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Effect of rootstock on growth, yield and fruit characteristics in cv. 'Bianca' pistachio (*Pistacia vera* L.) trees

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SUMMARY – This paper, following preliminary field evaluation trials started in 1993, reports a study on the effect of eight different in vitro-propagated clonal rootstocks (*P. atlantica* and *P. integerrima*) and one seedling rootstock (*P. terebinthus*) on the vegetative and productive behaviour of pistachio cultivar 'Bianca'. The trees, budded in 1991, were grown using standard cultural practices for dry-land farming in a sandy clay loam soil, located inland in Sicily. On average, clones of *P. integerrima* (I-6 and I-2) were the most vigorous rootstocks. Clones of *P. atlantica* had intermediate vigour. Rootstock significantly affect yield but not fruit weight, kernel to nut ratio, splitting and blanking percentages. The highest yield efficiencies were observed with I-4 and A-3 and A-5, whereas the lowest were obtained with I-6 and I-2 and A-8. Nut shape was significantly affected by the rootstock. Slight differences in leaf mineral content were observed among the tested graft combinations.

Key words: *Pistacia vera*, *P. integerrima*, *P. atlantica*, *P. terebinthus*, rootstocks, growth, yield, fruit characteristics, leaf mineral content.

RESUME – "Effet des porte-greffes sur la croissance, la production et les caractéristiques du fruit du cultivar de pistachier 'Bianca' (*Pistacia vera* L.)". Cet article donne les résultats d'une évaluation préliminaire commencée en 1993. L'étude se rapporte à l'effet de 8 porte-greffes de clones issus d'une propagation in vitro (*P. atlantica* et *P. integerrima*), et d'un porte-greffe issu de semence (*P. terebinthus*) sur l'activité végétative et reproductive de la variété de pistache 'Bianca'. Les plants, greffés en 1991, ont été cultivés selon la conduite habituelle en sec, dans un sol sableux-argileux localisé en Sicile. Les résultats obtenus montrent que les clones de *P. integerrima* I-6 et I-2 sont les plus vigoureux. Les clones de *P. atlantica* ont une vigueur intermédiaire. Le porte-greffe n'a pas d'effets significatifs sur le poids des fruits, le rapport fruit/noyau et les taux de déhiscence et de stérilité. L'efficacité de production la plus élevée a été observée chez la combinaison sur I-4, et sur A-3 et A-5, tandis que les valeurs les plus faibles ont été obtenues sur I-6 et I-2 et sur A-8. La forme du fruit a été significativement affectée par le porte-greffe. Pour les analyses foliaires, de légères différences ont été notées chez les différentes combinaisons testées.

Mots-clés : *Pistacia vera*, *P. integerrima*, *P. atlantica*, *P. terebinthus*, porte-greffe, croissance, production, caractéristiques des fruits, analyse minérale foliaire.

Introduction

Pistachio is an old and traditional crop in Italy, especially in Sicily, where most of the production is located. The Sicilian pistachio industry relies exclusively on a few cultivars, with cv. 'Bianca' accounting for over 90%, and only one rootstock, the wild and spontaneous *P. terebinthus* (Barone *et al.*, 1985). The heterogeneity of *P. terebinthus* seedlings rootstocks, their slow growth and the generally long unproductive period imposed on the scion, have created much dissatisfaction with this rootstock in Sicily (Caruso *et al.*, 1990; Barone and Caruso, 1996). In other countries, pistachio seedlings rootstocks from different species or hybrids have been reported to significantly affect the vigour, tree nutrition, early nut production, alternate bearing, blank nut production and, to some extent, the degree of shell splitting (Crane and Forde, 1976; Crane and Iwakiri, 1986; Ashworth, 1985; Walker *et al.*, 1987).

This paper, following preliminary field evaluation trials started in 1993 (Caruso *et al.*, 1996; Barone *et al.*, 1998), reports the results on vegetative growth, productive behaviour and nutritional status of cv. 'Bianca', as affected by eight different in vitro-propagated clonal rootstocks (*P. atlantica* and *P. integerrima*) and *P. terebinthus* rootstock seedlings.

Materials and methods

The trials were carried out on 45 bearing trees (five per rootstock) in an experimental orchard located inland in Sicily (20 km SW of Palermo, 350 m a.s.l.). Physical and chemical characteristics of the soil were: clay 22%, silt 9%, sand 69%, pH 6.4, active lime 0%, N 1.1‰, P₂O₅ 63 ppm, K₂O 126.7 ppm. The experimental design consisted of a randomized block with three-tree plots replicated five times. The scion cultivar was 'Bianca', which was budded in 1991 onto eight in vitro-propagated (Martinelli, 1987) clonal rootstocks (*P. atlantica* clones A1, A3, A5 and A8 and *P. integerrima* clones I2, I4, I5 and I6) and *P. terebinthus* rootstock seedlings (T9). The trees, 6x6 m apart, were grown using standard cultural practices for Sicilian dry-land conditions, except for limited irrigation during the first years.

In September 2002, when all the trees reached the first commercial production, yield per tree and trunk cross-sectional area (TCA - 10 cm above the graft union) were determined.

On a sample of 100 fruits per tree, nut fresh and dry weight, length, width, thickness, kernel dry weight, shell dehiscence and blank fruit percentage were estimated.

From five trees per rootstock, samples of 10 leaflets were taken from the mid-section of current shoots in May and analysed for the main mineral elements (N, P, K, Ca, Mg, Fe, Mn, Zn, Cu). Leaflets were washed in water, rinsed with distilled water, dried in a forced-air drying oven at 70°C to constant weight, ground in a Philips mill.

Analysis of total nitrogen and phosphorus was performed spectrophotometrically, after CEM microwave oven digestion in presence of Na₂S₂O₈ and KOH, by using the appropriate Spectroquant Merck Kits.

Determination of the remaining micronutrients was carried out after nitric acid/peroxide digestion by an HP 4500 ICP-MS instrument. All analyses were carried out using Milli-Q® Ultrapure Water and certified standards.

Data were assessed using ANOVA and differences analysed by Tukey's HSD Test ($P \leq 0.05$).

Results and discussion

The average trunk cross-sectional area growth recorded in 2002, i.e. twelve years after budding, is reported in Fig. 1. 'Bianca' on Integerrima clone 6 (I-6) grew significantly more (about twofold) than 'Bianca' onto Terebinth (T-9) or Integerrima 5 (I-5). Among the other tested rootstocks no other significant differences were observed. This result is consistent with previous observations indicating that I-2 and I-6 had the best initial growth rate but also that differences in tree growth rate tended to decrease sharply starting from the fifth year after budding (Barone *et al.*, 1998). Such a decrease in tree growth rates has been observed, as the orchard matures, also in other rootstock trials (Joley, 1969; Ferguson *et al.*, 1995).

The effect of the rootstock on nut yield, nut quality and yield efficiency is reported in Table 1 and Fig. 2. 'Bianca'/I-4 nut yield was significantly greater (three to fourfold) than those combinations onto T-9, I-6, A-8 and I-5. Consistently, the highest yield efficiency, calculated as the ratio between yield and TCA, was observed in 'Bianca'/I-4, significantly different with respect to combinations onto I-6, A-8 and I-2.

As far as nut qualitative data are concerned, no significant differences were observed among the tested rootstocks. Only slight differences (4-8%) were detected in the dimensional nut characteristics such as nut length, width, thickness and length to width ratio showing that a major effect is likely to be related to fruit load. In fact, the best dimensional characteristics were obtained with I-6 that, on the contrary, was among the worst in terms of nut yield per tree.

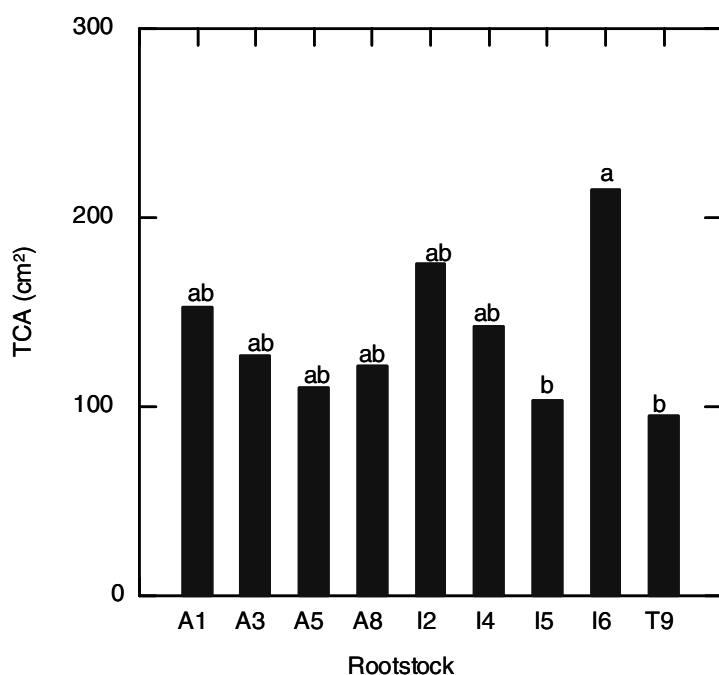


Fig. 1. Trunk cross-sectional area (TCA) of twelve years old 'Bianca' pistachio trees grafted onto 8 different clonal rootstocks (*P. Atlantica*, *P. Integerrima*) and *P. terebinthus* rootstock seedlings (Values with the same letter are not significantly different, $P \leq 0.05$).

The results of foliar mineral analyses are reported in Table 2. Although no general consideration about the diagnosing of any particular nutrient deficiency can be drawn, due to the unusual early time of sampling (Brown, 1995), some comparisons can be made among the behaviour of the tested rootstocks. The ability of the tested rootstocks to take up nutrients from the soil differed significantly for all the tested combination of cv 'Bianca' and for all the elements, except Manganese. As a whole, Nitrogen values resulted extremely low when compared to foliar mineral analysis performed at the beginning of the season, whereas Magnesium, in the average, resulted particularly high (Crescimanno *et al.*, 1987). Two rootstocks, A-8 and I-2, showed for almost all the minerals a particular high efficiency to supply nutrients to the scion at early stage of shoot development.

Conclusions

Rootstocks of different origin are confirmed to be able to influence growth of pistachio cv. 'Bianca' (Caruso *et al.*, 1990; Barone *et al.*, 1998) even once the trees have overtaken their vegetative phase. Among the tested rootstocks, Integerrima clone No. 2 and 6 showed the highest values of trunk cross-sectional area at the 12th year after grafting, especially when compared to Terebinth and Integerrima clone No. 5. Rootstock also affected partially productivity and yield efficiency, whereas no significant effect was observed on nut characteristics except for the dimensional nut characteristics.

In conclusion, even if Integerrima clone No. 2 and No. 6 can be considered interesting for their initial rapid growth, at the present time only with Integerrima clone No. 4 an acceptable compromise between vegetative and productive activities has been achieved in the tested conditions. As far as the different ability of the rootstock in the uptake of nutrients from the soil is concerned, further studies are required in order to ascertain the maintenance of the observed differences in the time course.

Acknowledgements

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Table 1. Nut yield, weight of 100 nuts, blank and split percentage and fruit characteristics of cv. 'Bianca' twelve years old pistachio trees grafted onto 8 different clonal rootstocks (*P. atlantica*, *P. integerrima*) and *P. terebinthus* rootstock seedling

Rootstock	Nut yield (kg)	100-nut weight (g)	Blank fruit (%)	Split (%)	Length (mm)	Width (mm)	Thickness (mm)	Length/width	Nut d.w. (g)	Kernel d.w. (g)	Kernel/nut (%)
A1	1.29 ab	99.46 n.s.	10.6 n.s.	24.0 n.s.	22.00 c	11.17 abc	10.09 abc	1.97 b	1.00 n.s.	0.46 n.s.	46.72 n.s.
A3	1.56 ab	98.25	13.6	32.6	21.76 c	11.08 abc	9.97 bc	1.96 b	0.98	0.44	44.94
A5	1.40 ab	107.52	5.0	37.0	22.06 c	11.31 abc	10.17 abc	1.95 b	1.08	0.50	46.43
A8	0.63 b	97.93	11.6	21.8	21.83 c	11.21 abc	10.20 abc	1.95 b	0.98	0.45	45.76
I2	0.87 ab	100.98	17.4	17.8	22.91 ab	11.50 a	10.31 ab	2.00 ab	1.01	0.45	44.90
I4	2.34 a	97.00	8.8	37.4	21.40 c	10.98 c	9.92 c	1.95 b	0.97	0.43	44.67
I5	0.70 b	99.75	11.0	27.2	22.21 bc	11.35 abc	10.42 a	1.96 b	1.00	0.44	44.55
I6	0.63 b	103.46	17.3	23.0	23.46 a	11.46 ab	10.41 a	2.05 a	1.05	0.49	46.44
T9	0.55 b	96.95	12.2	30.0	21.68 c	11.03 bc	10.07 abc	1.97 b	0.97	0.44	45.45

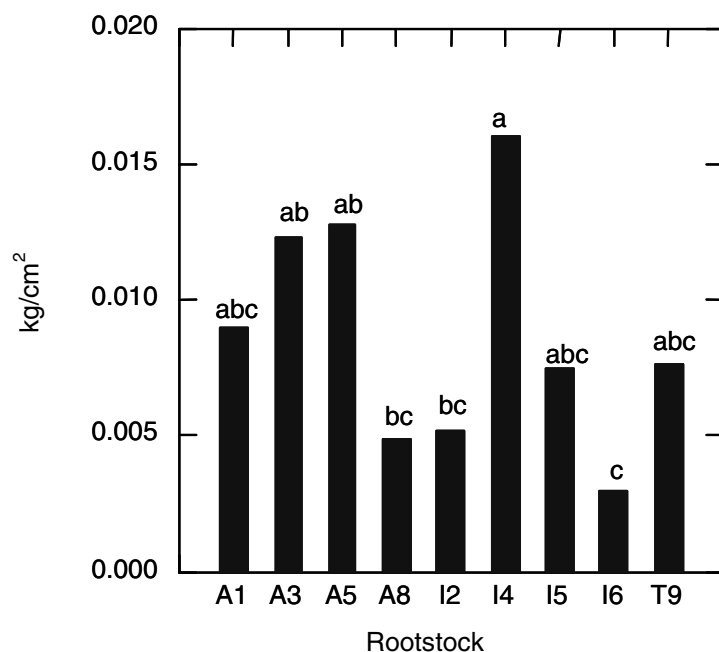


Fig. 2. Yield Efficiency (kg/cm²) of twelve years old 'Bianca' pistachio trees grafted onto 8 different clonal rootstocks (*P. atlantica*, *P. integerrima*) and *P. terebinthus* rootstock seedlings (Values with the same letter are not significantly different, $P \leq 0.05$).

Table 2. Foliar mineral content of cv. 'Bianca' twelve years old pistachio trees grafted onto 8 different clonal rootstocks (*P. atlantica*, *P. integerrima*) and *P. terebinthus* rootstock seedlings.

Rootstock	P %	N %	K %	Mg %	Ca %	Zn ppm	Cu ppm	Fe ppm	Mn ppm
A1	0.38 ab	0.75 abc	0.88 a	1.40 ab	0.48 c	37.26 b	26.01 b	117.04 b	28.60 ns
A3	0.41 ab	0.65 c	0.87 a	1.40 ab	0.22 a	20.86 a	11.28 a	43.55 a	13.35
A5	0.37 ab	0.86 bc	0.97 a	1.45 ab	0.23 a	17.35 a	10.67 a	43.02 a	14.52
A8	0.42 a	1.22 a	1.83 b	4.70 d	0.43 bc	32.23 b	28.33 b	108.14 b	22.25
I2	0.42 a	1.04 ab	1.85 b	3.53 c	0.55 c	32.46 b	31.14 b	130.44 b	26.78
I4	0.37 ab	0.77 abc	0.91 a	0.71 a	0.24 ab	19.26 a	12.07 a	35.07 a	13.34
I5	0.35 b	0.77 abc	0.76 a	1.17 ab	0.24 ab	17.17 a	7.26 a	33.40 a	14.03
I6	0.42 a	0.70 c	0.91 a	0.97 ab	0.25 ab	22.20 a	13.25 a	51.31 a	20.67
T9	0.40 ab	0.96 abc	1.13 a	1.64 b	0.26 ab	21.05 a	9.74 a	45.29 a	13.49

Values with the same letter within columns are not significantly different, $P \leq 0.05$.

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