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

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ABSTRACT: The purpose of this work was to study the influence of different varieties, sowing dates, plant populations and the date of harvest on the kenaf biomass quality and productivity, in Portugal, in order to access its potential as an industrial and energy feedstock. The productivity and the quality of the biomass were evaluated along the growing season. The following parameters were analysed: total aerial dry weight, organic matter content, nitrogen content and phosphorus content. At the end of the growing season, the fiber content and the heat of combustion were determined in order to evaluate the potentiality of this crop for pulp and fuel purposes. Productivity and biomass quality were affected by the sowing date but not by the plant population. Plants sowed earlier presented better productivities and better quality for fuel and pulp purposes than plants sowed latter. Tainung 2 and Everglades 41 presented similar productivities and mineral composition. The bark of Everglades 41 showed better quality for fuel purposes and the bark of Tainung 2 better quality for pulp purposes. There were no differences between the core material of both varieties. Productivity and Biomass quality were affected by the date of harvest beeing the early January harvest date the one to be chosen.
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. During the experimental period, 26th June 2003 – 5th January 2004, the average minimum temperature was 15.6ºC and the average maximum temperature was 23.0ºC, with a total 440 mm rainfall.

The experimental plots were established in a clayey and alkaline soil. Two kenaf varieties were studied, Tainung 2 and Everglades 41. The fields were sowed at 26th June and at 11th July. 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). 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 5 x 8 m^2.

During the growing season the vegetable material was harvested and the total aerial dry weight, the organic matter content, the nitrogen content, the phosphorus content, the fiber content and the gross heat of combustion were determined, in order to evaluate the productivity and the quality of the biomass. The chemical analysis were performed according to the following procedures: a) organic matter: by calcination at 550ºC for two hours, in a muffler furnace; b) nitrogen content: by the Kjeldahl method; c) phosphorus content: by the ascorbic acid method, after digestion of the sample; fiber: by the Weende method; gross heat of combustion: using an adiabatic calorimeter.

3 RESULTS AND DISCUSSION

3.1 Biomass Productivity

Fig. 1, 2 and 3 show the differences, in terms of the dry matter productivities between fields sowed at two different dates, between fields with different varieties and between fields sowed with different plant densities.

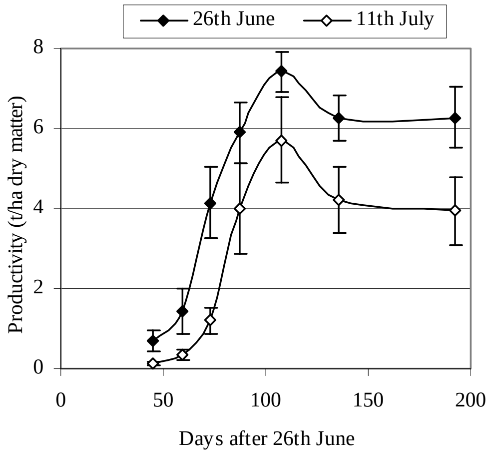

Figure 1: Productivities obtained in fields sowed in two different dates

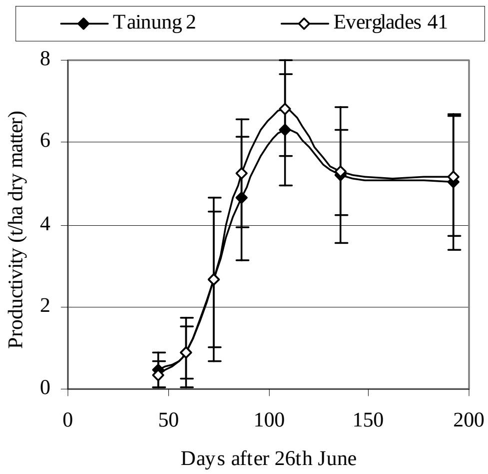

Figure 2: Productivities obtained in fields with different varieties

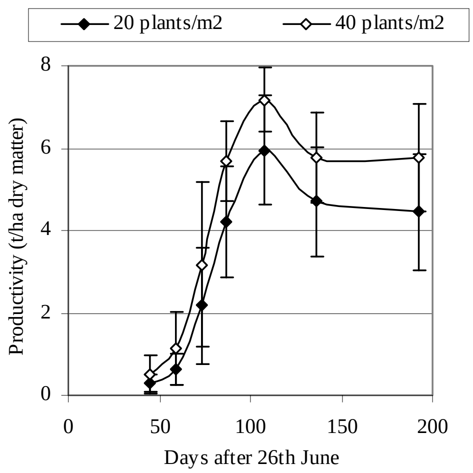

Figure 3: Productivities obtained in fields sowed with different plant densities

According to these results there were only statistical significant differences between fields sowed at two different dates. Plants sowed earlier (26th June) presented significantly higher productivities than plants sowed 15 days later (11th July). 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). However, this difference was not significant, chiefly because Kenaf reduces its population during the growing season, beeing this effect more pronounced in the fields sowed with a higher density [4]. By the end of the growing season, the fields sowed with the highest density had only 26 plants/m^2 (population reduction, 35%), while the fields sowed with the lowest density presented 17 plants/m^2 (population reduction, 15%).

The highest productivities, in all the fields, were obtained at 108 days after the 26th June sowing date (13th October 2003). After this date, the productivities lowered mainly due to the loss of the leaves. At the end of the growing season, the bast fiber represents 34-40% of the dry weight of the mature defoliated plant and the core representss the balance. The productivities obtained were also significantly lower than those obtained by other mediterranean partners of the Biokenaf project [5]. These lower productivities were mainly due to the difficulties experienced during the first year of the project, namely, due to the late sowing date and the heat wave experienced during the 2003 Summer [6].

3.2 Biomass Quality

Tables I, II and III show the moisture content, the nitrogen content and the phosphorus content of the plant material along the vegetative cycle.

Table I: Moisture content (%) of Kenaf, in leaves, core and bark, along the growing season.

Days after 26th June	Leaves	Core	Bark
45	83 ± 0	89 ± 1	89 ± 1
59	82 ± 2	86 ± 3	84 ± 2
73	83 ± 1	85 ± 2	80 ± 1
87	80 ± 0	79 ± 3	79 ± 1
108	81 ± 1	80 ± 3	79 ± 1
136	-	80 ± 2	77 ± 2
192	-	47 ± 8	32 ± 9

Table II: Nitrogen content (% dry matter) of Kenaf, in leaves, core and bark, sowed at 26th June (S_1) and at 11th July (S_2), along the growing season.

Days after 26th June	Leaves		Core		Bark	
	S_1	S_2	S_1	S_2	S_1	S_2
45	4.8	3.9	1.4	3.1	1.4	3.1
59	2.2	4.1	0.3	1.2	0.6	1.1
73	2.0	3.0	0.3	1.0	0.4	0.9
87	2.2	3.3	0.4	1.1	0.6	1.1
108	2.4	2.6	0.2	0.8	0.7	1.0
136	-	-	0.1	0.8	0.8	1.6
192	-	-	0.2	0.9	1.1	1.2

Table III: Phosphorus content (% dry matter) of Kenaf, in leaves, core and bark, along the growing season.

Days after 26th June	Leaves	Core	Bark
45	0.29 ± 0.02	0.26 ± 0.03	0.26 ± 0.03
59	0.32 ± 0.03	0.24 ± 0.03	0.19 ± 0.01
73	0.26 ± 0.03	0.19 ± 0.03	0.32 ± 0.04
87	0.31 ± 0.01	0.18 ± 0.02	0.20 ± 0.01
108	0.41 ± 0.03	0.18 ± 0.02	0.18 ± 0.01
136	-	0.22 ± 0.04	0.31 ± 0.03
192	-	0.14 ± 0.03	0.25 ± 0.03

In terms of moisture content, nitrogen content and phosphorus content, there were no statistical significative differences between the two varieties (Tainung 2 and Everglades 41) and between plants obtained in fields sowed with two different plant densities. In terms of phosphorus content, there were also no significant differences between plants obtained in fields sowed at two different dates. In terms of nitrogen content, plants sowed first, presented significant lower nitrogen content than plants sowed fifteen days later. Plants sowed earlier also presented, at the begginning of the growing season, lower moisture content than plants sowed fifteen days later. But this difference was only statistically significant for the core material. Nevertheless, at the end of the growing season there were no differences, in terms of the moisture content, between plants obtained in fields sowed at two different dates.

Moisture content decreased along the growing season, being lower at 192 days after sowing. At this date, bark presented less moisture than core material. Nitrogen and phosphorus content also decreased along the growing season. Nitrogen and phosphorus content are significantly higher in leaves than in stems. Although not significant, bark material presented higher nitrogen and phosphorus content than core material.

The fuel quality of the harvested biomass was evaluated in terms of the organic matter content, analysed along the growing season, and in terms of the gross heat of combustion analysed at the end of the growing season (Tables IV and V).

Table IV: Organic matter content (% dry matter) of Kenaf, in leaves, core and bark, sowed at 26th June (S_1) and at 11th July (S_2), along the growing season.

Days after	Leaves		Core		Bark	
26th June	S_1	S_2	S_1	S_2	S_1	S_2
45	91	89	85	80	85	80
59	91	87	92	83	90	84
73	91	90	93	87	91	89
87	91	90	95	90	91	90
108	90	90	95	89	90	88
136	-	-	93	89	91	87
192	-	-	94	92	89	81

Table V: Gross heat of combustion ($kJ.g^{-1}$ dry matter) of two varieties of Kenaf, Tainung 2 and Everglades 41, in core and bark, sowed at 26th June (S_1) and at 11th July (S_2), at the end of the growing season.

Days after	Tainung 2				Everglades 41			
26th	Core		Bark		Core		Bark	
June	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
136	17.6	16.4	13.1	12.9	17.8	15.9	14.8	13.7
192	17.5	16.7	13.2	13.1	17.8	16.3	14.6	13.9

In relation to the organic matter content (Table IV), the biomass presented better quality for energy purposes at the end of the growing season when the ash content was lower. In terms of the gross heat of combustion, there were no significant differences between the plants harvested 136 days after 26th June (early November) and the plants harvested 192 days after 26th June (early January). According to Tables IV and V, the bark presents an inferior quality for energy purposes than core, due to its lower organic matter content and due to its lower gross heat of combustion, at the end of the growing season.

In terms of organic matter content, there were no statistical significative differences between the two varieties (Tainung 2 and Everglades 41) and between plants obtained in fields sowed with two different plant densities. In terms of the gross heat of combustion, the bark of Everglades 41 presented significant higher values than the bark of Tainung 2, but the core of the two varieties presented similar values. In terms of this fuel quality parameter, there were no significant differences between plants obtained in fields sowed with two different plant densities.

Plants sowed first, presented significantly higher organic matter contents and higher calorific values than plants sowed fifteen days later.

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 VI).

Table VI: 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.

Days after	Tainung 2		Everglades 41	
26th June	Core	Bark	Core	Bark
108	32	33	32	37
136	41	38	36	30
192	42	39	39	33

In terms of the fiber content, there were no significant differences between plants obtained in fields sowed at two different dates and between plants obtained in fields sowed with two different plant densities. The bark of Tainung 2 presented a significant higher fiber value than the bark of Everglades 41, at the two last harvests (136 days and 192 days after 26th June). The fiber content of the core material of Tainung 2 and Everglades 41 are similar. There were, no significant differences between the fiber content of the bark material and the fiber content of the inner core material, for both varieties. There were no significant differences among the fiber content of the biomass obtained at 108, 136 and

192 days after sowing.

3.3 Harvest Date

The selection of the harvest date is very important because, according to the results presented in Figures 1, 2 and 3 and in Tables I to IV, has strong effects on the biomass productivity and biomass quality. Kenaf biomass is usually harvested after leaf fall, because, unlike traditional agricultural crops that are grown for their seed, kenaf is grown solely for its vegetation stalk. The standing of the kenaf plants in the fields until the defoliation of the stems, also allows the return of nutrients from the fallen leaves, namely, nitrogen, phosphorus and other minerals, back to the soil. According to Figures 1, 2 and 3, and although the highest productivity was obtained at 108 days after the first sowing date, the crop should only be harvested after this date, when all the leaves have already fallen. From the results obtained, there were no differences between the productivities obtained at 136 days and at 192 days after the first sowing date.

In order to meet the processing needs, as for the energy sector as for the pulp production sector, by the time of harvest the crop should have low mineral and water contents. In terms of the biomass quality, the composition of the biomass changed over the course of the growth period as nitrogen, phosphorus and water content decreased and organic matter increased (Tables I to IV). In relation to the nitrogen content, the phosphorus content, the organic matter content, the fiber content and the heat of combustion, there were no significant differences between the early November harvest and the early January harvest. However, the lowest values for the moisture content were registered at 192 days after the first sowing. Considering this result, it is possible to conclude that the best harvest date should be at the begginning of January, in the climatic conditions dominant at experimental site.

4 CONCLUSIONS

Productivity and biomass quality were affected by the sowing date but not by the plant population. Plants sowed earlier (26th June) presented better productivities and better quality for fuel and pulp purposes than plants sowed latter (11th July).

Tainung 2 and Everglades 41 presented similar productivities and in terms of mineral composition there were no differences between the two varieties. The inner core material of the two varieties, presented also, the same quality for energy and pulp purposes. However, the bark of Everglades 41 presented a higher calorific value than the bark of Tainung 2 and the bark of Tainung 2 a higher fiber value than the bark of Everglades 41.

Productivity and biomass quality were affected by the date of harvest. Regarding the requirements of the energy and pulp production industries, the early January harvest date should be the one to be chosen.

Before taking a decision concerning industrial utilization, assays at pilot level should be done. Figures obtained concerning actual quality 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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