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Variability and correlations in muskmelon in relation to the cultivation method

R. V. Molina[1], **F. Nuez**[1], **J. Cuartero**[2], **M. L. Goméz-Guillamón**[2] **and J. Abadía**[3]

[1] Departamento de Biotecnología, Universidad Politécnica, E-46020 Valencia, Spain
[2] Estacion Experimental "La Mayora", C.S.I.C., Malaga, Spain
[3] Centro de Edafología y Biología Aplicada del Segura, C.S.I.C., Murcia, Spain

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Summary. Six fruit characters have been measured in 23 cultivars of *Cucumis melo*, representing a wide geographical range. Plants were grown both in the greenhouse and in the field. When the 23 cultivars were analyzed together, the largest component of variance was found between cultivars under both growth conditions, suggesting the existence of large genetic diversity for all the characters studied. Generally, variance between plants within cultivars was less than or equal to variance between fruits within plant. This indicates that environmental variation is the most important part of the variation within cultivars. Correlations between pairs of characters at cultivar, plant and fruit levels were calculated from the variance-covariance components. In the majority of paired traits, the correlation values indicated that genetic and environmental factors may act in the same direction.

Key words: Muskmelon variability – Selection – Genetic correlations – Environmental correlations

Introduction

The exploitation of interspecific variability in *Cucumis* presents enormous difficulties (Den Nijis and Vissier 1985). Consequently, a realistic breeding program must be based on the use of intraspecific variability.

In comparison with other vegetable plants, very little attention has been given to the breeding of melons and, therefore, the intraspecific variability of this species is largely unexploited. Melon is not a strictly allogamous species and shows a variable proportion of cross-pollination (Ivanoff 1947; Whitaker and Bohn 1952; Nugent and Hoffman 1981), so that the existence of variability both between and within cultivars can be expected.

The present work was designed to evaluate the variability between and within 23 cultivars from very different geographic origins, when grown under both greenhouse and field conditions. Correlations between six characters of the fruit, calculated with the variance-covariance components both between and within cultivars, are discussed.

Materials and methods

Twenty-three cultivars of *Cucumis melo*, from a wide range of geographic origins, were used (Table 1), as described previously

Table 1. Melon cultivars tested and their origins

Code	Cultivar	Origin
1	Cantaloupe Amarelo	USA
2	Cantaloupe Crenshow	USA
3	Cantaloupe Jumbo Hale's Best	USA
4	Tokyo Gigant	Japan
5	Tokyo Early	Japan
6	Honey gold no. 9	Japan
7	Sakata's Sweat	Japan
8	Mochuelo	Spain
9	Ananas	India
10	Punjab Suneri	India
11	Perita	Spain
12	Verdejo	Spain
13	Amarillo Pintado	Spain
14	Melona Amarilla	Spain
15	Punteado Amarillo	Spain
16	Fondo Amarillo	Spain
17	Hilo Carrete	Spain
18	Blanco Liso	Spain
19	Meloncio	Mexico
20	Melon (Tapich)	Mexico
21	Calabaza Melón	Mexico
22	Melon (El Tepetate)	Mexico
23	Melon Criollo	Mexico

for studies in the field (Abadia et al. 1984) and in the greenhouse (Goméz-Guillamón et al. 1983).

The plants were cultivated both in polythene greenhouses and in the field. A randomized block design was employed for both cultivation methods and these had three replicate blocks of ten plants per block. Two fruits on each plant were monitored by recording the following parameters: weights of the individual fruits, length (polar diameter), width, flesh thickness, rind thickness (all were measured in the equatorial diameter) and soluble solids (°Brix).

The data from each replicate and both methods of cultivation were analysed by a nested analysis of variance-covariance at three levels: cultivar, the plants within the cultivar and the fruits within the plant. Variance-covariance components were calculated by the Anderson and Bancroft procedure (Anderson and Bancroft 1952). Correlations between the different characteristics studied were estimated from the covariance components.

To determine the level of uniformity within the cultivar, the data from the different cultivars were analyzed as a nested design with two levels: plant and fruit within the plant. The Calabaza melon, Tepetate melon and the Criollo melon cultivars germinated poorly, and only a small number of plants were obtained for each replicate; consequently, this analysis could not be carried out for these cultivars.

Results

Factorial analysis was carried out for each cultivation method in which the variety effect was crossed with the replicate effect and the plant effects were subordinate to variety × replicate interaction. No significant effects were found for replicates or cultivar × replicate interaction in either of the two methods of cultivation. Consequently, all the plants of the three replicate blocks were treated as one sample.

The variance component between the cultivars (S_C^2) was greater than the component between plants of the same cultivar (S_P^2) for both cultivation methods (field and greenhouse), and for all the characters studied (Table 2).

The S_P^2 was less than the component of variance between fruits (S_F^2) for all the characters for greenhouse-grown plants, but S_P^2 and S_F^2 were similar for field-grown plants (Table 2).

This analysis assumed uniformity between the cultivars for S_P^2 and S_F^2. However, the cultivars tested had very different characteristics and different origins, including both improved lines and relatively unselected traditional cultivars. Because of this, differences could exist between the S_P^2 and S_F^2 in the different cultivars, therefore, the coefficient S_P^2/S_F^2 was calculated for each cultivar (Table 3). In general, the range of variance between the cultivars was quite large. For the group of characters studied, 24% of the cultivars showed one component between plants, S_P^2, which was significantly larger than zero for both cultivation methods; this component of variation showed no significance for either of the two cultivation methods in 29% of the cultivars, while 48% of the cultivars displayed a significant S_P^2, either in the greenhouse or in the field, but not in both.

S_F^2 also showed a wide variation between cultivars but, nevertheless, the structure of the variation was that of a scale effect. For all the characters, and for both cultivation methods, it was observed that variability within cultivars was linearly related to the average value for that character. The regression of S_F^2 on the average fruit weight for the group of cultivars studied serves as an example (Fig. 1). For greenhouse and field cultivation, the determination coefficients were 0.88 and 0.61, respectively. The coefficients of variation, which are indicators of variability independent of scale effect, were very similar for a given character under both methods of cultivation (Table 4).

The covariances between each pair of characters were partitioned between cultivars, between plants within those cultivars and between fruits within plants, by employing a hierarchical covariation model similar to that used for the partitioning of variance. The correlations at cultivar, plant and fruit levels were calculated with the variance-covariance components (Table 5).

At the level of the cultivars, the weight, width of the fruit and the width of the fruit flesh were found to be strongly correlated (Table 5). Fruit length was mainly correlated with fruit weight; skin thickness, on the other hand, was related to the width of the fruit. The refractive index was only weakly correlated with the other charac-

Table 2. Relations between the components of variance for all the cultivars

		Weight	Length	Width	Flesh thickness	Rind thickness	Refractive index
S_c^2/S_p^2	Field	1.8	5.9	4.9	4.8	2.7	1.9
	Greenhouse	5.3	22.5	4.6	3.2	4.0	12.7
S_c^2/S_f^2	Field	1.8	5.2	3.1	2.3	1.6	2.1
	Greenhouse	2.9	7.3	2.3	1.2	0.4	3.2
S_p^2/S_f^2	Field	1.0	0.9	0.6	0.5	0.6	1.1
	Greenhouse	0.5	0.3	0.5	0.3	0.1	0.2

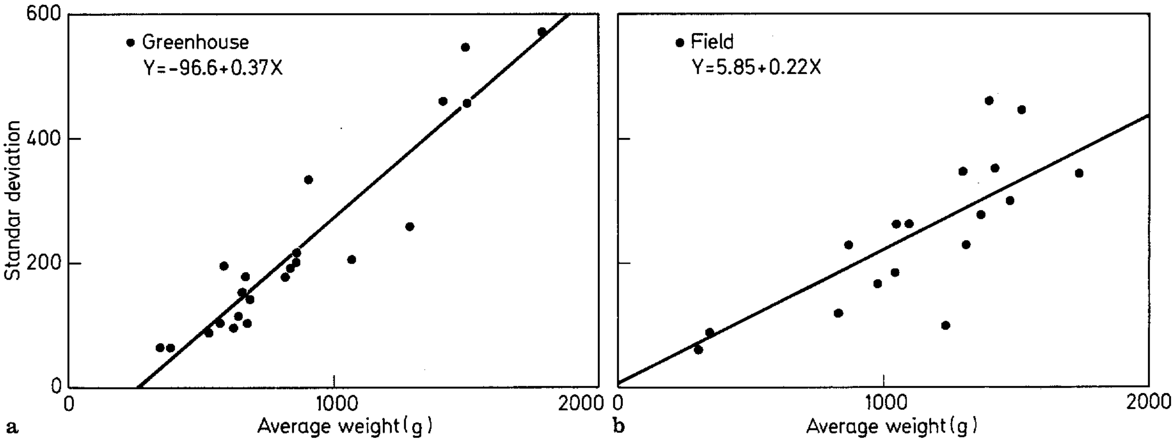

Fig. 1 a and b. Regression of S_F^2 over the average weight of fruit for the whole group of cultivars in both cultivation methods. (**a**) Cultivation under greenhouse; (**b**) cultivation in the field

Table 3. Relation S_p^2/S_f^2 for each cultivar in greenhouse and in the field

Cultivar	Field cultivation						Greenhouse cultivation					
	Weight	Length	Width	Flesh thickn.	Rind thickn.	Refrac. index	Weight	Length	Width	Flesh thickn.	Rind thickn.	Refrac. index
1	1.7	2.1	1.6	2.0	–	4.4	1.3	0.9	1.7	1.1	–	–
2[a]							–	–	–	–	–	–
3	–	–	1.4	1.4	5.0	–	–	–	–	4.0	–	–
4	4.4	1.8	–	–	4.0	–	0.7	–	–	–	2.0	2.0
5	1.1	–	1.1	–	2.0	–	–	–	–	–	–	–
6	1.2	–	0.9	1.0	2.5	1.1	1.8	1.1	0.7	–	–	–
7	–	2.9	3.0	1.9	–	4.0	1.2	–	0.8	–	–	–
8	5.4	4.0	–	–	–	–	–	0.8	1	–	–	1.4
9	–	–	–	–	–	1.3	–	1.0	–	0.7	–	–
10	2.4	6.4	2.6	2.4	4.9	3.1	1.4	1.5	1.4	–	–	–
11	1.8	1.7	1.3	1.3	–	2.4	0.7	–	1.1	–	0.5	–
12	–	1.2	–	–	–	1.3	1.0	–	0.9	0.9	–	–
13	1.4	–	2.9	1.2	–	1.1	2.3	3.3	1.1	1.2	–	–
14	–	1.8	–	2.7	–	–	1.3	0.8	3.1	1.4	–	–
15	–	–	2.1	3.0	–	–	–	–	–	–	–	–
16	–	–	–	0.6	1.6	–	0.8	–	0.8	0.7	1.2	–
17[a]							–	–	–	–	–	–
18	–	0.7	–	–	2.8	–	1.1	–	0.9	–	–	–
19	–	2.4	–	–	–	–	1.3	0.8	0.7	–	–	–
20[a]							0.6	0.4	–	0.3	–	–

[a] Cultivars only tested in the greenhouse
– Not significant

Table 4. Average values of the coefficients of variation (%) and their standard deviation for the whole group of cultivars

	Weight	Length	Width	Flesh thickness	Rind thickness	Refractive index
Field	22±4	10±6	8±2	12±5	29±12	17±6
Greenhouse	23±6	10±4	8±3	15±5	34±19	10±4

Table 5. Correlations at the levels of: cultivars (r_c), plant (r_p) and fruit (r_f) between the 6 characters

r_c r_p r_f	Field					
	Weight	Length	Width	Flesh thickness	Rind thickness	Refractive index
Weight		0.64[a] 0.86[a] 0.67[a]	0.83[a] 0.91[a] 0.85[a]	0.85[a] 0.61[a] 0.57[a]	0.59[a] 0.45[a] 0.43[a]	−0.08 0.15 0.12[a]
Length	0.82[a] 0.78[a] 0.72[a]		0.17[a] 0.85[a] 0.54[a]	0.31[a] 0.55[a] 0.34[a]	−0.12 0.4[a] 0.31[a]	−0.56[a] 0.13 0.07
Width	0.71[a] 0.77[a] 0.73[a]	0.25[a] 0.61[a] 0.46[a]		0.88[a] 0.71[a] 0.57[a]	0.73[a] 0.40[a] 0.39[a]	0.14 0.32 0.18[a]
Flesh thickness	0.56[a] 0.78[a] 0.57[a]	0.23[a] 0.51[a] 0.36[a]	0.68[a] 0.84[a] 0.62[a]		0.54[a] −0.13 −0.06	0.04 0.39 0.14
Rind thickness	0.86[a] 0.70[a] 0.17	0.61[a] 0.22[a] 0.11	0.75[a] 0.26 0.27[a]	0.39[a] 0.67[a] −0.01		0.34[a] −0.29 0.08
Refractive index	−0.46[a] −0.00 0.20[a]	−0.83[a] −0.03 0.07	−0.14 0.13 0.22[a]	−0.12 0.04 0.23[a]	−0.35[a] 0.09 0.06[a]	

[a] Significant correlations

ters, but its negative correlation with fruit length was noteworthy. The correlation coefficients were generally similar for both types of cultivation, but the correlations between weight and flesh width were weaker in the greenhouse than in the field.

At the level of fruits within the plant, the pattern of correlations was very similar to that described above for the cultivars, but the correlations between fruit width and flesh width, between fruit width and skin thickness, and between fruit length and the refractive index were weaker, while the correlation between fruit length and fruit width was stronger (Table 5). The small differences between cultivation methods were not significant.

At the level of the plant within the cultivar, the values of the correlation coefficients were closer to those at the level of the fruit than those at the level of the cultivar, although their values are slightly higher than the correlation coefficients at the level of the fruits (Table 5).

The correlations thus far described were calculated for the whole group of cultivars. The correlations between pairs of characters at the levels of the plant and of the fruit were also studied by double-hierarchical variance-covariance analysis.

In general, it was observed that when the overall correlation between any two characters was high (Table 5), this relationship held for the majority of the cultivars; however, when the values of overall correlation were low, the values of the individual paired correlations depended on the pair of cultivars being considered (Fig. 2). The observations were similar for correlations at the level of the fruits and at the level of the plant.

Discussion

Fundamentally, the S_C^2 is due to genotypic differences between the cultivars. The S_F^2 is due both to genotypic differences and environmental effects. S_F^2 may also reflect the fact that the fruits were produced at different times and different physiological states of development of the plant. This variance also includes those effects due to the micro-environmental differences which might have occurred during the different developmental stages.

The results reveal that the genotypic differences between cultivars were the principal source of variation. Large variation between cultivars has also been reported by other authors (Lippert and Legg 1972; Chhonkar et al. 1979; Kalloo and Sidhu 1982; Kalb and Davis 1984). This genotypic variation could be exploited by careful selection between cultivars.

The fact that the coefficient S_P^2/S_F^2 gave values ≤ 1 indicates that, within the plant, the intra-cultivar genotypic differences accounted for less of the variability than did environmental effects. A large environmental variability within cultivar has also been reported by Davis et al. (1964). Consequently, it would be difficult in gener-

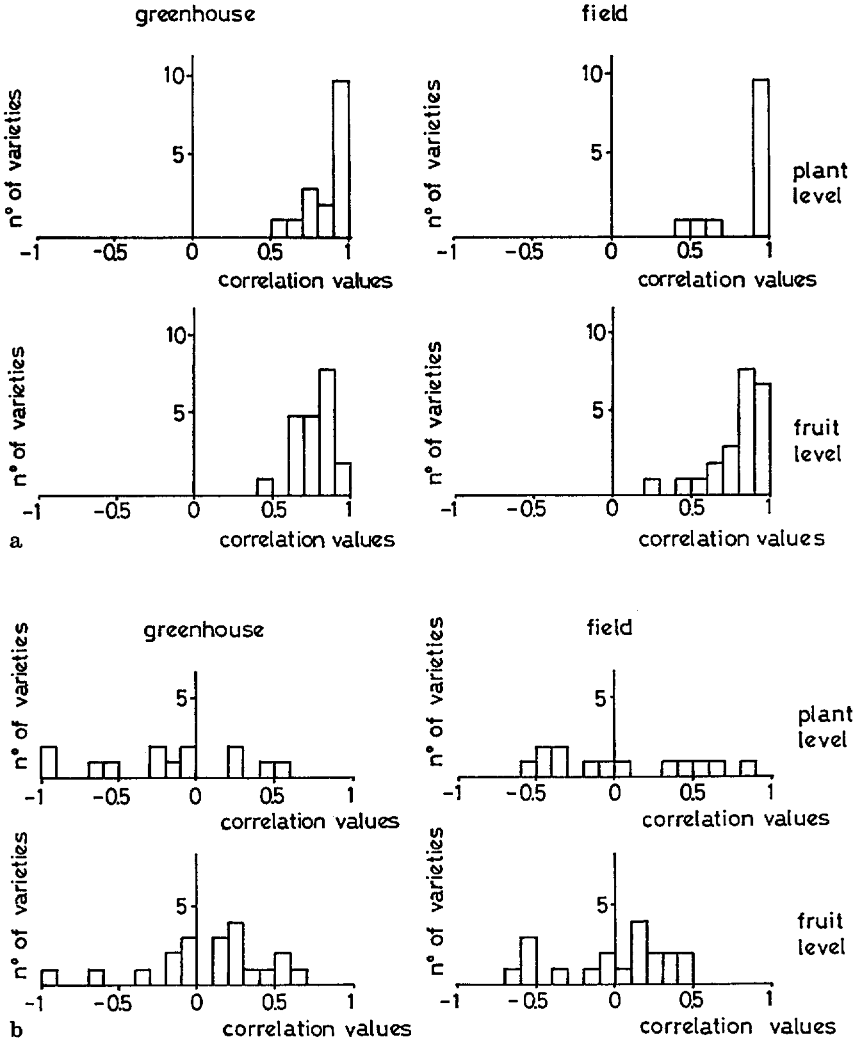

Fig. 2. Distribution of correlation values between two pairs of characters, at plant and fruit levels and in both cultivation methods. a Distribution of correlation between weight and length; b distribution of correlation between length and size

al for the breeder to exploit genotypic variation within cultivars. However, there are some cases in which this might be possible. Individual plants within cultivars 1, 6, 10, 11 and 13 exhibited variability for the majority of the characters under both cultivation methods and, therefore, selection within the cultivar would be possible. In cultivars 3, 5, 9, 15 and 19, under both cultivation methods there was only slight variability between the plants; thus, there is little potential for selection within the cultivar. The remaining cultivars displayed a variable behavior under each cultivation method and, in general, most of the characters showed little individual variability.

The variation between fruits within the plant was greater in the field than in the greenhouse. Since the coefficient S_P^2/S_F^2 was greater in the field than in the greenhouse, this suggests that S_P^2 in the field is greater than S_P^2 in the greenhouse. Since the genetic component of variation must be the same, the results indicate greater environmental variation in the plants cultivated in the field. Compared with other vegetable crops, muskmelons are extremely susceptible to environmental variation (Andrus and Bhon 1967; Ng et al. 1980) and the differences between plants in the field may reflect the larger environmental variability in the field than in the greenhouse.

Within either cultivation method, the variance between fruits within the plant was linearly related to the level of character expression. This indicates that the differences between fruits are the result of developmental differences and micro-environmental interaction; the longer the period of fruit development, the greater is the probability of influence by these factors. As the action of this factor is consistent for both cultivation methods, and due to the fact that the materials employed in this present work are largely derived from cultivars for field cultivation (in which they exhibit the greatest development), the greater value of S_F^2 found for the field would also be the consequence of a similar scale-effect between the cultivation methods.

We interpret the covariance data in a similar way. That is, that the covariance between cultivars was due fundamentally to genetic factors, while the covariance between fruits within the plant can be explained by physiological and environmental differences, and the covariance between plants within the cultivar would include genetic and environmental differences.

At the level of the cultivars, weight was correlated with fruit width and with fruit length. However, the correlation between fruit width and length was lower because of the varietal differences in fruit shape. In the sample of cultivars studied, some fruit forms were very elongated and other were ellipsoid.

The correlation observed between flesh width and fruit width appears to be associated with the domestication of *C. melo,* in that the development of flesh relative to seeds has been favored by artificial selection.

The lower correlations observed between weight, fruit width and flesh width in the greenhouse than in the field was due to the fact that in three varieties (Tokio Giant, Tokio Early and Criollo Melon), the fruit width and the flesh width decreased relative to the weight when the plants were grown in the greenhouse, while in the other varieties, these correlations remained unchanged.

The negative correlation found between fruit length and °Brix was due to the inclusion of cultivars with elongated fruits and low soluble solid contents. These cultivars are adapted to greenhouse cultivation and the correlation between length and °Brix was greater in the greenhouse than in the field. However, there was no correlation between length and °Brix for fruits within the cultivars, which suggests that the physiological factors regulating growth and those responsible for the soluble solids contents were independent. The correlation coefficients at the level of the cultivar between the weight and the fruit width, the weight and the fruit length, and between the refractive index and the fruit length are similar to the values for the genotypic correlations reported by Lippert and Hall (1982).

The correlations between fruit width and length was greater at the level of the fruit than at the level of the cultivar, and the fact that the correlation coefficient is quite high indicates that the two characters were influenced similarly by physiological and environmental factors.

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