New Breeding Lines Resistant to Tomato Mosaic Virus and Tomato Spotted Wilt Virus within the ‘De la Pera’ Tomato Type: UMH 1353 and UMH 1354

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‘De la pera’ is a tomato landrace that is very popular in a limited area in southeastern Spain. The fruits from this landrace are juicy and have a firm texture, a strong flavor, and a high proportion of seeds and mucilage. The fruit weight ranges between 75 and 125 g, and fruits are elongated-oval to bell-like in shape, with dark green shoulders and no ribs. Like tomatoes, they are very popular in a limited area in southeastern Spain.

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Table 1. Yield traits, titratable acidity (TA), and soluble solids content (SSC) of the two new breeding lines. The previously released breeding lines UMH 1415, UMH 1422, and UMH 1203 and the De la pera cultivar P21 are included as reference. All the accessions were grown in the spring-summer crop cycle during the last 4 years, under the typical growing conditions of the region. The mean of 10 fruits in the same stage of ripening (with >50% of the surface showing red color) per plot for each accession.

| Accession | Marketable yield (kg/plant) | Avg fruit wt (g) | Fruit no. per plant | TA (g/100 g) | SSC (°Brix) |
|-----------|-----------------------------|------------------|---------------------|--------------|------------|
| Open field, 2011 | | | | | |
| UMH 1353 | 4.89 | 90.5 b | 53.8 | 0.57 c | 4.59 |
| UMH 1354 | 4.21 | 80.9 a | 52.2 c | 0.49 b | 4.46 |
| UMH 1415 | 3.29 | 75.7 a | 43.2 b | 0.43 b | 4.31 |
| UMH 1203 | 2.41 | 76.9 a | 32.1 a | 0.44 b | 4.52 |
| P21 | 4.54 c | 114.2 c | 40.8 b | 0.34 a | 4.47 |
| Mesh-covered net house, 2011 | | | | | |
| UMH 1353 | 5.12 c | 86.6 b | 51.9 c | 0.71 b | 5.20 |
| UMH 1354 | 4.57 c | 77.6 ab | 50.2 c | 0.69 b | 5.28 |
| UMH 1415 | 3.94 b | 80.5 ab | 43.6 b | 0.57 ab | 5.22 |
| UMH 1415 | 3.79 b | 94.3 c | 26.6 b | 0.55 ab | 5.00 |
| UMH 1203 | 2.38 a | 72.5 a | 29.5 a | 0.43 a | 5.17 |
| P21 | 3.56 b | 82.5 ab | 38.2 b | 0.48 a | 5.23 |
| Mesh-covered net house, 2013 | | | | | |
| UMH 1353 | 5.73 c | 74.2 b | 77.6 b | 0.40 b | 4.57 a |
| UMH 1354 | 4.37 b | 63.5 ab | 71.7 b | 0.49 c | 4.58 a |
| UMH 1415 | 3.97 b | 60.5 ab | 66.3 b | 0.31 a | 4.74 ab |
| UMH 1415 | 4.09 b | 60.6 ab | 68.9 b | 0.38 b | 4.92 b |
| UMH 1203 | 2.59 a | 54.9 a | 46.5 a | 0.36 ab | 4.62 a |
| P21 | 3.03 a | 71.3 b | 42.3 a | 0.35 a | 4.71 ab |
| Mesh-covered net house, 2014 | | | | | |
| UMH 1353 | 4.77 bc | 75.1 b | 64.2 b | 0.42 c | 5.69 ab |
| UMH 1354 | 4.99 c | 76.6 b | 65.2 b | 0.36 b | 5.48 a |
| UMH 1415 | 4.12 b | 63.9 a | 64.4 b | 0.33 b | 5.59 ab |
| UMH 1415 | 4.32 b | 66.8 b | 54.7 b | 0.35 b | 5.51 b |
| UMH 1203 | 2.49 a | 72.1 ab | 35.1 a | 0.29 a | 6.33 d |
| P21 | 2.55 a | 65.5 | 40.5 a | 0.33 b | 5.93 c |

Plants were grown vertically with a single stem, with black plastic mulch to reduce the incidence of weeds, with 2.7 plants/m² in open field and 2.5 plants/m² in mesh-covered net house.

Mean of 6–8 plants per plot for two replicates.

Mean of 10 fruits in the same stage of ripening (with >50% of the surface showing red color) per plot for two replicates.

Mean values in a column followed by a different letter are significantly different according to the Newman-Keuls’s multiple range test (P < 0.05).

Origin

The breeding lines UMH 1353 and UMH 1354 were obtained by crossing a De la pera cultivar (accession P21, previously selected for fruit morphological characteristics, uniformity, and high yields) with the commercial cultivar Anastasia F1 (Seminis Vegetable Seeds, Saint Louis, MO). Anastasia F1 was used as the donor parent of the Tm-2e and Sw-5 genes (Pérez de Castro et al., 2007), conferring resistance to ToMV and TSWV, respectively. Six generations of backcrossing were performed to the De la pera cultivar using marker-assisted selection for the virus-resistance genes (Table 2). Several trials were carried out under different infection conditions (mechanical inoculation for ToMV and natural infection for TSWV) to check for the presence of resistance alleles in the first backcross (BC) generations and to assess the effectiveness of the molecular marker-assisted selection for virus resistance.

These new breeding lines UMH 1353 and UMH 1354 have shown higher marketable yields than UMH 1203 and yields similar to those of the traditional De la pera cultivar P21. Furthermore, the new breeding lines UMH 1353 and UMH 1354 are available for cropping in the spring-summer crop cycle, when the level of TYLCV incidence is lower. These new breeding lines UMH 1353 and UMH 1354, with genetic resistance to ToMV and TSWV, have shown higher marketable yields than the previously developed breeding lines UMH 1422 and UMH 1415 (around 35% greater in open field trial and ranging between 15% and 20% greater in mesh-covered net house trials) (Table 1).
among fruits and yields) was applied during
behavior (proper fruit set, sufficient uniformity
blossom-end rot) and good agronomic be-
markers. In addition, high selection pressure
for desirable ‘De la pera’ characteristics (bell
shape, green shoulder, low sensitivity to
blossom-end rot) and good agronomic beha-
(proper fruit set, sufficient uniformity
among fruits and yields) was applied during
the backcrossing process. Progenies for each
BC generation were screened with molecular
markers for Tm-2a and Sw-5 genes. All plants
containing the set of the two resistance genes
(usually between five and 10 plants) were
transplanted and then crossed with the re-
current parent. Only the best plants (between
two and four) were selected for further back-
crossing. After the selfing of two BCo double
heterozygous plants, followed by two gener-
ations of selfing and selection, the purebreed-
UMH 1353 and UMH 1354 lines, homozygous for Tm-2a and Sw-5 (Table 3), were selected using molecular markers.
These lines were then multiplied by self-
pollination in a greenhouse under controlled
conditions.

### Description and Performance

UMH 1353 and UMH 1354 have indeter-
minate growth with intermediate foliage
density and medium-sized fruits (70–90 g)
with bell shape and green shoulders (Fig. 1).
Both lines are homozygous for the Tm-2a
and Sw-5 resistance genes (Table 3). Between
2011 and 2014, we cultivated UMH 1353 and
UMH 1354 breeding lines together with three
previously developed breeding lines and the
cultivar P21 in different conditions (open
field and in mesh-covered net houses) in the
spring-summer crop cycle, the most widely
used cycle in the traditional area of cultiva-
tion for the ‘De la pera’ tomato. In terms of
desirable agronomic traits, UMH 1353 and
UMH 1354 surpassed UMH 1203 breeding
line that contained resistance to ToMV,
TYLCV, and TSWV. The increase in market-
able yield was especially significant for the
UMH 1353 and UMH 1354 lines, which
obtained nearly double the marketable yields
of the UMH 1203 line (Table 1). The market-
able yields of the UMH 1353 and UMH 1354 breeding
lines surpassed the yields of the previously
developed breeding lines in three of the four studied cycles. The marketable
yields of these new lines ranged between 4.21
kg/plant and 5.73 kg/plant, which are high for
a tomato landrace. In terms of the number of
fruits produced, the increases among the new
breeding lines with respect to the previously
developed lines were similar to increases in
marketable yield (around 50%). With respect
to the average fruit weight, however, differ-
ences between the lines were less pro-
nounced, with the new lines showing increases of around 15% to 20% with respect
to the other lines studied. Furthermore, UMH
1353 and UMH 1354 obtained titratable
acidity values similar to or higher than the
other breeding lines. In terms of soluble
solids content, significant differences were
only found in two of the four studied cycles,
with the UMH1353 and UMH1354 breeding
lines showing similar or lower values with
respect to the previously released breeding
lines and the traditional cultivar. The small
differences between the UMH1353 and
UMH1354 breeding lines can be seen in Table 1.

### Use

UMH 1353 and UMH 1354 have genetic
resistance to ToMV and TSWV, viruses that
often infect tomato landrace crops in south-
estern Spain, especially in open field condi-
tions (Cebolla-Cornejo et al., 2007). This
study found that 67% and 18% of the farms
or smallholdings analyzed near the city of
Valencia were infected with ToMV and
TSWV, respectively. The two new breeding
lines UMH 1353 and UMH 1354 are avail-
able for cropping in the spring-summer pro-
duction cycle, which is the most important
cycle in the traditional area of cultivation for
the ‘De la pera’ tomato. This is when the level of
TYLCV incidence is less intense due to the
low population levels of the whitefly vector
Bemisia tabaci (Genn.). Cultivation of these
breeding lines is also feasible in the summer-
autumn cycle (when the level of TYLCV inci-
dence is higher), either in greenhouses or
mesh-covered net houses with an enclo-
sure in good condition, making it possible to
effectively control the vector. As described
above, these two new breeding lines have
shown higher marketable yields than the
previously developed breeding lines. As
with previous releases produced by this
breeding program, UMH 1353 and UMH 1354 are
under study to be marketed by private
companies. These breeding lines may be used to develop F1 hybrids by
crossing them with other ‘De la pera’
landraces to increase yield by using genetic
resistance into other landraces.

### Availability

Small trial seed samples of all the breed-
ing lines are available for research purposes
(please contact authors).

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lines and De la pera cultivar P21 are included as reference.

### Table 2. Primer sequence, PCR conditions, and restriction enzyme using the molecular markers linked to
Tm-2a and Sw-5 genes.

| Gene   | Primer sequence                        | PCR conditions | Restriction enzyme |
|--------|----------------------------------------|----------------|-------------------|
| Tm-2a  | AGGTGGTTCACCCGATTTGAT                  | 35 55          | BsaRI             |
| Sw-5   | AAGCCGTGGCTTCCGTATTAACTGTA            | 35 50          | TruI              |

PCR = polymerase chain reaction.

### Table 3. Genotype for each resistance gene (RR: resistant homozygous, ss: susceptible homozygous) for the two new breeding lines. The UMH 1415, UMH 1422, and UMH 1203 breeding lines and De la pera cultivar P21 are included as reference.

| Breeding line/cultivar | Genotype | Tm-2a | Ty-1 | Sw-5 |
|------------------------|----------|-------|------|------|
| UMH 1353               | RR       | ss    | RR   |
| UMH 1354               | RR       | ss    | RR   |
| UMH 1422               | RR       | ss    | SS   |
| UMH 1415               | RR       | RR    | RR   |
| UMH 1203               | RR       | RR    | RR   |
| P21                    | ss       | ss    | SS   |

Fig. 1. Plants with fruits in different ripening stages of the breeding lines UMH 1353 and UMH 1354.
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