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SUMMARY – Several nut traits (nut weight, kernel weight, shelling percentage, shell dehiscence percentage and kernel colour) were recorded during two years in 407 pistachio seedlings, derived from 15 crosses. For all the traits, significant differences between progenies were observed. Regarding nut and kernel weight, results from the families were similar. Four crosses, 'Batoury' x 'C', 'Mateur' x 'C', 'Batoury' x 'Nazar' and 'White Ouleimy' x 'M-502', stood out for their interest, while 'Larnaka' x 'B' gave seedlings with small nuts. In relation to the parents, 'Batoury' and 'White Ouleimy' (females) and 'C' (male) were promising, while 'B' (male) was undesirable. Regarding shelling percentage, 'Larnaka' x 'M-502' was outstanding, differences between families, although significant too, were reduced. In relation to the percentage of split nuts, 'Larnaka' x 'Nazar' stood out. As regards the intensity of the green colour of the kernels, the family 'Mateur' x 'M-38' stood out.

Key words: *Pistacia vera* L., pistachio, breeding, cultivar, fruit, progenies.

RESUME – *"Caractères du fruit chez les descendances de pistachier". Différentes caractéristiques du fruit (poids de la pistache avec et sans coque, rendement au cassage, déhiscence de la coque et couleur du grain) ont été étudiées durant deux années sur 407 pistachiers, dérivés de 15 croisements. Pour tous les caractères on a trouvé différences significatives entre familles. Les résultats concernant le poids de la pistache avec et sans coque sont similaires. Quatre croisements, 'Batoury' x 'C', 'Mateur' x 'C', 'Batoury' x 'Nazar' et 'White Ouleimy' x 'M-502', se montrent intéressants, alors que 'Larnaka' x 'B' génère de petites pistaches. Les parents 'Batoury' et 'White Ouleimy' (femelles) et 'C' (mâle) sont intéressants, tandis que 'B' (mâle) est un mauvais géniteur. Pour le rendement au cassage se détache 'Larnaka' x 'M-502', bien que les différences soient réduites. La famille 'Larnaka' x 'Nazar' est intéressante pour le taux élevé de pistaches déhiscentes. 'Mateur' x 'M-38' se distingue pour l'intensité de la couleur verte des grains.*

Mots-clés : Pistacia vera *L., pistachier, amélioration, cultivar, fruit, descendances.*

Introduction

Since ancient times, the pistachio tree (*Pistacia vera*, L.) has been cultivated over wide areas of the central-western Asia and the Mediterranean basin. In spite of the antiquity of the crop, large growing areas and different conditions in which it develops, only a reduced number of cultivars have spread. Regarding other fruit crops, few pistachio cultivars have been described. This may be due to several causes: (i) the need to graft (more than in other species), both to reduce the number of unfruitful male trees obtained by sowing pistachio seeds and to use as rootstocks of wild *Pistacia* trees; (ii) long life of the tree; (iii) pressure of the severe environmental conditions; (iv) human selection; etc. (Maggs, 1973). Generally, in each producing area only native types are used. Cultivars hardly spread out of their original areas, probably due to the propagation difficulty of the species. There are important differences between cultivars grown in different zones (Whitehouse, 1957; Spiegel-Roy *et al.*, 1972; Kaska, 1990; Gökçe and Akçay, 1993; Sheibani, 1994; Hadj-Hassan and Kardouch, 1995; Vargas *et al.*, 1995b and 1997).

Until recently, works related to pistachio cultivar improvement have been scarce (Parfitt, 1995; Vargas *et al.*, 1996; Chao *et al.*, 1998; Chao and Parfitt, 2003; Mehlenbacher, 2003). Two features hinder breeding activity: (i) it is a dioecious species (the potential of male parents for some important productive characters is unknown); and (ii) it shows rather late bearing (long generation cycle). However, there are good prospects for the development of new cultivars, crossing superior male and female cultivars from distinct geographical origins.

A crossing programme was started in 1989 at IRTA-Mas Bové (Vargas *et al*., 1996). This project has generated information on the interest of cross-combinations and parents for some characters: vigour, juvenile period, blooming and leafing dates (Vargas *et al*., 1995a, 2001 and 2002; Vargas and Romero, 1998a,b). In this paper, observations on nut traits in pistachio progenies are gathered.

Materials and methods

Controlled crosses were made in the pistachio collection of IRTA-Mas Bové during two years, 1989 and, mainly, 1990. Seedlings were grown in containers and planted on the field in April 1992, with a randomized distribution. Several fruit characters were recorded during two years, 2000 and 2001, when the trees were 9 and 10 years old, in 407 seedlings, derived from 15 crosses between 6 female and 7 male pistachio cultivars from different countries (Tables 1 and 2). The five traits analysed were: (i) nut weight (g); (ii) kernel weight (g); (iii) shelling percentage (kernel weight x 100/nut weight); (iv) shell dehiscence percentage (% split nuts); and (v) intensity of the green kernel colour (subjective evaluation, ranging from 1 to 9).

Table 1. Crosses and number of seedlings

Cross	Number of seedlings
'Aegina' x 'Enk'	23
'Aegina' x 'M-502'	38
'Batoury' x 'C'	27
'Batoury' x 'Nazar'	14
'Larnaka' x 'B'	11
'Larnaka' x 'M-38'	35
'Larnaka' x 'M-502'	27
'Larnaka' x 'Nazar'	37
'Mateur' x 'C'	37
'Mateur' x 'M-36'	30
'Mateur' x 'M-38'	23
'Mateur' x 'M-502'	35
'Mateur' x 'Nazar'	33
'Sfax' x 'M-502'	26
'White Ouleimy' x 'M-502'	11
Total	407

Table 2. Female and male parents. Origin and number of crosses (NC) and seedlings (NS)

Females				Males			
Name	Origin	NC	NS	Name	Origin	NC	NS
'Aegina'	Greece	2	61	'B'	Greece	1	11
'Batoury'	Syria	2	41	'C'	Greece	2	64
'Larnaka'	Cyprus	4	110	'Enk'	Israel	1	23
'Mateur'	Tunisia	5	158	'M-36'	Syria	1	30
'Sfax'	USA	1	26	'M-38'	Syria	2	58
'White Ouleimy'	Syria	1	11	'M-502'	Italy	5	137
				'Nazar'	Israel	3	84
Total			407				407

Results and discussion

For all the traits, a significant correlation was found between the two years records (Table 3).

Table 3. Correlations records 2000-2001

Correlations	Nr†	r	S.L.
Nut weight 2000 - Nut weight 2001	146	0.71	0.0001
Kernel weight 2000 - Kernel weight 2001	144	0.67	0.0001
Shelling percentage 2000 - Shelling percentage 2001	144	0.26	0.0020
Shell dehiscence percentage 2000 - Shell dehiscence percentage 2001	146	0.56	0.0001
Kernel colour index 2000-2001	167	0.35	0.0001

†Number of seedlings observed in the two years.

Regarding nut and kernel weight, results from the crosses and parents were similar. Table 4 shows the mean nut weight of the progenies and Table 5 the comparison of some families with common female or male parents. Kernel weight records are included in Tables 6 and 7. Significant and important differences between progenies were observed. The crosses 'Batoury' x 'C', 'Mateur' x 'C', 'Batoury' x 'Nazar' and 'White Ouleimy' x 'M-502' stood out for their interest, while the cross 'Larnaka' x 'B' gave seedlings with small nuts. In relation with the parents, 'Batoury' and 'White Ouleimy' (females) and 'C' (male) were outstanding, while 'B' (male) was unsuitable for these traits.

Table 4. Nut weight (g). Records taken in 2000 and 2001. Mean of the progenies

Cross	Year 2000		Year 2001		Average 2000-2001	
	Nr†	Mean††,†††	Nr†	Mean††	Nr†	Mean††
'Batoury' x 'C'	11	0.97 a	24	1.06 a	27	1.04 a
'Mateur' x 'C'	20	0.94 a	32	0.98 b	34	0.97 b
'Batoury' x 'Nazar'	7	0.91	11	0.94 bc	13	0.94 b
'White Ouleimy' x 'M-502'	5	0.93	11	0.88 cd	11	0.90 b
'Larnaka' x 'Nazar'	11	0.80 b	35	0.84 de	36	0.83 c
'Larnaka' x 'M-38'	7	0.89	31	0.81 ef	32	0.81 c
'Mateur' x 'M-502'	21	0.83 b	30	0.79 ef	33	0.80 c
'Mateur' x 'M-36'	14	0.79 b	27	0.78 ef	30	0.78 c
'Larnaka' x 'M-502'	7	0.75	25	0.77 ef	27	0.78 c
'Aegina' x 'Enk'	8	0.79	20	0.76 ef	21	0.77 c
'Mateur' x 'Nazar'	9	0.64	30	0.78 ef	30	0.77 c
'Mateur' x 'M-38'	8	0.80	21	0.76 ef	22	0.77 c
'Sfax' x 'M-502'	15	0.83 b	23	0.75 f	24	0.76 c
'Aegina' x 'M-502'	14	0.75 b	32	0.76 ef	35	0.76 c
'Larnaka' x 'B'	2	0.39	11	0.38 g	11	0.38 d

†Number of seedlings observed.
††Comparison of means by Duncan's Multiple Range Test. Values with the same letter are not significantly different (95%).
†††Comparison of means only when Nr>9.

Table 5. Nut weight (g). Average 2000-2001. Mean of the progenies. Comparison of some progenies with common female or male parent (extracted from Table 4)

Cross	Mean†	Cross	Mean†
'Larnaka' x 'Nazar'	0.83 a	'White Ouleimy' x 'M-502'	0.90 a
'Larnaka' x 'M-38'	0.81 a	'Mateur' x 'M-502'	0.80 b
'Larnaka' x 'M-502'	0.78 a	'Larnaka' x 'M-502'	0.78 b
'Larnaka' x 'B'	0.38 b	'Aegina' x 'M-502'	0.76 b
		'Sfax' x 'M-502'	0.76 b
'Mateur' x 'C'	0.97 a		
'Mateur' x 'M-502'	0.80 a	'Batoury' x 'Nazar'	0.94 a
'Mateur' x 'M-36'	0.78 b	'Larnaka' x 'Nazar'	0.83 b
'Mateur' x 'M-38'	0.77 b	'Mateur' x 'Nazar'	0.77 b
'Mateur' x 'Nazar'	0.77 b		

†Comparison of means by Duncan's Multiple Range Test (95%). Values with the same letter are not significantly different.

Table 6. Kernel weight (g). Records taken in 2000 and 2001. Mean of the progenies

Cross	Year 2000		Year 2001		Average 2000-2001	
	Nr†	Mean††,†††	Nr†	Mean††	Nr†	Mean††
'Batoury' x 'C'	11	0.44 a	24	0.48 a	27	0.47 a
'Mateur' x 'C'	20	0.45 a	32	0.47 a	34	0.47 a
'White Ouleimy' x 'M-502'	5	0.44	11	0.42 b	11	0.43 b
'Batoury' x 'Nazar'	7	0.41	11	0.44 b	13	0.43 b
'Larnaka' x 'Nazar'	11	0.36 bc	35	0.40 bc	36	0.40 bc
'Larnaka' x 'M-502'	7	0.36	25	0.38 cd	27	0.38 cd
'Mateur' x 'M-502'	21	0.38 b	30	0.37 cd	33	0.37 cd
'Mateur' x 'M-36'	14	0.36 bc	27	0.37 cd	30	0.37 cd
'Sfax' x 'M-502'	15	0.39 b	23	0.36 cd	24	0.37 cd
'Larnaka' x 'M-38'	7	0.40	32	0.36 cd	33	0.37 cd
'Mateur' x 'Nazar'	9	0.31	30	0.37 cd	30	0.36 cd
'Mateur' x 'M-38'	8	0.37	21	0.36 cd	22	0.36 cd
'Aegina' x 'M-502'	14	0.34 c	31	0.37 cd	35	0.36 cd
'Aegina' x 'Enk'	8	0.36	20	0.34 d	21	0.35 d
'Larnaka' x 'B'	2	0.18	10	0.18 e	11	0.18 e

†Number of seedlings observed.
††Comparison of means by Duncan's Multiple Range Test. Values with the same letter are not significantly different (95%).
†††Comparison of means only when Nr>9.

Regarding shelling percentage, differences between families, although also significant, were reduced (Table 8). The cross 'Larnaka' x 'M-502' stood out.

In relation to the percentage of split nuts, the cross 'Larnaka' x 'Nazar' stood out, while on the contrary 'Batoury' x 'C' and 'Larnaka' x 'B' were uninteresting for this trait (Table 9). Concerning to parents (Table 10), 'M-502' and 'Nazar' (males) were outstanding and 'B' (male) inadequate.

For the intensity of the green colour of the kernels, the family 'Mateur' x 'M-38' pointed out, while

the seedlings from 'Larnaka' x 'B' had yellow kernels (Table 11). In relation to parents (Table 12), the males 'M-38' and 'M-502' (green) and 'B' (yellow) stood out.

Table 7. Kernel weight (g). Average 2000-2001. Mean of the progenies. Comparison of some progenies with common female or male parent (extracted from Table 6)

Cross	Mean†	Cross	Mean†
'Larnaka' x 'Nazar'	0.40 a	'White Ouleimy' x 'M-502'	0.43 a
'Larnaka' x 'M-502'	0.38 a	'Larnaka' x 'M-502'	0.38 b
'Larnaka' x 'M-38'	0.37 a	'Mateur' x 'M-502'	0.37 b
'Larnaka' x 'B'	0.18 b	'Sfax' x 'M-502'	0.37 b
		'Aegina' x 'M-502'	0.36 b
'Mateur' x 'C'	0.47 a		
'Mateur' x 'M-36'	0.37 b	'Batoury' x 'Nazar'	0.43 a
'Mateur' x 'M-502'	0.37 b	'Larnaka' x 'Nazar'	0.40 ab
'Mateur' x 'M-38'	0.36 b	'Mateur' x 'Nazar'	0.36 b
'Mateur' x 'Nazar'	0.36 b		

†Comparison of means by Duncan's Multiple Range Test (95%). Values with the same letter are not significantly different.

Table 8. Shelling percentage (%). Records taken in 2000 and 2001. Mean of the progenies

Cross	Year 2000		Year 2001		Average 2000-2001	
	Nr†	Mean††,†††	Nr†	Mean††	Nr†	Mean††
'Larnaka' x 'M-502'	7	47.73	25	49.28 a	27	49.05 a
'Sfax' x 'M-502'	15	46.78 a	23	48.74 ab	24	48.32 ab
'Mateur' x 'Nazar'	9	52.74	30	47.60 abc	30	48.21 abc
'Mateur' x 'C'	20	47.74 a	32	48.28 ab	34	48.19 abc
'Larnaka' x 'Nazar'	11	45.46 a	35	48.25 ab	36	47.90 abcd
'Aegina' x 'M-502'	14	45.82 a	31	47.76 ab	35	47.46 abcde
'White Ouleimy' x 'M-502'	5	47.46	11	47.34 abcd	11	47.42 abcde
'Mateur' x 'M-38'	8	46.17	21	47.70 ab	22	47.32 abcde
'Mateur' x 'M-36'	14	45.32 a	27	47.40 abcd	30	47.07 abcde
'Mateur' x 'M-502'	21	46.20 a	30	46.93 bcde	33	46.53 bcde
'Larnaka' x 'B'	2	44.93	10	46.48 bcde	11	46.41 bcde
'Batoury' x 'Nazar'	7	45.06	11	46.53 bcde	13	45.78 cde
'Batoury' x 'C'	11	45.58 a	24	45.41 cde	27	45.55 de
'Larnaka' x 'M-38'	7	45.36	31	45.31 de	32	45.38 e
'Aegina' x 'Enk'	8	45.87	20	44.87 e	21	45.06 e

†Number of seedlings observed.
††Comparison of means by Duncan's Multiple Range Test. Values with the same letter are not significantly different (95%).
†††Comparison of means only when Nr>9.

Table 9. Shelling dehiscence (%). Records taken in 2000 and 2001. Mean of the progenies

Cross	Year 2000		Year 2001		Average 2000-2001	
	Nr†	Mean††,†††	Nr†	Mean††	Nr†	Mean††
'Larnaka' x 'Nazar'	11	58.36 ab	35	83.94 a	36	80.50 a
'Larnaka' x 'M-502'	7	63.29	25	80.36 ab	27	77.67 ab
'Mateur' x 'M-502'	21	68.19 a	30	81.33 ab	33	76.67 ab
'Mateur' x 'Nazar'	9	55.67	30	78.23 ab	30	75.00 ab
'Mateur' x 'M-38'	8	60.88	21	75.29 ab	22	74.00 ab
'Larnaka' x 'M-38'	7	64.43	32	73.09 ab	33	72.24 ab
'Aegina' x 'Enk'	8	67.25	20	72.65 ab	21	72.10 b
'Sfax' x 'M-502'	15	68.07 a	23	71.96 ab	24	70.17 ab
'Batoury' x 'Nazar'	7	43.57	11	83.09 ab	13	69.39 ab
'Aegina' x 'M-502'	14	63.21 ab	32	69.16 abc	35	69.20 ab
'White Ouleimy' x 'M-502'	5	48.60	11	70.09 abc	11	66.73 abc
'Mateur' x 'C'	20	53.00 ab	32	71.31 abc	34	66.38 abc
'Mateur' x 'M-36'	14	51.86 ab	27	68.44 bc	30	64.03 bc
'Batoury' x 'C'	11	45.36 b	24	57.42 cd	27	54.11 c
'Larnaka' x 'B'	2	42.50	11	54.00 d	11	53.36 c

†Number of seedlings observed.
††Comparison of means by Duncan's Multiple Range Test. Values with the same letter are not significantly different (95%).
†††Comparison of means only when Nr>9.

Table 10. Shell dehiscence (%). Average 2000-2001. Mean of the progenies. Comparison of some progenies with common female or male parent (extracted from Table 9)

Cross	Mean†	Cross	Mean†
'Larnaka' x 'Nazar'	80.50 a	'Larnaka' x 'M-502'	77.67 a
'Larnaka' x 'M-502'	77.67 a	'Mateur' x 'M-502'	76.67 a
'Larnaka' x 'M-38'	72.24 a	'Sfax' x 'M-502'	70.17 a
'Larnaka' x 'B'	53.36 b	'Aegina' x 'M-502'	69.20 a
		'White Ouleimy' x 'M-502'	66.73 a
'Mateur' x 'M-502'	76.67 a		
'Mateur' x 'Nazar'	75.00 ab	'Larnaka' x 'Nazar'	80.50 a
'Mateur' x 'M-38'	74.00 ab	'Mateur' x 'Nazar'	75.00 a
'Mateur' x 'C'	66.38 ab	'Batoury' x 'Nazar'	69.39 a
'Mateur' x 'M-36'	64.03 b		

†Comparison of means by Duncan's Multiple Range Test (95%). Values with the same letter are not significantly different.

Table 11. Kernel colour index (scale 1-9). Records taken in 2000 and 2001. Mean of the progenies

Cross	Year 2000		Year 2001		Average 2000-2001	
	Nr†	Mean††,†††	Nr†	Mean††	Nr†	Mean††
'Mateur' x 'M-38'	9	6.78	22	5.82 a	23	6.04 a
'Larnaka' x 'Nazar'	12	6.50 a	35	5.69 ab	37	5.82 ab
'Larnaka' x 'M-38'	7	6.00	34	5.82 a	35	5.81 ab
'Mateur' x 'M-502'	21	6.00 abc	32	5.66 ab	35	5.80 ab
'Mateur' x 'C'	23	6.26 ab	35	5.54 ab	37	5.77 ab
'Mateur' x 'M-36'	14	6.43 a	27	5.48 ab	30	5.77 ab
'Aegina' x 'Enk'	8	6.25	22	5.64 ab	23	5.72 ab
'Batoury' x 'Nazar'	8	5.88	12	5.67 ab	14	5.68 ab
'Aegina' x 'M-502'	15	6.07 abc	35	5.43 ab	38	5.59 ab
'White Ouleimy' x 'M-502'	5	5.40	11	5.36 ab	11	5.41 b
'Mateur' x 'Nazar'	10	5.60 bc	33	5.30 ab	33	5.36 b
'Larnaka' x 'M-502'	7	5.71	24	5.21 ab	26	5.29 b
'Batoury' x 'C'	15	5.87 abc	24	5.04 b	27	5.26 b
'Sfax' x 'M-502'	18	5.44 c	24	5.17 ab	26	5.21 b
'Larnaka' x 'B'	2	5.00	11	4.36 c	11	4.45 c

†Number of seedlings observed.
††Comparison of means by Duncan's Multiple Range Test. Values with the same letter are not significantly different (95%).
†††Comparison of means only when Nr>9.

Table 12. Kernel colour index (scale 1-9). Average 2000-2001. Mean of the progenies. Comparison of some progenies with common female or male parent (extracted from Table 12)

Cross	Mean†	Cross	Mean†
'Larnaka' x 'Nazar'	5.82 a	'Mateur' x 'M-502'	5.80 a
'Larnaka' x 'M-38'	5.81 a	'Aegina' x 'M-502'	5.59 a
'Larnaka' x 'M-502'	5.29 a	'White Ouleimy' x 'M-502'	5.41 a
'Larnaka' x 'B'	4.45 b	'Larnaka' x 'M-502'	5.29 a
		'Sfax' x 'M-502'	5.21 a
'Mateur' x 'M-38'	6.04 a		
'Mateur' x 'M-502'	5.80 a	'Larnaka' x 'Nazar'	5.82 a
'Mateur' x 'C'	5.77 ab	'Batoury' x 'Nazar'	5.68 a
'Mateur' x 'M-36'	5.77 ab	'Mateur' x 'Nazar'	5.36 a
'Mateur' x 'Nazar'	5.36 b		

†Comparison of means by Duncan's Multiple Range Test (95%). Values with the same letter are not significantly different.

Conclusions

Significant and important differences in several nut traits between pistachio progenies were observed. Regarding nut and kernel weight, the crosses 'Batoury' x 'C', 'Mateur' x 'C', 'Batoury' x 'Nazar' and 'White Ouleimy' x 'M-502' stood out for their interest, while the cross 'Larnaka' x 'B' gave seedlings with small nuts. In relation to the parents, 'Batoury' and 'White Ouleimy' (females) and 'C' (male) were outstanding, while 'B' (male) was unsuitable. With regard to the percentage of split nuts, the cross 'Larnaka' x 'Nazar' stood out. For the intensity of the green colour of the kernels, the family 'Mateur' x 'M-38' showed promise.

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