POTENTIAL GROWTH AND BIOMASS PRODUCTIVITY OF KENAF *(HIBISCUS CANNABINUS L.)* UNDER CENTRAL GREEK CONDITIONS: II. THE INFLUENCE OF VARIETY, SOWING TIME AND PLANT DENSITY

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ABSTRACT: The adaptability, growth and productivity of the kenaf varieties Tainnung 2 and Everglades 41 were studied under two different sowing dates and two plant populations in a field experiment carried out under constraint free conditions in central Greece in 2003. Plant height, LAI and biomass production were measured in subsequent harvests throughout the growing period. It was found that both varieties performed similar growth, whereas growth and biomass yields were almost identical for the two different plant populations. On the contrary, significant differences were found with respect to the two different sowing times. The early plantings performed significantly ($P \leq 0.05$) greater growth trates (plant height, LAI, dry matter yield) throughout the growing period, reaching a maximum dry biomass yield of 22.74 t ha^{-1} by mid-October (17.35 t ha^{-1} dry stem), whereas the late crops did not exceed 16.08 t ha^{-1} (11.58 t ha^{-1} dry stem) by November. Considering that in both cases, similar growth rates were recorded during the growing period (maximum values about 240 kg ha^{-1}d^{-1}), the difference in biomass production was attributed to the larger period available for the early crop for maximum growth.
Keywords: Kenaf, biomass production, fiber crops.

1 INTRODUCTION

Kenaf (*Hibiscus Cannabinus* L., *Malvaceae*) is a tropical annual crop, currently receiving an increased attention by the EU for its multiple uses, which were described in detail in the first part of this work [1]. The greatest interest in kenaf arises primarily from its potential as a commercial fiber drop for newsprint pulp and other paper products [2],[3],[4] as well as for its suitability for use in building materials and as a substitute for fiberglass and other synthetic fibers [5],[6]. Kenaf is being introduced into arid regions [7], and is increasingly grown also in dry, marginal soils under water-limited conditions. However, only limited data on growth and productivity of kenaf are available under semi-arid conditions such as those prevailing in the Mediterranean. Among the various kenaf varieties, the late-maturity ones such as Tainnung 2 and Everglades 41 are very productive [8],[9],[10], with maximum total dry matter production of 20-24 t ha^{-1} [8]. Final production of kenaf seems to be determined by the duration of its growing period. Thus, sowing time is very important, and yields may be drastically reduced (30-40%) if sowing is delayed from May to June [11],[12],[13]. However, sowing time depends on the climatic conditions, since below a critical value of 20^{o}C, kenaf growth practically ceases [14],[15]. On the other hand, germination rate increases with increasing air temperature in the range 15-35^{o}C, with greatest rate at 35^{o}C [15]. High plant populations have been reported to exhibit higher fresh and dry matter yields [12],[13], [16],[17],[18],[19], up to 50 plants m^{-2}. However, the greater the plant density the lower the stem diameter [19],[20],[21], and the greater the proportion of long fibers in the stem [5].

The objective of the present work is to determine the potential growth and productivity of the two promising kenaf varieties Tainnung 2 and Everglades 41 under two different sowing dates and two plant populations in central Greece. Potential growth and productivity data under constraint free conditions (water, nutrients, etc) may serve as reference in future studies and analyses at lower hierarchical levels of production with the availability of water and/or nutrients at sub-optimal levels.

2 MATERIALS AND METHODS

The field experiment was carried out on a deep, fertile, loamy soil located in western Thessaly (central Greece) in 2003 (coordinates: 39^{o}25’43.4’’ N, 22^{o}05’09.7’’ E, altitude 107.5 m). The soil is classified as Aquic Xerofluvent [22], having groundwater table fluctuating from some 150-200 cm below the surface in May (artificial drainage) to deeper layers later in the summer. A 2x2x2 factorial completely randomized block design was used in three blocks. The factors were: a) Variety: V_1=”Tainnung-2”and V_2=”Everglades-41”, b) sowing date: S_1=May 20th and S_2=June 13th, and 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. The crop received drip irrigation at frequent intervals (3-5 days, see treatment I_3 in part 1) for full matching the potential evapotranspiration, the latter being determined using a class-A evaporation pan. All plots had received a basal dressing of 50 kg P ha^{-1} and 100 kg K ha^{-1}, while a top dressing of 100 kg N ha^{-1} was applied when the plants reached a height of 0.5 m. The growth (plant height, LAI) and the biomass productivity (leaves, stems, storage organs) of the crop were measured in subsequent harvests throughout the growing period and particularly on the dates: 30/6, 22/7, 12/8, 5/9, 27/9, 18/10, 8/11, and 28/11/2003. 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 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.

3 RESULTS AND DISCUSSIONS

3.1 Climatic conditions

The study area is characterized by a typical Mediterranean climate with hot, dry summers and cool, humid winters [1]. During the growing period of 2003, generally favorable conditions of temperature and radiation prevailed in the study area. Particularly, air temperature fluctuated in the range 23-25°C (optimum level for assimilation) until late August without reaching the high temperature peaks as in an average summer (reduced respiration). Temperature decreased sharply in early September but it remained at relatively high levels (18.6-21.0°C) until mid-October. 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. The prevailing weather conditions are presented into more detail and illustrated in part 1 [1].

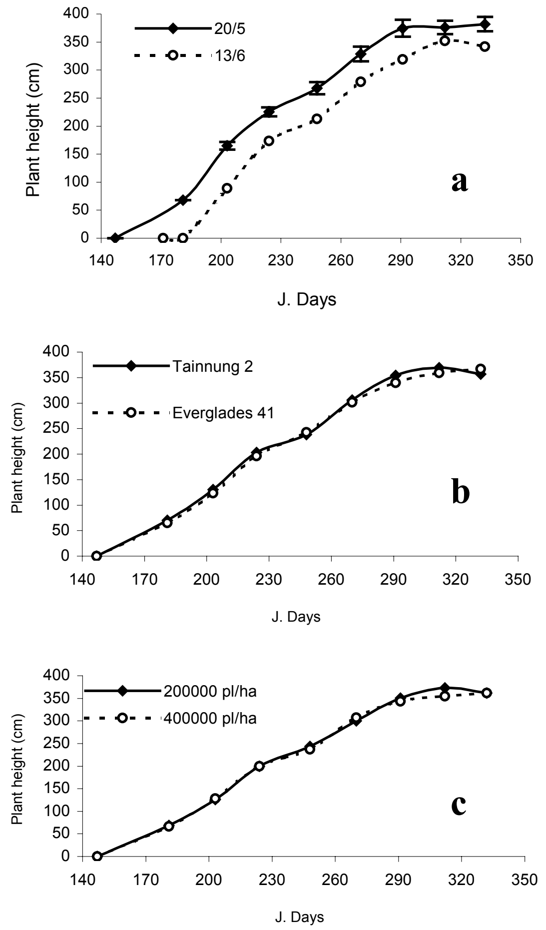

Fig. 1: Plant height of Kenaf grown under constraint-free conditions in central Greece in 2003 for the two different a) sowing dates, b) varieties, and c) plant densities. (Vertical lines represent $LSD_{0.01}$ if applicable).

3.2 Growth Characteristics

Figure 1 illustrates the plant height evolution of Kenaf for the studied varieties, plant populations and sowing times. It can be clearly seen that both varieties performed similar growth rates throughout the growing period (Fig. 1b). On the other hand, plant height evolution was almost identical for the two studied plant populations (Fig. 1c). As expected, significant differences in plant height were found between the early and late plantings, throughout the growing period (*P=0.01*). Concerning average growth rates, it can be observed that after an initial growth with relatively low rates, plant height increased with average rates of about 2.8 cm d^{-1} throughout the growing period. It is noticeable that the growth rates of the early and the late plantings run almost parallel to each other so that the difference in plant height remained almost the same, and the greater final height of the early crop was due to the its larger growing period (Fig. 1a). In line with earlier findings [8],[9], kenaf plants reached their maximum height upon flowering initiation, which was 382 and 342 cm, for the early and the late plantings, respectively (*P=0.01*).

Leaf area index is of great importance for light interception and for photosynthesis. As presented in Fig. 2a, the LAI of the early crop increased with low rates from emergence to the end of June, and with great rates until mid-August to reach a maximum value of 5.8. Then LAI decreased slightly, but until the end of September it remained above 5 (closed canopy), to degrease substantially thereafter, apparently due to the ageing and falling off of the older leaves at the advanced development stages. The LAI of the late crop increased with similar rates and reached by mid-August a peak value of 4.6 (*P=0.05*). Then it fluctuated around 4 (almost closed canopy) until the end of September to decrease substantially thereafter as in the case of the early crop. It should be noticed that both varieties exhibited similar leaf area development, and as illustrated in Fig. 2b, LAI evolution was almost identical for Tainnung 2 and Everglades 41. Finally, the LAI was affected by plant population but only at late development stages (after the end of August; Fig. 2c).

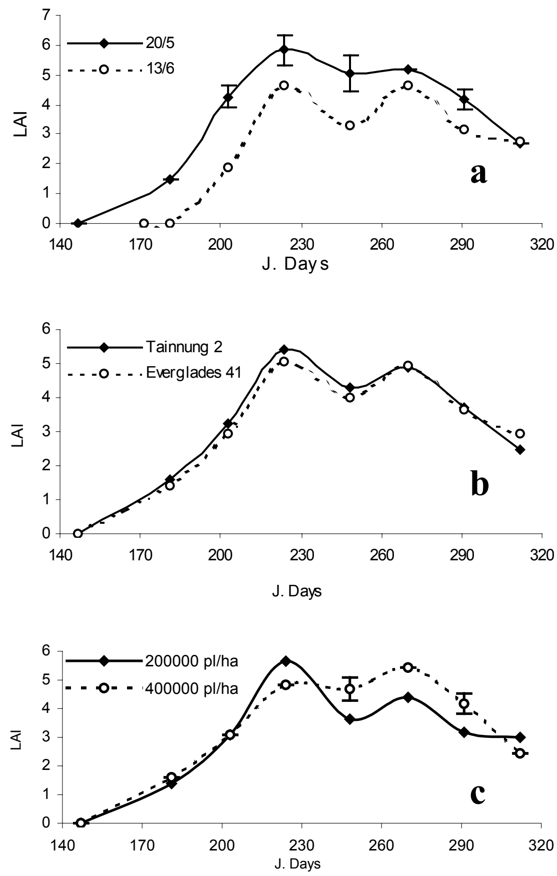

Fig. 2: LAI evolution of Kenaf grown under constraint-free conditions in central Greece in 2003 for the two different a) sowing dates, b) varieties, and c) plant densities. (Vertical lines represent $LSD_{0.01}$ if applicable).

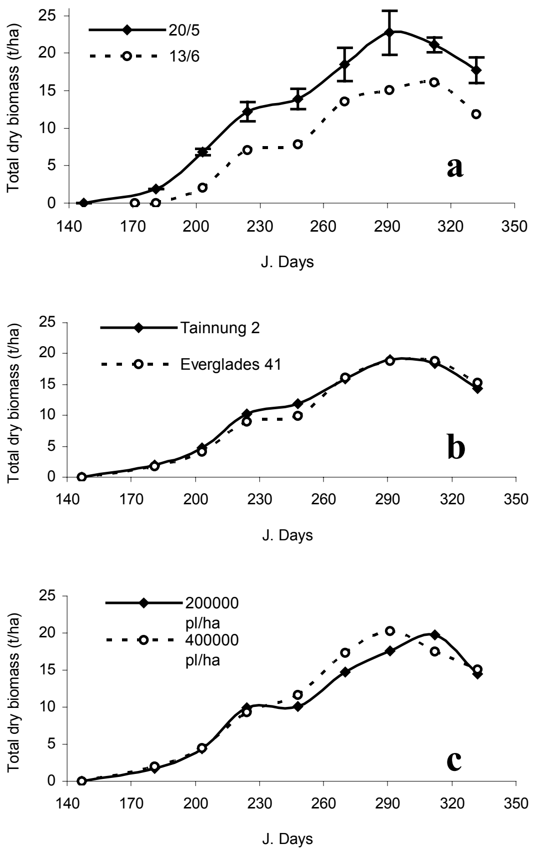

Fig. 3: Evolution of total (above-ground) dry biomass of Kenaf grown under constraint-free conditions in central Greece in 2003 for two different a) sowing dates, b) varieties, and c) plant densities. (Vertical lines represent $LSD_{0.01}$ if applicable).

3.3 Biomass production

Figures 3 and 4 present the increase in the total dry matter and the stem dry matter, respectively, for the two studied varieties, sowing dates and plant populations. It can be observed that plant population had a minimal effect on growth and final productivity of both kenaf varieties despite the slight superiority in LAI of the late crop at advanced development stages (Figs. 3c&4c). Apparently, under the prevailing climatic conditions, maximum productivity of kenaf may be obtained even with a population of 200000 plants ha^{-1}.

Figures 3b&4b show that both stem and total dry matter increased with similar rates throughout the growing period of the studied varieties. This might be explained if both varieties are characterized by similar assimilation and respiration rates. Actually, measured (unpuplished BIOKENAF project) data confirm similar light-response curves and maximum assimilation rate of about 30 kg CO_2 ha^{-1} h^{-1} for both varieties at light saturation and for leaf temperature 25-27°C.

As expected, a superiority of the early versus the late crop was found, performing significantly (*P=0.01*) higher stem and total dry matter production (Figs. 3a &4a), which confirms that kenaf final yield may be drastically reduced (>30%) if sowing is delayed by 2-3 weeks [11],[12,[13]. Figs. 3a & 4a show that both early and late crops exhibited similar growth rates so that 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. end of October; Figs. 3&4). Actually, after a period of establishment and initial growth (about one month), both early and late crops performed growth rates of about 240 kg $ha^{-1}d^{-1}$ until mid-August (160 and 80 kg $ha^{-1}d^{-1}$ for stem and leaf weight, respectively). Due to rather high temperatures and increased respiration needs by the end of summer, lower stem growth rates were recorded (100 kg $ha^{-1}d^{-1}$) and rather high rates of leaf senescence and drop in leaf weight (see also respective drop in LAI) so that overall growth rates were drastically reduced despite an estimated increase in leaf dry mass by 40 kg $ha^{-1}d^{-1}$ during the same period. Most probably, due to the more favourable temperature conditions prevailing in September, the crop continued growing until late October with rates of about 210 kg $ha^{-1}d^{-1}$ in total dry matter and 140-180 kg $ha^{-1}d^{-1}$ in stem dry matter, to reach by the end of October maximum dry biomass production of 22.74 and 16.08 t ha^{-1} for the early and late plantings, respectively, and maximum dry stem yields of 17.35 and 11.58 t ha^{-1}, for the early and late plantings, respectively. The subsequent drop in total dry matter during November (Fig. 3a) is due to the defoliation of the plants, whereas stem dry yield remained almost unaffected (Fig 4a).

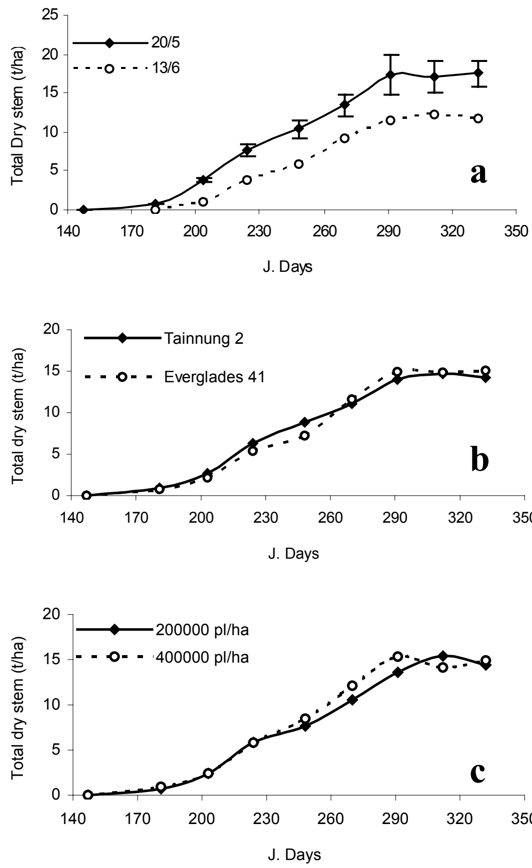

Fig. 4: Evolution of dry stem weight of Kenaf grown under constraint-free conditions in central Greece in 2003 for two different a) sowing dates, b) varieties, and c) plant densities. (Vertical lines represent $LSD_{0.01}$ if applicable).

Finally, it should be noticed that maximum growth rates here are by 15% lower than those recorded in the experiment described in part 1 (viz. 280 kg $ha^{-1}d^{-1}$). This difference is considered to be due to the different orientation of the planting rows, e.g. from east to west in this experiment versus from north to south in the experiment of part 1. The latter orientation is more advandageous before canopy closure since less radiation is lost to the ground but intercepted by the crop canopy. The subject, however, deserves further investigation.

4 CONCLUSIONS

It can be concluded that Tainnung 2 and Everglades 41 are high yielding kenaf varieties exhibiting similar growth rates under constraint free conditions as reflected by plant height, LAI and dry stem and total biomass production. Maximum growth rates may fluctuate in the range 240-300 kg ha^{-1} d^{-1}, resulting in final dry matter production and dry stem yield in excess of 22.5 and 17 t ha^{-1}, respectively. Crop growth as reflected by plant height, LAI and dry matter production is not significantly affected by plant population, so that maximum productivity may be obtained with 200000 plants ha^{-1}. Contrary to plant population, there is a significant effect of sowing time, so that a delayed sowing by 3 weeks may drastically reduce kenaf productivity due to the shorter period available for growth.

5 ACKNOWLEDGEMENTS

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