EFFECT OF N-NUTRITION AND IRRIGATION WATER ON CAROB-TREE *(CERATONIA SILIQUA* L.). GROWTH RESPONSES

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RESUMEN

EFFECTO DE LA NUTRICION Y AGUA DE IRRIGACION EN ALGARROBO *(CERATONIA SILIQUA* L.). RESPUESTAS DEL CRECIMIENTO

Este trabajo presenta resultados preliminares de un trabajo más amplio con el objetivo de clarificar la importancia relativa del agua y del nitrógeno como factores capaces de controlar la producción primaria de *Ceratonia siliqua* L. Arboles adultos de algarrobo han sido sometidos a tres diferentes niveles de irrigación, basados en los valores diarios de evaporación de una clase A –respectivamente 100 %, 50 % y 0 %. Para cada uno de ellos fueron aplicados dos niveles de nitrógeno –21 y 63 Kg ha^{-1}. Diferencias significativas fueron observadas en los aumentos en comprimido de los ramos y número de hojas al final del período de crecimiento, independientemente de las diferencias no significativas de los potenciales hídricos de la hoja al medio día, para todos los tratamientos. Estos resultados serán discutidos teniendo presente diferentes hipótesis. Los árboles más fertilizados presentaran un ligero aumento en el contenido en nitrógeno. Por otro lado, a pesar de los diferentes niveles de nitrógeno aplicados, es posible verificar un aumento del "N-pool" en los árboles, probablemente importante como mecanismo para aumentar la eficacia del uso del nitrógeno en condiciones de baja concentración de nutrientes en el suelo. Los resultados muestran que tanto el agua como el nitrógeno tienen un efecto positivo no crecimiento vegetativo del algarrobo.

Palabras clave: Algarrobo. Agua. *Ceratonia siliqua.* Fenología. Nitrógeno. Potencial hídrico de la hoja.

SUMMARY

This paper presents preliminary results of a work which aim was to clarify the relative importance of water and nitrogen as factors controlling primary production of *Ceratonia siliqua* L. Carob mature trees were submitted to three different irrigation levels based on daily Epan values - 100 %, 50 % and 0 %. For each water level two nitrogen amounts were applied - 21 and 63 Kg ha^{-1}. Significant differences were observed in branch length increment at the end of the growth season. The short-term responses to the water and nitrogen application improve vegetative growth independently of the insignificant differences in leaf water potential at midday, for all treatments. These results are discussed according to different hypothesis. The high fertilized trees presented a slight increase in leaf nitrogen content. Moreover it is possible to observe a "N-pool" due to translocation from senescent leaves, presumably important as a mechanism to increase nitrogen use efficiency under low nutrient availability. The results obtained show that both water and nitrogen have a positive effect on the vegetative growth of carob trees.

Key words: Carob-tree. ***Ceratonia siliqua.*** Leaf water potential. Nitrogen. Phenology. Water.

INTRODUCTION

Due to the scarcity of information about the factors which relate nutrition and available water in established carob *(Ceratonia siliqua* L.) tree orchards, it is not possible to determine or conclude the role of each one and their interactions on fruit production. Actually there is an important lack in the knowledge of physiological responses to limited supplies of water and nutrients on carob mature trees. The time of the year at which nitrogenous fertilizers are most efficiently applied is also a subject of debate.

Recent investigations have utilized carob seedlings in hydroponic culture to study physiological nitrogen nutrition (Martins-Louçao, 1985), nitrogen assimilation and uptake (Cruz *et al.*, 1987). Other investigators have reported data on the temperature and CO_2 concentration effects in carbon assimilation (Nunes and Correia, 1980; Nunes and Linskens, 1980) and the physiological and morphological adaptations to different light intensities (Catarino *et al.*, 1981). Some of the mechanisms associated to drought adaptation in young plants (Correia, 1988; Nunes *et al.*, 1989) and in trees on natural habitats (Lo Gullo and Salleo, 1988; Salleo and Lo Gullo, 1989) were also studied. More recently Correia and Martins-Louçao (1990) reported preliminary results on the vegetative growth and leaf nutrients of drip-irrigated young carob orchards.

All of these works emphasize the importance of morphophysiological adaptations of carob plants to seasonal drought and N-limited edaphic conditions, pointing ammonium-nitrate as the best nitrogen form for carob growth (Martins-Louçao and Duarte, 1987). However improved growth and crop production must be achieved to make possible the profitable use of existing carob plantations as well as the establishment of new, modern carob orchards. So, it is important to develop modern agro-techniques for the efficient use of combined irrigation and fertilization to optimize productivity of carob trees.

The purpose of the present study was to evaluate the relationship between different nitrogen fertilization and irrigation schedules on growth and nutrient content in mature carob trees. Changes in some aspects of the water relations from the beginning to the end of irrigation period were also observed.

MATERIALS AND METHODS

Experimental site

The orchard was located in the "Serra" region of Algarve, Portugal, approximately 6 Km of the Atlantic Ocean (37° 13' N, 7° 28' W). A sandy loam soil is established on a schist bedrock, characterized as Lhoq (FAO/UNESCO, 1985, in: Kopp *et al.*, 1989).

The climate is Mediterranean with an a annual rainfall 500-600 mm and PET (Penmam method) between 1150-1200 mm per year. The class A pan evaporation and precipitation at the experimental site are indicated in Table 1.

The orchard presented 30-40 year-old trees and was established in 12 x 12 m spacing. The hill slope was less than 10 %.

The field experiment consisted of three water levels and two nitrogen fertilizer amounts in a total of six treatments. Each one had 12 trees, replicated three times in a randomized complete block design. In each replicate, 2 trees were selected for phenology and water parameter measurements.

Irrigation and fertilization

The irrigation was based on the class A pan evaporation (Table 1). The water levels were 100 %, 50 % and 0 % Epan. The water was applied daily through the dry season between June and August. The irrigation amount applied is indicated on Table 2. For each water level, two fertilizer amounts were tested: 1.5 Kg Tree^{-1} (103.5 Kg ha^{-1}) and 4.5 Kg Tree^{-1} (310.5 Kg ha^{-1}). The treatments were:

1.5 Kg + 0 % Epan-Treatment 1.5/0.

1.5 Kg + 50 % Epan-Treatment 1.5/50.

1.5 Kg + 100 % Epan-Treatment 1.5/100.

TABLE 1

Classe A pan evaporation and rainfall in the observation period.

Observation period	P (mm)	Epan (mm)	x day^{-1} (mm)	Max (mm day^{-1})	Min (mm day^{-1})
May (21 days).	0	154.46	7.36	9.40	8.72
June (27 days)	31.5	234.82	8.69	14.94	6.00
July (28 days).	0	255.64	11.11	13.00	7.22
August (20 days).	0	185.18	10.89	13.00	6.50
TOTAL (96 days)	31.5				

4.5 Kg + 0 % Epan-Treatment 4.5/0.

4.5 Kg + 50 % Epan-Treatment 4.5/50.

4.5 Kg + 100 % Epan-Treatment 4.5/100.

On the 0 % water level the fertilizer was applied two months earlier in order to ensure the dilution through the last rainfall. For the other levels the fertilizer was applied at the beginning of the irrigation period.

The fertilizer had 20.5 % of nitrogen with equal parts of nitrate and ammonium and calcium in a proportion of 15 %. The applied nitrogen amount was, therefore, 21 Kg of N ha^{-1} for the 1.5 Kg of fertilizer and 63 Kg of N ha^{-1}, for the 4.5 Kg of fertilizer. The fertilizer was applied only once and spread all over the projected area of the canopy.

The irrigation consisted of a micro-sprinkler system, one per tree and close to the tree trunk, delivering 40 l h^{-1} in a wetting diameter of 3 m with a range of 360°. The electric conductivity of the water was 0.024 S m^{-1} with a pH of 7.7.

TABLE 2

Irrigation amount applied. Water losses during irrigation were not considered.

Water amounts applied by irrigation or rainfall (m^3 $tree^{-1}$)				
Treatments	June	July	August	TOTAL
0 %	0.27	0	0	0.27
50 %	0.32	0.43	1.15	1.90
100 %	0.36	0.86	2.02	3.24

Phenology

On the selected trees, 8 branches with a 100 cm branch length were marked on the canopy external side. Main branch length and leaf number were recorded at monthly intervals, from May to August 1991. At the harvest season fruit production was also recorded.

The relative growth rates (RGR) for each parameter were calculated for a week period with the formula:

$$RGR = (\text{Final value-initial value}).\ time^{-1}$$

Leaf water potential - LWP

In the same selected trees, LWP were determined (with a Scholander-type pressure chamber) in the 3rd - 5th pair of sunlight leaves taken from the south side of the canopy and on clear days. Pre-dawn and midday determinations were done between May and September during the irrigation and fertilization period. A filter paper was placed inside the pressure chamber in order to minimize leaf water evaporation. The leaves used for this determination were introduced in a plastic bag before cut.

Leaf nutrients

For each treatment, leaf material was dried at 80° for 24 h and subjected to conventional wet digestion before chemical analyses of macronutrients. N was determined according to Kjeldhal method, K by phlame photometry and P colorimatrically. Leaves were sampled mainly on the selected trees from May to November. In October, fresh leaf litter was also collected for each treatment.

The percentage of the nutrient pool annually retranslocated prior to leaf fall was calculated by the following equation:

100 × (maximum nutrient pool (g Kg^{-1} DW) - nutrientys in leaf fall (g Kg^{-1} DW) / Maximum nutrient pool (g Kg^{-1} DW).

Statistical analysis

Differences among treatments were compared by analysis of variance and covariance, using Snedecor F-test. The variations have been expressed as standard error.

RESULTS AND DISCUSSION

The number of leaves and branch increments are shown in Table 3 and 4, respectively. Variance analysis indicate similar responses for both parameters. In the first period (May/June), significant differences at 95 % level occurred between N-treatments. These results are probably related with the high investment of nitrogen required during the flush of vegetative growth from March to July (Cabrita and Martins-Loução, 1990). Moreover during this period the lowest soil nitrogen content was observed giving and indication of the intense N-uptake rate (Cabrita and Martins-Loução, 1990).

Using the June's increase as covariate, significant differences were observed in July, at 95 % level, between water treatments. However, at the end of the observation period (July/August) a significant interaction N × W was detected. This trend was verified after the establishment of irrigation shedule and support the growth response to the irrigation and fertilization application (Table 3 and 4).

Plotting the cumulative irrigation water versus relative growth rate for water and nitrogen levels, both parameters show similar behavior (Fig. 1 and 2). The highest slope is obtained for 4.5 Kg and 100 % in each case, indicating a W × N effect. Our data indicate that this interaction, during the summer drought period, may influence significantly the vegetative growth of carob mature trees.

TABLE 3

Average of leaf number increment ± standart error. Values at the end of the growth period (n = 48). F-test for water, nitrogen (N) and water x N interaction. (n.s.) not significant; (*) significant at 95 %.

Leaf number increment			
Treatments	May/June	June/July	July/aug
1.5 / 0	1.50 ± 0.3	0.54 ± 0.1	0.23 ± 0.0
1.5 / 50	1.42 ± 0.3	1.31 ± 0.2	2.10 ± 0.3
1.5 / 100	1.42 ± 0.3	2.35 ± 0.4	2.92 ± 0.3
4.5 / 0	2.60 ± 0.1	0.94 ± 0.1	0.06 ± 0.0
4.5 / 50	1.19 ± 0.4	1.20 ± 0.3	2.73 ± 0.3
4.5 / 100	1.70 ± 0.2	2.90 ± 0.3	4.08 ± 0.3
	F-test	F-test	F-test
Water	n. s.	*	*
N	*	n. s.	*
Water x N	n. s.	n. s.	*

TABLE 4

Average of branch length increment ± standard error. Values at end of the growth period (n =48). Details are the same as in table 4.

Branch length increment (cm)			
Treatments	May/June	June/July	July/Aug
1.5 / 0	1.06 ± 0.2	0.29 ± 0.0	0.10 ± 0.0
1.5 / 50	0.89 ± 0.2	0.79 ± 0.1	1.04 ± 0.2
1.5 / 100	1.06 ± 0.3	1.36 ± 0.2	2.30 ± 0.3
4.5 / 0	1.70 ± 0.4	0.55 ± 0.0	0.04 ± 0.0
4.5 / 50	1.09 ± 0.4	0.68 ± 0.1	1.48 ± 0.2
4.5 / 100	2.44 ± 0.3	1.95 ± 0.3	4.01 ± 0.5
	F-test	F-test	F-test
Water	n. s.	*	*
N	*	n. s.	*
Water x N	n. s.	n. s.	*

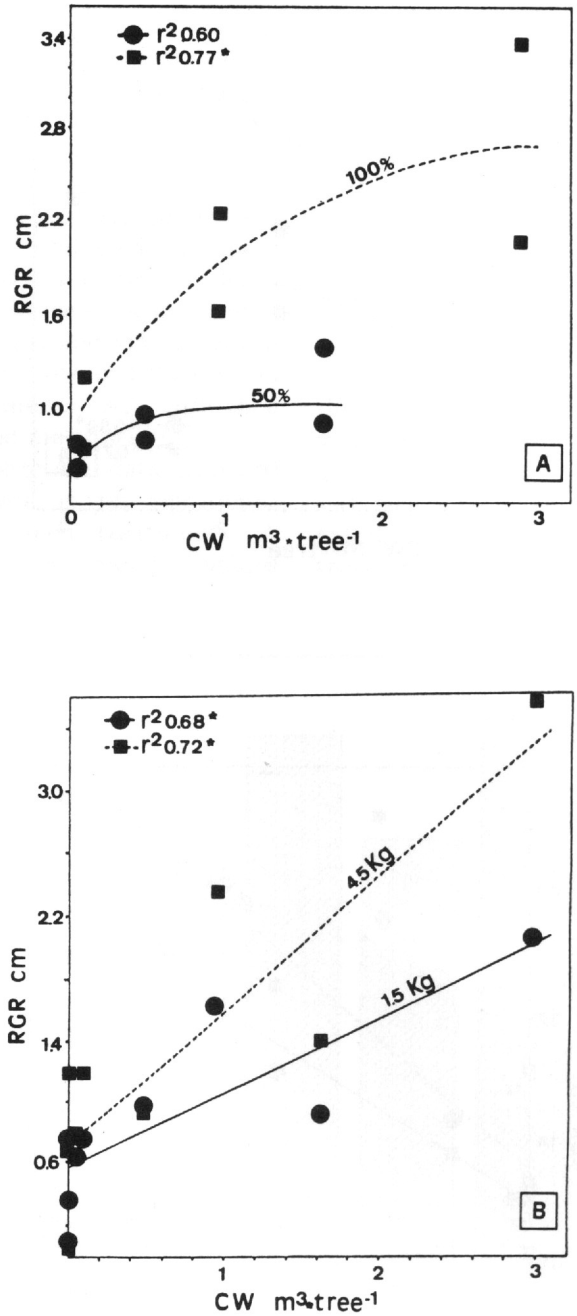

FIG. 1.–*Relation between cumulative irrigation water (CW) and relative growht rate (RGR) for branch length increment. (A) Regression for 50 % Epan (■) and 100 % Epan (●). (B) Regression for 1.5 Kg of fertilizer per tree (●) and 4.5 Kg (■). (*) Significant differences at 95 %.*

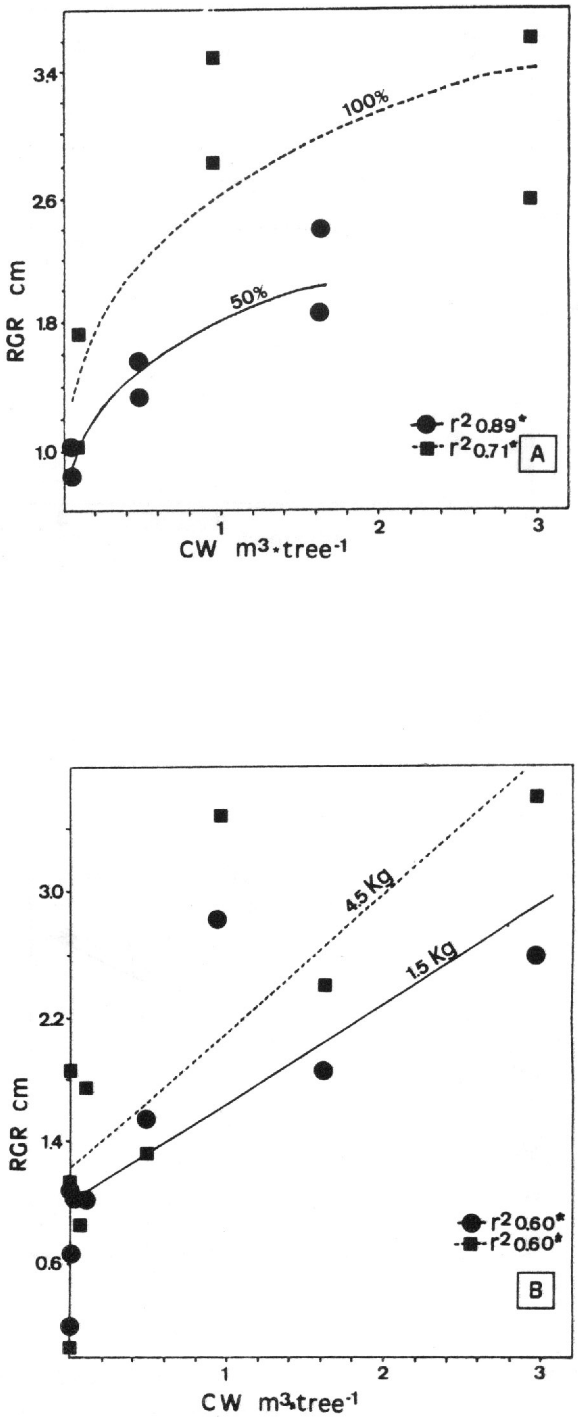

FIG. 2.–*Idem figure 1 for number of leaves.*

Fruit production (Fig. 3) was not clearly affected by the fertirrigation treatment. However it is important to notice that the treatment started on late Spring when fruit development was completely attained. Therefore, the effect of treatment was not manifestly reflected in these results (Fig. 3), as expected. Knowing the importance of water and N application on production, it would be interesting to see in future years if these treatments will influence fruit growth and maturation.

Leaf water potential data (Tabla 5) show that there is no significant differences between treatments. A substantial drop in "midday" values were observed between June and July. These results are probably related to the high evaporative conditions of the site (see Table 1) which triggers the osmotic adjustment of leaf tissue often occurring as a mechanism of acclimation to drought (Nunes *et al.*, 1989). The similarities of leaf water potential between treatments may also be correlated with the water spending strategy of this plant (Lo Gullo and Salleo, 1988) due to an high hydraulic conductivity (Salleo and Lo Gullo, 1989). These data are similar to those reported by Correia and Martins-Louçao (1990) in young drip-irrigated carob-trees and by Torrecillas *et al.* (1989)

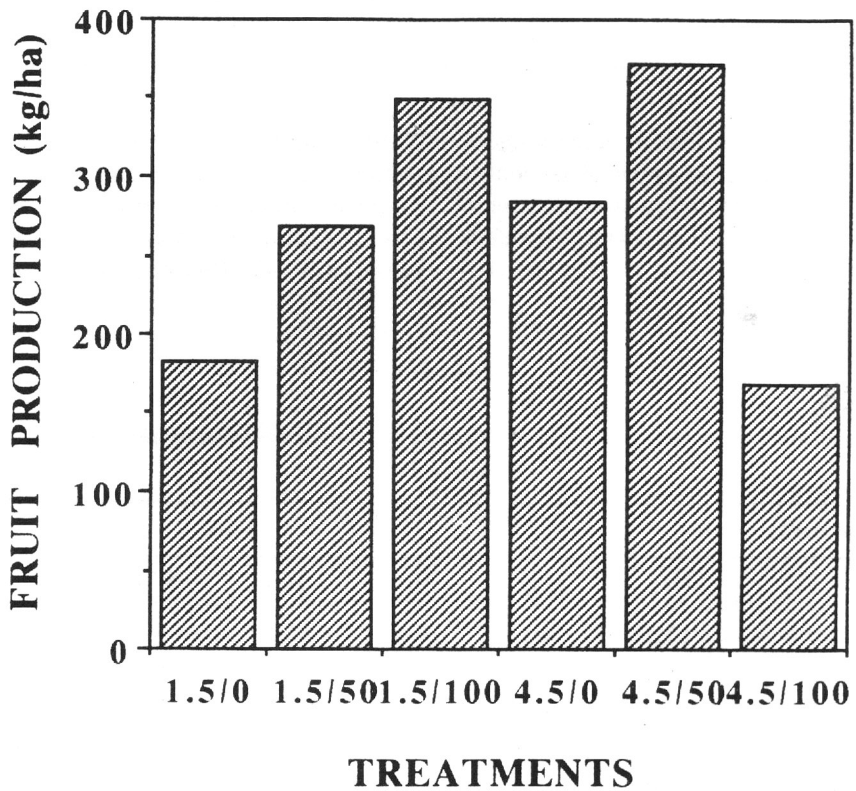

FIG. 3. *Fruit production in 1991 for all treatments.*

TABLE 5

Average and standard error of leaf water potential data. Details are the same as in table 4.

Leaf Water Potential (LWP x MPa)					
Treatments	June		July		August
	Midday	Pre-dawn	Midday	Pre-dawn	Midday
1.5 / 0	2.1 ±0.46	0.6 ±0.06	2.9 ±0.15	0.9 ±0.04	2.6 ±0.07
1.5 / 50	2.0 ±0.21	0.7 ±0.09	2.9 ±0.06	1.0 ±0.10	2.7 ±0.12
1.5 / 100	2.2 ±0.90	0.7 ±0.10	2.8 ±0.08	0.7 ±0.09	2.7 ±0.15
4.5 / 0	2.2 ±0.15	0.9 ±0.22	2.8 ±0.25	0.9 ±0.09	2.3 ±0.09
4.5 / 50	2.3 ±0.12	0.9 ±0.15	2.8 ±0.12	0.9 ±0.07	2.6 ±0.07
4.5 / 100	2.3 ±0.12	0.9 ±0.19	2.9 ±0.12	0.8 ±0.04	2.6 ±0.07
	F-test	F-test	F-test	F-test	F-test
Water	n. s.	n. s.	n. s.	*	n. s.
N	n. s.	n. s.	n. s.	n. s.	n. s.
Water x N	n. s.	n. s.	n. s.	n. s.	n. s.

in almond-trees. These works show that a considerable amount of water can be lost either by evapotranspiration or used for growth. Another possible explanation is the insufficient irrigation of the trees. Nevertheless had this been the reason we wouldn't have been able to observe the significant growth responses (Table 3 and 4). Regardless water irri-

TABLE 6

Leaf macronutrients (g kg^{-1} DW) for each treatment in two sampling periods, may and July.

Treatments	N		K		P	
	May	July	May	July	May	July
1.5 / 0	12.1	10.6	6.5	6.5	1.2	0.9
1.5 / 50	11.0	10.4	5.5	6.3	1.1	0.8
1.5 / 100	10.3	10.4	6.5	7.0	1.0	0.8
4.5 / 0	11.2	10.9	6.3	7.5	1.2	0.8
4.5 / 50	10.0	10.7	5.0	6.5	1.1	0.8
4.5 / 100	9.4	12.0	6.8	6.8	1.5	1.0

TABLE 7

Nitrogen retranslocation (%) of carob leaves sampled in October.

Treatments	N-retranslocation (%)
1.5 / 0	41.6
1.5 / 50	52.7
1.5 / 100	50.0
4.5 / 0	59.2
4.5 / 50	50.0
4.5 / 100	56.8

gation, growth responses could be mainly due to a nitrogen influence.

The pre-dawn values (Table 5), also similar for all treatments, suggest that carob-trees are able to draw moisture from deep in soil profile. Similar results were found in cork oak trees (Oliveira *et al.*, 1991).

Leaf nutrients contents (Table 6), do not show any difference between the two periods, despite the slight increase in nitrogen for the "4.5/100" treatment. The observation of N-content in freshly senescent leaves show that carob trees, independently of fertilization and irrigation treatments, present an efficient N-retranslocation (Table 7).

Nutrient retranslocation is very common in Mediterranean climates (Kruger, 1987) and specially under the edaphic conditions of this site which is highly N-limited. The N-pool strategy is also very common in many other fruit trees (Weinbaum *et al.*, 1984) showing that N fertilizer applications are sometimes inconclusive because of the adequate N reserves in trees. Besides, it is important to realize that in dioecious species, such as carob (Martins-Loução and Brito de Carvalho, 1989), female plants can evolve mechanisms which optimize water, carbon and nutrient use for production in environments in which those factors are limiting.

CONCLUSIONS

These results, which represent the basis of current and future research, illustrate the need to study the effects of fertilization and irrigation on the net production of this tree orchard. The short-term responses to the water and nitrogen application show a clear viability to improve vegetative growth in marginal lands. However, more data is need to access the effect of the discussed factors on reproductive growth and final yield. The implications of the stored nitrogen under N-limited conditions and the complex interactions between nitrogen and water availability within the trees are also factors important to be considered.

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