CHARACTERIZATION OF KENAF POTENTIAL IN PORTUGAL AS AN INDUSTRIAL AND ENERGY FEEDSTOCK – THE EFFECT OF DIFFERENT VARIETIES, SOWING DATES, PLANT POPULATIONS AND DIFFERENT HARVEST DATES, RESULTS FROM THREE EXPERIMENTAL YEARS

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ABSTRACT: The purpose of this work was to study the influence of different varieties, sowing dates, plant populations and the harvest date on the kenaf biomass quality and productivity, in Portugal, in order to access its potential as an industrial and energy feedstock. Biometrical parameters and the productivity of the biomass were evaluated at the end of each growing season, in the period 2003-2005. The following parameters were analysed: main stem height, diameter at the base, measurement of the leaf area index and of the specific leaf area and the total aerial dry weight. Biomass quality was also determined at the end of the growing season. The organic matter content, the nitrogen content, the phosphorus content, the fiber content and the heat of combustion were determined in order to evaluate the potentiality of this crop for pulp, fuel and other industrial purposes. Biometrical parameters, productivity and biomass quality were affected by the sowing date. Plants sowed earlier were higher, with a higher diameter at the base and higher leaf area index, presented higher productivities and higher energy content with lower N and P content than plants sowed later. Fields with higher plant populations also presented higher leaf area index and higher productivities but those plants presented a similar chemical composition to plants obtained from fields with lower plant populations. Everglades 41 presented higher leaf area index and higher productivities than Tainung 2, although this difference was not significant. Both varieties presented similar nitrogen and phosphorus composition. Everglades 41 showed higher energy content and Tainung 2 higher fiber content. Biometrical parameters, productivity and biomass quality were not affected by the date of harvest. The late October/early November harvest dates presented similar productivities and similar biomass quality than the December/January harvest dates.
Keywords: kenaf, crop cultivation, biomass composition

1 INTRODUCTION

Kenaf (*Hibiscus cannabinus* L.) is a short day, annual, herbaceous plant producing high quality cellulose. It is a member of the Malvaceae family along with cotton and okra, and is endemic to Africa [1]. The entire plant can be used to produce pulp for the paper industry. Lower quality paper can be made from the short wood fibers of the inner core, while high quality paper can be made from the long fibers of the bark [2]. Kenaf, as a high yielding plant, is also a potential energy crop when used as a whole crop. The residues from its different industrial processes can, as well, be utilized as energy sources [1].

In the scope of the project Biomass Production Chain and Growth Simulation Model for Kenaf (Biokenaf), supported by the European Union, the purpose of this work was to investigate the influence of crop management on the kenaf biomass quality and productivity, in Portugal, in order to access its potential as an industrial and energy feedstock. To do so, the effects of different varieties, sowing dates, plant populations and the date of harvest in the biomass quality and productivity, were studied.

2 MATERIALS AND METHODS

The experimental fields are situated in the Peninsula of Setúbal, in the south border of the river Tejo, near the estuary and the Atlantic coast (latitude 38º40' N, longitude 9º W, altitude of 50 m) where the climate is warm temperate.

The 2003 – 2005 experimental plots were established in a clayey and alkaline soil. Two kenaf varieties were studied, Tainung 2 and Everglades 41. In 2003, the fields were sowed at 26th June and at 11th July. In 2004, the fields were sowed at 12th July and at 2nd August. In 2005, the fields were sowed at 4th May and at 15th June. A row spacing of 0.50 m was used and two different distances within row were studied: 0.10 m (20 seeds per m^2) and 0.05 m (40 seeds per m^2). P-fertilizer (60 kg $P_2O_5.ha^{-1}$), K-fertilizer (120 kg $K_2O.ha^{-1}$) and ½ N-fertilizer (37.5 kg $N.ha^{-1}$) were applied at the time of sowing. The other ½ N-fertilizer was applied when the plants reached approximately 20 cm height (about one month after sowing). At the end of the growing season, harvest was done at two different dates. In 2003, the fields were harvested at 10th November and at 5th January 2004. In 2004, the fields were harvested at 3rd November and at 7th December. In 2005, the fields were harvested at 18th October and at 5th December.

All the fields were fully irrigated in order to compensate the water deficit of the soil, and to prevent water stress. A randomized block design with three replications was used. Standard basic plots had a surface area of 8 x 4 m^2.

At the end of the growing season the vegetable material was harvested and the following parameters were analysed: main stem height, diameter at the base, measurement of the Leaf Area Index (LAI) and of the Specific Leaf Area (SLA) and the total aerial dry weight. LAI was determined with a Li-3100C Area meter (LI-COR Biosciences). The organic matter content, the nitrogen content, the phosphorus content, the fiber content and the gross heat of combustion were also determined, in order to evaluate the quality of the biomass. The chemical analyses were performed according to the following procedures: a) organic matter: by calcination at 550ºC for two hours, in a muffler furnace (Heraeus Electronic); b) nitrogen content: by the Kjeldahl method (Nitrogen Analyser Tecator 1002, Nitrogen Digester Tecator 2006); c) phosphorus content: by the ascorbic acid method, after digestion of the sample (Spectrometer UV/Vis Cecil 9000); d) fiber: by the Weende method (Fiber Analyser Tecator Fibertec M1017); e) gross heat of combustion: using an adiabatic calorimeter (Parr).

3 RESULTS AND DISCUSSION

3.1 Meteorological Data (2003-2005)

Table I shows a resume of the meteorological data during the three year experimental period.

Table I: Meteorological Data during the three year experimental period

	2003	2004	2005
Minimum temperature (ºC)*	12.4	13.2	13.0
Maximum temperature (ºC)*	21.5	21.4	21.6
Total Precipitation (mm)	812	451	451
Total Evaporation (mm)	1090	1645	1318
Air humidity (%) at 9.00H*	81	73	70
Wind speed (m/s)*	1.6	3.4	3.4
Global solar radiation (kJ/m^2)*	19179	18084	18207

* Average

During the three year experimental period, the average minimum temperature was 12.9ºC and the average maximum temperature was 21.5ºC, with an average of 571 mm total rainfall per year. Average minimum and average maximum temperatures were in accordance with average results 1961-1990, respectively 12.8 and 20.8ºC. 2004 and 2005 were drier years when compared with average precipitation 1961-1990 (753 mm). 2003 was the year with higher precipitation and higher global solar radiation. 2004 was the year where a higher evaporation was observed.

3.2 Biomass Biometrical Parameters

Fig. 1, 2, 3 and 4 show the effect of different sowing dates on the biometrical parameters.

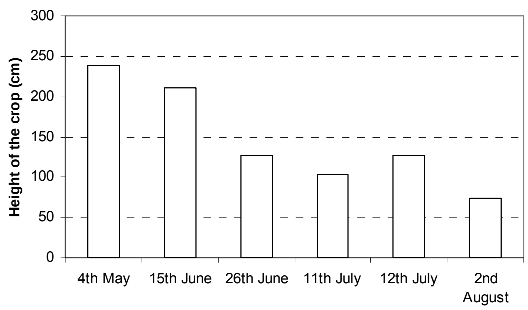

Figure 1: Effect of different sowing dates on the stem height

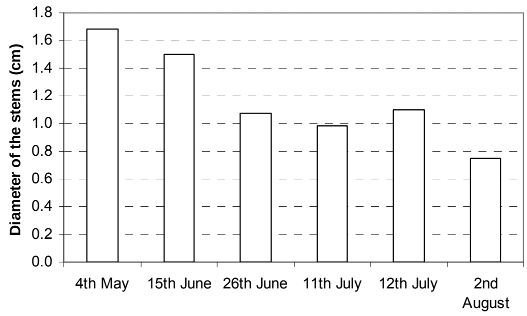

Figure 2: Effect of different sowing dates on the diameter of the stem at the base

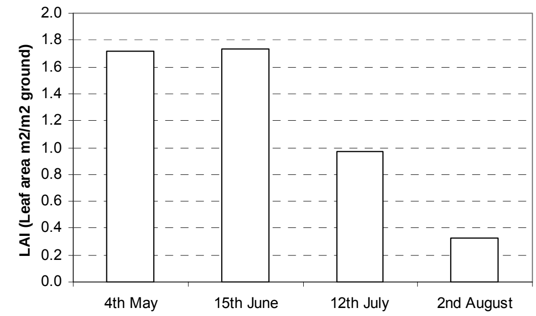

Figure 3: Effect of different sowing dates on the LAI

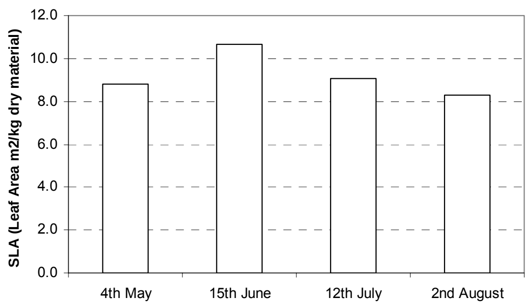

Figure 4: Effect of different sowing dates on the SLA

According to these results, at harvest, plants sowed earlier were significantly higher (Fig. 1), presented a higher diameter of the stem at the base (Fig. 2) and a higher LAI (Fig. 3) than plants sowed later. At harvest, no significant differences were observed in terms of the specific leaf area among different sowing dates (Fig. 4). Nevertheless, it was observed an increase of SLA from plants sowed in the beginning of May to plants sowed in the middle of June and then a decrease to plants sowed in July and August (Fig. 4).

Fig. 5, 6, 7 and 8 show the effect of different varieties, different plant densities and different harvest dates on the biometrical parameters.

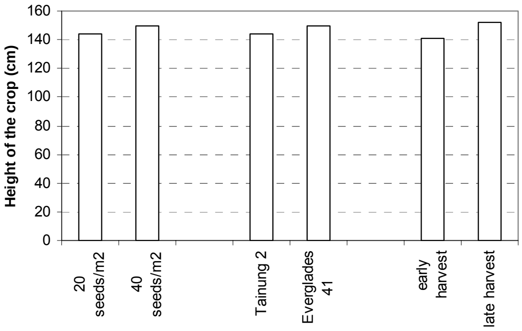

Figure 5: Effect of different varieties, different plant densities and different harvest dates on the stem height

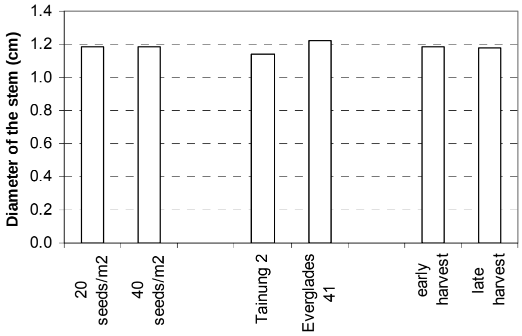

Figure 6: Effect of different varieties, different plant densities and different harvest dates on the diameter of the stem at the base

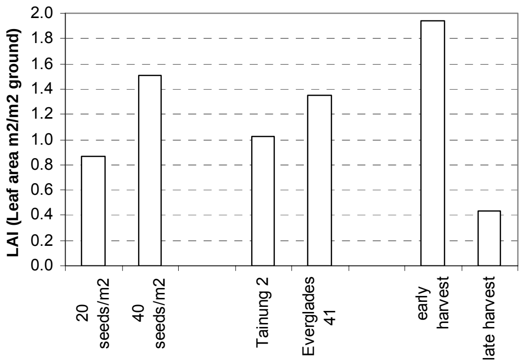

Figure 7: Effect of different varieties, different plant densities and different harvest dates on the LAI

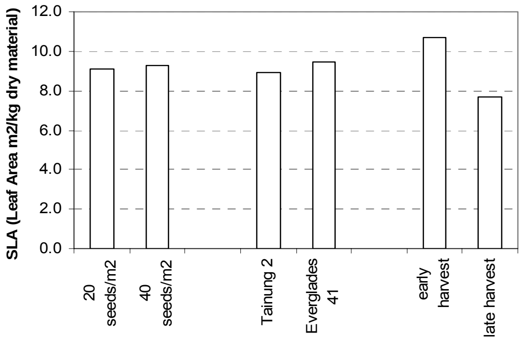

Figure 8: Effect of different varieties, different plant densities and different harvest dates on the SLA

According to these results, at harvest, in terms of the stem height (Fig. 5) and in terms of the diameter of the stem at the base (Fig. 6), no significant differences were observed between Tainung 2 and Everglades 41, between plants obtained in fields sowed with different densities and between plants harvested at different dates. In terms of the LAI, plants obtained in the fields sowed with the higher plant density (40 plants/m^2) presented higher values than those obtained in the fields sowed with the lower density (20 plants/m^2), due, logically, to the higher number of plants/m^2 (Fig. 7). Everglades 41 presented higher LAI than Tainung 2, due, mainly, to the shape of the leaf (Fig. 7). The early harvest presented also higher LAI than the late harvest (Fig. 7). This significant decrease was due to the fall of the leaves that occurred between the early and the late harvests. No significant differences were observed, in terms of the SLA, between Tainung 2 and Everglades 41 and between plants obtained in fields sowed with different densities (Fig. 8). Plants harvested earlier showed higher SLA (Fig. 8) because at the late harvest a major part of the leaves had already fallen down.

3.3 Biomass Productivity

Fig. 9 shows the effect of different sowing dates on the productivity of the fields.

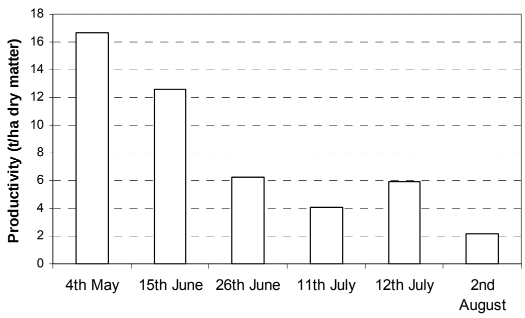

Figure 9: Effect of different sowing dates on the productivity of the fields

Fig. 10 shows the effect of different varieties, different plant densities and different harvest dates on the productivity of the fields.

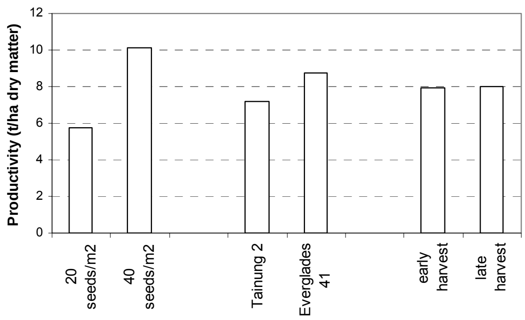

Figure 10: Effect of different varieties, different plant densities and different harvest dates on the productivity of the fields.

According to the results expressed in Fig. 9, fields sowed earlier presented significantly higher productivities than fields sowed later. So, according to these results, at the pedoclimatic conditions of South Portugal, kenaf should be sowed in early May.

According to Fig. 10, Everglades 41 presented higher productivities than Tainung 2, although this difference was not significant. This result was already expected since both varieties belong to the same group of the late maturity varieties. This group is considered to be more productive than the group of the early maturity varieties, due to the fact that they have a longer vegetative phase [3].

Productivities obtained in the fields sowed with the higher plant density (40 plants/m^2) were higher than those obtained in the fields sowed with the lower density (20 plants/m^2) (Fig. 10). This difference was statistically significant, although Kenaf reduces its population during the growing season, being this effect more pronounced in the fields sowed with a higher density [4].

Productivities of the fields at October/November are similar to the productivities obtained at December/January (Fig. 10).

At the end of the growing season, the bast fiber represents 35-40% of the dry weight of the mature defoliated plant and the core represents the balance.

3.4 Biomass Quality

Table II, show the moisture content, the nitrogen content and the phosphorus content of the plant material at the end of the vegetative cycle.

Table II: Moisture content (%), nitrogen content and phosphorus content (% dry matter) of Kenaf, in core and bark, at the end of the growing season.

Parameters	Core	Bark
Moisture (%)	79 ± 4	75 ± 5
Nitrogen (% dm)	0.35 ± 0.25	0.79 ± 0.36
Phosphorus (% dm)	0.30 ± 0.17	0.36 ± 0.18

dm – dry matter

In terms of moisture content, nitrogen content and phosphorus content, at harvest, no effects were observed due to the different varieties, the different plant populations and the different harvest dates [5]. In terms of the moisture content, no effect was also observed due to the sowing date [5].

In terms of nitrogen and the phosphorus content, at harvest, plants sowed early, presented significant lower nitrogen and phosphorus content than plants sowed later (Fig. 11).

At harvest, bark material presented less moisture and higher nitrogen and phosphorus content than core material (Table II). Nevertheless those differences are not statistically significant.

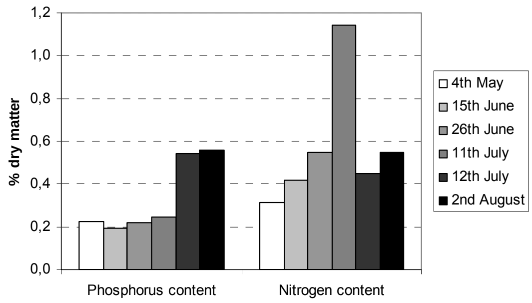

Figure 11: Effect of different sowing dates on the nitrogen and phosphorus content

The fuel quality of the harvested biomass was evaluated in terms of the organic matter content and in terms of the gross heat of combustion analyzed at the end of the growing season (Table III).

Table III: Organic matter content (% dry matter) and Gross heat of combustion (kJ.g^{-1} dry matter) of two varieties of Kenaf, Tainung 2 and Everglades 41, in core and bark, at the end of the growing season

	Tainung 2		Everglades 41	
	Core	Bark	Core	Bark
Organic matter (% dry matter)	95	90	95	90
Gross heat of combustion (kJ.g^{-1} dry matter)	15	12	16	14

According to Table III, core is more suitable for energy purposes than bark, due to its higher organic matter content and due to its higher gross heat of combustion, at harvest.

In terms of the organic matter content, at harvest, no effects were observed due to the different varieties (Table III), the different plant populations, the different sowing dates and the different harvest dates [5].

In terms of the gross heat of combustion, at harvest, no effects were observed due to the different plant populations and the different harvest dates [5]. But, Everglades 41 presented higher energy content than Tainung 2 (Table III) and the calorific values of the plants decrease with late sowing (Fig. 12).

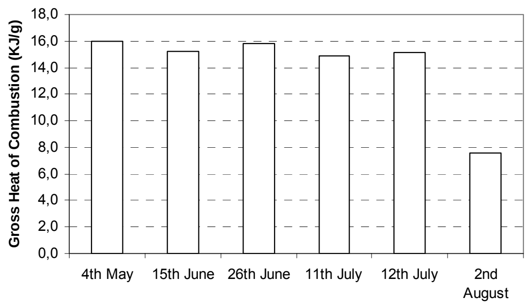

Figure 12: Effect of different sowing dates on the gross heat of combustion

In order to evaluate the quality of kenaf biomass for pulp production, the fiber content was determined at the end of the growing season (Table IV).

Table IV: Fiber content (% dry matter) of two varieties of Kenaf, Tainung 2 and Everglades 41, in core and bark, at the end of the growing season.

Tainung 2		Everglades 41	
Core	Bark	Core	Bark
40	38	37	33

In terms of the fiber content, there were no significant differences among plants obtained in fields sowed at different dates and between plants obtained in fields sowed with two different plant densities [5]. Harvest date didn't affect the fiber content, also [5]. Tainung 2 presented a higher fiber value than Everglades 41, at harvest (Table IV). Core material presented a higher fiber value than bark material, but this difference was not significant (Table IV).

4 CONCLUSIONS

Stem height, stem diameter, leaf area index, productivity, energy content, nitrogen and phosphorus content were affected by the sowing date but not by the harvest date. Plants from fields sowed earlier presented higher productivities, higher energy content and low nitrogen and phosphorus content than plants from fields sowed later.

Fields with higher plant populations presented higher leaf area index and higher productivities but those plants presented a similar chemical composition to plants obtained from fields with lower plant populations.

Everglades 41 presented higher leaf area index and higher productivities than Tainung 2, although this difference was not significant. Both varieties presented similar nitrogen and phosphorus composition. Everglades 41 showed higher energy content and Tainung 2 higher fiber content.

According to the results presented and discussed, kenaf, at the pedoclimatic conditions of South Portugal, should be sowed in early May. To obtain a higher production, a higher seed density should be used in the fields (e.g. 40 seeds/m^2). Nevertheless, a detailed studied is needed in order to conclude if the increment in productivity is sustainable.

Before taking a decision concerning industrial utilization, assays at pilot level should be done. Figures obtained concerning actual biomass characterisation values of the crops tested must be considered as indicative ones.

There is a need for further integration of agricultural practices and the energy and pulp production sectors. Energy crops for power and pulp purposes require quality specifications which, in some cases, are not fully met yet.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

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