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KENAF : ITS PROSPECT IN INDONESIA

A REVIEW

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ABSTRACT

Kenaf is a plant fibre with high potential as source of material industry. Originally, kenaf usage in Indonesia is still limited only for jute sacks material, which is then displaced by plastic sacks production. While at international scale, kenaf has been started to be developed as pulp material, polypropylene composite, fibreglass replacement, and particle board for automotive industry materials. Indonesia is a tropical country this condition which suitable for kenaf cultivation. However, research reports about kenaf potential usages are still few and limited in domestic level only. Whereas, Indonesian kenaf plant information is needed by international community to understand comprehensively about the potential of tropical plants. This article aims to provide an overview about kenaf cultivation potential and usages in Indonesia as well as the possibility of future development.

Key words: kenaf, fibre, prospect, potential.

INTRODUCTION

Kenaf (*Hibiscus cannabinus* L.) is a short-day-fibre plant that belongs to the family Malvaceae, genus *Hibiscus*, and Furcaria section. According to Dempsey (1975) in Taylor (1995) Kenaf is an English name. In Indonesia, kenaf was known as Jute Java (Java jute). In some countries kenaf was known as mesta (Indian, Bengali), palungi (India, Madras), deccan hemp (India, Bombay), bimli jute (India, Andhra Pradesh), Ambari (Taiwan), til, teel or teal (Arab and North Africa), papoula de Sao Francisco (Brazil), stokroos (Southern Africa), dah, gambo or rama (West Africa) (Taylor, 1995). According Miyake and Suzuta (1937) in Taylor (1995) there are more than 129 names of kenaf in worldwide. Kenaf came from Africa (Western Sudan) (Taylor, 1995).

Kenaf has been grown for thousands years in Africa. Its leaves were utilized as human foods and animal feeds, its bark fibre used as rope, and the core wood is used as fuel. This plant was introduced into South Asia around 1900. The main production areas were China, India, and Tashkent which formerly were parts of USSR. According to Heyne (1917), this plant was originally found in Africa which then brought to England and India, specifically to Madras and Bombay. The largest producers of kenaf in India are Andhra Pradesh and Tamil Nadu. Kenaf was introduced by Indian to Indonesia in 1904. This plant has been grown in Central Java, East Java, and Aceh. Development of kenaf cultivation in Indonesia began in 1979 through Program Intensifikasi Serat Karung Rakyat (ISKARA). However, fibre which produced from ISKARA program only reaches 20-30% from national needs. This fact showed that Indonesia national productivity is still low, but when it compared to the-productivity of five major fibre producing countries (Bangladesh, India, Nepal, Thailand, and Indonesia) kenaf fibre production in Indonesia was relative high, but lower than China (Sastrosupadi et al., 1996).

Kenaf has ability to adapt in wide environmental condition of climate and soil. These plants grow at 45°N to 30°S. Kenaf plant is tolerant in various daily temperatures between 10°C and 50°C, but it cannot stand snow. This plant grows best on daily temperature above 20°C with 100-125 mm of average monthly rainfall. This condition is found during rainy season in tropics and subtropics summer area. Kenaf is short day plant, but some cultivars are remain in the vegetative stage when the day period below 12.5 hours. Some cultivars that grown at 20°N were not start flowering in early September. At higher latitudes, plant shows late flowering behaviour. Different condition was happen in the equator area, early flowering plant grows extensively unless for photo-insensitive cultivar. Kenaf can grow on a variety of soil type, but it grows best on alluvial clay soil or sandy colluvial with pH 6-6.8. This plant is tolerant to high salinity, but sensitive to water loss (Prohati-Keanekaragaman Hayati Tanaman Indonesia, 2015).

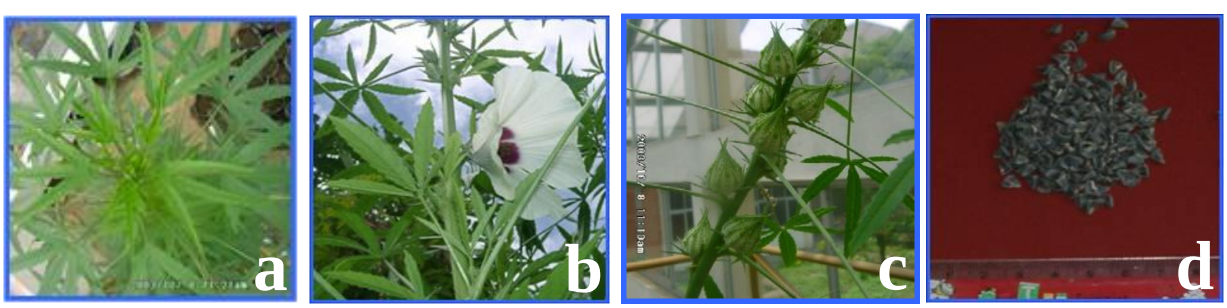

Figure 1. Kenaf Morphology. a. Leaves b. Flower c. Bud d. Seeds. (Arumingtyas, 2006).

Kenaf is annual plant with up to 3 meters high, stems are mostly bare, and some spiked. Some cultivars have flat stem, some cylindrical, its pigmentations are entirely green, red, green with purple, red entirely, and sometimes the half low part is green and the half above is pigmented. The leaves are alternate, stipules filiform, hairy with 5-8 mm in length, petiole length is 3-30 cm, the adaxial and abaxial surface were hairy and bristly, green to red colored. The lower leaves are heart-shaped (some references refer it as round-long) and the upper leaves are finger-shaped with deep cleavage (Arumingtyas, 2006, Figure 1a). Flowers emerge axillary, short stalks, yellow or red-purple in the middle (Arumingtyas, 2006, Figure 1b). Fruit is slightly rounded, coarse, and 1-2 cm of length (Arumingtyas, 2006, Fig. 1c). Seed shapes are kidney beans like triangular with sharp corners, 3-4 mm x 2-3 mm in size, gray or brown-black colored with bright yellow dot (Arumingtyas, 2006, Figure 1d).

KENAF IMPORTANTS: BENEFITS, PROSPECTS, AND ITS ECONOMIC POTENTIAL

Nowadays, kenaf has been grown for broader purposes, such as pulp materials, polypropylene composite in polymer industry (Anuar and Zuraida, 2011), replacement for fibreglass, animal bedding, board particle, absorbent materials for industry, planting media, fodder, organic filler for plastics as well as insulation (Taylor, 1995; Liu, 2001, 2003). Some automotive industries use kenaf fibres for body material, frame, and organic car floor as developed by Toyota Company. Matsushita Company has developed board particle from kenaf fibre and Nippon Electric Company (NEC) has developed a bio–plastic material from kenaf (Kenaf Green Industries Ltd., 2012).

USDA identified kenaf as the best non-wood paper pulp alternative for several reasons. Firstly, because of its rapid growth, kenaf reaches 12-18 feet in 150 days–while Southern Pine need 14 to 17 years before it can be harvested. Secondly, because of its high yield, Kenaf yields more fibre per acre which approximately 3 to 5 times yields of Southern Pine which produces 5-10 tons of dry fibre per acre. The third reason is because of its economical prospective in papermaking which needs less chemicals, heat, and time in kenaf fibres pulp production because it contains less lignin. Kenaf plant contains only 9% lignin, while Southern Pine contains 29% lignin. Lignin is resin material that binds cellulose fibres in plants or trees. Toxic chemicals such as chlorine were often predominantly used to eliminate lignin and bleach the wood pulp. Kenaf can be easily pulped and bleached with harmless chemicals, such as hydrogen peroxide (Anonymous, 2015)

Kenaf seed also has high economical value. Kenaf seed produces edible oil because it has the same composition as soybean and cottonseed sterols. Kenaf seed contains 6% of phospholipids, 0.9% sterols, and some essential fatty acids such as palmitic acid, oleic acid, and linoleic acid (Webber III and Bledsoe, 2002). Oil content of Kenaf is quite high it between 16-23.7% which make it very promising source for salads, cooking oils, lubricants, soap materials, linoleum, paint, and varnish (Duke, 1983). Kenaf seeds contains are listed on Table 1.

Table 1. Kenaf Seed Contents (http://www.ienica.net/crops/kenaf.pdf)

No.	Material	Percentage
1.	Water content	9.6
2.	Ash	6.4
3.	Fat/oil	20.4
	Palmatic oil	19.1
	Oleic acid	28.0
	Linoleic acid	44.9
	Stearic acid	6.0
	Alpha-linoleic acid	0.5
4.	Nitrogenous compounds	21.4
5.	Sugary compounds	15.7
6.	Crude fibre	12.9
7.	Others	13.9

There are 6 types of kenaf branching based on preliminary evaluation and characterization of International Jute Organization Project on *H. cannabinus* and *H. sabdarifa*. They are 0 for no branching or no growth of axillary buds, 1 for very weak branching, 3 for weak branching, 5 for moderate branching, 7 for strong branching, and 9 for very strong branching. Balittas Karangploso Malang has shown that there are 4 types of kenaf branching: unbranched, rudimentary, moderately branched, and branched (Hartati et al., 1996).

Kenaf seeds are found inside ovoid-shaped (oval) pointed tip capsule. These capsules are can be found on each leaves armpit on stems and branches (Webber III, Bhardwaj and Bledsoe, 2002). Kenaf seeds in USA have become commercial product. However, the availability of kenaf seed stock for seed planting is still limited. Some kenaf seed provider companies for seed planting are well known in Texas, California, and Florida. The examples of amous kenaf provider companies are Jupiter Seed Company and DBM Farms, Inc., KenafSeed.Com

Kenaf cultivar which has been grown by farmer is kenaf without branches. The increasing of kenaf branch number will increase stem biomass, fibre, and seed production. The increasing number of branches in the mutant peas K164, K524, K564, and K586 had increase the total length of stem as much as 2.7 to 5.3 times which compared to wild type Torsdag (Arumingtyas, 1992; Arumingtyas and Murfet, 1992). Blixt (1968) conducted mutation induction using 0.35% of EMS on Parvus variety which originally had 40.7m of branch total length and 134.7cm of main stem length, it produced many branch lines including WL5951 with 354.5cm of branch total length, and 99cm of main stem length (Arumingtyas, 1992). The total length of stem and branches of WL5951 is 2.6 times the length of the stem and branches of Parvus (Arumingtyas, 1992).

Increasing the number of branches can be done by performing genetic crosses with highly branched kenaf varieties. Unfortunately, many kenaf branched varieties that exist today are wild type which have unfavourable properties, such as hard germinated seed, small seed, short plants, etc. Furthermore, kenaf hybridization method for breeding is time consuming.

Considering of kenaf fibre pervasiveness, some farmers in Indonesia are starting to cultivate kenaf with hope it will bring them big profits. Kenaf cultivation in scattered area around East Java and Sulawesi could produce one to three tons of kenaf fibre from every one hectare of personal farmer agricultural land. Kenaf price is dependent international fibre price which currently valued about Rp 8000.00 to Rp 25.000.00 per kilogram. On average, farmers could sell about 100 tons of kenaf fibre for a month either from their own cultivation or from other kenaf farmers around East Java and gain up to Rp. 900 million (Marantina, 2013).

KENAF RESEARCH IN INDONESIA

Kenaf Breeding

Indonesian Sweetener and Fibre Crops Research Institute (Balai Penelitian Tanaman Pemanis dan Serat-Balittas) has found several new kenaf varieties, such as KR-15 which gained PVT (Plant Variety Protection-Perlindungan Varietas Tanaman) in November 2007. These varieties have high yield and can be grown in various regions in Indonesia. KR 15 has fair adaptation ability in dry land, bonorowo land, red-yellow podzolic soil, and peat (Balitbangtan, 2008). Over the past 20 years, 11 varieties of superior high fibre kenaf have been produced through breeding programs which generally resistant to flood (Sudjindro dan Marjani, 2009).

Kenaf Mutation

Mutation is an alternative way to increase the number of branches on kenaf. Ethyl Methane Sulfonate (EMS) is a chemical agent which widely used to enhanced mutation in plant. Mutation with EMS has been carried out at various plants. EMS is generally effective in mutant formation by increasing the number of branches, the number of seeds per plant, weight of 100 seeds, the number of pods or capsules, as well as fibre weight per plant, but decrease in plant height (Lamprecht, 1950; Monti and Scarascia Mugnozza, 1967; Blixt, 1968; Janna and Roy, 1975; Hazra and Shome, 1987; Hazra et al., 1987; Rameau et al., 1997; Mehandjiev et al., 1999).

Study about kenaf mutation in Indonesia has shown that EMS mutagen is capable in inducing gene alteration (Arumingtyas et al., 2010b). This alteration has induced variation number of branches on plant which grown from treated seeds (Table 1). EMS chemical formula is $CH_3SO_3CH_2CH_3$ with MW124.2. EMS can add alkyl group ($-CH_2CH_3$) at several places in nitrogen bases which cause transition. EMS also caused insertion or deletion of nitrogen base which led to serious genome damage (Russel, 1984; Sega, 1984; Greene et al., 2003). Gene alteration caused by EMS induction has been detected using Random Amplified Polymorphic DNA (RAPD).

Table 1. The number of survived plant and branched plan from seed treated with EMS (Arumingtyas *et al.*, 2010b)

EMS (%)	Survived plant (%)	Branched plant (%)
0	86.7 e	0.0 a
0.04	60.0 d	12.0 c
0.05	64.0 d	12.0 c
0.06	60.0 d	24.0 d
0.08	48.0 d	32.0 e
0.1	48.0 c	10.0 c
0.3	28.0 b	4.0 c
0.5	40.0 c	8.0 c
1.0	0.00 a	0.0 a

Values followed by similar character in the same column are not significantly different based on Tukey Test 5%

Treatment 1% of EMS caused seed not able to survive, however lower concentration of EMS caused plant to adapt and produce branches. Molecular identification of the genomic DNA alteration showed RAPD band variation (Arumingtyas et al., 2010b). There were 111 genomic DNA variations which detected by OPO and OPA (Operon Technologies seri O dan A) caused by EMS treatment (Table 2).

Table 2. DNA variation detected from 14 kenaf mutant lines using RAPD primers (Arumingtyas *et al.*, 2010b)

Primers	Fragment number	Polymorphic Fragment	Polymorphism Percentage
OPO-01	9	8	80.0
OPO-02	7	9	90.0
OPO-03	7	9	90.0
OPO-04	6	9	69.2
OPO-07	7	13	86.7
OPO-10	5	8	72.7
OPO-11	3	10	90.9
OPO-12	6	12	92.3
OPO-13	5	10	60.0
OPO-14	4	12	91.7
OPO-18	7	11	100.0
OPA-11	5	13	69.2
		Total 115	Average 82.7

Based on genomic DNA variation in RAPD band, some mutant with significant differences to the original line has been detected. Mutant 0.05 (14) treated with 0.05 % of EMS has very different morphology compared to the initial line of KR 11.

GENES INFLUENCING BRANCHING AND REPAIR MECHANISM ON KENAF

At least there were five branching responsible genes which have been identified on kenaf. The genes were gene which homologous to LAS of *Arabidopsis thaliana*, *Ls* of tomato, Moc1 of rice, and RMS1 on pea. There was also gene which homolog to AXR1 and AUX1 (Arumingtyas et al., 2006, Arumingtyas et al., 2010a). Ls, LAS and Moc genes are active before initiation of axillary meristem at the beginning of plant vegetative phase when abscisic acid (ABA) concentration is low and gibberellins are high, dormancy will break. Branch will be developed when Rms1 and Rms5 are active to influence auxin signalling and cause apical dominance break, meanwhile AXR1 and AUX1 genes received signal to produce auxin. Rms2 influence feedback signal by auxin to cytokinins which synergistically produce branch. EMS will influence Rms1, Rms2 and Rms5 activities and caused variation on branching habit (Arumingtyas et al., 2010a).

Besides the possibilities of kenaf mutation induction, there was also an indication of repair mechanism in kenaf. A photolyase gene which has role in repair mechanism from UV irradiation damage is has been detected on kenaf (Arumingtyas et al., 2012). Sub-fragments of it have been detected to have some degree of homology with the mRNA of type II CPD photolyase, PHR1, and complete cds of several plant species (*A. thaliana*, *Cucumis sativus*, *Spinacia oleracea*, *Stellaria longipes* and *Oryza sativa*). However, there was no evidence of 100% homology-which indicate the existence of sequence variation on kenaf CPD photolyase compared to those other plant species.

POLYMERS COMPOSITE

Researches of kenaf utilization in Indonesia mostly are now focusing on kenaf usage to polymer industry. Research on kenaf pulp utilization for manufacture found that kenaf pulp is suitable source for CA (cellulose acetate). CA is polymer which usually used in industry (Widyaningsih and Radiman, 2007). CA can be produced through 3 steps (initialitation, acetylation, and hydrolysis) with specific peak of acetyl group at 1237.4 cm^{-1}.

Study of kenaf fibre composite production using variation of sulphur 25 and 30 phr (per hundred rubbers) which consisted of compound natural rubber/ebonite and kenaf fibres has shown the increasing of composite tensile strength which related with the increasing of sulphur (Hariyanto, 2013). Diharjo (2007) investigated the bending strength characteristics of hybrid composite sandwich which strengthen with combination of kenaf fibre woven random fibre glass with Sengon Laut (*Albizia falcata*) wood. The composite sandwich structure was able to withstand greater loads than the composite lamina. Hybrid composites sandwich was able to withstand bending loads 10.93% above the GFRP (Glass Fibre Reinforced Polyester) composite sandwich. The increasing of bending strength is still can be done by increasing the composite side take thickness.

Suharty et al. (2013) was making bio composites from waste polypropylene with kenaf fibre amplifier using multifunctional compounds acrylic acid whether with cross-junction compound divinyl benzene or not. Biocomposites which consisted of waste polypropylene, acrylic acid, and kenaf fibre or waste polypropylene, divinyl benzene, acrylic acid and kenaf fibre have increased the tensile strength but decreased melt flow rate. Addition 20 phr of mixture fire retardant mixtures (nano $CaCO_3$ Na^+PP) to bio-composites consisting of waste polypropylene, divinyl benzene, acrylic acid, kenaf fibre has effectively increased the time to ignition and reduced burning rate which compared to bio-composites without any addition of fire retardant (Suharty et al., 2012)

Sumarji and Herman (2009) combined kenaf fibres with resin matrix composites to replace metal structure in order to produce fibre composite laminate. Through the compression molding method, hybrid composite sandwich composed of dua lamina hybrid composites with core center of Sengon Laut (*A. falcata*) was constructed. It was found that in 90° of direction on core thickness 20 mm with alkali 5% NaOH treatment for 2 hours was withstand 30.87 Mpa of tension in maximum bending stress. The decreasing of core thickness to 16 mm made the hybrid composite had maximum impact strength of 0.31577 joules/mm^2. Other then research of kenaf fibre utilization for textile material was also has been done. Indriani and Widiawati (2013) found the possibility to use kenaf fibres as textile materials because its filament shape was light weight and small size.

COLLABORATION AND KENAF FUTURE DEVELOPMENT

Indonesia has been known as the successor of kenaf developing and growing new superior variety. In the beginning, kenaf plant development was prioritized to be done in bonorowo lands (flooding land) which unsuitable for other crops when it’s flooded. However, the narrowing of bonorowo area (as result of irrigation improvement), kenaf plants were developed high acidity land in East Kalimantan and dry land in Java. Kenaf plant development was then prioritized on limited irrigated land and red-yellow podzolic soil area. Some of kenaf varieties developed by Balittas are KR 11 for bonorowo land, KR 14 and KR 15 for red-yellow podzolic soil, KR 9 and KR 12 for dry land. These varieties can be planted at any time because it less affected by photoperiod. Kenaf development area in Indonesia such as West Java, Central Java, East Java, Lampung, Riau, South Sulawesi, South Kalimantan, East Kalimantan, Central Kalimantan, and West Kalimantan (Santoso, 2009; Sudjindro dan Marjian, 2009; Supriyadi Dan Tirto Suprobo, 2009).

With kenaf fibre research developments of kenaf fibre car interior material, Toyota Boshuko was intended to carry out research collaboration with Indonesian Agency for Agricultural Research and Development (Balai Penelitian dan Pengmbangan Pertanian-Balitbangtan). This collaboration was signed on March 27, 2008 (Balitbangtan, 2008). PT Araco from Japan, the first automotive company in the world which used kenaf for luxury car interiors also had collaboration with Balittas before this collaboration studied kenaf variety possibility as source for car interior. During this time, PT Araco imported kenaf fibres from Vietnam. In Japan, kenaf can only be planted once a year which made kenaf fibre had to be imported from tropical countries. Because of kenaf can also grow in Indonesia, since the last three years the company which produces kenaf fibres was set up subsidiaries in Indonesia, called PT Kaderaar Indonesia (KI) (Puslima, 2013).

The potential market for kenaf is considerably big. Each month PT Toyota Astra Motor produces about 5,000 units of Kijang car. If one unit of Kijang requires 11 kg of kenaf fibre, it will take 55 tons kenaf fibres per month. Unfortunately, this huge market potential could be fulfilled by Indonesia (Puslima, 2013).

Considering of that situation, Indonesia possess some potentials such as the availability of superior kenaf variety which produced by Balittas, cultivation land, human resource to produce more superior variety of kenaf using alternative method (mutation breeding), and many researches of polymer composite that can be developed to produce an outstanding formula which should be exposed and utilised. Those potential were waiting for further act from the government to enhance the collaboration between researchers and industries to make these potential become true benefit.

Indonesia has potentials to develop kenaf for industry. Superior varieties of kenaf were available and ready to be developed for further usage methods. The research on developing formula for good polymer composite also has been conducted and ready to be implemented.

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