1 INTRODUCTION

Kenaf is an annual fiber crop of great interest for both the production of industrial raw materials and as bio-fuel under the pedoclimatic conditions of southern Europe. The main reasons for considering kenaf as a high productivity multi-purpose non-food of increasing importance for Europe are listed below:

- It is a multi-purpose crop and can provide raw material for industrial and energy applications. The 30-40% of the stem (bark) can be used for several high value fibre applications (1) while the 60-70% of the stem (core) among several industrial applications (2, 3) can be used for thermochemical process (combustion pyrolysis and gasification).

- The high biomass potential and the low inputs of the crop. Dry matter yields came up to 26 t/ha (4, 5, 6, 7, 8, 9, 10), have been reported and are comparable to the ones have been reported in similar works worldwide.

- It offers alternative land use and can be used in a crop rotation. Kenaf can be cultivated in rotation system. This is very important in areas devoted to monocultures (cotton, cereals) and although are supplementary irrigated performing very low yields, which are unsustainable without the EU policies.

- It is an annual non-food crop. As an annual crop, it is quite similar to other conventional field crops with respect to cultivation and harvest. The production and management systems are being developed for agricultural annual non-food crops such as kenaf, bringing thus costs of delivery down to commercially accepted levels. As an annual crop can be used where crop rotation is indispensable due to local crop disease, weed competition or soil fertility degradation.

Although kenaf is being cultivated worldwide mainly for fiber production, in Europe there is no much data concerning the adaptability, growth and biomass yields of the crop. There are only few references regarding the agronomic aspects of the crop at European pedoclimatic conditions. In these research activities the adaptability and biomass productivity of few kenaf varieties have been tested in southern Europe and high biomass yields, up to 26 t/ha (4, 5, 6, 7, 8, 9, 10), have been reported and are comparable to the ones have been reported in similar works worldwide.

In March 2003 a European Network was started entitled “Biokenaf-Biomass Production Chain and a Growth Simulation Model” aiming at addressing the sustainable yielding potential, the alternative industrial bio-products as well as the fuel quality of kenaf as a non-food crop, under certain cultivation techniques, in South Europe. The consortium of the project is presented in Table I.

The overall objective of the project is to introduce and evaluate kenaf as a non-food crop through an integrated approach for alternative land use in South EU that will provide diversified opportunities for farmers and biological materials for the “bio-based industries” of the future. The overall objective will be achieved through the following specific objectives:

- To determine the sustainable yielding potential of kenaf, as a non-food crop in all Southern EU countries.
- To develop a dynamic crop growth simulation model for kenaf yields predictions.
- To evaluate the effect of harvest timing and storage methods on quality of raw material.
- To evaluate the suitability of kenaf both for selected industrial and energy applications.
- To carry out environmental assessment and LCA and make scenarios for alternative land use.
- To conduct an economic evaluation of the whole production chain of the crop for alternative land use.
energy applications (combustion, gasification and pyrolysis) on the whole crop and the core fiber remaining after removal of the high value bark fiber.

Environmental impact assessment for the whole production chain of the crop and Life Cycle Analysis (LCA) taking into account both the industrial and thermochemical energy applications of the crop will be conducted in WP6. The valuable information that will be collected in the WP2, WP3, WP4, WP5 and WP6 will be used in WP7 for the cost analysis of kenaf as a “non-food crop” in comparison to other annual traditional crops.

In WP8, all the above-described work packages will be used as a base for the development of a Handbook and a Booklet for kenaf. In the Handbook and the Booklet apart from the project information, an extensive literature review will be included to define the state-of-the-art of kenaf in Europe.

3 RESULTS AND DISCUSSION

3.1 Adaptability and biomass productivity of kenaf in Southern EU countries

During the first two growing seasons a total number of 32 field trials were established in Greece, Italy, Spain, Portugal and France. The main factors that evaluated in all theses trials were sowing dates, plant densities, varieties, nitrogen rates and irrigation rates.

It should be pointed out that the achieved dry matter yields differ a lot ranging from 2 to 28 t/ha depending on the specific prevailing climatic conditions in the site of the trial, the time of sowing and of the applied cultural techniques.

Further to that it was found that the early sowing (end of April to middle of May) resulted in higher dry yields, while when the sowing postponed until the middle of June the achieved yields at the end of the growing season were two to three times lower (18 t/ha in Greece, end of April, 6 t/ha in Portugal – middle of July).

![Figure 1: Mean dry yields (t/ha) as affected by sowing date, plant density and variety (averaged overall sites).](image)

It was also recorded that fields with plant density of 400,000 plants/ha in general yielded higher compared to fields with density of 200,000 plant/ha. The superiority of the high density over the low density in terms of yields was usually small and for this not statistical significant (Figure 1). A clear superiority of high over the low density it was recorded in Spain with yields 26 t/ha and 21 t/ha, respectively.

A total number of six varieties were tested (five of them were late-maturity varieties while one was early-maturity
variety). It was generally reported that the late-maturity varieties (Tainung 2, Everglades 41, SF 459, Gregg, Dowling) were more productive compared to the early maturity variety (G4), since they have longer growing cycle (Figure 2). More specifically, the dry yields of the late varieties came up to 19 t/ha, while of the early variety came up to 10 t/ha (central Greece).

Figure 2: Dry matter yields (t/ha) for six tested varieties (five late and early) in Greece.

In most sites that the factor irrigation was tested it was found that there is clear and strong effect of applied water to the achieved dry yields. The most clear effect of water to dry yields was recorded in Spain that the plots that fully irrigated gave a productivity that was four times higher compared to the one recorded in the non-irrigated plots.

On the contrary, the increase of the nitrogen application found to have small or no effect on the development and yields of the crop. The most clear effect of the different nitrogen rates on yields was recorded in Spain that the produced yields were 2.8 (no fertilized), 5.9 (medium fertilized) and 6.2 t/ha (high fertilized). The mean dry yields (averaged overall sites) as affected by the factors irrigation and fertilization are presented in Figure 3.

Figure 3: Mean dry yields (t/ha) as affected by irrigation and fertilization.

3.2 Development of the growth simulation model

In the first year of the project, the main module of the kenaf model of the kenaf model was developed, for the qualification of the dry biomass produced per plant component as a result of radiation and photosynthesis, whereas water and nutrient availability were assumed at optimum level. In the second year, the module for the qualification of the water-limited production potential of kenaf was developed and is described. Thus, in this section crop performance is assumedly conditioned by the availability of light, temperature and water; the supplies of nitrogen and mineral elements to the crop are assumed not to constrain crop performance.

3.3 Harvesting of kenaf

For a period of two subsequent years two fields trials of 2 ha each were established in north east Italy. The cultivation of the crop in both trials was carried out by using common machinery that already existed in the area of the trial. In both years the harvesting of the crop was carried by using a chopper that is commonly used in the area of the trial to harvest maize during September. The chopped material had a size 34 mm. The choice if this size it was based on the needs of the Italian company KEFI producing among others insulation mats. Soon after the harvesting the chopped material was transported to KEFI premises for separation (bark and core) and production insulation mats from the bark. It should be pointed out that the harvesting is strongly depended on the market demands. This kind of harvesting was very efficient and the only weak point was the low bulk density of the chopped material that doesn’t make long transport economically convenient. Chopped material from kenaf was sent to A&F and BTG for testing other industrial applications of kenaf as well as the suitability of the crop for combustion, gasification and pyrolysis.

3.4 Industrial uses crop

In the first year of the project it was concluded, based upon a market and literature review that two were the most promising applications for kenaf: the application of the bast fibre in insulation mats (like in the case of KEFI company) and the application of the core as absorption particles. In the second year laboratory fractioning experiments were performed as well as a small trial on industrial scale with the chopped material received from north east Italy. It was found harvesting of the crop in winter has the advantage that the harvesting material has low moisture content but at the same time the long fibres of the bark lose the 60% of the their maximum strength. So, these fibres cannot be used in textiles or other applications that strong fibre bundles are needed, but it can be used in insulation mates that do not have to bear any load and where no strength of the bundles is needed.

The absorption experiments with kenaf in humid air of 90% showed higher equilibrium moisture content than for other natural fibres probably due to the higher pectin content compared to other natural fibres. The high moisture absorption increases the risk of microbiological affection of the fibres and this will be further investigated in the third year of the project.

3.5 Thermo chemical applications

During the first two years of the project samples of Kenaf that were grown in southern Europe were analysed regarding ash melting behaviour in order to determine the suitability for thermal conversion. It was found that the ash content of 2% for core and 2.4 % for whole stem, while the ash melting behaviour for both core material and whole plant had IDT above 1270°C, which is high for an herbaceous energy crop. Other crops like Miscanthus, Switch grass and Arundo have clearly lower IDT’s. This means that for energy purposes Kenaf has a clear advantage for thermal conversion.
During the third year, the following research activities will be executed (in line with the time frame of the work plan) will be combustion tests (with the Kenaf samples in a fluidised bed combustor), gasification tests (with the Kenaf samples in a fluidised bed gasifier) and pyrolysis tests (with the Kenaf samples in a rotating cone pyrolyser).

3.5 Environmental impact assessment and LCA

A questionnaire was produced in the first year of the project aiming to collect data from all partners that carry out field trials that will be used for the environmental impact assessment and LCA of the crop compared to other annual conventional crops. In the second year of the project some ecological criteria were studied (net avoided use of fossil energy, net avoided emission of greenhouse gases, net emission of acidifying gases, emission of ozone depleting gases, emission of nitrogen and other nutrients/minerals to soil and water, emission of pesticides, erosion, groundwater depletion, use of resources and water production and utilization) in order to compare the ecological sustainability and use of kenaf in southern EU regions and to compare the ecological sustainability of kenaf with the sustainability of other crops and of other energy sources.

3.6 Economic analysis of the crop

In the first year of the project a questionnaire regarding the cost production of the crop was distributed and the consortium and the data that was received were used to carry out a first estimation of the production of the crop. It was found out that high yields of 18 t/ha may be economically viable for kenaf as an energy crop on large fields (with relatively low fixed costs per hectare). Moderate yields of 15 t/ha could be economically viable for kenaf if the production price is 65euro/odt. In the third year of project the production cost will be estimated for each country.

3.7 Handbook and booklet for kenaf

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REFERENCES