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KENAF (*Hibiscus cannabinus* L.)

A Bibliographical Survey

By

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Contents

Domestic industries using jute and similar soft fibers are dependent upon imports. Foreign Commerce Weekly *(103)*[1] places burlap among those products that are essential to industrial preparedness, according to defense plans, and shows that India supplies 95 percent of such fibers.

Soft fiber from domestic sources for use as jute substitutes has been limited, because most of the fiber plants are tropical and subtropical in habitat and because labor costs have been more favorable for production in tropical countries.

Recent agronomic and engineering research suggests the possibility that some of the fiber-yielding plants may be adapted to Temperate Zone conditions and that costs of production may be reduced so that domestic production might be possible under the current necessity for industrial preparedness for defense.

Kenaf *(Hibiscus cannabinus* L.*)* is one of the soft fiber plants that shows promise as a domestic source of a soft fiber to substitute for and supplement jute. This bulletin is an attempt to review all pertinent literature and to list bibliography that may be of value to research men and others interested in the possible development of kenaf as a domestic crop.

History, Distribution, and Use

Kenaf fiber has long been used by native populations in Asia *(9, 25, 42, 56, 58, 69, 83, 111, 112, 113)* and Africa *(36, 55, 78, 107)*. Early literature indicates that the plant was apparently native to India. Linnaeus *(64, p. 979)* cites the names *Alcea benghalensis spinosissima* and *Ketmia indica,* which would seem to place the geographic origin in India. Hooker *(56)* states that the plant was cultivated generally throughout India and most tropical countries and that the plant was apparently wild east

[1] Italic numbers in parentheses refer to Bibliography, p. 13.

of the Northern Ghats in India. Watt *(111, 112)* records that the fiber of the plant was used by the agricultural classes locally but that the fiber was not a recognized article of commerce during the nineteenth century. In these same articles Watt summarizes the comparative data available at that time on *Corchorus, Crotalaria, Abutilon, Sansevieria, Sida, Abroma,* and *Malachra.*

Since the middle of the nineteenth century, kenaf has been recognized as an acceptable substitute for jute fiber in the manufacture of burlap, sacking, rope, cables, twine, and backing for rugs and carpets. Watt *(111)* also adds that the young shoots and leaves have been used as a vegetable, that the fibers have been used for paper manufacture, and that an edible oil is extracted from the seeds.

Of particular interest to those concerned with the history and distribution of *Hibiscus cannabinus* is a work by Miyake and Suzuta *(68)*, who have compiled a list of synonyms, together with geographical location, consisting of some 126 different names. This work shows that the term "kenaf" originated in the area of Iran, Turkestan, and Transcaucasia.

Current Importance and Use

Investigations resulting from the Strategic and Critical Materials Stock Piling Act of 1946 and the Defense Production Act of 1950 indicate that all fibers are of critical importance and that increased fiber production in accessible areas is necessary.

Production in the Western Hemisphere on a commercial scale was started in 1948 in Cuba[2] after extensive research studies that were begun in 1943 as a cooperative program between the United States Department of Agriculture and Cuban technicians.

A fact sheet on kenaf fiber production and Western Hemisphere defense by the United States Department of Agriculture *(99)* states that many agricultural products are packaged in jute burlap and sacking, including sugar, coffee, potatoes, chocolate, and some grains. Industrial uses include carpet and rug backing, wrapping twines, electrical insulation, upholstery webbing, calking materials, cotton-bale covering, and grain bagging. Jute fiber has proved to be very satisfactory for these and other uses. There is need, however, for a supplemental fiber that grows satisfactorily, is produced cheaply, and will be accessible if shipping is curtailed.

According to world fiber surveys by the Food and Agriculture Organization of the United Nations *(38, 39, 40)*, the world scarcity of jute, which has persisted throughout the postwar period, was intensified in 1948–49 by crop losses in Pakistan. High prices of jute resulting from a number of causes, chief among which was the partition of fiber-producing Pakistan from fiber-processing India and the accompanying economic and political disturbances, have forced other countries to seek substitute materials for jute. In the United States paper and cotton have been the

[2] UNITED STATES OFFICE OF FOREIGN AGRICULTURAL RELATIONS. EFFECTS OF COMMERCIAL USE AND SHIPMENT OF SUGAR BAGS MADE OF KENAF FIBER. Progress Statements Nos. 1–14 from Fiber Res. Proj. 1950. [Mimeographed.]

main competitors for jute. In Brazil a national program for expanding domestic production of jute and similar fibers that are indigenous has been instituted. The Argentine Government has announced a 5-year program for advancement and utilization of home-grown vegetable fibers to replace jute. Kenaf production is being encouraged in several Caribbean countries *(100)*. In the Belgian Congo *Urena lobata* (Congo jute) output continues to rise because of lively export demand. South Africa, a former large importer of Indian jute sacks and cloth, has established a full-scale jute substitution program, including domestic bag manufacturing. Some of this fiber is kenaf *(62)*.

The fact that so many countries have sought to find substitutes for jute during the past few years is proof of the current importance of this type of fiber. The availability of substitutes and the ready acceptance of the substitutes by the trade indicate that in the long run the competitive position of jute will depend on its cheapness relative to those substitutes.

Extensive tests reported in a series of United States Department of Agriculture Progress Statements[3] show that sugar bags made from kenaf are stronger than our present jute sugar bags. These tests and others show that the current demand for kenaf fiber is real. It is also evident from the records of a symposium on kenaf by Government and private research workers in January 1949 that, although kenaf shows great promise from the agronomic standpoint, there is need for processing facilities. This point was brought out in the symposium by A. A. Ort, of the Haytian American Development Corp. An excerpt from his remarks (unpublished) pertinent to this problem is as follows: "Not only is it necessary to have a supply of soft fiber, such as kenaf, in case of a national emergency but it is also necessary to have the 'know how' and the processing facilities. Defibering, spinning, and weaving facilities, such as would be required in case of war, are not now available in the western hemisphere."

Range of Adaptation

The potential wide range of adaptation of kenaf was recognized early by Watt *(111, 112)* and others. A review of the literature shows that kenaf has been grown in many parts of the world other than India. Of particular interest are the studies in Russia regarding the northern limit and range of kenaf.

References pertaining to the growth and value of kenaf as a crop are numerous during the first 20 years of the twentieth century. Some of these publications are valuable for background and historical development and others contain complete technical information for the period.

Of the more recent articles, perhaps that by Sircar *(89)* is one of the best summaries of the detailed technical, historical, and bibliographical information covering the possibilities in the production of jute and its substitutes in India.

The early literature pertaining to kenaf in India includes

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[3] See footnote 2.

Linnaeus *(64)*, Roxburgh *(83)*,Hooker *(56)*, and Watt *(111,112)*. Dunstan *(34)*, reporting on the laboratory analyses at the Imperial Institute in London, gives detailed data on fiber samples from various locations within the British Empire. In summary, these analyses indicate that the composition and properties of some of the better samples of fiber show that kenaf is deserving of attention in India. A bulletin by the Imperial Institute *(43)* covers the cultivation of jute and similar fibers. Mollison *(69)* enlarges upon a bulletin regarding the extension of the cultivation of fiber crops in India. He gives particular reference to kenaf plantings, with citations of the work done at the Agricultural Research Institute in Pusa, India.

The publication by Howard and Howard *(58)* is particularly useful, in that botanical descriptions of varieties are given, together with colored plates of some of the varieties.

Shaw *(87)* compares the characteristics of *Hibiscus cannabinus* L., *H. sabdariffa* L., and *H. sabdariffa* var. *altissimus* and notes that the selection *altissimus* is unlike the other forms of *H. sabdariffa* in that it has a tall unbranched habit of growth.

In 1935 Biswas *(9)* noted that *H. cannabinus* constituted the main source of material for the manufacture of paper in Dacca, West Bengal. This report indicates that kenaf has wide adaptation, as the plant is not uncommon in the lower Himalayas up to about 3,000 feet elevation.

Caldwell *(15)*, in 1936, in a comparison of kenaf with sunnhemp in India, adds support to earlier contentions that kenaf is capable of adapting itself to wide variety of climates and soils.

In 1937 Norman *(74)*, at the Rothamsted Experiment Station, studied the composition of some of the less common fibers, including *H. cannabinus, H. diversifolius,* and *Urena lobata.* A total of 27 different fiber plants were compared and results are given in tabular form, so that the characters of kenaf fiber are easily compared with those of similar fibers from other plant sources.

In the Western Hemisphere Corrêa *(16)* and Oliviera *(75)* reported kenaf in Brazil, Watkins *(109)* and Watkins and Allwood *(110)* found it in El Salvador, Skovsted *(90)* examined plants grown in Trinidad, and Malberti *(65)* reported kenaf in Cuba in 1931. In 1942 research in Cuba expanded as a result of fiber shortages brought about by World War II. The results of this research are to be found in works by Crane *(18, 19)*, Crane and Acuña *(20, 21, 22)*, Crane, Acuña, and Alonso *(23)*, and by Walker and Sierra *(106)*. This publication *(106)*, United States Department of Agriculture Circular 854, issued in July 1950, is especially noteworthy as a summary of work to date of the Cooperative Fiber Commission on kenaf as a crop for Cuba. The authors record recent data on cultural factors, such as time of planting, age at harvest, and seeding procedures as factors influencing yields of fiber and seed. Some of the conclusions in summary are: (1) That the best time to harvest kenaf for fiber ranges from 105 to 147 days, depending on date of plantings and weather; (2) that percentage of dry fiber content increases as plants grow older, about 2 percent in plants harvested at 42 days to about 10 percent in those harvested at 147 days; (3) that tensile strength of the fiber increases up to 105 or 126 days and thereafter remains the same; (4) that the best spacing in the row is 10 plants to the foot, and that 8- and 16-inch distances between the rows are best for producing fiber with high tensile strength; (5) that 20- to 30-pound-per-acre seeding rates produced the most fiber; and (6) that a 20-pound seeding rate by a broadcast method resulted in the highest yield of seed.

Buchholtz *(12)* records abstracts of selection work done in Uzbek in the North Caucasus and breeding work aimed toward adaptation. Nevinnyh *(72)* has studied the photoperiodic response of kenaf in Krasnodar as a means of selecting for adapted varieties. Poptzoff *(80)* investigated the after-ripening, influence of internal and external factors, and the resistance to high temperatures of the seeds of kenaf. Wasserman *(108)* reports that in 1935 Russia had 32,500 acres in kenaf production.

In Africa kenaf has been reported growing on a cultivated or semicultivated basis in the Transvaal and other parts of South Africa—in Natal *(78)*, in Nigeria *(55)*, in Sudan and Nyassaland *(90)*, and in Egypt *(36)*. The plant has been reported growing in a great number of locations in the wild state. This is evident from the work of Miyake and Suzuta *(68)*, who list a total of some 126 common names used in various parts of the world.

Persian varieties have been discussed by Popova *(79)*, Buchholtz *(12)*, and Nevinnyh *(72)*.

In Formosa the plant was studied by Miyake and Suzuta *(68)* and in Japan by Tabata and Tetsuka *(93)*. In Indochina, the plant is mentioned by Oudot *(76)* and by Hautefeuille *(52)*.

In Java considerable and intensive work has been done by Zegers Ryser *(115)*, Muller and Eek *(70)*, Bolhuis *(10)*, Kist and Friederick *(61)*, and Toxopeus *(95, 96)*.

Within the continental United States trials of kenaf have been reported by Ergle, Robinson, and Dempsey *(37)*, Eaton *(35)*, Ahlgren and Dotzenko *(3)*, and Robinson and Nelson *(82)*. Trials of kenaf have been reported in the States of Florida, Alabama, Texas, Arizona, Washington, New Jersey, and Maryland. These trials were limited to tropical types, namely, the varieties *viridis* and *vulgaris*. Unpublished results of preliminary evaluation of kenaf (P.I. Nos. 189207, 189208, 189209, and 189210) by the writer show that the plant will flower, set seed, and make acceptable vegetative growth under the conditions prevalent at Glenn Dale, Md., during the summer of 1950.

Agronomic and Cultural Aspects

Most of the work on kenaf as a crop was confined to the Old World until experimentation began in 1943 in Cuba. Crane *(19)* has summarized the background material as it relates to production in Cuba and has collated the Cuban work in respect to agronomic problems, such as varieties, photoperiod reaction, time of planting, rate of seeding, time of harvest for fiber and for seed, fiber yield, application of fertilizer, and retting and other processing of the fiber.

Some of the Cuban work deserves particular attention. Crane and Acuña *(20)* and Crane, Acuña, and Alonso *(23)* showed that under conditions prevailing in Cuba time and distance of planting had little influence on branching in the varieties *vulgaris* and *viridis*; that, regardless of the time of planting, kenaf flowers will not initiate until September or October when days are shortened to 12½ hours; that plantings for seed crop should be made in July or August and that plantings for fiber crop should be made in April or May; that highest yields were obtained from plots where plants were spaced 2 to 3 inches in rows spaced 20 to 24 inches apart. Crane and Acuña *(21)* conclude that kenaf for fiber should be harvested during the flowering stage to obtain best results as far as yield and separation of fiber are concerned.

Showing that different locations require different cultural practices, Watkins *(109)* reports that closer planting, 2 inches apart in rows 12 inches apart, was the optimum planting distance for conditions in El Salvador.

Another publication having probable value for further agronomic investigations is the work of Berland *(8)*. He reports that there is considerable variation in kenaf in regard to habit of growth, branching, and length of vegetative period. Likewise, Popova *(79)* shows that there are strain differences in regard to height of plant, thickness of stem, color of stem, leaves, flowers, seeds, and capsules. It is to be noted that the variability reported in kenaf might provide the means of adapting the plant to different locations and improving varieties by ordinary selection.

Investigations by Ergle and coworkers *(37)* on several fiber plants grown in test plots in Alabama are worthy of note. Of special interest are the data presented in tabular form, which show that kenaf produced a greater yield of fiber per land unit than did *Urena lobata*.

In 1943 plantings made at Angleton, Beaumont, College Station, and Weslaco, Tex., gave yields of 800 to 1,200 pounds of dry fiber per acre, according to Eaton *(35)*.

In a study of fiber production in India, with special reference to sunn-hemp and Bombay hemp, Caldwell *(15)* calls attention to the fact that the degree of adaptation of kenaf is not generally recognized and that kenaf is probably adaptable to a large variety of climates and soils. In this connection Wasserman *(108)* records that extensive experiments in Russia have proved that the northern limit of kenaf is 45° north latitude.

In 1948 Sircar *(89)* summarized information available in India on the uses, production, economics, and experimental work on the selection and breeding of hard, soft, and textile fibers. He states that kenaf yields a fiber similar to jute and is used as a jute substitute. Yield of dry fiber per acre throughout India varies from 300 to 800 pounds. Between 100,000 and 200,000 acres were producing kenaf. The Imperial Agricultural Research Institute at Pusa has isolated superior strains for production in Bombay and the Central Provinces. Sircar notes that much of the kenaf produced is grown as a mixed crop. He recommends that kenaf be grown as a pure crop either on a factory- or cottage-industry scale. He estimates that a total area in India of 75,000 acres would yield 300,000 maunds[4] of fiber.

A publication by Kirby *(60)* gives an account of the cultural aspects of kenaf production in the Empire as part of a review of the possibilities in production of fibers other than jute. Some of the information contained in this article may be applicable to Western Hemisphere conditions.

In 1918 Holland *(55)* reported kenaf to be an important cultivated plant by the Somono people in Nigeria, chiefly along the Niger and Bani riverbanks. On the good soils of the river bottoms, yields of 8,400 kilos of dry stalks and 1,596 kilos of fiber per hectare were obtained, and on less fertile soils, 7,000 kilos of dry stalks and 1,316 kilos of fiber per hectare.[5]

Regarding kenaf production in Egypt, El Kilany *(36)* reports that the plant has been known for a long time as "teel," but that it is never sown as an independent fiber plant. It is usually found as a hedge around cottonfields. It is noted that "teel" surpasses jute in being better adapted to poor soils, in not being so sensitive to soil alkalinity, and in being more drought-resistant.

The extensive work on kenaf in Russia during the period 1920–29 is summarized by Dounin and others *(28, 31, 32, 33)*. The publication on diseases *(32)* lists species of the following genera found on kenaf seeds: *Alternaria, Fusarium, Penicillium,* and *Trichothecium. Alternaria* and, particularly, *Fusarium* were found to penetrate seed tissues and account for the low germination of certain seed crops.

The report in Russian dealing with the quality of seeds *(28)* shows that germinating power of the seed may be increased by treatment with gaseous HCN (1 percent by volume at 17° to 20° C. for 1 to 4 hours). The minimum temperature for germination was found to be 6°, the optimum at 23° to 28°, and the maximum at 40°. Optimum pH of the germinating media was found to be between 6.5 and 7.0. Traces of zinc ions were found to stimulate seed germination.

The third publication by Dounin and Galitch *(31)*, dealing with the correlation between germination and seed sowing, showed that when a seed sample had 81.6 percent germinating seeds the number of equably distributed germinating seeds was equal to the number of unequably distributed seeds. It is stated further that, in order to obtain the most equable distribution of germinating seeds, it is very important to use seeds that contain at least 66.7 percent germinating seeds.

The fourth report of the series, which deals with the separation of good seeds *(33)*, concludes that the germination percentage of seeds that sink in water is often near 80 to 100 percent and that quality of a given sample can, up to a certain degree, be

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[4] The Indian Government standard maund is 82 2/7 pounds avoirdupois.
[5] 1 kilo = 2.2 pounds; 1 hectare = 2.47 acres.

judged by the number of seeds in the sample that sink in water. A drawing is included of a special apparatus used in the separation of seeds by specific gravity.

A later publication by Dounin *(30)* evaluates the oil extracted from kenaf seeds. Ripe seeds yield 20 percent oil. The properties and characteristics indicate that it is a semidrying type similar to sesame oil, peanut oil, and cottonseed oil.

At the Philippine Islands Agricultural Experiment Station at Los Baños, Laguna, in 1947 *(2)*, tests were designed to show the effect of different seeding rates on the flowering of kenaf (table 1). Results from these tests indicate that the optimum

TABLE 1.—*Flowering time, number of plants that flowered, and percentage of plants without flowers 149 days after planting* [1]

Plot No.	Plants to a square meter	Flowering time after date of planting	Plants that—		
			Flowered	Did not flower	
	Number	*Days*	*Number*	*Number*	*Percent*
1	15	104–134	149	1	0.66
2	50	105–148	472	28	5.60
3	60	107–149	530	70	11.66
4	70	109–149	442	258	36.85

[1] Data obtained from *(2)*.

rate of seeding is 50 or 60 plants to a square meter and that optimum stem length, stem diameter, and yield in terms of clean dry fiber are obtained from this same rate of seeding. According to the results obtained from the trial plots, the following yields are anticipated:

Plot	*Tons of dry fiber per hectare*
1	3.53
2	4.70
3	3.90
4	2.24

Current practices in retting are discussed by Watkins and Allwood *(110)* with respect to conditions in El Salvador. They found that tank retting at 34°C. gave the most rapid retting (29 hours) and that no retting took place at 40°. They also found that pH of the water did not influence the retting, except in the extremely acid range of 1 to 3 and the extremely alkaline range from 11 to 12 in both of which retting was inhibited. Fibers obtained from retting tanks held at the lower temperatures showed higher tensile strength.

Burkett and coworkers *(14)* found that in Cuba field retting produced more satisfactory fibers than did retting with plants that were artificially killed or permitted to die naturally before retting. Quality of fiber produced by drip retting was found to be unsatisfactory.

Breeding and Selection

Basic information on the structure and cytology of the kenaf plant is contained in some of the publications. Some of the data may be considered basic and fundamental for further studies in breeding and selecting and otherwise improving the plant for fiber or oilseed uses. A particularly valuable piece of work by Howard and Howard *(58)* presents colored plates and varietal descriptions. The colored plates include the varieties *simplex, viridis, vulgaris, ruber,* and *purpureus.* There is also a discussion of pollination, complete with sketches of the flower structures. The authors conclude that the constant differences observed between the seedlings of the types of kenaf render the production of a uniform fiber and pure seed a comparatively easy matter, especially since a certain amount of natural crossing takes place, indicating that controlled breeding is possible.

The anatomical and morphological study by Popova *(79)* on the Persian and Fergana races of kenaf shows that there is wide diversity of type and variation in vegetative and reproductive structures. This work suggests that by selection alone varieties suited to a wide range of climates and soils could be obtained.

Berland *(8)*, reporting on studies at the Tashkent Plant Breeding Station in Turkestan, indicates that the Persian strains are representatives of the variety *vulgaris* described by Howard and Howard *(58)*. The strains are divided into four groups according to the length of the vegetation period: (1) 90 to 110 days, (2) 110 to 120 days, (3) 120 to 130 days, (4) 130 to 150 days.

In 1934 Shaw *(87)* reported on improved varieties of kenaf in India. Particular reference is made to a comparison of the characteristics of kenaf with *Hibiscus sabdariffa* and *H. sabdariffa* var. *altissimus.*

Several investigations have been concerned with the cytology of kenaf. Breslavetz and others *(11)* reported the chromosome number to be $2n = 36$. Skovsted *(90, 91)* reported the same number as did Medvedeva *(66)*. Narasinga Rao *(71)* reported $2n = 72$, and Ford *(41)* reported the same chromosome number from material obtained from Ceylon.

Skovsted *(91)* summarizes all reports on the chromosome number in kenaf in tabular form. He states that—with the assumption that the results of the investigators are correct—it can be seen that kenaf exhibits polyploidy within the species. He states further that polyploidy has evidently been an important factor in the evolution of the Malvaceae in general. Interspecific polyploidy is very frequent throughout the family, and intraspecific polyploidy has been demonstrated in several species.

Toxopeus *(95)* notes progress in preliminary attempts involving crosses between eight different species in the genus *Hibiscus.* His tabulation (table 2), showing the results of these crosses, follows. Specific attention is called to F_3 progeny obtained from a cross involving *H. radiatus* × *H. cannabinus* that exhibit many characters specific for the parent species and which appear to be linked with high fertility.

TABLE 2.—*Results of crosses of Hibiscus spp.*[1]

Pistillate (♀) parent	Staminate (♂) parent [2]							
	H. cannabinus	*H. surattensis*	*H. sabdariffa*	*H. bifurcatus*	*H. rubidus*	*H. eetveldeanus*	*H. diversifolius*	*H. radiatus*
H. cannabinus, 2n = 36	+	−	(+)	▲	....	−	−	+
H. surattensis, 2n = 36	▲	+	▲	▲	▲	....	▲	....
H. sabdariffa, 2n = 72	....	(+)	+	△	....	....	....	....
H. bifurcatus, 2n = 72	+	(+)	▲	+	+	....	+	....
H. rubidus, 2n = 72	−	▲	+	....	+	....	▲	....
H. eetveldeanus, 2n = ?	+	....	+	....	....	+	....	+
H. diversifolius, 2n = ±180	+	....	....	....	....	....	+	....
H. radiatus, 2n = 72	+	....	+	....	....	....	....	+

[1] Adapted from table given in (*95*).
[2] + = Viable seeds; (+) = seeds with small embryos; ▲ = capsules with empty seeds; △ = empty capsules; − = no capsules.

In Java Badenhuizen *(5, 6)* states that *H. sabdariffa* (roselle) is cultivated as a crop because the yield is greater than that obtained from *H. cannabinus* (kenaf), but that kenaf has been found to be more resistant to disease than roselle. The author postulates that a tetraploid kenaf, induced by colchicine, might combine higher yield with greater resistance to disease.

Further studies by Toxopeus *(96)* on the effect of a 0.1 percent water solution of colchicine treatment on 25 seedlings of kenaf show that 4 of the treated plants exhibited typical properties of plants with doubled chromosome number. The plants had larger and thicker leaves, more vigorous growth, larger flowers with thick stiff corollas, enlarged diameter of the elementary fibers, and other elements of the bark and wood. However, all 4 deviates were sterile. No successful crosses were obtained with the deviates, though many were attempted.

In the same studies 25 seedlings of roselle were treated in a similar manner and 2 of the roselle tetraploids were male-sterile when selfed or sibbed, but when diploid kenaf was used as a pollen parent there was 100 percent fruit set and the fruits averaged 9 seeds per capsule. From these seeds 120 seedlings were grown. None of the seedlings exhibited common characteristics of the kenaf parent.

In Java Kist and Friederick *(61)* have conducted comprehensive experiments dealing with the culture and breeding methods employed with kenaf, *H. sabdariffa,* and other similar fiber crops. They record that some 10,000 crosses were attempted with kenaf and roselle. Their breeding project included line selection for high yield and resistance to *Phytophthora* spp., the crossing of nonresistant commercial varieties with wild varieties with repeated backcrossing, the interspecific crossing of roselle with kenaf, and colchicine treatments in attempts to obtain fertile tetraploids.

In Russia Nevinnyh *(72)* found that shortening the day to 10 hours accelerates development and suppresses growth, as is common with other short-day plants. Photoperiodic reaction is mentioned as a means of selecting kenaf. He states that kenaf is most sensitive to the action of a short 10-hour day in an early growth stage, i. e., when the plants are 12 days old. A short-term treatment of seedlings during the first 10 days gives a maximal acceleration of development without weakening growth.

Michailowa, as translated by Buchholtz *(12)*, reports that kenaf has been grown rather widely in various parts of the Soviet Union. Early plantings were confined almost entirely to the variety *vulgaris*. In the period between 1920 and 1925 a program of research resulted in the development of several outstanding selections that compared favorably with the types found in Iran, India, and Java both as to quality and fiber yield. The variety *purpureus* has yielded an especially good selection in No. 0139, which produces 19.9 dz. ha.[6] of fiber as against 16.0 dz. ha. for the standard types. Also, by crossing kenaf with *H. diversifolius*, a hybrid was produced that attained a height of 150 to 160 cm. and showed considerable reduction in the number of thorns on the shoots and leaf petioles.

Shchepkina *(88)* has studied the anatomy of stem and leaf structures of kenaf. Colored drawings show the differentiation of various tissues in cross-sectional detail of structural and vascular elements, as well as the location of crystalline and amorphous cellular inclusions found by microchemical techniques.

Specific details of the elements of the commercial fiber and other technical analyses of the fiber are to be found in a report by Schwede *(86)*, who concludes from the results of his investigations that the plant has good possibilities as a fiber plant for Russia.

In Lenkoran, Transcaucasia, Ustinova *(104, 105)* reports work on kenaf for the years 1937 and 1938. Her work involves interspecific hybridization within the genus *Hibiscus* and cross-pollination experiments with kenaf. She reports crosses involving *H. cannabinus*, *H. esculentus*, and *H. manihot*.

Tabata and Tetsuka *(93)* found that the response of kenaf to day length was variable, according to the variety. This report lends further evidence that selection for varying photoperiods is possible.

Uses Other Than Fiber

Uses of *Hibiscus cannabinus* for purposes other than fiber include utilization of the young leaves and shoots as a vegetable, of the seeds as a source of an edible oil similar to cottonseed oil, of the stalks as paper pulp, and the plant as a green manure.

The edible oil is perhaps deserving of some attention. Lewy *(63)* states that seed yields have been recorded in Cuba at 1,500

[6] 1 doz. (doppelzentner) = 100 kilograms; 1 ha. (hectare) = 2.47 acres.

pounds per acre and in El Salvador at 890 pounds per acre. By solvent extraction with petroleum ether the seeds yield 20 percent oil, and by pressure extraction 14 percent. The following comparison of kenaf, cotton, and kapok oils is given by Lewy (table 3).

TABLE 3.—*Comparison of kenaf, cotton, and kapok seed oils*[1]

Constituents of oils	Kenaf, El Salvador	Kenaf (*59*)	Cotton, El Salvador	Kapok (*59*)
Specific gravity at 15° C.	0.9175	......	0.928	0.920 to 0.93.3
Refractivity index	$N_D40°$ 1.4657	......	$N_D20°$ 1.4745	$N_D40°$ 1.4605 to 1.4657.
Acid value	4.7	......	......	
Saponification value	189.8	......	197.2	189 to 195.
Insaponification, percent	1.7	......	1.0	0.8 to 1.6.
Iodine number	[2]99.7	......	[2]108	86 to 100.
Reichert-Meisal value	0.5	......	......	0.1 to 0.2.
Hehner value	61.8	......	96.1	
Oleic acid, percent	......	45.3	......	
Linoleic acid, percent	......	23.4	......	
Palmitic acid, percent	......	14.0	......	
Stearic acid, percent	......	6.0	......	

[1] Adapted from Lewy (*63*).
[2] Determined by Hanus solution.

Lewy further states that kenaf cake is palatable to cattle. Composition of whole kenaf seeds, as reported by Michote *(67)*, is given as follows:

	Percent
Moisture	9.64
Mineral matter	6.40
Oil	20.37
Nitrogenous matter	21.44
Saccharifiable matter	15.66
Crude cellulose	12.90
Other matter	13.94

Analysis of the kenaf seed cake on a dry-weight basis is given as follows:

	Percent
Crude protein	33.0
Oil	6.0
Crude fiber	17.4
Ash	6.0
Nitrogen-free extract	37.6

Fertilizing value of the kenaf seed cake is analyzed as follows:

	Percent
Nitrogen (N)	5.25
Phosphoric acid (P_2O_5)	.95
Potash (K_2O)	3.74

Further work on kenaf seed oil has been published by Dekker *(24)*, Bauman *(7)*, Pieraerts *(77)*, Heim de Balsac *(53)*, Dounin *(30)*, and Jamieson *(59, pp. 59-60)*.

The possible value of kenaf as a green manure has been noted by Ahlgren and Dotzenko *(3)*. They state that under the hot and dry summer of 1949 a total yield of about 30 tons or more of green material was produced per acre in about 125 days at New Brunswick, N. J. They further state that a plant of such tremendous vegetative vigor, especially one containing so much fiber and woody material, should be studied further to determine its place in our agriculture.

Though Watt *(111)* and Biswas *(9)* record that the fiber of kenaf has been used for the manufacture of paper, this possible use has not been documented further by research.

Production Possibilities in the United States

In the United States experiments have shown that the plant can be grown in several States. However, relatively high labor costs of producing jutelike fibers in this country and the lack of harvesting and processing equipment have been, and still are, limiting factors in domestic production.

In Cuba, experiments under way for the development of harvesting and processing machinery may offer some encouragement toward the possible reduction in labor costs for production in the United States of kenaf fiber from Temperate Zone selections.

Bibliographical research and limited preliminary tests indicate that the development of Temperate Zone selections and varieties of kenaf appears to be possible if price and availability of imported fiber is such as to permit domestic competition. In any case, the preliminary phases of varietal development, seed increase, mechanization of harvesting, processing, expansion of weaving facilities, and marketing problems will be costly. The problem at present is essentially one of economics as affected by the strategic needs of industry.

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