EFFECTS OF IRRIGATION AND NITROGEN FERTILIZATION ON GROWTH AND YIELD RESPONSES OF KENAF IN SPAIN

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Abstract

Kenaf (*Hibiscus cannabinus* L.) is an annual plant that can be useful as a source of low cost natural fibre. It is a fast-growing plant, and can be used in the industry for a wide range of products, especially for his fibre content useful for the paper production industry. To the farming point of view this crop can be also seen as an useful alternative to the irrigated summer crops in our zone. However, there are few data about kenaf agronomy during the last decade for our continental climate.

The objective of this work was to study the effect of irrigation and nitrogen fertilization on plant kenaf yield, in central plateau of the Iberian Peninsula.

A field study was carried out in two years, 2003 and 2004, on a sandy clay loam soil (Calcic Haploxeralfs) at the experimental farm "La Canaleja" from INIA (Alcalá de Henares, Madrid) in order to determine the appropriate irrigation and nitrogen fertilization requirements. The kenaf ("Tainung 2" variety) was cultivated at four irrigation levels (I_0, without irrigation; I_{25}, 25% PET; I_{50}, 50% PET; I_{100}, 100% PET) and three nitrogen fertilization levels (1st year: N_0, 0 kg N/ha; N_{75}, 75 kg N/ha; N_{100}, 100 kg N/ha; and 2nd year: N_0, 0 kg N/ha; N_{75}, 75 kg N/ha; N_{150}, 150 kg N/ha). The plants were grown in 7x5 m^2 in a randomised block design with three replicates. The crop was harvested 7 times during the growing period, on samples of one-meter row for plant growth (plant height and basal stem diameter) and plant yielding components (dry biomass of leaf, bark and core) assessment.

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The maximum biomass production of kenaf was reached 130-140 days after sowing. Nitrogen fertilization had not significant effect, in the range of 0-150 kg N/ha, on kenaf plant growth and plant yield. We have found that the irrigation was the principal factor in the plant growth and plant yield of the kenaf crop for the two essayed years, and it affected significantly to the: plant height, stem diameter and also to the other yield components (leaf, bark and core). The I_{100} was the best treatment, and dry yields of 15 t/ha in total biomass and 10 t/ha in stem biomass may be obtainable under optimal conditions in the central plateau of Spain.

In the central region of Spain, were the kenaf trials were located irrigation practices should be performed at 100% PET. We have found that the reduction of water amount decrease the production of plant kenaf biomass in our climatic conditions. We have found also that in our climatic and crop rotation conditions it is not necessary the application of nitrogen fertilization.

Keywords: Kenaf; Fiber crop; Biomass production; Irrigation; Fertilization.

1. INTRODUCTION

Kenaf (*Hibiscus cannabinus* L.) is an annual plant that can be useful as a source of low cost natural fiber. It is a fast-growing plant, and can be used in the industry for a wide range of products (building materials, adsorbents, textiles, livestock feed, etc..), especially for its fiber content useful for the paper production industry (Webber and Bledsoe, 1993). The stem of kenaf have two principal components: the outer bark with long fibers (2-6 mm), making up some 35-40% of total stem weight; and the inner core with short fibers (0.6 mm), making up the remaining 60-65% (Wood *et al.*, 1983; Alexopoulou *et al.*, 2000). The knowledge of kenaf agronomy is important at present due to the increased number of new uses for kenaf plant.

To the farming point of view this crop can be also seen as an useful alternative to the maize crop as well as other vegetable irrigated summer crops in our zone. The establishment of the kenaf crop in Spain will depend if kenaf production can be competitive with other crops grown in the area. However, there are few data about kenaf agronomy during the last decade for our continental climate (Manzanares *et al.*, 1997).

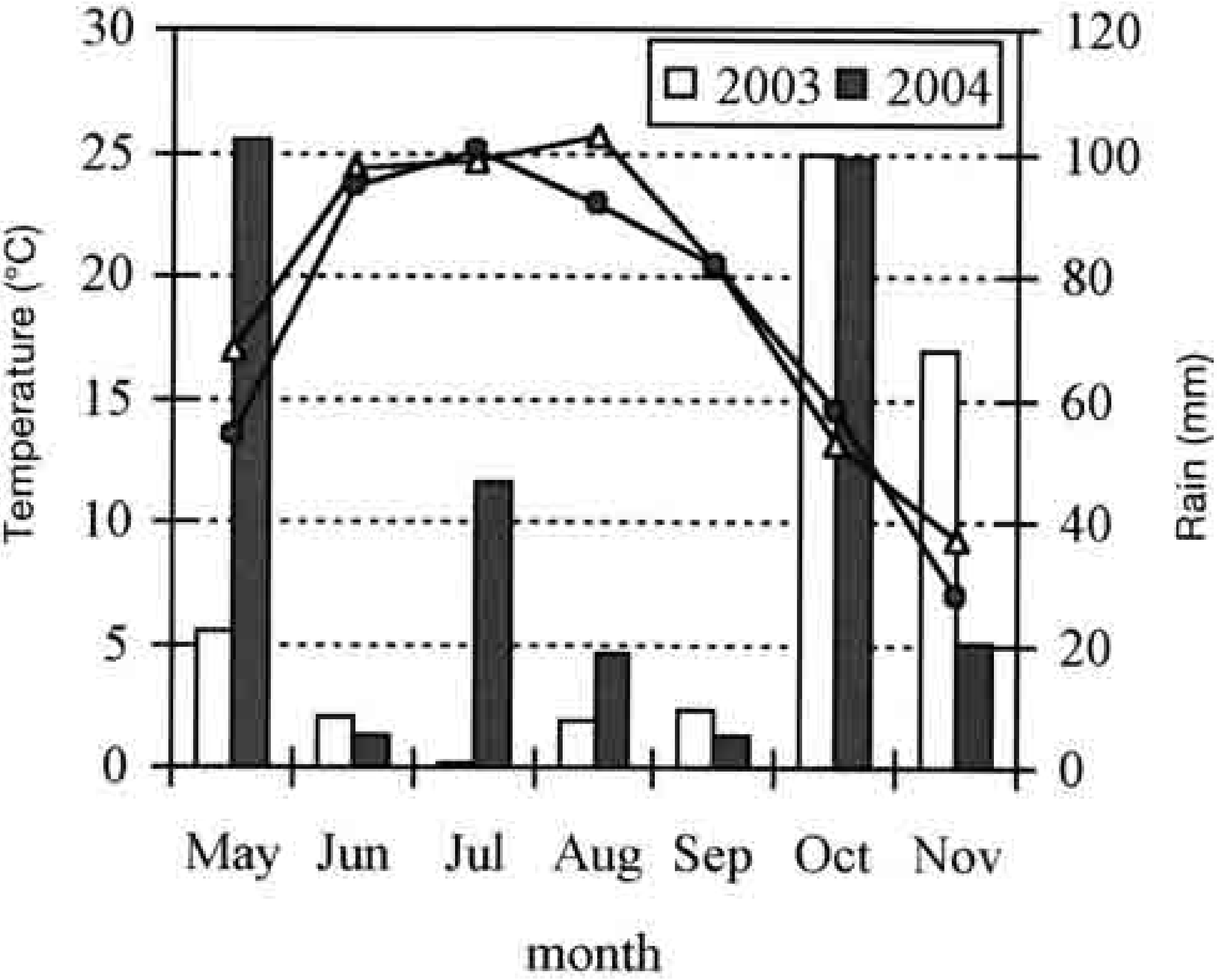
The main objective of this work was to study the effect of irrigation and nitrogen fertilization on plant kenaf yield, in the central plateau of the Iberian Peninsula.

2. MATERIALS AND METHODS

The field study was carried out in 2003 and 2004 on a sandy clay loam soil (Calcic Haploxeralfs) at the experimental farm "La Canaleja" from INIA (Alcalá de Henares, Madrid) in order to determine the appropriate irrigation and nitrogen fertilization requirements. Fig. 1 shows the mean temperature and rainfall in 2003 and 2004 during the kenaf crop cycle.

The kenaf ("Tainung 2" variety) was cultivated at four irrigation levels (I_0, without irrigation; I_{25}, 25% PET; I_{50}, 50% PET; I_{100}, 100% PET) and three nitrogen fertilization levels (1st year: N_0, 0 kg N/ha; N_{75}, 75

Figure 1. Meteorological data in Alcalá de Henares, (Madrid, Spain) in 2003 and 2004.



kg N/ha; N_{100}, 100 kg N/ha; and 2nd year: N_0, 0 kg N/ha; N_{75}, 75 kg N/ha; N_{150}, 150 kg N/ha;). The kenaf crop was sown using a row spacing of 0,5 m and a plant population of 200000 plants/ha. The plants were grown in 7x5 m^2 plots in a randomised block design with three replicates in each essay.

Growth and productivity data were harvested 7 times during the growing period. In each harvest a one-meter row was harvested, and leaves, bark and core were separated. The dry matter in plant yielding components was evaluated after drying the samples at 80 °C at constant weight. Also, the plant height and basal stem diameter were measured in five plants per plot.

The data were analysed using GLM procedures included in the SAS statistical package (SAS Institute Inc., 1988). Significant differences between means were estimated using Duncan's Multiple Range Test, p = 5% (Duncan, 1955).

3. RESULTS AND DISCUSSION

The Fig. 2 shows the effect of different irrigation levels on the evolution of kenaf growth parameters: plant height and basal stem diameter, for the two studied years (2003 and 2004). Irrigation treatments affected significantly to the kenaf growth: plant height and basal stem diameter in the two studied years (Fig. 2). The maximum growth of kenaf plants was reached with the I_{100} treatment: a final average height

Table 1. Effect of nitrogen fertilization and irrigation on the dry stem biomass yield, dry bark biomass, and dry core biomass at the end of growth period for 2003, and analyses of variance for the fertilization and irrigation variables. N, number of plots; DF, degrees of freedom; The letters in the columns indicate means showing a significant difference at the 5% level (Duncan's multiple range test).

		Dry biomass (t/ha)		
2003	**N**	**Stem**	**Bark**	**Core**
Nitrogen Fertilization				
N_0	12	6.4 a	2.1 a	4.3 a
N_{75}	12	5.8 a	1.9 a	3.9 a
N_{100}	12	5.2 a	1.8 a	3.4 a
Irrigation				
I_0	9	2.4 c	0.8 c	1.6 c
I_{25}	9	5.1 b	1.7 b	3.4 b
I_{50}	9	5.6 b	1.8 b	3.8 b
I_{100}	9	9.9 b	3.3 a	6.6 a
Overall Scores	36	5.8	1.9	3.9

		P		
Source of variation	**DF**	**Stem**	**Bark**	**Core**
Nitrogen Fertilization (F)	2	0.5750	0.6752	0.4359
Irrigation (I)	3	0.0001	0.0001	0.0001
F x I	6	0.5709	0.4435	0.4557

of 250 cm and a final average stem diameter of 22 mm, whereas de I_0 irrigated plants did not exceed 140 cm in height and 13 mm in stem diameter. The growth of kenaf variety Tainung 2 increased slowly with the kenaf plants under I_0, I_{25}, and I_{50} treatments, thereby I_{50} reduced growth by 30%, I_{25} by 45%, and I_0 by 50% when compared with I_{100} treatment for the 1st year (Fig. 2), whereas the reduced growth were 10%, 20% and 40% for I_{50}, I_{25}, and I_0 respectively for the 2nd year (Fig.2). Differently to irrigation, the nitrogen fertilization has not any effect on the plant growth parameters (plant height and basal stem diameter) for the two years (data not show).

The Fig. 3 shows the effect of different irrigation levels on the evolution of kenaf biomass production for the two years. Similar to the plant growth, the biomass production of kenaf was not affect by nitrogen fertilization for the two studied years (Fig. 3). This lack of response by kenaf to different nitrogen applications is according to the obtained results in different Mediterranean areas (Manzanares *et al.*, 1997; Danalatos and Archontoulis, 2004; Fernando *et al.*, 2004; González Moreno *et al.*, 2004). This is probably due to the low nitrogen requirements of the kenaf crop, or to the high capacity of the kenaf crop to extract the soil nitrogen.

The Fig. 4 shows the effect of different irrigation levels on the evolution of kenaf biomass production for the two years. The maximum yields of kenaf crop were obtained 130-140 days after sowing. After

Table 2. Effect of nitrogen fertilization and irrigation on the dry stem biomass yield, dry bark biomass, and dry core biomass at the end of growth period for 2004, and analyses of variance for the fertilization and irrigation variables. N, number of plots; DF, degrees of freedom; The letters in the columns indicate means showing a significant difference at the 5% level (Duncan's multiple range test).

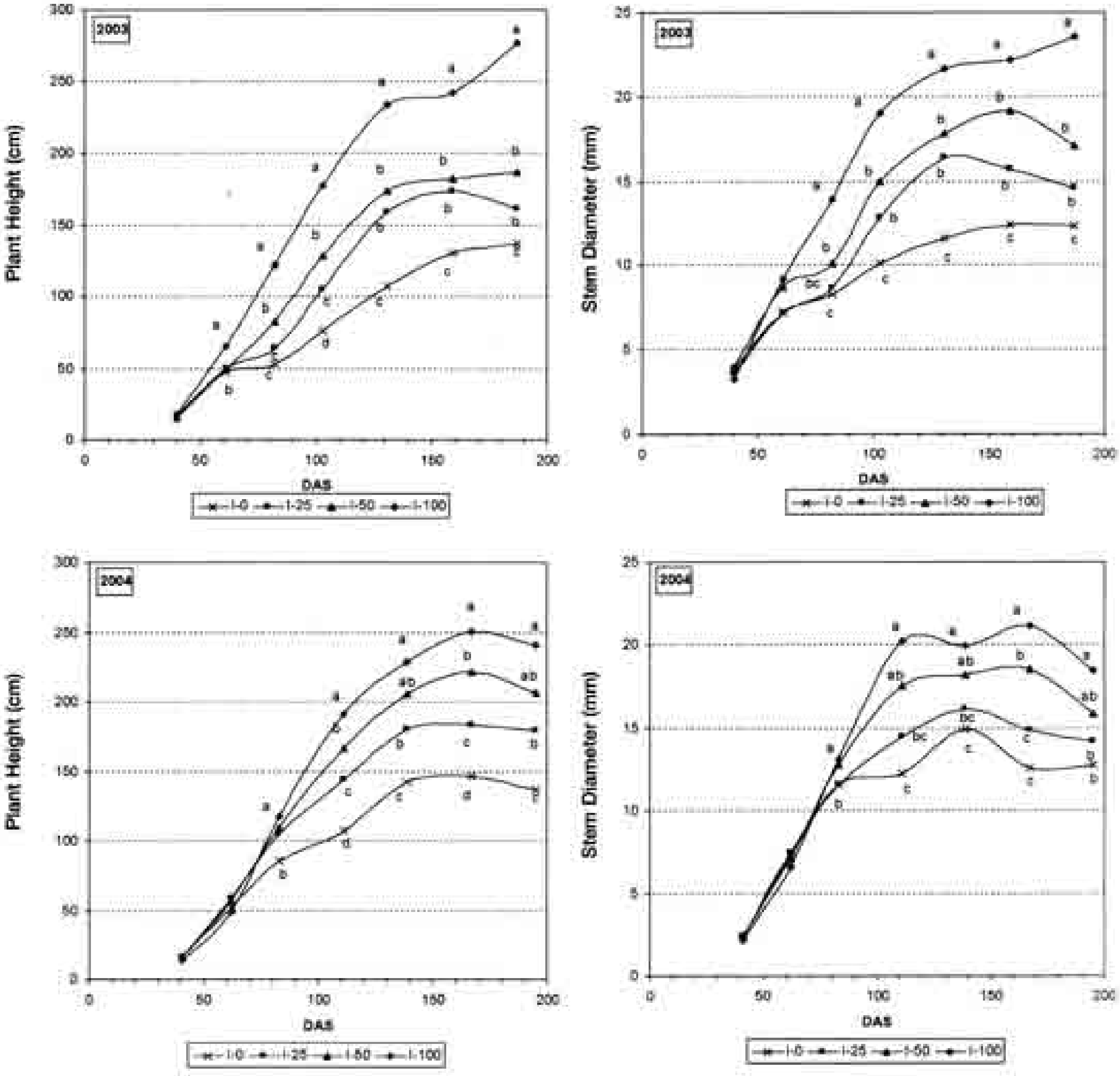
2004	N	Dry biomass (t/ha)		
		Stem	Bark	Core
Nitrogen Fertilization				
N_0	12	7.3 a	2.3 a	5.0 a
N_{75}	12	6.9 a	2.3 a	4.6 a
N_{150}	12	7.4 a	2.4 a	5.0 a
Irrigation				
I_0	9	3.8 b	1.2 b	2.6 b
I_{25}	9	6.4 ab	2.0 ab	4.4 ab
I_{50}	9	8.1 ab	2.6 ab	5.5 ab
I_{100}	9	9.7 a	3.2 a	6.4 a
Overall Scores	36	7.2	2.3	4.9

Source of variation	DF	*P*		
		Stem	Bark	Core
Nitrogen Fertilization (F)	2	0.9971	0.9930	0.9952
Irrigation (I)	3	0.0616	0.0296	0.0843
F x I	6	0.9694	0.9674	0.9694

these dates, the biomass production lowered mainly due to the loss of the leaves, and the stem yields remained constant after this moment. The irrigation treatments significantly affected to the kenaf productivity (Fig. 4). The higher yields of 15 t/ha were obtained with the I_{100} treatment for the two years (Fig. 4), and the highest dry biomass production of 16.7 t/ha was obtained in plots treated with N_0 (0 kg N/ha) and I_{100} (100% PET) in 2003, and 15.7 t/ha was obtained in plots treated with N_0 and N_{150}, and I_{100} in 2004. The deficit irrigation treatments (I_0, I_{25}, and I_{50}) significantly affect the biomass production, being the kenaf yields considerably reduced (Fig. 4), however an elevated productivity was obtained in half optimal irrigation (I_{50}) with good climatic conditions (2nd year). The kenaf crop need a good irrigation level to obtain high yields (Manzanares *et al.*, 1997; Ogbonnaya *et al.*, 1998; Danalatos and Archontoulis, 2004; Fernando *et al.*, 2004; González Moreno *et al.*, 2004; Nielsen, 2004), however the biomass production of kenaf is not regularly in all growing periods (Fig. 4), and probably the kenaf water needs may be different in each growing stage.

Also, the irrigation treatment influenced similarly to the others yielding components: stem, bark and core (Tables 1 and 2). The pattern of biomass production of stem, bark and core were similar to plant growth parameters and total dry biomass. The I_{100} was the best treatment for the two years (Tables 1 and 2), and the stem yield at the end of growth period were: 9.9 t/ha (bark: 3.3 t/ha; core: 6.6 t/ha) for

Figure 2. Effect of nitrogen fertilization and irrigation on the plant height and basal stem diameter throughout the growing period of kenaf in 2003 and 2004. DAS: days after sowing. The letters in each date indicate means showing a significant difference at the 5% level (Duncan's multiple range test).



2003 (Table 1), and 9.7 t/ha (bark: 3.2 t/ha; core: 6.4 t/ha) for 2004 (Table 2). The difference between I_{50} and I_{25} biomass production were not significant (Tables 1 and 2), and the effect of I_0 on reduction of biomass production was significant with the others irrigation treatments (Tables 1 and 2). The reduced stem productions were of 40%, 50% and 75% for I_{50}, I_{25}, and I_0 respectively for the 1st year when compared with I_{100} treatment (Table 1), and the reduced stem productions were of 20%, 35% and 60% for I_{50}, I_{25}, and I_0 respectively for the 2nd year (Table 2). These differences between the two years can be due to the different climatic conditions in each growing period (Fig. 1). Similar to the plant growth and total biomass, the stem, bark and core dry yields were not influenced by nitrogen fertilization for the two studied years (Tables 1 and 2).

Figure 3. Effect of nitrogen fertilization on the total dry biomass yield throughout the growing period of kenaf in 2003 and 2004. DAS: days after sowing. The letters in each date indicate means showing a significant difference at the 5% level (Duncan's multiple range test).

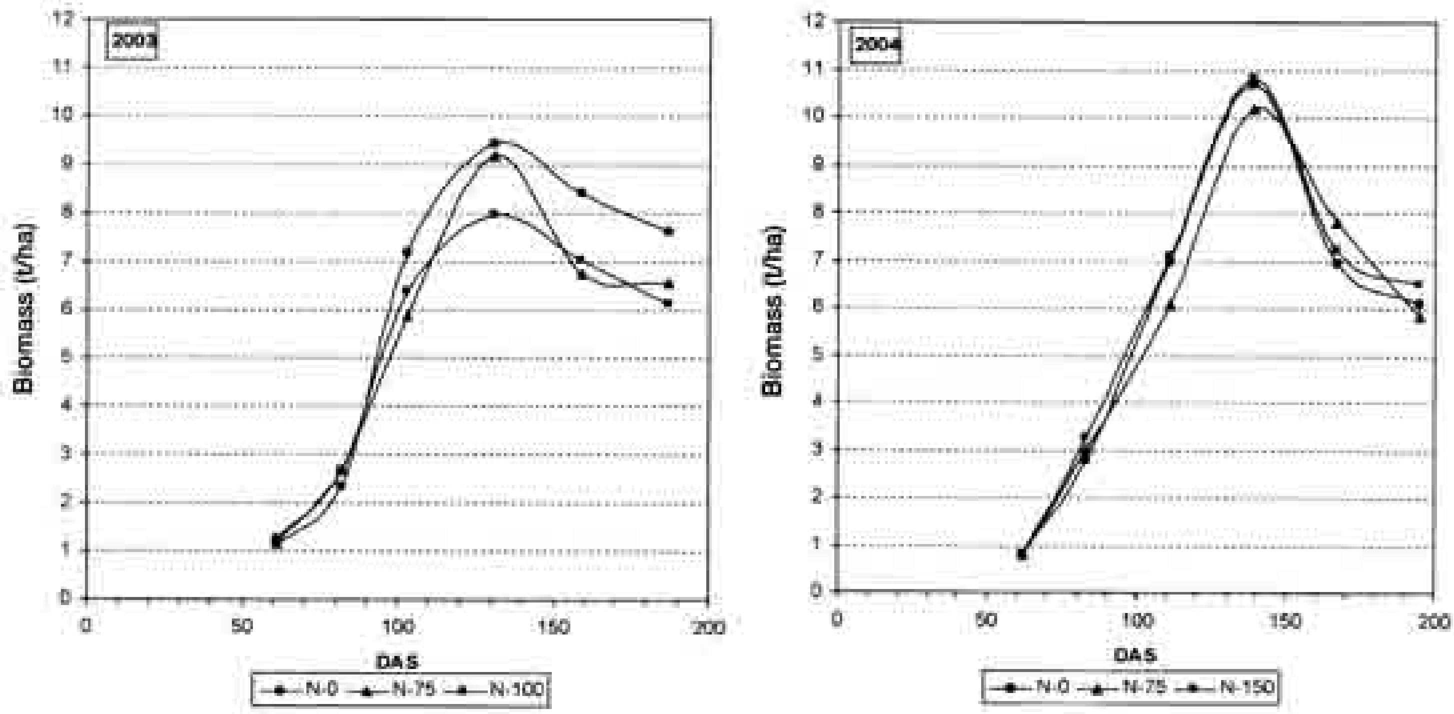
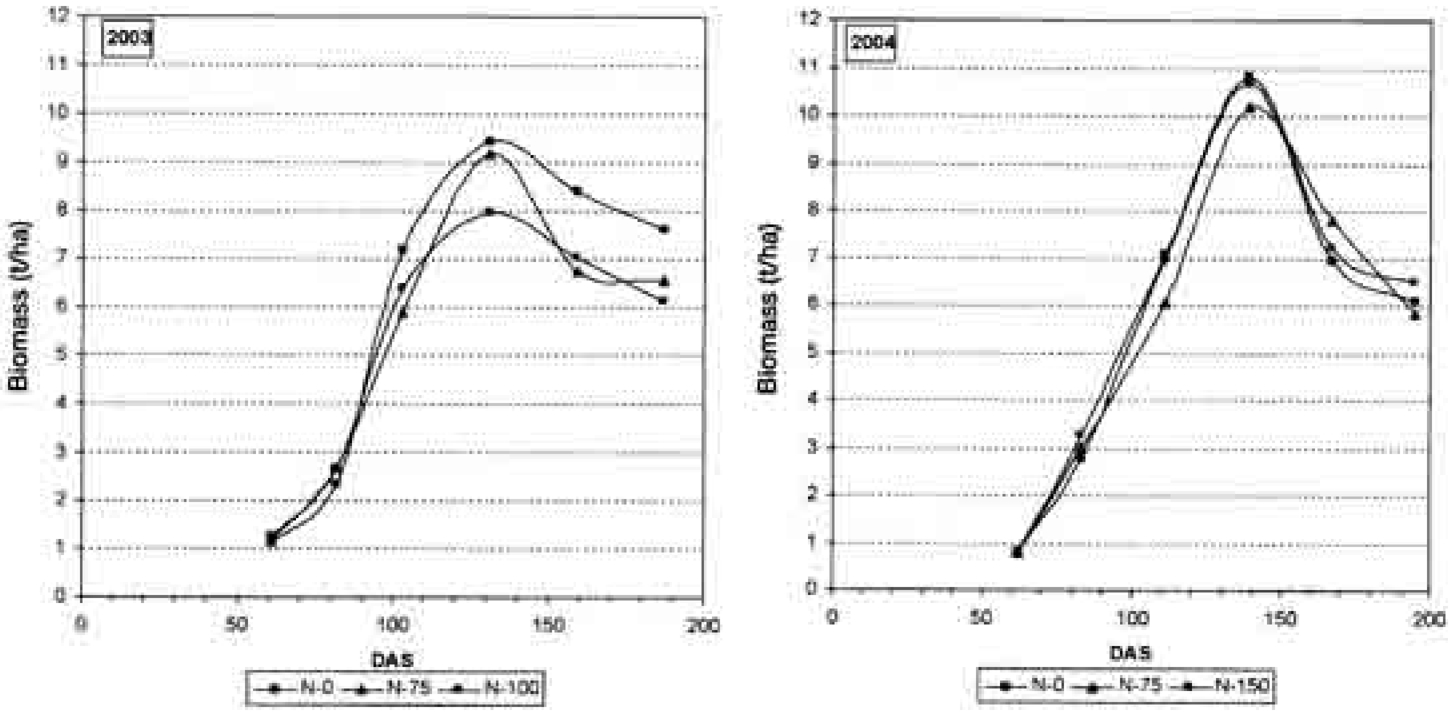


Figure 4. Effect of irrigation treatments on the total dry biomass yield throughout the growing period of kenaf in 2003 and 2004. DAS: days after sowing. The letters in each date indicate means showing a significant difference at the 5% level (Duncan's multiple range test).



4. CONCLUSION

We have found also that in our climatic and crop rotation conditions it is not necessary the application of nitrogen fertilization. In the central region of Spain, were the kenaf trials were located irrigation practices should be performed at 100% PET. Kenaf dry yields of 15 t/ha in total biomass and 10 t/ha in stem biomass may be obtainable under optimal conditions in central plateau of Spain. We have found that the reduction of water amount significantly decreases the production of plant kenaf biomass in our climatic conditions, but the use of regulated deficit irrigation strategies in specific growing periods of kenaf crop may be investigated in order to optimise the water inputs without to reduce the biomass production.

Acknowledgments

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