Kenaf: a possible multi-purpose crop for the Ord River Irrigation area

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Kenaf is a tropical crop which shows promise for use in paper pulp, oil and protein production; the young growth is a nutritious animal feed.

It has proved a highly productive crop in the Ord River Irrigation area, raising speculation about its possible use as a commercial crop there. In this article a CSIRO research worker describes the properties of kenaf and reviews research results with the crop on the Ord.

Kenaf (Hibiscus cannabinus) is an herbaceous annual closely related to the hollyhock. It is grown in many countries where its bark fibre is used in the same way as jute for the production of sacks and sacking.

Studies in the United States during the 1960s established that kenaf offered considerable promise for paper pulp production, and with raw materials for paper running low, research has been directed towards commercial utilisation of kenaf.

About 97 per cent of the world’s paper pulp now comes from wood but it seems unlikely that the world’s forestry resources can continue to meet the growing demand. Per capita annual consumption of paper in the USA is now 290 kg with increases up to 450 kg predicted by the year 2000. Australian per capita annual consumption has risen too, from 91 kg in 1961-1964 to 130 kg in 1972/73, and the increase is expected to continue.

Results of a research programme have been sufficiently encouraging to suggest that kenaf could be grown as a multipurpose crop in northern Australia. More research is necessary, however, to establish the technology for utilising kenaf, and to determine the economics of production of those end-products which appear technically feasible.
Trial plots of kenaf have been grown on the Ord since 1972 and intensive studies at Kimberley Research Station and the CSIRO Forest Products Laboratory, Melbourne, during the past two years have indicated its possibilities as a multipurpose crop. All the aboveground parts of the plant can be used—the stem for paper pulp, the leaves and young growth as animal feed, the juice as a protein source, and the seed as a source of protein and oil.

Kenaf is a tropical plant which grows best with mean daily temperatures of 30 to 35°C. Growth is slow at low temperatures and the plant is readily killed by frost. At present, kenaf is used only for the production of kenaf fibre for cordage and sacking. The fibre is generally produced by retting, a process in which the stems are soaked in water and bacterial and fungal action decompose the softer bark tissues, leaving the fibre bundles intact.

Recently, increasing use has been made of ribboning machines which remove the bark, reducing the volume of material to be retted. However, the need for considerable hand labour to cut and treat the stems to remove the fibre has so far restricted production to countries where labour is relatively cheap.

Kenaf is normally grown with plant populations of 200,000 to 500,000 plants per hectare and cultivars grown for fibre produce unbranched stems to a height of 6 m at these planting densities. Although cultivars have been produced which are largely insensitive to day-length, most kenaf cultivars are photosensitive and will flower only when day-length is less than about 12.5 hr.

The flowers are pale yellow with purple centres, and are borne on short stalks in the leaf axils on the upper portion of the stem. The seed develops in five-locular capsules with four to five seeds per capsule. The capsules of cultivated varieties are generally indehiscent and remain intact for several weeks after reaching maturity. The seed is small (1.5-3.3 g/100 seeds), black in colour and subreniform in shape.

Kenaf seed contains 16 to 22 per cent oil and 30 to 33 per cent protein. The oil has a similar fatty acid composition to cotton seed oil but does not contain gossypol, a polyphenolic compound in cotton seed which causes the oil to darken. Table 1 gives average fatty acid compositions of a number of seed samples of kenaf grown at the Kimberley Research Station, with typical values for cottonseed, sunflower and soyabean oils.

**Kenaf on the Ord**

The Ord climate is monsoonal with two well defined seasons; a wet season extending from about mid-November to March and a dry season from April to November. Average annual rainfall is 770 mm, of which about 90 per cent falls during the wet season. The amount and distribution of rainfall is too uncertain for rain-fed crops and irrigation is necessary to ensure satisfactory crop yields.

Field studies began at Kimberley Research Station in December, 1972, to assess the potential of kenaf for the production of paper pulp in the Ord Irrigation Area. There have shown that with irrigation, kenaf can be grown throughout the year. The crop has proved relatively simple to grow, with best growth in the wet season and slowest growth during the dry when temperatures are lower. Establishment has not been a problem even on rough seed beds.

Highest stem yields have been obtained with plant populations of 300,000 to 500,000 plants/ha, which required 15 to 20 kg/ha of seed. Sowing the crop on 1·1 m beds with 5 rows on a 20 cm spacing has given higher yields than single rows sown on 1 m ridges.

A range of kenaf cultivars has been tested and has shown wide diversity in growth habit, response to day-length and production. Use of day-length insensitive cultivars which flower only when the crop is approaching maturity seems necessary to obtain highest yields of stem material during the dry season. Day-length is less than 12.5 hours between mid-February and mid-October at the Ord and short-day cultivars sown during this period flower soon after emergence. This provides an opportunity to obtain seed from such cultivars as they are only 1·5 to 2 m high at maturity and can be direct headed.

The most successful cultivar for year-round production at the Ord has been cv. G-4 which is day-length insensitive and takes 7 to 10 months to reach maturity. It has also shown good resistance to lodging, an important characteristic on the Ord where very strong winds and heavy rain can occur during cyclonic conditions and convectional storms. Plants may grow to 6 m with little or no branching and give high yields of stems and seed. An area of 0·3 ha produced seed yields of 1·290 kg/ha during the 1973-74 wet season.

The dry weight yields of foliage, bark and woody core after 90-180 days and at maturity for wet and dry season crops of cultivar G-4 are shown in Table 2. Both sowings were irrigated as necessary to supplement rainfall. Superphosphate at 250 kg/ha was applied to each sowing and urea was applied at the rate of 370 and 550 kg/ha to the dry and wet season crops respectively.

Whole kenaf plants have a high crude protein content and dry matter digestibility in early growth stages, as indicated by the data in Table 3. This crop was sown on May 24, 1974, fertilised with superphosphate at 250 kg/ha and urea at 650 kg/ha and harvested after 40, 50, 60 and 70 days' growth. It made slow growth because of below-average temperatures but the crude protein production of 7·8 kg/ha/day for 70 days is comparable with that produced by a good quality lucerne hay crop.

Kenaf removes large amounts of nutrients from the soil, particularly nitrogen and potassium, and a crop yielding 3 tonnes/ha of foliage, 4 tonnes/ha of bark and 4·5 tonnes/ha of woody core in 150 days will take up about 210 kg/ha nitrogen, 13 kg/ha phosphorus and 180 kg/ha of potassium. Responses of kenaf to nitrogen and other nutrients are now being determined for the Ord.

Root knot nematodes are a possible pest and are considered to pose a serious threat to commercial development in the USA. Nematodes have been found on experimental sowings on Cununurra Clay at Kim-
berley Research Station but do not appear to have seriously affected growth. It is planned to measure their effect on crop yields and investigate possibilities for controlling the pest by crop rotations.

The leaf-eating caterpillar Spodoptera litura has proved a problem in some crops during the late wet season (February and March) and in the mid dry season (August and September). The problem is most serious during early growth, as plants damaged at the 2 to 3 leaf stage generally die. After the crop has grown to 1 to 1.5 m there is less risk of serious damage and it is possible that natural predators and parasites would maintain adequate control in commercial crops.

**Pulping**

Kenaf stems produce a pulp generally superior to hardwood pulps, and comparable in many respects with softwood pulps. Hardwoods, such as the Australian eucalypts, contain relatively short fibres averaging about 1 mm in length. Softwoods, such as spruce and radiata pine, contain fibres averaging 3 to 4 mm in length. Because of their longer fibre length softwood pulps produce papers with better tearing strength and enhance the creasing and folding properties of fibreboard containers.

Kenaf stems contain both short and long fibres. Bark fibres average 2 to 6 mm in length and can be used to produce a quality paper with good strength characteristics. The woody core fibres are short (0.5 to 0.7 mm) and produce a pulp comparable in strength properties with an average quality hardwood pulp; the bonding properties are good but the tearing strength is rather low.

The whole kenaf stem can be pulped or the bark and woody core can be separated and pulped separately but it seems probable that separation would be favoured commercially. The bark and wood are readily separated and because of their differing lignin content the two fractions require different concentrations of chemical and different cooking times. If pulped separately they can be blended at a later stage and the blend arranged to give pulps with different strength characteristics suitable for various grades of paper and paperboard. Both fractions are readily pulped by the soda process, giving pulp yields of about 50 per cent.

Pulps from both the bark and woody fractions drain rather slowly, the effect being more noticeable with pulps from the woody fraction. The rate of drainage is an important characteristic of pulps and in this respect kenaf pulps are inferior to both softwood and hardwood pulps.

Bark is the more valuable fibre component of the stem material and constitutes 35 to 40 per cent of the stem dry weight. It has a relatively low lignin content of 9 to 10 per cent and requires only a relatively mild pulping process. Promising results have been obtained with conventional pulping processes but a wide range of other pulping procedures are being examined. In

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*A mature crop of cultivar G-4 over 5 m in height*
view of the low lignin content it seems probable that bleaching techniques may be sufficient to remove the lignin and this could reduce processing costs. The ratio of bark to wood is inversely related to growth rate and is thus highest in the dry season when growth is slowest.

The wood fraction of the stem has a lignin content of 20 to 25 per cent, comparable with that of hardwoods. Conventional chemical pulping techniques produce a pulp comparable in strength characteristics with average hardwood pulp but investigation of the possibility of producing mechanical pulps is being undertaken.

Pulping tests conducted by the CSIRO Forest Products Laboratory on material harvested at Kimberley Research Station have indicated that paper making properties of the kenaf bark and wood are unaffected by the time of the year when the crop is grown, by plant population between 100,000 and 500,000/ha or by age of crop between 90 and 150 days. This means that date of sowing, date of harvesting and rate of seeding can be based solely on agronomic considerations and can be planned to ensure a maximum economic return.

Freshly harvested kenaf stems have a moisture content of 80 to 84 per cent, much of which can be removed by passing the stems through sugar-cane rollers. Preliminary studies indicate that pulping characteristics are improved if some of the stem juice is removed by crushing, a process which also reduces the amount of chemical required for pulping.

**By-products**

A number of by-products could become available if kenaf was established commercially.

**Leaf material**

In the sowings reported in Table 2 the dry weight yields of foliage (all leaves plus the top 60 cm of the stem) ranged from 1.4 to 4 tonnes/ha. The crude protein content of this material was about 20 per cent, which suggests that it could be a nutritious animal feed.

The data in Table 3 suggests that kenaf could be utilised as a high protein fodder crop. Dry matter digestibilities are high and indicate that the fibre content is low even in the 70 day material. For poultry and pig rations a minimum crude protein content of 16 to 17 per cent and a maximum crude fibre content of about 27 per cent would allow kenaf meal to be substituted for lucerne meal, and these requirements should be met if the crop is harvested within 60 days of sowing. In preliminary trials there was excellent regrowth on plots cut between 40 and 70 days after sowing and it should be possible to obtain at least two and possibly more cuts from the one sowing.

In digestion trials with sheep in Thailand, kenaf leaf meal was compared with lucerne leaf meal as a protein supplement for rice straw. The energy and protein in the kenaf-supplemented diet had higher digestibility although nitrogen retention was lower than with the lucerne/rice straw diet.

**Seed**

Seed of day-length sensitive cultivars can be obtained by direct heading if the crop is grown during the dry season, although the stems are tough and the bark fibres tend to wrap around the beaters. Harvesting can also cause some discomfort to operators as fine hairs from the surface of the capsules lodge readily in the skin and can cause a painful irritation.

Seed production of day-length insensitive cultivars poses a problem because of the height of the crop but trials are planned to check whether sugar-cane harvesters can be modified to harvest stems and seed.

Kenaf oil appears likely to be suitable for cooking and as a salad oil. The polyunsaturated fatty acid content (linoleic acid) is too low for it to be used for polyunsaturated margarines but it would appear suitable for the vegetable fraction of margarine blends.

The meal left after oil extraction has a crude protein content of about 35 per cent and has potential as a protein supplement in stock feeds. Tests are being made to assess its value for poultry feeding.

**Wood**

If kenaf was used commercially for paper pulp production some of the wood fraction could be surplus to requirements. This could be used...
in the manufacture of particle boards, as it has a low basic density of about 0.13 to 0.25 g/cc and is light in colour, two characteristics favourable to particle board production.

**Juice**

Up to 450 kg of juice is removed when a tonne of fresh stems is passed through cane rollers. This contains about 18 kg of solids, of which about 3 kg is crude protein, with the balance consisting of sugars and ash. About 20 per cent of the solids can be extracted by heating or the addition of acid, which denatures the proteins, reduces their solubility in water and leads to their precipitation. The precipitate is a protein-rich concentrate containing about 40 per cent crude protein and should have a high feeding value.

A possibility that has not been explored is feeding the juice directly to pigs. This is now done with expressed grass juice in Scotland, where pigs use protein and carbohydrates directly from the grass juice, thus saving costs of precipitation and drying.

**Prospects for kenaf in the Ord Irrigation Area**

Kenaf has proved a highly productive crop in the Ord Irrigation Area. Year-round growth is possible and would allow continuous production for export or supply to a local pulp mill. Limited stockpiling might be necessary at the mill to cover the wet season, when harvesting is uncertain.

Preliminary estimates of production costs indicate that kenaf could be produced at a cost comparable with that of eucalypt woodchips exported to Japan. Production costs, however, will be very dependent on nitrogen fertiliser costs.

High freight costs in northern Australia, and the low basic density of the stems, make it unlikely that kenaf could be shipped as a raw product unless it could be compressed into some form of high density pellet. If it is assumed that raw kenaf chips could be sold at the same price as eucalypt wood chips they would be worth about $30/tonne F.O.B. on a dry weight basis. In contrast, chemical paper pulp is worth about $250/tonne and newsprint about $330/tonne. The processed product is thus in a much better position to cover freight costs.

At present, the only prospect for using kenaf by farmers in the Ord River Irrigation Area is as a fodder crop in the early growth stages. However, it could possibly be developed as an oil seed crop.

The studies on kenaf indicate that it could be used for the production of paper pulp and a number of by-products, including edible oil, leaf meal and an oilseed meal. However, full utilisation would require the establishment of a pulp mill and factory facilities for processing the leaf and seed. This would require a large investment in plant and the availability of power, transport and port facilities. It would also require a long-term firm commitment to the sowing of an area of at least 10000 ha.

### Table 1—Average fatty acid composition (%) of kenaf, cottonseed, sunflower and soybean oils

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>Type</th>
<th>Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Kenaf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cottonseed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sunflower</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soybean</td>
</tr>
<tr>
<td>Palmitic</td>
<td>Saturated</td>
<td>22</td>
</tr>
<tr>
<td>Saturated</td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>Oleic</td>
<td>Unsaturated</td>
<td>31</td>
</tr>
<tr>
<td>Linoleic</td>
<td>Polyunsaturated</td>
<td>44</td>
</tr>
<tr>
<td>Linolenic</td>
<td>Polyunsaturated</td>
<td>...</td>
</tr>
</tbody>
</table>

### Table 2—Dry weight yields (tonnes/ha) of foliage, bark and woody core for a wet and a dry season sowing of Kenaf variety G-4

<table>
<thead>
<tr>
<th>SOWING</th>
<th>No of days from sowing to harvest</th>
<th>Dry weight yields (tonnes/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Foliage</td>
</tr>
<tr>
<td>Dry season</td>
<td>90</td>
<td>3.0</td>
</tr>
<tr>
<td>(sown July 9)</td>
<td>193</td>
<td>4.0</td>
</tr>
<tr>
<td>Wet season</td>
<td>98</td>
<td>2.6</td>
</tr>
<tr>
<td>(sown Dec 20)</td>
<td>183</td>
<td>2.4</td>
</tr>
</tbody>
</table>

### Table 3—Dry matter and crude protein yields, crude protein contents and dry matter digestibilities of kenaf crops harvested 40, 50, 60, and 70 days after sowing

<table>
<thead>
<tr>
<th>Days after sowing</th>
<th>Dry matter yields (kg/ha)</th>
<th>Crude protein yields (kg/ha)</th>
<th>Crude protein (%)</th>
<th>Dry matter digestibility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>820</td>
<td>214</td>
<td>26.2</td>
<td>74.8</td>
</tr>
<tr>
<td>50</td>
<td>1430</td>
<td>286</td>
<td>35.0</td>
<td>74.5</td>
</tr>
<tr>
<td>60</td>
<td>2870</td>
<td>504</td>
<td>17.6</td>
<td>69.2</td>
</tr>
<tr>
<td>70</td>
<td>4400</td>
<td>547</td>
<td>12.4</td>
<td>68.9</td>
</tr>
</tbody>
</table>

* Estimated by the in vitro technique