POTENTIAL GROWTH AND BIOMASS PRODUCTIVITY OF KENAF *(HIBISCUS CANNABINUS* L.) UNDER CENTRAL GREEK CONDITIONS: I. THE INFLUENCE OF FERTILIZATION AND IRRIGATION

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ABSTRACT: The growth and productivity of kenaf variety Tainnung 2 were investigated in a field experiment carried out in western Thessaly (central Greece) in 2003, as affected by three irrigation and four N-fertilization treatments. Plant height, LAI, and fresh and dry matter per plant organ were measured in subsequent harvests throughout the growing period. The results demonstrated a significant (P=0.05) effect of irrigation with a maximum dry biomass reaching 22.16 t ha^{-1} under full irrigation and by 13% and 42% lower productivity for irrigation inputs equal to 50% and 25% of the potential evapotranspiration, respectively. The leaf area index exceeded 7.0 under full irrigation but remained about 5 for the rest irrigation treatments. Stem biomass contributed to about 85% of the total dry biomass for all treatments by the end of the growing period. Contrary to irrigation, no effect of N-application was found, apparently due to the low nitrogen needs of the crop and the high fertility status of the study soil.
Keywords: Kenaf, biomass production, fiber crops.

1 INTRODUCTION

Kenaf (*Hibiscus cannabinus* L., *Malvaceae*) is a warm-season annual crop, relative to cotton, which has been suggested by several researchers for use as both fiber and fodder crop [1],[2]. Actually, kenaf is traditionally grown in east-central Africa, west Asia and in several southern states of America for fiber and oil seed (20% oil content) production, whereas it comprises an excellent forage crop [3], containing 18-30% crude leaf protein [4] and stalk protein 5.8-12.1% [3],[4]. In the last decade the crop received an increased attention by E.U. as a high yielding "non food crop" for fiber production and particularly for the newsprint paper pulp and other paper products industry [5],[6], as its fast-growing and high yielding pulp is easily obtained [5]. As a matter of fact, the stem of the plant contains two distinct fibers, the outer bark fibers making up some 35-45% of total stem weight and producing high quality pulp, and the inner core fibers making up the remaining 60-65% and produce low quality pulp [6],[7],[8]. Thus, kenaf is also an important source of textile fibres for the manufacture of twines, ropes, burlap bags and carpet backings using traditional retting ponds in Africa, Asia and Latin America [9],[10]. Kenaf is being introduced into arid regions [11], and is increasingly grown in other dry, light-textured, marginal soils under water-limited conditions. However, irrigation studies have mainly focused only on improving fiber production [12],[13], whereas on the other hand, there is a great inconsistency with respect to the effects of fertilization on kenaf stalk yields; researchers have reported both positive [14] and no benefits [15] from N-applications depending on soil type [16],[17] and soil fertility status [13],[18]. Very limited information on kenaf growth are reported from Greece [19],[20], pointing to the late-varieties Everglades 41 and Tainnung 2 as quite promising under Greek conditions. Since data on growth and productivity of kenaf are still minimal under semi-arid conditions such as those prevailing in the Mediterranean, the objective of this work is to determine the potential growth and biomass productivity of kenaf variety Tainnung-2 under central Greek conditions, as well as the influence of reduced irrigation and N-fertilization inputs on growth and biomass yield of this crop.

2 MATERIALS AND METHODS

A field experiment was carried out on a deep, fertile, loamy soil located in Palamas, Karditsa (central Greece) in 2003 (coordinates: 39°25'43.4'' N, 22°05'09.7'' E, altitude 107.5 m). The soil is classified as Aquic Xerofluvent [21], having groundwater table fluctuating from some 150-200 cm below the surface in May (artificial drainage) to deeper layers later in the summer. A 3x4 factorial completely randomized split-plot design was used in 3 blocks. The factors were a) irrigation (main plots) with three treatments: I_1=25%, I_2=50% and I_3=100% of the potential evapotranspiration, and b) nitrogen fertilization (sub-plots) in 4 treatments: N_0=control, N_1=50, N_2=100 and N_3=150 kg N ha^{-1}. The crop was sown on May 20th at distances of 0.50 m between the rows and 0.10 m within the rows. Emergence was recorded 4 days later and 50% flowering was recorded on October 11th. Irrigation was applied using an automatic drip irrigation system. The growth (plant height and LAI) and the dry biomass yield (leaves, stems, storage organs) were measured in subsequent harvests throughout the growing period and particularly on the dates: 29/6, 21/7, 11/8, 4/9, 26/9, 14/10, and 7/11/2003. Weather data (radiation, air temperature, rainfall, air humidity, wind speed and class-A pan evaporation rate; Table I) were recorded hourly on an automatic meteorological station installed next to experimental site. In a deep soil pit, which was dug on July 30th, the groundwater table was detected at a depth of 290 cm. The soil profile below the root-zone was at field capacity. Standard soil physical and chemical analyses were carried out at the Institute of Soil Mapping and Classification, Larissa).

Table I: Mean weather data and water applied as I_3-irrigation during the growing period of 2003.

temperature (°C)	22.0
rainfall (mm)	267
wind speed (m s^{-1})	0.97
relative humidity (%)	67.1
radiation (W m^{-2})	467
pot. evapotranspiration (mm)*	415
water input as I_3 irrigation*	350
effective rainfall (mm) *	70

[* note: during the irrigation period, 1/7-12/8/2003].

3 RESULTS AND DISCUSSION

3.1 Climatic conditions

The study area is characterized by a Mediterranean climate with hot, dry summers and cool, humid winters. The growing period in 2003 was characterized by somewhat lower temperatures than in an average year. As shown in Fig. 1, the air temperature fluctuated at levels similar to the climatic value until the first decade of July. Then and until the end of August, the temperature fluctuated in the range 23-25°C without reaching the high temperature peaks as in an average summer. Temperature decreased sharply in early September but it remained at relatively high levels (18.6-21.0°C) until the first decade of October (Fig. 1). During the warm season (June-end of September), total rainfall reached 120 mm (similar to the climatic average). Another 150 mm of rain were recorded during October (Fig. 1).

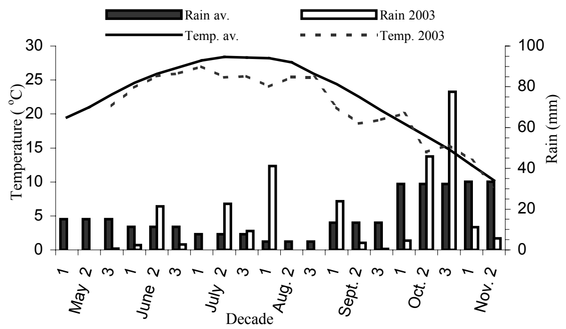

Fig. 1: Air temperature and precipitation (10-day mean values) recorded in the study area in 2003 and in an average year (average of 30 years).

3.2 Growth characteristics

The results demonstrated a significant (P=0.05) effect of irrigation on plant height, with the I_3-irrigated plants reaching growth rates up to 2.75 cm day^{-1} and a final height of 3.8 m (Table IIa), whereas the I_1 plants did not exceed 3.2 m in height by the end of the growing period. In all cases, the growth rates gradually decreased after flowering, in accordance to previous findings [22]. Contrary to irrigation, no effect of N-fertilization was observed on plant height.

Leaf area index (LAI) is of great importance for light interception and for photosynthesis. As presented in Table IIb and Fig. 2, LAI increased with high rates from the end of May until the first decade of August, reaching peak values in excess of 7 in the case of I_3 irrigation and about 5 for the rest two treatments.

Later on, due to ageing and falling off of the older leaves, LAI deceased gradually but until the end of September it remained at relatively high levels (closed canopy) in the case of irrigation I_3, contrary to the less irrigated treatments and especially I_1 that performed considerably lower LAI values.

Contrary to the effect of irrigation, no significant effect of nitrogen fertilization on LAI was found, as can be observed in Table IIb (see also figure 2).

Table II: Plant height (cm) and LAI evolution of Kenaf measured throughout the growing period (2003) as affected by the three irrigation treatments.

J.Days	I_1	I_2	I_3	LSD
	a: Plant height			
181	75	75	75	-
203	125	141	166	** 29.6
224	186	221	234	** 32.4
248	225	271	274	* 38.1
270	247	288	324	** 15.2
288	291	351	370	** 44.7
312	313	364	378	** 45.3
	b: Leaf area index			
181	1.5	1.5	1.5	-
203	3.6	3.7	4.9	** 0.89
224	5.2	5.5	7.5	** 1.51
248	3.9	4.3	4.9	ns
270	3.3	4.4	5.0	** 1.03
288	2.0	3.4	4.2	** 1.01
312	1.2	2.2	3.8	ns

(* P=0.05 and ** P=0.01)

3.3 Biomass production

As illustrated in Fig. 3, the growth and productivity of Kenaf variety Tainnung 2 were not influenced by N-fertilization in the range of 0-150 kg N/ha. This is apparently due to the low nitrogen needs of the crop and the relatively high fertility status of the study soil, which was previously cultivated with cotton.

Table III: Total and stem biomass (dry weights in t ha^{-1}) measured throughout the growing period of Kenaf in 2003 for the 3 irrigation treatments.

J.Days	I_1	I_2	I_3	LSD
	a: Total dry biomass			
181	1.716	1.716	1.716	-
203	6.111	6.038	8.207	* 1.397
224	9.894	11.778	14.183	** 3.126
248	11.82	12.99	14.36	ns
270	14.79	16.98	20.96	** 2.966
288	12.93	19.42	22.16	** 4.35
312	13.23	18.97	21.65	* 6.632
	b: Dry stem			
181	0.67	0.67	0.67	-
203	3.36	3.33	4.78	ns
224	5.99	7.67	8.48	ns
248	8.52	9.55	10.49	ns
270	11.24	12.51	15.46	* 2.21
288	10.41	15.11	16.61	** 4.19
312	11.61	15.36	17.97	** 3.81

(* P=0.05 and ** P=0.01)

Contrary to fertilization, a significant effect of irrigation was observed (Table IIIa, Fig. 3) with the I_3 treatment reaching maximum growth rates of about 180 and 100 kg ha^{-1}d^{-1} for stems and leaves, respectively, and total dry biomass of 14.18 t ha^{-1} by mid-August, versus I_2 and I_1

treatments reaching 11.78 and 9.89 t ha^{-1}, respectively.

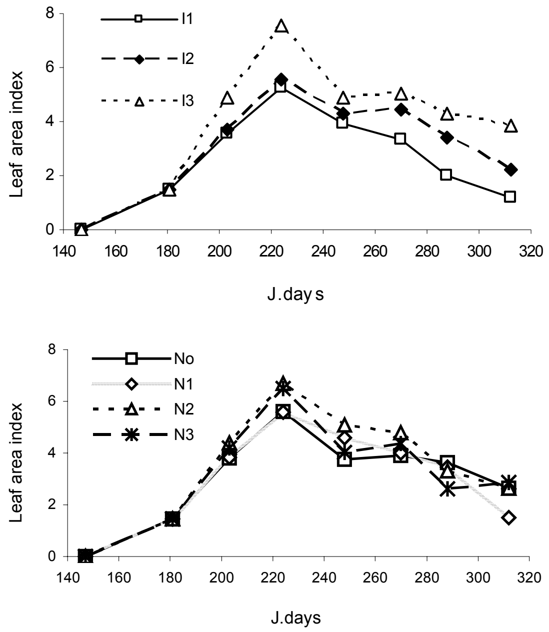

Fig. 2: LAI evolution of Kenaf grown in central Greece in 2003 as affected by three irrigation treatments (above) and four N-fertilization treatments (below).

The crop continued growing during late August but with lower rates (about half). This period was also characterized by a large falling off of the old leaves. Probably due to reduction in respiration caused by a drastic drop in temperature, growth rates increased through September and depending on the irrigation treatment, to reach finally total dry biomass production of 22.16 t ha^{-1} for treatment I_3, versus 19.42 t ha^{-1} and 12.93 t ha^{-1} for treatments I_2 and I_1, respectively.

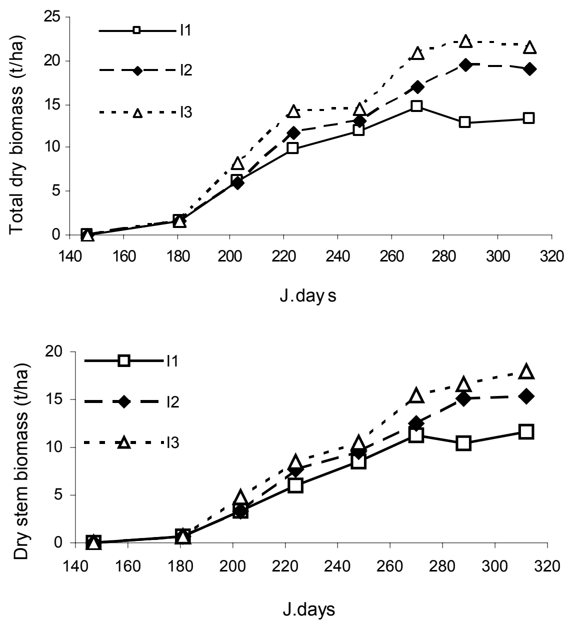

Fig. 3: The evolution of total dry biomass (above) and stem dry biomass (below) of Kenaf variety Tainnung-2 as affected by irrigation in central Greece in 2003.

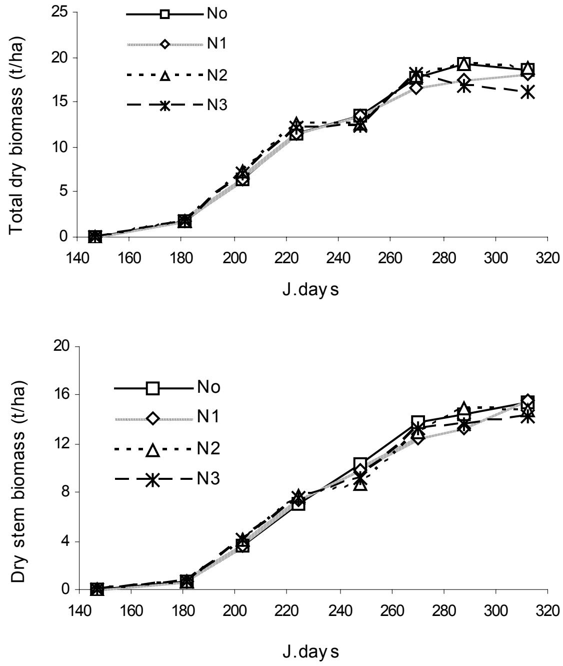

Fig. 4: The effect of N-fertilization on total dry matter (above) and stem dry matter (below) of kenaf variety Tainnung-2 as affected by irrigation in central Greece in 2003.

Table IIIb and Fig. 4 present the evolution of dry stem weight throughout the growing period. At the early development stages, dry stem weight comprised only 1/3 of total dry biomass; later on, this percentage increased to 63% by mid-August and 80-90% (according to the treatment) by the last harvest in November. Similar to the total biomass, stem growth was not influenced by N-fertilization in the studied range. Significant effect of irrigation was observed by the end of September to the beginning of November, with the I_3 and I_2 treatments to reach 17.97 and 15.36 t ha^{-1} in dry matter, whereas the rather drier treatment I_1 did not exceed 11.61 t ha^{-1} (Fig. 4 and Table IIIb) in dry stem weight.

4 CONCLUSIONS

It can be concluded that kenaf dry yields in excess of 22 t ha^{-1} in total biomass and 17 t ha^{-1} in stem biomass may be obtainable under optimal conditions in central Greece (potential productivity). Lower irrigation inputs significantly affect biomass production, but the productivity of variety Tainnung-2 might remain at considerably high levels for water inputs matching half of the potential evapotranspiration (e.g. in excess of 15 and 18 t ha^{-1} for stem and total dry biomass, respectively) in deep alluvial soils with an aquic moisture regime (e.g. Aquic Xerofluvents), covering large parts of the alluvial lowlands in central Greece and are artificially drained. Such soils may also perform relatively high yields, even in the case of rather low (supplemental) irrigation inputs.

Contrary to irrigation, no effect of fertilization was found in the range of 0-150 kg N ha^{-1}. This was apparently due to the high fertility status of the study soil. However, it points also to Kenaf as an alternative biomass crop with low nitrogen requirements and moderate to low water needs under Greek as well as more generally Mediterranean conditions. The subject is being further investigated.

5 ACKNOWLEDGEMENTS

This work was partially financed by the E.U. Project QLK5-CT-2002-01729 "Biomass Production Chain and Growth Simulation Model for Kenaf".

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