# GROWTH AND BIOMASS PRODUCTIVITY OF KENAF AS BIOMASS CROP IN CENTRAL GREECE

N.G. Danalatos[1], I.K. Mitsios[1] and S.V. Archontoulis[1,2]

[1] University of Thessaly, Dept. of Crop Production and Agricultural Environment, Fytoko, 38446, Volos, Greece.
[2] Wageningen University, Dept. of Plant Sciences, Crop and Weed Ecology Group, Haarweg 333, 6709 RZ Wageningen, The Netherlands. E-mail: sotirios.archontoulis@wur.nl

ABSTRACT: A two-year field experiment was carried out on a deep, fertile, aquic soil to study the potential growth and biomass productivity of two kenaf varieties (Tainnung 2 and Everglades 41) in central Greece in 2003 and 2004. A significant effect (*P=0.05*) of sowing time was found for both two years, with the early kenaf plantations performing considerably higher biomass yields. Biomass production fluctuated from 12.5 t ha$^{-1}$ (late plantation in 2004) to as much as 22.75 t ha$^{-1}$ (early plantation in 2003). Such a high biomass yield was obtained due to the earlier sowing date, the higher effective precipitation and the lower autumn temperatures (resulting in lower maintenance respiration) that occurred in 2003. Contrary to sowing time, no effect of plant density was observed in both years. Both cultivars exhibited similar growth rates (max 250 kg ha$^{-1}$d$^{-1}$), with a non-significant superiority of Tainnung 2 for the most of the cropping period. The specific leaf area of kenaf was not affected by the various treatments in any of the study years. As a general conclusion it can be stated that the earlier the sowing time the higher the yield of kenaf plants. Due to its high adaptability and biomass productivity under Greek conditions, kenaf seems to be a very promising alternative crop in the frame of low inputs agriculture, according to the E.U directives.

Keywords: kenaf, biomass production, fibre crops, Greece.

## 1 INTRODUCTION

Kenaf (*Hibiscus cannabinus* L., *Malvaceae*) is a tropical annual fiber crop. In the last years considerable efforts have been made to study the adaptability of kenaf varieties in European environments, with respect to crop performance under various soil and climatic conditions, proper planting time and population in Mediterranean and central European environments. The stem of kenaf contains two distinct fibers, the outer bark fiber comprising to 35-45% of total stem weight and producing high quality pulp, and the inner core fiber comprising the remaining 60-65% and producing lower quality pulp [1].

It was found that sowing time strongly depends on the particular climatic conditions. Previous experimental results [2, 3, 4] suggest that proper planting might occur in May, when soil temperature exceeds 15$^o$C. Concerning the proper plant density, the above authors showed that under Mediterranean conditions, populations of 20-25 plants m$^{-2}$ seem to be ideal for suitable growth, radiation efficiency and hence maximum final biomass production. Among the various kenaf varieties, the late-maturity ones such as Tainnung 2 and Everglades 41 were found quite promising, with maximum total dry matter production of 20-24 t ha$^{-1}$ [5].

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 present and compare such data collected in field experiments carried out in central Greece in 2003 and 2004. In particular, the leaf area index, the specific leaf area, the growth and the final yield of the two promising kenaf varieties Tainnung 2 and Everglades 41 are presented under optimum conditions for two different sowing dates, two plant populations and for two growing periods. These data were collected in field experiment carried out in an imperfectly drained, fertile loamy soil, typical of the (west) Thessaly plain, which is the greatest lowland in Greece and the centre of the country's agricultural production.

## 2 MATERIALS AND METHODS

### 2.1 Experimental area

A 2-year field experiment was carried out on a deep, fertile, loamy soil located in Palamas (Karditsa, western Thessaly, Greece, 3 km south east of the village of Palamas, coordinates: 39$^o$25'43.4'' N, 22$^o$05'09.7'' E, altitude 107.5 m) in the years 2003 and 2004. The soil is classified as Aquic Xerofluvent [6], having groundwater table fluctuating from some 150-200 cm below the surface in May (180 cm during the first decade of June) to deeper layers later in the summer. The soil under study is an imperfectly drained, calcareous (pH=8-8.2) loam (sand 40-42%, silt 40-41%, clay 18-19%) developed in recent alluvial deposits and represents a large part of the west Thessaly lowland (central Greece). The soil is has an organic matter content of more than 1% at a depth of 50 cm. Its high fertility status and water availability may ensure high growth rates and productivity of summer crops receiving only supplemental irrigation.

### 2.2 Experimental set-up

A 2x2x2 completely randomized block design was used in three blocks. The factors were: a) Sowing date: In 2004: $S_1$=June 1$^{st}$ and $S_2$=July 1$^{st}$, and in 2003: $S_1$=May 20$^{th}$ and $S_2$=June 13$^{th}$, b) Variety: $V_1$= Tainnung 2 and $V_2$= Everglades 41, c) Plant density: $D_1$=20 and $D_2$=40 plants m$^{-2}$. Sowing was done at rows 0.5 m apart with plant distances within the row of 0.10 m and 0.05 m for $D_1$ and $D_2$, respectively. All plots had received a basal dressing of 50 kg P ha$^{-1}$ and 100 kg K ha$^{-1}$ on 29-5-2003 and on 18/5/2004, while a top dressing of 100 kg N ha$^{-1}$ (as ammonium sulphate) was applied when the plants reached a height of 0.5 m.

### 2.3 Experimental procedures

The crop received drip irrigation (349 mm until 15/10/2003 and 500 mm until 07/10/2004) at frequent intervals, and for full matching the potential evapotranspiration (100% of PET), the latter being determined using a class-A evaporation pan. The dry biomass productivity (leaves, stems, storage organs) of the crop was measured in subsequent harvests throughout the growing period and particularly on the following dates: 30/6, 22/7, 12/8, 5/9, 27/9, 18/10, 8/11, and 28/11/2003 and on 4/7, 21/7, 4/8, 19/8, 8/9, 2/10, 30/10 and 19/11/2004. In each harvest, two strips of 2 m were sampled, and the plant material was weighed in the field and after drying at 90$^o$ until equal weights. Before drying, the plant material was separated into stems, leaves and storage organs. The area of green leaves (sub-sample) was additionally measured using a LAI-COR leaf area meter. This area divided over the dry leaf weight produced the specific leaf area (SLA, in $m^2$ $kg^{-1}$). Weather data (radiation, air temperature, rainfall, air humidity, wind speed and class-A pan evaporation rate) were recorded hourly on an automatic meteorological station installed next to the experimental site. All data were subjected to analysis of variance for each measured parameter using MSTAT-C (version 2.1, Michigan State University, 1991) software.

## 3 RESULTS AND DISCUSSION

### 3.1 Weather conditions

The study area and more generally the whole Thessaly lowland are characterized by a typical Mediterranean climate with hot, dry summers and cool, humid winters.

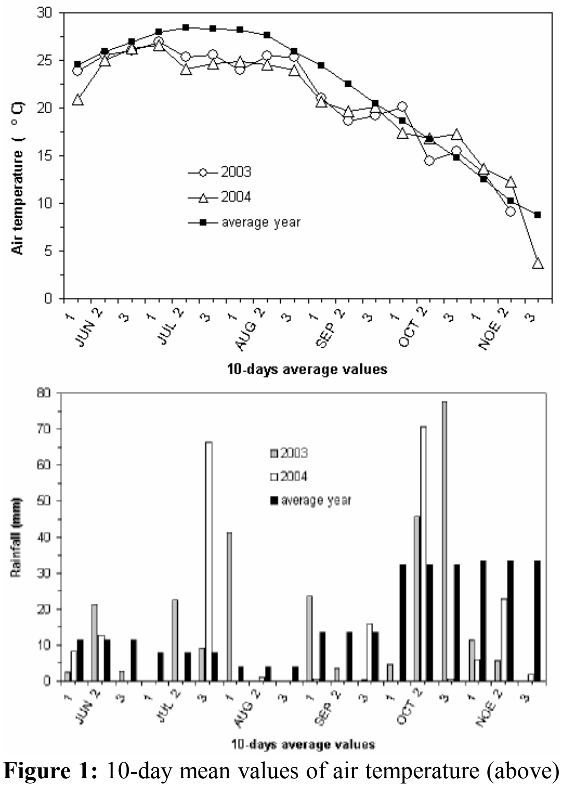


**Figure 1:** 10-day mean values of air temperature (above) and precipitation (below) in the study area in 2003 and 2004 as compared to the climatic values (30 year average).

As illustrated in figure 1, summer was somewhat less hot in both experimental years. Actually, during July and August, the air temperature fluctuated around 25 $^oC$, 4-5 $^oC$ lower than in an average year. During September of both years air temperature decreased rapidly to 20$^o$C (this drop affected growth, see below). After this period and until crop maturation, air temperature fluctuated at average levels. The total rainfall was 270 and 190 mm in the years 2003 and 2004, respectively. In both years, strong rainfalls (60-70 mm) occurred in the period from end July to early August in the study area.

### 3.2 Leaf area index (LAI)

Leaf area index is of great importance for light interception, photosynthesis, growth and final biomass productivity. As presented in Table I and Fig. 2, LAI reached a value around 2 ($m^2$ green leaf ▪ $m^{-2}$ ground area), 45-50 days after crop emergence, which reflects approximately 75% closed canopy. After this period, LAI continued to increase with high rates reaching maximum values of 3.6–5.8 (depending on the particular treatment) that were recorded 30-45 days later. Then, LAI decreased slightly to reach final values around 1.5-2.5 in November.

**Table I:** Leaf area index (LAI, $m^2$ green leaf ▪ $m^{-2}$ ground) for two kenaf varieties (V1: Tainnung 2 and V2: Everglades 41) as affected by two plant densities (D1: 20 and D2: 40 pl. $m^{-2}$) the years 2003-04. Crop 50% emergence refers to the early crop

| J. Day | V1 | V2 | LSD | D1 | D2 | LSD |
|---|---|---|---|---|---|---|
| 144 | 50% emergence 2003 | | | | | |
| 181 | 1.58 | 1.41 | ns | 1.39 | 1.60 | ns |
| 203 | 3.21 | 2.96 | ns | 3.09 | 3.09 | ns |
| 224 | 5.41 | 5.08 | ns | 5.66 | 4.83 | ns |
| 248 | 4.31 | 4.01 | ns | 3.64 | 4.68 | * 0.86 |
| 270 | 4.86 | 4.96 | ns | 4.39 | 5.43 | ns |
| 291 | 3.72 | 3.66 | ns | 3.17 | 4.17 | * 0.72 |
| 312 | 2.50 | 2.93 | ns | 3.00 | 2.43 | ns |
| 157 | 50% emergence 2004 | | | | | |
| 186 | 0.89 | 0.90 | ns | 1.04 | 0.76 | ns |
| 217 | 1.65 | 1.47 | ns | 1.49 | 1.63 | ns |
| 232 | 3.20 | 2.46 | ** 0.669 | 2.81 | 2.84 | ns |
| 252 | 4.41 | 3.27 | ** 0.981 | 3.79 | 3.89 | ns |
| 276 | 3.79 | 3.54 | ns | 3.42 | 3.92 | * 0.486 |
| 304 | 1.51 | 1.52 | ns | 1.38 | 1.65 | ns |

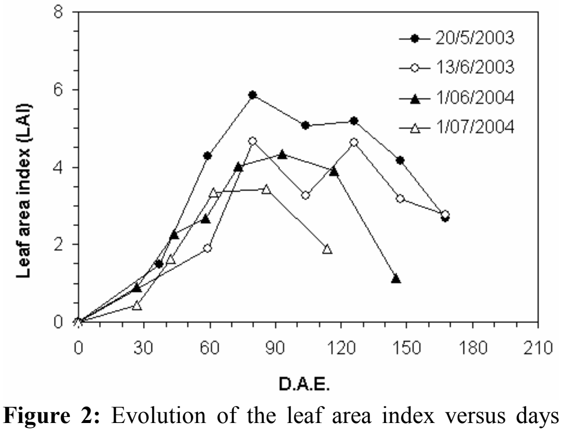


**Figure 2:** Evolution of the leaf area index versus days after emergence of kenaf grown under central Greek conditions for two experimental years and two different sowing dates per each year.

A clear superiority ($LSD_{0.05}$) of the early versus the late crop with respect to LAI was found in both years (Fig. 2). This is attributed to the more time available for growth. Comparing the two kenaf genotypes, a slight superiority of Tainnung 2 was observed in both years (Table I). Plant density had a minimal effect on LAI. As a conclusion, LAI fluctuated at levels satisfactory for optimal growth and plant productivity as it remain above 3 (>85% closed canopy) for a large part of the cropping period.

3.3 Specific leaf area (SLA)

The specific leaf area (SLA, normally expressed in $m^2\ kg^{-1}$) is a morphological plant characteristics; for a given species. Its value changes as a function of environmental conditions (mainly temperature and light intensity) and age of the crop [7]. SLA has received great attention, particularly after the development of models accurately simulating the production of assimilates and their distribution to the various plant organs. SLA decreases with time as the leaves mature, but increases with depth in the canopy as light interception decreases.

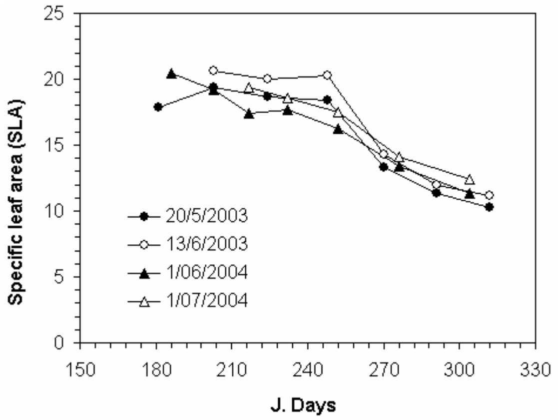


**Figure 3:** Specific leaf area of kenaf grown under central Greek conditions for two experimental years and two different sowing dates.

Fig. 3 shows that the SLA of kenaf remained at high levels, ranging from 18.5 to 21.5 $m^2\ kg^{-1}$ for a large part of the growing period, irrespectively of variety, plant density and sowing time. The somewhat greater SLA values of the late crop comparing to the early one were not significant (Fig. 3). Only after September, SLA decreased exponentially to reach after mid-October (flowering phase) values around 10-11 $m^2\ kg^{-1}$. The decrease in SLA by the end of summer coincides with leaf senescence and a sharp air temperature decrease (by 5°C, especially of the night temperature; see 3.1) in the study area. The further decrease in SLA is attributed to the rapid senescence of the old (thinner) leaves, so that the younger thicker leaves remain on the stand and determine the overall SLA-value. Kenaf is a short day plant (photoperiod sensitive), so the decrease of SLA might be described better by a combined function of radiation (amount and duration) and the thermal time concept. The subject is further studied.

3.4 Biomass production

Fig. 4 and Table II present the increase in the total dry and the stem dry weight (in $t\ ha^{-1}$), respectively, for two sowing dates, two genotypes and two plant populations. It can be noticed that plant density had a minimal effect on growth and final productivity of both kenaf genotypes, in both years (Table II). Apparently, under the prevailing soil and climatic conditions, maximum productivity of kenaf may be obtained even with a population of 200,000 plants $ha^{-1}$.

According to Table II, total dry matter increased with similar great rates throughout the growing period of both cultivars. In order to validate this, the assimilation rates for both genotypes were measured and showed that both cultivars performed high and similar photosynthetic rates ranging from 42 to 50 kg $CO_2\ ha^{-1}\ h^{-1}$, largely depending on the development stage [2].

**Table II:** Total dry biomass ($t\ ha^{-1}$) for two kenaf varieties (V1: Tainnung 2 and V2: Everglades 41) as affected by two plant densities (D1: 20 and D2: 40 pl. $m^{-2}$) in the years 2003 and 2004. 50% emergence refers to the early crop.

| J. Day | V1 | V2 | LSD | D1 | D2 | LSD |
|---|---|---|---|---|---|---|
| 144 | 50% emergence 2003 | | | | | |
| 181 | 1.94 | 1.75 | ns | 1.70 | 1.99 | ns |
| 203 | 4.77 | 4.09 | * 0.64 | 4.42 | 4.44 | ns |
| 224 | 10.25 | 8.95 | ns | 9.89 | 9.31 | ns |
| 248 | 11.85 | 9.89 | ns | 10.08 | 11.66 | ns |
| 270 | 15.87 | 16.15 | ns | 14.73 | 17.29 | ns |
| 291 | 19.03 | 18.83 | ns | 17.56 | 20.30 | ns |
| 312 | 18.43 | 18.76 | ns | 19.73 | 17.46 | ns |
| 332 | 14.32 | 15.25 | ns | 14.52 | 15.05 | ns |
| 157 | 50% emergence 2004 | | | | | |
| 186 | 0.73 | 0.78 | ns | 0.75 | 0.76 | ns |
| 217 | 3.36 | 2.91 | * 0.41 | 3.10 | 3.17 | ns |
| 232 | 6.31 | 5.44 | * 0.83 | 5.87 | 5.88 | ns |
| 252 | 10.13 | 8.68 | ns | 10.17 | 8.63 | * 1.43 |
| 276 | 13.45 | 11.97 | ns | 12.25 | 13.17 | ns |
| 304 | 15.52 | 14.24 | ns | 14.70 | 15.16 | ns |
| 324 | 12.74 | 12.64 | ns | 11.06 | 14.32 | * 2.58 |

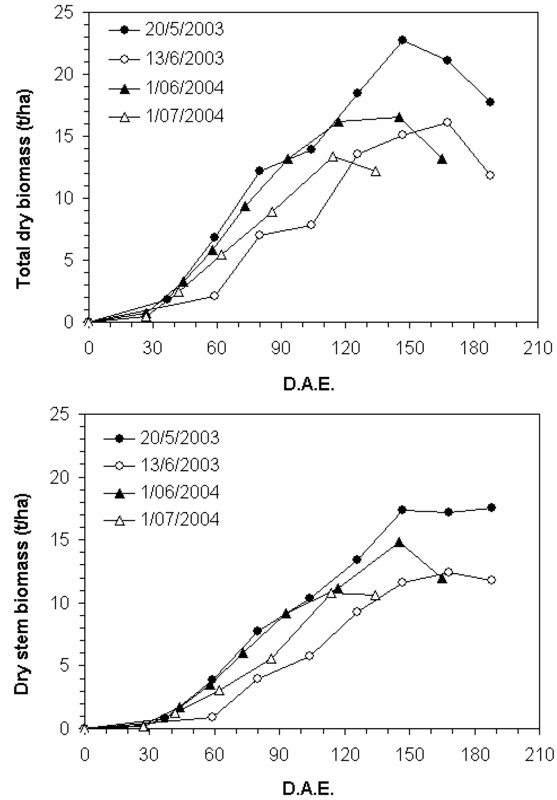


**Figure 4:** Total dry and dry stem biomass ($t\ ha^{-1}$) of kenaf grown under central Greek conditions for two experimental years and two different sowing dates each year. (D.A.E. = days after emergence).

A great superiority of the early versus the late crop was found, performing significantly (*P=0.05*) higher stem and total dry matter production (Fig. 4), confirming that kenaf yield may be drastically reduced (>30%) if sowing is delayed by 2-3 weeks. Since both early and late crops exhibited similar growth rates, the greater biomass production of the early planting can be attributed to the larger period available for growth as long as temperature exceeds 15°C (e.g. mid-October). Actually, after an initial lag period with relative low growth rates, both early and late plantings performed high growth rates reaching until the end of August 240-255 kg $ha^{-1}d^{-1}$ in total dry biomass and 155-185 kg $ha^{-1}d^{-1}$ in dry stem biomass. Maximum total dry biomass was recorded during mid-October (50% of flowering). The maximum stem and total dry biomass yields in 2003 were greater than those in 2004, reaching 16.08 (late planting) to 22.7 (early planting) tons total biomass per ha, and 12.4 (late planting) to 17.5 (early planting) t stem biomass per ha.

## 4 CONCLUSIONS

Based on the above results, it can be concluded that Tainnung 2 and Everglades 41 are two very promising kenaf varieties exhibiting high growth rates (average maximum rates 250 kg $ha^{-1}$ $d^{-1}$) and potential biomass production that may exceed 22 t $ha^{-1}$ (17 t $ha^{-1}$ in dry stems) in the case of early planting and plant population of 200,000 plants per hectare. However, this potential my be drastically reduced if planting and emergence of the crop is delayed by more than 2-3 weeks due to the shortening of the period available for growth. With such a high yield potential under Greek conditions, kenaf seems to be a very promising commodity, and its introduction to future crop rotations in Greece should be seriously taken under consideration, in the frame of the low-inputs and environmental friendly agriculture according to the E.U directives.

## 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".

## 6 REFERENCES

[1] Manzanares, M., Tenorio, J.L., and Eyerbe, L. 1997. Sowing time, cultivar, plant population and application of N fertilizer on kenaf in Spain's central Plateu. Biomass & Bioenergy Vol. 12, No. 4, pp. 263-271

[2] Danalatos, N.G., and Archontoulis S.V., 2004. Potential growth and biomass productivity of kenaf under central Greek conditions: II. the influence of variety, sowing time and plant density. Proceedings of the 2nd World Biomass Conference, 10-14 May, Roma, Italy, pp 319-322.

[3] Danalatos, N.G. and S.V. Archontoulis, 2005. Sowing time and plant density effects on growth and biomass productivity of two Kenaf varieties in central Greece. . Proceedings of the International Conference on Industrial Crops and Rural Development, 17-21 September 2005, Murcia, Spain, pp 889-901.

[4] Alexopoulou, E., Christou, M., Nicholaou, A., and Mardikis, M., 2004. The influence of sowing time and plant populations on kenaf growth and yields. Proceedings of the 2nd World Biomass Conference, 10-14 May, Roma, Italy, pp 304-7.

[5] Alexopoulou, E., Christou, M., Mardikis, M., Chatziathanassiou A., 2000. Growth and yields of kenaf varieties in central Crecee. Industrial Crop and Products 11, 163-172.

[6] USDA (Soil Survey Staff), 1975. Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. Agric. Handbook 466. Washington DC, 754 pp.

[7] Danalatos, N.G., Kosmas, C.S., Driessen, P.M., Yassoglou, N., 1994. The change in the specific leaf area of maize grown under Mediterranean conditions, Agronomie 14: 433-443.