EFFECT OF ROOTSTOCK ON TRUNK GROWTH AND FOLIAR MINERAL CONTENT IN CV. BIANCA PISTACHIO (*Pistacia vera* L.) TREES

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Abstract

Trunk cross-sectional area (TCSA) and mineral content were recorded for 4 years in the major Sicilian pistachio cultivar Bianca budded in 1991 onto eight in vitro-propagated clonal rootstocks (*Pistacia atlantica* and *P. integerrima*) and one seedling rootstock (*P. terebinthus*). The trees were grown using standard cultural practices for Sicilian dry-land farming in a fine sandy soil, located inland in Sicily (20 km SW of Palermo, 350 m a.s.l.). From nine trees per rootstock, samples of 10 leaflets from the mid-section of current shoots were taken yearly in August and analyzed for the main plant mineral elements (N, P, K, Ca, Mg, Fe, Mn, Zn, Cu and B). The TCSA was measured at the end of each growing season. Clones of *P. integerrima*, especially clone 2, proved to be the most vigorous among the tested rootstocks, with a TCSA more than three times that of *P. terebinthus*. Clones of *P. atlantica* were of intermediate vigor, but differences in TCSA among the rootstocks tended to disappear in the last year of observation. There were no particular significant differences in the foliar concentrations of N, P, Fe, Mn and Zn, whereas there were significant differences among the rootstocks for Mg and K. Clone 3 of *P. atlantica* was the most efficient in using Mg and *P. terebinthus* in using K. Finally, an antagonistic effect was detected between these last two elements, with a highly significant negative correlation between K and Mg.

1. Introduction

Pistachio is an old and traditional crop in Italy, especially in Sicily, where most of the production is located. There are two main growing areas; the most important is in the eastern province of Catania, with about 85% of the total of 4500 hectares, and the other is in the south-western provinces, in scattered settlements (Barone et al., 1985). 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*, traditionally budded *in situ* until recently, and used to establish a pistachio orchard or as a seed source for seedling rootstocks (Barone and Caruso, 1996). In the Sicilian pistachio industry, the use of *P. terebinthus* has ensured good adaptation to different soil conditions, a great tolerance to water stress, together with a low demand for fertilization and minimal cultural practices. Other interesting characteristics of *P. terebinthus*, such as its particular efficiency for Zn and Cu absorption, and its resistance to Armillaria root rot, are now being considered elsewhere for breeding programs (Krueger and Ferguson, 1995). Nevertheless, the heterogeneity of *P. terebinthus* seedling rootstocks, their slow growth and the generally long unproductive period imposed on the scion, have created much disaffection with this rootstock in Sicily. Consequently, because there are no reliable alternatives, this could prevent the spread of pistachio cultivation in this area.

In other countries, pistachio seedling rootstocks from different species or hybrids have been reported to significantly affect the vigor and nutrient status of the tree, early nut production, alternate bearing, soil-borne diseases, cold and salt tolerance and, to some extent, blank-nut production and the degree of shell splitting (Crane and Forde, 1976; Crane and Iwakiri, 1986; Ashworth, 1985; Walker et al., 1987). Nevertheless, all these rootstock effects are influenced strongly by the genetic variability among different seedling rootstocks (Crane and Iwakiri, 1986; Johnson and Weinbaum, 1987). Recently, clones of *P. integerrima* and *P. atlantica* have been obtained by in vitro propagation (Martinelli, 1986), so that in 1989 preliminary nursery tests were begun (Caruso et al., 1990) and subsequent field evaluation trials initiated to compare these clonal rootstocks with the traditional *P. terebinthus* seedling rootstocks (Caruso et al., 1996).

This paper reports the results of a 4-year period of observation on the vegetative growth and nutritional status of cv. Bianca, as affected by rootstock.

2. Materials and methods

The study was carried out in an experimental orchard at the Istituto di Coltivazioni Arboree of the University of Palermo, in a fine sandy soil, located inland in Sicily (20 km SW of Palermo, 350 m a.s.l.). The physical and chemical characteristics of the soil were: clay 22%, silt 9%, sand 69%, pH 6.4, active lime 0%, N 1.1‰, P_2O_5 63 ppm, K_2O 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 clonal rootstocks (*P. atlantica* clones 1, 3, 5 and 8 and *P. integerrima* clones 2, 4, 5 and 6) and one seedling rootstock (*P. terebinthus*). The trees, 7 x 7 m apart, were grown using standard cultural practices for Sicilian dry-land farming, except for limited irrigation during the first years. Starting in 1993, from nine trees per rootstock, samples of 10 leaflets were taken from the mid-section of current shoots yearly in August and analyzed for the main mineral elements (N, P, K, Ca, Mg, Fe, Mn, Zn, Cu and B). 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, and sieved using a 850 μm screen. Leaf nitrogen was determined using sulphuric acid/peroxide digestion and distillation by a micro-Kjeldahl method. P, K, Ca, Mg, Mn, Cu, Zn, Fe and B were analyzed after nitric acid/peroxide digestion, using an Inductively Coupled Plasma (ICP) spectrophotometer (Perkin Elmer Plasma 400). Analyses in 1996 were limited to the determination of N, P, K, Mg, Ca and Fe levels. Trunk cross-sectional area (TCSA) was determined by girth measurements using calipers 20 cm above the graft union at the end of each growing season. Data were assessed using ANOVA and differences analyzed by Tukeys HSD Test (P ≤ 0.05).

3. Results

The annual variation in tree growth, determined as the TCSA, is shown in Fig. 1, where increasing differences were particularly evident from 1994, i.e. the third year from budding.

Bianca on Integerrima clone 2 (I2) grew significantly better than Bianca with Terebinth 9 (T9; threefold less in 1995) or Atlantica 8 (A8) and I5. Trees on I6-I4 also grew significantly more than trees on T9 or I5. Terebinth was confirmed as the least vigorous among the tested rootstocks, particularly in the first years of growth. From 1995 (the fourth year from planting) differences in tree growth rate tended to decrease sharply.

Figure 1. Trunk cross-sectional area growth in the various selections

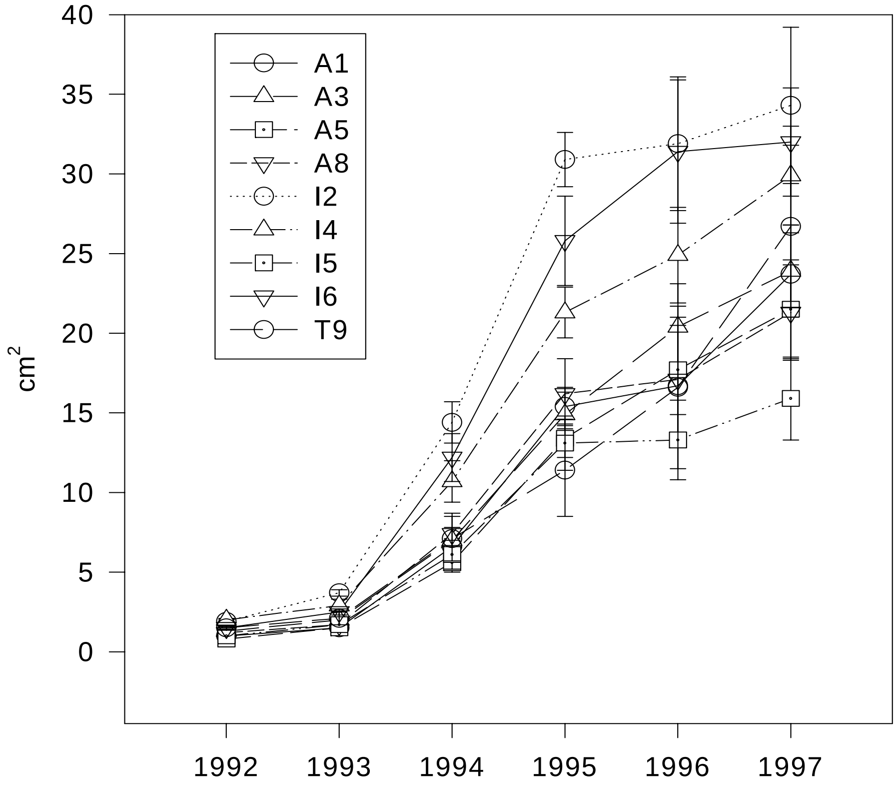


Figure 2. Potassium content in 1993.

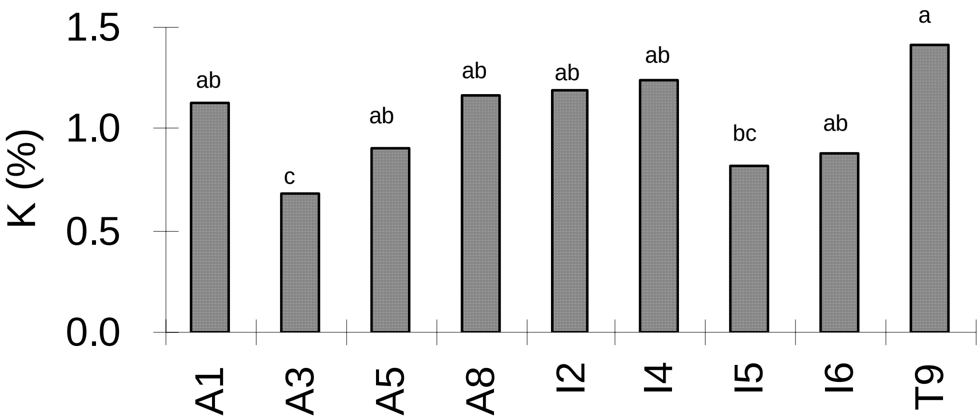


Figure 2. Magnesium content in 1993.

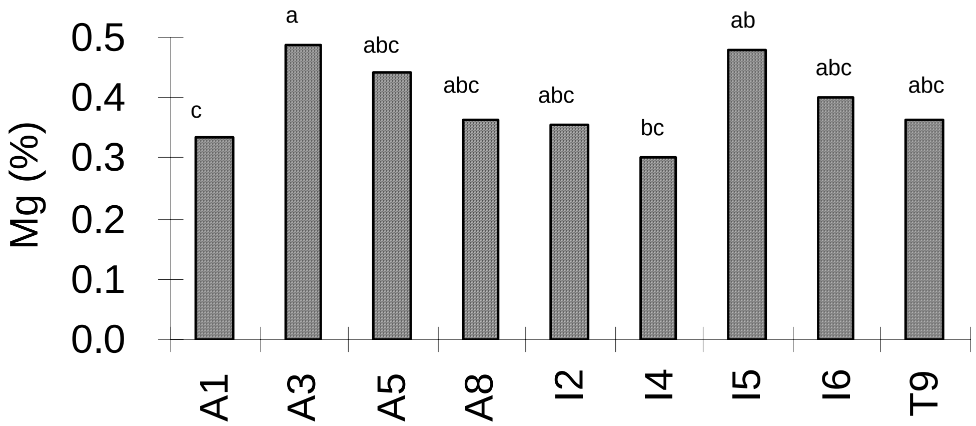


Table 1. - Significance of the effect of rootstock on the foliar mineral content of cv. Bianca pistachio trees

	1993	1994	1995	1996
N - Nitrogen	n.s.	n.s.	n.s.	n.s.
K - Potassium	*	*	n.s.	n.s.
P - Phosphorus	n.s.	n.s.	n.s.	n.s.
Ca - Calcium	n.s.	*	n.s.	n.s.
Mg - Magnesium	*	*	*	n.s.
Mn - Manganese	n.s.	n.s.	n.s.	-
Fe - Iron	n.s.	n.s.	n.s.	n.s.
Zn - Zinc	n.s.	n.s.	n.s.	-
B - Boron	n.s.	*	n.s.	-
Cu - Copper	*	n.s.	n.s.	-

***** = significant - Tukey's HSD Test ($P \leq 0.05$).
n.s**.** = not significant
- = data not available

The foliar analyses from Bianca showed no particular mineral deficiencies; the concentrations of nutrients in Bianca leaves were generally in the normal range (as suggested by Brown, 1995), except for Mg and B, which were consistently below or approaching the critical values. Nevertheless, there were no symptoms of nutrient deficiency throughout the experimental period. Conversely, the concentrations of P, Zn and Cu often exceeded the optimum, although the last two were very variable between trees. There was no general effect of rootstock on the uptake of macro- and micronutrients, as determined by Bianca leaf analysis. There were no significant differences in N, P, Fe, Mn and Zn, with mean values of 2.15%, 0.25% and 137, 29.1 and 82.6 ppm, respectively. The effect of rootstock was not significant in 1996, whereas in 1995 it was for Mg (only), in 1994 for Mg, Ca, K and B, and in 1993 for Mg, K and Cu (Table 1). Consequently, only significant differences are shown in Figs 2-9. In 1993 and 1994, clone A3 was the least efficient for K (Figs 2 and 3) and the most efficient for Mg (Figs 4-6). In contrast, Terebinth generally had the best absorption efficiency for K but was less efficient than the others for Mg. The lowest B content was found in Bianca trees on I5 and the highest on A5 (Fig. 7). In 1993 only, A8 was the most efficient for Cu utilization (Fig. 8) and in 1994, trees on I6 had the best uptake for Ca (Fig. 9). Finally, there was an antagonistic effect between K and Mg, with a highly significant negative correlation ($P \leq 0.01$, $r = -0.669$) between these elements in the results from 1993-1994 (Fig. 10).

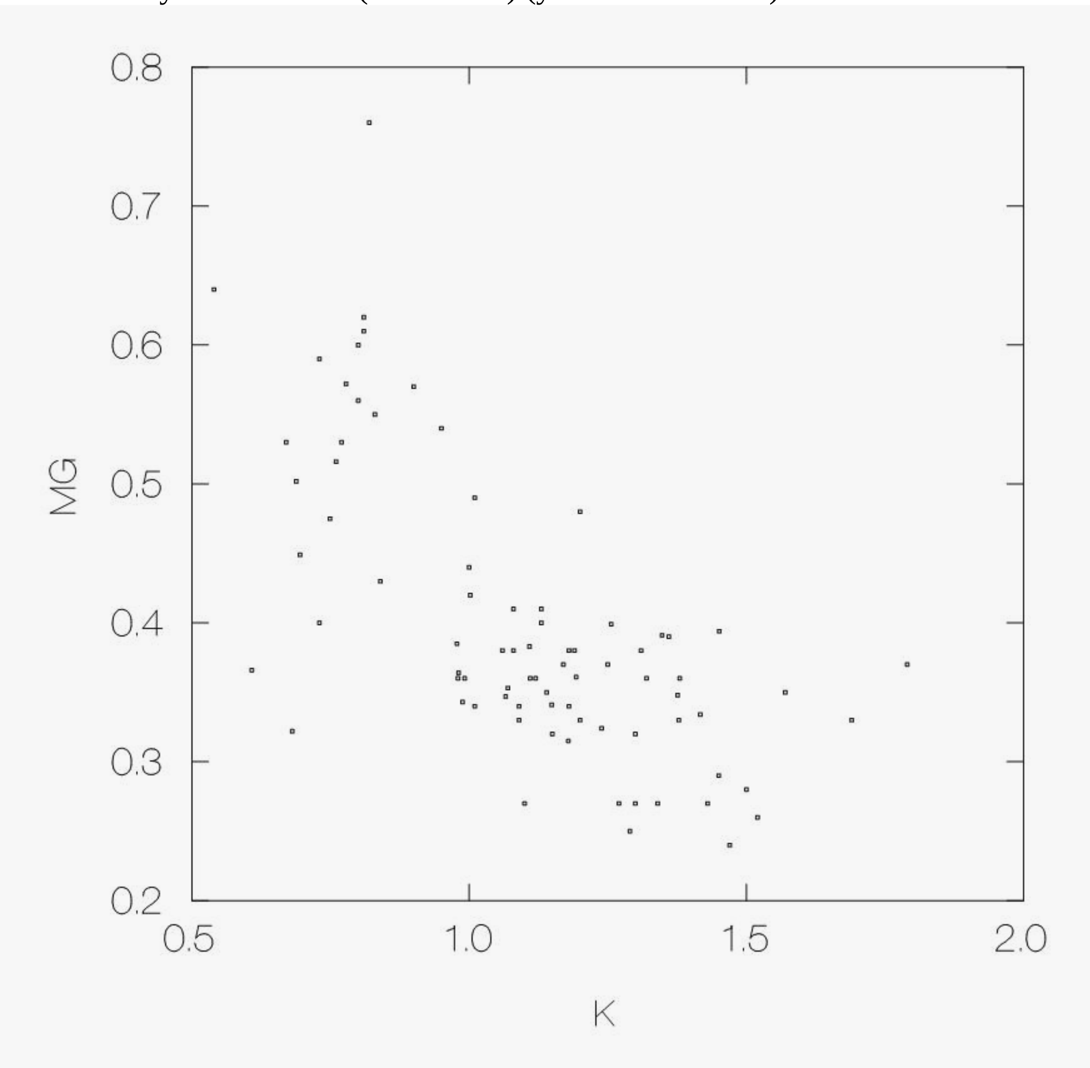
4. Discussion and conclusion

The yearly variation in TCSA showed that trees on I2 and I6 had a better initial growth rate than trees on the other tested rootstocks. This confirms previous nursery observations indicating that I2 and I6 provide budded plants more quickly than do other rootstocks (Caruso et al., 1990). Furthermore, this faster growth has been coupled in previous trials with early nut production, using several Italian and other scion cultivars (Barone et al., 1996). Nevertheless, as the orchard matures, differences in tree growth rates tend to decrease, as reported for other rootstock trials (Joley, 1969; Ferguson et al., 1995). In our conditions, this decrease can be attributed partly to the counterbalancing effect of summer pruning.

Although there were no particular mineral deficiencies, the results of foliar mineral analyses showed that some elements were below critical values, especially Mg and B. There were relatively small differences among the tested pistachio rootstocks in their ability to accumulate nutrients from the soil. Furthermore, the nutritional efficiency of a particular rootstock, if any, was not constant during the 4-year period, because the yearly fluctuation in mineral concentration was high. Overall, the I clones were less efficient than the A clones for boron uptake, confirming the findings of nutrient studies in California (Brown et al., 1994). On the contrary, the Terebinth, generally recognized to be the most efficient for Zn and Cu absorption (Brown and Ferguson, 1991), was not so in the present trial, except for K uptake. Trees on A3 and I5 seemed to be deficient in K in at least 2 of the 4 years, but these two rootstocks were the most efficient in Mg uptake.

The significant negative correlation between K and Mg suggests an antagonistic effect in the uptake of these two elements. Such an antagonism is well documented for fruit trees and crops other than pistachio.

Figure 4. The relationship between leaf potassium and magnesium contents as influenced by the rootstock (1993-1994) (y=0.689 – 0.236X).



In the apple leaf, Mg level decreased as the K level increased (Cassagnes et al., 1984); in banana, the K:Mg antagonism was reported stronger than that for K:Ca (Lahav, 1973); in citrus (Marchal et al., 1974) the Cleopatra mandarin rootstock strongly favored Mg uptake, with marked antagonism to K. The K:Mg antagonism was also reported for peach (Lalatta, 1986), vine (Bucher, 1978), blackcurrant (Sako and Laurinen, 1979) and tomato (Kolota and Orlowski, 1984). For pistachio cv. Aegina, Procopiu and Wallace (1978) reported the possible involvement of a nutritional disorder, i.e. a Mg-induced K deficiency, in determining severe leaf-scorch symptoms. We found no K deficiency in Bianca leaves, but Mg levels were lower than the critical value, although there is uncertainty about the assessment of the critical level of this nutrient (Brown, 1995). Brown and Ferguson (1991), studying the effect of pistachio rootstocks on the nutrition of the fruiting tree, reported large differences in the ability of the rootstock to supply Zn, Ca, K and Mg to the scion, but they reported no Mg deficiency symptoms even in the less efficient rootstocks.

However, as both K and Mg generally play a key role in fruit tree physiology, the observed antagonism between these elements in pistachio (and their ratio) deserves further investigation, especially where fertilizer application is concerned. Indeed, the possibility that K fertilizers depress Mg uptake (and vice versa) should be considered, particularly in areas where Mg (or K) deficiency is documented (Oberly and Boynton, 1966). Furthermore, Mg forms a major component of the total annual nutrient removal in fruit and leaf litter. Brown and co-workers (1995) reported a total of 39 kg/ha Mg removed by fruits and abscissed leaves in mature pistachio trees, more than double that of P (18 kg/ha).

Finally, as there is strong evidence that the foliar mineral content of the scion cultivar in pistachio is influenced primarily by crop load (Crescimanno et al., 1987; Uriu and Crane, 1977), a full fruit load must be present to ascertain the effect of the tested rootstock on the nutritional status of Bianca.

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