



The effect of various rootstocks on triploid watermelon yield and quality

Maria Victoria Huitrón, Manuel Diaz, Fernando Diánez and Francisco Camacho*

"Plant Yield in Mediterranean Crop Systems" Research Group. University of Almeria, Spain. *e-mail:fcamacho@ual.es

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Abstract

One of the problems related to intensive watermelon (*Citrullus lanatus* var *lanatus*, Thunb) yield is the increase of soil-borne diseases. The grafting technique is an alternative for reducing losses from these pathogens, making watermelon crops possible in areas where soil-borne diseases are a limiting factor. Two experiments were established for two years in "Almeria-type" plastic greenhouses in Almeria, Spain, to evaluate the influence of four rootstocks on cv. Reina de Corazones triploid watermelon yield and quality. These experiments did not use pollinating varieties. Ovary development was achieved with N-(2-chloro-4-pyridyl)-N-phenylurea (CPPU) plant growth regulator at a concentration of 200 mg.L⁻¹. Experiments were conducted under plastic greenhouses in the spring of 2003 and 2004. RS-841 and Shintoza (both *Cucurbita maxima* x *Cucurbita moschata*) were the rootstocks with the highest percentage of plants affected by nematode, *Meloidogyne incognita*. Reina de Corazones obtained its highest yield when grafted on PI-296341-FR *Citrullus lanatus* var *citroides*, with very low levels of parasitic nematodes (*Meloidogyne incognita*). None of these rootstocks significantly affected the quantity of total soluble solids, presenting values above 11.17° Brix.

Key words: *Cucurbita maxima* x *Cucurbita moschata*, *Citrullus lanatus* (PI-296341-FR), graft, plant growth regulator, resistance, root-knot nematode.

Introduction

Watermelon is a traditional, easily managed crop without much need for farm work, which is easy to do besides, where grower attention is mainly centred on disease control. One of limited factors on watermelon intensive cultivation under plastic has been the increase of soil-borne diseases, diseases caused by *Fusarium oxysporum* f.sp *niveum* and *Verticillium dahliae* and root-knot nematodes (*Meloidogyne* sp.)¹⁰. Vine decline caused by Melon Necrotic Spot Virus (MNSV) transmitted by a soil fungus *Olpidium radicale* (*O. bornovanus*)³ are noteworthy.

The first methods used in Spain to face soil-borne diseases problem were soil disinfection using various concentrations of all the components in methyl bromide + chloropicrin and at various doses and seed disinfection, with unsatisfactory results. Later, starting in the mid 70's, genes resistant to *Fusarium oxysporum* f.sp *niveum* were introduced in watermelon cultivars, but this measure proved insufficient¹. The solution was found by grafting watermelon onto rootstocks resistant to that disease. Grafting watermelon is cheaper, safer, and more effective against soil-borne pathogens than the use of methyl bromide. Besides, the latter is in the process of being banned worldwide as a consequence of damage to the ozone layer².

The first experiments with grafted watermelon plants in Spain were carried out in 1979¹, but grafted watermelon crops were not grown on a commercial scale until 1985, when commercial interspecific hybrids appeared, which has continued until the present with excellent results. This makes it possible to grow the crop on soil where *Fon* was a limiting factor, as is the case of Almeria and Valencia, where over 95% of watermelon is grafted¹.

In important production areas such as Almeria, Valencia and Murcia, where crops are repeated regularly, 30 million watermelon plants are grafted annually⁴, comprising around 12,000 hectares. At present almost all watermelon planting is done with plants grafted onto RS841 and Shintoza rootstocks, interspecific hybrids of *Cucurbita maxima* x *Cucurbita moschata*. Both of these provide effective protection against the majority of soil-borne pathogens, but not against nematodes⁵, which occasionally cause serious damage, especially in late planting⁹.

In searching for other, potentially promising options to fight nematodes, analysing the performance of other commercial cucurbit rootstocks was considered of interest. The use of cytoquines for ovarian development of the female flowers without the need of pollination was also considered important to avoid planting cv diploids, which involve other drawbacks.

Materials and Methods

Experiments were carried out in the greenhouse during two crop cycles (spring of 2003 and 2004) in the horticultural "Almeria-type plastic houses" production area. The "Almeria type" houses where they were grown appear flat; they are 3 m high along the centre, with a slanted roof falling for 4 m towards the sides, which are 2 m in height. They lie in an east-west direction. The plastic covering was a 200 µm tri-thermal polyethylene film, with a working life of 3 seasons. Ventilation of this module was passive with four side windows along the perimeter of the plastic house, for a ventilation surface of 11.9%. All the windows had black anti-trip mesh of 16 x 10 wires · cm⁻¹. The windows were opened and closed manually,

depending on the weather. As a climatic control strategy against high temperatures in the months of May and June, the plastic covering was limed with “Blanco de España” (calcium carbonate). The cultivar used, as mentioned in the previous section, was Reina de Corazones, which was grafted onto various rootstocks from the cucurbit family. They are the object of this study; some of their characteristics are shown in Table 1.

- Shintoza F₁. An interspecific hybrid of *C. maxima* x *C. moschata* with a powerful root system that hardly interferes with the characteristics peculiar to the grafted variety. Therefore, field results are good with regard to fruit quality and yield. High uniform germination was obtained in the seedbed, which increases the output of the grafted plant. Approach grafting is recommended.

- RS841 F₁. An interspecific *C. maxima* x *C. moschata* hybrid characterized as the one most frequently used on the market. The variety can obtain good sized, high quality fruit.

- *Cucurbita moschata* (Poir). A violin-shaped Italian pumpkin that provides less vigour to watermelon varieties than the RS841 and the Shintoza hybrids and is lower yield. However, fruit size is large.

- *Citrullus lanatus* var *citroides*. The PI-296341-FR line selected from wild watermelon, resistant to races 0, 1 and 2 of *Fusarium* wilt of watermelon; its performance is good against the disease. However, it is difficult to distinguish stock sprouts for elimination since its leaves are similar to the cultivated watermelon variety's leaves.

Grafts were made using the approach grafting method². In the case of the first experiment, planting was done at the permanent site on March 12, 2003. The following spring transplanting was carried out on February 16, 2004. Planting density for both years was 2500 plants · ha⁻¹. Soil disinfection was not carried out previously in both assays.

Ovary development was induced by applying a solution of 200 mg · L⁻¹ of CPPU both years that the experiment was conducted. The product used was Sitofex[®], which contains 1% (p/v) CPPU. It was applied by a manual atomizer with a spray nozzle control that provided only 0.6 mL to each ovary once flower petals were completely extended.

The experimental design for both seasons was complete random blocks with 4 repetitions, following the $y_{ij} = \mu_{ij} + \beta_{ij} + \beta_{ij} + \epsilon_{ij}$ additive linear model where $i = 1, 2, 3, 4$; and $j = 1, 2, 3, 4$ for both studies. All

data underwent variance analysis and means separation through Fisher's least significant difference procedure ($p < 0.05$). Linear regression analysis ($Y = \beta_1 X$) was conducted using the following procedure: 1) Estimation of unknown parameters (β_0 and β_1) through the least squares method, 2) Assessment of model fitness and 3) Model validation using Statgraphics Plus 4.0 for Windows.

Results and Discussion

Differences in climate and soil conditions where the experiments were conducted, favoured different crop performances from one year to the next, even in the same rootstocks. Therefore, it seems important to show results of the problems from both seasons before explaining yield and quality analyses.

There were problems in taking root, incompatibility and nematode disease in the 2003 experiment. After transplanting, plant death was observed due to poor root taking by the rootstocks and due to infections by root-knot nematode (*Meloidogyne incognita*). The number of plants was recorded that did not survive due to problems with root taking and incompatibility, while in plants with nematode disease the ones with the presence of root-knot were quantified. In regard to the percentage of plants affected by nematodes, all rootstocks showed some degree of disease, in the following order: Shintoza > RS841 > *C. moschata* > *C. lanatus*. The *C. maxima* x *C. moschata* hybrids, Shintoza and RS841, were the rootstocks that showed the highest percentages of diseased plants, 75 and 65.6% respectively. In Valencia similar results were found for a watermelon crop in the open field where Shintoza and BN911 (*C. maxima* x *C. moschata* hybrids) were reported as having a higher percentage of diseased plants⁹. In addition, they reveal the weaknesses of rootstocks against nematodes, with the following ratings: BN911 and Shintoza, very susceptible to *Meloidogyne incognita*, *C. moschata*, tolerant and PI-296341-FR *C. lanatus* var. *citroides* resistant. This sequence was similar in the 2004 experiment.

Yield and profit components: Table 2 shows the influence of various rootstocks on total yield (kg · m⁻² and kg/plant) and profit components (fruit/plant, fruit · m⁻² and kg/plant) for Reina de corazones in both experiments. Generally, yield values and profit components in the 2004 experiment, where there were no nematode disease problems, were greater and more homogeneous than those

Table 1. Response of cucurbits used as rootstocks in assays against pathogens and environmental stress. (Our own elaboration based on Miguel 1997 and Lee 2003).

Rootstocks	<i>Fusarium oxysporum</i> f. sp.				<i>Meloidogyne</i> Nematodes		Tolerance		Compatibility with watermelon
	FON	FOC	FOM	FOL	<i>incognita</i>	<i>hapla</i>	Low temperature	Salinity	
<i>Cucurbita máxima</i> x <i>Cucurbita moschata</i> (Shintoza)	HR	HR	HR	HR	S	S	HR	HR	HC
<i>Cucurbita máxima</i> x <i>Cucurbita moschata</i> (RS841)	HR	HR	HR	HR	S	S	HR	HR	HC
<i>Cucurbita moschata</i>	HR	HR	HR	SR	S	S	MR	MR	SC
<i>Citrullus lanatus</i> var <i>citroides</i> PI-296341-FR	HR	HR	HR	--	--	--	--	--	HC

FON: *Fusarium oxysporum* f. sp. *niveum*; FOC: *Fusarium oxysporum* f. sp. *cucumerinum*;

FOM: *Fusarium oxysporum* f. sp. *melonis*; FOL: *Fusarium oxysporum* f. sp. *lagenariae*;

HR: highly resistant; MR: moderately resistant; SR: slightly resistant; S: susceptible; HC: highly compatible; SC: slightly compatible;

from the first experiment in 2003. On the other hand, total yield (kg m⁻²), was statistically different in 2003, with higher values from combining Reina de Corazones with *C. lanatus* and RS841, rootstocks that did not present plant loss due to poor root taking, while *C. moschata* had the lowest values due to incompatibility problems^{5,7}. The yield obtained from *C. moschata* was similar to what was obtained in Valencia in open field crops⁹.

In the 2003 experiment, rootstocks with the highest percentage of plants affected by nematodes were Shintoza, RS841 and *C. moschata*, with similar percentages (75%, 65.6% and 62.5% respectively). However, there was a wide difference in yield. RS841 surpassed Shintoza by 43% and *C. moschata* by 50%. This may be due to the resistance to nematodes reported by Marin for RS841⁶.

There were significant differences in yield among treatments expressed as kg/plant in the experiment carried out in 2003 as a consequence of nematode disease. However, these differences disappeared in the study carried out in 2004.

Among the rootstocks studied, the high yield performance of *C. lanatus* is remarkable, corroborating it as a nematode-resistant rootstock. It showed the least variation between the experiment in 2003 and 2004 (5%). Besides, it obtained the highest yield per plant in the first experiment, surpassing *C. moschata* by 100%, the rootstock with the lowest value for this parameter.

In regard to the number of fruits per plant, significant differences were not observed among treatments in either experiment. Nevertheless, results corroborate that this parameter is the component having the greatest influence on yield (Fig. 1).

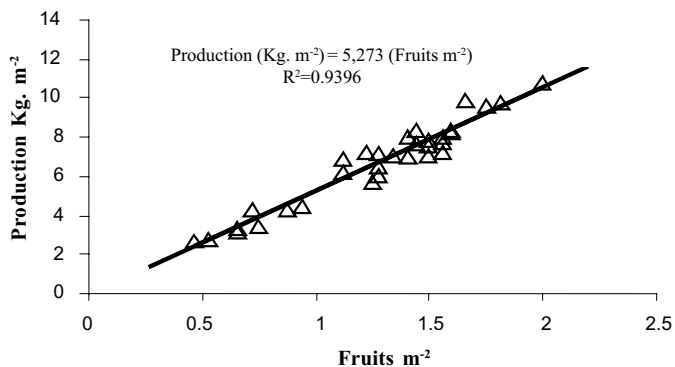


Figure 1. Relationship between number of fruits and yield. Experiments for 2003 and 2004 (The linear model is significant for $P < 0.05$).

Average fruit weight is influenced by plant vigour and the number of fruits set. There were significant differences for this profit component among rootstocks in 2003 only. The highest average fruit weight was obtained from grafts on *C. moschata* in the 2003 experiment and on *C. lanatus* in 2004, the plant material least susceptible to nematode disease (Table 1). Both rootstocks had the least number of fruits set in both experiments. Average fruit weight showed homogeneous performance in 2003 as well as in 2004.

Quality parameters: Table 3 shows the results of quality parameters, total soluble solids (°Brix), pH, pulp firmness and pistilar scar for both experiments. In 2003 all rootstocks were statistically the same in the accumulation of soluble solids, having values higher than 11 °Brix (Table 3).

Some authors have reported adverse effects from rootstocks on watermelon quality⁸ and even on melon^{11,12}. However, the value obtained for RS841 in the 2003 experiment was slightly higher than those obtained by Camacho and Fernandez¹ and values for *C. lanatus*, *C. moschata* and Shintoza, were similar to those obtained by Miguel *et al.*⁹, even when *C. lanatus* had the highest value, as in this experiment. On the other hand, in the case of pH, although there were significant differences only in the first experiment, values fluctuated between 5.21 and 5.42, while in the 2004 experiment they fluctuated between 5.03 and 5.11.

Pulp firmness did not show significant differences between treatments in either of the experiments, although values from the 2004 experiment were lower than those from the first one. This corroborates what Camacho and Fernandez expounded, that this parameter depends on harvesting time and not on environmental conditions or on whether the fruit comes from a grafted or non-grafted watermelon plant. Nevertheless, these values are greater than those shown by Camacho and Fernandez¹ in their work with Reina de Corazones on several rootstocks with bee pollination. Except for *C. lanatus* in the second experiment, all treatments surpassed the interval of values corresponding to “crunchy” watermelon¹.

Conclusions

1. Different rootstocks were affected by nematodes *Meloidogyne incognita* with unequal incidence: Shintoza, RS841 and *C. moschata* had a higher percentage of diseased plants, 75, 65 and 63% respectively while PI-296341-FR *Citrullus lanatus* var *citroides* had 25%.
2. Tolerance of the various rootstocks to nematodes was a determinant factor in cv Reina de Corazones yield.
3. The highest yield values were obtained with the combinations of Reina de Corazones grafted on PI-296341-FR *C. lanatus* var *citroides* and RS841. These rootstocks presented no problem in taking root or with incompatibility. Besides, the former was the rootstock least affected by nematodes.
4. All the rootstocks had a similar effect on watermelon pulp firmness and rind thickness.

Table 2. Effect of various rootstocks on yield and profit components for cv Reina de Corazones triploid watermelon, spring of 2003 and 2004.

Rootstocks Spring of 2003	(kg · m ⁻²)	kg · plant ⁻¹	fruit · plant ⁻¹	Fruit weight (kg)
<u>Shintoza</u>	4.32 bc	18.28 b	3.67 bc	5.00 a
<u>RS-841</u>	6.18 ab	24.71 ab	5.06 ab	4.87 a
<i>C. moschata</i>	3.48 c	15.90 b	2.96 c	5.41 a
<i>C. lanatus</i>	7.97 a	31.87 a	6.19 a	5.16 a
Significance	**	*	*	NS
Coefficient of variation (%)	41.4	39.2	39.3	7.82
Rootstocks Spring of 2004				
<u>Shintoza</u>	8.23 a	33.94 a	6.40 a	5.25 a
<u>RS-841</u>	8.32 a	34.30 a	6.43 a	5.51 a
<i>C. moschata</i>	7.06 a	35.06 a	6.45 a	5.47 a
<i>Citrullus lanatus</i>	8.13 a	33.57 a	5.99 a	5.63 a
Significance	NS	NS	NS	NS
Coefficient of variation (%)	14.1	11.7	10.1	17.3

NS, *, **, *** indicate not significant or significant at a level of significance of P= 0.05; 0.01 or 0.001 respectively.

Table 3. Influence of various rootstocks on total soluble solid content, pH, pulp firmness and pistil in cv Reina de Corazones watermelon. Experiments from spring of 2003 and spring of 2004.

Rootstocks Spring of 2003	°Brix	pH	Pulp firmness (kg · cm ⁻²)	Pistilar scar (mm)
<u>Shintoza</u>	11.22 a	5.42 a	2.29 a	14.07 a
<u>RS-841</u>	11.33 a	5.36 a	2.38 a	14.60 a
<i>C. moschata</i>	11.35 a	5.21 b	2.56 a	14.60 a
PI-296341-FR <i>C. lanatus</i>	11.68 a	5.21 b	2.65 a	15.45 a
Significance	NS	**	NS	NS
Coefficient of variation (%)	9.3	3.4	18.8	9.9
Rootstocks Spring of 2004				
<u>Shintoza</u>	11.23 ab	5.04 a	2.12 a	14.85 a
<u>RS-841</u>	10.85 bc	5.07 a	2.11 a	16.45 a
<i>C. moschata</i>	11.42 a	5.11 a	2.12 a	15.20 a
PI-296341-FR <i>C. lanatus</i>	10.50 c	5.03 a	2.88 a	16.07 a
Significance	**	NS	NS	NS
Coefficient of variation (%)	10.8	3.3	23.2	27.7

NS, *, **, *** indicate not significant or significant at a level of significance of P= 0.05; 0.01 or 0.001 respectively.

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