.01 a	—	—	4.31 ± 0.01 d	—
Centurión	—	4.35 ± 0.01 ab	—	—	—
Ercole	—	4.34 ± 0.01 a	—	—	—
Early Nemapride	—	—	4.37 ± 0.01 b	4.32 ± 0.02 d	4.32 ± 0.03 a
Guadajira	4.35 ± 0.01 bcd	—	—	—	—
Heinz-9661	—	—	—	4.19 ± 0.01 b	—
Soprano	—	—	—	4.31 ± 0.02 d	—
*Bostwick (estimation)**					
D-2-1-12-6	5.9 ± 0.6 bc**	4.4 ± 0.5 a**		4.5 ± 0.5 ab**	
D-2-1-12-15	6.3 ± 0.8 bcd	6.4 ± 0.6 ab		5.7 ± 0.8 bc	
E-2-5-1-8	8.2 ± 1.0 de	7.5 ± 0.8 b		5.0 ± 0.3 abc	
E-2-5-1-14	6.7 ± 0.5 cd	7.0 ± 0.6 ab		5.4 ± 0.3 abc	
F-11-7-2-8	4.4 ± 0.3 ab	6.2 ± 0.3 ab		3.2 ± 0.2 a	
F-11-7-2-16	6.7 ± 0.9 cd	6.3 ± 0.5 ab		4.5 ± 0.42 ab	
FM-6203	8.6 ± 0.6 e	6.4 ± 0.2 ab		6.0 ± 0.8 bc	
Gévora	6.3 ± 0.6 bcd	—		—	
H-324-1	6.1 ± 0.6 bcd	—		5.2 ± 1.1 abc	
Peelmech	10.6 ± 0.6 f	—		5.9 ± 0.2 bc	
Centurión	—	7.7 ± 0.8 b		—	
Ercole	—	6.6 ± 0.9 ab		—	
Early Nemapride	—	—		5.8 ± 0.3 bc	
Guadajira	4.1 ± 0.5 a	—		—	
Heinz-9661	—	—		6.9 ± 0.5 bc	
Soprano	—	—		7.3 ± 0.8 c	

* Mean ± standard error. ** Separation of means within a column by the Student-Newman-Keuls test with $p > 0.95$.

carry out a single mechanical harvest. Also, the mean weight of the fruit in these lines, between 60 and 95 g, is optimum to achieve a good yield in this type of harvest. Some of the lines (E-2-5-1-8 and E-2-5-1-14), with a smaller mean fruit weight, can be very promising candidates for the production of peeled whole tomatoes in small containers. The soluble solid contents is equal to or higher than that of commercial cultivars demonstrating the value of the materials developed for their industrial production. Although there is a known association between the high content of soluble solids and the low level of production (Stevens and Rick, 1986; Rodríguez *et al*., 1993a, 1993b; Martineau *et al*., 1995), this does not explain the higher levels of soluble solids since they were equal to or higher than values for the most productive hybrid cultivars. We consider in our case that the higher value of soluble solids is associated with the plant morphology, with an abundant foliage and therefore, a greater photosynthetic potential (Hewitt, 1979). Both the pH and the colour of the juice were suitable for industrial processing.

In the light of the results of the agronomical evaluation, the use of these crop lines is recommendable in areas with a high incidence of TSWV disease. Mo-

Table 4. Parameters of colour a/b and L of processing tomato crops studied

Lines	2000			2001	
	La Orden	Guadajira	Medellín	La Orden	A. de S. Serván
*Colour (a/b)**					
D-2-1-12-6	2.4 ± 0.0 cde**	2.4 ± 0.0 ab**	2.4 ± 0.0 abc**	2.5 ± 0.0 ab**	2.5 ± 0.0 a**
D-2-1-12-15	2.5 ± 0.0 bcd	2.5 ± 0.0 ab	2.4 ± 0.0 bc	2.5 ± 0.0 a	2.3 ± 0.0 b
E-2-5-1-8	2.3 ± 0.0 e	2.4 ± 0.0 ab	2.4 ± 0.0 bc	2.4 ± 0.0 c	2.3 ± 0.0 b
E-2-5-1-14	2.5 ± 0.0 abc	2.5 ± 0.0 ab	2.4 ± 0.0 c	2.4 ± 0.0 c	2.3 ± 0.0 b
F-11-7-2-8	2.6 ± 0.0 ab	2.5 ± 0.1 ab	2.4 ± 0.0 abc	2.5 ± 0.0 abc	2.5 ± 0.0 a
F-11-7-2-16	2.6 ± 0.0 a	2.5 ± 0.2 a	2.4 ± 0.0 ab	2.5 ± 0.02 ab	2.4 ± 0.0 b
FM-6203	2.5 ± 0.0 abc	2.5 ± 0.0 ab	2.5 ± 0.0 a	2.5 ± 0.0 a	2.5 ± 0.0 a
Gévora	2.4 ± 0.0 de	—	—	—	—
H-324-1	2.3 ± 0.0 e	—	—	2.4 ± 0.0 c	—
Peelmech	2.6 ± 0.0 a	—	—	2.4 ± 0.0 bc	—
Centurión	—	2.4 ± 0.0 ab	—	—	—
Ercole	—	2.4 ± 0.0 b	—	—	—
Early Nemapride	—	—	2.5 ± 0.0 ab	2.5 ± 0.0 ab	2.4 ± 0.0 b
Guadajira	2.5 ± 0.0 abc	—	—	—	—
Heinz-9661	—	—	—	2.4 ± 0.0 bc	—
Soprano	—	—	—	2.5 ± 0.0 abc	—
*Colour (L)**					
D-2-1-12-6	24.0 ± 0.4 ab**	23.5 ± 0.0 bc**	23.6 ± 0.1 c**	23.4 ± 0.1 bcde**	24.0 ± 0.1 bc**
D-2-1-12-15	26.4 ± 0.3 d	23.5 ± 0.1 bc	23.8 ± 0.1 c	23.3 ± 0.0 bcd	24.5 ± 0.1 c
E-2-5-1-8	23.1 ± 0.3 a	22.9 ± 0.1 ab	22.4 ± 0.2 a	23.0 ± 0.1 abc	23.5 ± 0.2 ab
E-2-5-1-14	24.8 ± 0.4 bc	22.9 ± 0.1 ab	22.4 ± 0.2 a	23.0 ± 0.2 abc	23.1 ± 0.2 a
F-11-7-2-8	25.5 ± 0.2 cd	22.9 ± 0.4 ab	23.6 ± 0.1 c	24.0 ± 0.1 e	23.8 ± 0.1 b
F-11-7-2-16	23.3 ± 0.1 a	23.0 ± 0.3 ab	23.7 ± 0.0 c	23.3 ± 0.1 bcd	23.2 ± 0.1 a
FM-6203	23.2 ± 0.2 a	23.7 ± 0.1 c	23.5 ± 0.1 c	23.3 ± 0.1 bcd	23.5 ± 0.1 ab
Gévora	24.0 ± 0.2 ab	—	—	—	—
H-324-1	27.5 ± 0.9 e	—	—	22.5 ± 0.1 a	—
Peelmech	23.3 ± 0.1 a	—	—	23.5 ± 0.4 cde	—
Centurión	—	22.6 ± 0.1 b	—	—	—
Ercole	—	21.9 ± 0.2 a	—	—	—
Early Nemapride	—	—	22.9 ± 0.1 b	23.0 ± 0.1 abc	24.4 ± 0.3 c
Guadajira	23.2 ± 0.1 a	—	—	—	—
Heinz-9661	—	—	—	23.8 ± 0.1 de	—
Soprano	—	—	—	22.8 ± 0.1 ab	—

* Mean ± standard error. ** Separation of means within the column by the Student-Newman-Keuls test with $p > 0.95$.

reover, a phytotechnical study that would optimize the most appropriate cultivation techniques for each line would enable higher yields to be obtained than in the above experiments and extension of the crop to other areas in which TSWV is not a limiting factor for crop development (Rodríguez *et al*., 1993a, 1993b).

In general, all the lines presented a certain degree of heterogeneity for some agronomical characters such as setting and fruit size which led to a lack of productive stability in the different experiments carried out. In the open pollination varieties included as controls there was also less productive stability than in hybrid crops. These drawbacks could be overcome by designing a breeding program to develop hybrids by carrying out complementary crosses between the previous lines. This would allow exploitation of heterosis and more stability against environmental or homeostatic conditions, characters typical of hybrid cultivars.

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