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Current situation of research into the pistachio tree (*Pistacia vera* L.) in the region of Castilla-La Mancha (Spain)

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SUMMARY - Since 1987 the CMA (Agricultural Improvement Centre) El Chaparrillo has conducted different activities to determine the real possibilities of adapting the pistachio tree (*Pistacia vera* L.) to the region of Castilla-La Mancha. During the ten-year period, the initial interesting theoretical expectations regarding its introduction have been confirmed in the experimental plots with studies on phenology, propagation, production, etc. There has been a significant and steady rise in farmers' interest in the crop in the region, as demonstrated by the fact that over the last two years almost 200 ha of *Pistacia terebinthus* L. have been sown in regular plantations, on which *Kerman, Napoletana, Peter* and *02-18* cultivars will be grafted in the next two years.

Key words: Cultivars, phenology, propagation, rootstock, production.

RESUME - *"Situation actuelle de la recherche sur le pistachier (*Pistachia vera *L.) dans la région de Castilla-La Mancha (Espagne)". Depuis 1987, le CMA (Centre d'Amélioration Agraire) s'occupe de différentes activités destinées à évaluer les possibilités réelles d'adaptation du pistachier (*Pistacia vera *L.) dans la région de Castilla-La Mancha. Dans ce dix années, on a pu confirmer les intéressantes expectatives théoriques qu'on a eues au début du projet, dans les parcelles expérimentales, en relation avec la phénologie, la multiplication, le rendement, etc. L'intérêt progressif de l'agriculteur pour cette culture dans cette région, a augmenté significativement vu que durant les deux dernières années on a planté près de 200 ha de* Pistacia terebinthus *L. qu'on va greffer avec les cépages cv.* Kerman*, cv.* Napoletana*, cv.* Peter*, et cv.* 02-18 *pendant les deux prochaines années.*

Mots-clés : *Cépages, phénologie, multiplication, porte-greffe, rendement.*

Introduction

Castilla-La Mancha is a region of Spain that lacks any alternatives to the predominant grape growing, where most of the land is laid fallow (900,00 ha) or is unproductive. In this region, two of the factors that limit fruit production, namely the lack of water and spring frosts, have their maximum influence. Almost 60% of the soil is alkali, sometimes containing more than 40% of active limestone with a pH in excess of 8. The high summer temperatures, with maximums of 43ºC, and the lack of rainfall during the summer months confirmed, at least in theory, that the pistachio tree could be adapted to this region. Therefore a study began in 1988 with the introduction of certain cultivars on arid trial plots distributed in different areas in the provinces of Toledo, Cuenca, Guadalajara, Albacete and Ciudad Real. The main objective was to use field experiments to verify the crop's good theoretical prospects, establishing its degree of adaptation in each area. The climatic adaptability of the cultivar would not only depend on late blossoming but also on aspects such as the ease of propagation, transplanting and productivity, whereas the presence of similar autochthonous species would be of importance for the rootstock.

The project has been co-ordinated from the CMA *El Chaparrillo,* located in Ciudad Real. The CMA houses the trial plot, as well as the reference plots, greenhouse and cultivars.

Since 1988 numerous graft propagation trials have been conducted in order to improve the technique and perform the operation in the right period (Couceiro and Mendiola, 1995).

In 1990 the regional autochthonous nature of the species *Pistacia terebinthus* L. was confirmed, and in 1991 different test were conducted to improve its seed germination technique (Couceiro, 1992).

In 1996 certain practical figures about the crop were published (Couceiro and Coronado, 1996). Among other things, the figures confirmed the late blossoming of the cv. *Kerman*, the resistance of the flower and the set fruit at temperatures of -2ºC and -1.5ºC for half an hour respectively, productivity similar to that of other producing countries, etc.

Material and methods

Before data was collected from the experimental plots, we conducted a theoretical study in the province of Ciudad Real, in which we examined the theoretical possibilities of adapting the pistachio tree to the area. During the study, data on sixteen climatic variables was collected from each provincial station. The data was then selected in accordance with the main bioclimatic factors of the species. The next step involved comparing the variables selected with the variables that occur in the species' centres of origin and diffusion, establishing areas where it could be introduced with good, medium and marginal theoretical levels of success.

Each province's experimental plot measured 2.8 ha and contained eight cultivars grafted onto four different rootstocks pollinated by eight different pollenizers in accordance with a completely random experimental design. The study of the adaptability of each cultivar to the conditions of each plot was based both on the phenology of the bloom and on vegetative development, and the latter aspect not only included the growth but also the strength of each rootstock. In order to conduct a study of the phenology of the species, it was first necessary to characterize the states by defining and describing them. This characterization was based on series of photographs taken every three days, from vegetative rest to the harvesting of the fruits.

On the greenhouse plot, efforts were devoted to issue of vegetative propagation by grafting, above all by budding, onto *P. terebinthus* L. and *P. atlantica* Desf., in an attempt to ascertain the best conditions both for implementation and for development. Other different tests were conducted to determine the possible influence of temperatures on the graft taking and posterior sprouting of graft.

On the reference plots a productivity study was conducted of the cultivars that performed best, at least in theory, both in the centres of origin and diffusion the species: on the dry-land reference plot (0.5 ha), *Kerman* and *Peter* cultivars on *P. atlantica* Desf. and on the irrigated reference plot, (0.25 ha) *Kerman*, *Peter* and *Mateur*, *Mateur M.* cultivars on *P. atlantica* Desf.

Results

Theoretical adaptation

Table 1 shows the different agroclimatic types classified in terms of their agroclimatic suitability, in terms of its general formula, based on the bioclimatic factors of the pistachio tree for each provincial station (Table 2), and the most similar agroclimate of the traditional producing countries (Table 3). The more than two thousand grafts made in the last eight years show no significant taking differences between the two main species of rootstocks, that is to say, *P. atlantica* Desf. and *P. terebinthus* L. As regards the influence of the movement of sap on the taking of the bud and growth of the shoot, Table 4 lists the data obtained from test A-1 on the influence of absolute maximum temperatures (AMT). Considering first of all the total number of buds that took root with each treatment (T2 = 38 and T3 = 29) an $\chi^2 = 1.21$; $p = 0.272$ was obtained, indicating that there are no significant differences. Moreover, when considering the average number of grafts that took in each treatment and not the total number, and taking into account that three blocks were used in each treatment, both the test *t* de *Student* ($t_2 = 1.96$; $p = 0.188$) and that of *Wilcoxon* ($Z = 1.60$; $p = 0.109$), also show that there are no significant differences between the two treatments. This lack of differences not only occurred in the number of grafts that took (T) but also in the number of grafts that sprouted (S) ($t_2 = 1.00$; $p = 0.423$; $Z = -1.00$; $p = 0.317$) and in the number of retained buds (R) ($t_2 = 2.65$; $p = 0.118$; $Z = -1.60$; $p = 0.109$). Therefore, and although in trial A-1 the interval of AMT between 35 and 40ºC (T-2) apparently has a more positive influence on the grafts taking root than when they occur between 30 and 35ºC (T-3), the fact is that these differences are not large enough to say that T2 is better than T3. Nonetheless, it seems that during the grafting period, sharp temperature changes play a more decisive role on graft taking that the temperature themselves, and affect it negatively.

Table 1. Agroclimatic suitability of the agroclimatic types of the different sites in the province of Ciudad Real (CR) (Spain) in terms of the general formula obtained form the values of each bioclimatic factor

E	Very good	S†	E††	Medium	S	E	Marginal	S
CR.76	A3(16) B3C3D3E2F3a2b2c2d3e3f3	11.2	CR.61	A3(0) B3C3D2E1F2a2b2c2d3e3f2	11.1	CR.42	A1(28) B3C3D2E2F3a2b2c2d3e3f3	1.1
CR.74	B3C3D3E2F3a3b2c3d3e2	11.2	CR.16	A2(22) C3 E2F3	-	CR.35	A1(28) B3C3D2E3F2a2b2c2d3e3f2	1.1
CR.71	A3(13) C3D2E3F3a2b2c2d3e3f2	1.1	CR.6	A2(24) B3C3D2E3F3a2b2c2d3e3f2	1.1	CR.63	A1(29) B3C3D2E3F2a2b2c2d3e3f2	1.1
CR.27	B3C3D2E3F3a2b2c2d3e3f3	1.1	CR.38	A2(24) B3C3D2E3F3a2b2c2d3e3f2	1.1	CR.77	A1(29) B3C3D2E2F3a2b2c2d3e3f3	1.1
CR.78	A3(15) C3 E3F3	-	CR.39	A2(25) B3C3D2E3F3a2b2c2d3e3f3	1.1	CR.31	A1(32) B3C3D2E2F3a2b2c2d3e3f3	1.1
CR.21	A3(17) C3 E3F3	-				CR.44	A1(35) B3C3D2E2F3a2b2c2d3e3f3	1.1
CR.9	A3(15) C3 E2F3	-				CR.40	A1(53) B3C3D3E3F2a2b1c2d3e2f3	1.1; 9
CR.54	A3(17) C3 E2F3	-				CR.17	A1(39) B3C3D2E2F3a2b1c2d3e3f3	1.1
CR.29	A3(25) B3C3D2E3F2a2b2c2d3e3f2	1.1				CR.53	A1(67) B3C3D2E3F3a2b1c2d3e3f3	1.1
CR.10	A3(5) B3C3D2E2F3a2b2c2d3e3f3	1.1				CR.43	B3C3D2E2F3a2b2c1d3e3f2	1.1
CR.18	A3(5) B3C3D2E2F3a2b2c2d3e3f3	1.1				CR.57	A1(61) B3C3D2E2F3a2b1c2d3e3f3	1.1
CR.15	A3(12) B3C3D2E2F2a2b2c2d3e3f3	1.1				CR.73	A1(77) B3C3D2E2F3a2b2c1d3e3f2	1.1
						CR.81	A1(81) B3C3D2E2F3a2b1c2d3e3f3	1.1
						CR.87	A1(47) B3C3D2E2F3a2b1c1d3e3f3	1.1
						CR.60	C3 b2c1d3e3f2	-
						CR.28	A1(42) C3 E2F3	-
						CR.34	A1(50) C3 E3F3	-
						CR.82	A1(61) C3 E3F3	-

†S: Producing town with similar agroclimatic type
††E: Weather station

Table 2. Coordinates of the weather stations in the province of Ciudad Real (CR) (Spain), listed in Table 1

Town	Longitude (W)	Latitude (N)
CR. 6. Alcázar de San Juan	3º 12'	39º 23'
CR. 9. Alhambra	3º 03'	38º 54'
CR.15. Almodovar del Campo (CCEA)	4º 11'	38º 43'
CR.16. Almuradiel	4º 11'	38º 43'
CR.17. Arenas de S. Juan	3º 30'	39º 13'
CR.18. Argamasilla de Alba	3º 05'	39º 08'
CR.21. Bolaños de Cva.	3º 40'	38º 54'
CR.27. Calzada de Cva.	3º 46'	38º 42'
CR.28. Calzada de Cva. (Cooperativa)	3º 46'	38º 42'
CR.29. Campo de Criptana	3º 07'	39º 24'
CR.31. Ciudad Real (Inst.)	3º 56'	38º 59'
CR.35. Chaparrillo	4º 01'	39º 01'
CR.38. Daimiel	3º 37'	39º 04'
CR.39. Encomienda de Mudela	3º 55'	38º 37'
CR.40. Entresierra	4º 03'	39º 02'
CR.42. Fontanosas	4º 33'	38º 46'
CR.43. Fuencaliente	4º 18'	38º 24'
CR.44. Fuenllana	2º 57'	38º 45'
CR.53. Llanos del Caudillo	2º 57'	39º 08'
CR.54. Labores (Las)	3º 31'	39º 17'
CR.57. Manzanares	3º 31'	38º 58'
CR.60. Molinillo (El)	4º 13'	39º 28'
CR.61. Navalpino	4º 35'	39º 15'
CR.63. Peñarroya	3º 00'	39º 03'
CR.71. Puertollano (Minas)	4º 03'	38º 40'
CR.73. Retuerta del Bullaque	4º 08'	39º 32'
CR.74. San Carlos del Valle	3º 14'	38º 51'
CR.76. Santa Cruz de Mudela	3º 38'	38º 38'
CR.77. Socuellamos	2º 47'	39º 17'
CR.78. Solana (La)	3º 14'	38º 57'
CR.81.Torre de Juan Abad (Las T.)	3º 10'	38º 40'
CR.82. Valdepeñas	3º 26'	38º 46'
CR.87. Villanueva de los Infantes	3º 00'	38º 44'

Identification and description of phenological states and substates on male and female cultivars

Photographs were taken every three days from the first sign of swollen bud until the fruit set or the end of pollen emission. Of all the photographs, those that showed a different state or a difference between two consecutive states were chosen. The states and substates were identified on the basis of the nomenclature used by Baggiolini (1952), that is to say, capital letters for the main states and numbers for the secondary states or substates (Table 5).

Table 3. Coordinates of the main areas of centres of origin and dissemination of the pistachio tree (*Pistacia vera* L.) considered for establishing climatic similarities with the stations of the province of Ciudad Real (Spain) listed in Table 1

Country	Town/city	Longitude	Latitude
1. Afghanistan	1.1. Kabul	69° E	34° N
2. Cyprus	2.2. Nicosia	33° E	35° N
3. USA (California)	3.1. Bakersfield	119° W	35° N
	3.3. Chico	121° W	39° N
	3.4. Davis	121° W	38° N
	3.5. Fresno	119° W	36° N
4. Greece	4.1. Athens	23° E	37° N
	4.3. Rhodes	28° E	36° N
5. Iraq	5.1. Mosul	43° E	36° N
6. Iran	6.1. Esfahan	51° E	32° N
	6.2. Kerman	57° E	30° N
	6.3. Mashhad	59° E	36° N
	6.5. Teherán	51° E	35° N
7. Italy (Sicily)	7.3. Bivona	13° E	37° N
	7.4. Caltanissetta	14° E	37° N
	7.5. Catania	15° E	37° N
	7.7. Mazzarino	14° E	37° N
	7.8. Palermo	12° E	37° N
8. Pakistan	8.1. Quetta	67° E	30° N
9. Syria	9.1. Aleppo	37° E	36° N
	9.2. Damascus	36° E	33° N
	9.3. Mouslimié	37° E	36° N
	9.4. Zébédani	36° E	33° N
10. Tunicia	10.1. Sfax	10° E	34° N
11. Turkey	11.1. Ankara	32° E	39° N
	11.2. Gaziantep	37° E	37° N
	11.3. Urfa	38° E	37° N
12. Turkmenistan	12.1. Kuska	62° E	35° N
	12.2. Turkman	60° E	40° N

Production of the dry-land and irrigated reference plots

Comparable to that of the producing countries. The yield per hectare and per tree results obtained in 1995 and 1996 (seven and eight years after planting respectively) confirm the high degree of similarity between harvests obtained in the producing countries (Table 6).

Tabla 4. Results of the pistachio tree (*Pistacia vera* L.) grafts sown on terebinth pistachio (*Pistacia terebinthus* L.) corresponding to test A-1 on the influence of absolute maximum temperatures on taking of graft

(i) By dates	T-2 (AMT 35-40ºC)			
	TG†	T††	S†††	R††††
30-VI	6.0	6.0	6.0	0.0
1-VII	6.0	3.0	3.0	0.0
19-VII	6.0	6.0	0.0	6.0
20-VII	6.0	5.0	3.0	2.0
21-VII	6.0	3.0	2.0	1.0
22-VII	6.0	4.0	2.0	2.0
23-VII	6.0	5.0	2.0	3.0
31-VII	6.0	6.0	5.0	1.0
	T-3 (AMT 30-35 ºC)			
5-VI	6.0	3.0	3.0	0.0
21-VI	6.0	5.0	2.0	3.0
22-VI	6.0	5.0	4.0	1.0
24-VI	6.0	5.0	3.0	2.0
25-VI	6.0	1.0	1.0	0.0
26-VI	6.0	4.0	4.0	0.0
9-VII	6.0	3.0	2.0	1.0
25-VII	6.0	5.0	2.0	3.0

(ii) By blocks	T-2			T-3		
	T (%)	S (%)	R (%)	T (%)	S (%)	R (%)
B1	11.0	5.0	6.0	10.0	5.0	5.0
B2	16.0	12.0	4.0	10.0	10.0	0.0
B3	11.0	6.0	5.0	9.0	6.0	3.0
Totals	38.0	23.0	15.0	29.0	21.0	8.0

†TG: Total grafts
††T: Grafts taken
†††S: Grafts sprouted
††††R: Sown buds retained (green yet without sprouting)

Table 5. Identification and description of each of the phenological states observed in pistachio tree (*Pistacia vera* L.) flower buds

Female inflorescence			Male inflorescence		
State	Substate	Description	State	Substate	Description
A	0	Sleeping bud	A	0	Sleeping bud
B	0	Swollen bud	B	0	Swollen bud
C	0	Longitudinal growth. Separation of bracts	C	0	Protective bracts start to separates
	1	Clearly separated bracts		1	Bracts are separated and more visible
D	0	End of cluster are seen to appear among the bracts	D	0	Stamens start to appear among the bracts
	1	Cluster still closed		1	Stamens are easy to see. The bracts are still visible
E	0	Cluster start to open	E	0	Stamen cluster are closed. The bracts can no longer be seen
	1	Cluster fully open		1	The cluster open and start to take on a yellowish tone
F	0	Recently-set reddish fruit observed	F	0	The stamens start to yellow
	1	The mesocarpium of the fruit start to yellow at the base		1	The anthers are completely yellow
	2	Mesocarpium completely yellow		2	Cluster fall
M	0	Reddish-white mesocarpium			

Table 6. Comparative analysis between performance of the species *Pistacia vera* L. (cv .*Kerman*) of the experimental plots and the plantations of the centres of origin an production

Plot	Experimental plots				Centres of origin or production					
	Year	Condition	Yield†		Country	Cultivar/s	Year	Condition	Yield†	
			Kg ha^{-1}	Kg per tree					Kg ha^{-1}	Kg per tree
Ref. CMA	7	Irrigated	100.0	0.2	USA	*Kerman*	7	Irrigated	448.0	-
	8		1,000.0	2.3			8		897.0	-
Ref. Alm.	7	Arid land	150.0	0.6	Spain	*Kerman*	7	Arid land	238.0	1.0
	8		600.0	2.4			8		619.0	2.6
					Mexico	*Kerman*	7	-	-	0.8
							8		-	1.0
					Tunisia	Autoch-thonous	7	Arid land	-	2.0
							8		-	0.4

†Kilograms in shell with 7% among humidity
Source: Navarrete, (1989), Citing Commission data on California Pistachio tree; Ribera *et al.,* (1996); Figueroa, (1986); Jacquy, (1972)

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