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Photosynthetic characteristics of six Pistachio cultivars

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SUMMARY - For the female pistachio (*Pistacia vera* L.) cultivars 'Bianca', 'Kerman', 'Larnaka' and 'Red Aleppo' and the male cultivars 'Ask' and 'Peter', the following parameters were assessed by means of a portable infrared gas analyser: net carbon dioxide assimilation, stomatal conductance, transpiration, photosynthetic photon flux, photosynthetic efficiency and water use efficiency. The two male genotypes, characterized by high stomatal conductance and transpiration rate and by high to medium net CO_2 uptake, were separated from the other cultivars by principal component analysis. As for female cultivars, 'Larnaka' and 'Bianca' showed the highest and the lowest rate of carbon assimilation, respectively, 'Kerman' and 'Red Aleppo' were very close to each other. Moreover, 'Larnaka' achieved the best compromise between assimilation and transpiration rates, as indicated by its higher water use efficiency.

Key words: *Pistacia vera*, leaf gas exchanges, female and male genotypes.

RESUME - *"Caractéristiques photosynthétiques de six cultivars de pistachier". En ce qui concerne les cultivars femelles de pistachier (*Pistachia vera *L.) 'Bianca', 'Kerman', 'Larnaka' et 'Red Aleppo' et les cultivars mâles 'Ask' et 'Peter', les paramètres suivants ont été évalués à l'aide d'un analyseur à gaz infrarouge portable : assimilation nette de dioxyde de carbone, conductance stomatale, transpiration, flux photosynthétique de photons, efficacité photosynthétique et efficacité de l'utilisation de l'eau. Les deux génotypes mâles, caractérisés par un taux élevé de conductance stomatale et de transpiration, et par une absorption nette de CO_2 allant de moyenne à élevée, ont été séparés des autres cultivars par analyse en composantes principales. En ce qui concerne les cultivars femelles, 'Larnaka' et 'Bianca', ils ont montré respectivement le taux le plus élevé et le plus faible d'assimilation du carbone, tandis que 'Kerman' et 'Red Aleppo' étaient très proches l'un de l'autre. En outre, 'Larnaka' a présenté le meilleur compromis entre les taux d'assimilation et de transpiration, comme l'indique sa meilleure efficacité d'utilisation de l'eau.*

Mots-clés : Pistacia vera, *échanges foliaires de gaz, génotypes mâles et femelles.*

Introduction

Studies on leaf gas exchanges allow a direct evaluation of the physiological responses to the environmental conditions which can have an influence on the potential productivity of crop plants.

Unlike other woody species, very few studies have investigated photosynthetic responses in nut crops, especially in *P. vera* L. For this latter, trials have been carried out to assess the rates of net CO_2 uptake and stomatal conductance in seedlings or one cultivar (Lin *et al.*, 1984; Walker, 1990; Vemmos, 1994; Novello and de Palma, 1995; de Palma *et al.*, 1996), but photosynthetic activity of different pistachio genotypes have never been compared. The investigation and comparison of different cultivars tested under the same environmental conditions might allow to detect physiological variability within the species, that can be related with vegetative and productive performances.

In the last few years, a research on the pistachio physiological activity has been undertaken on four female and two male pistachio cultivars native from different areas. The female cultivars are: 'Bianca' (syn. 'Napoletana') the main Italian cultivar; 'Larnaka', from Cyprus, characterized by high productivity; 'Kerman', the main cultivar in USA, originated from Iranian seeds, and 'Red Aleppo' (syn. 'Ashoury'), that is one of the best cultivars from Syria. The male cultivars are 'Peter', a vigorous genotype selected in California and considered as one of the most performing pollinators, and 'Ask', selected in Israel, less vigorous than the former (Crane and Maranto, 1988;

Al-Nabelsi, 1995; Vargas *et al.*, 1995). The first findings of this study will be discussed in the present work with the aim to assess and compare rates of net photosynthesis and related parameters among genotypes.

Materials and methods

The trial was carried out at the experimental farm of Istituto di Coltivazioni Arboree - Bari University on young non-bearing irrigated trees of the female cultivars 'Bianca', 'Kerman', 'Larnaka', 'Red Aleppo' and of the male cultivars 'Ask' and 'Peter', which were all grafted on rootstock *Pistacia integerrima* Stewart.

By means of a portable infrared gas analyser (ADC, LCA-4 system, Analytical Development Co., Hoddesdon, UK) the following parameters were assessed per leaf area unit: net carbon dioxide assimilation (Pn, μmol m^{-2} s^{-1}), stomatal conductance (g_s, mol m^{-2} s^{-1}), transpiration (E, mmol m^{-2} s^{-1}), photosynthetic photon flux (PPF, μmol m^{-2} s^{-1}), quantum yield (Φ, Pn:PPF ratio), water use efficiency (WUE, Pn:E ratio).

Four trees per cultivar were selected and five leaves per tree were chosen from the medium portion of shoots around the canopy. Measurements started in the first week of August 1995 and were repeated in mid June and late July 1996, on cloudless days with PPF >1600 μmol m^{-2} s^{-1} at the leaf surface.

Data were statistically evaluated by general linear model procedure and by principal component analysis of SAS software (SAS Institute, Cary-NC USA).

Results

The mean value of Pn was the highest for the male 'Peter' (28.26 μmol m^{-2} s^{-1}) which was followed by the female 'Larnaka' (25.50 μmol m^{-2} s^{-1}) and the male 'Ask' (23.87 μmol m^{-2} s^{-1}), while the female 'Bianca' showed the lowest rate (20.49 μmol m^{-2} s^{-1}); the same pattern was found as for Φ (Table 1). 'Peter' and 'Ask' had the highest rates of E, while no difference was found among female cultivars. As concerns g_s, 'Peter' exceeded all the other cultivars while 'Ask' exceeded only 'Bianca'. The WUE ranged between 6.24 μmol CO_2 mol^{-1} H_2O in 'Larnaka' and 5.07 μmol CO_2 mol^{-1} H_2O in 'Bianca'; the rates found in 'Larnaka' and 'Peter' were statistically higher than those found in 'Ask' and 'Bianca'; the other cultivars showed intermediate values.

Table 1. Summary of the mean analytical values of the photosynthetic parameters

	Pn (μmol m^{-2} s^{-1})	g_s (mol m^{-2} s^{-1})	E (mmol m^{-2} s^{-1})	Φx1000 (μmolCO_2 μmolquanta^{-1})	WUE (μmolCO_2 mmolH_2O^{-1})
Peter	28.26^{a}	0.233^{a}	4.900^{a}	15.35^{a}	6.01^{a}
Larnaka	25.50^{b}	0.194^{bc}	4.429^{b}	13.46^{b}	6.24^{a}
Ask	23.87^{bc}	0.208^{b}	4.834^{a}	12.44^{bc}	5.22^{b}
Red Aleppo	23.39^{bc}	0.183^{bc}	4.429^{b}	12.19^{bc}	5.73^{ab}
Kerman	22.45^{cd}	0.189^{bc}	4.225^{b}	11.79^{cd}	5.71^{ab}
Bianca	20.49^{d}	0.174^{c}	4.312^{b}	10.50^{d}	5.07^{b}

a,b,c,d: Mean separation within columns by Duncan test at P<0.05

The principal component analysis (PCA) showed the first two PCs accounting for 78% and 21% of the total variability, respectively (Table 2). Variables mostly linked with PC1 were Pn, Φ, g_s and E, while WUE was the only variable mostly linked with PC2. The correlation matrix of the

cultivar mean values revealed a non-significant relationship WUE *vs* E (r = 0.07) and WUE *vs* g_s (r = 0.39).

Table 2. Eigenvectors (W) and loadings (L) of the first 2 PC from PC analysis. Eigenvalues and their contribution to total variation are listed at the bottom of columns

Parameters	PC1		PC2	
	W	L	W	L
Pn	0.50	0.99	0.11	0.12
g_s	0.48	0.94	-0.27	-0.28
E	0.40	0.79	-0.58	-0.59
Φ	0.50	0.99	0.12	0.12
WUE	0.33	0.65	0.75	0.76
Eigenvalue	3.89		1.03	
% of total variability	78		21	
Cumulative % of variability	78		99	

By considering cultivar and parameter association through eigenvectors (Table 3) and the mean values of the measured parameters (Table 1), 'Larnaka' appeared mainly characterized by high WUE and, to a lesser extent, by high Pn and Φ. Cv. 'Red Aleppo' had low g_s and high WUE, 'Kerman' a high WUE and low E, 'Bianca' exhibited a negative link with all the parameters, especially WUE and Pn. Cv. 'Peter' appeared mainly characterized by high g_s, Φ and Pn values, while 'Ask' by high E and g_s values with low values of all the other parameters. Cv. 'Peter' had a slightly positive association with WUE while 'Ask' had a marked negative link.

Table 3. Eigenvectors

	Pn	g_s	E	Φx1000	WUE
Larnaka	0.56544	-0.12353	-0.34428	0.50669	1.28403
Red Aleppo	-0.22785	-0.66548	-0.32758	-0.26068	0.14910
Kerman	-0.57996	-0.36540	-1.05856	-0.50307	0.09457
Bianca	-1.31456	-1.08880	-0.74665	-1.28857	-1.32432
Peter	1.60063	1.71611	1.35731	1.65807	0.77740
Ask	-0.04370	0.52710	1.11975	-0.11244	-0.98078

In Fig. 1, the bidimensional graphic projection of the total statistical variance and the chart of variables, both issuing from PCA, were plotted together in order to elucidate the relative position of the six pistachio cultivars within the total variability expressed by their photosynthetic characteristics. Cv. 'Larnaka' was in the same vectorial direction of the variable WUE while 'Bianca' was found in the opposite quadrant. 'Peter' had an intermediate position between g_s and the overlapping variables Pn and Φ and was in the same quadrant as 'Ask'. 'Red Aleppo' and 'Kerman' were quite opposite to the variables g_s and E.

Discussion

Because of the absence of any fruit sink effect in the young female trees, data from male and female genotypes were more comparable and could be considered as a baseline for the evaluation of ecophysiological traits in pistachio cultivars.

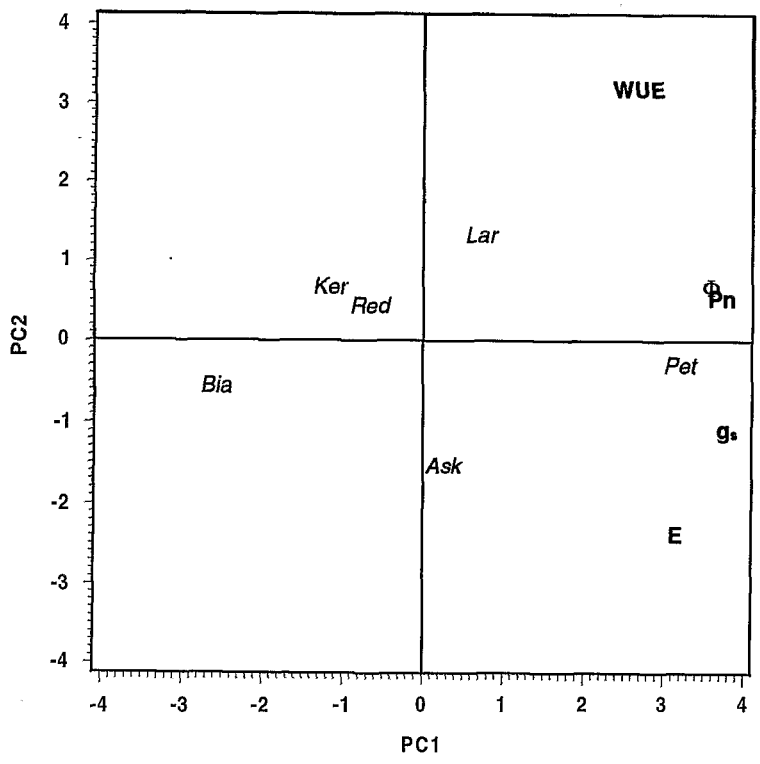

Fig. 1. Bidimensional graphic projection of the total statistical variance (cultivar abbreviations in italic).

Although pistachio cultivars exhibited differences in terms of rates of net CO_2 uptake and related parameters, all the tested genotypes showed an intense activity of leaf gas exchange resulting in high levels of net photosynthesis, photosynthetic efficiency per light intensity and leaf water use efficiency. Cultivars of *Pistacia vera* are late shooting and have been selected in growing areas characterized by limiting ambient conditions as for warm air temperature and low soil and air humidity, thus their high ecophysiological efficiency might be considered as an adaptive response to obtain an elevate amount of carbon assimilation in a relatively short period of time and an elevate rate of carbon assimilation per unit of transpired water. The lack of correlation WUE *vs* E and WUE *vs* g_s agree with previous observations on young irrigated pistachio trees (Novello and de Palma, 1995) and would seem to prove that, under irrigated conditions, a strong stomatal control on water use efficiency might not be necessary in pistachio leaves, since high levels of leaf water use efficiency are assured by high rates of CO_2 fixation rather than by low rates of H_2O vapour loss. Under warm ambient conditions and intense light intensity an active leaf transpiration might be useful to limit the increment of leaf temperature.

Basing on photosynthetic characteristics, PCA separated from the other cultivars the two male genotypes 'Peter' and 'Ask', which were characterized by high stomatal conductance and transpiration rate as well as by high and medium net CO_2 uptake respectively (Fig. 1). It is to notice that, as concerns the vegetative traits, 'Peter' and 'Ask' have been reported as characterized by high and medium vegetative vigour, in the same order. Among female cultivars, 'Larnaka' was well separated from 'Bianca' since they showed the highest and the lowest photosynthetic response, respectively; 'Kerman' and 'Red Aleppo' were at intermediate level and had quite similar rates of leaf gas exchange.

In particular, 'Larnaka', that is known for its good potential productivity, exhibited a tendency to achieve the best compromise between assimilation and transpiration rates.

On the whole, to assess and compare photosynthetic responses of several pistachio cultivars under same environmental conditions provided helpful information to better understand some

ecophysiological behaviours of the species and to individuate some differences that could characterize genotypes. However, a more complete investigation, involving a larger pistachio germplasm and a wider range of physiological measurements, could allow a better evaluation of both the ecophysiological variability of the species and the cultivar photosynthetic response to the ambient conditions.

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