KENAF—AN ANNUAL PULP CROP FOR THE UNITED STATES

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More than a decade ago, kenaf (*Hibiscus cannabinus L.*) was recognized as having favorable pulping characteristics. Results of subsequent field trials immediately indicated a good cropping potential. Much additional effort, largely to the exclusion of other promising species, has, in recent years, been expended to ascertain if kenaf can become a commercially feasible new crop.

Traditionally, kenaf is best known as a source of cordage fiber for twine, rope, bagging, textile fiber, and the like. Workers in the United States note its possibilities as cattle feed [23] and its actual use as support for pole beans [5]. A wealth of information on production, pests, breeding, and equipment is provided in the *Proceedings of the Second International Conference on Kenaf* [15]. Three papers dealing with kenaf for pulp appear in this proceedings. In 1967, a conference on kenaf for pulp was held in Florida, and attendees observed field harvestng and laboratory pulping demonstrations. The purpose of the Conference was to bring together individuals and organizations who were interested in the production and utilization of kenaf as a pulping raw material for exchange of information and ideas . The Proceedings of the Conference have been published[14]. While many problems of production, storage, and processing remain to be solved, these are not considered to be insurmountable.

TAPPI, the U.S. counterpart of IPPTA, has a Nonwood Plant Fibers Committee which serves to provide for an exchange of information on the use of nonwood fibrous plant raw materials in the manufacture of pulp and paper. Membership on the committee is made up of pulp and pulp equipment representatives and of crop and utilization scientists. Kenaf, because of its favorable potential, has been emphasized by the Committee since its conception. This committee sponsored the Florida conference in 1967.

Interest among the U.S. pulp industry in nonwoody fiber sources, especially kenaf the front runner seems to be rising because of :

(a) the existence of localized wood shortages particularly hardwoods,

(b) the scarcity of labor and high costs of labor and mechnical harvesting,

(c) severalfold potential yield advantage of kenaf or other annuals over trees,

(d) increased per capita consumption of pulp products, and

(e) competition for wood by other users such as the building industry and recent increases in lumber prices.

A few pulp companies are actively studying the feasibility of utilizing kenaf fiber in their operations. Others are expected to do the same when some of the problems such as nematode susceptibility and storage are more nearly resolved. Kenaf has potential as an important new crop in the United States.

UTILIZATION OF KENAF FOR PULP

For many years the U.S. Department of Agriculture has given consideration to the use of nonwoody plant fibers in pulp and paper. Much of the early effort was concerned with the possible use of crop residues, especially sugarcane bagasse and grain straw. In 1956, a new approach was taken in which new plant species were appraised strictly as sources of pulp. These species would, then, have to have suitable characteristics to compete with wood for pulp, and to compete with established field crops for acreage in a given region. Kenaf seems to meet all of the criteria.

Utilization studies on kenaf have been reported in a series of papers published in TAPPI. In the initial paper, kenaf was given a five-point rating—the best possible—which covered botanical aspects, chemical composition, fiber dimensions, individual inspection, and maceration yield [9]. The average fiber lengths, respectively, for the bast and woody core were 2.6 and 0.5mm. The maceration yield was 50 per cent. This favorable initial evaluation, coupled with good agronomic traits, led to further study of composition [10], fiber dimensions, pulping processes [1], and blends [2].

An excellent 1969 planting of kenaf at Glenn Dale, Md., part of which will be consumed in compositional studies at the USDA's Northern utilization Laboratory, Peoria, Ill., is shown in Figure 1.

A detailed summary of the utilization and pulping characteristics of kenaf has been included in a USDA Production

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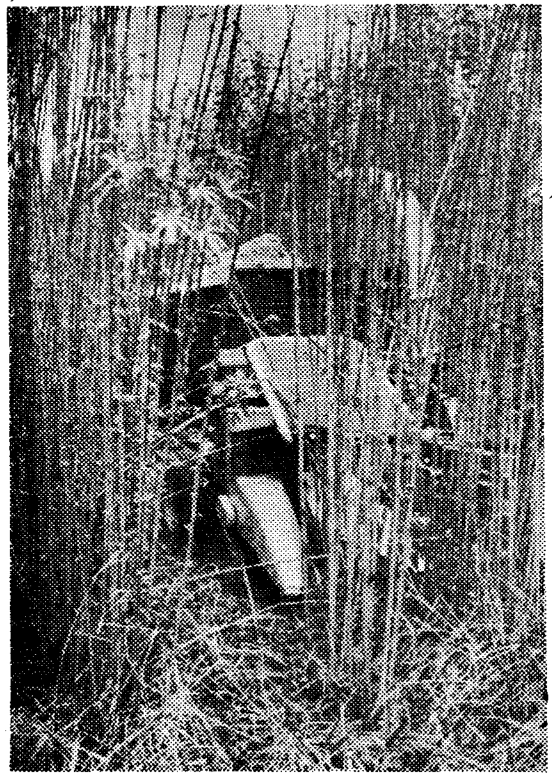

Figure 1.—Dr White examines a kenaf plant from a 1969 Maryland planting. Topped, air-dried plants of the variety Everglades 71 were provided from this planting for utilization studies.

Figure 2.—Harvesting a tall (about 6 m) crop of kenaf in Florida with a one-row forage chopper and a self-unloading trailing silage wagon.

Research Report [18]. A few summary remarks will be made here.

In general, fiber dimensional characteristics are intermediate to those of soft—and hardwoods. Strength properties in comparison with those of wood can in part be attributed to these intermediate fiber dimensions. In a study of 3 pulping processes at 3 levels of chemical concentration, greater pulp yields were obtained with less consumption of chemical with a neutral-sulfite process (alkaline). Initial freeness for the kenaf pulps ran about 200 ml SR lower than the commercial wood pulps. Kenaf pulps were superior to hardwood pulps in strength.

Selected kenaf pulps have been blended with selected wood pulps[2]. A reasonably wide range of properties can be achieved through such blends. Studies of blends for specific types of paper are needed.

No specific type of Paper has been determined as preferable for the incorporation of kenaf fibers. However, kenaf should prove to be a very versatile raw material for pulp and papermaking.

CULTURE

Varieties.—Most of our field research has included Everglades 71 and frequently its sister variety Everglades 41. These varieties resulted from intensive breeding efforts on kenaf as part of a cordage fiber research program which was discontinued in 1965. Anthracnose—resistant plants from Salvadorian (P.I. 207883) serve as the basis for these varieties ([28]) as well as for several Cuban (C) and Guatemalan (G) varieties. Varietal tests have generally included Everglades 71, Everglades 41, C-108, C-2032, Cubano, G-4, and G-45. Additional varieties including HC 583 and HC 584 from India; SH/15R, GR 25/63, and ST/11760 from South Africa; certain G varieties and others have not been sufficiently tested for yield and disease resistance. Yields for several varieties mentioned above have been reported [17].

The variety Everglades 71 is recommended for U.S. plantings which involve only one variety. It has deeply lobed leaves; requires about a 12½ hour day for floral initiation; and is resistant to anthracnose, and consistently high-yielding, with good standability. Seed production can be achieved only in the very lowest latitudes in the U.S. We usually obtain seed of photosensitive varieties from Haiti or El Salvador.

Planting dates.—In adapted areas, which include all of the nonmountainous areas in southeastern United States, kenaf can be planted as soon as danger of a killing frost is past. Some soil-warming enhances quick emergence and rapid seedling growth. There should be ample moisture in a firm seed bed at planting. At most South eastern locations, planting can be done before May 1. Planting should be delayed somewhat beyond May 1 at more northerly locations. In north Florida, it may be possible to plant by mid-or late March.

Planting rates and methods— Rates will depend on row width, germination percentage of seed, and the desired intrarow density. Usually, a rate of 5.6 to 11.2 kg/ha of high quality seed is ample. Seed with a germination percentage below 80 is not recommended for use. As the row width is increased, the seeding rate usually will decrease. The rate should be increased for more northerly locations to help compensate for less plant growth. At Glenn Dale, Md., a population of 197,000 or more plants per ha resulted in the best drymatter yield [20]. A seeding rate of 6.7 kg/ha should achieve this population. Allowance for less than 100 percent germination and some field mortality is essential. Some varieties seem to yield well when grown in low densities. In a Florida test for example, the varieties Cubano and BG 52-75 yielded approximately 22.4 metric tons with 53,100 plants and 20.2 metric tons with 82,750 plants per ha in rows 48 cm apart [13]. BG 52-75 responded the same way in a Louisiana test. [17]. More consideration needs to be given to this apparent varietal response to plant density.

Conventional planting equipment commonly used for grain sorghum or corn with the proper plates can be used to plant kenaf. Outlets in grain drills can be plugged as appropriate to give the desired row width. With drills, there is a tendency to plant the seed too deep. A planting depth of 1.3 to 2.5 cm is preferred for most conditions. Careful attention must be given to suitable plates for row planters. Little has been done to determine the best size and shape of openings in planter plates for kenaf seed. Round openings such as those used for sorghum or small-seeded soybean varieties have been used sucessfully. The relative new flexi-type planters do a better job of seed placement and often permit more row-width adjustment than older types of planters.

Row width.—Dry-matter yields from row-width studies at a given location provide the best guide as to the proper row-width. However, other factors such as weed control and adaptability of harvesting equipment to specific widths must be considered. In a detailed multi-year study in North Carolina, the highest dry-matter yields were obtained from rows 36 cm apart [3]. This row width may not provide adequate weed control on a large-field scale basis. Thus, because no effective herbicide is available, it may be necessary to use 51 or 76 cm or wider rows to permit cultivation for weed control.

Excellent yields have been obtained from 97-cm bedded rows in north Florida [5]. However, there is a good chance that yields could be improved by narrowing the rows to 76 cm apart. Because plants often attain a height of 5.5 to 6.1 m at this location, a fairly wide row is necessary for harvesting with a row-forage chopper.

In general, we recommend row widths of 51 to 76 cm which permit field cultivation as necessary for weed control. Other widths may prove more suitable for a given situation, and refinement of this recommendation is expected as better chemical weed control and other changes or information becomes available.

Fertility requirements.—Experiments have not shown clear-cut responses to nitrogen applications. We recommend soil tests and the subsequent application of the suggested rates of lime, phosphorus. and potassium. For infertile, light soils, high rates of nitrogen should be applied preferably in split applications. Suggested nitrogen rates for Leon fine sand, an infertile soil near Gainesville, Fla., are 56 to 112 kg/ha before planting and a supplementary application of 90 to 135 kg/ha some 4 to 5 weeks after planting [4]. For heavier more fertile soils nitrogen rates of 84 to 112 kg/ha should be adequate. Additional research on fertility requirements is needed, and the suitability of slow release nitrogenous fertilizers should be studied.

BREEDING AND NEMATODE RESISTANCE

Root-knot nematodes have long been recognized as a serious problem in kenaf production [12, 13, 27]. For this reason much breeding work has been directed toward achieving genetic resistance.

In previous work attempts were made to increase resistance through interspecific and intraspecific hybridization [11, 26, 29]. Screening work was initiated at Tifton, Ga., in 1968 and at Savannah, Ga., in 1969, by methods adapted from Minton, *et al.* [7]. All available *H. cannabinus* material is to be screened for resistance* to *Meloidogyne incognita acrita M. arenaria, M. hapla*, and *M. javanica*. Tests have also included a limited number of roselle (*H. sabdariffa* L.) entries.

Results, to date, indicate that kenaf is, as a rule, resistant to *M. hapla*, the northern root-knot nematode, and highly susceptible to the other three species [6]. Individual plant selections from screening tests remain in the process of evaluation. Roselle, in contrast appears to have a degree of resistance to all four species of root-knot. Although most roselle entries tested show some galling in greenhouse tests, it is much less than is found on kenaf entries, and field tests indicate that roselle has effective field resistance at least regarding *M. incognita acrita* and *M. javanica*.

Hexaploids derived from (kenaf X roselle) interspecific crosses [26] hsve been found moderately resistant to *M. incognita acrita* [24]. This material has not yet been checked for resistance to the remaining root-knot species, but is being increased in preparation for further greenhouse namatode testing and field tests for yield and other agronomic characteristics.

Once root-knot resistance is identified in *H. cannabinus*, it will be transferred into the best available agronomic lines of kenaf.

HARVESTING

In the United States harvesting and subsequent handling of kenaf from the field to the mill or storage site must be completely mechanized. Several systems have been tried. The most suitable system is to direct harvest the standing crop with high capacity forage choppers. Choppers with a reel or cylinder-type cutting action are more satisfactory than fly-wheel types because a cleaner, more precise chop is attained. Row headers handle a tall crop better than cutter-bar headers. A Texas study[21] showed that kenaf could be harvested with a forage chopper (commercially available) for as little as $1.35 per dry ton (2,000 lb). Choppers will satisfactorily harvest kenaf in the green or air-dry (crop killed frost or chemicals) condition. A harvesting demonstration is shown in **Figure 2.**

DRY-MATTER YIELD

If kenaf is to be harvested with a chopper at moisture levels above 30 to 35 percent, special storage provisions will be necessary. For a green chop, removal of the leafy top portion is desirable. Air-dry material could be stored in open or covered piles. Suggested methods for preserving green chopped kenaf[18] include:

(a) stored like corn silage in pit, trench, or bunker silos,

(b) submerged in water,

(c) stored in sealed and air evacuated enclosures of plastic sheeting.

(d) dried artifically to a safe moisture level, and

(e) stored in open piles with continuous or intermittent spraying with water.

DRY-MATTER YIELD

General.—Yields have been reported for several locations. Exceptionally high experimental yields have been obtained in Florida, Georgia, Texas, and Indiana. In the southeastern United States, dry-matter yields, on a field-scale basis, of 12 to 18 metric tons or more per ha should be feasible.

For Yield determinations, we prefer that estimations be made on a dry-weight basis. Plants are cut from a measured area within each plot, weighed, and subsampled for moisture determinations. For prefrost harvests,

[1]The absence or reduction of root-gall formation is accepted by the authors as an indication of resistance in this paper and other preliminary work.

we recommend that leaves (from moisture subsamples) be removed, weighed, and dryed in conjunction with the stems, so that dry-matter yields of whole plants, stems, and leaves can be computed separately.

Yield Comparisons with Roselle.—Roselle is, like kenaf, grown as a source of cordage fiber. Since roselle was given a favorable utilization rating[9]; and has root-knot nematode resistance, we decided to compare yields of roselle with kenaf. Results from 1969 tests at Glenn Dale, Md., and Savannah, Ga., are reported below. Yield comparisons are also being made in several Southern States.

The Maryland planting was seeded on May 5, thinned to 4 plants per 30 cm of row on June 16, and harvested on October 23 after a killing frost on October 18. Entries, yields, and other information are presented in **Table 1.** The kenaf variety had a two-fold or more yield advantage over the roselle test entries. All of the roselle entries showed higher susceptibility to *Botrytis* infection than Everglades 71. The amount of lodging at harvest was low and did not differ greatly between test entries (not shown in table). Since root-knot nematodes are not a problem at this location, further effort with roselle does not seem merited. The early growth of roselle seedlings was quite slow compared to the kenaf entry.

TABLE 1.—HEIGHT, YIELD, AND DISEASE COMPARISONS OF ROSELLE VARIETIES AND KENAF AT GLENN DALE, MD., IN 1969

Variety	Plant height[1] cm	Dry-stem yield per ha[2] metric ton	*Botrytis* infection[3]	Stem color
Kenaf:				
Everglades 71	319 a	18.24 a	1.1	green
Roselle:				
THS-12	223 c	6.97 b	3.0	red
THS-17	235 bc	7.79 b	3.2	red
THS-30	232 bc	8.12 b	2.1	green[4]/
THS-44	244 b	8.89 b	2.1	green*/
A59-56	240 b	9.20 b	2.0	green

[1]Means with the same letter or letters in common are not significantly different at the 1-percent level according to Duncan's Multiple Range test.

[2]Scored according to the severity of *Botrytis* infection; 0=none to 5=plants dead.

[3]Red spot occurs on stem at leaf axils.

[4]Means with the same letter or letters in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.

The Savannah test was seeded on April 17 and thinned to 4 plants per 30 cm of row. Harvest was on November 4, prior to frost. The data are presented in **Table 2.**

TABLE 2.—Height, yield, population and root-knot rating of roselle varieties and kenaf at Savannah, Ga., in 1969

Variety	Dry-stem yield per ha[1] metric ton	Plant height[1] meter	Plant population[1] thousand	Root-knot rating[2] gall index
THS-30	12.72 a	3.5 a	223 a	1.0
A60-234	12.00 ab	3.0 a	183 abcd	1.0
A59-56	11.99 ab	3.2 a	192 abc	1.0
A59-57	11.40 ab	3.5 a	178 bcd	1.0
THS-44	11.37 ab	3.4 a	210 ab	1.0
Everglades 71 (kenaf)	11.36 ab	2.9 a	192 abc	3.4
THS-24R	11.34 ab	3.2 a	180 abcd	1.0
THS-12	10.18 ab	3.4 a	141 d	1.0
THS-22	9.69 ab	3.2 a	158 cd	1.0
THS-17	6.70 b	3.0 a	166 cd	1.0

[1]Means with the same letter or letters in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.

[2]Gall ratings on a scale of 1=no galls to 5=very severe galling on a ten-plant sample drawn each plot.

As in the Glenn Dale test, the early growth of roselle was much slower than the kenaf entry. As shown in **Table 2**, the desired plant population of 198,000 plants/ha was not achieved for most entries. This was likely due to poor germination.

In contrast with the Glenn Dale location, the location at Savannah is heavily infested with the nematode species, *M. javanica*. This fact alone appears to sufficiently explain the poor performance of Everglades 71.

The typical nonuniformity of nematode infestation is evidenced by the fact that the kenaf variety produced both the high-yielding and low-yielding plots of the entire test. The high-yielding plot was free of root-knot nematode galls while the low yielding plot was severely galled.

The possible yield advantage of roselle should be further investigated in areas having a long-growing season and a heavy root-knot nematode infestation. A system of rotation of these two similar crop species might provide maximum yields prior to the development of resistant kenaf varieties.

OTHER POTENTIAL ANNUAL SOURCES OF PULP

Many species have been screened over a period of years as possible sources of raw material for pulping [8, 9]. Of these, *Crotalaria juncea* L., *Cannabis sativa* L., *Sorghum almum* Parodi, and selected accessions of *S. bicolor* (L.) Moench have shown good utilization and agronomic characteristics. *C. juncea* is used for pulp (mainly the bast fibers) on a limited scale [19]. With a successful breeding program for improving yield, standability, disease resistance, and seed production, this species would have excellent crop potential. We hope that this type of intensive breeding effort will be possible in the future. Okra (*Hibiscus esculentus* L.) while of poor chemical composition had a higher average woody fiber length (0.92) than kenaf [9]. While some okra varieties are tall growing in southern locations, their yield potential does not compare favorably with kenaf. Because *Cannabis sativa* (hemp) contains the drug marijuana, we have excluded this species from our trials. Considerable analytical and agronomic data (unpublished) has been accumulated on pulp sorghums. Because of a limited program and the more imminent possibility of commercializing kenaf, we are not presently working with these very productive sorghum accessions.

Species for which more field evaluation is desirable include *Crotalaria incana* L., *Aeschynomene scabra* G. Don, *Sesbania exaltata* (Raf.) Cory, and others.

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