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Rootstock resistance to fusarium wilt and effect on fruit yield and quality of two muskmelon cultivars

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Abstract

Pending the release of new genetic material with satisfactory resistance, grafting techniques may represent a quick, though expensive method for controlling race 1,2 of *Fusarium oxysporum* f. sp. *melonis* in Italian growing regions of melon (*Cucumis melo* L.). We evaluated the potential of grafting for resistance to this pathogen in 13 commercial melon rootstocks and various *Cucurbitaceae* spp. and determined productivity and fruit quality characteristics of grafting on resistant rootstocks. Following inoculation, P360 and PGM 96-05 commercial rootstocks, as well as *Benincasa hispida*, *Cucumis metuliferus*, *Cucumis ficifolius*, *Cucurbita maxima*, *Cucurbita moschata*, and *Lagenaria siceraria* were resistant to the race 1,2 of Fusarium. Yield and quality attributes of scion cultivars (Supermarket and Proteo) grafted on P360 and PGM 96-05 rootstocks were not improved relative to ungrafted controls. Grafts onto *B. hispida* negatively influenced both yield and fruit quality, while *C. metuliferus*, and *C. zeyheri* had negative impacts on productivity and fruit quality, respectively. These results indicate that rootstock influences on disease resistance as well as productivity and quality of scion fruit are important in determining the potential utility of grafting applications.

Keywords: Grafting; *Fusarium oxysporum* f. sp. *melonis*; *Cucumis melo*; Disease resistance

1. Introduction

Soil-borne diseases such as Fusarium wilt (causal agent: *Fusarium oxysporum* f. sp. *melonis*), may heavily affect melon (*Cucumis melo* L.) either during early cultivation in the plastic tunnel or later under field production conditions. Four races of *F. oxysporum* (0, 1, 2, and 1,2) have been identified (Risser et al., 1976), however only the first three are

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efficiently controlled by the single dominant genes *Fom*-1 and *Fom*-2 which are both already present in commercial F_1 hybrids. Race 1,2 is wide spread in Italy and represents about 50–60% of the tested isolates (Tamietti et al., 1994; Belisario et al., 1998), and it is not yet suitably controlled by appropriate genetic resistance.

Pending the release of new genetic material with satisfactory resistance, grafting techniques may represent a quick, though expensive, method for controlling race 1,2 of *F. oxysporum* f. sp. *melonis*. In the last 20 years, cultivation of grafted plants has largely increased for both *Solanaceae* (e.g. eggplant and tomato) and *Cucurbitaceae* (e.g. melon and watermelon), especially when adequate disease resistance is not available in commercial hybrids (Morra, 1997; Morra et al., 1997). Although used in the past, *Cucurbita ficifolia* and *Cucurbita moschata* along with *Benincasa hispida* and *Lagenaria siceraria* have been now abandoned as rootstocks because of their low affinity with cultivated melon (Morra, 1997). F_1 hybrids Dinero, Jador, Belimo, Orca, grafted on different types of melon, are recently preferred in Italy (Morra and Bilotto, 1998).

The rootstock can also greatly influence plant growth, yield, and fruit quality (Lee, 1994). Both fruit harvest duration and fruit size of melon cultivars grafted onto rootstocks having vigorous root systems are significantly increased compared to those from intact plants. Effects of rootstocks on fruit quality are often detrimental. However, these vary greatly with the scion cultivar.

In this study, we determined Fusarium resistance in accessions of *Cucurbitaceae* species along with commercial rootstocks considered tolerant to race 1,2 of *F. oxysporum* f. sp. *melonis*. The selected genotypes were evaluated in terms of productivity and fruit quality in different grafting combinations with two commercial cultivars.

2. Materials and methods

2.1. Properties and sources of genotypes

Table 1 shows the genotypes tested. These include commercially available F_1 hybrids as rootstocks tolerant to Fusarium race 1,2 and resistant to other ones, and some accessions of *Cucurbitaceae* spp., that were provided from germplasm collections in Spain, Czech Republic, United States, Peru, Italy and Israel. Inoculation tests also included Italian cv. Retato degli Ortolani, used as a susceptible control to all races, and the French line Isabelle which is characterized by partial resistance to race 1,2. The hybrids Accent, Divar IV, Portinnesto retato, and Soldor, resistant only to the Fusarium races 0, 1, and 2, were also included as further susceptible controls in the inoculation tests with Fusarium isolate of the race 1,2.

2.2. Inoculation test

Artificial inoculations were performed under controlled conditions ($T = 24 \pm 1$ °C; photoperiod: 16 h light/8 h dark) on 15 plantlets per genotype at the first-true-leaf stage. The inoculum used was a fungal suspension containing 10^6 conidia ml^{-1} collected from 12-day-old PDA (potato dextrose agar) cultures of the Italian highly aggressive isolate

Table 1
Commercial rootstocks of melon and *Cucurbitaceae* spp. tested for resistance to the race 1,2 of *F. oxysporum* f. sp. *melonis*

F_1 hybrid name or accession number of *Cucurbitaceae* spp.	Provenance
Commercial rootstocks	
XHP 16017 Hy[a]	ASGROW
Greffor[a]	CLAUSE
Soldor[a]	CLAUSE
Divar IV[a]	ESASEM
Portinnesto liscio[a]	ESASEM
Portinnesto retato[a]	ESASEM
P360[b]	SAIS
Accent[a]	NUNHEMS
Belimo[a]	NUNHEMS
Dinero[a]	NOVARTIS
Orca[a]	TEZIER
Jador[a]	VILMORIN
PGM 96-05[b]	VILMORIN
Cucurbita spp.	
B. hispida (local accession)	USDA Plant Introduction Office, Maryland, USA
C. ficifolius (acc. No. 5119)	Universidad Politecnica de Valencia, Spain
C. figarei (acc. No. 09-H41-0577)	University of Olomuc, Czech Republic
C. metuliferus (local accession)	University of Bar-Ilan, Department of Life Sciences, Ramat-Gan, Israel
C. zeyheri (acc. No. 8686)	Universidad Politecnica de Valencia, Spain
Cucurbita maxima (local accession)	Peru
C. moschata (acc. No. 09-H42-0688)	University of Olomuc, Czech Republic
L. siceraria (local accession)	Istituto Sperimentale per l'Orticoltura, Pontecagnano, Salerno, Italy

[a] *C. melo*.
[b] *C. maxima* × *C. moschata*.

ISPaVe No. 1018 of *F. oxysporum* f. sp. *melonis*, VCG 0134, belonging to the race 1,2 W which produces wilting symptoms in susceptible plants (Tamietti et al., 1994). After removing the plantlets from the seedling pots, roots were washed in tap water and pruned to about 1.0–1.5 cm. Plantlets were then transplanted into pots filled with sterile mould and were inoculated at the base of each plant with 5 ml of the conidial suspension. Water-inoculated plants represented controls. To facilitate inoculum absorption into the soil, the seedling trays were kept at 24 ± 1°C, and were watered the day after inoculation. Number of healthily, symptomatic (progressive yellowing and/or wilting of leaves) and dead plants per genotype was recorded every 2 days from symptom appearance on the susceptible control to the 40th day after inoculation. Inoculation tests were repeated three times.

2.3. Crop conditions and plant sampling

Once selected, the genotypes best controlling race 1,2 of *F. oxysporum* were used as rootstocks for the melon cultivars Supermarket (SAIS) and Proteo (S&G Sandoz Seeds) to evaluate the impact of rootstock on yield and fruit quality. These cultivars were chosen because they represented the most wide spread cultivars in Italian melon growing regions. Field studies were conducted in 1998 and 1999 at the Viterbo University Experimental Farm, in Central Italy (latitude 42°25′N, longitude 12°08′E, altitude 310 m). The soil was a sandy loam soil with 1.8% organic matter, pH 7.1 (1 soil:2.5 water), 0.88 g kg^{-1} total N, 21 mg kg^{-1} P (Olsen method), and ammonium acetate extractable nutrients as follows: 3.4 g kg^{-1} K, 3.1 g kg^{-1} Ca, and 0.2 g kg^{-1} Mg. Randomized complete block designs were used for the two factorial field experiments with treatments replicated four times. The treatments were defined by a factorial combination of two melon cvs Supermarket and Proteo (scions), and seven resistance rootstocks (*B. hispida*, *C. metuliferus*, *C. zeyheri*, *C. moschata*, *C. maxima*, PGM 96-05, P 360). Check treatments with ungrafted cultivars (Proteo and Supermarket) were also included in the field experiments. Each experimental plot had 24 plants and only the central 6 plants were harvested.

The plants were transplanted in single rows with black polyethylene mulch film on 15 May 1998, and 7 May 1999. Plants were spaced at 0.9 m between plants and 2 m between rows, with a density of 4500 plants/ha. Water was applied by drip irrigation positioned under the polyethylene mulch film. Irrigations were scheduled on the basis of crop evapotranspiration which was estimated using a Class A pan and specific melon crop coefficients (Doorembos and Pruitt, 1977). In both years, preplant broadcast diammonium phosphate fertilizer (18-46-0) was applied at 200 kg ha^{-1} (36 kg N ha^{-1}, 41 kg P ha^{-1}) to all plots. An additional 80 kg N ha^{-1}, 73 kg K ha^{-1}, and 66 kg Ca ha^{-1} were applied as potassium nitrate (13-0-44) and calcium nitrate (15.5-0-0-19 Ca) through the drip irrigation system in equal portions at 14 weekly intervals starting 2 weeks after field planting. Weeds between the polyethylene mulch films were controlled by one preplant application of glyphosate at 3.4 kg ha^{-1}. Aphids and powdery mildew were controlled by an application of imidacloprid (0.25 ml ha^{-1}) and two applications of micronized sulfur (3.7 kg ha^{-1}). Maximum and minimum average temperatures during the period from transplanting to plot harvesting ranged from 28.6 to 13.6 °C in 1998 and from 27.9 to 16.1 °C in 1999. Total rainfall was 236 mm in 1998 and 182 mm in 1999. Marketable fruits were collected at ripening, and the number of fruits per plant and fruit weight were determined. Eight fruits of each treatment were chosen at random to assess the soluble solids contents. The selected fruits were cut into slices to remove rinds and seeds. The pulp of each fruit was liquefied and the juice obtained was used to determine soluble solids concentrations (°Brix) by an Atago N1 refractometer at 20 °C. Analysis of variance of the treatment effects on measured traits was performed using the GLM procedure of SPSS (SPSS 7.5, 1997). A Duncan's Multiple Range test was used to separate main effect means, when the *F*-test was significant.

3. Results and discussion

3.1. Fusarium resistance

Mean values of three inoculation tests dealing with race 1,2 of *F. oxysporum* f. sp. *melonis* indicate that the commercial rootstocks PGM 96-05 and P360 had 100% plant survival which clearly differed from the other genotypes screened (Fig. 1). Reactions of the F_1 hybrids Belimo and XPH 16017 HY to the fungus resulted in intermediate levels of survival,

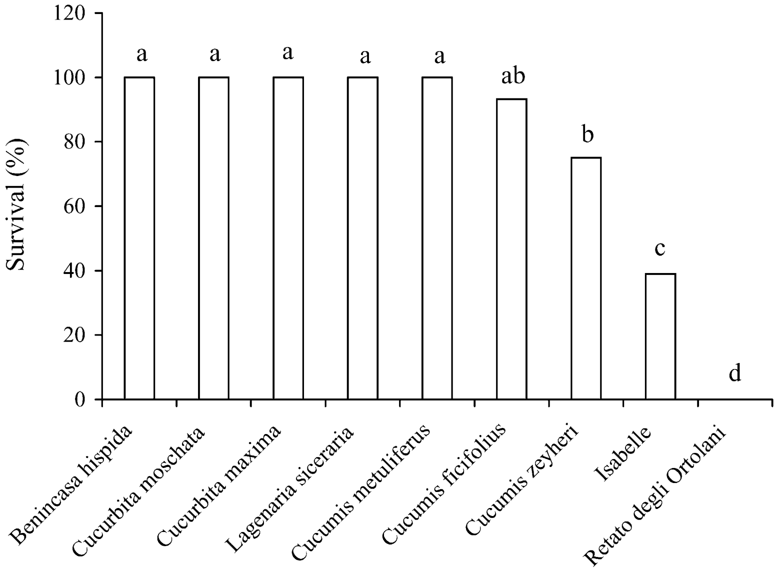

Fig. 1. Melon commercial rootstock reaction to inoculation with *F. oxysporum* f. sp. *melonis*, race 1,2 (mean of three inoculation tests). Means separation by Duncan's Multiple Range test, $P = 0.05$.

comparable to those of the partially resistant control Isabelle, but significantly different from those of either PGM 96-05 and P360 or from those observed on the remaining genotypes. Two other groups of rootstock reactions to the fungus are seen in the survival percentages of Orca, Dinero, and Greffor (16–19%), and of Portinnesto liscio and Jador, which had 11 and 15% survival, respectively. Small morphological or growth differences, mainly due to a non-homogeneous germination within the genotypes, could be responsible for some possible changes in the reaction of individual plants to the fungus. The genotypes Jador, Divar IV, Portinnesto retato, Soldor, and Accent were susceptible as the control Retato degli Ortolani. Previous analyses indicated that the same materials provided also a good control of the single races 1 and 2 of the fungus (Trionfetti Nisini et al., 1999).

Cucurbitaceae spp. such as *B. hispida*, *C. metuliferus*, *C. moschata*, *C. maxima*, and *L. siceraria* were immune to fungus damage (Fig. 2). *C. zeyheri* showed a partial resistance to the fungus (75% of surviving plants), but at a higher level than the control Isabelle.

3.2. Yield and fruit quality

Cultivars Proteo, and Supermarket, grafted on *Cucurbitaceae* spp. and commercial rootstocks selected as resistant to race 1,2 of the fungus, were evaluated in terms of yield and quality (Tables 2 and 3). Although selected as rootstocks resistant to race 1,2 of *F. oxysporum*, *C. moschata* and *C. maxima* were excluded from the experiment because of their low affinity for each scion cultivar utilized (death of about 80% grafted plants). This phenomenon along with an abnormal formation of callus tissue at the grafting site was evident during fruit ripening and harvesting.

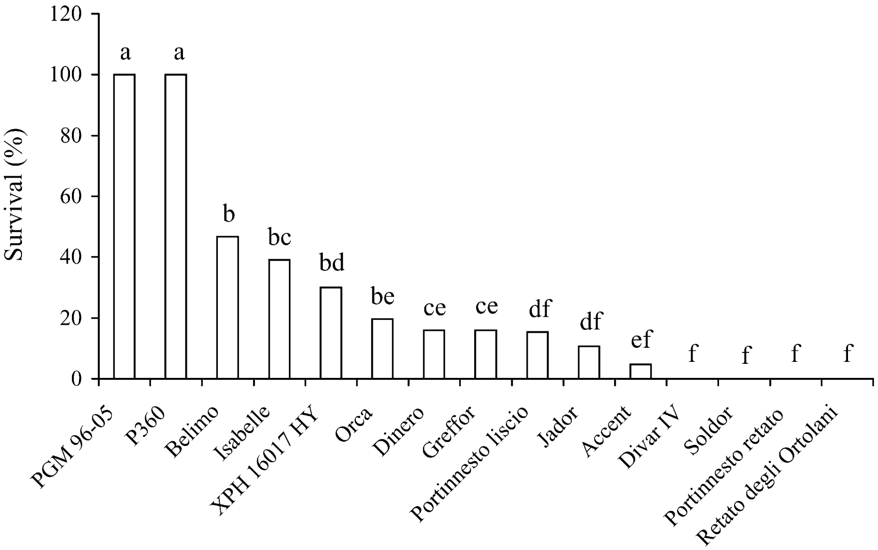

Fig. 2. Different *Cucurbitaceae* reactions to inoculation with *F. oxysporum* f. sp. *melonis*, race 1,2 (mean of three inoculation tests). Means separation by Duncan's Multiple Range test, $P = 0.05$.

In both years, fruit mass of the combinations PGM 96-05 × Supermarket and P360 × Supermarket were similar or higher than in control (Table 2). PGM 96-05× Proteo and P360 × Proteo presented the highest fruit mass, while the lowest fruit mass were recorded for the combination *B. hispida* × Proteo (Table 3).

Significant differences were found in the fruit number per plant between controls and grafted plants (Tables 2 and 3). The majority of grafted plants had a similar fruit number compared to the ungrafted cultivar, except those grafted onto the *C. zeyheri* and *B. hispida*

Table 2
Effects of rootstocks on mean fruit mass, fruit number, yield and soluble solids concentration of cultivar Supermarket by year[a]

Treatment	Fruit				Yield (kg m^{-2})		Soluble solids (°Brix)	
	Size (kg/fruit)		Number (fruit/plant)		1998	1999	1998	1999
	1998	1999	1998	1999				
Supermarket (S)	1.15 b	1.20 ab	4.4 a	5.2 a	2.28 ab	2.81 a	9.8 a	10.3 a
B. hispida × S	1.11 b	1.09 b	2.8 b	3.9 ab	1.40 c	1.94 bc	9.4 b	9.0 c
C. metuliferus × S	1.14 b	1.24 ab	3.8 a	5.2 a	1.95 b	2.88 a	9.6 ab	9.2 bc
C. zeyheri × S	1.14 b	1.13 b	2.7 b	2.9 b	1.40 c	1.51 c	9.8 a	10.2 a
PGM 96-05 × S	1.31 a	1.25 ab	3.9 a	4.6 a	2.29 ab	2.57 ab	10.2 a	10.0 a
P360 × S	1.31 a	1.39 a	4.1 a	5.0 a	2.38 a	3.10 a	10.2 a	9.9 ab

[a] Mean separation within each column with the same letter are not significantly different using Duncan's Multiple Range test, $P = 0.05$.

Table 3
Effects of rootstocks on mean fruit mass, fruit number, yield and soluble solids concentration of cultivar Proteo by year[a]

Treatment	Fruit				Yield (kg m^{-2})		Soluble solids (°Brix)	
	Size (kg/fruit)		Number (fruit/plant)		1998	1999	1998	1999
	1998	1999	1998	1999				
Proteo (P)	1.64 bc	1.59 bc	4.5 a	4.9 a	3.30 a	3.48 a	12.0 a	12.4 a
B. hispida × P	1.36 d	1.38 d	2.6 c	3.3 c	1.58 c	2.24 b	10.2 b	11.6 b
C. metuliferus × P	1.56 bc	1.46 cd	4.2 ab	5.1 a	2.99 a	3.39 a	11.0 ab	11.7 b
C. zeyheri × P	1.54 c	1.54 bc	3.4 bc	3.9 bc	2.33 b	2.73 ab	11.6 a	12.4 a
PGM 96-05 × P	1.73 a	1.72 a	4.0 ab	4.2 ab	3.08 a	3.23 ab	11.2 ab	12.1 ab
P360 × P	1.72 ab	1.67 ab	4.4 ab	5.1 a	3.38 a	3.80 a	11.0 ab	12.1 ab

[a] Mean separation within each column with the same letter are not significantly different using Duncan's Multiple Range test, $P = 0.05$.

rootstocks which were always significantly lower than the controls (Table 2). Similar results were observed with Proteo cultivar as scion (Table 3).

Significant differences were found in the marketable yield between controls and grafted plants (Tables 2 and 3). In both scion cultivars, grafting combinations involving PGM 96-05, P360, and *C. metuliferus* yield was comparable to the controls while productivity significantly decreased with *B. hispida* and *C. zeyheri* (Tables 2 and 3). Contrary to findings of Ruiz and Romero (1999), we did not observe an increase in yield in grafted plants relative to ungrafted controls. In term of fruit quality, soluble solid concentration of ungrafted control Supermarket was significantly higher in both years than cultivar grafted on *B. hispida* and *C. metuliferus,* while no differences were found among ungrafted control and cultivar grafted on PGM 96-055, P360, and *C. zeyheri* (Table 2). Similar results were observed with Proteo cultivar as scion (Table 3). Detrimental effects on fruit quality of rootstocks were also reported by Lee (1994).

4. Conclusions

On the basis of the results obtained in these experiments on melon, grafting effectiveness seems to be determined not only by the disease resistance of the rootstocks but also by their influence on both production and fruit quality. The rootstocks PGM 96-05 and P360 were resistant to race 1,2 of *F. oxysporum* f. sp. *melonis* and were also the best genotypes capable of significantly improving the productivity without detrimental effect to fruit quality of the cultivars used as scions. They can be considered as the most interesting rootstocks for melon.

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