Relationship between the Effects of Salinity on Seedling Leaf Area and Fruit Yield of Six Muskmelon Cultivars

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Abstract. Six muskmelon (*Cucumis melo* L.) Galia-type cultivars ('Delada', 'Gallicum', 'Galar', 'Melina', 'Regal' and 'Revigal') were tested for salt tolerance at the seedling stage and during growth in the field. Three levels of salinity (EC_w 2.5 (control), 5.0 and 7.5 $dS\cdot m^{-1}$), established by adding NaCl to fresh water, were used. The effect of salinity on seedling growth was assessed by measuring the total leaf area 36 days after sowing. 'Melina' was the most tolerant at this stage and during subsequent growth in field, with a relative seedling leaf area of 60 and a relative yield of 66 at 7.5 $dS\cdot m^{-1}$ salinity, both expressed as a percentage of the values obtained at the control level of salinity. 'Delada' was the most sensitive to the highest level of salinity at both stages, with relative seedling leaf area and yield of 51 and 56, respectively. For all cultivars, a highly significant correlation ($r = 0.99$) was established between the influence of salinity on seedling leaf area reduction and on decrease in yield during field culture. The results indicate that the reduction in seedling leaf area can be a good selection criterion to facilitate rapid screening for salt tolerance in muskmelon.

Muskmelon is grown commercially in southeastern Spain where salinity is the major yield-limiting factor of crops. Although muskmelon has been described as moderately salt-tolerant (Meiri and Plaut, 1981; Nerson and Paris, 1984; Nukaya et al., 1980; Shannon and Francois, 1978) and is an important crop in areas where salinity is common, yield losses often occur when certain salinity thresholds are exceeded. These thresholds can vary with the culture medium used, the type of salinity, particular plant growth stages, cultivar, etc. (Mangal et al., 1988; Nukaya et al., 1980).

Differences in salt tolerance have been reported among muskmelon cultivars (Mangal et al., 1988; Mendlinguer and Pasternak, 1992b; Shannon and Francois, 1978; Shannon et al., 1984). Tests are needed each year to evaluate the salt tolerance of new and untested muskmelon cultivars under various cultural conditions.

Seed germination in a salty medium is often used as an index of resistance to salinity stress in several crops. However, Noble (1983) and Guerrier (1984) could find no physiological evidence to link salt tolerance during germination with tolerance at later stages. Recent experiments with muskmelon cultivars have shown that no correlation exists between salt

tolerance during seed germination and salt tolerance at later stages of plant development (Franco et al., 1993a; Mendlinguer and Pasternak, 1992a; Nerson and Paris, 1984; Nukaya et al., 1980; Shannon et al., 1984). However, a close relationship has been established between the influence of salinity on seedling growth and on the yield of muskmelon during hydroponic culture (Franco et al., 1993a; Nukaya et al., 1980), sand culture (Nukaya et al., 1980), and in field conditions (Nerson and Paris, 1984). Several criteria have been used to evaluate seedling growth, such as elongation of the primary root (Nerson and Paris, 1984), seedling height (Nukaya et al., 1980), or leaf area expansion (Franco et al., 1993b; Nerson and Paris, 1984). Indeed, the effect of salinity on seedling leaf area is one of the easiest vegetative attributes to quantify and has shown a high correlation with the effect of salinity on fruit yield (Franco et al., 1993a, 1993b).

The purpose of this work was to determine, for six muskmelon Galia-type cultivars, the effects of saline irrigation water on seedling leaf area and fruit yield, and to determine whether there is any correlation between such effects. If such a relationship were found to be significant, it would considerably facilitate future salt tolerance studies in muskmelon.

Materials and Methods

Six muskmelon Galia-type hybrid cultivars ('Delada', 'Gallicum', 'Galar', 'Melina', 'Regal', and 'Revigal') were grown under three irrigation salinity levels, representing

two typical salinity conditions and a control.

Seedling growth. For each cultivar and salinity treatment, 10 seeds were sown in polystyrene boxes containing frustum-shaped pockets (4 × 4 cm in section and 50 mL capacity) filled with a culture medium of 25% vermiculite, 60% black peat, and 15% sphagnum peat. The characteristics of the medium were as follows: 1) bulk density, 190 $kg\cdot m^{-3}$; 2) total pore space, 91% by volume; 3) volume of air after irrigation, 21% by volume; 4) easily available water, 30% by volume; 5) electrical conductivity in a saturation extract (EC_e), 0.4 $dS\cdot m^{-1}$; 6) NPK concentration ($mg\cdot L^{-1}$): 220 N, 107 P, and 240 K.

The seeds in the boxes were left to germinate for 4 d in a dark germination chamber at 21 °C and 95% humidity. The boxes were then placed in a greenhouse and three salinity treatments established by adding NaCl to a base nutrient solution. This solution was made up using fresh water with an electrical conductivity (EC_w) 0.9 $dS\cdot m^{-1}$ and pH 7.6. The composition of the base nutrient solution was ($\mu mol\cdot L^{-1}$): NO_3^- , 5000; $H_2PO_4^-$, 4500; Cl^- , 4000; SO_4^{2-} , 2300; HCO_3^- , 500; Ca^{2+} , 4500; K^+ , 3500; Na^+ , 2900; Mg^{2+} , 1300; NH_4^+ , 500; Fe (as Fe-EDTA), 26.8; Mn (as Mn-EDTA), 10.9; Zn (as Zn-EDTA), 1.8; Cu (as Cu-EDTA), 0.8; B (as $Na_2B_4O_7$), 11.8 and Mo (as $NaMoO_4\cdot 2H_2O$), 0.4. Properties of the solution were: EC_w 2.16 $dS\cdot m^{-1}$ and pH 5.8. EC_w values were raised to 2.5 (control), 5.0 and 7.5 $dS\cdot m^{-1}$. Irrigation water was supplied via the outlets of a spaghetti-type emitter, arranged for each seedling at a discharge rate of 1 $L\cdot h^{-1}$. Seedlings were irrigated four to six times daily. Frequency of irrigation depended on plant need for water. Amounts of treatment solution were identical for all treatments, and amounts per plant were increased with time (100 to 220 $mL\cdot d^{-1}$) to keep pace with the increased demand due to the seedlings' growth. Caution was exercised to ensure that no solution was spilled on the leaves during watering. Seedlings were watered sufficiently to ensure that excess salt was leached with each watering. Equal EC_w of the applied and drained solutions ensured that the seedlings were being subjected to the appropriate saline concentrations. Salinity treatments were maintained throughout the experiment. We used three replications per treatment.

The effect of salinity on seedling growth was assessed by measuring the total leaf area of 10 seedlings 36 d after sowing using a Delta-T gauge (Delta-T Devices, Cambridge, U.K.), and then calculating the mean value.

Field experiment. The field trial was conducted in Campo de Cartagena, on the Mediterranean coast of Spain (37° 45'N; 0° 59'W), using cultural practices common to commercial muskmelon production in this area. The climate of the region is characterized by mild, slightly rainy winters and hot dry summers. The soil is a silt loam, with an electrical conductivity of the saturation extract (EC_e) of 2.3 $dS\cdot m^{-1}$.

Thirty-six-day-old seedlings, grown under the above control conditions, were transplanted into raised beds on 17 April. Trickle irrigation

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Table 1. Seedling leaf area $\pm$ SE 36 days after sowing of six muskmelon Galia-type cultivars irrigated by three salinity treatments.

Cultivar	Leaf area ^a (cm ² /plant)		
	Salinity, EC _w (dS·m ⁻¹)		
	2.5 (control)	5.0	7.5
Delada	22.61 $\pm$ 0.57 (100)	14.81 $\pm$ 0.68 (65.5 c ^y)	11.58 $\pm$ 0.52 (51.2 c)
Gallicum	24.70 $\pm$ 0.71 (100)	17.09 $\pm$ 0.73 (69.2 b)	13.93 $\pm$ 0.42 (56.4 b)
Galor	26.94 $\pm$ 0.75 (100)	19.29 $\pm$ 0.52 (71.6 b)	14.98 $\pm$ 0.54 (55.6 b)
Melina	35.77 $\pm$ 0.69 (100)	28.01 $\pm$ 1.06 (78.3 a)	21.32 $\pm$ 0.66 (59.6 a)
Regal	27.14 $\pm$ 0.77 (100)	19.30 $\pm$ 0.87 (71.1 b)	14.98 $\pm$ 0.53 (55.2 b)
Revigal	27.58 $\pm$ 0.61 (100)	18.78 $\pm$ 0.77 (68.1 bc)	15.69 $\pm$ 0.71 (56.9 b)

^aNumbers in parentheses are relative values (percentage of control).

^yMean separation for relative values in the same column by LSD at $P \leq 0.05$.

Table 2. Fruit yield $\pm$ SE of six muskmelon Galia-type cultivars grown under three irrigation salinity conditions

Cultivar	Fruit yield ^a (kg·m ⁻²)		
	Salinity, EC _w (dS·m ⁻¹)		
	2.5 (control)	5.0	7.5
Delada	3.60 $\pm$ 0.27 (100)	2.46 $\pm$ 0.21 (68.3 c ^y)	2.01 $\pm$ 0.11 (55.8 c)
Gallicum	4.23 $\pm$ 0.41 (100)	3.11 $\pm$ 0.24 (73.5 bc)	2.58 $\pm$ 0.26 (61.0 ab)
Galor	3.69 $\pm$ 0.33 (100)	2.81 $\pm$ 0.25 (76.1 ab)	2.12 $\pm$ 0.12 (57.4 bc)
Melina	3.51 $\pm$ 0.36 (100)	2.79 $\pm$ 0.30 (79.5 a)	2.32 $\pm$ 0.11 (66.1 a)
Regal	4.05 $\pm$ 0.32 (100)	3.12 $\pm$ 0.28 (77.0 ab)	2.30 $\pm$ 0.14 (56.8 bc)
Revigal	3.06 $\pm$ 0.45 (100)	2.25 $\pm$ 0.20 (73.5 bc)	1.83 $\pm$ 0.08 (59.8 b)

^aNumbers in parentheses are relative values (percentage of control).

^yMean separation for relative values in the same column by LSD at $P \leq 0.05$.

lines, with pressure-compensated emitters at 4 L·h⁻¹ spaced at 0.5 m intervals along the line, were placed 2 m apart, at the center of the beds. In each bed, seedlings (one per emitter) were planted adjacent to each emitter in a row and within 15 cm of the trickle line. The irrigation and fertilization regimes followed those recommended for the area during the spring-summer growing season. In the control plots, tensiometers were installed in the row midway between plants at depths of 15 and 30 cm. All the plants were irrigated identically, based on daily tensiometer readings. No differences in flow rate were found between emitters. No plants showed nutrient deficiency symptoms at any time during the experiment.

Three levels of salinity (EC_w), 2.5 (control), 5.0, and 7.5 dS·m⁻¹, were established by adding NaCl to fresh water with an EC_w 1.6 dS·m⁻¹. Saline water was applied daily throughout the experiment in sufficient quantities to encourage adequate leaching to prevent salt accumulation in the root zone. The soil was sampled frequently in the root zone and the EC_e was determined.

Six plants of each of the six cultivars were used for each salinity level. The experiment was laid out in a completely randomized block design with three replicated blocks.

Statistical analysis. Data from the above studies were analyzed. Analysis of variance and regression were conducted by using the Statgraphics program version 7.0 (STSC, Rockville, Md.). Seedling leaf area and fruit yield data are presented as mean $\pm$ SE; mean separation for relative values was performed by using least significant difference (LSD). The relationship between the effects of salinity on seedling leaf area and fruit yield was calculated by using linear regression analysis of pooled data from the six cultivars.

Results and Discussion

The total leaf areas of the seedlings grown under the control conditions (2.5 dS·m⁻¹) showed differences between the six cultivars 36 d after sowing (Table 1).

The effect of salinity on seedling growth was evaluated by comparing relative leaf area

as a percentage of the control areas. Salt tolerance may be expressed in terms of absolute growth at a given salinity or in relative terms. However, a relative measure is especially important in a study such as this, where fast- and relatively slow-growing cultivars are compared. 'Delada' was the most affected by salinity and 'Melina' the least, while the other four cultivars showed intermediate responses (Table 1). The reduction in leaf area was substantial in the seedlings of all cultivars (40%–49% of the control) at a salt level of 7.5 dS·m⁻¹. These values are similar to those found in previous studies involving 'Revigal', both for seedlings of the same age (36 d) and for seedlings at 53 d (Franco et al., 1993a, 1993b).

Fruit yields of all six cultivars were relatively high under the control conditions (Table 2), but decreased linearly with increasing irrigation water salinity. Similar results have been found for many melon cultivars, including Galia-type by Nukaya et al. (1980), Meiri and Plaut (1981), Mangal et al. (1988), Franco et al. (1993a), and Mendlinger (1994). For the six cultivars investigated here, the decrease in yield reflected the decrease in mean fruit mass, while the quantity of fruit produced was not significantly affected (data not shown). Franco et al. (1993a), Mendlinger (1994), and Meiri et al. (1995) have also reported similar results for muskmelon under saline conditions.

At increased salinity levels, 'Melina' showed the lowest fall in yield whereas 'Delada' showed the greatest reduction of the six cultivars. This result corresponds closely with the behavior of these cultivars at the seedling growth stage. All the cultivars showed a considerable drop in yield (34% to 44 % of

Fig. 1. Fruit yield of muskmelon expressed as a function of total leaf area of seedling 36 days after the seed was sown. The regression represents pooled data from six Galia-type cultivars (○, 'Delada'; ▽, 'Gallicum'; □, 'Galor'; △, 'Melina'; ◇, 'Regal'; ▼, 'Revigal') grown at two irrigation salinity levels (EC_w 5.0 and 7.5 dS·m⁻¹) relative to their respective control (grown at EC_w 2.5 dS·m⁻¹), with the controls (●) expressed as 100. $Y = -6.425 + 1.041X$; $r = 0.989$ ($P < 0.001$).

the control) when they were grown under the highest level of salinity ($7.5 \text{ dS}\cdot\text{m}^{-1}$) (Table 2). This decrease in yield is slightly less than the reduction in leaf area exhibited by the seedlings under the same salinity conditions (Table 1), and reflects the results of Nerson and Paris (1984) and Franco et al. (1993a).

For all the cultivars, the yield obtained during field culture at EC_w of 2.5, 5.0, and $7.5 \text{ dS}\cdot\text{m}^{-1}$ was closely correlated with the leaf area reductions obtained at 36 d of seedling growth at the same three salinity levels (Fig. 1). The regression of pooled data from the six cultivars shows a high and significant ($P \leq 0.001$) correlation coefficient ($r = 0.989$). A similar relationship was also found by Franco et al. (1993b) between the influence of salinity on total leaf area of the seedlings and on the fruit yield obtained from muskmelon 'Revigal' hydroponically grown in a greenhouse. In our study, the points fall very close to the 1 : 1 line (Fig. 1), indicating that the salt tolerance of muskmelons assessed by relative growth and expressed as the total leaf area of seedlings is directly related to the salt tolerance of mature field-grown muskmelons expressed as fruit yield.

Our study suggests that the early leaf area growth of seedlings can be used as an accurate and fast indicator when screening muskmelons for salt tolerance. New tests will be needed to validate this indicator for higher salinity levels.

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