Chapter 1
Origin, Description, Importance, and Cultivation Area of Kenaf

E. Alexopoulou, Y. Papatheohari, M. Christou and A. Monti

Abstract This chapter discusses the origin and taxonomy of kenaf, the description of the plant parts (stems, leaves, flowers, seeds, and root), the importance of the crop worldwide, the cultivation area, as well as its importance. Kenaf (*Hibiscus cannabinus* L.) is an annual spring crop cultivated for long (4000 BC). It originated from Africa, disseminated in the 1900s in Asia (in India and then in China) and in the 1940s from Asia to northern and central USA. Kenaf belongs to the Malvaceae family and section Furcaria. It is closely related to cotton, okra, hollyhock, and roselle. Nowadays it is being cultivated in 20 countries worldwide and its total production (kenaf and allied crops) is 352,000 tons (2010/2011). Currently, China and Pakistan are the main producers. In the last part of the chapter the importance of the crop is discussed. Kenaf is an annual non-food fiber crop that used to be cultivated for numerous uses (paper pulp, fabrics, textiles, building materials, biocomposites, bedding material, oil absorbents, etc.). Recently, it is also considered as an important medicinal crop as its seed oil is recorded to cure certain health disorders and help in the control of blood pressure and cholesterol.

Keywords Kenaf • Origin • Genus • Crop importance • Cultivation area • Crop taxonomy • *Hibiscus cannabinus* L • Family Malvaceae • Furcaria section • Crop description • Stems • Flowers • Leaves • Seeds • Root • Multipurpose crop • BIOKENAF project • Annual crop • Fiber crop • Non-food crop • Energy uses • Fibers • Bark • Core • Spring crop

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1.1 Introduction

Kenaf is an annual spring crop cultivated for long (4000 BC) and its origin is from Africa. It belongs to the Malvaceae family and section Furcaria. Kenaf is closely related to cotton, okra, hollyhock, and roselle. It is a short day crop cultivated from 300 S to 450 N. Research on agronomics and end uses of the crop has been carried out worldwide during the last century. Many varieties are available worldwide (with short, intermediate, and long date habits).

It is considered an important bast fiber crop and used to be cultivated for its fibrous stem (contains long and short fibers in its stem fractions; bark and core, respectively) with numerous industrial applications (paper and pulp, fabrics, textiles, biocomposites, insulation mats, absorption materials, animal bedding, etc.). Recently, kenaf is being considered as an important medicinal crop. It was found that its oil has high contents of polyunsaturated fatty acids (PUFA). Its seed can cure many health disorders and diseases such as blood pressure, cholesterol balance, and some types of cancers. Thus, kenaf can be considered a dual non-food crop cultivated for its fiber and/or its oil production. This chapter describes in detail the crop origin and taxonomy, the plant parts, its cultivation area worldwide, and explains why kenaf is an important non-food crop with many alternative or complementary uses.

1.1.1 Origin of the Genus

Kenaf (*Hibiscus cannabinus* L.) has been cultivated for long, probably as early as 4000 BC (Roseberg 1996). It originated in Africa, where diversified forms of the species are found growing widely as a component of the native vegetation of the countries of East Africa (Wilson and Menzel 1964; Wilson 1978; Dempsey 1975; Li 1990). The existence of semi-wild kenaf in Africa (Kenya and Tanzania) might be an indication of the origin of the cultivated kenaf from this continent (Chen et al. 2004). So far, the research on the origin of kenaf has been based on field surveys and investigations and no data on genetic studies have been collected to prove its origin.

At the beginning of the eighteenth century, kenaf was introduced into southern Asia and was first cultivated and commercially utilized in India (Dempsey 1975). The knowledge of how kenaf was introduced in India is limited but it is known that it came from Africa (Roxburgh 1795; Royle 1855; Hooker 1875; Howard and Howard 1911). The cultural interaction between ancient Egypt and the Indus may have played an important role for kenaf's dissemination from Africa to India, from where kenaf cultivation was expanded to other Asian countries. In the beginning of 1900, kenaf was disseminated into mainland China from Taiwan (Dempsey 1975; Charles 2002; Li 2002).

In 1902, Russia started to produce kenaf. Kenaf was cultivated commercially as a fiber crop in Asia and the USSR in the 1930s. During the Second World War, as foreign fiber supplies were interrupted, kenaf research and production was started in the U.S. to supply cordage material for the war effort (Wilson and Margaret 1967; Dempsey 1975). Accessions collected from Asia and central and North America were found to have close genetic relationships (Chen et al. 2004). More than 500 plant species were evaluated in the USA in the 1950s in order to cover the increasing future fiber demands in the USA. Kenaf was evaluated as an excellent cellulose fiber source for a large range of paper products (Nelson et al. 1962).

Currently, many countries pay more attention to kenaf research and cultivation because of its high biological efficiency and wide ecological adaptability. Kenaf is more commonly called “the future crop” (Mazumder 2000; Cheng 2001). Nowadays, kenaf is commercially cultivated in more than 20 countries, particularly in China, India, Thailand, and Vietnam (FAO 2003) but the knowledge of dissemination of the crop worldwide is still limited. Although kenaf originated from Africa, its production in Africa is very low. In 2010, the total production in Africa was just 3 % of the world production (FAO 2010).

Kenaf is connected with a long list of over 120 common names (Sellers and Reichert 1999) such as mesta, teal, ambari hemp, and rama that reflect the diversification and common uses of this crop. In English, the common name of kenaf in India is mesta, palungi, deccan hemp, and Bimli jute; in Taiwan it is ambari; in Egypt and Northern Africa it is til, teel, or teal; in Indonesia it is Java jute; in Brazil, it is papoula de Sao Francisco; in South Africa it is stokroos; and in West Africa it is dah, gambo, and rama (Taylor 1995).

1.1.2 Taxonomy of Kenaf

Kenaf is a short day annual herbaceous plant that belongs to the Malvaceae, a family notable for both its economic and horticultural importance. The genus of *Hibiscus* is widespread, including some 400 species. Kenaf is closely related to cotton, okra, and hollyhocks. Next to cotton, it is the most widely cultivated fiber plant in the open country and can be found extending from Senegal to Nigeria. Kenaf, along with roselle, is classified taxonomically in the Furcaria section of Hibiscus.

The Furcaria section has about 40–50 species (Su et al. 2004) that were described throughout the tropics and they are closely related morphologically (Dempsey 1975). Kenaf is closely related to cotton (*Gossypium hirsutum* L.), okra (*Hibiscus esculentum* L.), and hollyhock (*Althaea rosea* L.). In some places, roselle (*Hibiscus sabdariffa* L.) is also called kenaf.

The chromosome number in the section Furcaria is a multiple of 18 in all the species, which have been counted. Natural species have been found with a chromosome number of 36 (kenaf and other species), 72, 108, 144, and 180. The diversity in numbers of chromosomes found in section Furcaria is not common in the plant kingdom. This chromosome diversity is reflected in the morphological and physiological diversity in the crop. This diversity represents a rich source of material potentially useful for kenaf breeding. A genome analysis had been carried out and it was found that kenaf and roselle share a common set of chromosomes (one genome) (Wilson 2000).

1.2 Description of the Crop

1.2.1 Stems

Kenaf stems are generally round with thorns ranging from tiny to large such as on a blackberry bush depending on variety. The stem color varies from pure green to deep burgundy. Kenaf plants tend to grow as a single unbranded stem when planted at high production densities of 170,000–220,000 plants/ha with a height of 2.5–6 m. Kenaf stems have a thin bark over a woody core, surrounded by a leaf tuft (Kaldor 1989) (Fig. 1.1a). The stems contain two major fiber types, one with long fibers situated in the cortical layer, and the other with short fibers located in the ligneous zone.

The central area of the stem, corresponding to pith, consists of sponge-like tissues. The outer bark contains bast fibers of an average length of 2.5 mm and woody core fibers of an average of 0.6 mm. Kenaf fibers have three principal chemical constituents, which are the α-cellulose (58–63 %), hemicelluloses (21–24 %), and lignin (12–14 %). The minor constituents in kenaf stems are 0.4–0.8 % fats and waxes, 0.6–1.2 % inorganic matter, 0.8–1.5 % nitrogenous matter, and traces of pigments. In total, these minor constituents account for about 2 % (Stout 1981). The ash contained is higher in the bark (5.5–8.3 %) than in the core (2.9–4.2 %) while for the whole stem it is 2.1–6.5 %.

The core contains more lignin and less cellulose than the bark (Clark et al. 1971). The bast fiber compromises 35–40 % of the dry weight of the plant mature stem; and the core compromises the balance (Muchow 1983). The fiber content of the kenaf bark

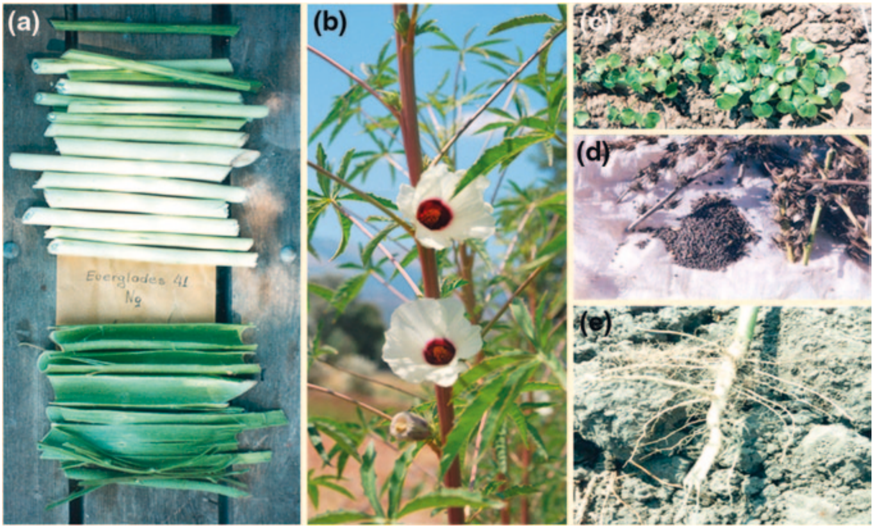

Fig. 1.1 Kenaf parts (stem fractions, flowers, young seedlings, seeds and capsules, and root) (*source* BIOKENAF project)

content is about 50–55 %, increasing according to the plant population density, while the less valuable short fibers make up about 45–60 % of the inner core (Clark and Wolff 1969; Wood et al. 1983). Lower quality paper can be made from the short wood fibers of the core, while high quality paper can be made from the long fibers of the bark. Consequently, the core is more difficult to pulp than the bark, requiring more alkali and giving lower pulp yields; the resultant pulps are relatively slow draining with poor strength characteristics (Touzinsky et al. 1972; Bagby et al. 1975).

In a USDA study it was found that after maceration of green and field-dried kenaf, the average fiber length was 2.5 mm and the average width was 17 μm. The woody core fibers had an average length of 0.6 mm and an average width of 33 μm (White et al. 1970). The fiber length of softwoods is around 3.5 mm and of hardwoods, around 1 mm (Rydholm 1985). Hence, kenaf bast fibers are longer than hardwood fibers, but shorter than softwood fibers while the core fibers are shorter than hardwood fibers. Besides fibrous tissues, kenaf contains a non-fibrous tissue in the center of the stem, called pith.

1.2.2 Leaves

The leaf shape varies and depends strongly on the variety. Kenaf varieties are divided into two categories; the (Everglades 71) varieties with deeply lobed leaves (usually called split or divided) and (Everglades 41) varieties with shallowly lobed leaves (usually called entire). The divided leaf shape can create a problem because it resembles marijuana (Fig. 1.1b). The entire leaf type has leaves that resemble those of its relatives such as okra and cotton (Baldwin 1994b). The leaves in the divided leaves varieties are deeply lobed with 3, 5, or 7 lobes per leaf.

The first few juvenile leaves of all kenaf seedlings have an entire shape (Fig. 1.1c). When the young plants start to develop, additional leaves are produced that start to differentiate. It can develop 3–10 entire juvenile leaves before the first divided leaf appears (Charles 2002). On the underside of the mid-vein of each leaf there is a nectar gland (Dempsey 1975). The seed capsule also has a nectar gland and both leaves and capsules are visited in large numbers by wasps.

When the plants are at an immature stage of growth (about 6 feet tall), the leaves contain 18–30 % crude protein on dry matter basis and for this reason it can be used as animal feed. The stems defoliate after the first killing frost and this drop returns significant qualities of nitrogen in the soil as well as calcium, magnesium, phosphate, and potassium. At the time of defoliation, the nitrogen content could be up by 4 % of the dry weight (Hollowell 1997).

1.2.3 Flowers

The flowers of section Furcaria are characterized by having a calyx with prominent central rib and two prominent marginal ribs. These rigid structures apparently are used for supporting the fragile and delicate petals. Also, the flowers of all species have more or fewer narrow bracts, which are borne below the calyx. The tip of these bracts may be unforked as in kenaf or forked, according to the sectional name Furcaria. Kenaf flowers are typical of hibiscus genus, showing the characteristic fused statement column.

The flowers are large (7.5–10 cm), bell-shaped, and wide open with five petals. The flower color ranges from light cream to dark purple, with a number of shades between them, but apparently never in bright yellow, pink, or red tones. Many cultivars have flowers with a deep red or maroon center. They are borne on short stalks on the leaf axils on the upper portion of the stem and the main apical meristem retains its capacity for vegetative growth (Fig. 1.1b).

While the flowering per plant can last 3–4 weeks or more, each individual flower blooms for only one day. The flowers open early in the morning, begin to close about midday, and close in the mid-afternoon and never open again. The anthers release the pollen (which is bright orange or bronze color) about the time when the flower opens, and the style emerges shortly thereafter. The five-part stigma expands; the lobes become turgid, but do not touch the anthers. The corolla closes spirally so that the anthers are pressed in contact with the stigma and self-pollination can be done unless cross-pollination has already been recorded (Howard and Howard 1911).

Like its relative species such as cotton and okra, kenaf's flowers and nectaries attract a number of insects, which pollinate (and cross-pollinate) the flowers (McGregor 1976). Pate and Joyner (1958) stated that kenaf has been classified on several occasions as a self-pollinating crop, but more recently, it has been classified as a cross-pollinate crop. Because of the moderate level of cross-pollination, the seed obtained is frequently not true to type (Baldwin 1994a, 1996). The cross-pollination crop in kenaf can be varied from 2 to 24 %.

1.2.4 Seeds

After pollination, seed capsules are formed that are 1.9–2.5 cm long and 1.3–1.9 cm wide. The seed develops in five-lobular capsules. Each capsule contains five segments with a total of 20–26 seeds/capsules (Dempsey 1975). The seed capsules are covered with small hairy structures that are irritating to the human skin. The capsules of the cultivated varieties are generally indehiscent and remain intact for several weeks after reaching maturity. From pollination, the seeds require 60–90 days in frost-free conditions to mature. According to Baldwin (1994), kenaf seeds take roughly 45 days to ripen. The seed is small (1.5–3.3 gr/100 seeds), black in color, and subreniform in shape (Fig. 1.1d). The seed retains viability for about 8 months under ordinary storage conditions. Kenaf seeds are grayish brown, approximately 6 mm long and 4 mm wide (35,000–40,000 seeds per kg).

The seeds contain 20 % and the oil has a similar fatty acid composition to cottonseed oil but does not contain gossypol, a polyphenolic compound in cottonseed which causes the oil to darken (Wood 1975). Kenaf oil is characterized by a high phospholipids content compared to most edible oils (Mohamed et al. 1995). The high oil content of kenaf seeds loses its viability when exposed to high temperature and increased humidity.

According to the chemical composition of kenaf seeds is 9.6 % moisture content, ash 6.4 %, fatty oils 20.4 %, nitrogenous matter 21.4 %, saccharifriable matter 16.7 %, crude fiber 12.9 %, and other matter 13.9 %. In the same study it is reported that the fatty oils correspond to five acids which are: palmitic oil 19.1 %, oleic acid 28 %, linoleic acid 44.9 %, stearic acid 6 %, and alpha-linolenic acid 0.5 %.

Previous studies reported that Kenaf seed contains 16–22 % oil and 30–33 % proteins and the Palmitic, oleic, and linoleic acids were reported as major fatty acids in kenaf oil (Hopkins and Chisholm 1959; Subbaram et al. 1964; Tolibave et al. 1986; Singh 1988). The minor fatty acid contents of kenaf seeds were the palmitoleic (1.6 %), linoleic (0.7 %), and the stearic (3.5 %) (Mohamed et al. 1995).

1.2.5 Root

The plant has a long effective tap root system and relatively deep, wide-ranging lateral root system making the plant drought tolerant. Further to that, kenaf with its tap root system is considered to be an excellent user of residual nutrients from previous crops (Fig. 1.1e).

Kenaf root has deep root exploration that reaches to more than 1 m depth (Fig. 1.2). Kenaf roots are sensitive to plow-pan and maybe to other structural accidents or compactions.

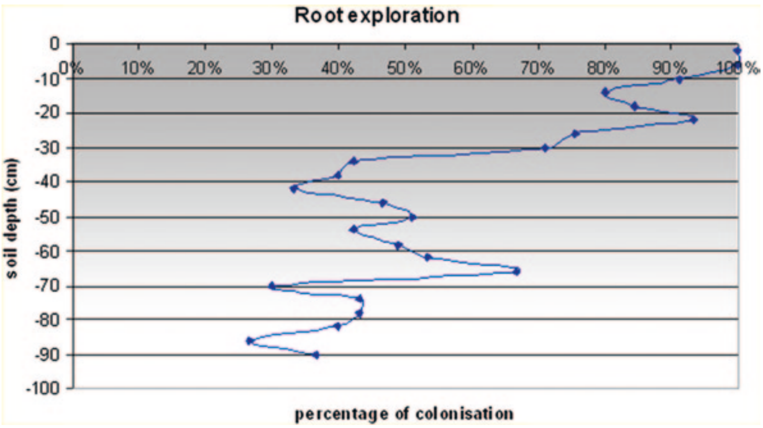

Fig. 1.2 Kenaf root profile in a soil profile of 100 cm (*Source* INRA, BIOKENAF project)

1.3 Area of Cultivation

In 1985, the global kenaf production reached an all-time high of 2.8 million tons. After this time, kenaf production has shown to follow a declining trend. In 1995, the production of kenaf and allied fiber crops was 753,000 tons and continued to decline. Currently (2010/2011), kenaf is an important cash crop in many developing countries like, China, India, and Thailand. Nowadays, it is not easy to find any huge cultivation area of kenaf in the main producing countries of China and India and the crop is only planted on marginal lands with poor or no management. Japan consumes nearly all of the Asian kenaf production. The Japanese industry has set a short-term goal of 1 %, which would require about 300,000 tons of raw kenaf. In the longer term, the Japanese industry has set a goal of 10 % (Wood 1998).

An area of cultivation of 1,000 ha is reported in the USA (Kulger 1996). In 1999, an area of 2500 ha was planted in Texas, Mississippi, and Missouri for a number of fiber applications. In 2000, almost 10,000 ha of kenaf were cultivated in various parts of the United States. The four main areas of commercial kenaf activity in the USA are Georgia, Texas, Mississippi, and New Mexico. In Australia, there is no commercial production of kenaf and all the present fiber production is for experimental purposes.

In Europe, a cultivation area of 700 ha is reported in Bologna (Italy). The harvested material is being used from the company KEFI ITALIA, located close to Bologna, to produce insulation mats from the bark material (www.kenaf-fiber.com).

The production (in thousand tons) of kenaf and other allied crops (1995–2011) is presented in Fig. 1.3.

In 2010/2011, the total production of kenaf and allied crops recorded in the Far East was 82.5 %, in Latin America and the Caribbean countries it was 9 %, in Africa it was 4 %, in developed countries it was 2 %, and in the Near East it was 1 %. The production recorded in 2010/2011 was only 36 % of that recorded in 1994/1995.

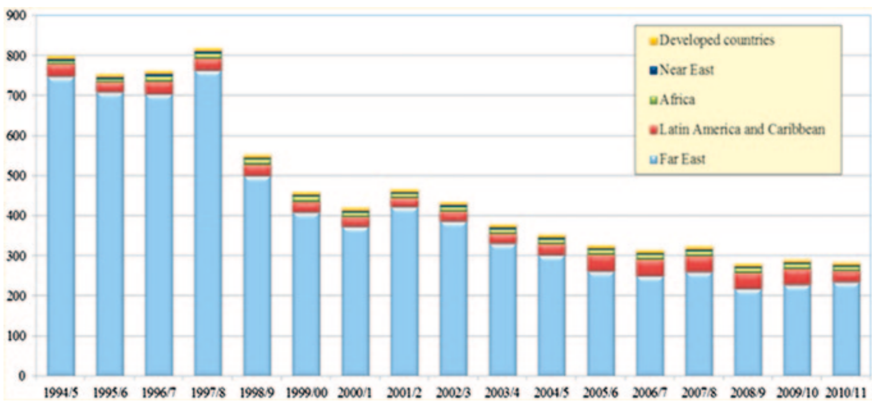

Fig. 1.3 World production (thousand tons) for kenaf and other allied fiber crops (1994–2011)

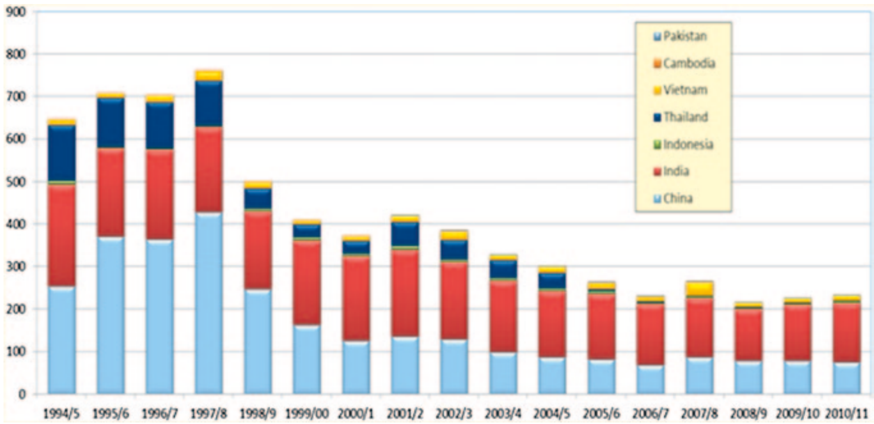

Fig. 1.4 Kenaf and other allied crops production (thousand tons) in the main cultivation countries

In Fig. 1.3 is presented the production of kenaf and allied crops in the countries of the Far East. Almost 60 % of the kenaf production in the Far East countries (2010/2011) is in Pakistan (140 thousand tons), with China contributing 32 % of the total production, Pakistan 5 %, and Indonesia 1 %. The average overall production in 2010/2011 in countries of the Far East corresponds to 36 % of the production in 1994/1995. In Thailand, the kenaf production became much less in 2010/2011 corresponding to 1.4 % of the total production in 1994/1995 (Fig. 1.4).

1.4 Importance of the Crop

Kenaf is a traditional third world crop that is poised to be introduced as a new annually renewable source of industrial fiber in the so-called developed economies. The traditional uses of the crop were the fiber production from its stem (Dempsey 1975) as well as the food use. Kenaf in Africa had several non-fiber uses. People ate the scions and leaves either raw or cooked. The crude protein in the dry leaves is quite high (30 %) and in some countries was consumed as a vegetable. Due to its high crude protein it can be used as animal feed (Zhang 2003). Kenaf seeds are used for oil production and the various plant parts are used in medicines and in certain superstitious rites.

Kenaf, like all other important fiber crops (jute, roselle, hemp, flax, ramie, etc.), can be pulped to make a range of paper and pulps comparable in quality to those produced from wood. With forests dwindling and virgin wood becoming more expensive and the increasing demand for paper products, it can be understood why non-wood fiber crops such as kenaf are so important (Wood and de Jong 1997, Fried 1999). Kenaf in a period of 6 months can reach a plant height of 3–4 m and its production is two to three times higher (per ha and per year) than the southern pine forests (Fried 1999).

Although the importance of the crop is mainly with regard to paper pulp production, kenaf is being characterized as a multipurpose crop because it has a number of additional industrial applications. Thus, kenaf fibers (either derived from the bark or the core of the plant stem) can be an excellent source for several other uses such as for fabrics, building materials (particleboards, low-density panels, wall paper backing, furniture underlays etc.), bedding material, poultry and/or cat litter, oil absorbent, etc. (Kugler 1988; USDA 1988; Perry et al. 1993; Kulger 1996; Borazjani and Diehl 1994; Ramaswamy and Easter 1997; Kaldor et al. 1990). Additionally, the whole plant has high protein and good digestibility and may be pelletized.

Research work on kenaf is being carried out worldwide (USA, Australia, South America, Thailand, India, and Japan). Early research was started in the United States of America in the 1940s in order to use kenaf as a substitute for jute due to the supply distribution from the Far East during World War II (Roseburg 1996). In 1960, kenaf was selected by the United States Department of Agriculture from among 500 crop species (which included hemp) as the most promising non-wood fiber alternative for pulp and paper production. Since then, in the framework of national programs, a large amount of research work has been carried out resulting in a complementary mechanized approach, which has reduced labor requirements and environmental impacts. Nowadays, in USA more resources are asked for putting into work focusing on market development instead of the standard production research.

In Australia, the research on kenaf was initiated in 1972. The research was specifically directed toward growing the crop for production of paper and the field program was supported by studies on the paper making properties of the stem material. The research undertaken clearly confirmed the potential of kenaf as a feedstock for paper production and established the cultural practices necessary to cultivate the crop. The crop has not yet commercialized in Australia due to the fact that Australian pulp mills are mainly based on wood (Wood 1998).

Kenaf has been accepted by the European Community as a "non-food" crop with high production of biomass, composed primarily of cellulose-rich stalk (Venturi 1990; Webber 1993). It was designated for utilization in the production of industrial fiber. The research at the European level on kenaf started in the early 1990s and developments on the crop have been concentrated in the Mediterranean region with sub-tropical climates and have been focused mainly on the primary production in the framework of a European demonstration project aimed at testing kenaf as raw material for paper pulp production. In view of this project (EUROKENAF), demonstrative fields were carried out in all the Mediterranean countries to produce the raw material for its several uses.

The BIOKENAF project (www.cres.gr/biokenaf) offered an integrated approach for kenaf covering the whole production chain (production, harvesting, and storage) testing the suitability of the crop for industrial products (high added value) and energy. This integrated approach was carried out taking into consideration the environmental and economic aspects of the crop and through a market feasibility study was led to the production of industrial bioproducts and biofuels with respect to security of supply and sustainable land management.

In the BIOKENAF project (2003–2007), kenaf was considered an annual fiber crop of great interest for both the production of industrial raw materials and as bio-fuel under the pedoclimatic conditions of south Europe. The main reasons for considering kenaf as a high productivity multipurpose non-food of increasing importance for Europe are discussed below.

It is a multipurpose 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 fiber applications, while 60–70 % of the stem (core) among several industrial applications can be used for thermochemical process (combustion pyrolysis and gasification).

It has high biomass potential with relatively low inputs. Dry matter yields of up to 26 have been reported. Under semi-arid conditions, such as prevailing in Mediterranean areas, it requires 250–400 mm of water, which is much lower than in conventional land-use types (including maize, sugar beet, alfalfa, etc.) largely resembling cotton in its water requirements. On the other hand, considering the low N requirements (50–100 kg N/ha), this crop is believed to comprise an important alternative land use in lands with poor and moderate water availability.

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

As an annual crop, it is 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, thus bringing costs of delivery down to commercially accepted levels.

Recently, kenaf is considered as a valuable dual purpose crop (fiber and medicinal plant) native to India and Africa (Mohamed et al. 1995). Kenaf is composed of various bioactive components including tannins, saponins, polyphenolics, alkaloids, fatty acids, phospholipids, tocopherol, and phytosterols (Mohamed et al. 1995). This plant has been reported to be anodyne, aperitif, aphrodisiac, fattening, purgative, stomachic, and has long been used in traditional medicine to treat bilious conditions, bruises, and fever (Coetzee et al. 2008; Kobasy et al. 2001; Mohamed et al. 1995; Nyam et al. 2009).

A fairly new application is to use it as a food additive. Dry, powdered kenaf leaves when added to different kinds of foods showed improved contents of calcium and fiber, while the taste remained the same. It has been reported as an ideal food additive and its leaves can also be used as tea. Currently, it was also characterized as a dual crop; crop that can be cultivated for its fibers and/or for its seeds (oil production). From the seed oil and other parts of the crop, medicines can be produced.

The interest in natural fibers is also increasing lately due to new environmental legislation and concerns, resulting in a growing market for biodegradable and recyclable materials. The total worldwide demand for fiber (cellulosic, cotton, wool, man-made, others) is predicted to increase from approximately 50 million tons/year (1999 figure) to 130 million tons/year by 2050 (in line with the predicted growth of the world's population). Europe has already an established bioeconomy, with plants being the basis of European industries with an annual turnover of more than € 1 trillion (Plants for the Future Platform, 2005). But in order to rise to the challenges of a growing population, dwindling resources, and the environment, the new economy has to be knowledge based.

1.5 Conclusions

Kenaf is an annual spring crop originating from West Africa (4000 BC). In the eighteenth century it disseminated to Asia and from there went to North and Central America. It is known by more than 120 common names, worldwide. When it is cultivated in high populations it has an erect and unbranched stem. Its stem has two fractions; the bark with long fibers and the core with short fibers. In the middle of the core, the pith can be found that has great absorbing capacity. It is a self-pollinating crop and the cross-pollination varies from 2 to 24 %. Its seeds contain up to 22 % oil and have high content of polyunsaturated fatty acids. It has an effective tap root that makes it drought tolerant.

Currently, it is cultivated in more than 20 countries. Kenaf production was maximized in 1985 and thereafter started to decline. In 2010/2011, the total production of kenaf and other allied plants was 284,000 tons. It is mainly cultivated in Far East Countries; 60 % of the total kenaf production is derived from Pakistan, followed by China (26 %). In the area of its origin (Africa), kenaf production was only 4 % in 2010/2011.

Kenaf can be grown for numerous end uses. The traditional uses of the crop were to produce fiber and food. The fibers can be used to make cordage, rope, burlap cloth, and fish nets because of its rot and mildew resistance (Cook 1960). A range of new applications have been added to the traditional ones, for example: medicines, food additives, oil absorbents, medium for mushroom cultivation, natural fiber/plastic compounds, building materials, biocomposites, as well as for animal bedding and poultry litter.

References

Bagby MO, Cunningham RL, Clark TF (1975) Kenaf pulp-soda vs sulphate. Tappi J 58:121–123

Baldwin BS (1994a) Physiological maturity determination and germination of kenaf seed. Sixth Annual International Kenaf Conference New Orleans, LA

Baldwin BS (1994b) Selection and breeding of kenaf for Mississippi. In: Fuller MJ (ed.) A summary of kenaf production and product development research 1989–1993. Mississippi Agriculture and Forestry Experiment Station Bulletin 1011, Mississippi State University, Mississippi, (33 pgs.), p. 9

Baldwin BS (1996) Adaptation of kenaf to temperate climatic zones. In: Janick J (ed) Progress in new crops. ASHS Press, Arlington, pp 402–404

Borazjani A, Diehl S (1994) Kenaf core as an enhancer of bioremediation. In: Goforth CE, Fuller MJ (eds.) A summary of kenaf production and product development research, 1989–1993.

Mississippi Agriculture and Forestry Experiment Station Bulletin 1011, Mississippi State University, Mississippi, pp. 26–27
Charles L (2002) Trends in New Crops and New Use. ASHS Press, Alexandria
Chen YY, Lin LH, Wu JM, Qi JM, Zhou RY (2004) Genetic effect analysis of some field and quality traits of kenaf hybrid and parents. Plant Fibers Prod 26(6):261–266
Cheng Z (2001) Kenaf research, products and applications in Japan (in Chinese). Plant Fibers Prod 23(3):16–24
Clark TF, Bagdy MO, Cunningham RL, Touzinsky GF, Tallent WH (1971) Pulping of kenaf bark and woody fractions: preliminary investigations. TAPPI. Non-wood plant fiber pulping. Progress Report No. 2: 153–159
Clark TF, Wolff IA (1969) A search for new fiber crops, XI. Compositional characteristics of Illinois kenaf at several population densities and maturities. Tappi J 52:2006–2116
Coetzee R, Labuschagne MT, Hugo A (2008) Fatty acid and oil variation in seed from kenaf (*Hibiscus cannabinus* L.). Ind Crops Prod 27:104–109
Cook JG (1960) Handbook of textile fiber. Merrow publishing, Watford
Dempsey JM (1975) Fiber Crops. The University Press of Florida, Gainesville 457 pp
FAO (2003) Consultation on natural fibers, The production and consumption of kenaf in China. ESC-Fibers Consultation No: 03/6
FAO (2010) World production of jute, kenaf and allied fibers
Fried R (1999) Kafus environmental industries: producing forestry products without trees. Corp Environ Strategy 6(4):378–386
Hollowell JE (1997) Nutritional and yield evaluation of kenaf (*Hibiscus cannabinus* L.) as a potential high quality forage for the southern United States, MS Thesis, Mississippi State University, Mississippi State, MS
Hooker JD (1875) Flora of British India, vol 1. L. Reeve and Co., London
Hopkins CY, Chisholm MJ (1959) Fatty acid of kenaf seed oil. J Am Oil Chem Soc 36:95–96
Howard A, Howard GLC (1911) Studies in some Indian fiber plants. On some new varieties in *Hibiscus cannabinus* L. and *Hibiscus sabdariffa* L. Indian Dept Agr Mem Bot 4:1–36
Kaldor AF (1989) Preparation of kenaf bark and core fibers for pulping by the Annkel method. Tappi J 72:137–140
Kaldor AF, Karlgren C, Yerwest H (1990) Kenaf—a fast growing fiber source for papermaking. Tappi J 11:205–209
Kluger DE (1988) Kenaf newsprint: realizing commercialization of a new crop after four decades of research and development, A report on the kenaf demonstration project. USDA-CSRS, Washington, DC 13 pp
Kobaisy M, Tellez MR, Webber CL, Dayan FE, Schrader KK, Wedge DE (2001) Phytotoxic and fungitoxic activities of the essential oil of Kenaf (*Hibiscus cannabinus* L.) leaves and its composition. J Agric Food Chem 49:3768–3771
Kulger DE (1996) Kenaf Commercialization: 1986–1995. In: Janick J (ed) Progress in new crops. ASHS Press, Arlington, pp 129–132
Li AQ (1990) Report of the germplasm collecting for jute and kenaf in Kenya (in Chinese). Plant Fibers Prod 1:16–21
Li D (2002) Kenaf production, research and development in China. International kenaf symposium. T.N. USA
Mazumder BB (2000) A combination treatment of kenaf bast fiber for high viscosity pulp. J Wood Sci 46:364–370
McGregor SE (1976) Insect pollination of cultivated crop plants. Chapter 7: small fruits and brambles. Kenaf (*Hibiscus cannabinus* L.), family Malvaceae. USDA, Washington, DC
Mohamed A, Bhardwaj H, Hamama A, Webber C III (1995) Chemical composition of kenaf (*Hibiscus cannabinus* L.) seed oil. Ind Crops Prod 4:157–165
Muchow RC (1983) I. Effect of sowing date on the growth and yield of kenaf (*Hibiscus cannabinus*) grown under irrigation in tropical Australia. Phenology and seed production. Field Crops Res 7:81–90

Nelson GH, Nieschlag HJ, Wolff IA (1962) A research for new fiber crops, V. Pulping studies on kenaf. Tappi J 45:780–786

Nyam KL, Tan CP, Lai OM, Long K, Che Man YB (2009) Physicochemical properties and bioactive compounds of selected seed oils. LWT-Food Sci Technol 42:1396–1403

Pate JB, Joyner JF (1958) The inheritance of a male sterility factor in kenaf, *Hibiscus cannabinus* L. Agron J 50:402

Perry RC, Jones DE, Bhangoo MS (1993) A preliminary study on kenaf as a feed for livestock (1992). Proceedings of 5th Annual International Kenaf Association Conference, March 3–5, 1993, Fresno CA, 45–48

Ramaswamy GN, Easter EP (1997) Durability and aesthetic properties of kenaf/cotton blend fabrics. Textile Res J 67:803–808

Roseberg RJ (1996) Underexploited temperate industrial and fiber crops. In: Janick J (ed) Progress in new crops. ASHS Press, Alexandria, pp 60–84

Roxburgh W (1795–1819) The plants of the coast of Coromandel. George Nicol, London

Royle JF (1855) The fibrous of India. Smith, Elder & Co., England

Rydholm SA (1985) “Chemical pulping” In Pulping processing. Robert E Krieger Publishing company, Malabar, pp 439–715

Sellers TN, Reichert A (1999) Kenaf properties, processing and products. Mississippi State University, MS

Singh DP (1988) Breeding mesta (*Hibiscus cannabinus* and *H sabdariffa* L.) for better quality. Induction of mutations superior in fats, fatty acids and amino acid content. Genet Agric 42:273–282

Stout HP (1981) Jute and kenaf. In: Handbook of fiber science and technology. Marcel Dekker, New York, pp. 701–726

Su J, Chen A, Lin J (2004) Genetic diversity, evaluation and utilization of kenaf germplasm in China. Plant Fiber Prod 26:5–9

Subbaram MR, Rajagopal NS, Paulose MM, Subarao R, Roomi MW, Achaya KT (1964) Component fatty acid analyses by reversed-phase partition chromatography. J Sci Food Agric 15:645–652

Taylor S (1995) Kenaf. New Crio FactSHEE (http://www.hort.poudue.edu/newcrop.CropFactSheets/kenaf.html)

Tolibave I, Mukhamedova Kh, Glushennkova AI, Tursunkhodzhaev AS (1986) Lipids of kenaf wastes. Kim Prir Soedin 6:686–688

Touzinsky GF, Clark TF, Tallent WH (1972) Characteristics of sulphate pulps from kenaf bark and core. TAPPI. Non-wood plant fiber pulping. Progress Report No. 3, pp. 25–53

USDA (1988) Kenaf paper—a forest-saving alternative. Agric Res 36:6–8

Venturi G (1990) II kenaf, *Hibiscus cannabinus*, a new alternative crop? L’Informatore Agrario 46:5–8

Webber ChL III (1993) Yield components of five kenaf cultivars. Agron J 85:533–535

White GA, Cummins DG, Whitely EL, Fike WT, Greig JK, Martin JA, Killinger GB, Higgins JJ, Clark TF (1970) Cultural and harvesting methods for kenaf. USDA Prod. Res. Report 113. Washington, DC. Wilson and Margaret, 1967

Wilson FD (2000) Kenaf history and botany. American Kenaf Society (http://www.kenafsociety.org/KENAFbotany.htm)

Wilson FD, Menzel MY (1964) Kenaf (*H. cannabinus* L.), roselle (*H. sabdariffa*). Econ Bot 18:80–91

Wlison FD (1978) Wild kenaf, *Hibiscus cannabinus* L. (Malvaceae), and related species in Kenya and Tanzania. Econ Bot 18:80–91

Wood IM (1975) KENAF a possible multi-purpose crop for the Ord River irrigation area. Journal of Agriculture 16:14–18 Western Australia

Wood IM, de Jong S (1997) Plant fiber crops. In: Keith H (ed) The new rural industries. A handbook for farmers and investors, pp. 453–463

Wood I (1998) Kenaf: The forgotten fiber crop. Issue No 9, www.newcrops.uq.edu.au/newslett/ncn10212.htm

Wood IM, Muchow RC, Ratcliff D (1983) Effect of sowing date on the growth and yield of kenaf (*Hibiscus cannabinus* L.) grown under irrigation in tropical Australia. II. Stem production. Field Crops Res 7:91–92

Zhang T (2003) Improvement of kenaf yarn for apparel application. Master thesis of Louisiana State University, US