# MANIPULATION OF THE VEGETATIVE AND REPRODUCTIVE CYCLE OF PISTACHIO (*PISTACIA VERA* L.)

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**SUMMARY** - A study on the effects of Hydrogen-Cyanamide (Dormex®) and urea treatments onto vegetative and reproductive Pistachio (*Pistacia vera* L.) cycle was carried out on bearing and non-bearing 15 year-old trees of cv Bianca grafted onto *P. terebinthus*, in a commercial Pistachio orchard located at Caltanissetta (Sicily). The aim of the study, was to extend and improve leaf functionality by anticipating time of bud break and by sustaining leaf nitrogen level. On March 2002 and February 2003 vegetative terminal dormant buds were sprayed with 3% and 4% solution of Hydrogen-Cyanamide (Dormex®), respectively. Foliar applications of urea (0.25%) were executed early in the summer. The timing of budbreak was not affected by the Dormex® treatment in 2002, however shoot growing rate, number of nodes and leaf area per shoot were significantly higher on the shoots treated with Hydrogen-Cyanamid in comparison with the control. Nitrogen foliar applications increased leaf $CO_2$ assimilation rate and shell dehiscence and decreased the percentage of blank nuts and fruit abnormalities.

**Key words:** *Pistacia vera*, hydrogen-cyanamide, urea, alternate bearing.

***RESUME -*** *Une étude de l'éffet du Cyanamide d'hydrogène (Dormex®) et de l'urée au cours du cycle végétatif et reproductif du Pistachier (Pistacia vera L.) a été conduit chez des arbres charges et décharges agés de 15 ans. Le cultivar est le Bianca greffé sur P. terebinthus dans un champ commercial de Pistachier localisé à Caltanissetta (Sicily). L'objectif de l'étude c'est de élonger et améliorer le fonctionnement de la feuille par l'anticipation du débourrement des bourgeons et de maintenir le taux d'azote foliaire. En mars 2002 et février 2003, les boutons terminaux, végétatifs dormants ont été pulvérisé par une solution de Dormex® respectivement à 3 % et 4 %. L'application foliaire de l'urée à la dose de 0,25% n'a été exécuté qu'au début de l'été. En 2002, la date de débourrement des boutons n'a été pas affecté par le traitement avec Dormex®, le taux de croissance du rameau, le nombre de neuds et la surface foliaire par rameau ont été hautements significatifs chez les rameaux traités par le Dormex® comparé au traitement temoin. Suite à l'application foliaire de l'azote, les taux d'assimilation foliaire en* $CO_2$ *et de déhiscence de fruits ont augmenté alors que le pourcentage de fruits stériles et anormales à diminué*.

***Mots clés:*** *Pistacia vera*, *Cyanamide d'hydrogène, urée, altèrnance de production*.

## INTRODUCTION

Alternate bearing in pistachio has been related to a resource competition between reproductive and vegetative organs (Crane and Nelson, 1972; Crane et al., 1973). Although such hypothesis needs more investigation, it is clear that sink-source competition plays an important role on summer inflorescence bud abscission phenomenon. Carbohydrate reserves have a key role in supporting early season growth and in buffering the surpluses and shortage of carbon (Wardlaw, 1990; Weinbaum et al., 1994b).

In pistachio, vegetative and apical inflorescence buds swells at almost the same time in late March. Shoot extension begins generally in April and terminates in the middle part of May while concurrent inflorescence growth and endocarp (but not seed) enlargement occurs (Caruso et al., 1987). Early in the season carbohydrate and nitrogen demand for vegetative and reproductive growth is met by redistribution from storage pools in perennial tree organs (Picchioni et al., 1997).

Takeda and co-workers (1980) strongly supported the idea that fruits are the strongest sinks and that most of the photosynthates are accumulated in developing fruits. Caruso et al., (1993) reported significant effects between crop load adjustment and both the percentage of inflorescence buds retention and shoot growth. More recently, on trees in a natural bearing/non bearing cycle in comparison with manually debudded trees, differences in starch content on leaves, shoots and one-year old wood with highest level of starch on debudded trees organs, have been reported (Marra et al., 1998).

In pistachio, due to the simultaneous vegetative and flower budbreak, the competitions for nutrients arise very early in the season. However, only in late July, when active embryo growth occurs, inflorescence bud drop became evident (Caruso et al., 1995).

Moreover, later in the season, the strong draw of nutrient pools by the fruits, is evident when the leaf of heavy cropped trees starts to loss its functionality and abscise earlier than the leaves of non-bearing trees (Marra et al., 1998). Picchioni and co-workers (1997) reported a decline in leaf N concentration during seed fill in pistachio and walnut (Weinbaum et al., 1994a), whereas leaf nitrogen content remains stable during fruit maturation in non alternate bearing species such as almond (Weinbaum et al., 1986).

Lovatt and co-workers (2002) with foliar application of low-biuret urea combined with 6-benzyladenine obtained to increase bud retention and cumulative yield in a five-year period.

Hydrogen cyanamide (Dormex®) has been successfully tested for anticipate bud break on various fruit crop species (Di Lorenzo et al., 1991; Cartabellotta et al., 1994; Vizzotto et al., 1996a,b; Inglese et al., 1998; McPherson et al., 2001; Williamson et al., 2001). To date, research on $H_2CN_2$ in pistachio has been limited (Küden et al., 1995).

Our objective, as part of a research activity on alternate bearing in Pistachio, was to try to manipulate the vegetative and reproductive pistachio cycle in order to extend and improve leaf functionality, thus hypothetically improving the carbon budget available to the tree. This aim was pursued by the applications of Dormex® for anticipating time of bud break and of low-biuret urea for sustaining leaf nitrogen level.

## MATERIALS AND METHODS

Trials were carried out on fifteen bearing and ten non-bearing 15 year-old Pistachio trees of cv. Bianca grafted onto *P. terebinthus*, spaced 5 per 6 m apart, in a commercial orchard located at Caltanissetta (Sicily - 37°26'02" N, 370 m a.s.l.).

On March 2002 and February 2003, ten trees (five bearing and five non-bearing) were treated with 3% and 4% solution of Hydrogen-Cyanamide (Dormex®), respectively. Dormex®, watered down with distilled water, was manually brushed (up to dripping) onto each vegetative terminal dormant bud. Foliar application of 12 L per tree of a solution of 0,25% urea (low-biuret) was applied on five bearing trees in early June and again in early July 2002. Finally, five bearing trees (B) and five non-bearing trees (NB) were left as control.

In all treatments, four branches per tree were tagged and used for periodic determination of timing of bud break, shoot length and basal diameter, inflorescence bud drop intensity, number of nodes per shoot, number of leaves and leaflets per shoot.

In 2003 one untagged branchlet per tree and per treatment was periodically sampled, starting from May, and brought to the lab for destructive analyses. These samples were used to replicate the above mentioned measurements, and to determine the leaflet area and the dry matter content of each part of the branchlet.

From July to October 2002, photosynthetic activity and leaf chlorophyll content, on fully expanded terminal leaflets onto bearing and non-bearing shoots of each thesis, were periodically measured.

Photosynthesis measurements were performed on cloudless days (PPFD >1600 μmol $m^{-2}$ $s^{-1}$) with a portable infrared gas analyzer (Ciras-1 by PP-Systems®).

Yield per tree was assessed at harvest time (29/08/02). Finally, the tagged branches and fruit samples for each treatment were used in the lab to determine the dry matter content of each part and to measure fruit fresh and dry weight, length, width, thickness, shell dehiscence and blank fruit percentage.

All the data collected were submitted to ANOVA and differences analysed by Tukey's HSD test ($P \leq 0.05$).

## RESULTS AND DISCUSSION

The average phenological status of vegetative buds in bearing and non-bearing trees submitted to 2002 Dormex® treatment is reported in Fig. 1.

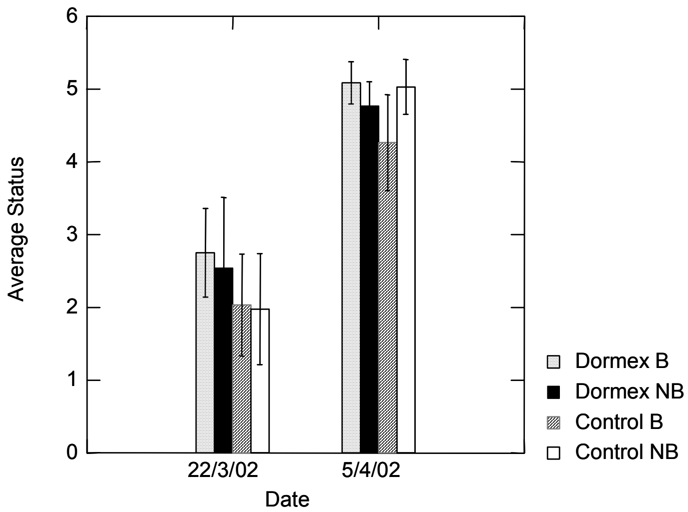


Fig. 1. Average status of vegetative buds in bearing (B) and non-bearing (NB) "Bianca" pistachio trees (2002).

Time of vegetative bud break was not significantly affected by the treatment both on bearing and non bearing trees. Nevertheless, Dormex® treatment revealed to be able to enhance shoot growth (Fig. 2).

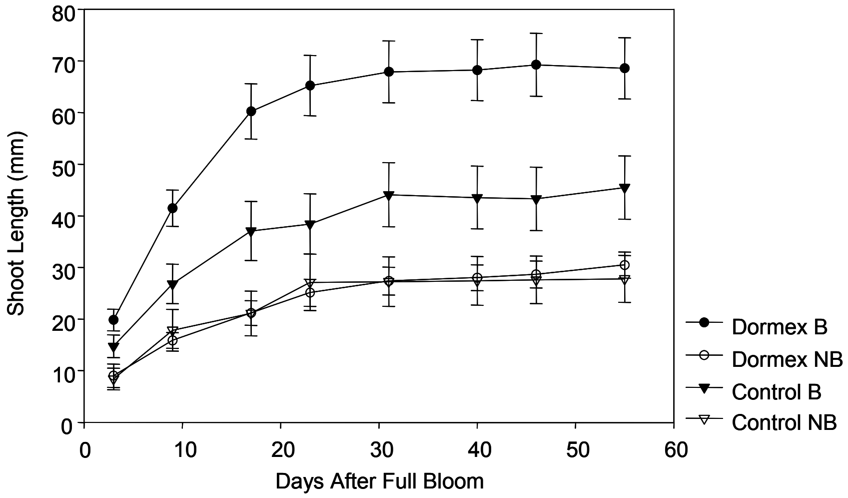


Fig. 2. Shoot growth of bearing (B) and non-bearing (NB) "Bianca" pistachio trees (2002).

This effect was already evident soon after bud break. At the end of the observation period shoot length of the control resulted to be about 60% only that of the trees submitted to Dormex® treatment in B trees and about 70% in NB trees. This result was mainly due to the differences observed in the length of the internodes and, partially, in the number of nodes (Tab. 1).

Table 1. Average leaf area; leaf area, number of nodes and length of internodes per shoot in bearing (B) and non-bearing (NB) "Bianca" pistachio trees.

| Treatment | Average Leaf Area* ($cm^2$) | Leaf Area per Shoot at Harvest ($cm^2$) | Number of Nodes 55 DAFB* | Length of Internodes (mm) 55 DAFB* |
|---|---|---|---|---|
| Dormex B | 127.4 ± 3.9 | 666.2 ± 33.5 | 6.85 ± 0.21 | 10.0 ± 0.87 |
| Control B | 118.5 ± 3,9 | 559.5 ± 33.0 | 5.80 ± 0.21 | 7.20 ± 0.87 |
| Dormex NB | 140.8 ± 3.2 | 826.3 ± 41.5 | 7.05 ± 0.28 | 3.96 ± 0.23 |
| Control NB | 124.4 ± 3.2 | 705.4 ± 41.5 | 6.30 ± 0.28 | 3.16 ± 0.23 |

* Measured at the end of shoot elongation

Also total leaf area per shoot was positively affected by the treatment. As a whole, it is worthwhile to observe that leaf area per shoot confirmed to be negatively affected by fruit load and that shoot length is related to the bearing status of the previous year (Barone et al., 1995; Marra et al., 1998; Weinbaum et al., 1994b).
The time course of average phenological stages of the vegetative buds in 2003 trial is reported in Fig. 3. An earlier and more intense development of the vegetative buds was observed after Dormex® treatment in comparison to the control. A partial recover by the control was evident only by 40 days after Dormex® treatment.

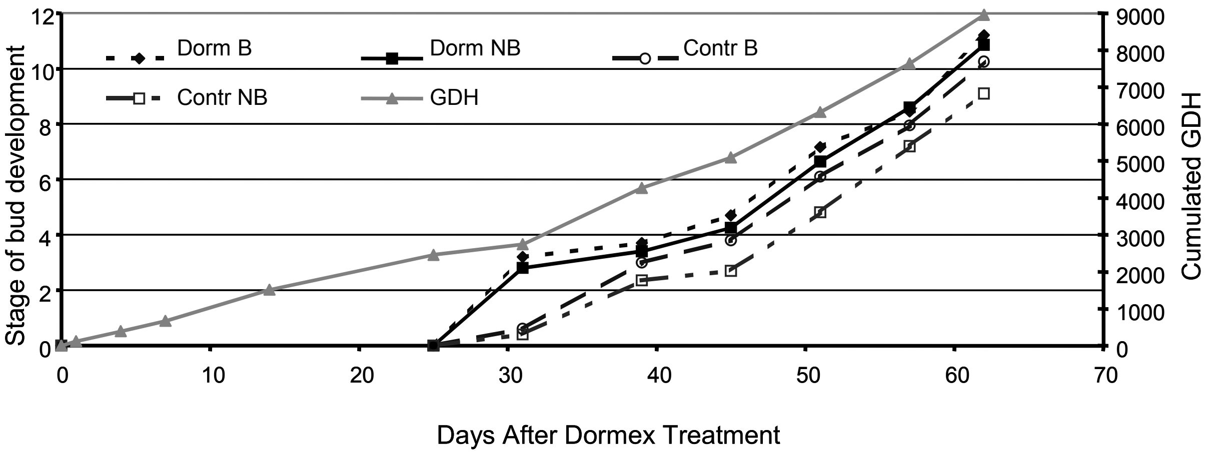


Fig. 3. Average Stage of vegetative buds in bearing (B) and non-bearing (NB) "Bianca" pistachio trees, related to cumulated Growing Degree Hours (GDH) from the date of Dormex® treatment (25/02/2003).

Dormex® seemed to be able to enhance the effect of temperature. In fact, while evolution of vegetative buds in control trees followed the GDH pattern, in the case of Dormex® the buds reacted in a more pronounced way to same amount of heat available in the environment. Unfortunately, data about chilling completion are not available in this study but it could be speculated about an earlier rest completion in Dormex® trees than the control, as already observed for other fruit species (Dozier et al., 1990; Erez, 1995; Miranda Blanco et al., 1997).
Again, in 2003 observations shoot growth was positively affected by the Dormex® treatment (Fig. 4) A similar effect was observed by Fayek and co-workers (1995) on apple.

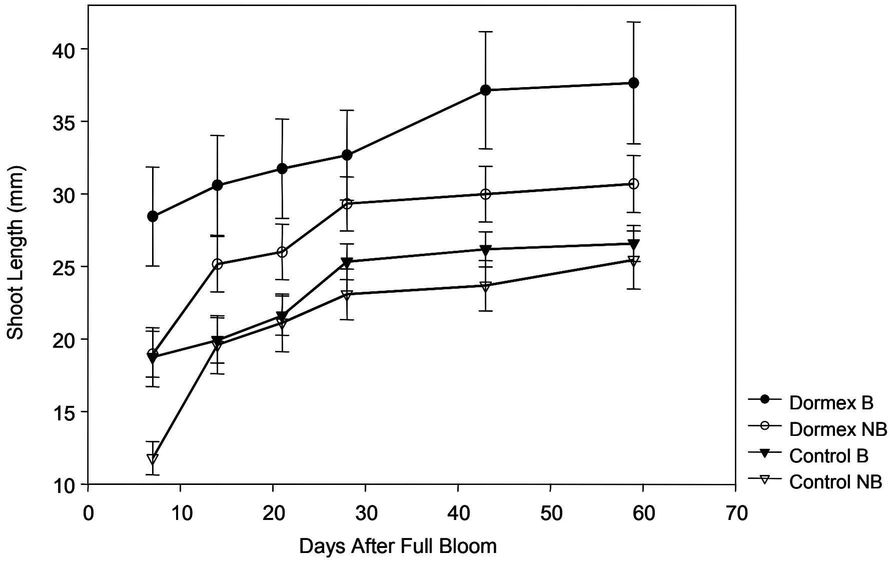


Fig. 4. Shoot Growth in bearing (B) and non-bearing (NB) “Bianca” pistachio trees (2003).

Data regarding number of leaves per shoot and leaf area per shoot measured at 59 days a.f.b. confirmed the effect already observed in 2002 trials (Tab. 2).

Table 2. Number of leaves per shoot and leaf area per shoot 59 days a.f.b. in bearing (B) and non-bearing (NB) “Bianca” pistachio trees (2003).

| Treatment | N. of Leaves per Shoot 59 DAFB | Leaf Area per Shoot ($cm^2$) 59 DAFB |
|---|---|---|
| Dormex B | 6.35 ± 0.20 | 1099.55 ± 69.73 |
| Control B | 5.95 ± 0.17 | 904.23 ± 71.14 |
| Dormex NB | 6.79 ± 0.14 | 1325.87 ± 63.28 |
| Control NB | 6.32 ± 0.17 | 909.56 ± 52.92 |

As far as the effect of urea application is concerned, in 2002 trials, maximum assimilation rate determined on fully expanded terminal leaflets showed to differ significantly onto bearing shoots of urea treated trees in comparison to the control. Soon after harvest, in fact, photosynthetic activity was enhanced by foliar urea applications, whereas it remained almost steady in the control (Fig.5). As a consequence, water use efficiency of the leaves after harvest time was considerably higher in trees submitted to urea than the control (Fig.6).

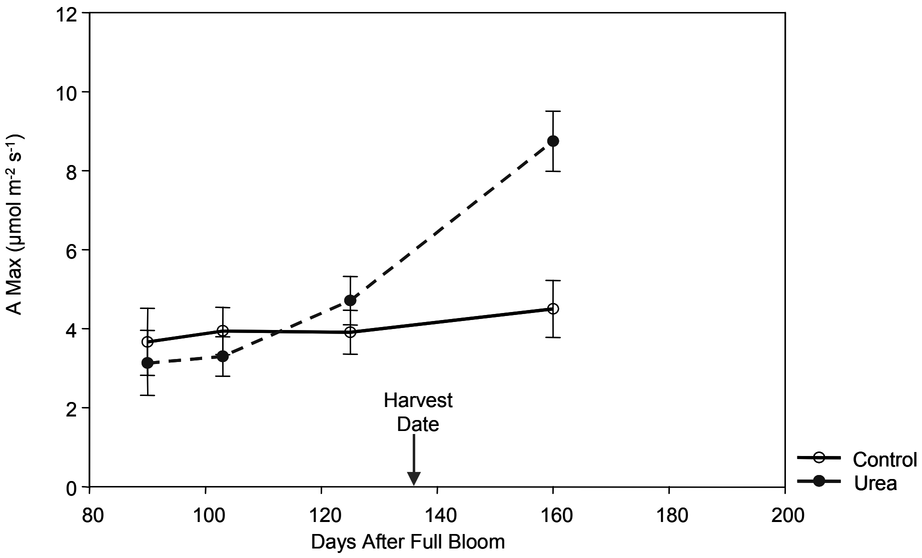


Fig. 5. Maximum $CO_2$ net assimilation rate on bearing “Bianca” pistachio trees (2002).

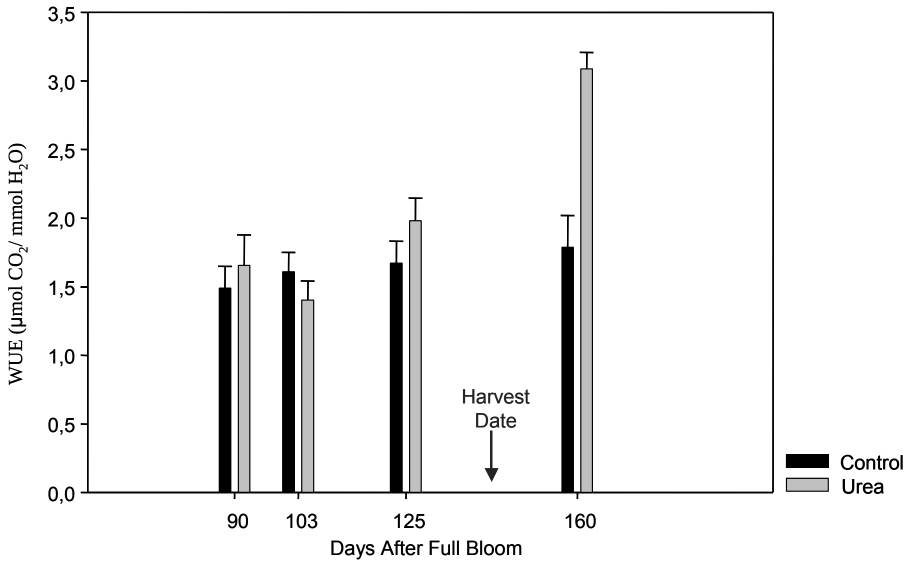


Fig. 6. Water Use Efficiency on bearing “Bianca” pistachio trees (2002).

Table 3 summarizes the results of the applied treatments onto 2002 yield and nut characteristics. Dormex®, in spite of the effects showed on vegetative growth, significantly affect only few of the considered variables. On the contrary, urea improved qualitative traits such as split (two-fold of increase) and blank percentages (three-fold of decrease) together with nut and kernel weights. No effect was observed as far as inflorescence bud drop or yield per tree are concerned.
The conspicuous, positive effects onto split values obtained by urea applications, although the mechanism of nut shell splitting is unknown (Freeman and Ferguson, 1995), may be related to the observed parallel improvement of the kernel weight. The small incidence of blank phenomenon, that is recognized to be mainly linked to seed abortion (Crane, 1975), is perhaps to be related to a better fulfilment of developing fruits demand for resources.

Table 3. Yield per tree, shell dehiscence, nut and kernel traits, percentage of blank fruits, percentage of inflorescence bud drop, at harvest (29/08/02), in bearing "Bianca" pistachio trees.

| Treatment | Yield* (kg tree$^{-1}$) | Split (%) | Nut Length (mm) | Nut Width (mm) | Nut Fresh Weight (g) | Nut Dry Weight (g) | Kernel Dry Weight (g) | Blank Fruit (%) | Inf. Bud Drop (%) |
|---|---|---|---|---|---|---|---|---|---|
| Urea | 12.2 n.s. | 71a | 19.7 n.s. | 11.1 n.s. | 1.40a | 0.97a | 0.45a | 5a | 73.9 n.s |
| Dormex | 9.8 | 35b | 19.5 | 11.2 | 1.33a | 0.93b | 0.43b | 14b | 78.9 |
| Control | 12.3 | 32b | 19.8 | 11.3 | 1.27b | 0.86b | 0.41c | 15b | 68.2 |

* Before dehulling.
n.s. = non significant
Value with the same letter within columns are not significantly different, $P \leq 5$.

## CONCLUSIONS

Dormex® and Urea applications, proved to be able to manipulate in various ways vegetative responses by Pistachio cv Bianca trees. In fact, Dormex® treatment enhanced vegetative activity and, specially when it was applied early at 4% concentration, it allowed both to anticipate vegetative bud break and to increase shoot growth and total leaf area per shoot. Although in this study we do not have sufficient data to develop a complete C budget analysis, it is likely that such modifications can be beneficial for improving C availability for the tree, specially when considering the high demand for carbohydrates in bearing trees (Weinbaum et al., 1994b; Nzima et al., 1997; Marra et al., 1998).
Nitrogen supplied by two consecutive urea foliar applications, by positively influencing max assimilation rate, water use efficiency and nut characteristics, showed to be a powerful tool to improve leaf functionality late in the season and therefore allowing to meet the higher N demand in on year trees (Durzan, 1996; Picchioni et al., 1997; Weinbaum et al., 1994b).

It should be pointed out that the above mentioned results may positively affect the amount of resources available for the trees, thus potentially influencing tree performance in subsequent years.
Nonetheless, in 2002 trials (data from 2003 trials are still ongoing) we did not obtain any effect on the degree of inflorescence bud retention, i.e. no impact on the alternate-bearing cycle.

However, long term beneficial effects of the repetition of such interventions cannot be excluded since improvements of leaf area and leaf functionality have been already partially achieved. These results can be profitable to fine-tune nutrients use and management in pistachio orchards. However, other cultural practices such as irrigation should be taken into account in an overall perspective of obtaining more constant and profitable tree performances.

Finally, in order to better evaluate the carryover effects of manipulation techniques onto vegetative and reproductive behaviour of pistachio trees, further studies aiming at the definition of a complete carbon and nitrogen balance of the trees in a pluriannual basis are needed.

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